

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN



STUDENT and
INSTRUCTOR
MANUAL

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RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN



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COURSE REFERENCES

**FEDERAL EMERGENCY MANAGEMENT AGENCY
NATIONAL URBAN SEARCH AND RESCUE RESPONSE SYSTEM
STRUCTURAL COLLAPSE TECHNICIAN TRAINING MANUAL**

**CALIFORNIA STATE FIRE TRAINING
RESCUE SYSTEMS 1 TRAINING MANUAL**

**CALIFORNIA STATE FIRE TRAINING
RESCUE SYSTEMS 2 TRAINING MANUAL**

**RAMSET
POWDER FASTENING SYSTEMS**

**PARATECH
RESCUE SUPPORT SYSTEMS**



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We wish to acknowledge and thank the members of the following committees. Without their hard work and dedication, this course would not be possible.

FEMA STRUCTURAL COLLAPSE TECHNICIAN CURRICULUM DEVELOPMENT COMMITTEE AND CONTRIBUTORS

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ACKNOWLEDGMENTS AND REFERENCES

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TOPIC 1-1: INTRODUCTION AND ADMINISTRATION

TERMINAL OBJECTIVE

- The student will receive all information regarding administration and operational requirements for successful completion of this course.

ENABLING OBJECTIVES

- Receive an introduction to all instructors and support staff.
- Receive instructions on starting times and attendance requirements for successful completion of the course.
- Receive information and the necessary paperwork to complete all administrative processes required for successful completion, including:
 - Administrative paperwork.
 - Task book.
 - Course critique.
 - Process for reporting injuries.
- Receive an overview of the criteria for successful completion of the course.
- Receive an overview of the student manual.
- Be assigned to a squad for operational periods.
- Introduce themselves if applicable.
- Receive a schedule of events and rotation times, course agenda, and information regarding the location of specific events.

ADMINISTRATIVE MATTERS

- Welcome and introduction of instructors and students.
- Starting times, attendance requirements, and skills evaluation.
- Rotation and squad assignments.
- Site rules
- Contact numbers for emergencies and review of emergency / medical plan.
- Paperwork requirements.

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COURSE OVERVIEW AND REQUIREMENTS

- The Federal Emergency Management Agency (FEMA) has an 80 hour course entitled Structural Collapse Technician (SCT).
 - The equipment list can be found in the FEMA Urban Search and Rescue (USAR) Type 1 cache list.
 - The knowledge, skills, and abilities (KSA's) requirements can be found in the National Fire Protection Association (NFPA) 1006 and 1670.
 - After successful completion of this course, each student is certified and recognized as a Structural Collapse Technician by FEMA.
- The State of California has a 40 hour advanced rescue skills course entitled Rescue Systems 2 (RS2).
 - Low Angle Rope Rescue Operational (LARRO) and Rescue Systems 1 (RS1) are prerequisites prior to entry into RS2.
 - The equipment list can be found in Firescope ICS-USAR-120-1.
 - The KSA's requirements can be found in NFPA 1006 and 1670.
 - ◆ RS2 meets most of those requirements.
- This course is designed to bridge the training gap between RS2 and SCT.
 - As a supplement to RS2.
- Additional KSA's that are necessary in gaining full competencies to respond to and operate at technical rescue incidents are outlined in NFPA 1006 Standard for Technical Rescuer Professional Qualifications and NFPA 1670 Standard on Operations and Training for Technical Rescue Incidents.
- These KSA's are prerequisites that each student must have successfully completed prior to entry into this course:
 - Rescue Systems 2
 - Rope Rescue Technician
 - Confined Space Rescue Technician
 - Trench Rescue Technician
 - Vehicle and Machinery Rescue Technician
 - Hazardous Materials Operations
 - Water Rescue Awareness
 - Online training certificate of completion for the Structural Engineering Systems Lecture
 - Online training certificate of completion for students being certified to use the Ramset SA270 Powder Actuated Tool

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COURSE OVERVIEW AND REQUIREMENTS (Continued)

- After successful completion of this course, each student will be recognized by FEMA, the California State Fire Marshal, and the California Emergency Management Agency (Cal EMA) as a Structural Collapse Technician.
- There are specific requirements that must be met by each student in order to obtain a certificate of completion for this course:
 - Show up on time, work as a team member, and remain safe.
 - Successfully complete all practical work stations.
 - Successfully demonstrate all skills as outlined in the student task book.
- Each student is continually evaluated by the instructor during classroom and manipulative sessions to ensure that the objectives at each station have been met.

STUDENT MANUAL

- Each manual has been set up to provide the student with the information needed to successfully complete this course.
- Each manual has a task book that lists all of the skills that must be successfully completed for the student to pass this course.

SAFETY ISSUES

- Safety is the responsibility of the individual, the team, and the instructor. Practice safety at all times.
- Safety officers will be on site and have the authority to shut down any operation.
- Any injury, no matter how minor, shall be reported to the instructor for proper care and documentation.
- Students and instructors will wear all necessary personal protective equipment during all evolutions, including but not limited to:
 - Helmet
 - Eye protection
 - Long pants (long sleeve shirts or jackets recommended)
 - Steel toed boots
 - Leather work gloves
 - Hearing protection (where applicable)
 - Respiratory protection (where applicable)
 - Knee and elbow protection (where applicable)
 - Dust mask or half face APR
 - Foul weather gear (when applicable)
 - Sunscreen
- Students should not eat or drink on site without assuring proper hygiene is addressed. Handy wipes or other hand washing must occur prior to eating.
- No smoking on site. Smoking areas to be designated.

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SAFETY ISSUES (Continued)

- Students, Squad Leaders, and instructors should ensure that everyone stays hydrated.
- Students should always be aware of their surroundings, including the following:
 - The potential for tool movement and reaction.
 - The potential for concrete or steel movement.
 - Keeping hands and feet from pinch points.
 - Communicating with squad personnel to ensure that operations are understood.
 - Shifting or moving overhead loads.
 - Flammable materials and products.
 - Vehicle and heavy equipment movement on site.
 - Electrical safety.
 - Personal and team member fatigue.
 - Fall hazards.
 - Slip / trip / water hazards.
- Please address any questions or concerns with the instructor.

IF AT ANYTIME A STUDENT OR INSTRUCTOR SEES AN IMMINENT SAFETY HAZARD WHICH MAY RESULT IN INJURY, THE COMMAND / ACTIVITY SHALL BE STOPPED!

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TOPIC 1-2: SAFETY

TERMINAL OBJECTIVE

- The student will understand the importance of including sound safety practices in all phases of planning and rescue operations.

ENABLING OBJECTIVES

- Understand the importance of safety during all phases of a mission.
- Understand the importance of recognizing and mitigating safety hazards.
- Understand the importance of incorporating safety into rescue planning and briefing.
- Adopt and employ the concept of "LCES".
- Be able to perform a risk / hazard analysis for a specific incident and suggest actions to minimize risks and / or eliminate hazards.
- Understand issues related to personal and team security zones, as a planning tool.
- Understand the importance of safety risk and hazard identification.

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INTRODUCTION

Search and rescue (SAR) is one of the most dangerous types of emergency response activities that can be performed. It exposes the team members to many hazards for which they have little training and virtually no experience to combat. The application of the most current SAR techniques and safe methods of operation are vital to the accomplishment of that mission.

- Safety is a very situational dependent issue.
- Safety is most importantly, an attitude. It is necessary to have a positive attitude about safety. It becomes a balance between accomplishing the task in the shortest possible time and minimizing the risk associated with the task.
- The most effective path is generally the one which expedites the operation AND provides accepted safety practices. This allows the victim to be rescued in a timely manner and the rescuers to return from the task unharmed.
- Keep in mind that when the team deploys, the rescue team will face the probability of many challenges and multiple rescues over extended periods of time. So, stay healthy, share lessons learned, and be safe.

PHASES

- Preparedness
 - Training
 - Exercise
- Deployment
- On-site operations
- Demobilization
- Return to state of readiness

Risks and Hazards

Response team personnel conducting search and rescue and support activities are exposed to many risks and hazards including, but not limited to:

- Damaged infrastructure
- Air transportation
- Secondary collapse from aftershock, vibration, gravity, and explosions
- Unfamiliar surroundings
- Unstable structures
- Fall or trip hazards
- Falling material or flying objects
- Exposure to hazardous materials
- Decontamination
- Exposure to smoke, dust, etc.
- Fire and explosion

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Risks and Hazards (Continued)

- Excessive noise
- Electrical hazards
- Confined space operations
- Oxygen deficient atmospheres
- Contaminated air and water
- Electrocution from damaged utilities
- Dangerous equipment
- Armed thieves and looters
- Fitness for duty
- Excessive fatigue, sleep
- Food services
- Adverse weather
- Stress
- Security
- Safety equipment
- Escape routes
- Safety zones
- Personal hygiene
- Hydration

RISKS & HAZARDS

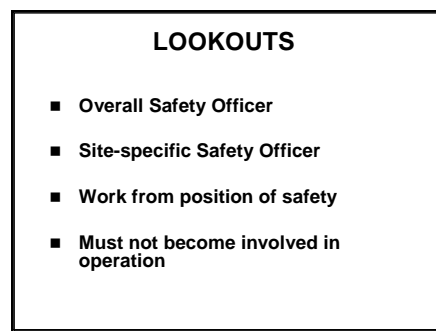
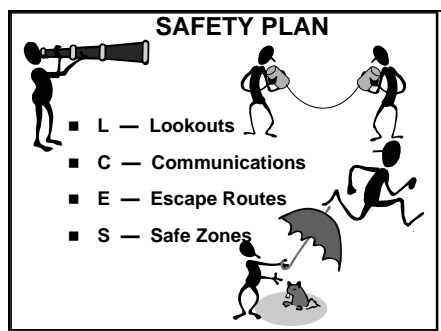
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|--------------------------------|-----------------------------|
| ■ Damage to infrastructure | ■ Contaminated air & water |
| ■ Air transportation | ■ Dangerous equipment |
| ■ Secondary collapse | ■ Armed thieves and looters |
| ■ Unfamiliar surroundings | ■ Fitness for duties |
| ■ Unstable structures | ■ Excessive fatigue, sleep |
| ■ Fall/trip hazards | ■ Food services |
| ■ Falling material | ■ Adverse weather |
| ■ Exposure to hazmat | ■ Stress |
| ■ Decontamination | ■ Security |
| ■ Exposure to smoke, dust, etc | ■ Safety equipment |
| ■ Fire & explosion | ■ Escape routes |
| ■ Excessive noise | ■ Safety zones |
| ■ Electrical hazards | ■ Personal hygiene |
| ■ Electrocution | ■ Hydration |

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SAFETY PLANNING

The multi-hazard safety plan is a guide to the basic elements of safety for a variety of incidents. There are four components to this plan; Lookouts, Communications, Escape routes, and Safe zones. The acronym LCES should be used as a reminder of these components. In any operation, these areas must be addressed to ensure the safety and accountability of all response team members.



L – Lookouts

This is normally the function of the dedicated Safety Officer. That person is the objective observer not involved in the “hands-on” portion of the operation. They are free to watch over the entire operation identifying potentially dangerous situations and mitigating them before they become disastrous.

- Several categories of Safety Officer exist.
 - An overall Safety Officer for the response team is necessary.
 - A site specific Safety Officer may be a person or team assigned to a single location to monitor the existence of a special hazard.
 - ◆ Some examples of the latter might be; one person designated to stand guard over an electrical box while rescue workers operate in a confined space, or a two person team tasked with hiking up a slope to serve as early warning team for rescuers working below a dam during earthquake aftershocks.
- Safety Officers or Lookouts work from a position of safety and clear visual access just outside of the direct work area.
 - They should not become involved with the actual “hands-on” portion of the operation. To do so would possibly limit their ability to be that objective observer capable of identifying hazards.
 - They should be readily identifiable to all, by their radio designation and by wearing a Safety Officer vest or in a small group identified during the safety briefing.
 - Team members tasked with this responsibility must resist the temptation to become involved in the tactical operations. This requires self-discipline. Remember though that the direct success of the mission depends upon the ability to counteract hazards before they become problems.

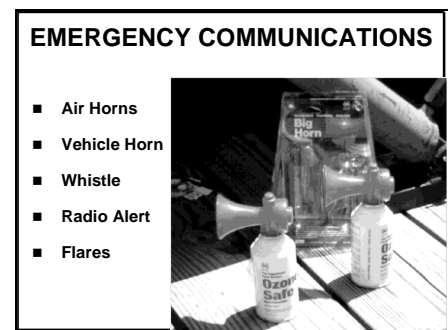
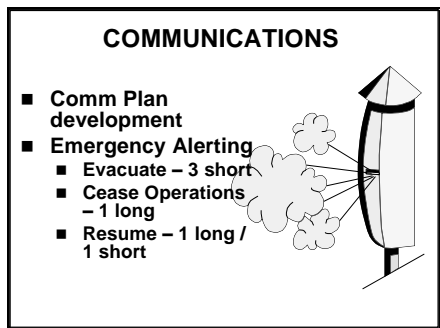
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C - Communications

The formal communications plan will be developed by the Communications Specialist. This plan will identify the Command, Tactical, and Special radio channels. These are the operations personnel's lifeline to the outside for resources, support, and safety. This plan will be provided as part of the response team action plan.

- The following emergency alerting system is to be used in the event of problems at the work site:
 - Evacuate - 3 short blasts (1 second each)
 - Cease Operations - 1 long blast (3 seconds duration)
 - Resume Operations - 1 long and 1 short blast
- The method of delivery may vary depending upon the device available.
 - As an example, by placing two radios together, speaker to microphone, and depressing the transmit buttons a loud tone is heard on all other radios tuned to that frequency.
 - Air horns, car horns, whistles, the P.A.S.S. device, and clear text over the radio are all excellent methods for signaling. The point is that during the safety briefing, before beginning work, identify the specific methods of signaling that will be used at the work site should a problem arise during that operational period.



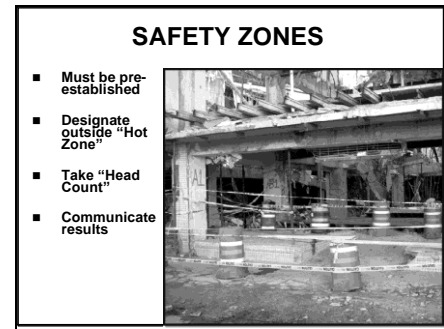
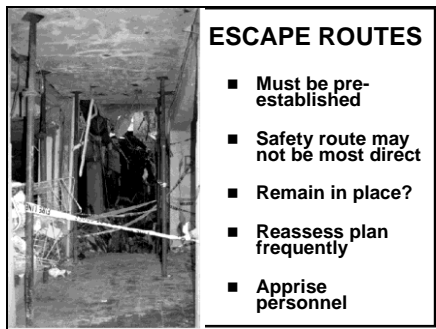
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E - Escape Routes

An escape route is a pre-established path to an area of safe refuge.

- The safest method of exiting an area may not be the most direct route.
 - As an example, after an earthquake structural columns may still be standing but subject to collapse during an aftershock.
 - The most direct route to safe refuge may lie directly in the collapse path of the column. The route giving the column a wide berth will be the safest.
 - Another consideration is to remain in place. If the working area has been shored and leaving this area exposes the rescuer to a variety of hazards, stay put.
- The rescue situation is often dynamic, constantly changing. This can occur as a result of external forces or as a result of the rescuer's action. The escape plan should be constantly updated to reflect changes in situation.
 - As a new plan is developed, each team member must be made aware of the change in operation. An acknowledgement of understanding must also be received from each team member.
 - If the order is not repeated, the new plan is probably not clear to each member of the team. The result can be injury or death.



S - Safe Zones

Safe zones, also referred to as "safe havens" are the pre-established areas of safe refuge, safe from hazards. This could be a designated area outside the hot zone or agreed upon safe areas within the hot zone. If the safe zone is within the hot area, rescuers may have to construct that area around the victim and themselves.

- An example of this is when a victim is trapped inside a collapsed structure and rescuers have shored the immediate area. In this case, the proper response for rescuers would be to hold their position during an aftershock.
- Part of the safety plan should provide for a designated safe zone where a team "head count" is taken. This count should be immediately communicated to the next in the chain-of-command to provide for 100% accountability in the event of an emergency.

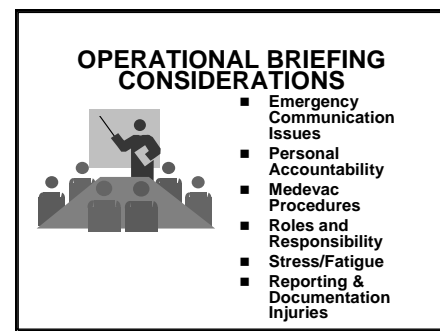
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CHAIN-OF-COMMAND

Consult the response team organization chart for chain-of-command. This chart will list the entire team and who reports to who.

- The Rescue Specialist will report to the Rescue Squad Leader, who reports to the Rescue Team Manager, who reports to the Task Force Leader.
- The safety briefing will identify who is in each rescue squad and who is designated as the Rescue Squad Leader.
- The safety briefing will be given by the Rescue Team Manager or their appointed Squad Leader. Managers and leaders for support functions will also be identified at this time. This is the Rescue Specialists' opportunity to identify the entire team for the next operational period.



SAFETY OFFICER

The Safety Officer for the operational period will be identified. This will leave no doubt as to who is filling that position.

- The offgoing Safety Officer will pass on all pertinent safety information to the oncoming Safety Officer at shift change.

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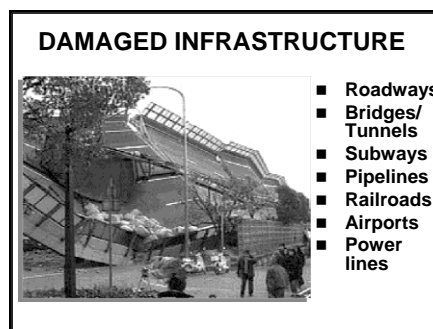
SAFETY PLAN (LCES)

This portion of the safety briefing will cover lookouts (or Safety Officer), communications, escape routes, and safe zones. This information will be developed by advance recon of the work site by team managers or will be passed on from the previous teams operation.

- This is a dynamic process, once the response team has arrived at the site another assessment should be made.
 - If there are any changes to the safety plan, it should be modified then and all team members must acknowledge those changes. Those changes effecting the entire operation should be communicated up the chain-of-command immediately. Those that are site specific can be passed on to the next operational team.
 - The safety plan will review the signal for immediate evacuation, cease operations, and resume operations. It will also identify the area designated for the head count in case of emergency evacuation.

RISK ASSESSMENT COMPONENTS

- Damaged infrastructure (communications, roadways, bridges, railroads, air traffic control)
 - Assume all infrastructure has been compromised even though prior intelligence may have stated otherwise. Although telephone and cell systems may have survived the disaster intact, they will soon be overloaded by responder and/or public demands.
 - Traffic congestion will always occur following a disaster. The affected public will be evacuating the area as responders are moving toward the disaster.
 - USAR vehicles must be clearly marked and warning lights should be used to facilitate arriving at target sites. Assessment vehicles must be equipped with four wheel drive. Standard vehicles will have difficulty traversing terrain while getting to and around work sites. Consider using ATVs as mules.



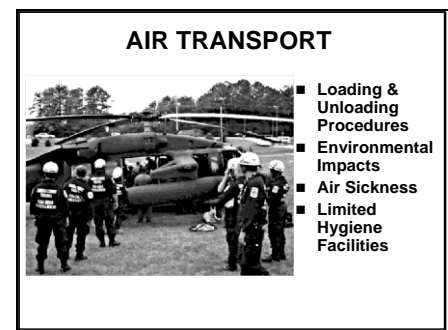
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RISK ASSESSMENT COMPONENTS (continued)

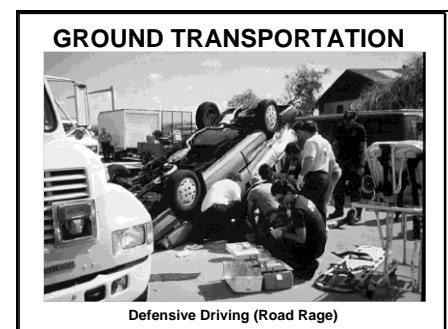
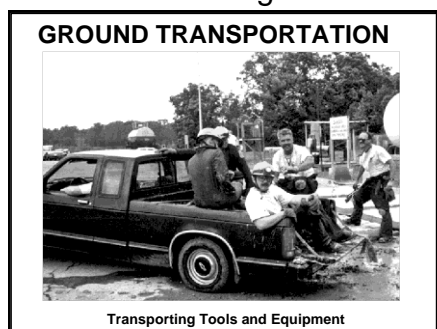
■ Air transportation

- One method of travel frequently used by response teams is helicopter. Be sure to receive a pre-flight safety briefing before boarding and follow instructions furnished by the pilot or loading supervisor.
- Following a disaster unusual hazards may exist that the pilot may not be familiar with. Unsafe acts on the part of the pilot and crew can also be a problem.
- Some of the issues to be concerned with include overloading, proper clearances for takeoff and landing, rotor wash, security around the helicopter, and adequate intercom capabilities so that team members can communicate during flight.



■ Ground Transportation

- Response teams, in general, have a long way to go towards understanding and following good safety practices when using ground transportation. Pay special attention to the following issues:
 - ◆ Never transport personnel and equipment on a open vehicle.
 - ◆ Provide safe seating for all personnel.
 - ◆ Never drive and navigate at the same time.
 - ◆ Cover tools and equipment for security purposes.
 - ◆ Familiarize the team with the assigned vehicle.
 - ◆ Conduct maintenance checks each day.
 - ◆ Maintain adequate fuel levels.
 - ◆ Travel in a convoy when possible.
 - ◆ Properly identify vehicles.
 - ◆ Red tag unsafe vehicles.



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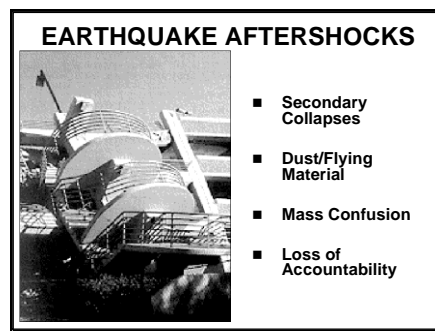
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RISK ASSESSMENT COMPONENTS (continued)

- Secondary collapse (aftershock, wind, vibration, removal of debris, gravity, explosions)
 - With the constant threat of terrorist attacks, it is essential that response teams pay special attention to a very new and potentially deadly threat. Secondary explosions are becoming common techniques used to cause serious injury and possibly many deaths for response teams.
 - Everyone has to heighten their awareness to their surroundings. There are no second chances when explosions are used for this purpose. It is safe to assume that a secondary device is involved, unless proven otherwise.



- Earthquakes aftershocks
 - Severe aftershocks following a major earthquake are common and can create additional injuries and fatalities.
 - Unstable structures including bridges, overpasses, high rises, and water towers may suffer further collapse as a result of aftershocks.
 - First responders must be constantly aware that they may be effected by such events and take the necessary precautions while conducting their operations.
 - Many injuries and deaths of first responders could be prevented if more precautions against additional aftershocks were taken.



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RISK ASSESSMENT COMPONENTS (continued)

■ Unfamiliar surroundings

- Traffic directional signs and other land marks may not survive the disaster impact. Traditional road maps may not be valid following a major disaster. Extra care to avoid accidents must be taken because the “new” landscape is distracting and may be confusing.
- Team members should not conduct assessments and drive a vehicle at the same time. A designated driver with no other responsibility must be assigned to provide transportation for the team.



■ Unstable structures

- Injuries to emergency responders, in many cases, are the result of falling debris and compromised surfaces. Team members must take extra precautions to minimize injuries by wearing required safety gear when working in the affected area. An injury during an operation becomes a team liability, which may prevent the completion of the task.



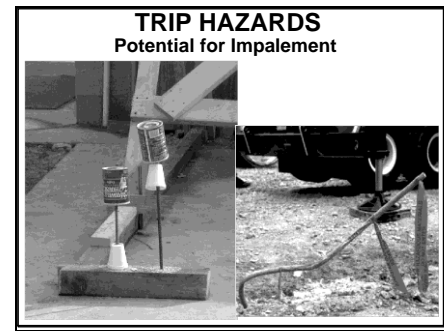
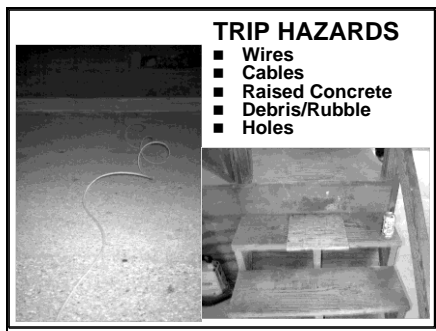
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RISK ASSESSMENT COMPONENTS (continued)

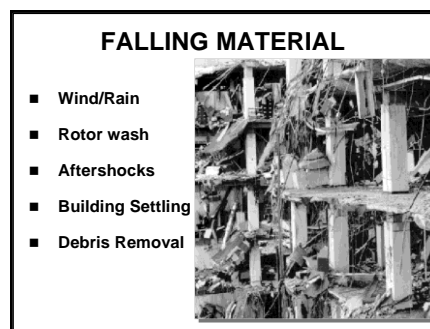
■ Fall or trip hazards

- Trip hazards are a common cause of falls resulting in injuries. This hazard is commonly found in the Base of Operations (BOO) and work site. In most cases, these hazards can be easily mitigated once identified. Some common trip hazards are:
 - ◆ Downed wire
 - ◆ Electrical cord
 - ◆ Holes
 - ◆ Uneven sidewalk / roads
 - ◆ Protruding rebar, ect.



■ Falling material or flying objects

- Displaced material may be everywhere. Aftershocks or wind may cause displaced objects to become airborne.
- Eye and head protection are essential. Eye injuries are especially painful and immediate treatment will be required to prevent further injury. Eye and head injuries are a liability to the team and may even require medical evacuation.
- Contact lens wearers are especially vulnerable. Responders with contact lenses should bring an extra pair of glasses.



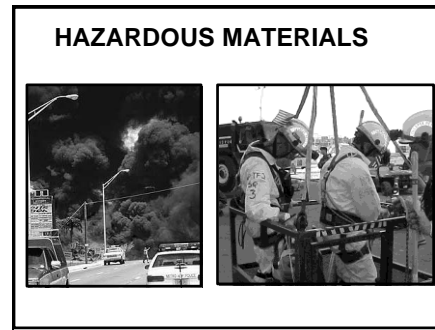
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RISK ASSESSMENT COMPONENTS (continued)

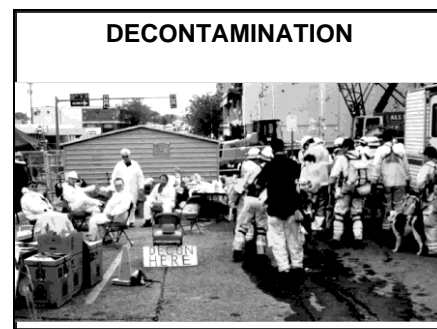
■ Exposure to Hazardous Materials

- There is a significant risk of exposure to hazardous material during the mission. There are two kinds of exposure to be consider prior to entering the impact area: direct exposure from an area that has been contaminated, and indirect exposure from moving water or a cloud/vapor plume moving through or beyond the impact area.
- Most facilities (major targets) such as hospitals, labs, universities, manufacturing plants, and warehouses have a broad array of hazardous material on site. Other major sources containing hazardous material are underground pipe lines, railroad cars, and trucking companies. Displaced power line transformers may also pose a significant risk to assessment teams.



■ Decontamination

- When initiating patient care or working around body fluids, use all proper protective equipment.
 - ◆ This includes at least gloves, mask, and eye protection.
- The team member should remove gloves carefully in order to prevent contamination.
- All medical waste should be properly disposed of in devices such as sharps containers and biohazard bags.
- If possible, wash hands thoroughly after each victim contact.
- Clean all equipment not discarded as soon as possible. Ensure canines are decontaminated.

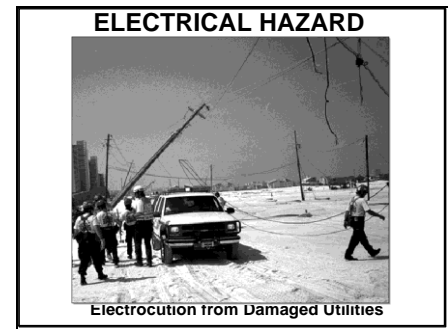
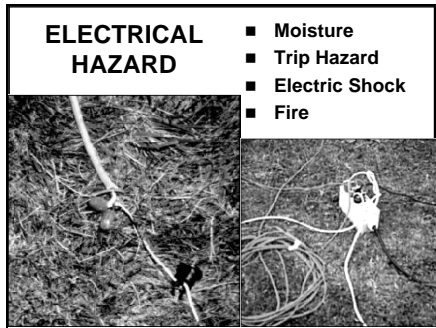


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RISK ASSESSMENT COMPONENTS (continued)

- Electrical hazards
 - Response teams have to be especially aware of electrical hazards that are commonly found during disaster response operations. There are many electrical related fatalities associated with disaster response operations. Some of the things to consider are:
 - ◆ Re-energizing power grids.
 - ◆ Improper electrical cord for current requirements.
 - ◆ Jury rigged connective boxes.
 - ◆ No weather protection.
 - ◆ Power line back feed (generators).



- Confined space operations with oxygen deficient atmospheres
 - Most fire department response teams should be properly trained to deal with this type of hazard. Adhering to proper protocols is the key.
- Contaminated air, water, and fuel
 - Contamination of air, water, and fuel sources following a disaster is likely. It is best to assume contamination has occurred until proven otherwise. Ensure that you have an adequate supply of water and fuel before entering the affected area. All response teams should have water purification units as part of their cache.

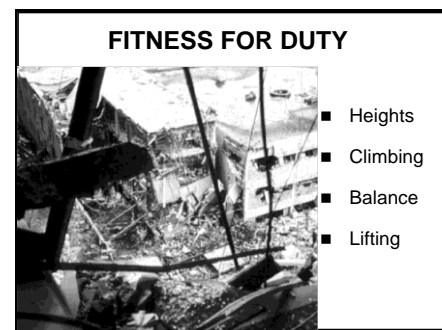


RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

RISK ASSESSMENT COMPONENTS (continued)

- Dangerous equipment
 - The Heavy Equipment and Rigging Specialist (HERS) is trained to aid the Safety Officer in anticipating and identifying the hazards posed by the use of heavy equipment at the disaster site. Hazards include:
 - ◆ Pinch zones created as a crane rotates on the base.
 - Need to cordon off the area around the crane with flagging tape.
 - ◆ No fly zones when rubble is being removed.
 - ◆ Overloads caused by the operation of excavators.



- Fitness for duty
 - Fitness for duty is sometimes a sensitive subject, especially when there is no national standard for response teams.
 - The better physical and mental condition that a team member is in prior to deployment, the better the individual will be able to perform their duties during extended operations.
 - Many response team members return home after a deployment run down and very ill. This problem can be minimized by improved fitness levels.
 - Disaster environmental issues to prepare for:
 - ◆ Working at heights.
 - ◆ Extensive climbing.
 - ◆ Prolonged heavy lifting.
 - ◆ Confined Spaces.
 - ◆ Walking on unbalanced objects.
 - A critical issue to remember is, that the adverse effects of drugs and alcohol consumption will interfere with sharp motor skills.

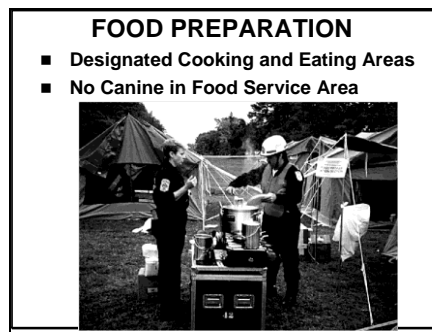
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

RISK ASSESSMENT COMPONENTS (continued)

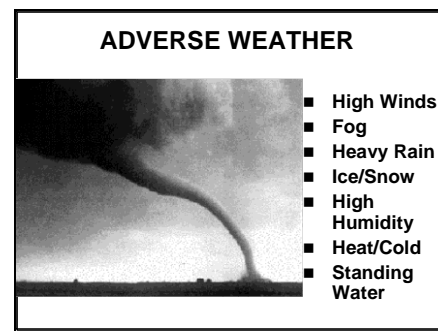
■ Food services

- Response team members need to be aware of diets and food preparation in the disaster environment. Our ability to preserve and process food in the field is very basic.
- Perishable foods need to be continuously monitored to ensure freshness. Spoilage in hot moist climates can happen surprisingly quick.
- Special precautions for monitoring food stock have to be followed. There is nothing more dangerous than a stale sandwich made using mayonnaise.
- Consider using freeze-dried products whenever possible.
- Civilians, with good intentions, will donate food to team members. Watch out! The consequences may be dysentery or food poisoning.



■ Adverse weather

- It is essential that you are prepared for any kind of weather change prior to leaving your point of departure. A weather change that the team is ill equipped to handle could jeopardize successful and timely completion of the mission.
- Rain and cold weather gear, as well as appropriate amounts and types of clothing, are required for all deployments. Wet and cold conditions could cause illness or injury among team members which would interfere with completing the assignment.



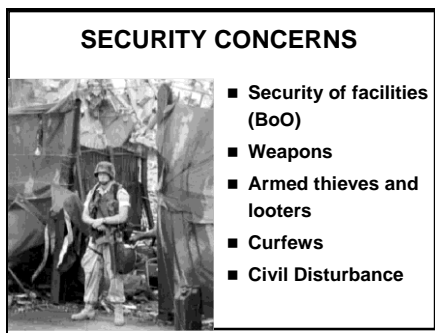
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

RISK ASSESSMENT COMPONENTS (continued)

■ Security

- Don't always count on a disaster area being secure. In many cases, one may find civil disturbance is jeopardizing response initiatives which further complicates the mission. These areas must be avoided until conditions are sufficiently safe for team members to perform their tasks.
- Area security is a state/local government's responsibility. In some cases, police escort may be necessary. Uniformed personnel may be targeted by undesirables seeking to take advantage of the damaged infrastructure.
- The work site may be a target of armed thieves and looters. Individuals may represent themselves as local rescue workers and blend into the operation. Watch for suspicious behavior.
- Irate relatives may also be present. Emotions may be high and abnormal behavior can occur. Look out for potential hostile situations.



SAFETY EQUIPMENT AND PERSONNEL ISSUES

RESPIRATORY PROTECTION

Protect the airway. Concrete dust, when inhaled, is an irritant to the alveoli of the lungs. When this membrane becomes irritated, fluid is secreted to protect the lining of the lungs. Unprotected rescuers and patients can contract pneumonia as a result of inhaling these particles.

Doctors have calculated the danger of inhaling small amounts of toxic materials over the years, however, they cannot predict the danger associated with inhaling large quantities over a short period of time. Don't take the chance, protect your airway.

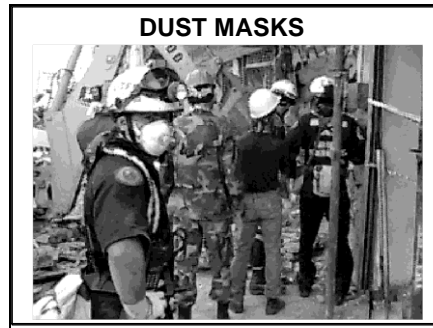
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STRUCTURAL COLLAPSE TECHNICIAN

RESPIRATORY PROTECTION EQUIPMENT

■ Dust Mask

- Simple paper or cloth mask which fits over the mouth and nose to filter out non-toxic particles.
- Will not filter out toxic materials and cannot be used in toxic environments
 - ◆ When exposure to silica is suspected (cutting or drilling through concrete or masonry materials creating dust), rescuers must wear an N95 NIOSH certified dust mask.
 - ◆ When exposure to asbestos is suspected, a P100 NIOSH certified dust mask must be worn.
- Cannot be used in an oxygen deficient atmosphere where the oxygen level is less than 19.5%.



■ Respirator

- Mask normally made of plastic which, depending on the design, fits over the mouth and nose or has a full face piece design which covers the entire face.
- With the appropriate filters, the respirator can filter out some, but not all toxic particulates.
- Cannot be used in an oxygen deficient atmosphere where the oxygen level is less than 19.5%.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

RESPIRATORY PROTECTION EQUIPMENT (continued)

■ Self Contained Breathing Apparatus (SCBA)

- SCBA supplies air to the wearer for a limited amount of time, from 10 to 40 minutes. It can be used in toxic and oxygen deficient environments. The SCBA face piece covers the entire face as well as the mouth and nose. The SCBA is bulky and can be difficult to use in confined spaces. When low on air, the bottle must be recharged or replaced. The SCBA is portable to the rescue site and is not tied to an external air source.



■ Supplied Air Breathing Apparatus (SABA)

- The SABA supplies air to the wearer for virtually unlimited amounts of time via an air source (large bottles or a compressor) outside the area of use. It can be used in toxic environments as well as oxygen deficient atmospheres.
- The air is supplied from the source through a supply line, through the regulator where the pressure is reduced, and to the rescuer who wears an SCBA style face piece.
- The rescuer also carries a small emergency air supply tank in case of emergency. This emergency supply is rated for 10 minutes, but may only deliver from 2 to 3-1/2 minutes of air depending upon the exertion rate of the wearer.
- The SABA is not as bulky as an SCBA and is easier to use in a confined space but the rescuer is limited in distance by the length of line and, most importantly, time to escape in the event the emergency air supply is needed.
- For confined space entries, the SCBA or SABA will be used if atmospheres are toxic or the oxygen levels are below 19.5%. Also, the rescuer should never place themselves in a position where they remove any portion of the breathing apparatus to get closer to the victim. Removing any portion of the breathing apparatus may cause the seal of the face piece to be broken, even just for seconds, causing severe consequences.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

RESPIRATORY PROTECTION EQUIPMENT (continued)

■ Monitoring Devices

- Ensure that appropriate monitoring equipment is available and utilized to support on-site operations including:
 - ◆ Atmospheric monitoring devices for checking toxic and oxygen levels
 - ◆ Structural stability monitoring equipment for determining building movement.

RESCUE TOOLS AND EQUIPMENT

All rescue tools should be operated and maintained in accordance with the manufacturer's guidelines. The maintenance should be documented. Many of these tools are dangerous because they cannot distinguish the rescuer from the material to be cut, broken, crushed, bent, folded, spindled, or mutilated. Always operate tools with respect.

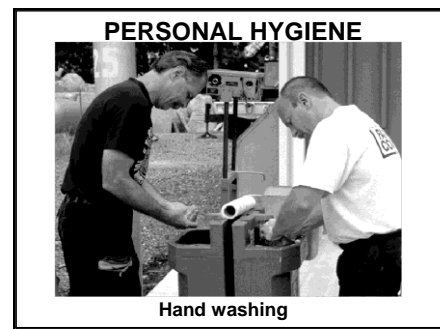
- The Rescue Specialist should only use tools that they have been properly trained to use. Some on-the-job training may occur out of necessity. When this happens, always emphasize the safety aspects of the operation. Use tools only for their designed purpose. Failure to do so will add a victim to the rescue and take a tool out-of-service.
- Anticipate the consequences of your actions. Observe those around you, for your safety as well as theirs. Turn off tools when not in use and store them in a tool staging area or return them to logistics. A cluttered work site will lead to tripping hazards and damaged tools.
- Light dim or dark areas during rescue operations to ensure proper operation of all tools and equipment. Protect personnel from electrical shock hazards. Fuel gasoline or diesel powered equipment in a designated safe area, away from active operations. Whenever possible, rotate rescue tools to provide for on-site inspection and maintenance.
- Provide hearing protection to rescuers and patients to protect them from excessive noise levels (greater than 90 decibels).
 - Provide patients with a helmet, eye protection, blanket, or other protection when necessary.
 - Advise patients of your operation before starting. This will help them for what will follow.
 - Allow patients the ability to participate in their own rescue. Do not treat them like a manikin.
 - Do not be surprised if the patient comes up with a better suggestion for their own rescue. They are a captive audience and subject to your plan, but some do know their immediate position better. From that perspective, their input may be invaluable.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

SAFETY EQUIPMENT

- All response team members must take personal responsibility to ensure that when they are deployed, they have the appropriate safety equipment assigned to them.
- Each member is responsible for the accountability of such property. The equipment cache may have additional equipment and supplies for expendable items.
- These items should be with each team member at all times:
 - Safety boots
 - Respiratory protection
 - Helmet
 - Headlamp
 - Spare batteries
 - Hearing protection
 - Eye protection
 - Gloves
 - Protective clothing
 - Radio (optional)



PERSONAL HYGIENE

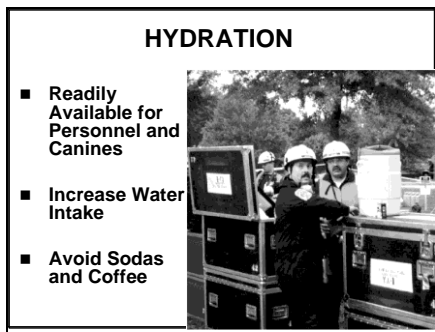
- Maintaining good personal hygiene is critical during disaster response operations.
- Having adequate changes of clothing is essential for maintaining good health practices.
- Exposure to unhealthy situations is an inevitable part of disaster response but it is the team member's responsibility to take extra precautions to minimize the exposure.
- Special consideration should be given to the following:
 - Feeding and hydration at the BoO and at the work site.
 - Keeping sleep and rehab areas free of unnecessary negative health exposures.
 - Hand wash stations where ever possible.
 - Canine relief and rehab areas established and enforced.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

HYDRATION

- Ensure all team members are following appropriate hydration practices.
- An ample amount of fluids should be readily available at all facilities including:
 - BoO
 - Work site
 - Command Post
 - Rehab area
 - Transport vehicles
- Avoid the use of carbonated drinks. Stay with water and juices if possible.



SAFETY CONCERNS DURING MOBILIZATION

- Safety concerns during mobilization include:
 - Assessment of their current physical fitness.
 - Successful completion of a current physical examination.
 - Current health assessment
 - Proper inoculations.
 - Appropriate personal safety equipment on hand.
 - Adequate prescription drugs

RESPONSE TEAM WELFARE CONCERNS

- A long, multiple day operation soon leads to fatigue and increases the chance of injury to team members. Proper shift length needs to be enforced and appropriate rehab facilities should be provided if possible. These facilities (tents, bldgs.) should be inspected to ensure quality rest can be obtained. Some things to consider are:
 - Individual sleep habits (snoring or talking in sleep)
 - Barking canines
 - Pagers/cell phones
 - Aircraft overflights
 - PA systems
 - Noise from generators

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

TOPIC 1-3: STRUCTURAL ENGINEERING SYSTEMS

This module is intended to provide the Structural Collapse Technician with information on the engineering aspects of structural collapse.

This module is divided into five parts:

- PART 1 MATERIALS, STRUCTURAL SYSTEMS, AND BUILDING CHARACTERISTICS
- PART 2 CAUSES OF COLLAPSE
- PART 3 COLLAPSE PATTERNS
- PART 4 HAZARD IDENTIFICATION, INTRODUCTION TO ASSESSMENT AND MITIGATION
- PART 5 URBAN SEARCH AND RESCUE STRATEGY AND STRUCTURE SIZE-UP

PART 1 MATERIALS, STRUCTURAL SYSTEMS, AND BUILDING CHARACTERISTICS

TERMINAL OBJECTIVES

- The student will understand the essential materials and components of structures, and how they behave when subjected to extreme loading.
- The student will understand how buildings are classified by Engineers and their common characteristics.

ENABLING OBJECTIVES

- Understand the basics of how various building materials resist forces.
- Understand the importance of ductile and brittle behavior.
- Understand the concept of vertical and lateral load resisting systems.
- Understand structural redundancy.
- Understand the characteristics of common types of buildings found within the United States.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

FORCE TYPES

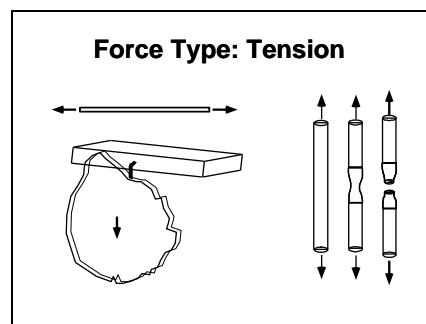
Individual **loads**, usually referred to as **forces**, can be divided into four types; **tension**, **compression**, **bending**, and **shear**.

- When a force is applied to an individual member, it produces **stress**, which is defined as the force divided by the cross-sectional area on which it acts.
 - A 1000 lb. force (also called 1 Kip or 1K) acting in tension on a 2"x 2" steel bar produces a tension stress of 250 lbs. per square inch (psi).

TENSION FORCES

Tension forces stretch members of steel or wood. Concrete and masonry have no reliable tension strength.

- When a moderate tension force is applied, a steel bar will lengthen. When the force is removed, the bar will return to its original length. This change is called **elastic** behavior and can be repeated many times in competent steel and wood members.
- If a much larger force is applied to the steel bar, it will start to lengthen more rapidly. When this lengthening occurs, the cross-section of the bar will start to get smaller (neck down). When the force is removed, the bar will not return to its original length since it has experienced permanent yielding (**ductile** behavior).
- The ductile behavior of steel in tension provides the special property of forgiveness (warning of failure) and response that makes it especially desirable in resisting dynamic loading.
 - Ductile behavior is the ability of a material to stretch and/or bend without suddenly breaking. After the load is removed, it can remain stretched or bent and then be re-loaded.
 - ◆ One can bend rebar into a hook and unbend it without breaking it.
 - **Brittle** behavior means that the material will break without warning (catastrophic failure).



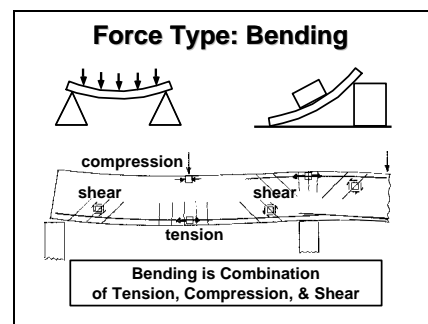
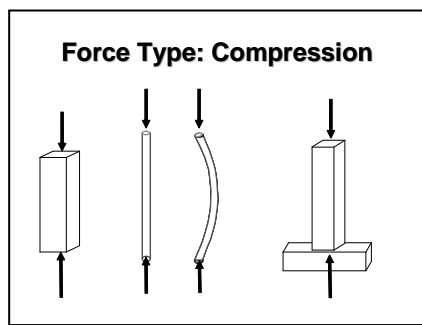
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COMPRESSION FORCES

Compression forces push on members and can lead to the crushing of materials.

- At bearing surfaces between wood or concrete beams and columns, crushing can also occur.
- Crushing failures tend to give warning, such as local splitting of concrete and the noisy, slow, compression of wood fibers.
- When long, slender members are loaded in compression, they can fail suddenly by buckling (bowing).
 - This type of sudden failure should be avoided.



BENDING FORCES

Bending forces occur mostly when vertical loads subject to gravity are applied to floor slabs and beams. Bending forces also occur in sloped roof rafters and in the sloped slabs found in rubble piles.

- Bending causes the bottom of a simple beam to become stretched in tension and the top to be pushed together in compression.
- Continuous beams and cantiliver beams experience tension forces at the top and compression forces at the bottom near their supports. In the mid-span of continuous beams, the forces are in the same location as for simple beams and slabs.
- Vertical cracks develop near the mid-span of concrete members since the tension force causes the concrete to crack. The reinforcing steel (rebar) will then resist the tension force.
 - Observing this cracking in damaged structures can aid in monitoring and determining the potential for collapse.
 - Stable hairline cracks are normal, but widening cracks indicate impending failure.
- Structural steel and reinforced concrete, moment- resistant frames experience tension and compression stresses on opposite faces (similar to continuous beams). These stresses can reverse themselves during earthquakes and high winds.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

SHEAR FORCES

Shear force can be described as the tendency to tear the member's surfaces apart.

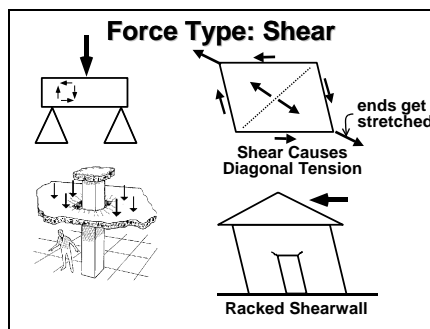
- Shear stresses occur in all beams and are greatest in areas adjacent to supports.
 - Consider a beam made from a group of individual books as they sit on a bookcase, with a long threaded rod extending all the way through them, tightened with nuts at each end. If this beam is placed so that it spans the gap between two tables and someone attempts to push one of the books down to the floor, a shear force will be exerted on the surface of the books immediately adjacent to the one being pushed.
- In concrete beams, these shear stresses cause diagonal tension cracks because concrete is very weak in tension.
- When an element is loaded in shear, it will tend to change from a square to a parallelogram. As this change happens, the element stretches in one direction, thereby causing tension across the diagonal.
 - This diagonal cracking should be monitored in damaged beams, girders, columns, and walls.
- Wood beams are strong in tension and compression but are particularly weak in shear.

Punching shear occurs where a flat, two-way concrete slab is connected to a column and the tendency of the slab is to drop as a unit around the column.

- The column appears to punch through the slab.
 - Cracking that indicates the over-stress leading to this type of collapse is most visible on the top surface of the slab, which is often covered by debris during USAR operations.
 - The debris may be causing the overload, and also make it difficult to assess, since the cracking may not be visible.

Bolt shear is the tendency of a steel, pin-like connector (such as a bolt, nail, or screw) to break across it's cross-section.

- A roll of coins is sheared off as each coin slips past another.
- This type of failure can be sudden.
 - Nail failures in wood structures, which involve some degree of pullout, can occur with enough deformation to give warning.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

BUILDING WALL SHEAR AND OVERTURN FORCES

Lateral forces (forces applied horizontally to a structure) derived from winds or earthquakes cause shear and bending forces in walls.

- The shear forces tend to tear the wall surface, just as if someone had a piece of paper attached to a frame and changed the frame's shape from a rectangle to a parallelogram.
 - This changing of shape is called **racking**.
 - When shear walls are pushed out of plumb in their plane, they are said to be racked.
- At the ends of shear walls, there is a tendency for these walls to be lifted at the end where the lateral force is applied and a tendency for the wall to be pushed down at the end away from the force.
 - This action is called **overturning**.

MATERIAL PROPERTIES

WOOD

Wood is tough, light, fibrous, fire supporting, cut from living trees, and graded by humans.

- It has defects like knots, splits, and non-straight grain that concentrates stress.
- The growth pattern of fast growing springwood, compared to that of slower growing summerwood, leads to structural problems. These problems include:
 - Weakness in cross-grain tension and compression.
 - Weakness in shear strength parallel to the grain.
 - Shrinkage and splitting.
- Live wood may be as much as 50% water, while older, seasoned wood (as found in a structure) may contain as little as 10% water. The volume of the wood can change as much as 10% over this range.
- Shrinkage (usually in width or depth, not length) causes special problems in bolted connections. Splits may be formed that allow the bolt to slip out of the joint along the split.
- Connections are best made by bearing one member on its supporting member, however, metal connection devices can be successfully used.
 - Nailed connections perform well as long as splitting is avoided.
 - Bolting may be successful if adequate spacing and edge distances are provided.
- Properly proportioned wood structures can exhibit ductility.
 - When wood posts are kept short and bear on the cross-grain surfaces of beams or sole plates, slow crushing of the cross-grain can warn of failure.
 - Box cribbing will exhibit this same failure mode since all the load is transferred in cross-grain bearing.
- The plywood sheathing of wood structures makes them very tough and earthquake resistant as long as the sheathing is nailed properly.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

STEEL

Steel is tough, strong, ductile, can be formed into any shape, but needs to be fireproofed.

- It starts to lose strength above 700° F.
- It has the almost magical property of ductility. It can be stressed beyond its elastic limit and severely bent but still have enough strength to resist failure.
 - This property makes it the ideal structural material, in that it gives warning of collapse (has forgiveness).
- Steel is strong with respect to tension, compression, and shear.
- Steel beams must be laterally braced so as not to buckle about the weak axis, especially if the ductile performance required for earthquake resistance is expected.
- Steel framed structures must be properly proportioned in order to avoid the overloading of columns.
 - Diagonal bracing members can overload columns during earthquakes if these columns are not proportioned such that their strength exceeds the total force that can be delivered to them by the diagonals.
- Steel can be very efficiently connected by bolting or welding (older structures used rivets instead of bolts).
- Welded joints must be properly designed and constructed or they can fail because of their brittle nature.

CONCRETE

Concrete is essentially cast rock that is strong in compression but weak in tension and shear.

- Steel bars are cast into concrete to provide for the longitudinal tension force. Enclosing type steel ties and stirrups are added for confinement and shear resistance.
- Sufficient steel can be added to provide adequate toughness for seismic resistance, enabling reinforced concrete to exhibit ductile properties similar to those of structural steel.
- Concrete can also be reinforced by adding high strength cable or bars that are **pre-tensioned** prior to their being loaded by the structure's weight (pre-stressed concrete).
 - Structures of this type may be pre-cast in a factory using pre-tensioned reinforcing that is stretched in a form and then bonded to the concrete when it is cast.
- Another method is to place cables that are enclosed in plastic sleeves in the forms at the job site, pour the concrete, and then stretch and anchor the cables after the concrete has cured and achieved sufficient strength (**post-tensioned**).
 - In this case, the cables are not bonded to the concrete but only anchored at the edges of the structure.
 - ◆ These unbonded cables can cause difficulties when dealing with a damaged post-tensioned structure.
- Concrete shrinks, cracks, and creeps under normal circumstances, and this normal behavior needs to be differentiated from the cracking and spalling that indicates failure.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

CONCRETE (Continued)

- Concrete is easily connected together if cast-in-place but must be very competently connected together if it is pre-cast.
 - Since pre-cast concrete members (especially pre-stressed, pre-cast members) can be very strong, the joints that connect them must be very tough (ductile) in order to resist the high dynamic forces generated by an earthquake.
- Properly reinforced concrete can provide seismically resistant construction if the reinforcing is proportioned such that the confining tie, hoop, and stirrups are sufficient to resist the shear that can be generated by the overall structure.
- Wall-like structures of cast-in-place and pre-cast concrete have outperformed frame type construction in most earthquakes.

UNREINFORCED CONCRETE

- Unreinforced concrete walls can be found in structures built before about 1910.
 - These structures perform very poorly in earthquakes, as they tend to break into large pieces defined by shrinkage cracks or original pour joints (very brittle material).

REINFORCED MASONRY

Reinforced masonry is made from clay brick or hollow concrete blocks, formed into walls using mortar joints and a concrete grout filling the interior cavities in seismically resistant construction.

- Since masonry properties are similar to concrete, reinforcing steel bars are normally added to provide tension and shear resistance.
 - In reinforced brick masonry, two single-brick thick outer layers (wythes) are laid up and then rebar and grout are placed between the layers.
 - ◆ The wythes are connected with large wire to prevent blowout when the grout is poured.
 - ◆ Small, heavy wire, ladder type reinforcing is used at the joints in some cases.
 - In concrete hollow unit masonry (CMU), each block comes with preformed cavities.
 - ◆ As the units are laid up, horizontal reinforcing (small rebar or large wire) is placed in the joints.
 - ◆ After the wall reaches a predetermined height, vertical rebar is placed in specified cells and then grout is poured to bond the reinforcing steel to the concrete units.
- Masonry wall construction is highly dependent on workmanship if it is to provide adequate mortar and grout strength.
 - These products are often mixed on the job in small quantities.
- Adequately reinforced masonry walls can be used in seismically resistant construction and can exhibit very good ductility if carefully designed and constructed.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

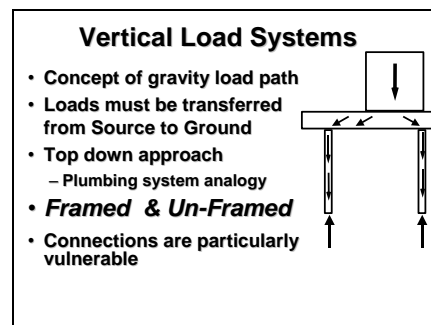
UNREINFORCED MASONRY (URM)

- Unreinforced masonry structures are not currently built in seismic risk areas, but many structures with URM walls still exist throughout the world.
- This is a very brittle material.
- Walls were constructed with a thickness of three or more bricks laid long ways, side by side, five or six layers high (courses), and then a layer was placed with the bricks at 90° (header course), and so on.
- URM walls date back to the late 1800's in California, and back to the 1700's in other parts of the United States. The strength of the bricks is generally higher outside of California.
- The strength and seismic performance of unreinforced masonry is highly dependent on the mortar strength.
 - The shear strength of mortar can vary from 15 psi to over 150 psi and is determined by both the proportion of lime to Portland cement and the workmanship.
 - ◆ Lime produces a nice, buttery mortar, but too much of it produces a low strength.
 - ◆ Lime can also be leached out of the mortar by water over time.
- Decorative veneers are a special seismic problem.
 - Veneers are often laid up with building paper between them and the URM wall, and are anchored with wire or galvanized ties.
 - ◆ The ties normally corrode away within 20 years or so, leaving a heavy brick face just waiting to peel off when subjected to a lateral load.
 - Masonry veneers are also found on the outside surface of wood walls.
 - ◆ There, veneers are subject to the same anchorage problems, as well as being dynamically incompatible with the flexibility of the wood walls.
- URM walls are made from native stone in many places in the world and have performed very poorly in earthquakes.

VERTICAL LOAD RESISTANT SYSTEMS

Structural members in these systems can be divided into two types:

- Those that form horizontal (or sloped roof) planes.
- Those that provide the vertical support for these planes.



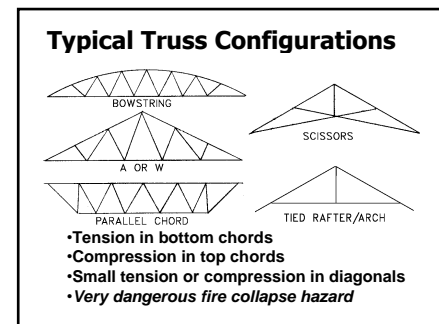
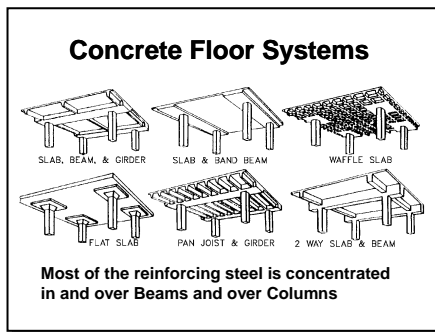
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

HORIZONTAL MEMBERS

Horizontal members support floor or roof planes and are normally loaded in bending.

- Wood
 - Rafters, joists, purlins, beams, and girders
- Steel
 - Corrugated sheets (filled with concrete), joists, purlins, beams, and girders
- Reinforced concrete floor systems may be of many types. All have some relationship to the economy of providing adequate structural depth with available forming materials.
- Pre-cast concrete floors may contain planks, cored slabs, single or double tees, beams, and girders. Most modern systems in California combine a cast-in-place overlay slab to provide adequate interconnection of individual members and overall planar stability.
 - These individual members need to be interconnected to their support planes in order to provide the lateral stability to resist the extreme fiber compression forces associated with bending, which occur on the top or bottom of the members.



TRUSSES

Trusses are special vertical, load resistant members that use greater depth for structural efficiency but require lateral bracing of compression members.

- Trusses are usually made from wood or steel, although concrete is used in some areas of the world.
- Individual members are stressed in either tension or compression, although stress may reverse itself in some members because of changes in live loads (people, vehicles, and rain/snow).
- Compression members are usually governed by buckling, and tension members are usually governed by their connections.
- Trusses have not performed well in many situations of overload, fire, and when wood tension has performed poorly.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

VERTICAL SUPPORT MEMBERS

Vertical support members are normally configured as bearing walls or columns.

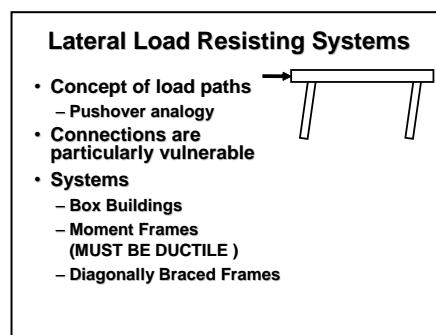
- In wood and light frame steel systems, the bearing walls are made using closely spaced columns (studs at 16" to 24" oc) that must be interconnected by a skin in order to provide the lateral stability that will allow the individual members to be loaded with respect to compression without buckling.
- Concrete and masonry bearing walls are proportioned so as to carry heavy vertical loads depending on their height to thickness ratio.
- Individual columns (posts) normally carry large compression forces and may be made of wood, steel, or reinforced concrete. In all cases, the load capacity is based on the member's slenderness ratio (L/D) as well as the adequacy of the connection between the column and the horizontal system.
- All vertical load systems need some system to provide for lateral stability (the proper alignment of the vertical load path). These lateral load systems need to be capable of resisting lateral forces that constitute at least 2% of the structure's weight (much more in seismic zones).
- Vertical load systems are usually configured as either framed or unframed systems, but may be a combination of both.
 - **Framed** systems have a uniform grid of columns and beams. Steel and concrete frame buildings are common examples.
 - ◆ Since spans tend to be longer, the collapse of one column may involve an area twice the column spacing in each direction.
 - **Unframed** systems usually employ bearing walls for vertical support.
 - ◆ Since spans tend to be shorter and have more redundancy, they tend to perform better under extreme loading. Collapse area may be limited to only one room, or between one pair of walls.

LATERAL LOAD RESISTANT SYSTEMS

Most structures can be grouped into two basic types of lateral load resistant systems:

- Shear wall/box systems
- Frame systems

Buildings may contain sections of each type. Some buildings have been designed with a dual system containing both types of lateral bracing in order to provide a more redundant system, which is highly desirable.



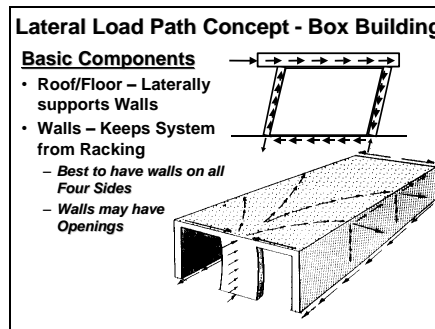
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

SHEAR WALL/BOX BUILDINGS

Shear wall/box buildings are buildings with exterior walls that provide bearing strength as well as seismic resistance. They may or may not have interior, structural walls. Floors and flat or sloped roof planes called diaphragms form the horizontal surfaces to complete the boxes, with the walls forming the sides.

- In the typical action of a box structure subjected to lateral loads, floor and roof planes act like giant beams as stresses in tension and compression are generated at the edges and shear stresses are distributed throughout the plane.
- The floor and roof planes (diaphragms) span horizontally between exterior (and sometimes interior) walls, which provides each horizontal plane with lateral support. The shear walls are in turn loaded by the floor diaphragm and must be capable of resisting both the shear stresses and bending stresses caused by overturning.
- Floor and roof diaphragms are made of plywood, diagonal wood sheathing, corrugated metal deck (with and without concrete topping), and concrete.
- Shear walls are made of plywood and solid wood sheathing over studs, concrete, and concrete block.
- In the very lightweight wood systems, the skin (sheathing) carries all of the lateral shear force but is a minor vertical support member. In concrete and concrete block systems, the vertical and lateral loads are carried by bearing walls and the relatively heavy reinforced concrete slab.



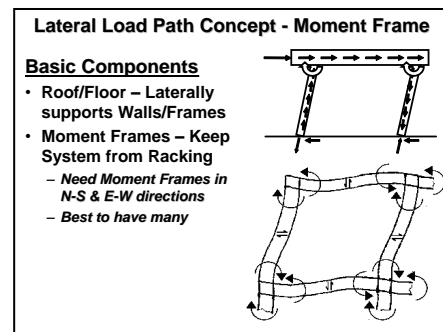
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

MOMENT-RESISTANT FRAME BUILDINGS

The walls for this type of building are normally constructed for enclosure purposes only and may be of glass, light framing with a non-structural covering (such as plaster veneer, brick or stone, or finish wood), or a combination of pre-cast concrete and glass. Large, evenly spaced columns of steel or reinforced concrete carry the vertical load.

- The floor and roof diaphragms are constructed as in the box system. However, the forces developed in the diaphragms are usually smaller since they do not have to span as far.
- Lateral load resistance is provided by the interconnection of large, tough floor beams or girders, and the columns. The frame made by the beams and columns is kept from changing into a parallelogram by making the connections as strong as the members. Structural steel and well confined, heavily reinforced concrete are used today for these moment-resistant frames.
- Structural toughness (the ability to repeatedly sustain reversible stresses in the inelastic range without significant degradation) is essential for a moment-resistant frame. Most concrete frames built before 1965 in California (and other seismic zones with similar building codes) were not constructed with much structural toughness.
- Structural steel frames have out performed concrete frames in the past. There are examples of lightly connected steel frames that survived the San Francisco 1906 earthquake. However, they were susceptible to fire damage.
- Tall buildings with moment-resistant frames may generate significant tension and compression forces in the exterior and/or corner columns. High tension can be very detrimental to older concrete frames since severe cracking can result in catastrophic failures when the loading is reversed and the member is also required to resist bedding. High compression forces in steel frames can cause buckling of either tube or wide-flange columns.
- Modern building codes require that the columns be stronger than the sum of the connecting beams at any story, so that when inelastic action occurs it will form hinges in the beams, not the columns. Since modern steel moment-resistant frames are connected by welding, good workmanship is critical. Visual inspection and ultrasonic testing are normally required to assure quality.
- Moment-resistant frames can be used in combination with concrete shear walls to provide a dual system.
- Older, pre-1960, steel moment-resistant frames may be covered with cast-in-place concrete fireproofing (important identification information).



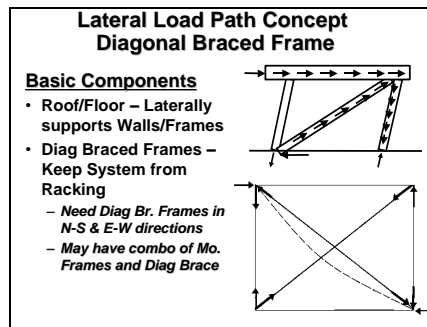
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

DIAGONALLY BRACED FRAME BUILDINGS

These buildings are constructed similarly to moment-resistant frame structures.

- The lateral load resistance is provided by adding diagonal members between columns to prevent lateral racking.
- Alternately reversing tension and compression forces are generated in the diagonal members, which are usually made of structural steel, although reinforced concrete has been used, especially in Central and South America.
- Diagonal members should be able to resist both tension and compression. The whipping action of slender rod cross-bracing can allow too much distortion. An exception is that light, steel frame, industrial buildings have performed reasonably well with slender rod cross-bracing, since corrugated metal finishes are quite flexible.
- The columns in diagonally braced frames need to be proportioned so that they are stronger than the tension capacity of the braces that are connected to them. This proportion assures that failure will not occur in the columns, yet it has only been required in recent building codes.
- Diagonal members are normally made from double angles or tube sections, and connections must be carefully detailed and built, in order to prevent local buckling and/or other joint failure.
- Diagonally braced frames have been used in combination with moment-resistant frames to provide a highly desirable dual system. They are configured as braces within a moment-resistant frame bay to provide a bracing system that combines the toughness of a moment-resistant frame with the rigidity of a braced frame.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

REDUNDANCY

Redundancy in a structure means that there is more than one path of resistance for lateral forces.

- Especially in seismic zones, it is important for the lateral load system to possess some degree of redundancy.
- Redundancy can be achieved by:
 - More than one shear wall panel or more than one diagonal brace in every line of resistance.
 - A moment-resistant frame with many columns and beams, all with ductile connections.
 - A dual system, like shear walls in addition to a moment-resistant frame.

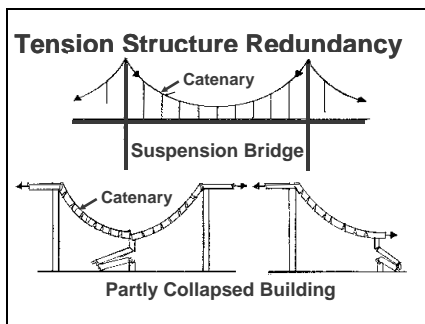
Redundancy

- Multi - Elements
(at least 2 in every line of resistance)
 - Box Buildings
 - Diagonal Braced Frames
- Majority of Connections
 - Moment Frames
- Dual Systems
- Collapse Preventers

SUSPENSION/TENSION STRUCTURES

Suspension/Tension structures are not commonly used in building structures. These very efficient structures require significant height (cable drape) to span great distances.

- Earthquake damaged, reinforced concrete slabs often form tension-like structures after the failure of a vertical support. Failures of a vertical support will cause unplanned tension forces in the remainder of the structure, which may cause lean-over of the remaining walls.
- This action can prevent complete collapse, but it leaves a condition that is difficult to assess. The slabs may be hanging on reinforcing steel with unknown and/or unreliable embedment.

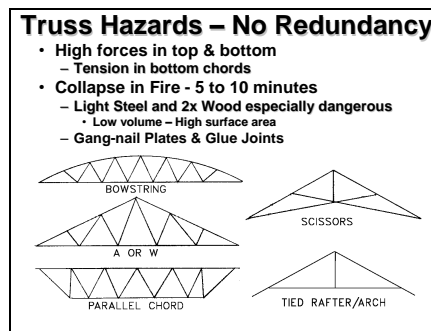


RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

TRUSS HAZARDS (NO REDUNDANCY)

- Wood trusses have failed many times due to seasonal defects. Wood checks (splits) that occur near the ends of tension members have led to many pull-through bolted connection failures. Overloads due to rain or snow can lead to sudden collapse resulting from a compression member buckling or a tension connection failure. The use of closely spaced trusses with gang-nail connection plates and specially fabricated wood with steel pin connected bars has improved the reliability of wood trusses.
- Steel trusses have been fairly reliable, but they are also susceptible to sudden compression member failure, due to a temporary overload and loss of stability resulting from inadequate bracing.
- Trusses present special problems when shoring a hazardous structure. The support provided by the shoring must be applied so as not to cause a stability problem or overload of a small or inadequately braced individual truss member. It is usually a bad idea to shore a truss at the bottom.
- Light wood and steel trusses are very susceptible to sudden collapse due to fire.
 - Wood trusses with 2" members, connected by gang-nails or glue, provide an abundance of fuel in ceiling spaces, and collapse quickly.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

BUILDING TYPES AND CHARACTERISTICS

ATC-20, Procedures for Post Earthquake Safety Evaluation of Structures and ATC-21, Rapid Visual Screening of Buildings for Potential Seismic Hazards, were funded by FEMA and written by the Applied Technology Council (ATC) in 1988. The ATC was created by the Structural Engineers Association of California to develop and manage research and other projects that add to the body of knowledge regarding structures.

- ACT20 and ACT21 define twelve specific building types based on how they respond to earthquakes.
 - They are defined by the type of material used in construction as well as the type of lateral load resistant system employed.
 - ◆ For example, concrete construction has a C1 Type that has a moment-resistant frame, a C2 Type that is a box building with shear walls for lateral resistance, and a C3 Type to cover the many buildings that have a moment-resistant frame with masonry infill walls for a fireproof exterior enclosure.
 - ◆ One exception is that wood buildings are subdivided by size into W1 for smaller residential structures and W2 for structures over 5000 sq. feet.
 - The W2 classification covers apartments that are two stories and more as well as commercial, institutional, and industrial structures.
- The FEMA USAR Response System has adopted the ACT20 nomenclature for use in identifying damaged structures.
- Other systems, such as the Building Code and Francis Brannigan's Building Construction for the Fire Service, are based on resistance and response to fire. They are not specific enough to be useful in describing structural response to earthquakes and the other destructive forces encountered in USAR. Another book written for the fire service that is highly recommended is, Collapse of Burning Buildings by Chief Vincent Dunn, Fire Department of the City of New York. It describes many actual incidents and gives the reader a real insight from lessons learned.

Building types - ATC-20

- W1 Dwellings & small wood buildings
- W2 Wood bldg over 5000sf & 3+ story
- S1 Steel moment resisting frames
- S2 Braced steel frames
- S3 Light metal buildings
- S4 Steel frames w/C I P conc walls

Building types - ATC-20

- C1 Concrete moment resisting frames
- C2 Concrete shear wall buildings
- C3/S5 Conc/steel frame w/urm infill walls
- TU/PC1 Tilt-up concrete wall building
- PC2 Precast concrete frame buildings
- RM Reinforced masonry buildings
- URM Unreinforced masonry building

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

PROBLEM BUILDINGS

These are building types that have been susceptible to earthquake and/or wind damage in the past.

- The list includes most structural types.
 - S2, C1, C3/S5, TU, PC2, and URM are expected to be the most susceptible to earthquake damage throughout the United States.
 - W1 and W2 residential structures have also experienced a large number of failures on the U.S. west coast, since they are the most prevalent building type. There is the potential for the entrapment of victims in W2 multi-story wood structures.
 - Poorly connected W1 and W2 wood structures are also very vulnerable to wind damage.
 - Type S3 is listed since it is very susceptible to damage by wind.
 - Many S1 structures experienced cracks in their welded connections during the Northridge (Los Angeles) earthquake, which is of great concern to the design profession. None of these buildings were damaged to an extent that would cause collapse, but they may become a problem in future earthquakes.
- Earthquakes consistently cause damage to buildings with an irregular shape and inconsistent stiffness.
 - Earthquakes produce motions (not forces), and the shaking is able to find these inconsistencies, thereby causing severe overloading.
- Earthquakes and windstorms affect different types of structures.
 - Mass and rigidity develop high forces due to earthquakes but provide resistance to high winds.

Problem Buildings

- W 1 & 2 1 to 3 story houses & 2 to 4 story apartments (especially pre 1970)
- S1 Frames w/brittle welded conns
- S2 Frames where column capacity is less than capacity of diag braces
- S3 Light structure vulnerable to Wind
- C1/C3 Pre 1971 bldgs (espec pre 1941)
- PC2/TU Factory built precast & tilt-up wall
- URM 1 to 8 story (most 3 story & less) + steel & conc frames w/URM infill
- Others Irregular - soft story, open front

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

WOOD FRAME BUILDINGS (W1 AND W2)

These structures can vary from one to four stories and contain from 1 to over 100 living units. W2 structures are larger than 5000sq. feet.

- The principle weakness may be in the lateral strength of walls or interconnection of the structure, especially at the foundation.
- Wood structures are unique in that the vertical load resisting systems (joists, beams, studs, and posts) are covered with a skin to form the lateral load resisting system. This is different than other bearing wall systems.
- Common problems in strong earthquakes are:
 - Walls that are weakened by too many openings becoming racked (rectangles become parallelograms).
 - ◆ This weakening can cause a significant offset of one floor from another, and in severe cases, collapse has occurred.
 - Relatively modern W2, two and three story wood apartment buildings, may have walls that are braced using only plaster/gypsum board, let-in bracing, or inadequately designed plywood.
 - ◆ These structures may experience brittle, first story failures, especially when upper story walls do not align with lower story walls.
 - ◆ These structures are especially vulnerable to earthquake damage when lightweight concrete fill has been added to provide better sound control (greater mass means that greater earthquake force is generated).
 - W1 houses with crawl spaces can shift or slide off their foundations.
 - Masonry chimneys can crack and fall off or into the structure (mostly W1 type).
 - Masonry veneers can fall off walls and shower adjacent areas with potentially lethal objects (especially deadly for W2 types).
 - Structures can separate at offsets in floor/roof levels (such as porches and split level houses).
 - A great danger of fire exists for these structures due to the presence of so much fuel.

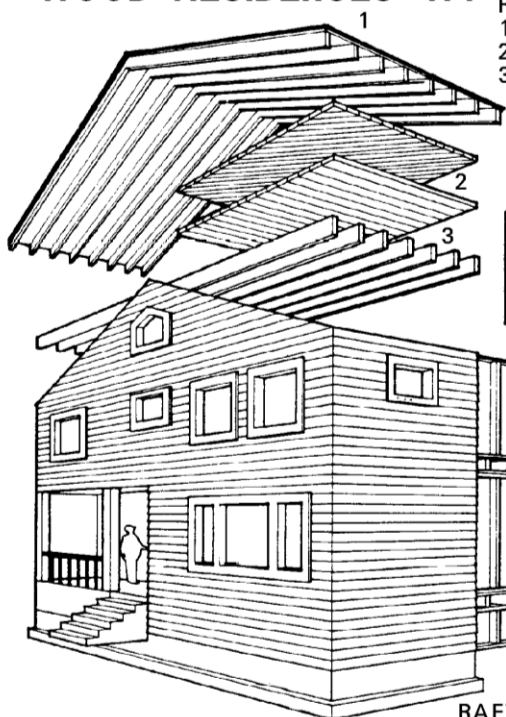
W1 & 2 Type Characteristics

- Bearing Wall System
 - Light Frame (2X wood framing or light gage steel framing) Un-Framed System
- Typical Occupancies
 - Residential, light commercial – up to 4 stories
- Key Performance Aspects
 - Many walls create redundant structures w/ significant overstrength, generally ductile failure modes, depending on sheathing type.
- Combinations
 - May be built above R/C parking garage
 - Frequently used for interior partitions in residential and commercial masonry structure

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

WOOD RESIDENCES - W1



Roof/Floor Systems:

1. wood rafters and spaced or solid sheathing
2. wood ceiling joist with finish
3. wood floor joist and solid 1x sheathing or plywood sheathing in newer houses

Wall Systems:

4. Wood finish on studs or Stucco on solid wood sheathing: plywood, 1x straight or diagonal boards.
5. Wood studs either platform framed as shown or balloon framed

Other Features:

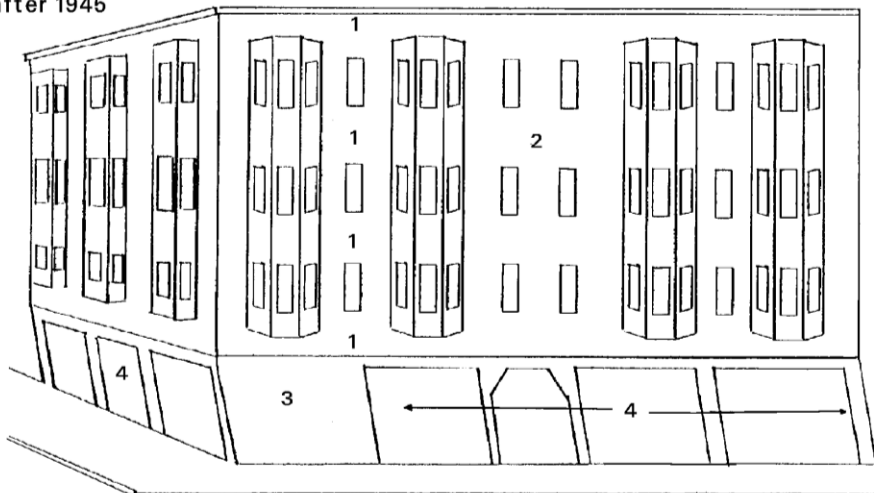
6. Masonry chimney
7. Cripple wall below 1st floor (often w/vent holes)
8. Floor joist may bear directly on footing.

BOX TYPE STRUCTURE

RAFTERS, JOIST, & STUDS are VERTICAL LOAD SYS.
SHEATHING is LATERAL LOAD SYSTEM

WOOD FRAME APARTMENT BUILDINGS - W2

1. 2x wood joist at roof/floors with 1x wood sheathing or plywood (post 1945)
2. Wood studs, platform framed with wood sheathing:
1x horizontal - pre 1935
1x diagonal - pre 1945
Plywood, Gypsum, or wire after 1945
3. Walls may have masonry veneer especially in first story
4. First story garage openings create a weak/soft story. This can be overcome by using properly designed shearwalls or by changing the garage to a concrete structure with strong shearwalls.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

STEEL, MOMENT-RESISTANT FRAME BUILDINGS (S1)

Steel, moment-resistant frame buildings may be from one to over one-hundred story office buildings with glass or other non-structural exterior coverings.

- Steel buildings in general have performed well, but in recent earthquakes moment-resistant frames have exhibited the following problems:
 - In both the Northridge and Kobe earthquakes, the violent shaking caused some welded connections to crack.
 - No buildings of this type collapsed during these earthquakes, but a few were racked out of plumb, and new better performing joints have been designed to repair or replace questionable ones.
 - ◆ Since these connections are what give moment-resistant frames their lateral resistance, it is possible that a future great earthquake (magnitude 7.5 to 8.5) could cause a catastrophic collapse, especially if the following occur:
 - Shaking lasts for more than 30 seconds.
 - A structure has little redundancy (only a few columns with welded joints), and the joints are the type that can crack and fail.

S1 Type Characteristics

- Frame System
 - Heavy Structural Steel (hot rolled sections)
- Typical Occupancies
 - Office & Commercial, Industrial, Highway bridges
 - 2 to 100 stories
- Key Performance Aspects
 - Normally well-engineered; Members very ductile.
 - Overall performance dependent upon connections
 - welds may be brittle.
 - PC or URM, Ext wall panels usually perform badly
- Combinations
 - Precast or CIP concrete floors w/ or w/o metal deck
 - Masonry, precast or metal curtain walls;
 - URM partitions

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

DIAGONALLY BRACED STEEL FRAME BUILDINGS (S2)

These buildings may be from one to twenty story office buildings with glass or other non-structural exterior coverings.

- Steel buildings in general have performed well, but those with diagonal bracing have had the following problems:
 - Buildings that contain slender rod cross-bracing may experience excessive distortion (story drift) that can lead to the shedding or significant damage to brittle finish materials such as glass, masonry veneer, or pre-cast concrete panels. The whipping action has caused some slender cross-braces to break.
 - When the braces/columns are not properly proportioned, especially in taller frames, the great tension strength of the braces can cause compression (buckling) failure of columns.
 - ◆ The catastrophic failure of the twenty story Pino Suarez tower in Mexico City in 1985 is attributed to this effect.
 - When tube type members are used for diagonals, sudden local crippling at cross section corners has resulted. This crippling can occur when cold rolled tubes are used since high stresses are originally induced during forming.
 - Inadequate detailing or workmanship of connections has caused local failures, such as the buckling of connection plates and the rollover of beams. Although collapse has not resulted from these failures, significant non-structural damage has occurred.

S2 Type Characteristics

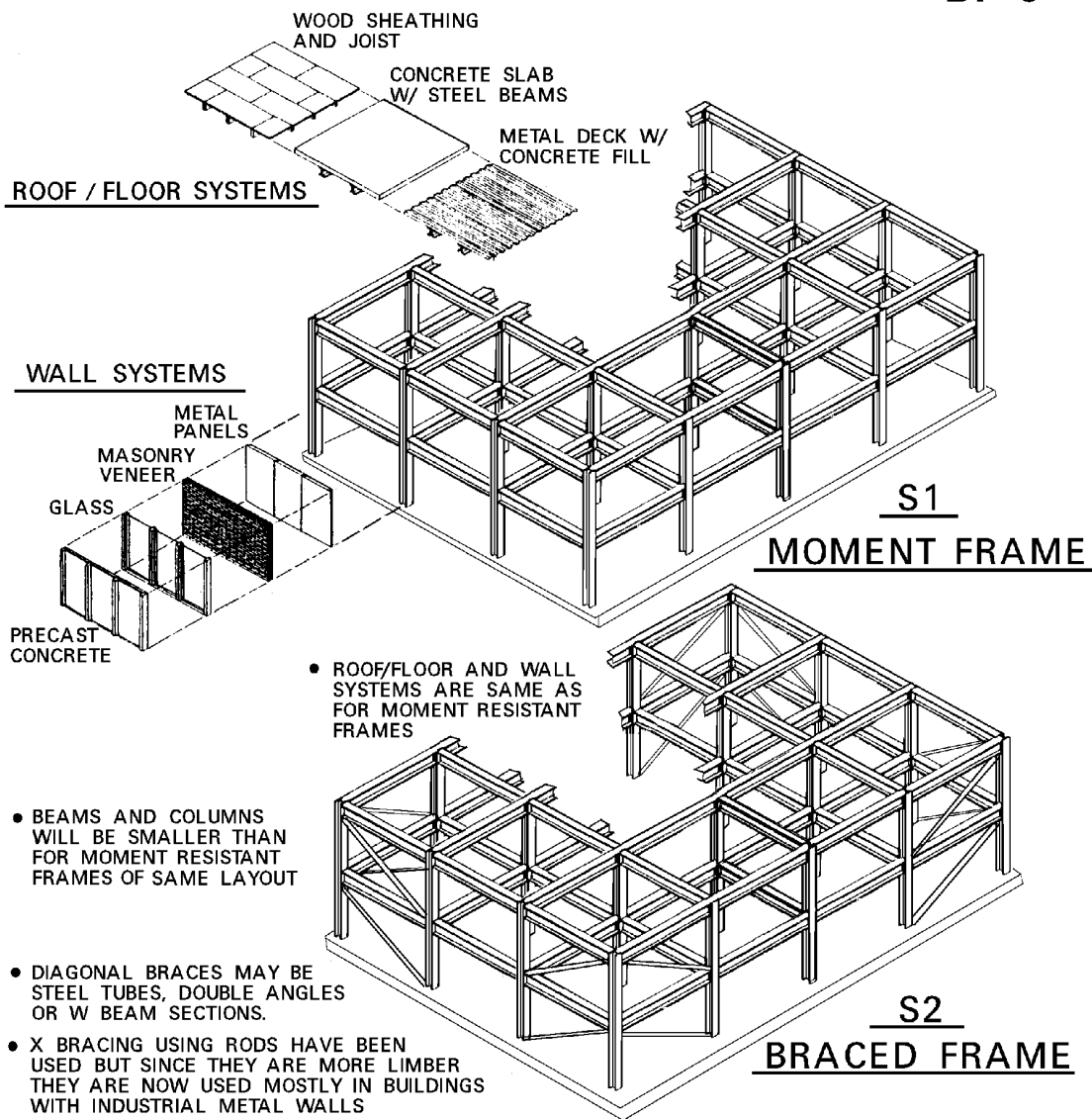
- Frame System
 - Heavy Structural Steel (hot rolled sections)
- Typical Occupancies
 - Office & Commercial, Industrial,
 - 2 to 30 stories
- Key Performance Aspects
 - Normally well-engineered; Members very ductile.
 - Overall performance dependent upon connections and proper proportioning of column strength
- Combinations
 - Precast or CIP concrete floors w/ or w/o metal deck
 - Masonry, precast or metal curtain walls
 - Exterior precast walls may perform badly

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

STEEL FRAME BUILDINGS S1 & S2

BF-5



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

LIGHT METAL BUILDINGS (S3)

Light metal buildings are normally one story, pre-engineered buildings sheathed with metal siding and roofing.

- These structures have been damaged during earthquakes due to poor connections and field errors, such as incomplete welding of joints, however, most of these structures respond well to earthquakes because of their lack of mass and abundance of flexibility.
- During strong windstorms, light metal structures have exhibited the following problems:
 - The building walls and roof lose sheathing, and the purlins plus girders that were braced by the sheathing will buckle, often leading to the progressive buckling collapse of the entire structure.
 - Doors and windows are blown in, leading to greatly increased outward pressures on the leeward wall and roof followed by the shedding and, in most severe cases, progressive collapse.
 - Tie-rod bracing can be broken or stretched by whipping action. Also, rod end connections can fail as a result of a pullout or prying action.
 - Lower cord bracing at end walls can buckle due to wind pressure against the wall. Since these structures have little redundancy, performance is usually governed by the behavior of the weakest link (the failure of one element can lead to a progressive/domino type of collapse).

S3 Type Characteristics

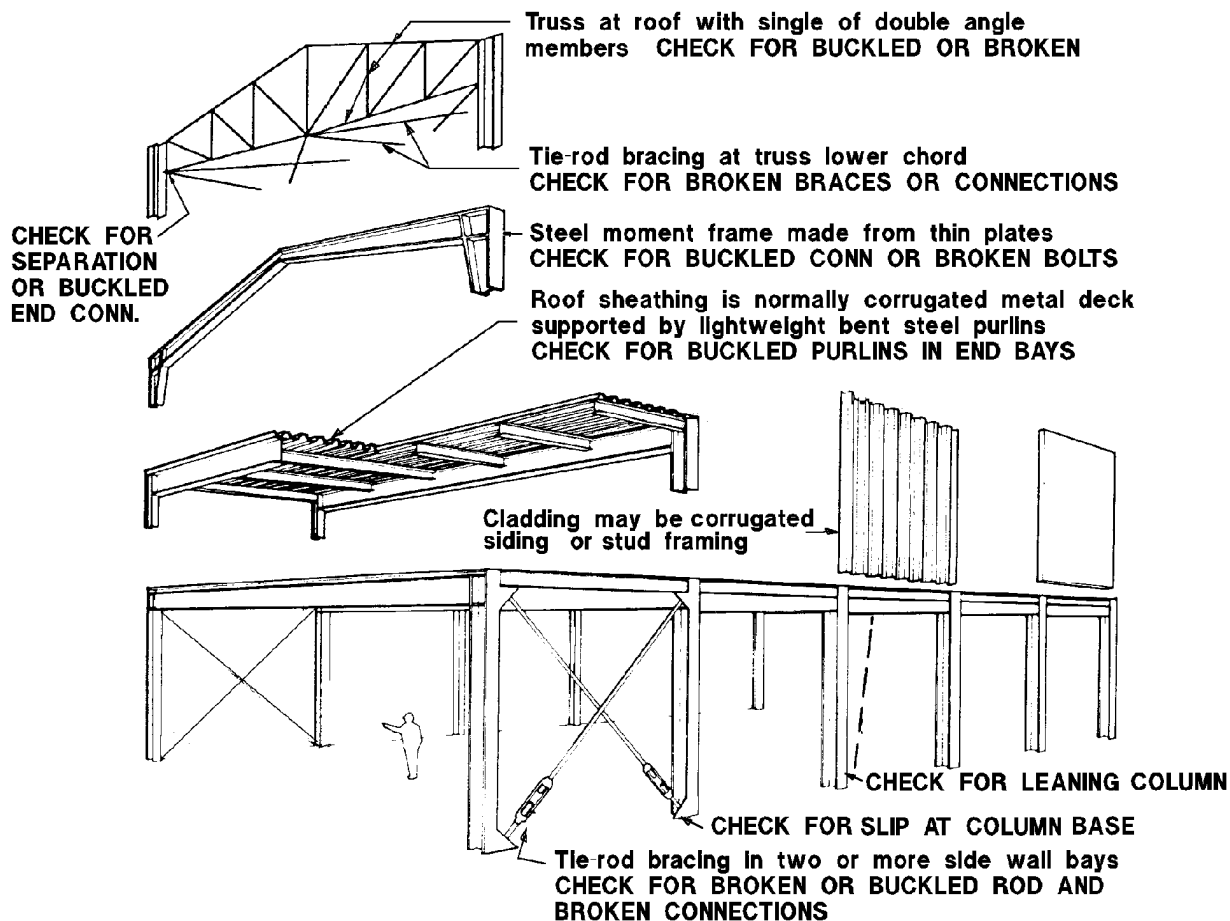
- **Frame System**
 - Light-gage Steel (pre-fab metal buildings)
- **Typical Occupancies**
 - Office, Industrial & Commercial
 - Low-rise up to 3 stories
 - Most industrial/commercial are single story
- **Key Performance Aspects**
 - Highly engineered
 - Little redundancy or overstrength; very flexible
- **Combinations**
 - May have wood or light gage metal interior partitions and mezzanine
 - Masonry, precast, tilt-up or metal curtain/exterior walls

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

LIGHT METAL BUILDINGS S3

BF-7



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

CONCRETE FRAME BUILDINGS (C1 AND C3)

C3 types have infill walls and C1 do not. Older frames are from one to thirteen stories high and have URM infill walls. Older frames in California had thin concrete infill walls on property lines in some cases. The most hazardous configurations include soft (high and open) first stories, open front buildings (typical of retail one and two story), and corner buildings (torsion problems).

■ The common earthquake problems are:

- Columns break at the intersection with the floor beam. Inadequate rebar and ties do not confine the concrete when it is subjected to high shear and tension stresses.
- Short columns in the exterior walls experience high shear and tension stresses focused into them by the surrounding concrete mass.
- Bending and punching shear failure occurs at the intersection of flat slabs and columns.
- URM infill can fall off or pop out of surrounding frames. In addition, URM infill can cause columns to shear off at the floor line or at the top of the URM.
- Weak concrete and poor construction can make all the above conditions worse and more likely to lead to a larger collapse.

C1 Type Characteristics

- Frame System
 - Heavy Floor Structure - CIP Non-ductile Reinf Conc
 - CIP Ductile Reinf. Conc., CA & WA post 1980
- Typical Occupancies
 - Office & Commercial, Highway bridges
 - 2 to 30 stories
- Key Performance Aspects
 - Non-ductile = brittle failure modes when loaded beyond capacity; Cracking generally means significant loss of strength
 - Ductile = robust structural system can absorb considerable energy and sustain considerable cracking w/o loss of integrity
- Combinations
 - Various types of infill & partitions = C3 Type

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

CONCRETE MOMENT RESISTING FRAME C1

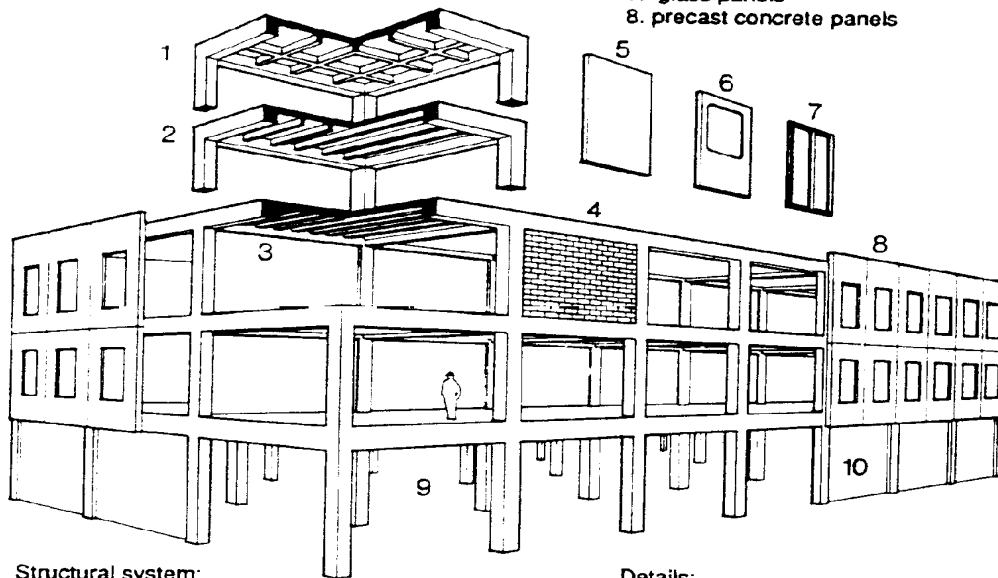
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Roof/floor diaphragms:

1. concrete waffle slab
2. concrete joist and slab
3. steel decking with concrete topping

Curtain wall/ non-structural infill:

4. masonry infill walls
5. stone panels
6. metal skin panels
7. glass panels
8. precast concrete panels



Structural system:
9. distributed concrete frame

Details:
10. typical tall first floor (soft story)

CONCRETE SHEARWALL BLDG C2

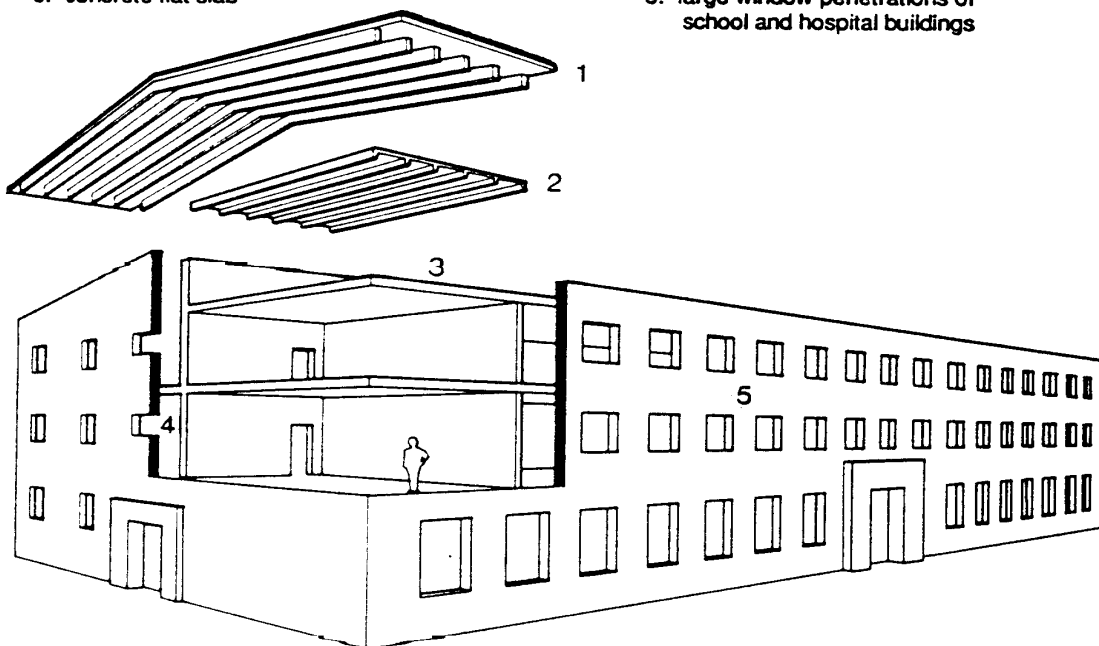
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Roof/floor span systems:

1. heavy timber rafter roof
2. concrete joist and slab
3. concrete flat slab

Wall system:

4. interior and exterior concrete bearing walls
5. large window penetrations of school and hospital buildings



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

CONCRETE SHEARWALL BUILDINGS (C2)

These buildings are from one to thirteen stories high with walls on all four sides and/or within the structure as corridor, stair, or other divisions between spaces. Walls may have openings "punched in" as doors or widows, but in more modern buildings, the openings may be in groups that are placed between solid wall sections.

- These buildings rarely collapse in earthquakes but damage can occur, such as:
 - X cracking of wall sections between punched in openings.
 - Severe cracking of shallow wall/floor header sections that frame between solid wall sections.
 - Severe cracking or collapse of columns that occur in soft stories of otherwise uniformly stiff shearwall buildings (soft first story).

C2 Type Characteristics

- Frame & Bearing Wall System
 - Heavy Wall Structure - Reinforced Concrete Shearwalls
- Typical Occupancies
 - Residential, commercial, institutional and industrial
 - 1 to 20 stories
- Key Performance Aspects
 - Excellent quake, windstorm, blast & fire resistance
 - Special wall edge reinforcing provides ductility and improved ability to resist unanticipated loads
- Combinations
 - Structure may contain non-structural, non-ductile elements; Curtain walls & URM partitions

PC2 Type Characteristics

- Frame System – (Residential Bearing Wall Sys)
 - Precast Concrete columns, beams & slabs
 - May have CIP floor fill in CA & WA
 - Residential usually have PC bearing walls
- Typical Occupancies
 - Parking Garages, Office, Residential, & Commercial
 - 1 to 12 stories
- Key Performance Aspects
 - May have highly engineered prestressed systems – especially Parking Garages.
 - Brittle connections with little reserve strength
 - Bearing wall systems are highly redundant – better performance
- Combinations
 - Precast panels used for floors and roofs of masonry and steel frame structures.
 - Commonly used for curtain walls

PRECAST CONCRETE FRAME BUILDINGS (PC2)

These buildings are usually from one to ten stories high, although precast wall panels may be used in taller buildings. Floors and roofs may be tee, double tee, or hollow core concrete plank sections supported by precast girders and columns. Lateral resistance is often provided by reinforced masonry or concrete walls, but buildings that rely on moment resistant frames have performed very poorly (Armenia).

- The common earthquake failures are:
 - Joint failures at joints between the roof/floor and walls, between roof panels, between wall panels and floor beam-column joints. This can lead to complete collapse as the building breaks into it's original precast concrete parts.
 - Wall panels separate from building and can fall. If panels are non-bearing only, local failure may be the result. In cases where the floors/roof are supported by the panels, walls can also collapse.
 - Progressive collapse can be caused by a joint failure between a column and beam or between a slab and wall panel. This then results in failure of the structure just above, due to lack of support, and also to the structure below, due to debris loading.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

PRECAST CONCRETE BUILDINGS PC2

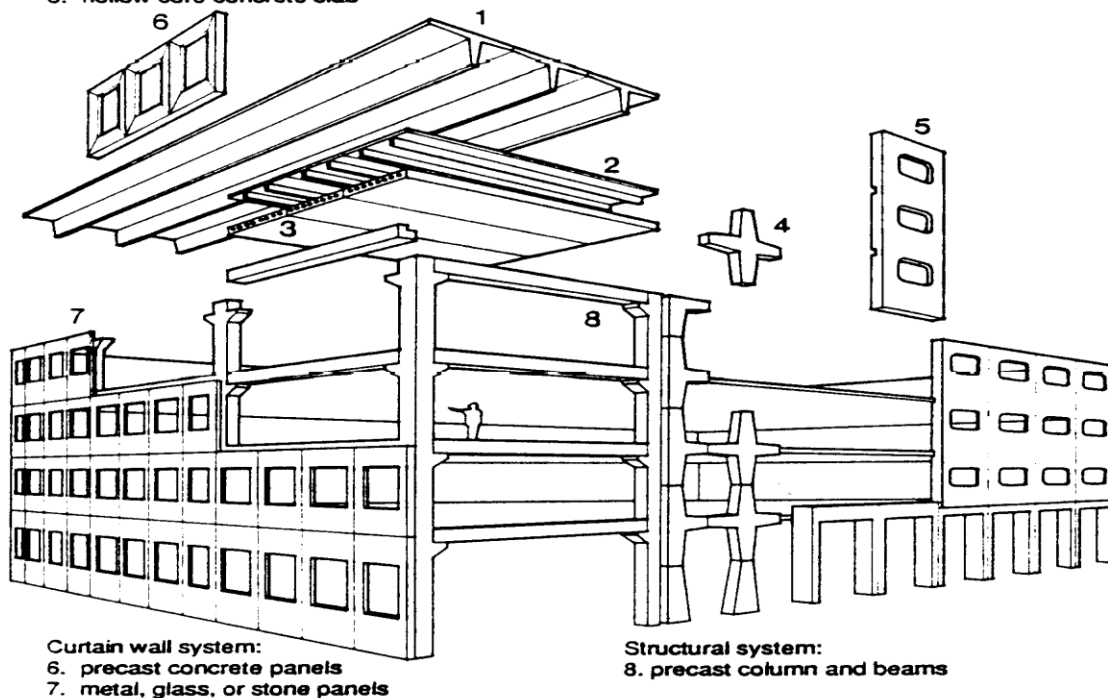
BF-10

Roof/floor span systems:

1. structural concrete "T" sections
2. structural double "T" sections
3. hollow core concrete slab

Wall systems:

4. load-bearing frame components (cross)
5. multi-story load-bearing panels



Curtain wall system:

6. precast concrete panels
7. metal, glass, or stone panels

Structural system:

8. precast column and beams

TILT-UP CONCRETE WALL BUILDING

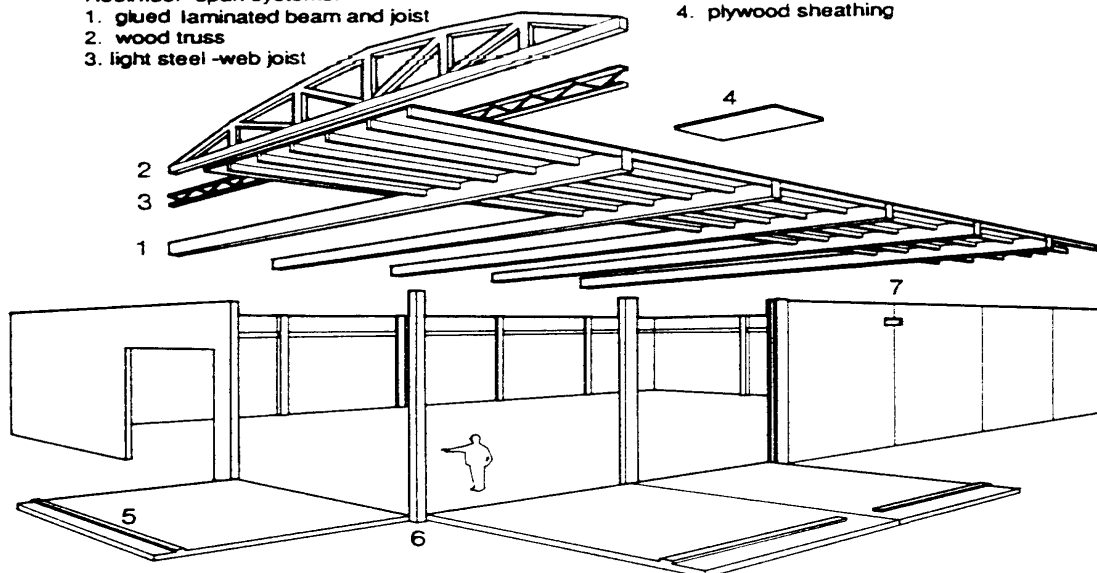
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Roof/floor span systems:

1. glued laminated beam and joist
2. wood truss
3. light steel -web joist

Roof/floor diaphragms:

4. plywood sheathing



Details:

5. anchor bolted wooden ledger for roof/floor support

Wall systems:

6. cast-in-place columns—square, "T" shape, and "H" shape
7. welded steel plate type panel connection

**ONE STORY TILT-UP BUILDING
(MAY ALSO BE 2 OR 3 STORY)**

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

TILLT-UP CONCRETE WALL BUILDINGS (TU)

These buildings are usually one story with a wood roof, but may also be up to three stories. They may have wood floors, concrete floors, steel framing with concrete filled metal deck floors, or with up to 1½" concrete fill on a wood floor.

■ The common earthquake problems are:

- Walls separate from wood floors/roof causing at least local collapse of the floor/roof, or possible general collapse of the walls and floor/roof.
 - ◆ This problem occurred during the Northridge earthquake to approximately 400 buildings, most of which had strap connections that were cast into walls and bolted to roof members.
- More substantial connections that can resist both tension and compression appear to be required, since it has been demonstrated that forces as high as 200% g can be generated at the mid-span of wood roof diaphragms.
- Suspended, precast concrete wall panels can fall off buildings. (Note: suspended concrete wall panels could be a problem on S1, S2, C1, C2, PC2, and RM buildings)
- Walls may have short, weak columns between window openings that fail due to inadequate shear strength. Large buildings that have a T, L, or other non-rectangular footprint can have failures at the intersecting corners.
- The major weight of these buildings is normally in the walls, and most failures are limited to exterior bays of the buildings supported by the walls.

TU Type Characteristics

- Interior Frame & Exterior Bearing Wall System
 - Modern low-rise, most single story but up to 4 stories.
 - Long span roof (50ft+) and floors (25ft+).
- Typical Occupancies
 - Office, commercial, light industrial and institutional
- Key Performance Aspects
 - Robust wall panels dependent upon diaphragms for out-of-plane support.
 - Wall/diaphragm connection vulnerable – Retrofit in CA
- Combinations
 - Light frame or steel joist diaphragms
 - Lt wt. concrete floor fill in multi story bldgs

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

UNREINFORCED MASONRY BUILDINGS (URM)

These buildings are usually from one to six stories high with URM bearing walls, wood floors, and wood interior, bearing and non-bearing partitions.

- There are estimated to be as many as 50,000 in California, however, most have been strengthened. This would include steel and concrete frames with URM infill.
- In addition to bearing wall URM buildings, there are structures with unreinforced or under-reinforced hollow concrete block walls, and native stone, adobe, ect., bearing wall structures.
- Masonry veneer may be found on URM bearing wall structures, and wood or light metal frame structures.

Types of URM Buildings

- **Brick bearing wall buildings -**
 - URM exterior walls w or w/o URM veneer
 - Wood floors & interior wood walls.
- **URM infill - in concrete or steel frames.**
 - Infill is brick, hollow clay tile, hollow CMU
- **CMU - Hollow conc block bearing wall .**
 - May have bond beams at floor & roof
 - Tie Beam/Tie Col is currently used in Florida
 - May also have vertical bars at edges of opngs

Types of URM Buildings

- **UR or Under-reinforced Brick cavity walls.**
 - Insulation layer between masonry layers
 - May be used as infill or as bearing walls with bond beams.
- **Masonry veneer on wood/steel studs**
 - Anchorage is all important due to interaction of brittle wall covering on flexible structure.
- **Native stone, adobe, mud, etc. bearing wall buildings.**

URM Type Characteristics

- **Bearing Wall System**
 - Heavy Wall Structure Unreinforced Masonry (includes unreinforced brick and CMU used for low-rise bldgs)
 - Older "red brick" with bond/header courses
 - Lack of strap anchors & ties (except Retrofit in CA)
- **Typical Occupancies**
 - Residential, commercial, and industrial
 - 1 to 8 stories
- **Key Performance Aspects**
 - Brittle with little capacity to resist unanticipated loads. Numerous interior walls may prevent floor collapse
- **Combinations**
 - Heavy timber, light frame or steel joist diaphragms, with concrete floor fill in multi story bldgs.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

UNREINFORCED MASONRY URM

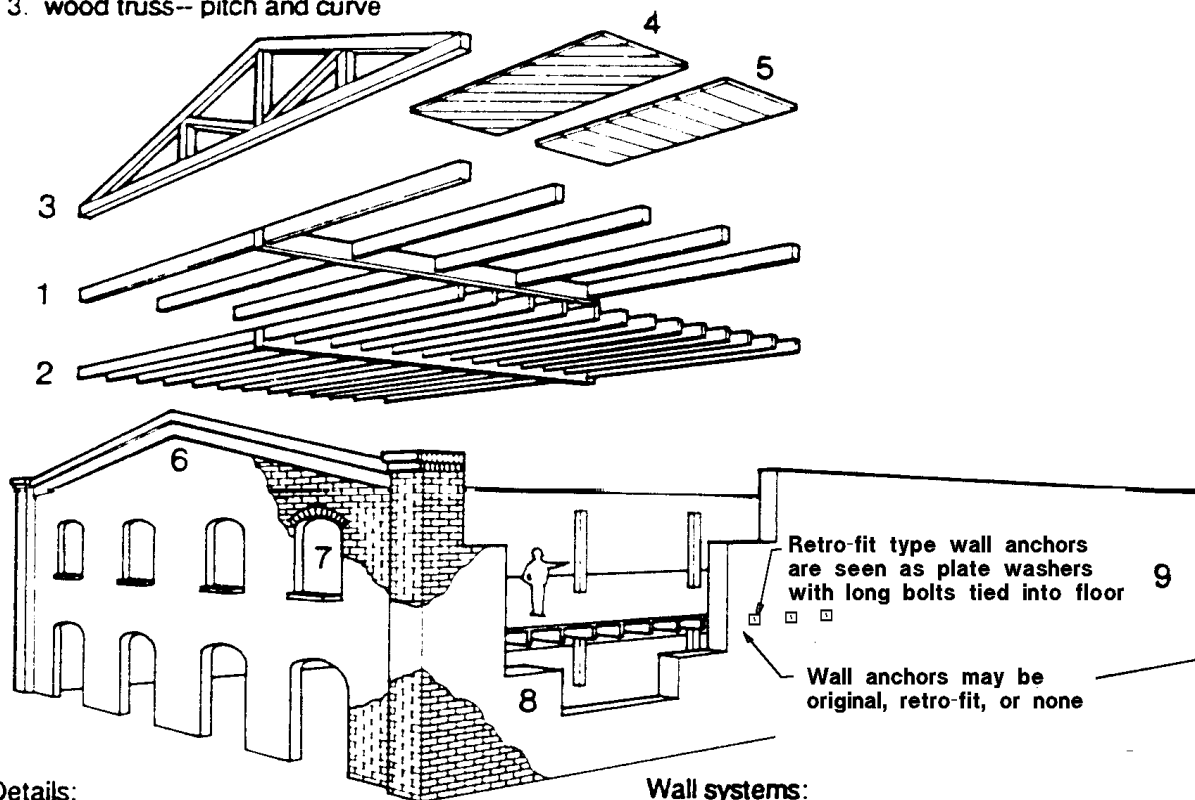
BF-13

Roof/floor span systems:

1. wood post and beam (heavy timber)
2. wood post, beam, and joist (mill construction)
3. wood truss-- pitch and curve

Roof/floor diaphragms:

4. diagonal sheathing
5. straight sheathing



Details:

6. typical unbraced parapet and cornice
7. flat arch window openings

Wall systems:

8. bearing wall-- four or more wythes of brick
9. typical long solid party wall

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

The following problems are common in earthquakes:

- Parapets and walls fall off buildings due to inadequate anchors.
 - The parapets and upper story walls are most likely to fall first due to experiencing higher inertial loads.
- Multi-thickness walls split and collapse or break at openings.
- Mortar is often weak and made with too high of a lime content.
- URM walls that are more heavily loaded by roofs and floors tend to perform better than ones that are parallel to framing, since the load of the floor tends to compress the URM together.
- Roof/floors may collapse if there are no interior wall supports and if the earthquake has a long enough duration.
 - Interior wood bearing and non-bearing walls will often support the roof and floors, especially in buildings with shorter spans.
- Older steel frame buildings with unreinforced or lightly reinforced masonry infill often shed this brittle covering as they flex to resist the earthquake.
- Broken bricks often line the streets where these buildings are located, and people can be trapped on the sidewalk or in automobiles.
- Cavities are usually formed by wood floors in familiar patterns of V, Lean-To, and complicated Pancake.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

PART 2 CAUSES OF COLLAPSE

TERMINAL OBJECTIVES

- The student will understand environmental and human caused forces.
- The student will understand how those forces effect structures and USAR operations.

ENABLING OBJECTIVES

- Understand the types of forces that load structures.
- Understand the method that is used to classify structures and the types of problems that buildings have experienced.
- Understand the collapse patterns that have occured that will give us some insight into how structures will behave in the future.

EARTHQUAKE BASICS

Earthquakes are catastophic events that occur mostly at the boundries of portions of the Earth's crust called tectonic plates. When movement occurs in these regions along faults, waves are generated at the Earth's surface that can produce very destructive effects. The things that USAR response personnel need to know about these events will be summerized.

Earthquake Basics

- Extent of damage is determined by
 - type of shaking that occurs at site
 - coupled with the structures response
- Magnitude (energy release)
 - determines POTENTIAL number of effected structures
- Aftershocks
 - Earthquakes are unique type of Disaster
 - just keeps on giving

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

EARTHQUAKE MAGNITUDE

Earthquake magnitude refers to a way of measuring the total energy released by an earthquake, which could also relate to the total damage done (all else being equal).

- With respect to an earthquake with a larger magnitude, the following can be said:
 - The maximum intensity of the shaking may be similar to a small quake.
 - The duration of the shaking at the fault is longer.
 - The length of the fault break is longer, which directly relates to duration.
 - The area of the Earth that will be affected by intense shaking is much larger, and therefore, the potential for greater USAR involvement is much larger.

AFTERSHOCKS

These smaller earthquakes occur after all large earthquakes.

- They are usually most intense in size and number within the first week of the original earthquake.
- They can cause significant re-shaking of damaged structures, which makes earthquake induced disasters more hazardous to USAR than most others.
- A number of moderate earthquakes (6+ magnitude) have had aftershocks that were very similar in size to the original earthquake.
- Arrays of strong motion instruments can be set out after an earthquake, and data from aftershocks will allow the mapping of the fault surface. These instruments can also be coupled with a warning system to notify a USAR Task Force before the effect is felt at a building site.
- Aftershocks diminish in intensity and number with time. They generally follow a pattern of there being at least one large (within one Richter magnitude) aftershock, at least ten lesser (within two Richter magnitude) aftershocks, one hundred within three, and so on.
 - The Loma Prieta earthquake had many aftershocks, but the largest was only magnitude 5.0 with the original earthquake being near magnitude 7.1.
- Wood, masonry, and concrete structures have collapsed during aftershocks (even during one of the relatively moderate 5.0 Loma Prieta aftershocks).

Aftershocks

- Smaller quakes that occur on same fault as original quake.
 - Minor fault adjustments
- Occur after most quakes regardless of size of original shock
- Some have been almost as large as original. (in range of M 6)
- Will occur during US&R Ops since are most prevalent in first week.

How Many Aftershocks ?

- USGS - Rule of Thumb
 - For every single decrease in magnitude, get 10 fold increase in number
- If original quake is M 7
 - 1 or so aftershock in range of M 6
 - 10 " " " " 5
 - 100 " " " " 4
 - 1000 " " " " 3
- Have fewer as time passes
 - Day 2 = 1/2 as many as day 1
 - Day 3 = 1/3 as many as day 1
 - Day 4 = 1/4 as many as day 1, etc

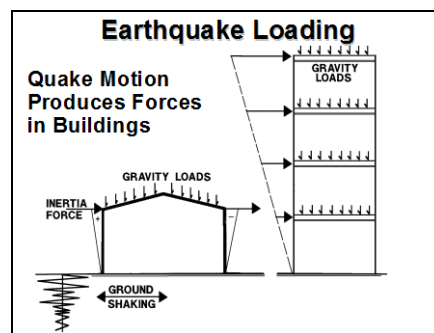
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

BASIC STRUCTURAL LOADING

EARTHQUAKES

- Some of the most destructive effects caused by earthquake shaking are those that produce lateral loads in a structure. The shaking causes the foundation of a building to oscillate along a more or less horizontal plane. The building mass has inertia and wants to remain where it is. Therefore, lateral forces are exerted on the mass in order to bring it along with the foundation. This dynamic action can be simplified (in an upside-down way) as a group of horizontal forces that are applied to the structure in proportion to its mass, and to the height of the mass above the ground.
- In multi-story buildings with floors of equal weight and relatively light walls, the loading is further simplified as a group of loads, each being applied at a floor line and each being greater than the one below, in a triangular distribution. Seismically resistant structures are designed to resist these lateral forces through inelastic action and must be detailed accordingly. These loads are often expressed in terms of a percentage of gravity weight and can vary from a few percent to nearly fifty percent of gravity weight.
- There are also vertical loads generated in a structure by earthquake shaking, but these forces rarely overload the vertical load resisting system. Earthquake induced vertical forces have caused damage to heavy concrete structures with a high dead load compared to designed live load. These vertical forces also increase the chance of collapse in concrete frame buildings due to either increased or decreased compression forces in the column (increased compression that overloads columns or decreased compression that reduces column bending strength).

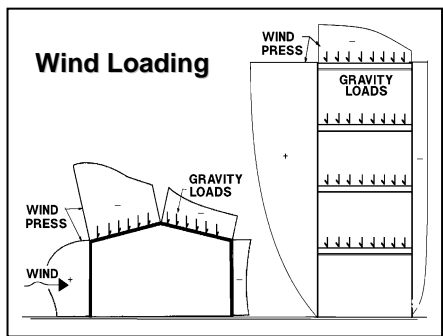


RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

WINDSTORMS

- Forces are generated on the exterior of the building based on it's height, local ground surface roughness (hills, trees, other buildings), and the square of the wind velocity. The weight of the building, unlike the earthquake condition, has little effect on wind forces but is helpful in resisting uplift.
- Unless the structure is penetrated, all forces are applied to the exterior surfaces of the building, in contrast to earthquakes, in which both exterior and interior walls are loaded proportionally to their weight.
- Wind pressures act inward on the windward side of a building and outward on most other sides and most roof surfaces. Special concentrations of outward force resulting from aerodynamic lift occur at building corners and roof edges, especially overhangs.
- Wind pressure becomes much greater with increased speed.
 - The pressure is proportional to the speed squared. That is, the pressure from a 100 mph wind is 4 times as great as a 50 mph wind.
 - ◆ Hurricane speeds vary from 74 mph to 155 mph.
 - ◆ Tornado speeds can exceed 250 mph.
- The overall structure must be designed for the sum of all lateral and uplift pressures. Individual parts must be designed to resist the outward and inward pressure concentrations and must be connected to supporting members (beams, columns, walls, and foundation) to form a continuous resistance path. Forces are also generated on structures by airborne missiles that vary in size from roofing gravel to entire sections of roofs.



Destructive Windstorms

- **Hurricanes**
 - Large circular systems created by low pressure over ocean near equator
 - May be 100 + mi. in diameter, winds up to 150mph
 - Damage due to wind + storm surge
 - Wind Force is Proportional to Speed²
 - Force from 100mph = 4 times that from 50mph
- **Tornadoes**
 - Violent vortices originating over land, usually created by colliding air masses.
 - May be 1 mi. in diameter, winds up to 300mph

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

EXPLOSIONS

Explosions occur when a solid or concentrated gas is transformed into a large volume of hot gases in a fraction of a second.

- In the case of high explosives, detonation (conversion of energy) occurs at a very high rate (as high as 4 mi/sec).
- Low explosives (such as gunpowder) undergo a rapid burning at the rate of about 900 ft/sec.
- The resulting rapid release of energy consists of sound, heat, light, and a shock wave that propagates radially outward from the source at subsonic speeds for most low explosives and at supersonic speeds for high explosives.
- It is the high magnitude of a very short duration (milliseconds) shock wave, consisting of highly compressed particles of air that causes most of the damage to structures.
- When natural gas explosions occur within structures, gas pressures can build up within confined spaces, causing extensive damage.

Explosion Basics

- Explosion is chemical reaction involving:
 - Rapid expansion of Gas
 - Liberation of Heat
 - Explosion is defined as bursting of an enclosure due to development of internal pressure
- High Explosive (Primary & Secondary)
 - Primary Explosives - detonate by simple ignition due to spark, flame, impact or friction
 - Secondary Explosives – are relatively insensitive to simple ignition and are detonated by shock from a Primary Explosive
 - Detonation results when a combustion zone (conversion of energy) proceeds at greater than the speed of sound (as high as 4 miles/sec)

Explosion Basics

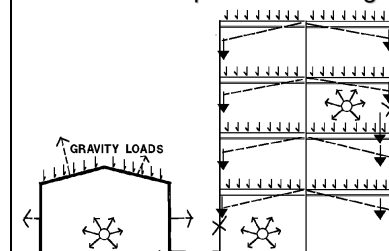
- Low Explosive (or Propellants)
 - Deflagration (rapid burning) results when a combustion zone proceeds from the ignition point at less than speed of sound
 - Black Powder, Rocket Fuel, Flammable Gas, Dust
 - If Low Explosives are confined they can Detonate
- Detonations vs Deflagrations
 - Detonation pressures usually much higher
 - Deflagration duration is normally longer
 - If collapse is not initiated, effects of Detonation can be more localized

- In all explosions, large, weak, and/or lightly attached wall, floor, and roof surfaces may be blown away.
- The columns and beams in steel frame structures may survive a blast, but their stability may be compromised by the removal of their bracing elements (floor diaphragms, shear walls).

Explosion Effects

- Rapid release of Energy
 - Sound (bang) and Heat and Light (Fireball)
 - Shockwave (very high, but short duration pressures)
- Shockwaves (Pressure Wave)
 - Propagates, radially outward in all directions from source and causes most of the damage to Structures
 - Diffracts, creates both amplifications and reductions
 - Short term nature (milliseconds) allows structures to survive much higher than "Static Design" pressures
- Other Effects
 - High speed winds (sucking effect after wave passes) propels debris
 - High intensity, short duration ground shaking

Interior Explosion Loading

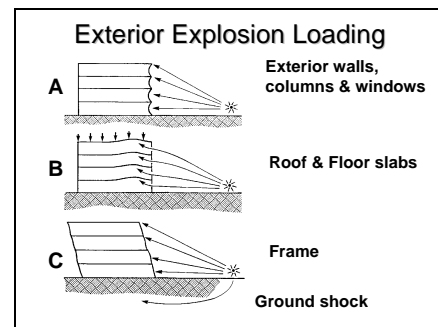
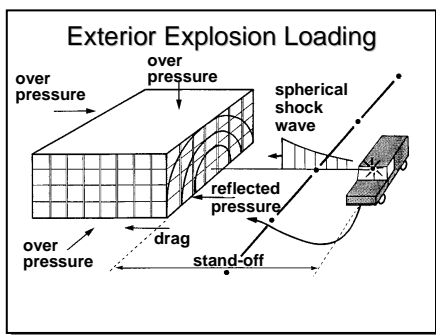


RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

EXPLOSIONS (Continued)

- In large explosions, concrete slabs, walls, and even columns may be blown away, leading to conditions that will produce a progressive collapse.
 - In 1960, a progressive collapse started when a natural gas explosion caused the collapse of an exterior wall on the 18th floor of a 22 story building.
 - ◆ The force of the falling weight of the floors above caused all the floors to collapse to the ground.
- In the case of an exterior explosion from a bomb, the shock wave is initially reflected and amplified by the building face and then penetrates through openings, subjecting floor and wall surfaces to great pressure.
 - Diffraction occurs as the shock wave propagates around corners, creating areas of amplification and reduction in pressure.
 - Finally, the entire building is engulfed by the shock wave, subjecting all building surfaces to the over-pressure.
 - A secondary effect of an air-blast is a very high velocity wind that propels debris outward (as deadly missiles). In addition, a high intensity, short duration ground shaking (earthquake) may be induced.
 - In very large explosions at close proximity to reinforced surfaces, the effect can be so severe that the concrete is locally disintegrated and separated away from the reinforcing steel.
 - Lighter wood, steel frame, and even pre-cast concrete buildings can be leveled by explosions as the wall and floor and/or roof planes are blown away, leading to an overall stability loss.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

EFFECTS OF FIRE ON STEEL STRUCTURES

The excess heat caused by fire will have the following negative effects: expansion, loss of structural rigidity, and loss of strength.

■ Expansion

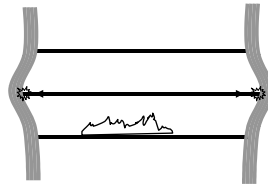
- The coefficient of thermal expansion increases with temperature. At 70° F, it is .00065 inches per inch for a 100° F change in temperature, and this increases to .0008 inches per inch at 1000° F.
- The total change in length for a change in temperature of 1000° F is about 10 inches.
- In structures where lateral restraint is provided by walls or rigid columns, this excessive expansion can cause connections to fail and horizontal members to buckle.
- Excessive expansion can also include destabilizing forces in columns and exterior walls.

Fire Effects on Steel Structures

- Expansion
 - About 10" in 100ft from ambient to 1100°
- Loss of flexural rigidity
 - Significant above 800°
 - Both Yield Point & Stiffness are reduced
 - Deflected Floor is Warning Sign
- Significant loss of strength above 1000°
 - Strength OK up to approx 700°
 - Drops below Design Strength at 1100°
 - At 1000° both Stiffness and Strength are 50%

Effects of Fire – Expansion (10 " in 100 ft)

Can cause restrained connections to fail
Can destabilize columns

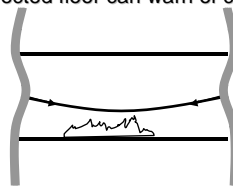


■ Loss of structural rigidity

- Both the yield strength and modulus of elasticity of steel drop to about 75% of normal values when the temperature reaches 800° F. They drop at an increasing rate at greater temperatures.
- In fires, this drop results in the formation of "draped" or "bellied" beams and girders that generate significant tension stresses in their connections.
 - ◆ These stresses can lead to the failure of the joints and collapse of floor sections.

Effects of Fire – Loss of Rigidity

Catenary forces can cause connections to fail and then destabilize columns
Deflected floor can warn of collapse



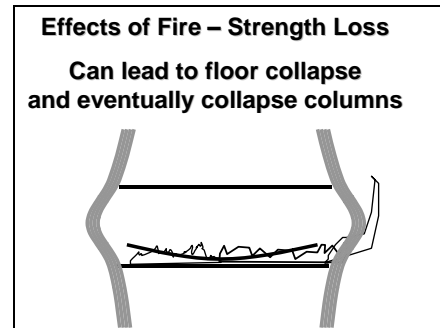
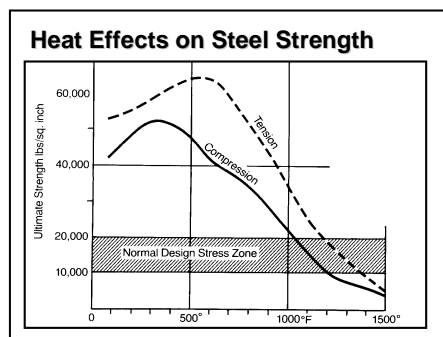
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

EFFECTS OF FIRE ON STEEL STRUCTURES (Continued)

■ Loss of strength

- Steel actually gains strength when the temperature is raised from ambient to about 700° F.
- For the normal structural steel used in buildings, both the strength and stiffness are reduced to about 50% at 1000° F.
- Steel drops below the design strength at about 1100° F, and failure of a loaded structure will occur more quickly above this level.
 - ◆ Collapse due to strength loss is usually seen first in floor members, especially lightweight members such as bar joists and other trusses.
 - ◆ Heat is concentrated at the underside of floors, and low mass, high surface area members will be heated most rapidly.
- Columns have a much better chance of surviving the effects of fire.
 - ◆ They usually have some sort of covering, even if it is not fire rated.
 - ◆ They are usually made from heavier, more compact sections.
 - ◆ They may be able to dissipate the heat if they extend to floors above the fire area.



Effects of Fire – Strength Loss

- Worst effects on Joist, Beams, & Girders
 - Heat Concentrates and is Trapped on Horizontal Surface
- Less effect on Columns
 - Usually have some Protective Covering
 - Columns are thicker members
 - Heat dissipates into Continuous Column Sections in Floors, Above & Below

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

EFFECTS OF FIRE ON STEEL STRUCTURES (Continued)

■ Building Code Fire Resistive I.D.

- Building codes divide buildings into five categories based on the combustibility of the materials and amount of fire resistance.
- They are listed as Type 1 through Type 5, with Type 1 being the most fire resistive and Type 5 being the least fire resistive.

Building Code Fire Resistive I.D.

- Type 1 - Non-combustible Construction
 - 4-hour Exterior Walls
 - Structure has 2 & 3-hour Fire Protection
- Type 2 - Non-combustible Construction
 - May have 1-hour or Non-rated Protection
- Type 3 - Non-combustible Exterior Walls
 - 4-hour Exterior Walls
 - May have combustible Roof, Floor & Interior Walls, w/ or w/o Fire Protection
- Type 4 - similar to Type 4
 - Lower Fire Protection Requirements
- Type 5 - Wood or Lt. Metal frame
 - May require 1 hour Exterior and Dividing Walls

■ Fire effects on Type 1 steel structures.

- Before the attack on the World Trade Center on 9/11/01, no Type 1, multi-story, fireproofed steel structure had ever collapsed due to fire.
- A few of this type had burned for several hours, but none had collapsed.
- The most notable of this type occurred at One Meridian Plaza in Philadelphia, when, based on the inadequacy of water supply, the decision was made to withdraw fire forces. The fire then burned through 10 floors, slowly transferring from floor to floor, until it was extinguished by an upper floor fire sprinkler system.
- Spectacular high-rise fires in both Los Angeles and Las Vegas burned for hours but did not cause structural collapse. Well organized evacuations were accomplished in both cases, with helicopters being used successfully in the early 1980's to remove occupants from the Las Vegas fire.

Fire Effects on Steel Structures

- Type 1 Steel Buildings
 - Prior to 9/11 no Type 1, Fire Protected Steel Building had ever collapsed due to Fire
 - Some had burned for many hours
 - One Meridian Plaza, Philadelphia, 1991, 19 hours (11 hours uncontrolled)
 - Interstate Bank, L.A., 1988, 4 ½ hrs
 - MGM Grand Las Vegas, 1981, 11 hrs
 - Multi-Helicopter Rescue from Roof
 - Changed fire protection/warning requirements

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

EFFECTS OF FIRE ON STEEL STRUCTURES (Continued)

- Fire effects on unprotected steel structures.
 - Several spectacular fire-caused collapses of unprotected, long-span, low-rise steel structures have occurred.
 - McCormick Place was a large exhibition hall in Chicago that burned in 1967 with a loss of \$154 million.
 - ◆ No fireproofing was required since the steel truss roof structure was more than 30' above the floor.
 - ◆ Exhibition booths, that in some cases were two stories high, produced the fire load.
 - ◆ Once started, the fire was able to produce enough heat to cause the roof structure to collapse.
 - Cobo Hall in Detroit was also an exhibition facility whose roof was constructed of unprotected, light steel trusses.
 - ◆ The roof and some walls completely collapsed due to a contents fire in 1960.
 - NFPA has published reports regarding these incidents to inform firefighters of the dangers of sudden collapse in these light and long span steel structures. Building codes have been changed to limit the use and permitted fire load for this type of structure.

Fire Effects on Steel Structures

- Unprotected Steel Building problems
 - Long span, low rise truss and bar joist structures had spectacular collapses
 - McCormick Place, Chicago – 1967, \$154mil
 - 30ft clear height Exhibition Hall
 - Fuel from 2 story high exhibits
 - Cobo Hall, Detroit, 1960
 - Bar joist roof & walls became spaghetti
 - Commonly used in Gyms & Arenas
 - High School to Professional

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

EFFECTS OF FIRE ON STEEL STRUCTURES (Continued)

■ Collapse of World Trade Center, Building 7.

- The collapse of World Trade Center, Building 7 was probably the first Type 1 high-rise steel structure to collapse solely due to fire. It collapsed, starting at the bottom, after burning for about seven hours and it appeared that the interior collapsed first. There are several factors that could have contributed to the collapse.
 - ◆ The fire sprinkler system was ineffective because of an inadequate water supply and the situation made worse by a broken water main. Most systems are designed to extinguish only localized fires.
 - ◆ The building was constructed over an existing electrical substation that required the use of several transfer trusses. Main columns were terminated at the fifth floor.
 - ◆ Emergency generators and 275 gallon gas "day tanks" were placed on the fifth, seventh, and ninth floors.
 - ◆ Pipes from a 6,000 gallon tank on the second floor and/or two 11,000 gallon buried tanks supplied most of the "day tanks".
 - ◆ Fuel from broken pipes and/or the tanks could have contributed to the fire (though this theory is a subject of study).

Collapse of WTC - 7

- Fire started at about 1000hrs
- FDNY abandoned fire suppression by 1200hrs
 - Sprinkler system ineffective due to break in water main
 - Design of most Fire Sprinkler Sys assumes smaller fires – overwhelmed by large fires
- Collapsed at about 1720hrs
 - Collapse started near bottom of building
 - Initiated by interior collapse
 - Building imploded – stayed within its own footprint

Collapse of WTC - 7

- Potential Configuration Problems
 - WTC 7 built over Electrical Substation
 - Used 3 Transfer Trusses at 5th to 7th FI Level
 - 6 locations of generators & 4- 275 gal fuel, "Day Tanks" - on 5th, 7th, 8th & 9th floors
 - Some Generators & Tanks were near Trans Trusses
 - Most day tanks were resupplied through pipes from one-6000 g tanks on 2nd fl & 36,000 g in four tanks under ground level loading dock
 - Fuel from tanks or broken pipes MAY have contributed to the fire – NO CONFIRMATION

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

EFFECTS OF FIRE ON STEEL STRUCTURES (Continued)

- Collapse of World Trade Center Tower 1 and 2.
 - World Trade Center Tower 1 and 2 probably collapsed due to a combination of factors.
 - ◆ After the plane struck the towers, the redundant outrigger truss system at the top of the structure redistributed the vertical loads that had been carried by the severed and badly damaged exterior columns to adjacent columns.
 - ◆ The debris from the plane probably dislodged a significant amount of the sprayed-on fireproofing, especially from the floor trusses.
 - ◆ The jet fuel fire ignited the contents of the building.
 - ◆ The ensuing fire then caused the initial collapse of the un-fireproofed floors.
 - ◆ Once the collapse was started, the load of the upper floors and the dynamics of the moving mass made it impossible to stop.

Collapse of WTC – 1 & 2

- Redundancy permitted structure to resist initial damage
 - Load re-distribution highly stressed many elements
 - Reduced lateral support for other highly stressed elements
- Fire effects
 - Further increase stresses due to expansion
 - Caused failure of some connections
 - Weakened highly stressed elements
- Once collapse initiated, debris weight on lower floors caused progressive collapse

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

EFFECTS OF FIRE ON OTHER STRUCTURES

- Type 3 and Type 5 buildings that have light wood trusses, especially those that "clear-span" between walls, have collapsed suddenly.
 - The situation is especially dangerous when the light trusses are constructed in the hidden space above a ceiling. An undetected fire can spread rapidly, fed by the abundant fuel, and cause a sudden collapse.
 - The NFPA states that 34 firefighters have been killed in 19 incidents involving wood trusses from 1997-1999.
- Type 3 buildings with concrete or masonry walls and wood roofs have been the scene of deadly fires.
 - The wood roof/floors often collapse due to burn-through and can pull exterior masonry or concrete walls in or leave them standing in an unbraced condition.
 - These structures tend to have longer span trusses, and a Lean-To collapse or fire caused expansion can push out the exterior walls.
 - The collapse of a roof truss that supports sloped rafters in an end bay can also cause exterior walls to be pushed out (parapets over storefronts are especially vulnerable).
- Type 3 buildings with light steel roofs have also been the scene of deadly fires.
 - In 2007, the sudden collapse of a light steel roof at a furniture warehouse caused the deaths of nine firefighters.
- Concrete structures can be damaged due to spalling, and shear walls can be cracked due to floor expansion. This situation is less deadly but should be carefully considered.

Fire Effects on Other Structures

- Type 3 & 5 Buildings with light wood trusses have been a deadly, sudden collapse problem
 - 34 Firefighters killed in 19 incidents - 1977 thru 1999
 - Prior to 9/11 were the most deadly building types
- Type 3 Bldgs – Conc/Masonry walls, wood roof
 - Burnout of wood roof/floors creates dangerous, unbraced heavy walls
- Type 5 over Type 1 Concrete Garage
 - Firestorm consumed Wood Apartment which caused Expansion Damage to RM Garage Shearwalls

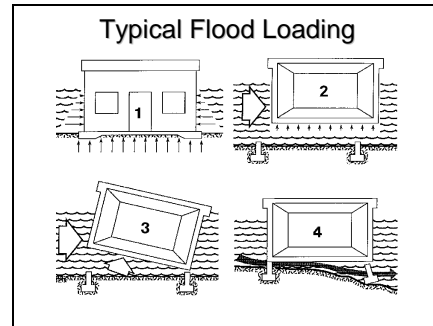
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

FLOOD

Forces are generated on buildings due to hydrostatic lateral and lifting pressure, hydrodynamic forces, and debris impacts.

- Hydrostatic pressures can highly load foundation and basement walls and lift structures when the water level is not equalized between exterior and interior spaces.
- Hydrostatic pressure can also lift wood floors and roofs off their bearings.
- River and ocean currents will load frontal and side walls that are submerged, and ocean waves and step-up flows can produce pressures as high as 1000 psf.
- Debris varying in size from floating wood pieces to floating structures can impact a building causing anything from broken windows to a total collapse.



FLOOD/STORM SURGE AND TSUNAMI

- Water in motion can do considerable damage to substantial structures as seen in the 2004 and 2005 hurricanes, as well as the Indian Ocean Tsunami.
- Events that may lead to a USAR deployment include floods that may result from a swollen river or a failed dam, or a tidal surge associated with a hurricane or a tsunami.
 - For a hurricane induced storm surge, evacuation of threatened areas generally minimizes or prevents victims.

Flood Types

- Riverine
 - Slow Inundating Type
 - Fast moving, Flash Flood
- Hurricane - Tidal Surge
 - Fast Moving at Coast
 - Rains may lead to Riverine Flooding
- Tsunami
 - Create Catastrophic Waves – more than one
 - Can move inland for one mile or more
 - Create massive debris flows

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

LANDSLIDE, MUDSLIDE, DEBRIS AVALANCHE

- An avalanche is a closely related hazard involving frozen water rather than soil.
- Devastating mudslides, sometimes called debris avalanches, have occurred in many locations throughout the world.
- They most often occur due to the saturation of surface soils caused by torrential rain. This may cause a mass movement of soil that can devastate most everything in its path.
- On steep hillsides, where upper soils may be marginally stable at normal moisture content, the saturation can de-stabilize the equilibrium by:
 - Increasing the weight of the soil mass,
 - Reduce the shear strength of the soil by separating the grains/particles,
 - Lubricating the interface between shallow soils and a more dense, impervious rock material below.
- In most circumstances, viable voids are unlikely, given the flowability and pressures of the material and the lack of oxygen within the material.
- The greatest concern for Structures Specialists in these events would be dealing with potentially unstable soil masses and collapsed structures shifting under the pressures and movement of the debris. As water flows out of the mass, it may consolidate, causing continual movement and settlement.
- At higher water contents, the soil behaves as a very heavy (i.e. 145 pcf. concrete) fluid, therefore trenches into the soil/debris mass should be shored/braced for twice the forces normally assumed in trench rescue.
- The headscarp and upslope debris, and debris mass, all should be monitored for movement.

Landslide, Mudslide – Debris Avalanche

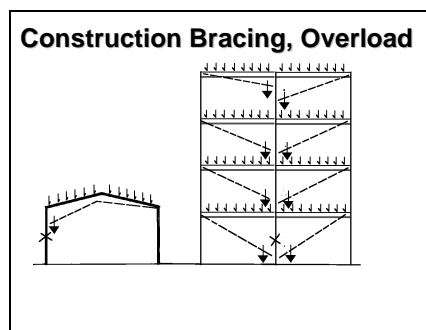
- Often occur due to saturation of surface soils
 - Torrential rains – 6 or more in/day
- Soils on steep hillsides may be marginally stable
 - High water content increases weight and reduces shear strength (inter-pore pressure)
 - Lubricates underlying soil/rock interface
- Produces four US&R issues
 - Continued flow from Headscarp
 - Consolidation/movement as debris mass gives-up water
 - Trench bracing to resist concrete like material
 - Flowability reduces chance of survivable voids
- Need Monitoring of Headscarp and Debris Mass

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

CONSTRUCTION BRACING, URBAN DECAY, AND OVERLOAD

- These sudden collapses usually occur due to gravity loading when a vertical support is either inadequate, overloaded by snow, overloaded because of a plugged roof drain, or reduced in capacity because of age, corrosion, or non-engineered alteration.
- Failures of this type occur all too frequently, but most often affect only one structure at a time. In some cases, structures with hazardous conditions have been left standing (for example, multi-story URM walls left unsupported when wood floors pancaked).



VEHICLE IMPACT LOADING

- Structures have been severely damaged and set on fire by vehicle impacts.
- A 1989 train derailment in California led to a well organized, integrated response that was successful in saving a victim in what was originally perceived as an un-survivable condition.

Vehicle Impact Loading

- Planes, Trains, Boats, & Highway Vehicles have impacted Structures
- Collapse and often Fires have resulted
- 1989 Train Derailment in So Cal buried several homes.
 - CAL OES organized and directed a successful deployment of K9 Search to aid local Fire/Rescue forces
 - Demonstrated Value of Integrated US&R

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

PART 3 COLLAPSE PATTERNS

TEMINAL OBJECTIVES

- The student will be able to recognize the collapse patterns that are unique to common building types when subjected to different types of extreme loading.
- The student will be able to use this knowledge to determine locations of potential victims.

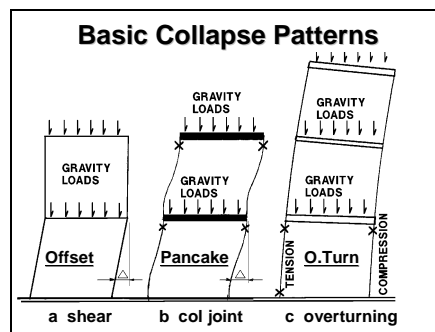
ENABLING OBJECTIVES

- Understand basic collapse patterns.
- Understand earthquake collapse patterns.
- Understand windstorm collapse patterns.
- Understand flood collapse patterns.
- Understand blast collapse patterns.
- Be able to focus on survivable voids and potential victim locations.

BASIC COLLAPSE PATTERNS

Most building collapses occur due to a loss of stability. The basic shape is significantly changed when subjected to a combination of forces. The new changed shape is much less capable of carrying the forces, therefore, the structure will rapidly continue to change untill it finds a new shape that is stable. A typical example of lost stability is that of the slender column that "gets out of the way of the load by buckling" as the load comes to rest on the ground.

- Basic collapse patterns include the following:
 - Inadequate shear strength.
 - Inadequate beam/column joint strength.
 - Tension/compression failure.
 - Wall-to-roof interconnection failure.
 - Local column failure.
 - Single floor collapse.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

INADEQUATE SHEAR STRENGTH

Inadequate shear strength failures are normally caused by earthquake shaking, but high velocity winds can produce the same effect. It is most commonly seen in wood structures that have weak wall sheathing or walls of insufficient length. It may also be seen in buildings with unreinforced masonry and/or unreinforced concrete walls, as well as in diagonally braced steel frames. In rare instances it could occur when reinforced concrete walls are present.

- Basic instability occurs when the gravity load is offset a distance that is large enough to overcome the shear capacity of walls at a particular level, usually on the first story.
- The horizontal resistance required to maintain stability in the racked condition is proportional to the percent of offset. For example, when a 10' high story is offset 1', then 10% of the total gravity load above that level is required to keep the parallelogram from becoming flatter. This is the offset collapse pattern.

INADEQUATE BEAM/COLUMN JOINT STRENGTH

Inadequate beam or column joint strength failures are caused mostly by earthquake shaking of buildings that have joints with poorly confined concrete.

- The cycling of the structure when excited by the earthquake causes moment-resistant joints to unravel as concrete chunks are stripped away from the reinforcing steel cage.
- The gravity load can no longer be supported by these columns, and it drives the structure earthward until it stops on the ground or lower floors that have sufficient strength to stop the falling mass.
- This type of collapse may result in a pancaked group of slabs held apart by broken columns and building contents, or a condition in which columns are left standing, punched through slabs. The slabs may or may not be horizontally offset from each other.

TENSION/COMPRESSION FAILURE

Tension or compression failure is caused mostly by earthquakes and usually occurs in taller structures with concrete shear walls and/or concrete or structural steel moment-resistant frames.

- The tension that is concentrated at the edges of a concrete frame or shear wall can produce a very rapid loss of stability.
- In walls, if the reinforcing steel is inadequately proportioned or is poorly embedded, it can fail in tension and result in the rapid collapse of the wall by overturning.
- A more common condition occurs when the tension causes the joints in a concrete moment-resistant frame to lose bending/shear strength. A rapid degradation of the structure can result in partial or complete pancaking, as in the case with beam or column failure.
- The failure of the Pino Suarez Tower is an example of how poorly proportioned, steel structures can catastrophically overturn as a result of the compression failure of the columns.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

WALL-TO-ROOF INTERCONNECTION FAILURE

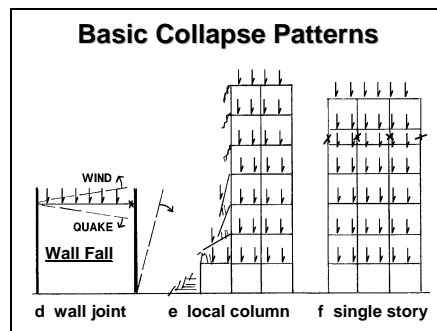
In wall-to-roof interconnection failure, stability is lost since the vertical support of the roof/floor is lost, in addition to the horizontal out-of-plane support of the wall.

- This condition can be triggered by any of the destructive forces previously mentioned.

LOCAL COLUMN FAILURE

Local column failure can lead to a loss of stability and/or a progressive collapse in a part of a structure and may, again, be caused by any of the previously mentioned forces.

- Pre-cast concrete and structures that have wood floors tend to be more susceptible to a progressive type of failure because of a lack of continuity in these construction configurations.



SINGLE FLOOR COLLAPSE

Single floor collapse has occurred in earthquakes due to pounding or vertical irregularities that focus the damaging effects on a single story.

- Most common of this type of collapse is a soft first story.

BASIC COLLAPSE PATTERNS SUMMARY

In most collapses (except cases in which wind causes lifting), the driving force is the gravity load acting on a structure that has become unstable because of horizontal offset or insufficient vertical capacity. In addition, subsequent lateral loads from wind or aftershocks can increase the offset, exaggerating the instability. The structure is often disorderly as it collapses. Some parts may remain supported by adjacent un-collapsed bays as tension structures.

The issue in USAR is not the academic one of how the structure collapsed but what additional collapse is possible, how stable is the existing configuration, and where are the most probable location of survivors.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

NFPA COLLAPSE PATTERNS

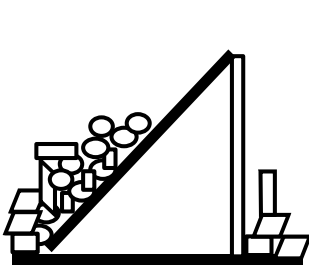
There are five collapse patterns that have been defined by the NFPA 1670 Committee. This committee sets the standards for various types of training that involves first responders.

These five were taken from World War II Civil Defense documents, and are useful in communicating basic patterns.

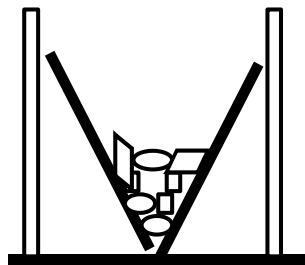
Understanding the types of collapse patterns will provide valuable information in determining everything from the need for shoring, the types of shoring to be used, possible victim location, victim access, and the probability of victim survivability.

It should be noted that one may find more than one collapse type in addition to the primary type at a given incident.

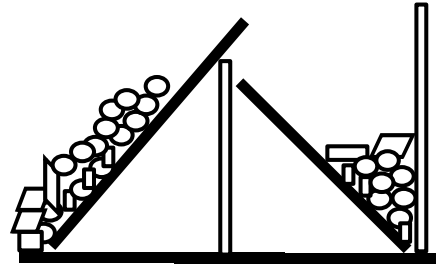
NFPA 1670, 5- Collapse Patterns Based on WW-2 Arial Bomb Damage



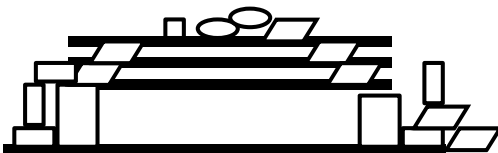
Lean-To



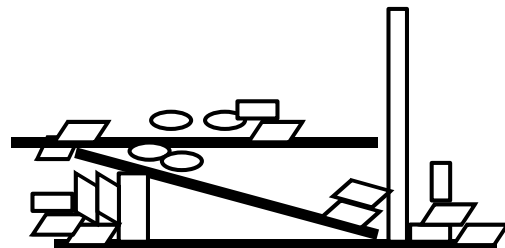
Vee



A-Frame



Pancake



Cantilever

We will look at All Collapse Types

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

EARTHQUAKE COLLAPSE PATTERNS

BASIC PRINCIPLES

- Earthquake shaking causes damage to structural load resisting systems.
- Gravity causes structural collapse.
- Redundancy and ductile behavior can prevent or reduce the extent of a structural collapse.
- Brittle behavior enhances the possibility and increases the extent of a structural collapse.

EARTHQUAKE SURVIVABILITY

The focus of USAR is to find and remove as many trapped victims as possible. The survival rates decrease with time. The first 24 to 36 hours are often referred to as the golden hours. Even though survivors have been located and removed after as many as 14 days for earthquakes, these are rare occurrences. It is important that responders use their knowledge of collapse patterns to assist search in prioritizing the disaster site.

Earthquake Survivability Survival vs Time of Extrication

1 Hour	95 %
1 Day	81 %
2 Day	37 %
3 Day	34 %
4 Day	19 %
5 Day	7 %
Individuals have survived for as long as 14 days in confinement	

Earthquake Collapse Patterns

- **Light Frame - Wood Frame Buildings**
1 to 4 stories, Residential & other
 - Offset Collapse Pattern
- **Heavy Wall - URM, TU, & other low rise w/Concrete or Masonry Walls**
 - Wall Fall Collapse Pattern
- **Heavy Floor - Concrete Frame Bldgs**
 - Pancake, Overturn & Soft First Story Collapse
- **Precast Concrete - fairly Heavy Floors & some w/Heavy Walls**
 - Random Fall Collapse Pattern
- **Diag. Braced Steel Frame**
 - Overturn Collapse Pattern

BASIC BUILDING TYPES

Based on previous earthquakes, the ATC-20 building types can be further divided into five separate groups, each exhibiting a distinctive collapse pattern. These groups are:

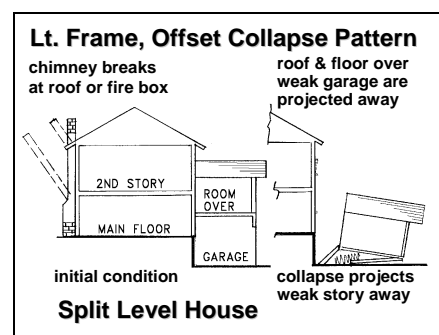
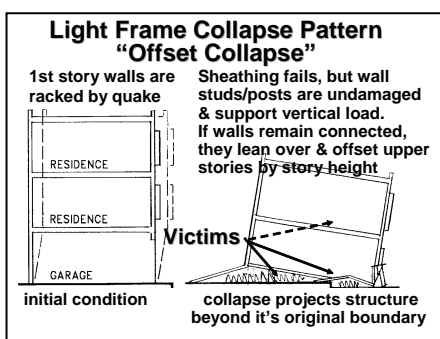
- **Light Frame** (mostly wood frame)
- **Heavy Wall** (URM, tilt-up, and other low-rise buildings with concrete and masonry walls)
- **Heavy Floor** (concrete frame buildings and highway bridges)
- **Pre-cast Concrete Buildings** (fairly heavy floors and some heavy walls)
- **Steel Frame Buildings** (either moment frame or diagonally braced frame buildings)
- Most collapse problems have occurred in diagonally braced buildings.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

LIGHT FRAME COLLAPSE PATTERNS

- These structures are unique in that they may be described as skin and bones structures. The lateral load resisting skin is separate from the vertical load resisting studs, posts, and columns. In an earthquake, the sheathing is the element that attempts to resist the lateral movement, and the bones only receive additional stress if they are located at the edges of walls.
- Collapse usually occurs when the sheathing on the lower walls have insufficient strength to resist the lateral forces and the walls rack (become parallelograms). This is called an offset collapse pattern.



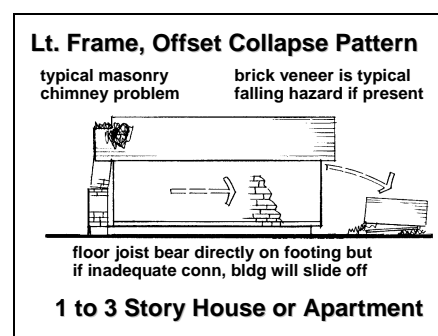
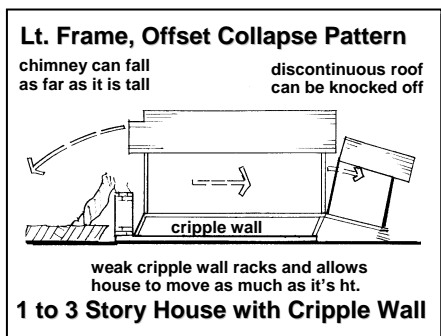
- If there is a sufficiently heavy load on these walls, they can completely collapse as the top of the wall moves sideways a distance equal to its height.
- This movement causes part or all of the building being projected away from its original foundation by the height of the story walls that fail.
- This offset can occur in a split level house as well as a three or four story building.
- When the bottom story of a multi-story, light frame structure fails in this way, additional stories can collapse due to the impact of the first story hitting the ground.
- In an offset collapse, most victims will be found within the story or stories that have offset and collapsed. Due to the light nature of wood construction, furniture, appliances, kitchen cabinets, etc may form voids. The safest access will be achieved by cutting through the wood floors from the uncollapsed story above. However, in multi-story, stacked construction, rescuers must recognize that there has been an offset between stories, by the width of the offset.
- Victims may be found above the offset story, as they may have been injured due the sudden and violent movement of these upper stories as the structure below offsets.
- In some light frame, wood construction, there is a crawl space below the first story. Structures of this type may be as tall as three stories. In older construction of this type, the crawl space walls were not properly strengthened with structural sheathing, and are vulnerable to an offset collapse, due to a weak story.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

LIGHT FRAME COLLAPSE PATTERNS (Continued)

- Most modern buildings of this type have plywood sheathing in the crawl space. Most old building of this type in California and Washington have been strengthened, and are much less susceptible to this type of collapse.
- In wood structures, when the lower floor rests directly on the foundation, but is not well connected to that foundation, the entire structure can slide over or off the foundation.
- In all cases, a great danger of fire exists as a result of the combination of broken gas (or other fuel) lines and combustible debris.



HEAVY WALL COLLAPSE PATTERNS (URM)

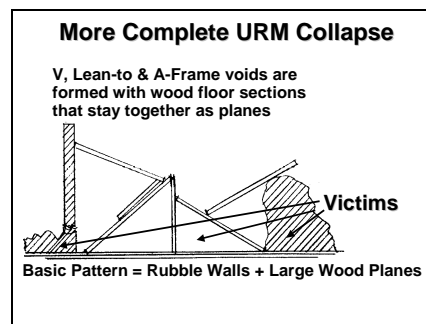
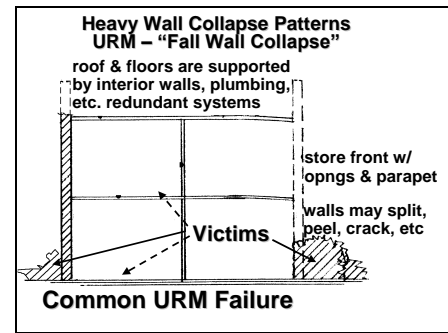
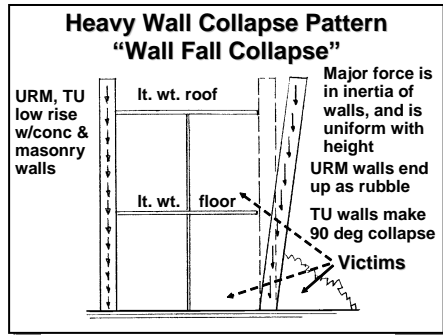
- Collapse is usually partial and is strongly related to the heavy, weak bearing walls falling away from the floors. This is the wall fall collapse pattern.
- In URM buildings, the walls normally fall away from their original position but most often do not project out as far as their height.
- The combination of the weak interconnection of the masonry pieces and gravity tends to cause the debris to stay within 10 to 15 feet of the building face.
- When property line walls fall on an adjacent, lower building, these structures will usually have some sort of roof/floor collapse.
- In many URM wall fall collapses, large, room size, void spaces remain within the structure. Most occupants in that case are likely to have exited. Areas outside and adjacent to the walls where parts of the heavy walls have fallen often contain badly injured or dead victims.
- When sections of the wood roof and/or floors collapse, many easily accessible voids can be created by furniture, machinery, appliances, etc.
- In a collapse resulting from the failure of interior columns or fire, a very precarious situation involving multi-story heavy walls that are left standing without any laterally supporting floors/roof is possible. Under such conditions, it is probable that the walls could fall in such a way that they extend their full height along the ground, and trap and kill anyone outside the building
- The combination of broken gas lines and debris can lead to fire.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

HEAVY WALL COLLAPSE PATTERNS (URM) (Continued)

- Experience with this type of building lead to the development of the 5 NFPA collapse patterns.



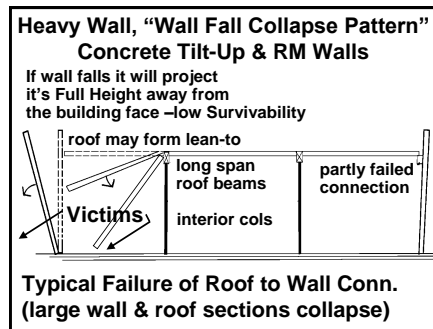
- In the Lean-to, V, and A-Frame collapse patterns, large voids may be created. However, the trapped victims may be found on top of the sloped floor, near the bottom. The contents of this space above the floor have slid to this location, and may have captured victims as well. It should be easy to access this type of collapse, but care must be taken when moving heavy objects, and some shoring may be advisable.
- In this type of collapse, victims may also be trapped below the sloped floor at the shallow end. In this case, access may be made by cutting through the floor. Unless it has been carefully evaluated by a Structures Specialist, the URM walls should not be breached.
- For Pancake and Cantilever collapse patterns, survivable voids may be formed between floors by furniture, machinery, appliances, etc, if the weight on the floor is relatively light. Access may be made by cutting the wood floors, or by finding roof hatches, stairs, or elevator shafts.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

HEAVY WALL COLLAPSE PATTERNS (TILT-UP)

- Walls in tilt-up buildings normally fall away from the roof or floor edge, but since they are very strong panels, the top of the wall will fall as far away from the building as its height. This wall fall collapse is somewhat different from one that involves URM construction.
- Since tilt-ups have longer roof/floor spans, the adjacent section of roof will usually collapse, although it may still be supported at its far end, and form a Lean-to collapse.
- Tension forces will be imposed on the roof system, therefore, all beam-to-beam and beam-to-column connections may be damaged and/or pulled out.
- Since tilt-up walls are relatively strong and collapse as a unit, it is unlikely that victims in the wall fall zone can survive
- Within the structure, since the roof is relatively long span and light, lean-to voids may be created. In this case, victims should be found under to sloped surface near the bottom.
- If there are interior partitions within the structure, many types of survivable voids can be formed, including Lean-to, A-frame, V, or one or more levels of a pancake.



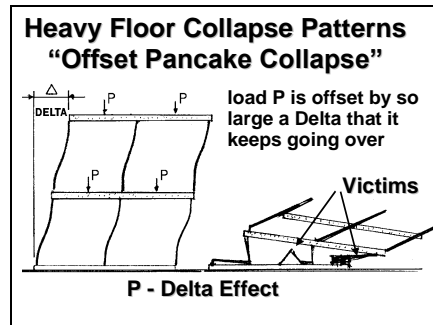
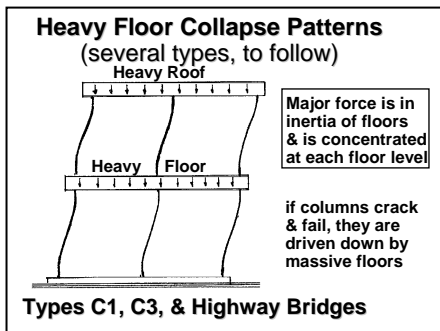
HEAVY FLOOR COLLAPSE PATTERNS

- A heavy floor collapse can be partial to complete. It is usually caused when columns are weakened at the column-floor joints by an earthquake motion and then unable to support the heavy floors.
- The collapse patterns are varied. They include pancake, offset pancake, soft story (mostly first story), overturned, and torsion (corner buildings).
- These heavy floor structures usually fall on themselves, but they can project laterally as they fall, if the columns and/or walls are strong enough not to fracture. In other words, the columns can fail due to hinging at the top and bottom, and then the collapse becomes an offset pancake.
- Voids can be very difficult to access. They are usually still well interconnected with reinforcing steel, and fairly well intact. Although time consuming, access can be made by breaching the concrete slabs from above with saws and drills.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

HEAVY FLOOR COLLAPSE PATTERNS (Continued)

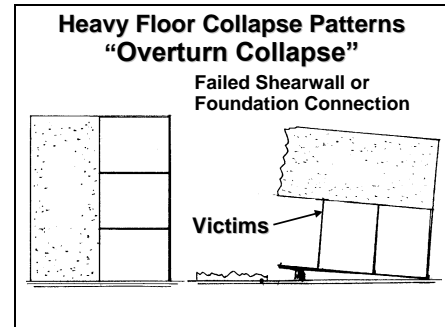
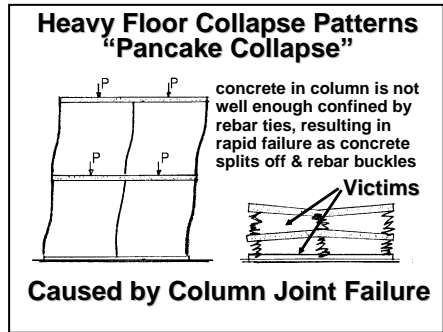


- If the floors are sloped, similar to a Lean-to collapse, triangular voids can be formed. It is most likely that entrapped victims will be found above and below floors at the bottom of the slope, and access should be sought within the void. However, since the floors are heavy and may have been forced down by upper stories, fully pancaked floors may also be found in this type of collapse.
- Complete pancake collapse can occur when the column-floor joints fail and the structure is so heavy that gravity causes it to collapse onto itself.
- The height of the remaining voids between floors in Pancake collapsed buildings will depend on what projections the slabs originally had (like beams and thickened slabs at columns) and broken concrete columns or partly crushed contents.
- Victim access is difficult, but can be done by saws and drills in the hands of trained rescue personnel. The mostly intact slabs can span obstructions and form life saving voids, but they are also much more difficult to breach than wood floors.
- Earthquake motion can cause reversing tension and compression forces at the faces of tall, moment-resistant frame structures. When these earthquake induced forces in the exterior columns abruptly change from tension to compression, a sudden and progressive failure can occur. If several stories are effected, this can lead to a pancake collapse. However, some taller heavy floor structures have been subjected to overturn collapses.
- Overturn collapses have occurred in these taller structures when columns or walls fail due to tension and shear failure at the base. The leading cause of this is inadequate anchorage to the foundation.
- Under these conditions, the structure can project sideways by its full height.
- Survivability has been high in this type of collapse, since the original structural configuration has been maintained above the lower story.
 - The victims in the upper stories may have been thrown about and injured, but they can be easily accessed using ladders, man lifts, etc. There were many collapses of this type following the Taiwan earthquake in 1999, and most of the occupants survived.
- A soft first-story collapse occurs in buildings that are configured such that they have significantly less stiffness (many fewer walls or no walls) in the first story than in the stories above.

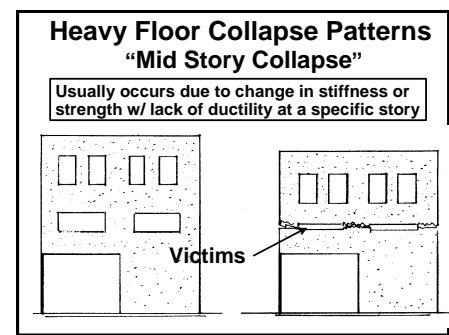
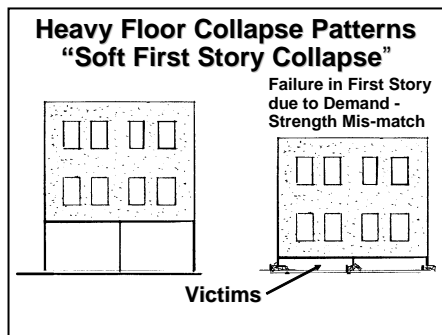
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

HEAVY FLOOR COLLAPSE PATTERNS (Continued)



- This configuration often occurs in building where the first story occupancy is commercial (few if any walls are desired) and the upper stories are residential.
- The quake damage becomes focused on the soft story, and what lateral resistance that is present becomes overwhelmed.
- A soft first story configuration is not viable in any type of rigid construction (concrete, masonry, etc), and even wood structures with this defect perform poorly .
- The collapse is often limited to the one soft story, as the building becomes about one story shorter.
- Most all victims will be found within the first story, and the survival rate is very high above the second floor.
- The first story should be accessed by cutting through the second floor, although properly trained search dogs can be directed into the first story voids from ground level.



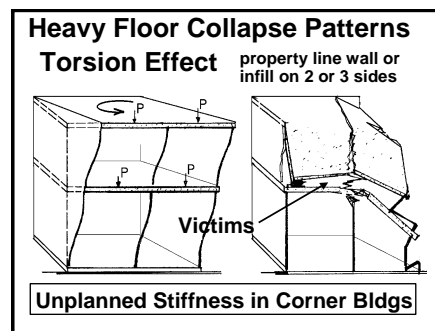
- A mid-story collapse can occur when a middle story is configured with much different stiffness than the stories above and below. This can occur at any abrupt change in stiffness.
- It can occur when a story has no walls and the ones above and below have significant walls.
- It can occur when a story has stiff, short columns and the ones above and below have longer, more limber columns.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

HEAVY FLOOR COLLAPSE PATTERNS (Continued)

- Survival should be high above and below the collapsed story, however, access to stories above may be blocked.
- The victims within the collapsed stories should be accessed by breaching from the story above. Also, an access to the upper stories from below needs to be created in order to allow those trapped above the collapse to exit and rescuers to access the floor to be breached.
- Pounding can cause a mid-story collapse, leaving a difficult problem to assess because the remaining floors are overloaded.
- A pounding collapse normally occurs when two adjacent buildings have floors that are at different elevations.
- The very stiff /strong edge of a floor in one building will cause the collapse of the adjacent building's column when they collide.
- The victim access issues are essentially the same as for mid-story collapse.
- Torsion effects occur in concrete frame structures when URM infill is placed within the concrete frames on the exterior property line walls for fire resistance. This occurs in corner buildings, where the street side concrete frames have only light transparent, infill (open sides). The property line walls, prior to being cracked by earthquake motion, are stiffer than all the other moment resistant frames in the building. This can cause a temporary eccentric condition that can lead to collapse of the beam-column frames on the street sides of the building.
- In most cases, only the structural bays next to the street sides will collapse, leaving a significant part of the structure relatively undamaged.
 - The collapse zone will normally be some combination of a Pancake and Lean-to collapse, since some of the floor slab will be hanging off the uncollapsed area.
- Most of the victims will be found in these collapsed areas, adjacent to the two street sides.
- Search and victim access should be attempted by working from the uncollapsed area at each floor level, into the collapsed area.
- Voids will be created by pieces of structure and projecting structural elements, as well as the shape if slabs remain hanging from the uncollapsed structure.
- If viable victims are found, local and multi-story shoring may be used to reduce risk.



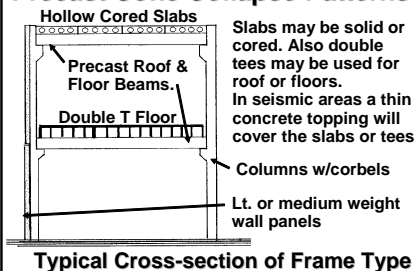
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

PRE-CAST CONCRETE COLLAPSE PATTERNS

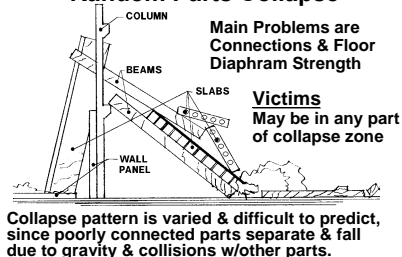
- A pre-cast concrete collapse is usually caused when the pre-cast parts become disconnected from one another and the structure very rapidly loses stability.
- The collapse normally contains numerous layers of broken and unbroken pieces of slabs, walls, beams, and columns. The best description of this is a collapse of random parts.
- It is difficult to predict how far the parts can be projected away from the original structure's position or if survivable void spaces will be created. Gravity normally will drive parts downward without projecting them laterally away from the building, but they may form a relatively compact rubble pile.
- Victims are normally located within the rubble, but survivability has been low. Voids can be created, but there is no regular pattern.
- The voids can be difficult to access, but the slab can be removed, layer by layer, since interconnection is normally poor to non-existent.
- If the structure contained single or double tee floor members, they have two inch slabs through which access openings can be cut. If a topping slab originally covered the tees, breaching will be more difficult.
- Pre-cast concrete parking garages have performed particularly badly.
- They may be as large as 400' x 400' and be as many as eight stories tall.
- Outside of California, most do not have a cast in place floor topping to help tie the structure together.
- In some cases, a cast in place slab may be installed that is supported by pre-cast beams and columns. This configuration should perform better, especially if there are shear walls.

Precast Conc Collapse Patterns



Slabs may be solid or cored. Also double tees may be used for roof or floors. In seismic areas a thin concrete topping will cover the slabs or tees

Precast Conc Collapse Patterns "Random Parts Collapse"

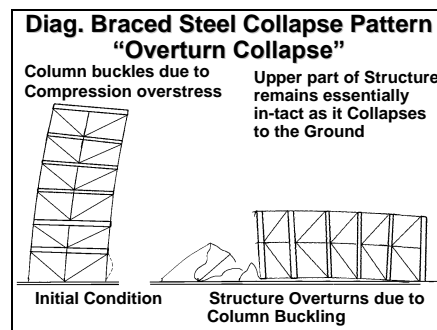


RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

STEEL FRAME COLLAPSE PATTERNS

- Collapse is usually caused when columns are not proportioned so that they are capable of receiving the combination of structure weight and the vertical component of the earthquake load that can be delivered by the diagonal braces connected to them.
- The affected column or columns can buckle, causing a catastrophic, overturning failure.
- This effect is attributed to the catastrophic failure of the Pino Suarez, 20 story tower during the 1985 Mexico City earthquake.
- The victims in this type of collapse should be found in the overturned part of the structure. The victims may be accessed within the open areas of the structure that are now laying nearly horizontal.
- In some cases when tube type members are used for diagonals, sudden local crippling at cross-section corners has resulted. This can occur when cold rolled tubes are used, since high stresses are originally induced during forming.
- Inadequate detailing or workmanship at connections has caused local failures such as buckling of connection plates and roll over of beams.
- The result of this type of failure rarely causes collapse, but damage can be caused to non-structural elements such as rigid wall panels, stairs, and interior finishes.



WINDSTORM COLLAPSE PATTERNS

WINDSTORM BASICS

- Wind forces normally affect light, poorly, or non-engineered structures and generate both static and dynamic pressures on exterior surfaces and impact forces from missiles/debris.
- High winds can peel off light roof/canopies, and any type of "Open" structure is very vulnerable.
- Well engineered structures are designed to resist wind forces by elastic action (in contrast to the inelastic response that is assumed in earthquake design), therefore, it is unusual to have this building class sustain significant wind damage.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

WINDSTORM BASICS (Continued)

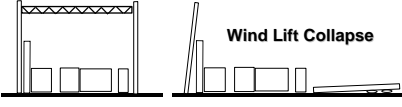
- A very common occurrence is a wind lift collapse.
- If the roof is blown off, the wall support is lost and the walls may collapse inward or outward, depending on what other elements (such as wall corners/intersections of intermediate floors) are available to provide redundancy.
- This type of collapse can even occur in heavy wall buildings, especially if large, metal doors are present.
- Missiles can penetrate glass openings or doors blow in, structures change from "closed" to "open" type, and roof and/or leeward walls are blown out.
- Victims, if they have not evacuated prior to the hurricane, would not likely survive if caught beneath a heavy wall.

Windstorm Basics

- Light, poorly or non-engineered structures are most vulnerable
- High winds peel off light roof/canopies
 - Any type of open structure – very vulnerable
- Airborne missiles penetrate – cause collapse by impact or by creating open structure
- Storm Surge/high waves can cause collapse/damage to engineered structures
 - Windstorms often produce flooding – even if no wind damage

**Common Windstorm Collapse Pattern
“Wind Lift Collapse”**

- Roof blows off, and Walls Collapse due to lack of Lateral Support
- Missile penetrates glazed opening or door blows in, structure changes from "closed" to "open", roof blows off and walls fall (in or out)
 - Even tilt-up concrete, and other Heavy Wall Bldgs



Wind Lift Collapse

- A storm surge, associated with coastal windstorms, can produce collapse of lighter structures and even damage to engineered structures.
- The destructive tidal surge of Hurricane Ivan in September 2004 caused damage to freeway bridges and concrete buildings as well as lighter structures.
- Windstorms often produce flooding even if there is little wind damage.
- Tornadoes, with winds above 200 MPH, can damage all but the most well engineered and well constructed buildings.
- The most destructive tornadoes have lifted train locomotives.
- Light structures are extremely vulnerable to the lifting forces generated by tornadoes.
- The most effective defense against loss of life, is to have some part of a structure be designed as a shelter.
- In some cases, tornado warning can be given, but they are only warning that the conditions are present in a general area, and not the precise location where one will occur.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

MOST COMMON WIND COLLAPSE

- Probably the most vulnerable structures are light metal buildings and mobile homes.
- Light metal buildings are often penetrated by the wind and then the skin and supporting roof members are compromised. Something as simple as not having a flutter resisting rubber gromet under the roof panel screw heads, can start a “Weak Link Behavior” collapse.
- Mobile homes are often factory built at minimum cost. In older models, the connection between the metal frame and wood walls were made using very light 24 gage straps and staples. More modern models use 16 gage straps and screws.
- In any case, the tie-down straps need to be properly installed, not taken out of the way for convenience.
- Part or all of a light roof may be blown off and the walls, could then, collapse due to lack of lateral support.
- Very tall walls may be blown in or out causing the roof to collapse.

Common Windstorm Collapse Pattern Most Vulnerable Structures

- Light Metal Bldgs - collapse due to buckling or bending failure of long span roof, pull out of frame base
 - Weak Link Behavior – starts with something as simple as roof sheathing being blown off due to lack of rubber grommet under screw head
- Mobile Homes – collapse due to inadequate connection to base frame
 - Newer models use 16ga strap w/screws
 - Older models used 24ga. w/ staples

Problematic Building Types

- Wood Houses
- Mobile Homes
- Other Frame, multi-residence condos
- Light Metal Buildings
- Commercial & Industrial - URM, RM, TU
- Aircraft Hangers
- Large, Long Span Structures

- Types of structures that are seriously damaged by hurricanes usually fall into three categories:
- **Pre-engineered buildings** usually consist of moderate span steel framing with metal siding or masonry wall construction. They are usually commercial and light industrial buildings.
- **Marginally-engineered buildings** have some combination of partly reinforced masonry, light steel framing, steel joist, wood trusses, and/or wood rafters. The exterior walls may be masonry, stucco, or siding, and there may be large truck-doors.
- **Un-engineered buildings** such as homes and apartments.

Problematic Special Buildings

- Aircraft Hangers
 - very high winds lifted roof which released top attachment of large sliding doors
 - aircraft inside were destroyed by swinging or falling doors
- Large, Long Span Structures
 - under engineered Precast Concrete

Hurricane -Storm Surge Damage to Larger Structures

- Surge/Buoyancy Lifts and Displaces PC Slabs & Highway Bridge Slabs
- Surge/Buoyancy Lifts and causes Uplift Failure of Flat Slabs
- Scouring Undermines Foundations and causes Partial Collapse

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

MOST COMMON WIND COLLAPSE (Continued)

- Storm surge can damage large, heavy structures that have not been designed for adequate uplift.
- Precast concrete highway bridge slabs and dock slabs can be displaced by this surge.
- Second story flat slabs have collapsed due to the uplift pressure causing a punching shear failure at supporting columns (upward punch).
- Scouring has caused the undermining of foundations, leading to the partial collapse of multi-story structures.

COMMON WINDSTORM DAMAGE

- Structural hazards created by windstorm damage include:
- The partial removal of the roof and/or wall skin in a light frame building. Partial loss of the lateral load resisting system.
- Peeling of the outer layer of multi-layer, cavity-type, masonry bearing wall (lightly reinforced, eastern-type construction).
- Removal of masonry veneers on wood and metal frame walls.
- Removal of roofing materials: clay/concrete tile, shingles, gravel, etc.
 - All items can be destructive missiles.

Common Windstorm Damage

- Partial removal of roof/wall skin
- Masonry wall peel - older URM or modern, insulated, masonry cavity walls
- Removal of masonry veneers - low & high rise
- Loss of roofing material - tile, shingle, gravel
- All become destructive missiles

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

FLOOD COLLAPSE PATTERNS

COMMON FLOOD COLLAPSE PROBLEMS

- Common flood collapse problems include:
- Structures move partly or completely off their foundations.
- They can slide if moved completely off or tumble if one side stays attached. Structures that have been moved may be repaired but should initially be considered hazardous.
- Foundation and/or basement walls may have walls broken, offset, and/or badly cracked due to hydrostatic and/or hydrodynamic forces.
- Slabs on graded and shallow foundations can be undermined by swift moving water.
 - Undermined foundations may result in a hidden problem that would need to be carefully investigated.
- Wall, floor, and/or roof collapse may be caused by impact from objects as large as residential structures.

Flood Damage Patterns

- Riverine or Coastal Flooding
- Most damage is to light structures
- Moving water can impact & collapse or flow past & peel off the lt. walls of bldgs
- Waterborne debris - can cause collapse by penetrating structures
- Fast moving river or tidal surge can cause collapse/damage to engineered structures
- Slow moving water can produce buoyancy + standing water effects

Common Flood Damage

- Light frame structure shifted off foundation
 - Buildings can slide if free of foundation or will tumble if one side stays attached
- Broken and/or tilted foundation walls
- Undermined foundations & slab on grade
 - Potential for subsidence, geotechnical effects
- Buildings impacted by debris
 - 1st & 2nd floor joist may be lifted off bearings, in unstable condition
 - Need to determine high water mark

COMMON FLOOD DAMAGE PROBLEMS

- A high water mark will normally indicate the extent of flood damage in structures that have remained in place.
- Buoyancy can cause parts of the structure to be lifted.
- Wood floors and roofs can be lifted off their bearings by hydrostatic pressure, leading to a hidden hazardous support condition.
- Long-standing water can cause geotechnical problems, leading to subsidence.
- In addition to structural damage, wood floors that have been submerged may become warped.
- Flooding can cause black mold to occur, especially in hidden, enclosed spaces that are not dried rapidly.
 - Black mold can cause severe health problems.
- Flooding may also lead to many hazardous materials problems.

RESCUE SYSTEMS 3

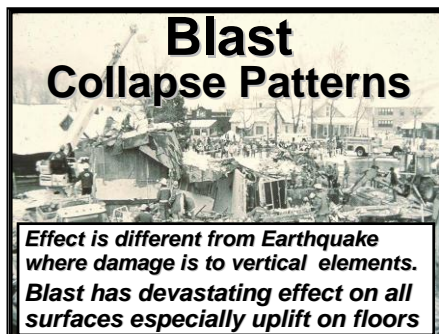
STRUCTURAL COLLAPSE TECHNICIAN

BLAST COLLAPSE PATTERNS

BASIC EXPLOSION EFFECTS

These effects are very different from those caused by earthquakes, where the damage causing collapse are the vertical elements (column connections and shearwalls). The pressures exerted on buildings by explosions may be many orders of magnitude higher (5000 psi+) than normal design pressures, but their duration is in milliseconds, and they are inversely proportional to the cube of the distance from the center of the source.

- Damage to structures may be severe, but it is only a fraction of what a proportional static pressure would cause.
- When large surfaces are engaged by blast pressures, they will be moved as the shock wave passes, but the direction of the net force (initial uplift, overpressure) will be determined by the complexities of the wave path and time.
- Heavy columns tend to survive but may have some of the floors that load and laterally brace them removed.
- Steel frames, beams, and columns may also survive but without all their intended bracing.
- The wall and floor planes in frame as well as box buildings have large surfaces that will receive most of the blast pressure. They likely will be ripped away from their connections, leading to the collapse of at least part of the structure.
- Occupants within the blast zone are usually killed or severely injured. There is little record of anyone surviving when they have been exposed to the direct blast pressure.
 - However, if individuals are shielded from the blast pressure by concrete walls or other heavy, strong components of the structure they may survive
- Since the floors of a structure are usually thrust upward, and then collapse into a dense rubble pile, survivability is very low.
 - If somehow protected from the direct effects of the blast, victims may be injured by flying objects, especially glass shards.



Basic Explosion Effects

- Large pressures exerted by explosions
 - Short Duration - only Milliseconds
 - Rapidly dissipates with distance
- Severe damage to structures
 - Effects surfaces in all 6 directions
- Effects of fast moving shock wave
 - May be very complex
 - Lift from Inside then Push Down from Outside
 - Pull-out Walls then Push them IN

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

BLAST EFFECTS ON SPECIFIC BUILDINGS

The most predictable blast damage by structure type:

- **Wood Frame (W):** The light wall and roof planes can be blown away and/or shredded. Leveling all or at least a significant part of the structure can occur.
 - Occupants within light structures have little protection, and are normally killed or severely injured.
- **Steel Frame (S1 and S2):** A well designed steel frame may be relatively resistant since beams and columns have resistance to both upward and downward loads as well as tough connections and small dimensions.
- Light floor framing such as metal deck with concrete fill or bar joist may be separated from beams since they have large areas and small connections that can be unzipped.
- The most likely scenario is for at least part of the frame to remain, but beams may be twisted, with large areas of the floor diaphragm missing. This is called a lift and drop collapse.
 - The occupants on the floors that are lifted and collapse have little chance of survival. They are normally found within the tightly packed rubble at the “ground” level.

Blast Effects on W & S Buildings

- **W - Wood Structures**
 - Light wall/roof surfaces are blown away. Remainder collapses
 - End up with leveled structure
- **S1 & S2 - Steel Frame Structures**
 - Beams / columns have small dimensions and are very resistant to sudden forces.
 - Light floors may be blown away, leaving poorly braced beams & columns.
 - “Lift and Drop Collapse”

Blast Effects on S3 Buildings

- Wall & roof panels are easily blown away. and steel framing may be pushed over
- Blast at Explosives Manufacturing Plant near Reno NV ,1998.
 - First explosion was in primer mixing room
 - Set off 2nd blast and completely disintegrated structures.
 - Miraculously 12 of 16 workers escaped

- **Light Metal (S3):** The light metal roof and wall panels can be easily blown away, leaving a bare, poorly braced frame.
- Roof, purlins, and wall girders normally have relatively light connections and may be removed with the metal panels.
- The frames may collapse from lack of lateral support and/or push from the blast pressure.
- The result can be a completely collapsed pile of bent and twisted steel members (structural steel spaghetti).
- Occupants within these light structures have little protection, and are normally killed or severely injured. They may be found at some distance from their original position.

RESCUE SYSTEMS 3

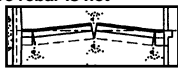
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BLAST EFFECTS ON SPECIFIC BUILDINGS (Continued)

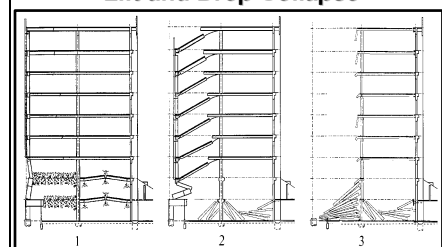
- **Concrete Frame (C1, C2, and C3):** The lift pressures have had devastating effects on concrete slabs in gravity-type designs.
- One-way slabs hinge up because of the lack of top reinforcing at mid-span and continuity splices in bottom bars at supports.
- A critical location for flat slabs is at the columns where the uplift pressure causes the slab column joint to fail in upward punching shear, followed by a combination of gravity and positive overpressure that tends to drive the already damaged slab downward. This is a lift and drop collapse pattern.
- The remaining structure may contain columns that are standing, exposed for several stories without the lateral bracing that the collapsed floors used to provide.
- This occurred in both the 1993 World Trade Center and Murrah Federal Building disasters. Large areas of several floors collapsed, leaving columns that extended as far as six stories without lateral support.
- These columns, still heavily loaded were vulnerable to a sudden collapse and needed to be braced to reduce the risk to rescuers.
- The occupants on the floors that were lifted and collapsed had little chance of survival. They were found within the tightly packed rubble at the “ground” level, some as far as 50 feet from their original position.
- In the Murrah Building collapse several individuals were spared since they were standing and waiting for the elevator that had very strong concrete walls. The walls shielded them from the blast pressure, any the elicitor walls kept the floors in that area from collapsing.
- In C3 type concrete frame buildings, the URM infill is particularly vulnerable to blast pressure (large areas and very little resistance to the lateral pressure).

Blast Effects on Concrete Structures “Lift and Drop Collapse Pattern”

- Lift forces have especially devastating effects on gravity designed slabs
 - When gravity force is overcome, slabs and beams can hinge where rebar is not continuous
 - At mid-span and at span ends
- This can result in multi story columns left standing w/o enough lateral bracing
 - Multi level collapse is then probable



Probable Collapse Sequence “Lift and Drop Collapse”



Example of Blast Survivability Oklahoma City Example

- 359 people were in the building when the bomb was detonated
 - 517 persons were injured, Total in area
 - 169 individuals were killed, including 19 children & 1 volunteer nurse
- Final live person (15 y.o.) was found at 1700hrs and removed by 2030hrs on Day 1
 - Many were accessible by remaining stairs or aerial ladder
- Almost all of the deceased victims were within the collapse zone
 - 6 were in adjacent buildings, 1 in street

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

BLAST EFFECTS ON SPECIFIC BUILDINGS (Continued)

- **Pre-cast Concrete (PC2):** In pre-cast frame type structures, the lightly (gravity) connected floor slabs and wall planes can be blown away, leaving unbraced beams and columns.
- If beam/column connections are minimal, entire sections of the structure could collapse. Progressive collapse has occurred when only one column was dislodged by a relatively small gas explosion in a multi-story, pre-cast structure.
- In box type PC2 (such as the barracks in Saudi Arabia), the wall and floor slabs nearest the blast may be dislodged and broken loose at their joints.
- The multi-cellular character of these structures (created from closely spaced bearing walls) will, however, tend to limit the collapse damage to those areas where the bearing capacity of wall panels is lost.

Blast Effects on PC2 Buildings

- PC2 - Frame type structures
 - pressures can dislodge walls, slabs
 - beams & columns then effected by lack of bracing.
 - break/damage many connections
 - progressive collapse possible.
 - Due to missing supports and dis-continuous members.
- PC2 - Box type structures
 - pressures can dislodge walls & slabs
 - break/damage many connections
 - better response in multi wall buildings

Compare Murrah Bldg w/ Kobar Towers Similar size Bomb & Number of Occupants



- | | |
|-------------------------|-----------------------|
| • Brittle, Conc Details | • Ductile Connections |
| • Anti-Redundant | • Highly Redundant |
| • 45% Collapse | • 10% Collapse |
| • Collapse/Falling Haz | • Falling Haz |
| • 168 Killed | • 19 Killed |

- Compare the survivability of the Murrah Building and the Kobar Towers, to demonstrate that ductility really does make a difference. There were the same number of occupants and similar blast size for these structures.
- The Murrah Building, even though it was a cast in place concrete structure, performed poorly due to the brittle reinforcing steel configuration (few continuous bars) and anti-redundancy (all columns did not extend to the ground at the building face exposed to the blast).
- The Kobar Towers was a highly redundant, PC concrete multi-wall structure with reasonably ductile connections, and the collapse was limited for the blast facing walls.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

BLAST EFFECTS ON SPECIFIC BUILDINGS (Continued)

- **Post-tensioned Concrete:** If the unbonded cables are damaged, becoming un-tensioned in only one small area of a floor slab, the entire length of the these cables can be affected, which can lead to the collapse of the full length of the floor.
- This type of slab is also very susceptible to upward pressures since the cables are normally draped to lift the weight of the structure. Therefore, the original structure will have less resistance to the blast uplift pressure than reinforced concrete. Also, the concrete may break into very small pieces.
- Pancake or some sort of draped slab pancake collapse can be formed in the floor structure adjacent to the blast zone.
- Victim survivability within the blast area would be low, and access by breaching the concrete slabs, if pancaked, should be used to access victims. However, in areas where these slabs are still intact there are special problems that should be address by a Structures Specialist.
- If the post-tensioned forces have been released, the slabs will act as brittle, un-reinforced concrete.
- If the post-tensioning forces are still active, great care must be taken if any of the cables need to be cut.

Blast Effects on Buildings

- Postensioned Concrete - very vulnerable to uplift pressures. progressive failure within entire slab due to loss of tension in unbonded cable
- TU, RM, & URM - large wall & roof surfaces effected. Lifted roof and blown out ,farside walls

Blast compared to very short term - high velocity wind w/special effects

- **Heavy Wall (TU, RM, and URM):** Blast pressures will tend to engage the wall and roof surfaces, severing connections and blowing large sections away.
- For interior blasts, walls will blow out, and roof sections will be lifted. Adjacent parts of the structure can also collapse from the loss of vertical and/or lateral support.
- For blasts initiated outside the building, the near walls may be shattered or blown in, followed by roof sections being lifted, then dropped, and sections of the far side blown out.
- Victim survivability is very low within the blast affected area, as well as in the area where the heavy walls will fall.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

PART 4 HAZARD IDENTIFICATION, INTRODUCTION TO ASSESSMENT AND MITIGATION

TERMINAL OBJECTIVES

- The student will understand the most common signs of distress exhibited by damaged structures.
- The student will understand the most common hazards found in damaged structures, and the methods used to mitigate them.

ENABLING OBJECTIVES

- Understand crack patterns in reinforced and unreinforced concrete.
- Understand hazard identification in the five types of buildings:
 - Light Frame
 - Heavy Wall
 - Heavy Floor
 - Precast Concrete
 - Steel Frame
- Understand structure hazard assessment and mitigation.
- Understand methods to monitor stability.
- Understand methods to monitor the disaster site.

CRACK PATTERNS IN REINFORCED AND UNREINFORCED CONCRETE

CRACKS IN REINFORCED CONCRETE AND MASONRY

A favorite statement in building design and construction is “if it’s not cracked, it’s not concrete”, because cracks must form in concrete for the reinforcing steel to be stressed in tension. Most normal concrete develops cracks that are narrow (hairline) from shrinkage, temperature change, and predictable structural behavior.

Cracks in Reinforced Concrete & Reinforced Masonry

- Shrinkage cracks
- Temperature cracks
- Tension cracks
- Diagonal tension cracks in beams
- Diagonal tension cracks in walls

If it's not Cracked it's not Concrete

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

SHRINKAGE CRACKS

- Shrinkage cracks usually occur in slabs, beams, walls, and even in columns within 60 days of the pour, after the concrete is allowed to dry.
- Diagonal cracks will originate from most re-entrant corners in slabs and walls, that is, window, door, and floor openings.
- Straight cracks (more or less) occur often at 5 ft to 20 ft on center in long walls and/or floor surfaces, depending on the amount of reinforcing steel, numbers of pour joints, and curing conditions.
- The reinforcing steel within the structure is intended to hold the structure together as it shrinks and keep these cracks small.

Shrinkage & Temperature Cracks

- Occur in slabs, walls, beams, & columns.
- Diagonal cracks originate at re-entrant corners in slabs & walls (openings)
- Transverse (more or less straight) cracks occur at 5 to 20 ft apart in long slabs & walls
- Nominal rebar normally keep cracks small

TEMPERATURE CRACKS

- Temperature cracks occur in roughly the same pattern as shrinkage cracks and are difficult to differentiate from them.
- When the temperature of a concrete structure is decreased, it must shorten (shrink), therefore, it cracks, and the reinforcing steel attempts to hold it together.
- Reinforced concrete structures will experience plainly observable temperature/shrinkage cracking when subjected to the winter cold.

TENSION CRACKS

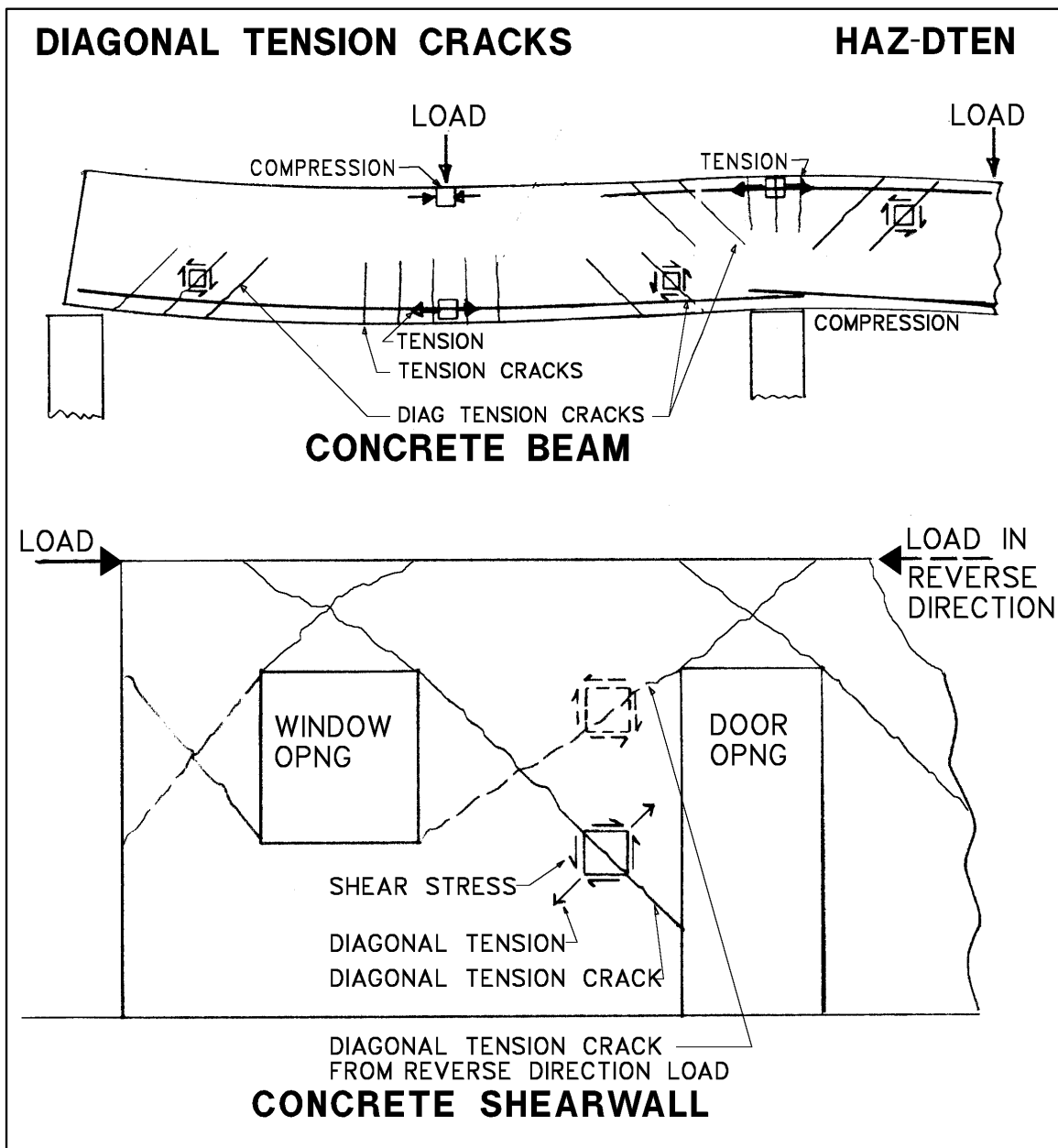
- These cracks most often occur in concrete slabs and beams when bending caused tension forces stretch the reinforcing steel.
- Cracks must form in the concrete in order to transfer the force to the steel, but the cracks are normally quite numerous, small, and undetectable (except to the trained eye).
- They form perpendicular to the long axis of the member, and as long as they remain hair like, the structure is behaving normally.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

DIAGONAL TENSION CRACKS

- Diagonal tension cracks occur in the high shear stress zones of beams and girders in a typical pattern (HAZ-DTEN) under normal vertical load conditions.
- In shear walls, large diagonal tension cracks will form when the walls are heavily loaded by severe earthquake shaking (HAZ-DTEN).
- Earthquakes will normally cause a diagonal crack in each direction (cross cracking) in the highly stressed areas of shear walls (that is, between window openings and over stacked door openings) since the shear force reverses, causing diagonal tension cracking in each direction.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

CRACKS IN REINFORCED CONCRETE WALLS

- The stability of concrete box buildings will probably depend on the post-cracked strength of the shear walls. Even with unsightly diagonal cracking, a shear wall may still have significant strength (HAZ-CK).
- The clamping action of the gravity loads, as well as the vertical rebar, will tend to hold the irregular surface of the cracks together, preventing the opposing surface from sliding. In addition, the rebar that cross the crack can act as dowels.
- Both these resistive actions are lessened when there is enough shaking or continued re-shaking from aftershocks. The crack widens, concrete chunks fall out, and the rebar can be seen in an offset curved condition. In this latter degraded condition, a shear wall has become unreliable and must be evaluated accordingly.

■

CRACKS IN UNREINFORCED MASONRY WALLS (URM)

- Shrinkage, temperature, and diagonal tension/shear wall cracks occur in URM walls as well as unreinforced concrete walls. In these walls, cracking indicates a significantly degraded structure.
- Diagonal tension cracks form in these walls between openings, as they do in reinforced concrete walls, because of earthquake shaking. In addition, cracks are often created at wall corners, with the bottom of the crack at the corner and the top extending up to the roof. These cracks are caused by the action of the disconnected roof diaphragm pushing against the corner, attempting to push it out. URM diagonal cracks tend to follow a stair step pattern (HAZ-CK), that is, the crack follows the weaker mortar, rather than going through the bricks. This action results in cracked surfaces that are smoother than those in reinforced concrete.
- Masonry walls with significant diagonal tension cracks must be considered capable of a sudden, brittle failure. Some clamping force on the horizontal steps of the cracks exists due to the gravity force, but no vertical bars exist to add clamping or dowel action. The greater smoothness of the joints also reduces the friction that could be developed by the clamping of the vertical force.
- Unreinforced concrete walls also perform poorly during earthquakes. They tend to break apart in pieces defined by whatever crack pattern existed before and/or according to the original pour joints. Fortunately, there are very few of these in earthquake areas.

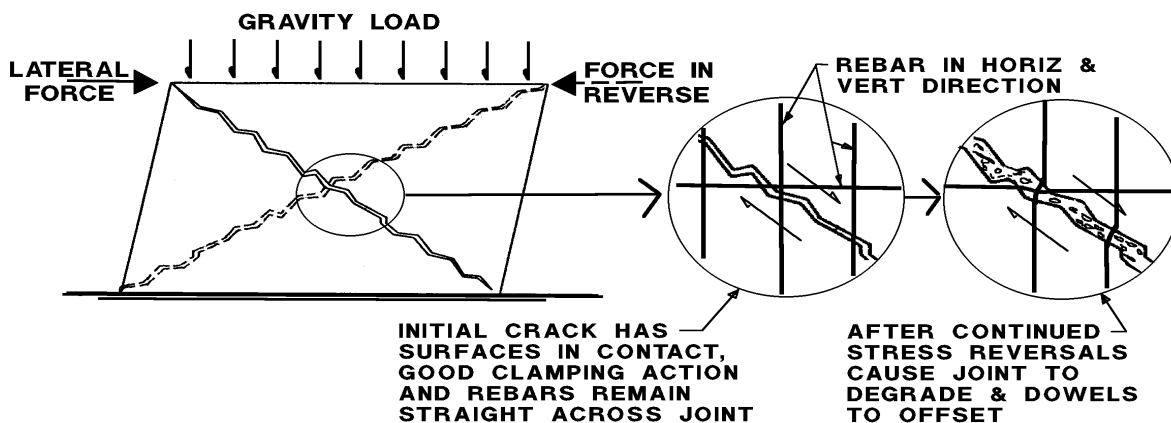
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RESCUE SYSTEMS 3

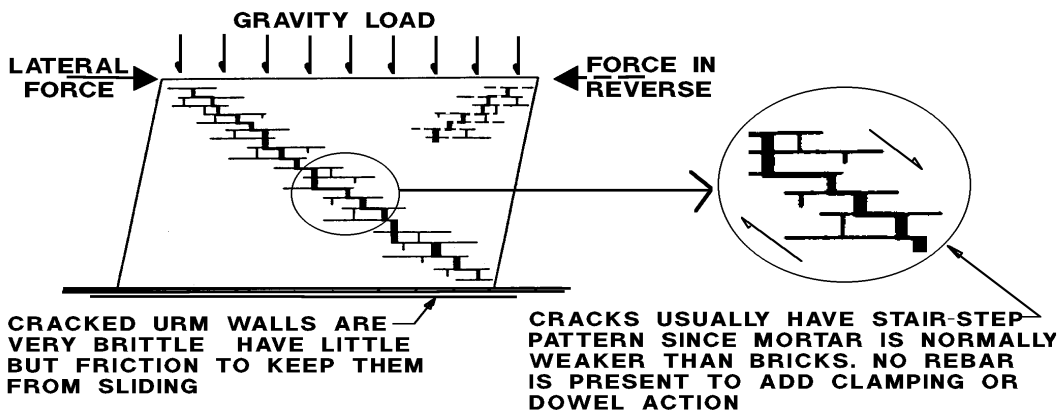
STRUCTURAL COLLAPSE TECHNICIAN

SHEARWALL CRACK PATTERNS

HAZ-CK



REINFORCED CONCRETE SHEARWALL



URM SHEARWALL • UNREINFORCED CONCRETE = SIMILAR

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

HAZARD IDENTIFICATION IN DAMAGED STRUCTURES

In damaged, partially collapsed and collapsed structures we can identify three types of hazards:

- Falling, in which part of the structure or its contents are in danger of falling.
- Collapse, in which the volume of an enclosed space made by the structure will be reduced as stability is lost.
- Other, which includes toxic gas, carbon monoxide, asbestos, and other hazardous materials.

Hazards in Damaged Structure

- **Falling hazards**
- **Collapse hazards**
- **Other hazards**

Identification Problems

- Judgments cannot be precise
- Partially collapsed structures difficult
- Collapsed structure has come to rest, but it is now weaker and more disorganized than original structure.
- Earthquake may have caused partial collapse, but building remainder may be weakened & ready to collapse in Aftershock.
- **Structures Collapse in Aftershocks**

- With falling and collapse hazards, the degree of hazard strongly relates to mass and how additional failure may occur. A sudden failure potential must be recognized with brittle material as opposed to structures in which material ductility and redundant configuration could provide some warning of an additional collapse.
- The problem of identifying, let alone properly evaluating, these hazards, is staggering. A well-trained engineer may, at best, be able to rate the risk of various hazards on some arbitrary scale like bad, very bad, and deadly. We must consider that:
- Judgments cannot be precise.
- We must try to identify brittle versus ductile behavior.
- Partial collapse is very difficult to assess.
- The cause of the condition is very important (for example, earthquake with expected aftershock or windstorm).
- In evaluating, if a specific structure is at rest, one could state, positively, that the structure that was moving had enough resistance to stop moving and come to an “at rest” condition. However, the damaged structure is difficult to assess, weaker, and more disorganized than the original.
- Try to identify the load path and visualize what happens during an aftershock or wind gust.
- Small, nonstructural elements and debris (loose materials) may be greater hazards than overall structural stability, especially in wind gusts and small aftershocks.

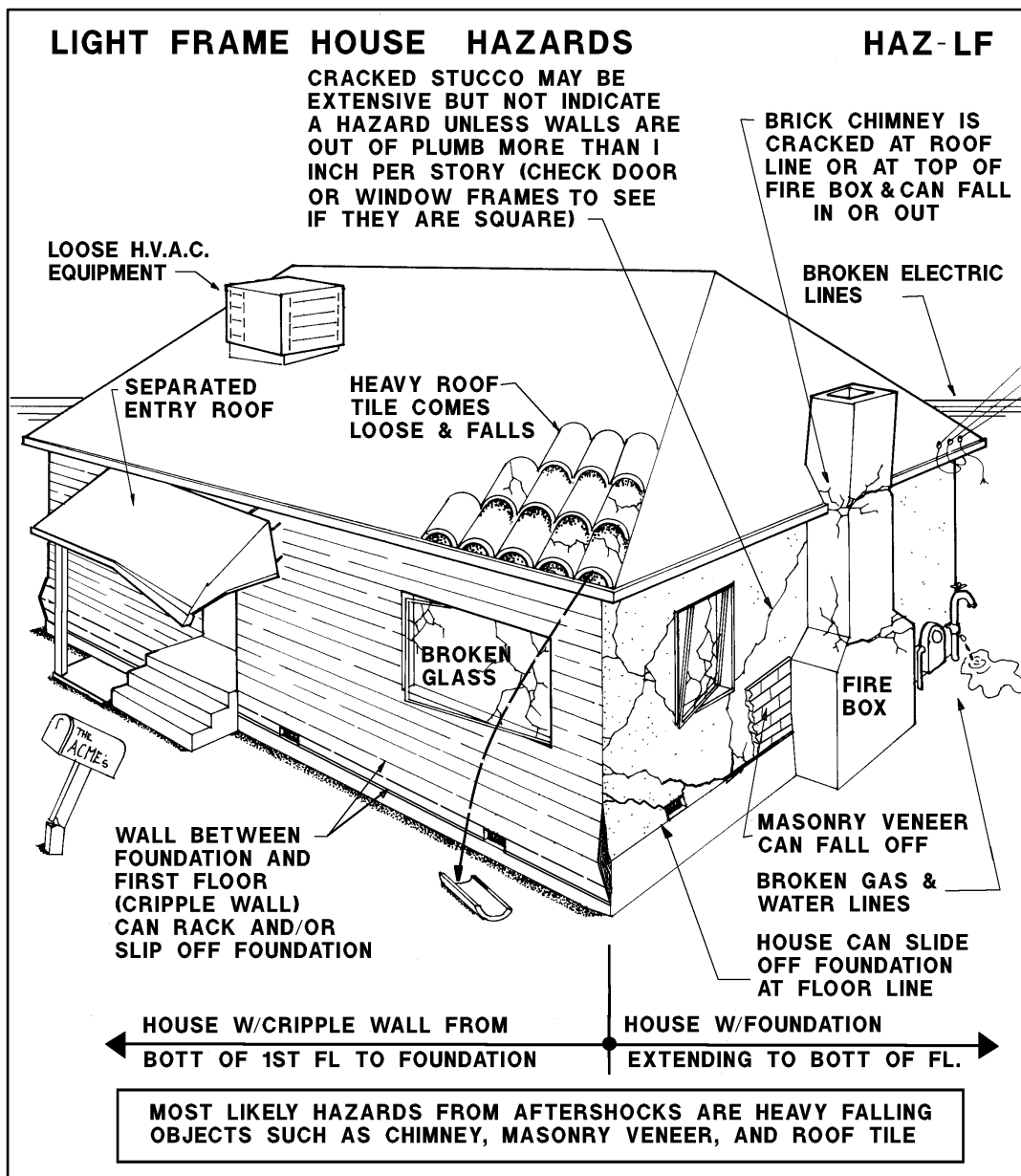
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

LIGHT FRAME BUILDING HAZARDS

The principal weakness is in the lateral strength of walls and connections.

- Check Points (HAZ-LF):
- Badly cracked or leaning walls.
- Residence offset from foundation.
- Leaning first story in multi-story buildings.
- Cracked, leaning masonry chimney or veneer.
- Separated porches, split level floors/roof.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

LIGHT FRAME BUILDING HAZARDS (Continued)

- In structures of less than three stories, additional collapse is unlikely because of the light weight of this type of construction.
- Collapse of this type is often slow and noisy.
- Falling masonry chimneys and masonry veneers are the most brittle types of behavior for these structures.

LIGHT FRAME • MULTI-STORY HAZARDS

HAZ-LF3

CHECK ELECTRIC LINES

HEAVY ROOF TILE COMES LOOSE & FALLS

HEAVY CONTENTS OF BALCONIES COULD FALL

CHECK GAS & WATER LINES (INDIVIDUAL OR GROUP METERS)

BASE OF WALL MAY NOT REMAIN ANCHORED TO SOLE

BADLY CRACKED FINISH IN RACKED, WEAK STORY. WHAT IS SHEATHING ?

- PLYWOOD
- DIAGONAL SHTG
- STUCCO ONLY
- STUCCO OVER PLYWOOD
- STUCCO OVER GYPSUM BOARD
- BRITTLE SYSTEM CAN COLLAPSE IN AFTERSHOCK
- PLYWOOD OR DIAGONAL SHTG SYSTEM WILL DEPEND ON HOW BADLY NAILS HAVE PULLED-OUT OR PULLED-THRU

- IF WALLS HAVE MASONRY VENEER LETHAL FALLING HAZARD EXISTS
- LOOK-OUT FOR BROKEN GLASS

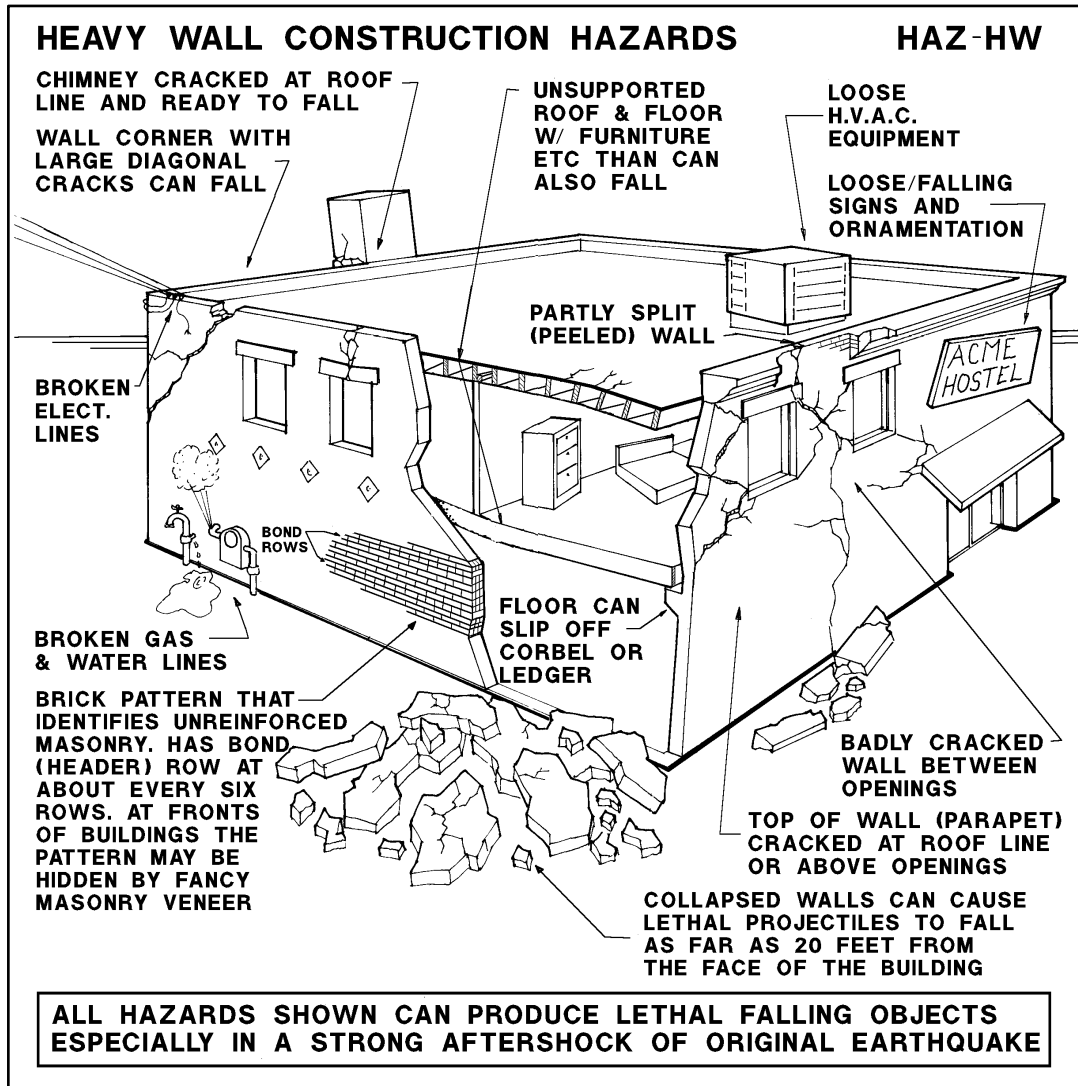
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

HEAVY WALL BUILDING HAZARDS

The principle weakness is in the lateral strength of walls and their connections to the floors/roof.

- Check points (HAZ-HW):
- Loose, broken parapets and ornamentation.
- Connection between the floor and wall.
- Cracked wall corners, openings.
- Peeled walls (split thickness).
- Unsupported and partially collapsed floors.
- All failure will probably be brittle.
- Falling hazards are very common in unreinforced masonry buildings because of the combination of weak and heavy wall elements. Collapse of adjacent buildings can occur as a result of the falling hazard of party walls.



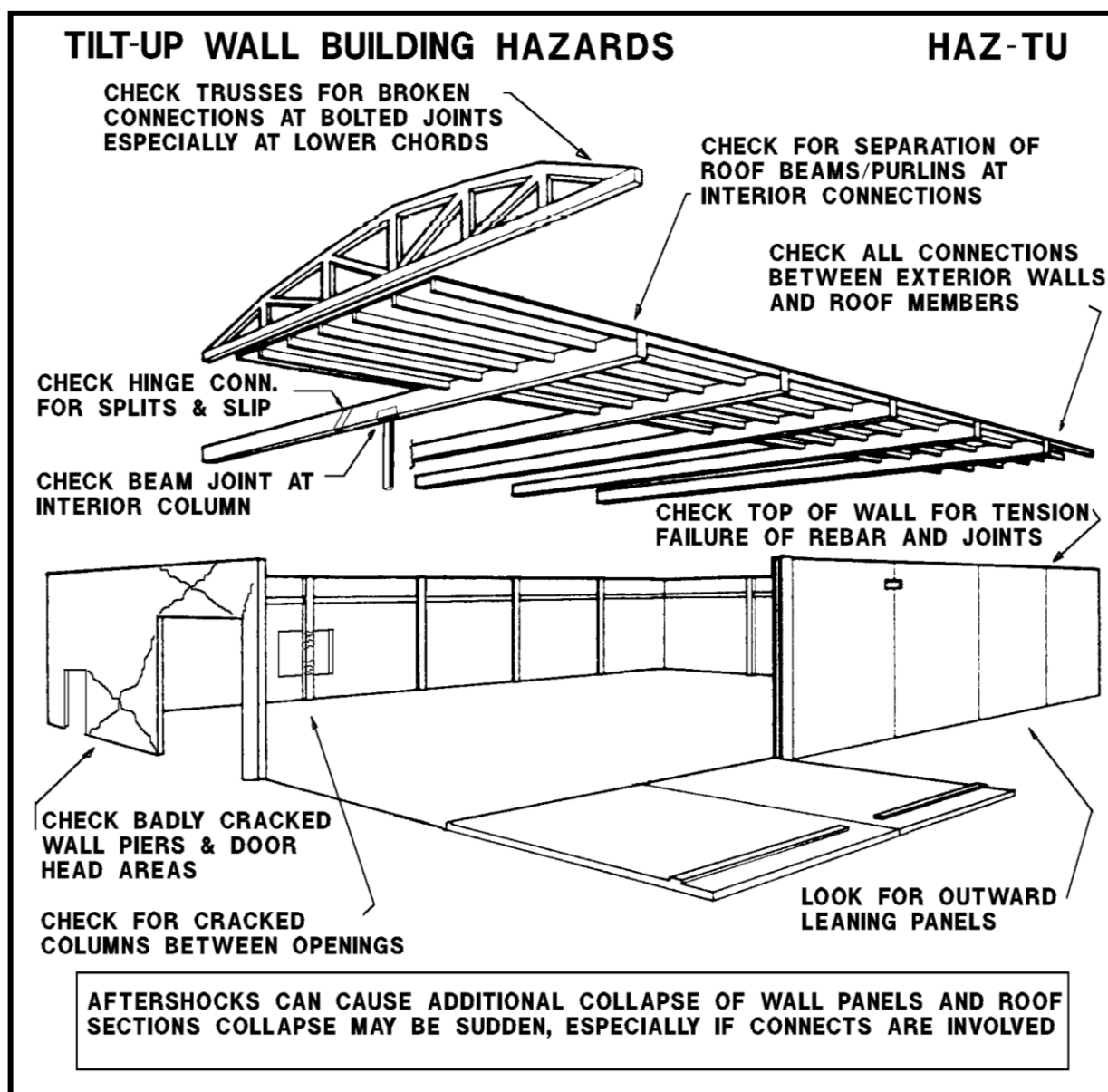
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

HEAVY WALL BUILDING HAZARDS (Tilt-Up)

The principle weakness is in the connections between the wall and floor/roof. (Low-rise, reinforced masonry wall buildings with light roofs are similar)

- Check Points (HAZ-TU):
- Connection between the floor/roof and exterior wall.
- Connection between the beams and columns, both exterior and interior.
- Badly cracked walls and/or columns.
- The connection failure will often be brittle. The wall/column failure and shear failure may be more ductile, but single curtain wall reinforcing provides little confinement.



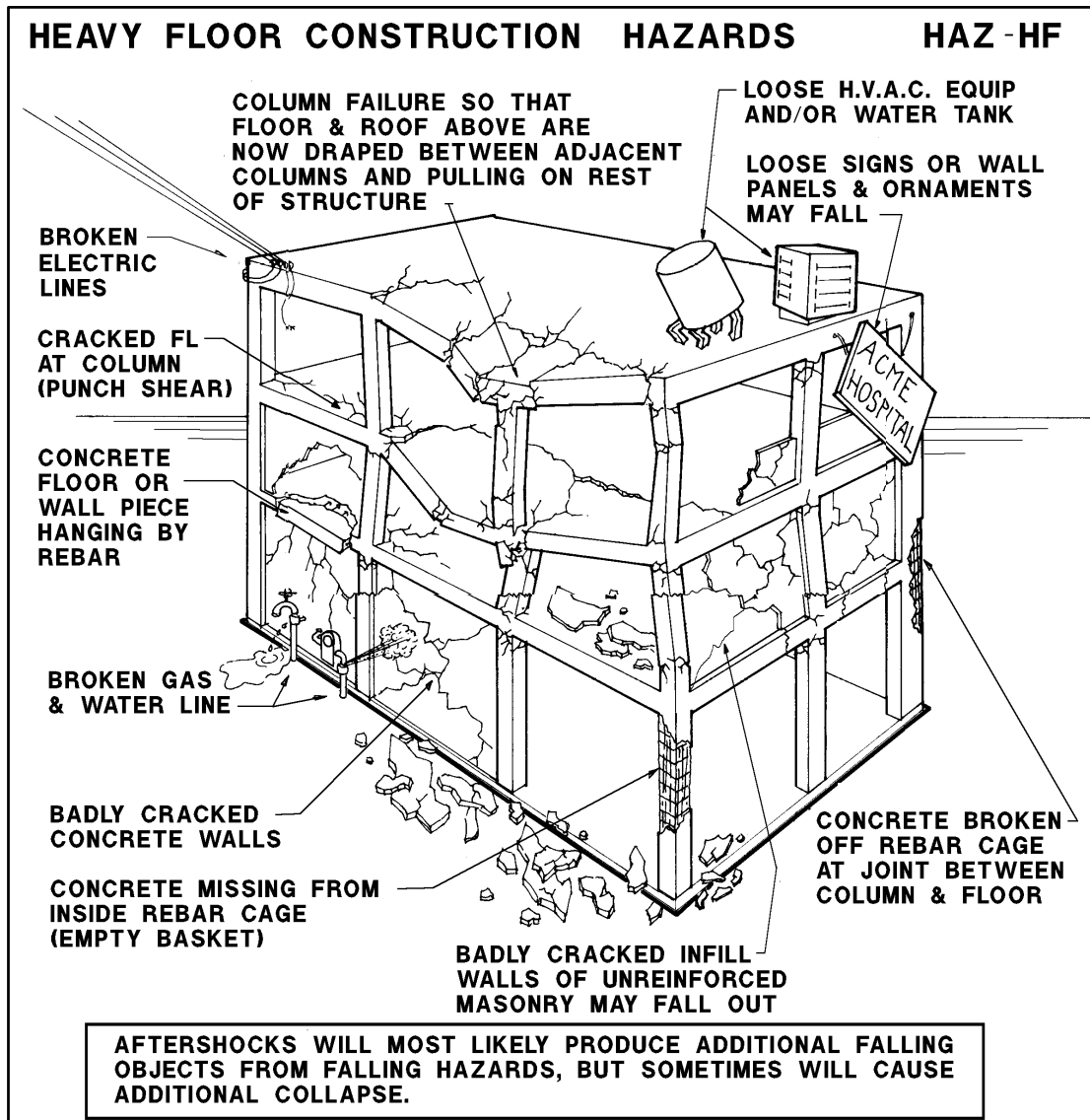
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

HEAVY FLOOR BUILDING HAZARDS

The principle weakness is a lack of adequate column reinforcement that can properly confine the concrete and an inadequate connection between the slabs and columns.

- Check Points (HAZ-HF):
- Confinement of concrete in columns (empty basket).
- Cracking of columns at each floor line (above and below floor).
- Diagonal shear cracking in major beams adjacent to supporting columns and walls.
- Cracking in flat slabs adjacent to columns.
- Attachment of heavy non-structural, unreinforced masonry walls (infill walls).
- Cracks in concrete shear walls and/or stairs.
- Ductile behavior may still be possible if the concrete is confined by reinforcing and the reinforcing is still within a lower yielding range.



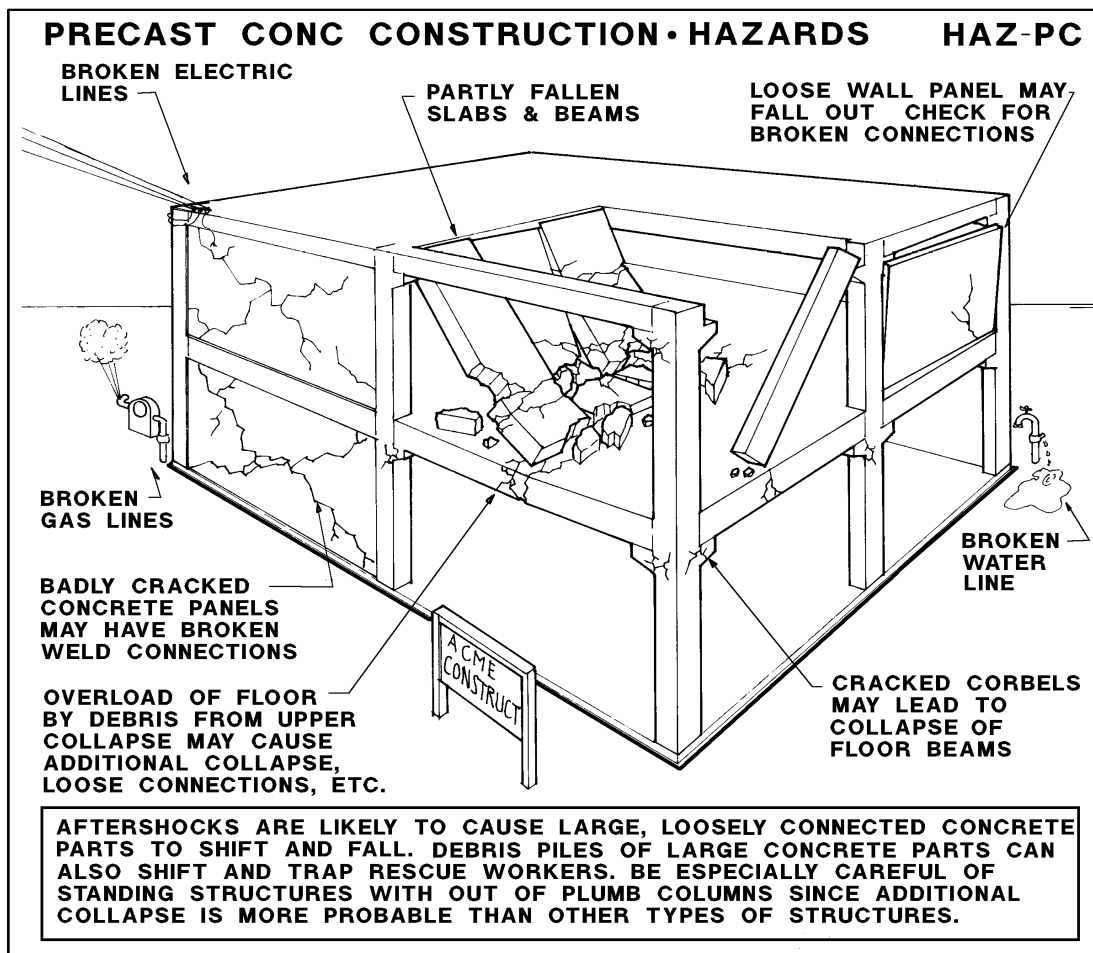
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

PRECAST CONCRETE BUILDING HAZARDS

The principle weakness is the interconnection of parts: slabs to walls/beams, beams to columns, walls to slabs, etc. It is very difficult to make connections adequate enough to transfer the strength of parts, connections necessary to survive a maximum earthquake. These buildings can have fairly heavy walls and floors, but neither is as heavy as heavy wall or heavy floor types.

- Check points (HAZ-PC):
- Beams to column connections, broken welds, and cracked corbels.
- Column cracking at top, bottom, and wall joints.
- Wall panel connections.
- Shear wall connections at floors and foundation.
- Badly cracked walls.
- These structures are often made from lightweight concrete. It should be noted that lightweight concrete splits more easily than normal weight concrete.
- Most failures that occur due to broken connections will be brittle.
- Since individual building parts may be quite strong, cracked concrete failures may be ductile if adequate bonded reinforcing is present.
- Depending on the extent of collapse, many falling hazards may be present.



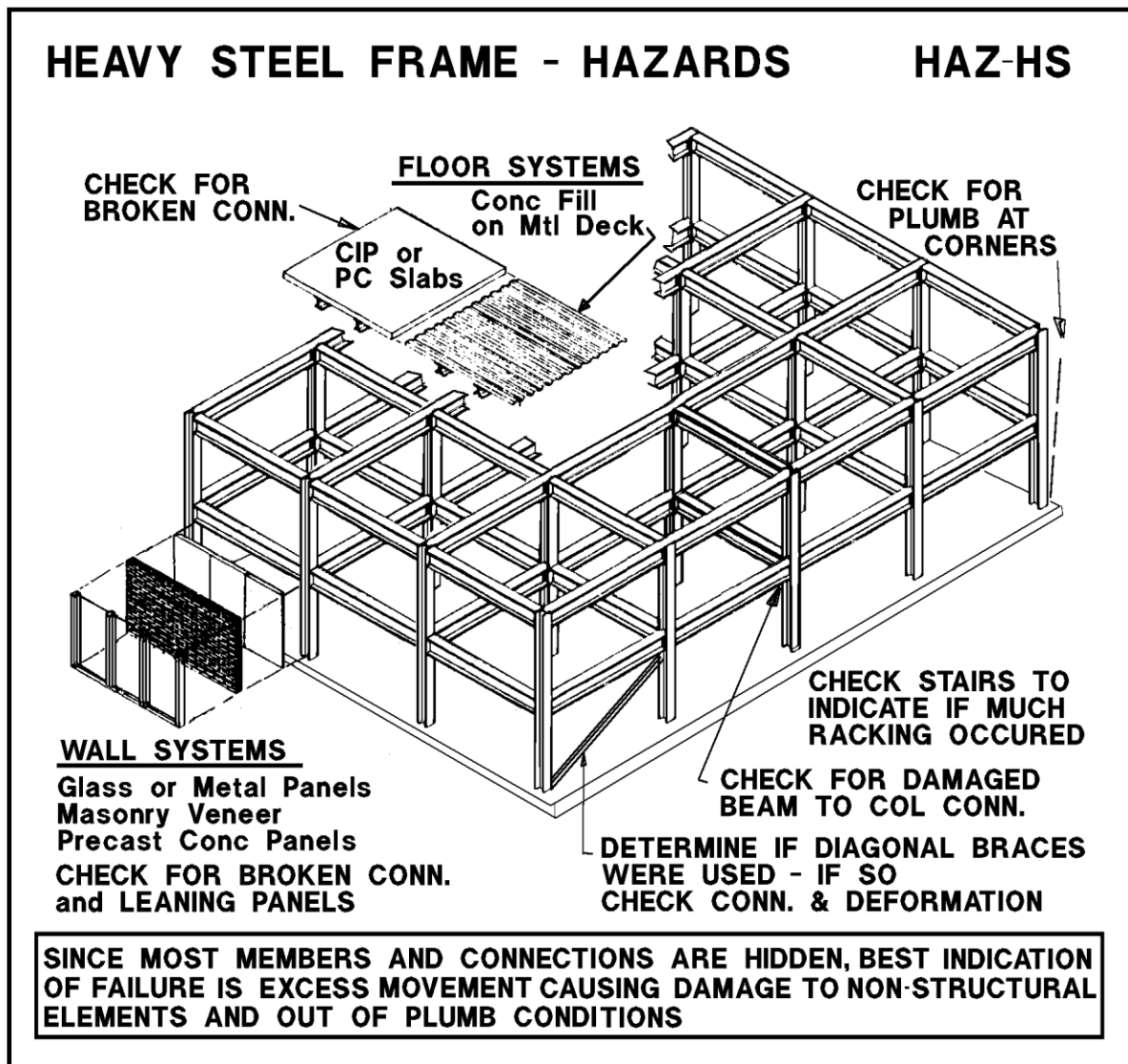
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

STEEL FRAME BUILDING HAZARDS

The principal concerns are the potential for building cladding to become falling hazards, and the cracking of welds in the main, moment resistant connections. Both of these hazards have occurred during earthquakes. Following earthquakes in 1985, 89, 93 and 94, building codes now require improved ductility in both the cladding attachments and the moment resistant connections.

- Check points (HAZ-HS):
- Exterior cladding for leaning or broken connections.
- Indications of movement (plumb corners, stairs, and non-structural damage) as clues to potential structure damage.
- Main beam/column connections (may need to remove finishes or fireproofing).
- Broken/damaged floor beam connections and, if present, broken PC slab connections.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

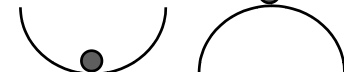
POST-TENSIONED CONCRETE SLAB HAZARDS

- There are many types of structures that have floor slabs that are reinforced by high strength cables that are cast in place in a sheath, then stressed after the concrete is cast and cured (post-tensioned).
- These structures can perform very badly when subjected to extreme loading, and most always exhibit brittle behavior. The most common examples of structures where post-tensioned slabs may be found are:
 - Multi-story parking garages.
 - First floors of apartment houses that are built over parking.
- Since the cables often extend the full length of these slabs, if it becomes damaged at one end or section, it will become “unstressed” over the entire length of the structure. Therefore, this type of slab has the very undesirable characteristic of being “anti-redundant”.
- It may become necessary, during a USAR Incident, to cut through a post-tensioned slab that still has stressed cables. This takes proper care and protection.

Other Hazard I. D.

- PostTensioned Concrete Slabs present unique Hazards
 - After cables become loose, slabs act more like unreinforced concrete.
 - Cables normally extend full length/width of slab . (? loose full length of cable)
 - If cables are still stressed, must cut with great care.
- Geologic Hazards - effect structures

Stability



By Definition Stable System will come back to Original Position

In US&R, we need to deal with Structures that are “At Rest” & just barely in “Equilibrium”

HAZARD IDENTIFICATION SUMMARY

- The problems of identifying hazards after a structural collapse are extremely difficult.
- Buildings are often complicated, and there are many different types and configurations.
- What remains after the triggering event may have come to rest, but the danger of further collapse and/or falling objects is often present.
- A damaged structure may be “at rest”, but that does not mean that they are stable.
- A properly trained USAR engineer (Structures Specialist) should help identify these hazards.
- Hazards should be have probable risk factors assigned to them.
- Measures to mitigate the danger can then be factored into the overall search and rescue effort.
- Brittle conditions pose the greatest threat because of the possibility of sudden failure.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

HAZARD ASSESSMENT FOR USAR

Based on the previous section on Hazard Identification, we need to add some additional considerations for USAR, since we may need to enter damaged structures.

- Assessment applies to the building structural system and individual void systems.
- The first question should be, "do we need to be in this area at all?"
 - Hazard avoidance is the preferred option.
 - What are the global versus local hazards?
- Look up first! Small, nonstructural elements may be the greatest hazards.
 - Debris and other loose materials can fall in wind gusts and aftershocks. These are hazards during hazard assessment.
- Identify vertical and lateral load systems.
 - How have the load carrying systems been changed?
 - Will the structure exhibit brittle or ductile behavior?
 - What redundancy is present?
- Can the hazards be mitigated to an acceptable level?
- What is the risk during the mitigation?
- Check for potential instabilities.
 - Building stability and rubble stability.
- What caused the collapse?
- Has the structure collapsed to a stable position?
- What if there is an aftershock?
 - What is the plan?
 - What are the escape routes and/or safe zones?
- Before changing the existing configuration, evaluate the effect of the change on the load paths.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

HAZARD MITIGATION

The basic alternatives to deal with structural collapse or falling hazards are as indicated below.

- **Avoid:** Plan the direction of USAR activities as far away as possible from a hazard and its effects.
- Gaining access into a badly collapsed structure should start from the top rather than from the edge (between layers) or by tunneling.
- The use of mining techniques when tunneling and shoring with individual vertical posts has led to aftershock caused shore failures. Consider alternatives, consult with others, and be as resourceful as possible.
- **Exposure reduction:** One of the most efficient methods of hazard reduction is to limit the time of exposure rescuers are exposed to a potentially dangerous situation.
- Because of the natural tendency of rescuers to be helpful and to be part of the action, one will often find more than the minimum required number in a confined space, especially when a live rescue is nearing completion.
- Risk is a function of both severity and exposure.
- **Remove:** Removal may be more efficient than shoring.
- Parts of URM walls may be removed by hand using aerial ladders for upper portions or in larger pieces using a crane and clamshell.
- Pre-cast concrete sections are more easily removed by small cranes or other concrete removal machines because of their moderate size and lack of interconnections compared to cast-in-place concrete.
- If at all possible, lift off, push over, or pull down (safely of course) should be a first choice.

Intro to Hazard Mitigation

- **Avoid**
 - Need effective barrier system
- **Removal**
 - Lift off, push over, pull down
- **Exposure reduction**
 - How long do we need to be in the area?
 - Risk is a function of severity and exposure
 - limit time exposed to hazard
 - limit number of personnel exposed

***Similar to Time, Distance, & Shielding
Rule used in Hazmat***

Other Hazard Mitigation

- **Vertical & Lateral Shoring**
 - system with slow failure mode
- **Lateral Bracing**
- **Lateral Tieback**
 - when shoring isn't practical
- **Vertical Tieback**
 - use crane to hang structure
- **Monitor - with alarm & escape system**
- **Recognize & Refer Hazard (hazmat)**

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

HAZARD MITIGATION (Continued)

- **Shore:** Provide both vertical and lateral support. Build safe haven areas with special emphasis on slow, forgiving failure modes. The lateral bracing of damaged columns, beams, and entire leaning buildings may be required. Tension tieback bracing can also be effective for holding walls, and cranes have been used to temporally suspend parts of damaged buildings.
- **Monitor:** Methods include the use of crack measuring devices, Theodolites and Total Stations, and other tilt measuring devices (change in tilt) to monitor damaged structures. To be effective, these devices must be continually read and have the data recorded. There should also be an effective alarm system that activates an efficient evacuation plan.
- **Recognize** and refer hazardous materials to HAZMAT Specialists. Eliminate/shut off all possible fire hazards.

METHODS TO MONITOR STABILITY

The fundamentals of structural monitoring for USAR include:

- A monitoring plan.
- An effective emergency communication plan.
- Monitoring tools.
- Trained monitoring personnel.

Elements of Monitoring

- Monitoring Plan
- Record Keeping
- Emergency Communication Plan
- Monitoring Tools
- Properly Trained Personnel

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

MONITORING PLAN

Similar to a design performance memorandum, the monitoring plan establishes the expected performance levels for the structure being monitored.

- Identifies what structure or component is being monitored, why, and for how long monitoring, should continue.
- Establishes control and reference points, ensuring the accuracy of the monitoring. Identifying survey targets on a damaged structure may not be possible so finding appropriate targets that will telegraph incipient movement is critical.
- Control points should be visible in various conditions and from at least two monitoring locations (to observe movements in X-Z and Y-Z directions).
- Must establish the tolerances, which create a “CAUTION” or an “ALARM” notification.
- Caution levels might include movements that are out of the expected, but not large enough to warrant evacuation.
- Alarm levels would include movements that telegraph impending collapse and evacuating rescue personnel is appropriate.
- NOTE: Expected movements due to thermal expansion/contraction shouldn’t initiate a “CAUTION”.
- Must utilize an effective emergency communication system used to inform command of changing site conditions and the potential for site evacuation.
- Must document all readings, expected direction of movement(s), potential failure-modes and effects, observations, and readings.
- An effective record keeping system is well organized and keeps the Task Force Leader and Incident Command informed of site conditions.
- Typically, the documentation is included in the Operational Action Plan.

Record Keeping

- Written Records need to be kept of all Monitoring Devices (forms shown next)
 - Record at least Hourly during first 5 days
 - All Monitoring Devices, inc Crack Monitors
- Recording System could be setup and kept by IST Structure Spec Staff
 - Each TF Structure Spec should keep own Unit Log (ICS 214) including Monitoring Data
 - Need to share data at every shift change, assuming no significant movement
 - Part of normal Hand-Off
 - Report info in Operational Action Plan (OAP)
 - OAP is generated by the IST, TAP by the Task Force

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

EMERGENCY COMMUNICATION PLAN

- Effective monitoring must utilize an effective warning system that informs Incident Command of potential structural movement (CAUTION) and includes a signal system to communicate site evacuation (e.g. three long horn blasts). The FEMA Incident Support Team and Task Force Leader(s) must persuade the Local Incident Command to integrate the local monitoring plan into the overall site safety plan.
- All rescue personnel must understand and be able to hear the warning device.
- All must know their evacuation route, and to whom they are to report (Accountability).

Emergency Comm. Plan

- Effective Warning System
 - For Caution and Alarm Warnings
- Involves Coordination
 - FEMA Task Force Leaders
 - FEMA Incident Support Team
 - Incident Command
- All must understand, and be able to Hear Warning Signals
- All must know their Evacuation Routs, and to Whom they Report

MONITORING TOOLS

The following indicators have been used to monitor damaged structures in an attempt to warn of change in stability:

- Engineers Transit and/or Total Station.
- Electronic Tilt-meter Systems.
- Wireless Building Monitoring System.
- Electronic Levels.
- Smart Tool and Smart Level.
- Laser pointers or Level.
- Plumb bob.
- Crack measuring device.
- Wind Speed Measuring Devices.

US&R Monitoring Devices

- Theodolite and Total Station
 - Reflectorless Total Station
- Electronic Tilt Meter
- Electronic Level
 - SmartLevel & SmartTool
- Laser Levels
- Plumb bob
- Crack measuring devices
- Wind Speed Measuring Devices

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

THEODOLITE AND TOTAL STATION

Have been successfully used to monitor damaged structures, including falling and collapse hazards.

- They are capable of very remote sightings on damaged structures that allow the observer to operate without significant risk.
- It is not required that the monitoring point be able to be physically accessed (only clearly observed).
- For reliable and repeatable results it is necessary to establish control points, such as back sight lines, that allow for re-setup of the instrument. This may be problematic following earthquake aftershocks when many structures and ground surfaces have been moved and possibly disrupted.

■ Theodolite/Total Station Surveying Methods

There are at least three methods that may be used when operating a Theodolite.

- **Method One** is to establish a vertical control line that will compare a point on the structure to a fixed point on the ground, in order to monitor any changes in a leaning column or wall.
 - ◆ This method is simple and provides reliable control and repeatability. Especially post aftershock.
- **Method Two** is to use the Theodolite to establish a reference point on an adjacent, stable structure, and then turn a series of horizontal angles to locations of interest on the damaged structure.
 - ◆ In this case, we may be limited by the angular accuracy of the Theodolite.
 - ◆ This method requires the additional step of crosschecking the reference point to assure that an observed movement has been accurately measured.
- **Method Three**, the Theodolite may be used to spot check a single point on a structure, measuring any movement using the telescope crosshairs.
 - ◆ This method is inefficient, not repeatable, and not normally recommended.
 - ◆ There may be instances where quick, short term monitoring of this type is all that is required, based on short term risk.

Use of Devices

Theodolite/Total Station

- Theodolite/Total Station may be used to detect small movement in remote structures

Method 1 - Establish a vertical line that will compare a point on a dangerous building to a point on the ground to detect additional tilt / movement

Method 2 - Use a Reference Point on an adjacent building, and turn an angle to several locations of potential movement on a questionable structure

Method 3 - Just do a spot check on an individual point on a damaged structure, such as Falling or Collapse Hazards (Total Station could measure X, Y, & Z)

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

THEODOLITE ADVANTAGES AND DISADVANTAGES

- Advantages:
 - Allows for observation without making contact with the structure, and very distant observation with the ability to zoom in on a structure.
- Disadvantages:
 - Expense.
 - Need well trained personnel.
 - Subject to false readings when the instrument is accidentally bumped.
 - Readings are not as intuitive to unfamiliar personnel.
- Theodolites have been often been used poorly and without reference marks, as well as proper records and warning systems.
- As a result, erroneous readings have caused false alarms to be sounded.
- This is an intolerable condition that can undermine the credibility of a monitoring system.
- The most common cause of false readings is inadvertent movement of the tripod.
- Need to establish effective barrier control systems around the Theodolite monitoring stations.
- Previously established, back sights and reference points can minimize these problems.
- At earthquake caused incidents, one must also plan for aftershocks by setting up the instrument and the reference points properly.

Use of Devices Theodolite/Total Station

- Advantages
 - Observation w/o contacting structure
 - Make Distant Observations
 - Ability to Zoom - In on structure
 - Observe many points from One Location
- Disadvantages
 - Cost of instrument
 - 20sec Theodolite = \$2000
 - 5sec Reflectorless Total Sta = \$6500
 - Need Trained Operators
 - Readings not Intuitive
 - Need stable Reference/Control points
 - Difficult establishing post aftershock control?
 - Can't Use w/Face Mask

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

WIRELESS BUILDING MONITORING SYSTEM

Is available from: Exponent Technology Development www.Exponent.com

- A full system consists of four, bi-directional sensors that can be read by either one of two iPAQ Pocket PC (or a laptop computer). A full system has 2 spread spectrum receivers.
- Receivers have a range to 1000' with clear sight line, but is less if the signal is obstructed by heavy structures and/or metal.
- The software is set to poll each sensors at 10 sec intervals. It checks the signal for interference, and an audible ping is heard as each sensor "reports" good data.
- A lower frequency "clunk" is heard if a sensor is not operating properly or turned off.
- The software can be set to trigger an alarm at any preset angle change (alarm can be sounded through an earpiece).
- The tilt meters are sensitive to an angle change of .05°.
- Wireless Building Monitoring System units are packaged in Pelican Cases, each having:
 - Two sensors with 7 day, 12v. batteries & cables.
 - One receiver with Blue Tooth communication.
 - One PDA with Pocket PC 2003 or Mobile 5 Op System.
 - Software, manuals & connecting hardware.
- In 2005, FEMA purchased, two full systems for each IST (Four Pelican Cases + small case with drill-driver, etc).



Use of Devices – WBMS

- Advantages
 - Monitor 4 or more locations at once
 - Very accurate and can set Alarm for any amount of movement
 - Portable Receiving/Alarm System
 - Remote Observation (up to 1000 ft)
 - Can Use w/Face Mask
- Disadvantages
 - High cost (\$18,000 per full-system, 2005)
 - Need Qualified, Techno-Operator
 - Need planned, periodic battery recharge system
 - Need to place Sensors on Structure
 - They have remote, 7-day, 12v batteries

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

ELECTRONIC LEVEL

Sensitive to an angle change of 0.1° , with a digital read-out. Can be purchased at Home Depot type stores and tool mail order houses for about \$100 (2005).

- They can be mounted on a structure, the angle recorded, and any subsequent change would then need to be read by a task force member.
- In order to mount the SmartTool on a concrete structure, the following needs to be done:
 - Place a 1 x 1 x 1/8 x 0'-9" steel angle that has been attached to the structure with putty type epoxy or 1/4" concrete screws placed thru 5/16" holes that have been drilled in the angle (angle may be left in place).
 - Then use a 2 1/2" C-clamp to make a removable, but positive connection.
 - They are supplied with a battery saver feature that turns them off in 5 min. if no change in angle is sensed.

Made by: MACKLANBURG-DUNCAN www.amazon.com/toolcrib

Use of Devices – Electronic Levels

- Electronic Levels should be placed in pairs on structure to measure change in any angle (Vertical or Horizontal)
 - Measures angle change of 0.2 degrees
 - Cost is in \$100 range, each
 - Must be continually read (no alarm)
 - New lower cost model cannot be set on zero when placed in vertical position
 - Use binoculars for remote reading
 - Must alter device to turn battery saver off
 - Mount on steel angle using magnetic tape and/or a C-clamp

Use of Electronic Levels

- Advantages
 - Low cost
 - Long battery life (about 40 hours)
 - Easy to read
- Disadvantages
 - Not as accurate as Tiltmeter
 - Need to place on structure
 - Need to place 2 in each location to measure angle change in N-S + E-W direction
 - Need to dedicate someone to read them – line of sight
 - Need to modify Battery Saver Function

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

LASER LEVEL

May be used to measure an angle change of about 0.2°. They may be purchased at Home Depot stores for less than \$100 (RoboToolz) in a 3-beam or single beam configuration, and come with magnets embedded in their bottom surface. There are also more versatile models, such as the Hilti PMP-34 that are sold in kit form. It can be configured as a 3 beam, 2 beam, or 1 beam tool. It also is self leveling, but this feature can be cancelled.

- The RoboToolz may be mounted on a structure using the same steel angles as for the SmartTool, however they have a strong magnet, so the C-clamp is not required.
- The Hilti PMP-34 also has magnets, plus several mounting devices.
- Place a target within 75' of the device with an X on it to observe the structure's movement.
- Can use the 3 beam laser level with 2 targets to observe movement in two directions. Otherwise, it would require that two single beam lasers be mounted in a mutually perpendicular orientation (same as SmartTools).
- The RoboToolz use AAA batteries that last only 12 hours, but the Hilti PMP-34 uses 4 AA batteries that last 40 hours.

Use of Laser Levels

- Advantages
 - Low cost
 - Easy to read
- Disadvantages
 - Not as accurate as WBMS
 - Need to place on structure
 - Need to place 2 targets for each location to measure angle change in N-S + E-W direction
 - Someone to read them – line of sight
 - Need to replace batteries
 - Every 12 hrs for RoboToolz
 - Every 40 hrs for Hilti

Use of Devices - Plumb Bob

- Use a Plumb bob hung from small structure to compare to a point on the ground/pavement
 - Allows one to observe change in a leaning structure
- Advantages
 - inexpensive, easy to use, no special skills (a rock on a string will suffice)
- Disadvantages
 - requires one to attach to structure, constant observation, not too accurate

PLUMB BOB

Can be used for moderate structures to determine changes in position of one story from another, between a story and the ground, or between an upper part of the wall and the ground.

- Can measure and record the changes in a leaning structure when no other device is available.
- **Benefits:** Inexpensive and simple to use. No special skills are required.
- **Disadvantages:** Personnel must attach plumb bob to the structure and constantly observe it.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

CRACK MEASURING DEVICE

Can be used to monitor cracks in concrete or masonry shearwalls or concrete moment frame structures in several ways. It is important to know if the cracks in a damaged building are of a constant width or enlarging.

- Methods that have been used include:
 - Marking an "X" across the crack with the center on the crack. Significant lateral movement changes can be observed.
- Placing folded paper in cracks or use automobile thickness gages (.004" to .025") to measure a specific location.
- Adhesive or other tape may be placed across the joint to measure change, but dusty conditions may prevent the tape from adhering.
- Two parallel sticks (rulers) can be taped across a crack with a perpendicular line being drawn across both of them (or existing lines on two rulers can be aligned). If the crack changes width, then the originally straight line will be offset.
- Plastic Strain gages (about \$16 ea. in yr. 2000) may be placed across cracks to also indicate change (mount with paste type, quick set epoxy or concrete screws).
 - Made by: Avongard, (www.avongard.com).
- Epoxy inexpensive glass slides across a crack. If the crack moves the slide will crack.

Crack Monitoring

- Draw or sawcut 'x' centered on crack
- Use inexpensive (\$15) plastic strain gage can be placed at crack
- Spray paint cracked area
- Place shims/cards in cracks
- Inexpensive, easy to read change, but need to be checked (up close) periodically

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

METHOD TO MONITOR THE DISASTER SITE

SEISMIC TRIGGER DEVICE

Can be installed at the site to sense the initial P waves of strong aftershocks. Since the P waves travel at 5 km/sec maximum and the damaging S waves follow at approximately 3 km/sec, a warning signal could be triggered at a building site prior to the damaging effects of the S wave.

- The device comes in a portable carrying case and would need to be bolted to a solid slab/foundation, etc. somewhere near a damaged building.
- For sites within 10 km of the aftershock origin, there would not be enough warning to be useful.
- For sites over 50 km away, there would be time to escape, cover, etc. (7 seconds +).
- A device of this type was used at a site after the Loma Prieta earthquake. The current cost of the device is approximately \$6000.00 and is manufactured by:

Earthquake Safety Systems
2064 Eastman Ave., Ste 102 Ventura, CA 93003
(805) 650-5952

Method to Monitor Disaster Site

- P vs S wave - time delay
 - P wave travels faster than S waves
 - If distance from Fault to Site is more than 50km there is opportunity to warn of Aftershocks
- Seismic Trigger deployed at Disaster Site
 - Warns when P wave arrives
 - Destructive S wave arrives later
- Pager System
 - Pagers at disaster site are signaled from sensors at fault that measure Aftershocks

AFTERSHOCK WARNING SYSTEM

The U.S.G.S. and others have discussed making an aftershock warning system available to USAR task forces during the first week after an earthquake.

- The system uses an array of sensors near the fault to detect aftershocks.
- A warning signal is relayed by repeaters to individual pagers that will be given to each task force that is involved in rescue operations.
- For sites that are about 10 km from the active fault, there will be only 3 seconds warning.
- For sites that are 50 km away there will be 12 seconds warning (proportionally greater warning for greater distance from aftershock origin).

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STRUCTURAL COLLAPSE TECHNICIAN

PART 5 URBAN SEARCH AND RESCUE STRATEGY AND STRUCTURE SIZE-UP

TERMINAL OBJECTIVES

- The student will understand the phases of a large disaster and how a FEMA USAR Task Force can be deployed to perform it's initial tasks.
- The student will understand the FEMA USAR Marking System.
- The student will understand the most appropriate strategies to be used in order to effect rescues in various types of structures.

ENABLING OBJECTIVES

- Understand the phases of a large disaster.
- Understand information gathering.
- Understand rapid recon/triage and the search process.
- Understand building identification marking.
- Understand structure/hazard evaluation marking.
- Understand search assessment marking.
- Understand victim location marking.
- Understand basic building search and rescue strategy.
- Understand the use of a metal detector and cutting post-tensioned concrete and cables.

RESCUE SYSTEMS 3

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PHASES OF A LARGE DISASTER

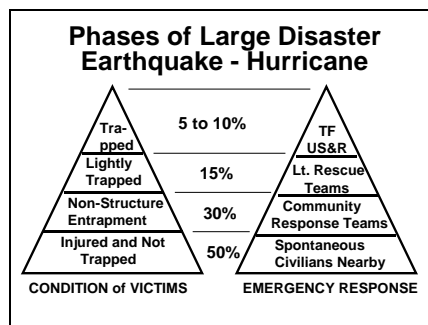
It is important to understand the typical chronology of a USAR incident, especially one caused by a devastating earthquake. The emergency response normally occurs in the following phases:

Initial spontaneous response

- Unskilled, neighbors, community response teams, passers-by will heroically help remove lightly trapped and/or injured victims. These rescuers have often acted far beyond their normal skill level and often save three-fourths or more of the total. Survival rates are relatively high, since victims are normally not entrapped. Professional firefighter, law enforcement officers, and emergency medical personnel may participate and better organize the response. This phase will often end during the first night.
- Planned Community Response:
- Local trained community response teams. Call-out and visual search would be used to locate and rescue the non-structurally trapped. Some lifting of objects (furniture, bookcases, etc.) would be done as well as mitigation of hazards (extinguish small fires, turn off gas, observe/refer hazardous materials).
- Void Space Rescue:
- Local emergency services rescue forces. Search elements would help prioritize the site to make better risk versus benefit judgments. Rescue would proceed using existing cavities, duct/plumbing shafts, basements, and/or small cut openings in easily breachable floors and walls. Some shoring might be done to provide safe haven areas and otherwise protect emergency responders and/or victims. This phase may start the first day, but often, not until after some organizing efforts have taken place, requiring at least one hour.

Technical, Urban Search and Rescue

- Trained USAR forces, aided by equipment. Site or sites would be re-evaluated, re-searched, and prioritized for the ten daylong effort. Extensive cutting, shoring, etc. may be done to penetrate the structure. Cranes may be used to remove layers of structural debris or parts of the structure that are hazardous.

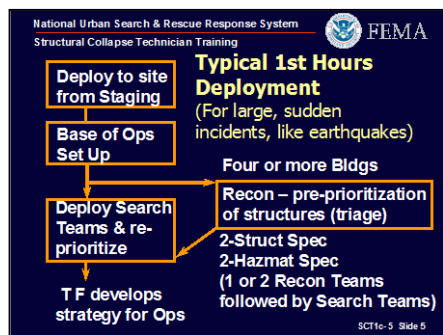


RESCUE SYSTEMS 3

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TYPICAL FIRST HOURS OF DEPLOYMENT

- Large, sudden incident, like an earthquake.
- There are many possible scenarios to which a USAR Task Force or a number of Task Forces could respond. However, our operating system description envisions that, during initial setup, a decision needs to be made as to the most appropriate deployment of Task Force Structure Recon and Search components. Some initial questions that need to be answered are:
 - Is Rapid Recon/Triage needed or have others established initial priorities?
 - Will the Task Force deploy the Recon Team(s) in order to pre-prioritize the structure?
 - What sort of Search Team configuration will be used? (Detection Team(s), Location Team(s)).
- How many building have been assigned to the Task Force, and does Search and Recon need to be carried out at one or more locations?
 - How remote are the buildings assigned to the Task Force?



Information Gathering by TF

- Critical for transition from Initial Phase to deployment of US&R TF
- First responders may have experienced:
 - long period of emotional & physically draining work
 - need to feel that no-one else is trapped
 - need to feel closure
 - requests by relatives/friends to find their loved ones (they KNOW they are alive)

INFORMATION GATHERING

INITIAL INFORMATION GATHERING

Information gathering techniques will be crucial to the efficient transition of the USAR forces into the incident. It is important for these incoming forces to carefully verify information obtained from the first responders and other individuals at the disaster site. By the time the information exchange takes place, the first responders will probably be subjected to the following:

- A long period of physically and emotionally draining work. Feelings that it's not possible that other victims have survived within a badly collapsed structure.
- A need to experience closure, that the incident is over.
- Feelings by relatives/friends of the missing, that they have surely survived and are entrapped.

The information gathering must, therefore, proceed as swiftly and unemotionally as possible, while testing all current assumptions.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

RAPID RECON/TRIAGE AND THE SEARCH PROCESS

RECON (FORMERLY CALLED STRUCTURE TRIAGE)


The intent of pre-prioritization and identification of structures for a large, earthquake-like incident is to make more efficient use of search teams.

This can be done immediately after a suddenly occurring disaster by special assessment teams or local responders.

It can also be done by FEMA USAR Task Force(s) after they have been assigned to a specific area.

- The assumption in this case is that local responders have been overwhelmed, and a rapid recon process will help focus the task forces on their life saving work.

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Recon - (formerly structure triage)

Pre-Prioritization & I.D. of Structures

- Done immediately after disaster by special assessment team or by local emergency responders - or
- Done immediately after deployment of US&R Task Force - all structures in assigned area
 - Rapid assessment w/ scoring system and sketch map of area w/ bldg I.D.
 - TF Recon Team(s) would be followed by Search Team(s) within 15-30 minutes

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Rapid Recon Process

- Recon Team to rapidly assess & I.D. first 2 or 3 structures - (all in 15 to 30 minutes)
 - Pre-prioritizes these structures and reports findings for the follow-on Search Team(s)
 - Search Team(s) re-prioritize based on viable victim finds
- Recon Team moves-on to next 2 or 3 structures
 - Process continues until all assigned structures have been assessed
 - Recon Team continues to record and report findings

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RAPID RECON PROCESS

A more rapid method for pre-prioritization and identification of structures for a large, earthquake-like incident was adopted in 2008.

Previously, it was envisioned that a Structure Triage would be accomplished by the Structures Specialist (StS) and Hazmat Specialist (HMS) during the first hour or more of a deployment. In this process, search teams would not be deployed until the triage was completed. This would be too time consuming, and the newly adopted process proceeds as follows:

- The Recon Team would be sent out first to quickly assess and identify the first two or three structures.
- They would report their findings to the Search Team Manager (or other designated leader).
- Search teams would re-prioritize these 2 or 3 structures, based on viable victim finds, and rescue could be started in the highest priority structure.
- The Recon Team would have moved on to the next 2 or 3 structures, and report those findings.
- The process would continue until all assigned structures had been searched, and the task force was clearly focused on rescue operations in the highest priority structures.

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RECON AND SEARCH TEAM CONFIGURATION

Although this rapid recon process is intended to be flexible and incident dependent, the teams are most likely to be staffed by the following:

- **Recon Team:** Search Team Manager (STM), StS., HMS., and Technical Information Specialist.
- **Search Detection Team:** STM, Canine Search Specialist, Tech Search Specialist, Medical Specialist, Rescue Specialist, and StS.
- **Search Location Team:** Similar to Detection Team

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Team Configuration
(Incident dependent, emphasize flexibility)

- **Recon Team**
 - Struct Spec, Hazmat Spec, Tech Info?, Search Team Mgr?
- **Search Teams**
 - Detection
 - Location

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Team Tasks

- **Recon Team**
 - Hazmat Evaluation and Detection
 - Rapid Structure Triage/ Assessment
 - Scoring based on "Expert Judgment"
 - Provides initial prioritization
- **Search Detection Team**
 - Victim Detection, Search Marking & re-prioritization
 - Detailed Hazards Assessment & Marking
- **Search Location Team**
 - Victim Location & Start Rescue

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TEAM TASKS

Recon Team

- Provide initial hazard assessment and detection, with a scoring system based on expert judgment. They would then provide feedback of initial prioritization.

Search Detection Team

- Provide victim detection that could re-prioritize the structures for the Search Location Team(s). They would also provide detailed hazard assessment, and mark the structure with appropriate Search and or Structure Hazard Markings.

Search Location Team

- Would locate victims, assess their condition, and start rescue. They would also mark the appropriate areas with Victim Marking.

Recon

- The following information needs to be considered in determining the risk/benefit analysis that will aid in prioritization.
- Disaster Type
- The type of disaster would determine several things such as:
- The potential for aftershocks following an earthquake.
- The severity of damage from a blast.
- Any unknown existing deficiencies for sudden collapse without apparent cause.
- Occupancy
 - The type of activity done in the building, and where most individuals would have been located. May be time of day dependant.

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TEAM TASKS (Continued)

- Time of Day
 - Refers to the time of the event which caused the collapse. This is a critical factor when combined with the occupancy.
- Structure Size/Type
 - Indicates the potential number of victims, plus difficulty of access and hazards.
- Collapse Type
 - Indicates the type of voids and potential for victim survival.

OTHER CONSIDERATIONS


- Prior Intelligence
 - Information gathered from the general public, local authorities, first responders, etc. relating to any known trapped victims.
- Search and Rescue Resources Available
 - Does the particular building require resources beyond what is readily available to the task force (i.e., is heavy equipment required to gain access).
- Structural Condition of the Building
 - Generally, can search and rescue operations proceed with a minimum of stabilization effort.

RECON SCORING CRITERIA

The following will be evaluated in assessing the **probability of having viable victims**:

- Number of potential victims: low medium high
- Time required to access victims: 1hr 6hrs 12 hrs
- Type of voids: compact separated open
- The following will be evaluated in **assessing risk**:
- Chance of further collapse: low medium high
- Number of falling hazards: low medium high
- Condition of void support: good poor unknown

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Recon Scoring Criteria

- Criteria for Probability of Viable Victims
 - Potential number trapped - low med high
 - Time req'd to access victims - 1hr 6hr 12hr
 - Type of voids - compact separated open
- Criteria for Assessment of Risk
 - Chance of further collapse - low med high
 - Number of Falling hazards - low med high
 - Void support condition - good poor unknown

RESCUE SYSTEMS 3

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RECON STRUCTURE CLASSIFICATION

Each structure would be given a two letter classification to indicate the probability of being able to rescue viable victims, and a two letter classification for assessment of risk. These classifications would be based on the scoring criteria previously presented, and require “expert judgment” to be applied by the StS and HMS.


For probability of being able to rescue viable victims:

- LP indicates Low Probability
- MP indicates Moderate Probability
- HP indicates High Probability

For Assessment of Risk:

- LR indicates Low Risk
- MR indicates Moderate Risk
- HR indicates High Risk

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Recon Structure Classifications

- For Probability of Viable Victims
 - LP = Low Probability
 - MP = Moderate Probability
 - HP = High Probability
- For Assessment of Risk
 - LR = Low Risk
 - MR = Moderate Risk
 - HR = High Risk

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"NO GO" CONDITIONS

These would include structures that are on fire, have significant hazmat spills, or otherwise have conditions that would make search and rescue operations too risky. Buildings with "no go" conditions would be expected to be re-evaluated when those conditions were mitigated, and some comment would be made regarding this should be communicated to the STM or other designated leadership.

A better term for these conditions would be “slow go”, since that would better indicate that after the extreme hazard has been eliminated, the building might be searched.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN


HOW CLASSIFICATIONS ARE APPLIED

After assessing each of the three criteria for probability of viable victims, each structure would be given a classification of LP, MP, or HP.

After assessing each of the three criteria for assessment of risk, each structure would be given a classification of LR, MR, or HR.

- This process required the StS and HMS to make rapid, value judgments in a very short time.
- Assessing for the probability of viable victims should include considerations such as potential numbers, ease, difficulty, and risks involved with their extrication.
- It should be understood that it is possible to have more than one structure with the same classification.

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How Classifications are applied


- Each structure would be classified for Probability and for Risk.
 - Requires StS and Hazmat to make rapid, value judgments.
 - Probability includes considerations such as potential number of victims and ease of extrication
 - More than one structure could have the same classification.
- Examples
 - HP, LR and LP, HR

EXAMPLES OF RISK LEVEL

The companion recon form Recon-2 will provide a list of collapsed structure conditions that could be considered low, moderate, and high risk.

This will provide the StS some backup information to aid in making the difficult judgments that are required in this rapid recon process.

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Examples of Risk Level

- Low
 - Pancake concrete slabs
 - Soft 1st story collapse
 - Wood 1 & 2 story
- Moderate
 - Partly collapsed concrete
 - Racked wood 3 story+
 - Free standing URM/Conc walls – plumb
 - URM w/ Lean-to, V, Wall Fall collapse
- High
 - Partly collapsed PC or PT conc.
 - Uncollapsed & leaning
 - Free standing URM/Conc walls – leaning
 - Many falling hazards

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RESCUE SYSTEMS 3

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INFORMATION TO BE USED TO DETERMINE POTENTIAL NUMBER OF VICTIMS

Number of Potentially Trapped Victims

- Would be assessed knowing the type of occupancy, the floor area of collapsed structure, the time of day the incident occurred, and the type of collapse.

The following are the average total number occupants for various occupancies that are used in the triage process:

- **Based on units rather than area:**

Schools	25 to 35 students per classroom
Hospitals	1.5 occupants per bed
Residential	2.0 occupants per bedroom
Others	1.5 occupants per parking space

- **Based on area:**

			Variation
Schools, Library	1 per	70 sq. ft.	50-100
Hospitals	1	100	80-150
Multi Residential	1	200	100-300
Commercial	1	100	50-200
Office, Inc Govt.	1	150	100-200
Public Assembly	1	25	10-050
EOC, PD, FD	1	125	100-150
Industrial	1	200	100-300
Warehouse	1	600	400-900

- **Other methods** to estimate the number of occupants in a building would be either of the following:

- Number of cars in the parking lot for assembly, office, and commercial occupancies.
- Number of bedrooms in residential occupancies, that are involved in the collapse.

New Recon-1 Form

- New forms Recon-1 and Recon-2 have been developed to replace the Triage Forms, TRI-1 and TRI-2.
- Form Recon-1 is shown on the next page. Recon-2 is similar, and has instructions for using the new recon forms.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

Recon Form - Recon-1 Date/Time: _____ By: _____ Page _____ of _____

Task Force: _____		Date/Time of Disaster: _____		See Form Recon-2 for Instructions	
AREA MAP					
BLDG. ID: _____ FLOOR AREA: _____ No. STORIES: _____ OCCUPANCY: _____ MATERIAL (Circle all that apply) WOOD CIP CONCRETE STEEL URM TILT-UP PT CONC PC CONC OTHER: _____		Criteria for Probability of Viable Victims (check one in each line) POTENTIAL NUMBER TRAPPED LOW _____ MEDIUM _____ HIGH _____ TIME REQ'D TO ACCESS VICTIMS 1 HR _____ 6 HR _____ 12 HR _____ TYPE OF VOIDS COMPACT _____ SEPARATED _____ OPEN _____ Criteria for Assessment of Risk (check one in each line) CHANCE OF FURTHER COLLAPSE LOW _____ MEDIUM _____ HIGH _____ No. OF FALLING HAZARDS LOW _____ MEDIUM _____ HIGH _____ VOID SUPPORT CONDITION GOOD _____ POOR _____ UNKNOWN _____		CLASSIFICATION (Circle one each line) LP MP HP LR MR HR	
GPS Coordinates _____ Notes: _____		SLOW- GO (circle if applies) FIRE HAZMAT OTHER: _____			
BLDG. ID: _____ FLOOR AREA: _____ No. STORIES: _____ OCCUPANCY: _____ MATERIAL (Circle all that apply) WOOD CIP CONCRETE STEEL URM TILT-UP PT CONC PC CONC OTHER: _____		Criteria for Probability of Viable Victims (check one in each line) POTENTIAL NUMBER TRAPPED LOW _____ MEDIUM _____ HIGH _____ TIME REQ'D TO ACCESS VICTIMS 1 HR _____ 6 HR _____ 12 HR _____ TYPE OF VOIDS COMPACT _____ SEPARATED _____ OPEN _____ Criteria for Assessment of Risk (check one in each line) CHANCE OF FURTHER COLLAPSE LOW _____ MEDIUM _____ HIGH _____ No. OF FALLING HAZARDS LOW _____ MEDIUM _____ HIGH _____ VOID SUPPORT CONDITION GOOD _____ POOR _____ UNKNOWN _____		CLASSIFICATION (Circle one each line) LP MP HP LR MR HR	
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BLDG. ID: _____ FLOOR AREA: _____ No. STORIES: _____ OCCUPANCY: _____ MATERIAL (Circle all that apply) WOOD CIP CONCRETE STEEL URM TILT-UP PT CONC PC CONC OTHER: _____		Criteria for Probability of Viable Victims (check one in each line) POTENTIAL NUMBER TRAPPED LOW _____ MEDIUM _____ HIGH _____ TIME REQ'D TO ACCESS VICTIMS 1 HR _____ 6 HR _____ 12 HR _____ TYPE OF VOIDS COMPACT _____ SEPARATED _____ OPEN _____ Criteria for Assessment of Risk (check one in each line) CHANCE OF FURTHER COLLAPSE LOW _____ MEDIUM _____ HIGH _____ No. OF FALLING HAZARDS LOW _____ MEDIUM _____ HIGH _____ VOID SUPPORT CONDITION GOOD _____ POOR _____ UNKNOWN _____		CLASSIFICATION (Circle one each line) LP MP HP LR MR HR	
GPS Coordinates _____ Notes: _____		SLOW- GO (circle if applies) FIRE HAZMAT OTHER: _____			

RESCUE SYSTEMS 3

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FEMA BUILDING MARKING SYSTEM

The marks are as follows:

- BUILDING IDENTIFICATION MARKING
- STRUCTURE/HAZARD EVALUATION MARKING
- SEARCH ASSESSMENT MARKING
- VICTIM LOCATION MARKING

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FEMA Bldg Marking Sys

- Building I.D. Marking
- Structure / Hazards Evaluation & Marking
- Search Assessment Marking
- Victim Location Marking
- Search Marking Example

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BUILDING IDENTIFICATION MARKING

The standard system for locating a building on any block involves the following considerations:

- Use existing numbers and fill in unknowns.
- If the numbers are all unknowns, keep numbers small, on odd and even sides.

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FEMA Building I.D. System
I. D. by Street & Number

■ Case 1 - If some numbers are known, fill in

702 704 708 710

600 700 Block Alpha Street 800

701 703 705 707 709

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I. D. by Street & Number

■ Case 2 - No numbers known, use low no's

900 902 904 906 908

800 900 Block Alpha Street 1000

901 903 905 907 909

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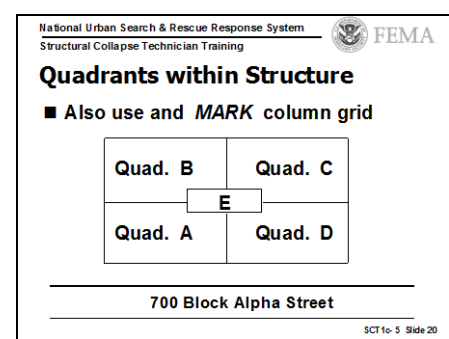
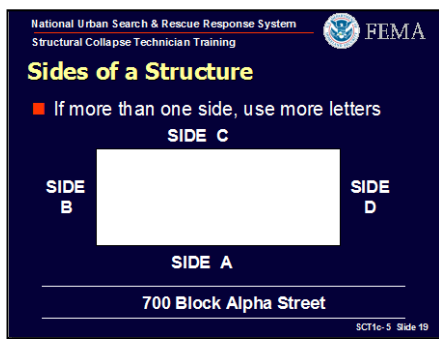
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

BUILDING IDENTIFICATION MARKING (Continued)

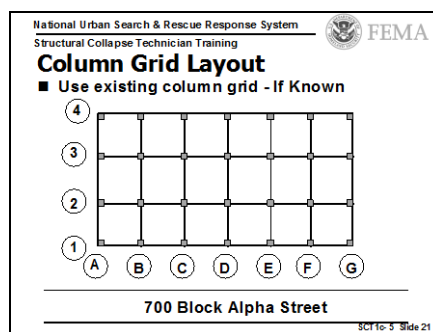
The standard system for building layout is as follows:

- Sides A, B, C, and D start at the street and go clockwise.
- Stories are designated as 1 (or ground), 2, 3, 4.
 - Make sure that everyone understands where the 1st (or ground floor) is and whether there are any basements.
- Basements are designated as B1, B2, and B3.



Quadrants within a building are marked according to the following system:

- Mark A, B, C, D, etc. on the long side, and 1, 2, 3, etc. on the short side.
- It is more helpful to mark an appropriate number on each column for structures with a regular (or irregular) layout.
- Column numbers should be large enough to be read from a distance (such as by a crane operator).
- Use existing column numbers if known.
- If designation is unknown, it is best to use letters on the long side and numbers on the short side, starting at the left/front corner.

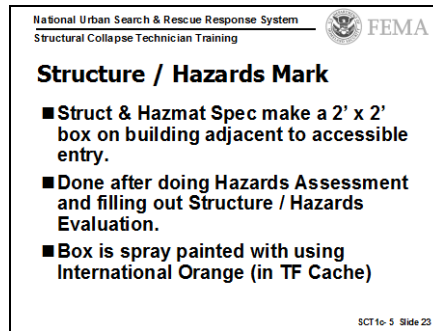


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STRUCTURAL COLLAPSE TECHNICIAN

STRUCTURE/HAZARD EVALUATION MARKING

This mark would normally be drawn on structures in a large incident with many damaged buildings, when the StS. and HMS. need to leave a particular site and assess another. In an incident with a single structure involved, when the StS. and HMS. remain at the site, there would be no need to draw the mark.



A detailed structure/hazard evaluation should take place **after** a priority list of structures has been established by the leadership using recon or just common sense if only a few structures are involved. The structure/hazard evaluation form has been deliberately made different from search and victim marking. The greatest area of concern is not with the fully collapsed structure but with those that have only partly collapsed. The StS and HMS should be prepared to fill out the USAR Structure/Hazard Evaluation Form, identifying structure type, occupancy, hazards, etc (probably at the beginning of search operations). In addition, the StS will generate notes and diagrams regarding search operations. However, in some cases, the assessment will only indicate that the building is too dangerous to conduct USAR operations until significant, and time consuming mitigation is completed.

- The “open box” indicates a structure with low risk for USAR operations. It may be significantly damaged, but has a low probability of further collapse.
- The previous versions of this mark said “Structure is accessible and safe for search and rescue operations. Damage is minor with little danger of further collapse”.
- The term “safe” was inaccurate, since all structures that would be the focus of USAR would be hazardous. The new term “low risk” is more appropriate.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

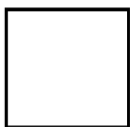
STRUCTURE/HAZARD EVALUATION MARKING (Continued)

TASK FORCE BUILDING MARKING SYSTEM

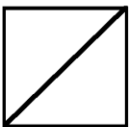
STRUCTURE/HAZARDS EVALUATION

UHR-4 08

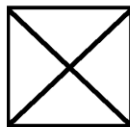
STRUCTURAL SPECIALIST MAKES A 2'x2' BOX ON BUILDING ADJACENT TO MOST ACCESSIBLE ENTRY. THIS IS DONE AFTER DOING HAZARDS ASSESSMENT AND FILLING OUT HAZARDS ASSESSMENT FORM. BOX IS SPRAY PAINTED WITH INTL ORANGE AND MARKED AS FOLLOWS:



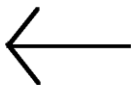
LOW RISK FOR US&R OPERATIONS (BUT NOT SAFE) DAMAGE IS SUCH THAT THERE IS A LOW PROBABILITY OF FURTHER COLLAPSE. (may be pancaked bldg, soft 1st story, or up to 2-story wood construction)



MODERATE RISK FOR US&R OPERATIONS STRUCTURE IS SIGNIFICANTLY DAMAGED. SOME AREAS MAY BE LOW RISK, BUT OTHER AREAS MAY NEED SHORING, BRACING, MONITORING, OR REMOVAL OF HAZARDS.



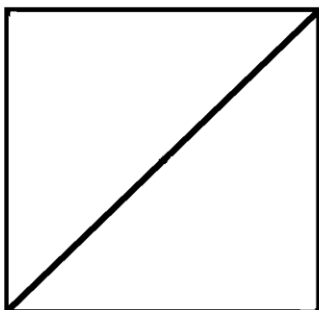
HIGH RISK FOR US&R OPS AND MAY BE SUBJECT TO SUDDEN COLLAPSE. REMOTE SEARCH OPS MAY PROCEED AT SIGNIFICANT RISK. IF RESCUE OPS ARE UNDERTAKEN, SIGNIFICANT, TIME CONSUMING MITIGATION SHOULD BE DONE.



ARROW LOCATED NEXT TO THE MARKING BOX INDICATES THE DIRECTION OF SAFEST ENTRY TO THE STRUCTURE.

HM

INDICATES HAZMAT CONDITION IN OR ADJACENT TO STRUCTURE. S&R OPERATIONS NORMALLY WILL NOT BE ALLOWED UNTIL CONDITION IS BETTER DEFINED OR ELIMINATED.



15JUL92 1310 HRS
HM - NATURAL GAS
OR-1

(DO NOT ENTER BUILDING
UNTIL GAS IS TURNED OFF)

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

STRUCTURE/HAZARD EVALUATION MARKING (Continued)

- The three different marks (Open Box, Single Diagonal, and Cross) indicate the level of risk, and are consistent with the terms used during recon. For a large, multi-structure incident, this detailed assessment would most likely be completed by a StS. and HMS. assigned to the Search Detection Team (as they are starting search operations). The StS. and HMS. that are part of the Recon Team would, initially, only have time to complete the recon forms, and a rapid assessment.
- Following this evaluation, the Structure/Hazard Evaluation Marking would be placed on the building near each entry.

US&R STRUCTURE / HAZARDS EVALUATION FORM - HAZ-1				BY: _____	
Where required, circle all the information or items that apply.				NOTE: AFTERSHOCKS MAY CAUSE ADDITIONAL DAMAGE OTHER THAN NOTED.	
STRUCTURE DESCRIPTION: Bldg ID: _____ No. Stories: _____ No. Basements: _____			BUILDING MARKING: <div style="display: flex; align-items: center; justify-content: center;"> <div style="border: 2px solid black; width: 40px; height: 40px; margin-right: 10px;"></div> <div> Date/Time of Evaluation: _____ Date/Time of Catastrophe: _____ </div> </div>		
MATERIALS: <div style="display: flex; justify-content: space-around; font-size: small;"> Wood Concrete Steel URM PC Concrete </div> Other: _____			TYPE OF COLLAPSE: <div style="display: flex; justify-content: space-around; font-size: small;"> Pancake Soft 1st Floor Wall Failure </div> <div style="display: flex; justify-content: space-around; font-size: small;"> Torsion Middle Story Overturn </div> Other: _____		
FRAMING SYSTEM: <div style="display: flex; justify-content: space-around; font-size: small;"> Shearwall Moment Frame Braced Frame </div> Other: _____			LOCATION OF VOIDS: <div style="display: flex; justify-content: space-around; font-size: small;"> Between Floors Basement Shafts </div> Other: _____		
OCCUPANCY: <div style="display: flex; flex-wrap: wrap; font-size: small;"> <div style="width: 33%;">Hospital</div> <div style="width: 33%;">Police Station</div> <div style="width: 33%;">Fire Station</div> <div style="width: 33%;">Emergency Operations Center</div> <div style="width: 33%;">Office Building</div> <div style="width: 33%;">School</div> <div style="width: 33%;">Public Assembly</div> <div style="width: 33%;">Industrial</div> <div style="width: 33%;">Hotel</div> <div style="width: 33%;">Apartment</div> <div style="width: 33%;">Retail Store</div> <div style="width: 33%;">Other:</div> </div>			DESCRIPTION OF UNSAFE AREAS & HAZARDS: _____ _____ _____ _____ _____ _____		
VICTIM & OTHER INFORMATION: _____ _____ _____					
LOCATION OF BEST ACCESS & SAR STRATEGY: _____ _____ _____					
SKETCH: <div style="border: 1px solid black; height: 150px; width: 100%; position: relative;"> <div style="position: absolute; top: 0; left: 0; right: 0; bottom: 0; background: repeating-linear-gradient(45deg, transparent, transparent 2px, black 2px, black 4px); background-size: 20px 20px;"> </div> </div>					

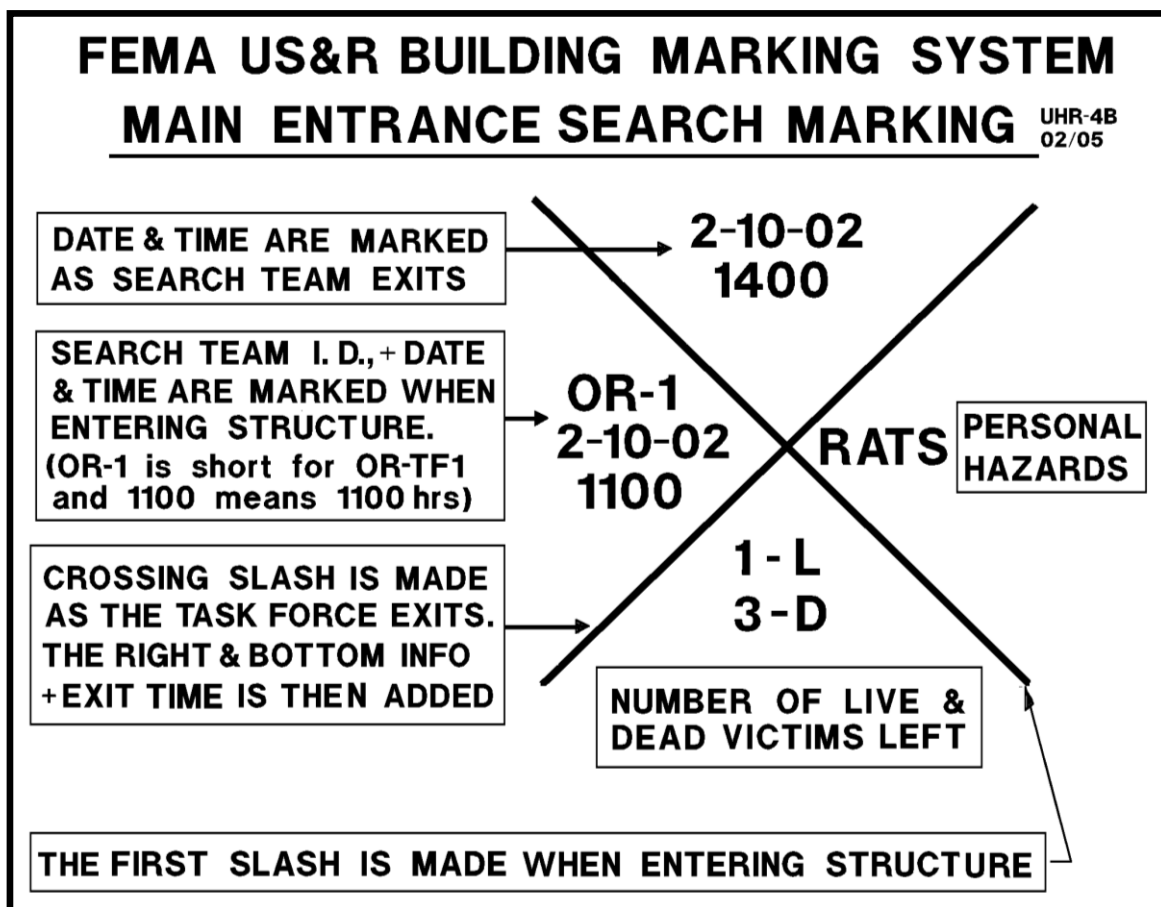
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

SEARCH ASSESSMENT MARKING

Search Assessment Marking is designed to perform two functions:

- When USAR personnel enter the building or parts of the building, they draw an initial line so that **others will be informed of ongoing operations**. In addition, they mark in the left quadrant the task force identifier, plus date and time they have entered. The time, date and identifier will inform others as well as provide critical data should there be a question regarding the task force's safety in the event of a secondary incident.
- Upon entering, the searchers should proceed in a consistent pattern in order to assure that all areas are searched. Go to the right and always keep to the right in every room is a common method, but go left, stay left is also used. Be consistent and search all areas.
- When operations are completed in the building (or parts of the building), the crossing diagonal line will be drawn and information in the remaining three quadrants will be added to indicate what was found and accomplished. This marking will also indicate that the task force has exited safely.
- The finished mark can then indicate to other USAR forces the **outcome of previous operations**.



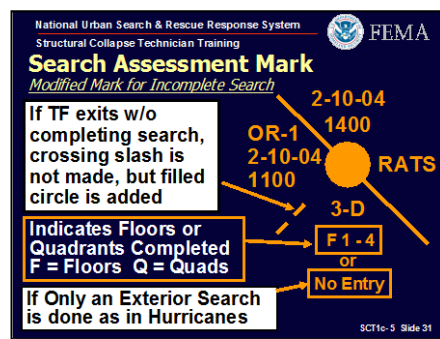
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

SEARCH ASSESSMENT MARKING (Continued)

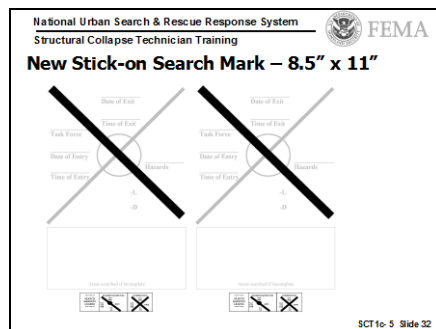
INCOMPLETE SEARCH ASSESSMENT MARKING

- The method for a task force to indicate it has performed an incomplete search. The task force may have entered the structure and only completed some of the floor or, as in the case of hurricanes, the search may have been of the exterior only.
- The extent of the search should be determined by information that is placed in the box below the Search Marking.



STICK-ON SEARCH ASSESSMENT MARKING

In September 2006, a stick-on search marking was approved, in order to reduce the use of paint in incidents like hurricanes where many structures are involved.



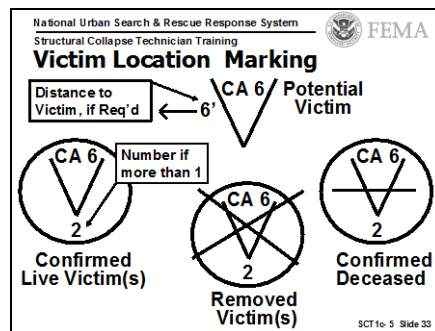
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

VICTIM LOCATION MARKING

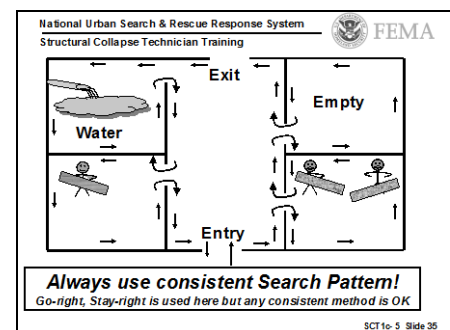
This marking is used to indicate the location of each victim discovered at the USAR site.

- The marking is made with orange spray paint or crayon.
- The marking will normally be initiated after a search is performed unless the victim is immediately removed.
- The "V" is intended to be about 2' high and located as near to the victim as possible.
- It could be painted on a nearby wall surface or directly on a piece of rubble.
- An arrow may be added to indicate the exact victim location.
- The task force identifier example "CA 6" should be included.
- The circle is added when the victim is confirmed.
- As an example, the "V" could be placed when only one canine has indicated that a victim has been located. The circle could be added when the initial find is confirmed by another canine or some other search tool.
- However, when canines are working in pairs, no mark should be made after the first dog indicates a victim because it may influence the second dog.
- A horizontal line is added if the victim is confirmed to be dead.
- A large "X" is drawn completely through the circle after the victim has been removed.



An example that illustrates the use of the search assessment and victim location marking.

- The basic information is as follows:
- It has a front entry and a rear entry/exit.
- There are four enclosed rooms in the building.
- Room 1 has four dead victims.
- Room 2 is empty except for normal contents.
- Room 3 has a broken water pipe and is flooded.
- Room 4 has one live victim.
- The search team will need to decide what search pattern to use as they search the building.
- The pattern that is illustrated here is the “Go Right, Stay Right Pattern”.
- Any pattern may be used, as long as it is consistent and covers all areas of the building.
- The Search Team Manager should determine the most appropriate pattern, no later than when the search team is planning to enter the building.

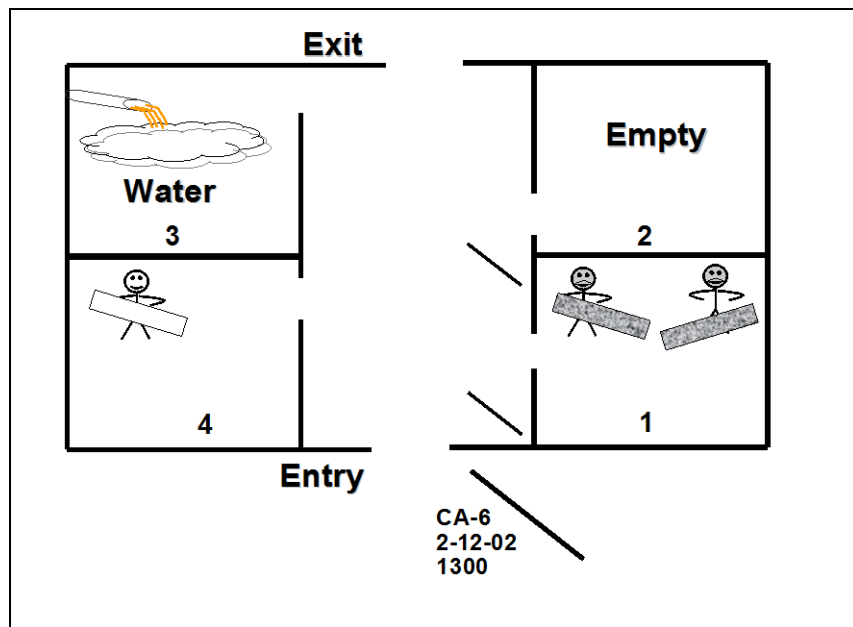


RESCUE SYSTEMS 3

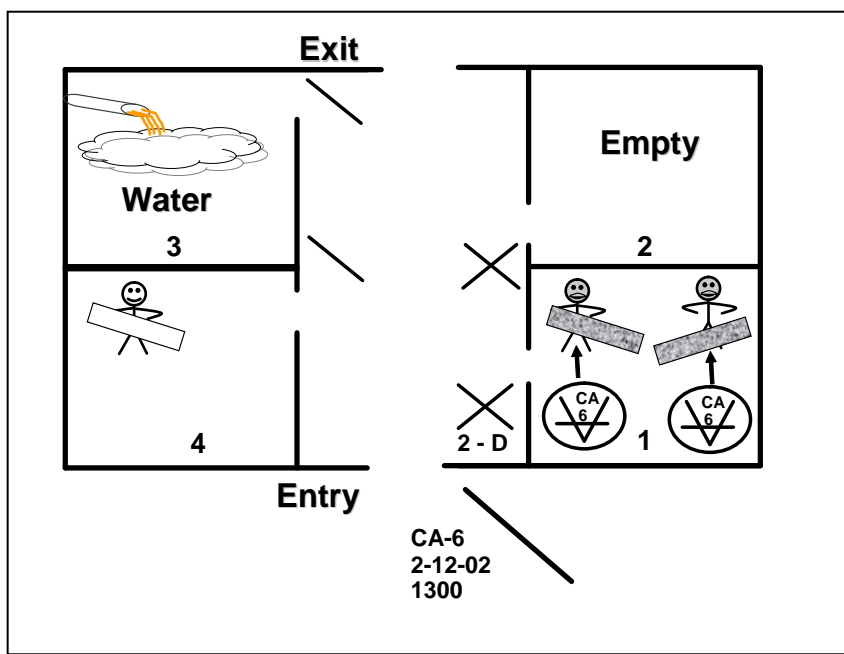
STRUCTURAL COLLAPSE TECHNICIAN

SEARCH ASSESSMENT AND VICTIM LOCATION MARKING EXAMPLE (Continued)

- Make the first slash with TF ID, date, and time by the point of entry. Enter the building, then enter rooms 1 and 2 after making a single slash by each door.



- Exit rooms 1 and 2. Make a second slash and record findings. Then enter rooms 3 and 4.

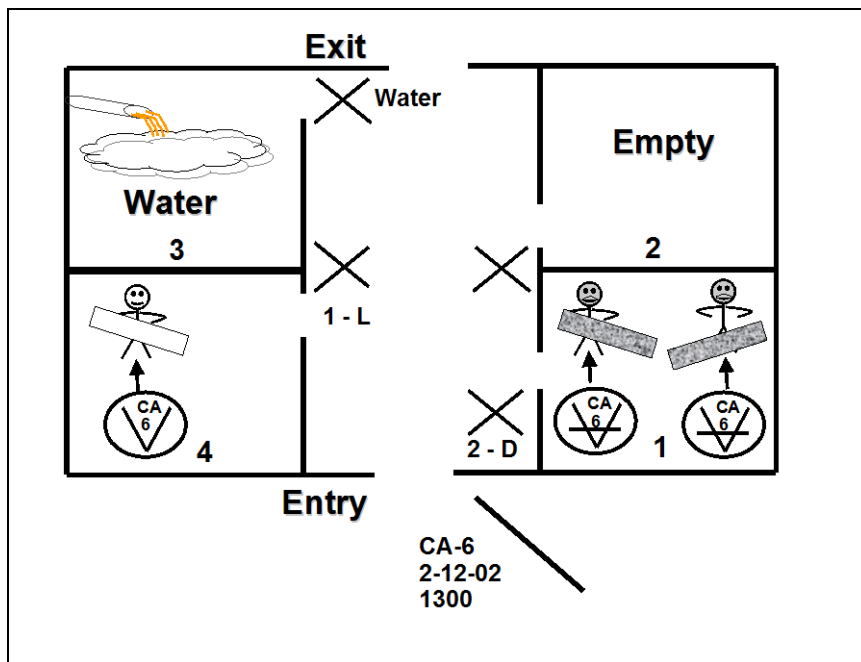


RESCUE SYSTEMS 3

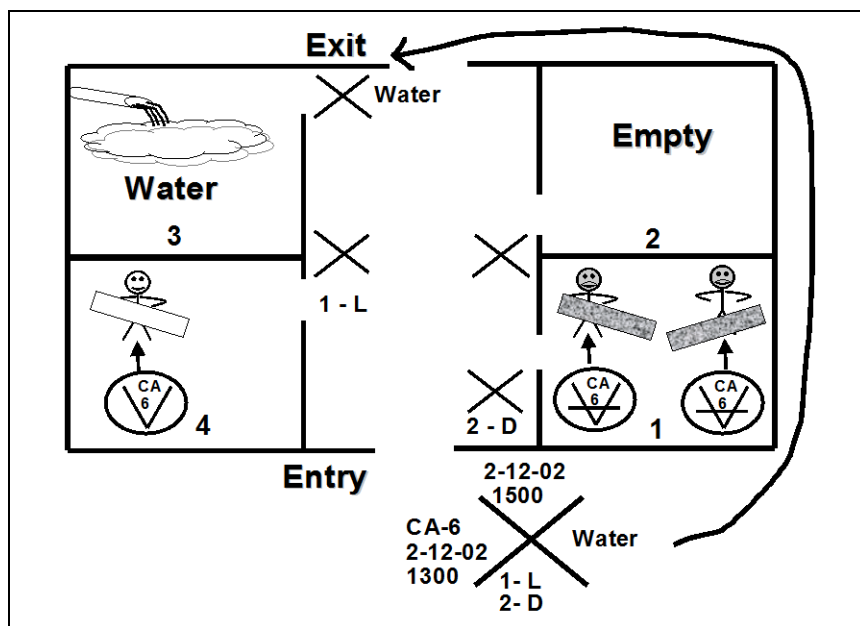
STRUCTURAL COLLAPSE TECHNICIAN

SEARCH ASSESSMENT AND VICTIM LOCATION MARKING EXAMPLE (Continued)

- Exit rooms 3 and 4. Make a second slash and record findings.



- Exit the building. Make a second slash, complete all data, and prepare to go to the next building or assist with rescue at this building. If the exit might be approached by another USAR unit without seeing the front entry, repeat the marks at the exit location.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

DISASTER SITE SIGNALING AND BARRICADES

Effective emergency signaling is essential for the safe operation of USAR team personnel operating at a disaster site.

- These signals must be clear and universally understood by all USAR team personnel.
- These signals are used throughout the world.

Disaster Site Audio Signaling/Alerting

Air horns or other appropriate hailing devices shall be used to sound the appropriate signals as follows:

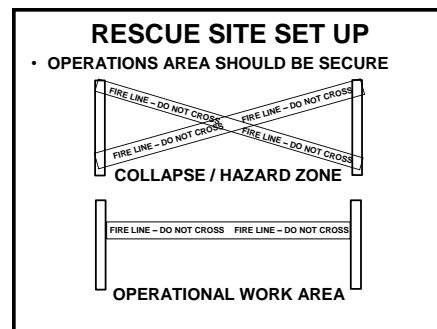
- Cease Operation/All Quiet:
- 1 long blast (3 seconds) = **STOP**
- Evacuate the Area:
- 3 consecutive short blasts (1 second each) = **OUT, OUT, OUT**
- Conduct a radio roll call to account for all personnel. When all personnel are accounted for, the radio signal "all clear" will be broadcast on the command channel.
- Resume Operations:
- 1 long and 1 short blast = **OK**

National Urban Search & Rescue Response System
Structural Collapse Technician Training

Disaster Site Audio Signal/Alerting
(Use Air horn or / Loud Whistle)

- **Cease Operations/All Quiet**
 - 1 long blast = STOP
- **Evacuate the Area**
 - 3 short blasts = OUT, OUT, OUT
- **Resume Operations**
 - 1 long & 1 short blast = Oh. K.

SCT16-5 Slide 38



Disaster Site Barricades

General cordon markings (cordon banners, flagging, etc.) are used for a small, defined area. They can be enlarged to include other non-buildings (for example, a bridge, dangerous zones, NBC, or security). Large areas may require fences and/or patrol.

- Operational Work Zone
- Collapse/Hazard Zone

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

BASIC SEARCH AND RESCUE STRATEGY

BASIC PLAN FOR INDIVIDUAL BUILDINGS

Basic Approach to US&R

- Identify the Problem
 - Prioritize
- Find Victims
 - Re-prioritize
- Remove Victims
 - Medically stabilize
- Create NO NEW VICTIMS

Basic Building SAR Plan (initial phases)

- Reconnoiter
 - determine structure type
 - obtain / draw plans
 - access hazards
 - interview neighbors, etc.
- Prioritize Site
 - develop hazard mitigation alternatives
 - callout / listen search
 - condition of voids & basement

Reconnoiter Site

Collect as much information as possible.

- Determine the structure type to better assess type of failure, type of hazards, ease of entry and cutting.
- Interview neighbors, survivors, interested people (how many potential victims, where were they last seen, location of stairs, elevators, basement, etc.).
- Obtain a building plan and/or draw a crude plan with special emphasis on probable location of voids, existing shafts, and basement.
- Search Specialists should reassess the building in detail to reidentify hazards.

Prioritize Site

- Use collected data to obtain the best risk/benefit ratio.
- Conduct a callout/listen search.
- Plan shoring at access points and/or use the most efficient access.
- Determine the condition of the basement.
- Avoid falling hazards unless they can be removed and/or shored.

Initial Search

Properly trained search dogs and electronic locators can be used successfully to locate deeply buried victims.

Even properly trained dogs may only be able to indicate direction of scent, which is not necessarily the location of the victim.

Electronic devices, operated by trained personnel, can detect victims that are instructed to make tapping noises.

- "Send out" search dogs as far as possible. Check alerts with a second dog/observer/handler.
- Use listening/seismic finders to hear victim noise.
- Explore all existing vertical shaft openings.
- Explore horizontal openings with great care (send a dog in and keep people out).
- Search from safe, stable areas into unstable areas.
- Reprioritize the site (location of potential live victims).

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

BASIC PLAN FOR INDIVIDUAL BUILDINGS (Continued)

Selected Cutting and Removal

Based on priorities of initial search and probable hazards.

- Cut vertical openings and research, recheck with dogs and/or listening/viewing devices.
- Place initial shoring for access.
- Avoid unshored overhead structures.
- Recheck all shoring after cutting and removal (loading can change).
- Continue the process of cutting layers, researching, and reprioritizing.
- Stabilize the area around the victim and give medical aid.

Heavy Search and Rescue

- Continue search after prolonged cutting and/or removal.
- Give the victim aid and gain information regarding additional victims.
- Recheck all shoring after cutting and removal, since loading can change.

SEARCH AND RESCUE PLAN / LIGHT FRAME

Search Items

- Callout/listen search may be effective due to the lower density of wood floors.
- Acoustic listening devices will probably be more effective than seismic type sensors in these buildings that have wood floors and walls. Broken wood is a relatively poor transmitter of vibrations.
- Dogs may be able to detect sent through cracks in wood floors if they are not heavily covered.

Hazard Reduction Items

- Shut off the gas and electricity and reduce other fire hazards. (This applies for all types of buildings).
- Assess for chemical hazards (What's in the typical kitchen/garage?).
- Remove or avoid a leaning chimney.
- Place vertical and/or lateral shores as required.
- Victim Access Items
- Use horizontal entries through cavities or walls.
- Make vertical access through holes cut in the roof/floor.
- Remove or shore hazards as required.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

SEARCH AND RESCUE PLAN / HEAVY WALL (URM/TILT-UP)

Search Items

- Callout/listen search may be effective due to the lower density of wood floors.
- Acoustic listening devices will probably be more effective than seismic type sensors. Most of these structures will have wood floors that have collapsed in large planes and badly broken masonry, both of which are relatively poor transmitters of vibrations.
- Dogs may be able to detect scent through cracks in wood floors if they are not heavily covered.

Hazard Reduction Items (URM)

- Shore hazardous floors with vertical shores.
- Remaining uncollapsed URM walls are brittle (aftershock/wind falling hazards). Either avoid, remove, tieback, or raker shore them. May need to shore in both inside and outside direction.
- Beware of all falling hazards (peeled, cracked, and split URM walls are very brittle). There is a high potential for falling and collapse hazards.

Hazard Reduction Items (Tilt-up/Low Rise)

- Use diagonal or raker shores for hazardous walls.
- Shore hazardous roof and floor beams, etc.

Victim Access Items (URM)

- Use horizontal entries thru existing openings with great care.
- Vertical access through wood floors should be easy and the least dangerous.
- Avoid cutting large beams and more than two joists in a row.
- Avoid cutting walls. Holes can greatly reduce the strength of poorly cemented walls (most are important bearing walls).
- Beware of roof, floor joists, and beams that are not sitting on their original flat bearings or ledges. They can slide down walls and produce outward forces as they move to find a stable position.
- The basement may provide good access, but should be shored for safety. Failure of wood columns or beams can be sudden.
- Hand removal of bricks may be required.
- Large pieces of a wall may be removed by clamshell or other bucket with a thumb (need to prevent parts from falling).

Victim Access Items (Tilt-up/Low Rise)

- Use horizontal entries thru existing openings with great care.
- Vertical access through wood roof/floors should be easy and the least dangerous.
- Holes in wall panels should be made a minimum of 2' away from joints. If the wall has a concrete pilaster or column, an opening may be cut next to a column on the side away from the joint.
- Wall panels and large pieces of roof may be lifted by a crane or other equipment.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

SEARCH AND RESCUE PLAN / HEAVY FLOOR (CONCRETE FRAME)

Search Items

- Not likely to hear the callout of victims through floors due to the high density of concrete.
- Seismic listening devices can be the most effective in these heavy structures, especially when floor slabs remain intact and form thin void spaces as in pancake type collapse.
- Dogs will indicate the direction of the scent that may be flowing around large slabs, back and forth across the building. The location of a victim must be interpreted from conditions. The area should be rechecked by dogs after layers have been removed. The best time to use dogs is in early morning and at dusk when the scent is rising.

Hazard Reduction Items

- In a partially collapsed building, (upper floors, etc.) it is very important to check the floors that support the debris load.
- Read cracks to determine if more and progressive collapse is probable.
- Multi-story shoring may be the only safe procedure.
- It normally takes at least three undamaged floors to support shores from one damaged floor that contains little debris. If heavy concrete debris from upper floors is present, shores need to extend down to additional, undamaged floors (two more floors per 12" of debris).
- Shore/avoid badly cracked beams.
- Shore/avoid hanging slabs/beams.
- Shore heavily loaded flat slabs (punching shear).
- Beware of all falling hazards (parts of slabs, walls, etc.). May be hanging from exposed rebar (how well is rebar embedded?).
- Monitor the structure for lateral movement with a Theodolite or other tilt measuring device.

Victim Access Items

- Use any existing vertical shaft.
- The basement may be a good access, but need to evaluate the floor slab above and possibly shore. How many basement levels?
- Preferred access is usually made by cutting through slabs from above collapse.
- Best to cut slabs mid-way between beams and columns.
- Check for the thinnest slab area. Pan joist and waffle slabs have ribs spaced every 3' or so with a 3" to 4" thick slab between.
- Do not cut columns (usually do not need to).
- Avoid cutting concrete or masonry walls. They may be bearing walls. If there is a masonry infill wall in a concrete frame, cutting is possible (check first to see if the frame is loading the wall due to the collapse).
- Remove concrete slabs with a crane after all the rebar is cut.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

SEARCH AND RESCUE PLAN / PRECAST CONCRETE

Search Items

- Callout/listen search may be effective. It depends on the size of the voids between larger pieces of concrete.
- The effectiveness of listening devices will depend on the interconnection of the collapsed, structural parts. Acoustic sensors may not be effective in compact rubble, and seismic sensors may not be effective due to poor transfer through badly broken concrete parts.
- Canine search may be effective (again depending on compactness of concrete rubble).

Hazard Reduction Items

- Remove or avoid hanging pieces of the structure. There may be many loose or poorly connected pieces of precast concrete. Use cranes and other equipment.
- Shore beams adjacent to badly cracked columns.
- Remove or shore tilted wall panels or pieces.
- Partially collapsed buildings may have adjacent slabs and/or wall panels that have damaged connections that may break loose in aftershocks or if loading shifts.

Victim Access Items

- Cut cored slabs and "T" slabs at the edges (thinnest part of the section, away from ribs).
- Cut half of the hole in each of the two adjacent precast pieces.
- Don't cut the ribs in "T"s or walls and do not cut columns.
- Walls may be cut with care.
- Cut holes at least 2' away from the joints.
- Consider the problems of shoring versus removal (removal may be more efficient).
- Check the wall welded joints for signs of movement.
- Some walls may be infill URM and may be cut if not loaded by collapsed concrete pieces.
- Basements may not be good access unless basement walls and the first floor slab are cast in place concrete. Shoring may be required in any case.
- Use horizontal access through existing cavities (use great care).
- Lift off loose concrete pieces with cranes or other equipment.
- Great care must be taken when lifting and/or shoring large concrete pieces, since adjacent pieces may shift.
- Precast concrete will often weigh about 75% of normal concrete (150pcf). It also splits more easily.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

METAL DETECTOR

Metal detectors should be used to locate rebar or prestressed cables prior to cutting slabs and walls. This can keep from dulling bits and inadvertently cutting cables.

- Metallescanner Pro by Zircon is a magnetic type that is small and can determine the location of rebar as much as 4" deep. Cost \$100
- Devices are available with costs from \$400 to \$2000.

Metal Detector

- Needed to keep drill bits from hitting rebar
- Also to find posttensioning
- New device by Zircon Corp 1997
 - Metalliscanner - Pro (cost = \$100)
 - Available from Tool Crib (800) 358-3096
 - May be sold at Home Depot/Base, etc
 - Micropowered viewer - ?
- More expensive (up to \$2000) devices are available

CUTTING POST TENSIONED CONCRETE (CABLES)

Post-tensioned concrete contains steel cables (1/2" dia.) enclosed in a long plastic casing (sometimes called casing, sheath or sleeve). They are placed in the forms prior to the pour, and when the concrete hardens, the cables are tensioned using a special hydraulic jack assembly.

Post-tensioned cables are then anchored in special steel fittings at each edge of the concrete floor, but remain separated from the concrete by the plastic casing (Unbonded).

- When tensioned cables need to be cut during USAR operations, special care needs to be taken to deal with the tension force that will be released.
- Cables are most often placed in a draped configuration within the concrete. The cable is placed near the bottom of the slab or beam near mid-span, and near the top where cables pass over supporting columns or beams.
- It is best to use a torch to cut the cables, since the tension should be released slowly. A carbide saw could be used to carefully cut the cables, one wire at a time.
- If the cable is not cut slowly so that the force can be gradually released, parts of the cable may violently explode out of the concrete structure.
- Depending on where the cable is cut, it may explode above the floor near their supports, below the floor near mid-span, or out of the end or side of the concrete slab like a spear, and injure or kill.

The task force can mitigate this problem by clearing an area that measures, at least 10' on either side of the cable for the full length of the slab or beam. In addition, the area outside the building should be cleared for 100' and/or barricaded to deal with the threat of the cable spear.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

TOPIC 2-1: PNEUMATIC SHORES

TERMINAL OBJECTIVE

- The student will understand the function and capacity of pneumatic shores used in Urban Search and Rescue to support damaged structures.
- The student will understand why and how shores are constructed.

ENABLING OBJECTIVES

- Determine the appropriate shore to be constructed.
- Construct various pneumatic shores.
- Understand how to inspect constructed shores.

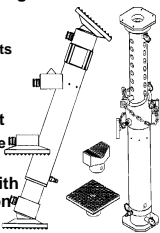
PNEUMATIC SHORES

Lightweight aluminum pneumatic piston ram shore, which is highly adjustable with ranges up to 16 ft. They can be configured with various end connections.

- Paratech manufactures 3" diameter Struts in four ranges of length (2 to 8 feet). **Dark grey anodized color.**
- Paratech also makes a 3½" diameter, Long Strut, in three ranges of length (6 to 16 feet). **Gold anodized color.**

Pneumatic Shores – Class 1

- Adjustable Shore up to 16 ft long
Manufactured by Airshore, Paratech, & Holmatro
 - Holmatro only makes short struts
- Have Swivel & other feet
- Hand tighten (snug) using adjustable collar or sleeve nut
 - May use up to 50psi air pressure to raise into position
- Design Strength decreases with length and should be based on tests using swivel ends
- Best use is as Initial, Spot Shore



What About using Extensions for Pneumatic Shores?

- Don't use extensions unless you have to
- Shipping Pallet size is 104" x 84"
 - this is a problem for 10' to 16' Strut
- Extensions available in lengths from 1' to 6'
- Joint between Strut & Extension must be tested to demonstrate adequate strength
- **PARATECH & AIRSHORE** have successfully tested their joints and recommendations for struts used with one extension are included in the SS FOG and the following

- When used in trenches, these shores are initially set with pressurized air.
 - After securing the shore in place with a large locking nut or steel pins with a collar, the safe working load can range from 20,000 lbs. for a 6-foot shore to 3000 lbs. for a 16-foot shore.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

PNEUMATIC SHORES (Continued)

- When used in USAR operations, these shores should be hand tightened, so as not to apply any sudden pressure to a damaged structure.
 - Air may be used to raise vertical struts, but the pressure must be limited to a maximum of 50 psi to minimize the potential for an accident.
 - The sleeve nut or steel pins are used to adjust length.
 - They may be included in a system with a header, a sole plate, and bracing, but are considered best as temporary shores that allow braced systems to be installed at reduced risk.

PARATECH Rescue Struts – Load Table

Based on Tests by Paratech,
Reviewed by Wiss, Janney, Elstner, Engineers

Avail in 1.5 to 3ft, 2 to 3ft, 3 to 5ft, & 5 to 7.2ft
Extensions avail. In 12", 24" and 36" lengths
(use max. of one extension per strut)

Length	Ave Ult	Design Strength Based on Safety Factors	
		3 to 1	4 to 1
2 ft	87,000 lb	29,000 lb	21,750 lb
4 ft	71,750 lb	23,920 lb	17,940 lb
6 ft	56,500 lb	18,830 lb	14,125 lb
8 ft	48,100 lb	16,030 lb	12,025 lb

- The manufactures also make simple aluminum tubing extensions in lengths from one to six feet.
 - Extensions should only be used when other alternatives are not available.
 - Only one extension should be used with each strut.

Recommended Safe Working Strength Paratech Long Shore Struts in US&R

- Paratech Long Shore Struts are 3½" in diameter (Gold Anodized), which is larger than original 3" dia. Paratech Rescue Struts.
- Paratech Rescue Struts (3" dia., Dark Grey) should be used ONLY up to 8 feet long
 - They have a strength similar to the 3½" struts for lengths up to 6 feet
 - Strength drops to about 14,000 lb for 8 ft length
 - See Manufacturers recommendations.

Recommended Design Strength PARATECH Long Shore Struts in US&R

Length	Load	Comment
16 ft	3500 lbs	May use one 6ft extension
15	4500	"
14	5500	May use one 6 or 4ft ext.
13	6500	"
12	7500	May use one extension
11	10000	"
10	12000	"
9	16000	Do Not Use Extensions
8	20000	"
7 & 6	22000	"

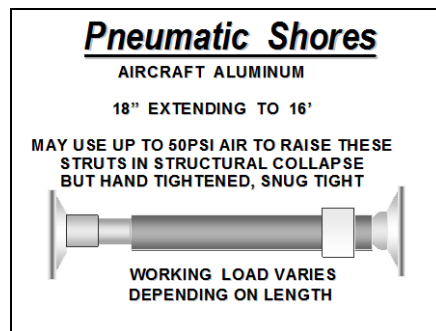
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

PRECONSTRUCTED VERTICAL SHORING

Pneumatic shores, with one or more shores with wood or metal rail header.

- Metal ends should be nailed to the header and sole plate.
- One manufacturer sells a clamp fitting that allows for, nailed 2x 6 "X" bracing to be installed.
- Pneumatic shores are best used as temporary shores.
- Some manufacturers provide a header rail that may be pre-assembled with two or more struts to provide for a pre-constructed, vertical shore.
- **WARNING** – The use of air pressure to raise these shores into place has caused accidents. Air pressure should be limited to 50 PSI, and **All Pneumatic Struts Should Be Hand Tightened.**



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

LATERAL SHORING SYSTEMS

- Principles of trench shoring may sometimes need to be applied to USAR operations, where pulverized masonry rubble tends to cave into an otherwise accessible space.
- Pneumatic Shores may be used in vertical applications since they have positive locking devices.

ONE-SIDED TRENCH SHORE

- This type of shoring is needed when one side of a trench has caved-in, or for basement excavation cave-ins.
 - This type of shore needs to be designed by a qualified Structures Specialist.
 - If no soil evaluation is available, one must assume Class C soil (Uniform Pressure = $80h + 72\text{psf}$).
- Bracing frames (like Double Rakers) may be placed 4ft o.c.
 - Use 30 or 45 degree slope depending on height.
 - Sheathing between frames may need to be 3x or 4x.
 - The anchor system is very important.
 - Perpendicular bracing needs to be installed.

RAKER SHORES

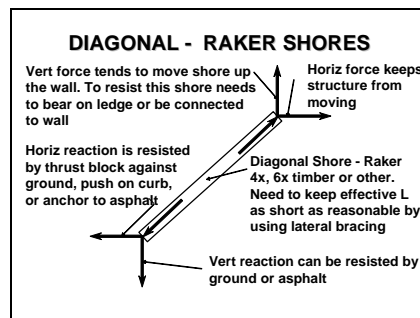
- Useful in bracing unreinforced masonry (URM) and other heavy walls that have cracked, (especially at corners) and / or are leaning away from the building.
- Need to be configured in a system that will account for both vertical and horizontal components of force in diagonal member
- The vertical component may be resisted by:
 - Friction, which may be increased in a full triangular configuration, by applying more horizontal load at the base, against the wall. However, friction should not be considered as reliable, especially during aftershocks.
 - By placing drilled-in anchors through the wall plate into the masonry. This may be too dangerous in some areas of badly cracked walls.
 - By bearing the wall plate against a projection in the wall surface, or by placing the raker at an opening and nailing a cleat onto the plate so that it will bear on the opening head.
- The required horizontal force may be less than two percent of the wall weight, since URM walls are seldom left standing very far out of plumb. However, since aftershocks are likely to occur, raker systems should be designed for about 10 percent of the weight of the wall and roof that is within the tributary area that they support.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

RAKER SHORES (Continued)

- Rakers should be built away from the dangerous area next to wall and then carried or walked into place.
 - Rakers should be spaced at 8ft maximum on center.
 - When the insertion point is greater than 8ft, the Raker needs to be configured with a mid-height brace.
- Rakers may be configured using the full triangle method or as a **Flying Raker**.
 - The preferred **Solid Sole Raker** may be built on concrete, asphalt, or soil.
 - The **Split Sole Raker** is not used when working with pneumatic shores.
 - Full triangle Rakers should always be built in groups of 2 or more, with lateral bracing systems connecting them together.



- Lateral bracing, consists of continuous horizontal struts (capable of resisting compression and tension) and diagonal bracing (in either the **V** or **X** configuration)
 - When the height of the Raker requires a mid-brace, horizontal struts are placed at the bottom, middle, and top of the Raker.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

RAKER ANGLE

The angle between the ground and a diagonal (Raker) brace member should be as small as practicable.

- If the angle is 30 degrees, the horizontal force applied to the wall is 87% of the force in the diagonal, and the upward force that needs to be resisted at the wall face is only 50% of the diagonal force. Limited access normally prevents using 30 degrees.
- When the angle increases to 60 degrees the horizontal is 50%, and the vertical is 87%.
- At 45 degrees the two are equal at 71% of diagonal force.
- The disaster "field" conditions such as need for access, available timber length, and / or clearance, normally limit the choice to either 45 or 60 degrees.
 - The simplest to build are 45 degrees (1 to 1) and 60 degrees (1.7 to 1). Both are extensively used in USAR.
 - The 60 degree angle is preferred for the Flying Raker.

PNEUMATIC SHORES USED AS RAKERS

A quick, temporary raker can be constructed using pneumatic shores.

- They can be used as individual units, but should be configured in a system of two rakers that are interconnected with 2x6 wood bracing.
- Special rails and connections are available from Paratech, as well as base plate and bracing connections.

Recommended Design Strength for <i>PARATECH</i> Struts Raker System		
• System is made from 2 rakers spaced 8ft max. apart with X-bracing.		
• Rakers need to be attached to wall surface and restrained at ground.		
• For use 45 degree angle.		
Raker Length	Height to Insertion	Horiz. Design Load on 2 Rakers w/ X-bracing
16 ft	11.0 ft	5000 lbs
15	10.5 ft	6400
14	10.0 ft	7800
13	9.0 ft	9200
12 & less	8.5 ft	10,600 lbs

- Pneumatic shores can be used as temporary rakers. They would be replaced with a properly braced wood system for ongoing operations.

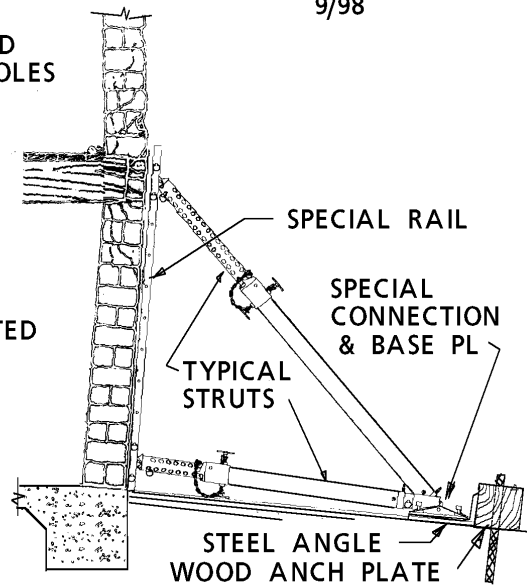
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

PNEUMATIC STRUTS USED AS RAKERS

- INDIVIDUAL RAKERS CAN BE CONFIGURED FROM TWO STRUTS (UP TO 16FT LONG) AND A SPECIAL RAIL THAT HAS CONNECTION HOLES
- MANUFACTURED BASE PLATE CAN BE CONNECTED TO PAVING THRU EXISTING HOLES USING STEEL BARS/DRILL-INS. STEEL ANGLE CAN BE ADDED UNDER BASE PLATE TO PROVIDE SURFACE TO BEAR ON TYPICAL WOOD SOLE PLATE ANCHOR
- THESE CAN BE MADE INTO SYSTEM USING TWO OR MORE INDIVIDUALS, INTERCONNECTED WITH HORIZONTAL + DIAGONAL 2x6 WOOD BRACING CONNECTED TO MANUFACTURED CLIPS (THAT HAVE WOOD NAILERS)
- RAKER RAILS NEED TO BE PINNED TO WALL AS W/TYP RAKERS. THESE CAN PROVIDE A QUICKLY PLACED, INITIAL SYSTEM TO BE FOLLOWED W/TYP WOOD SYSTEM

SHOR-16a
9/98



INSPECTION OF USAR SHORING

- Following its installation, USAR shoring should be periodically inspected. The Structure Specialist should perform inspections at the following times:
 - Just prior to and / or following the 12-hour shift change.
 - Following any significant change in loading, such as following earthquake aftershocks, when expecting and following the occurrence of high winds, and following any secondary disturbance like a secondary explosion.
 - Prior to and following the removal of significant amounts of debris.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

Paratech Deployable Raker System General Information

Paratech Struts Maximum Buckling Strength Values (excluding Extensions)

Table 1

Strut Length (Feet)	Maximum Buckling Strength Pounds
16 (12' to 16' Strut)	8,500
14 (12' to 16' Strut)	15,500
12 (12' to 16' Strut)	20,000
12 (8" to 12' Strut)	28,000
10 (8' to 12' Strut)	33,000
10 (8' to 10' Strut)	42,500
8 (6' to 10' Strut)	63,000

Paratech Struts Recommended Safe Working Values (excluding Extensions)

Table 2

Strut Length (Feet)	Maximum Buckling Strength Pounds
16 (12' to 16' Strut)	3,000
15 (12' to 16' Strut)	4,500
14 (12' to 16' Strut)	6,000
13 (12' to 16' Strut)	7,000
12 (12' to 16' Strut)	7,000
12 (8' to 12' Strut)	10,000
11 (8' to 12' Strut)	10,000
10 (8' to 12' Strut)	12,000
10 (6' to 10' Strut)	16,000
9' (6' to 10' Strut)	16,000
8' (6' to 10' Strut)	20,000
7 (6' to 10' Strut)	22,000
6 (6' to 10' Strut)	22,000

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

Recommended Safe Working Load
When Raker Angle is 45 Degrees
(Two Cross Braced Raker Shores)

Table 3

Raker Strut Length	Maximum Height to Insertion point (ft)	Maximum Load Pounds
16	11.0	5,000
15	10.5	6,400
14	10.0	7,800
13	9.0	9,200
12	8.5	10,600

Recommended Safe Working Load
When Raker Angle is 60 Degrees
(Two Cross Braced Raker Shores)

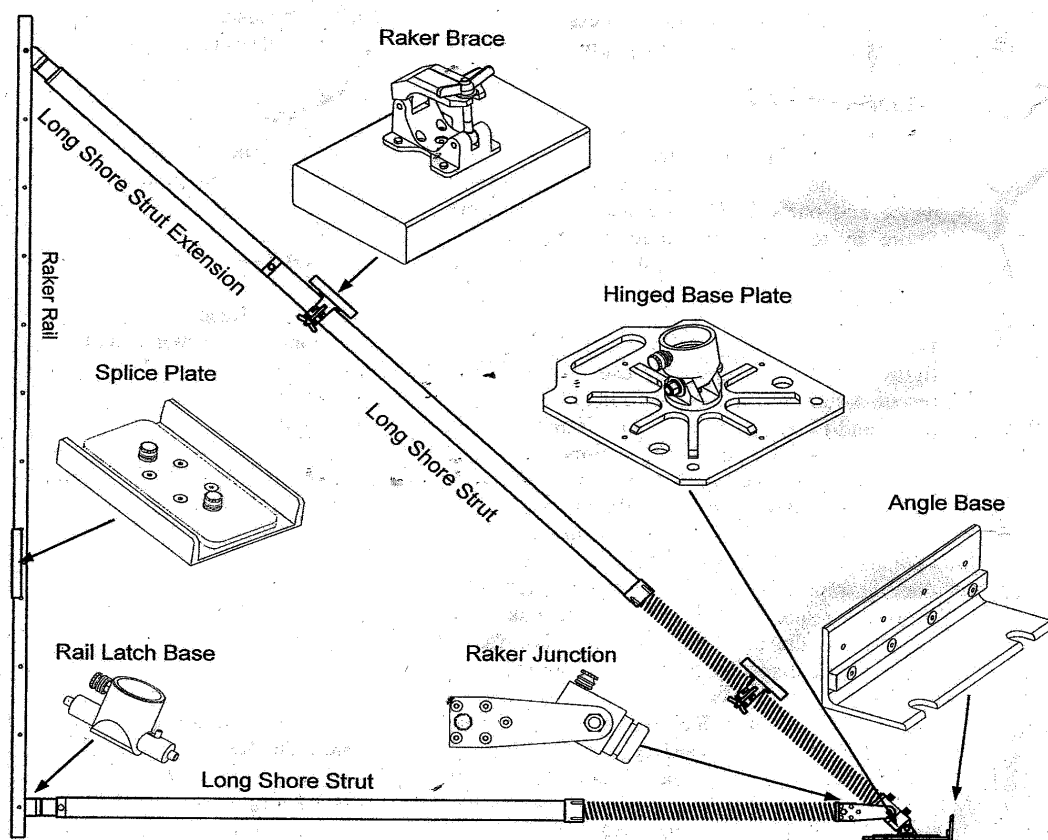
Table 4

Raker Strut Length (ft)	Maximum Height to Insertion Point (ft)	Maximum Load Pounds
16	13.8	3,000
15	13.0	4,500
14	12.0	5,500
13	11.25	6,500
12	10.4	7,500
11	9.5	10,000

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

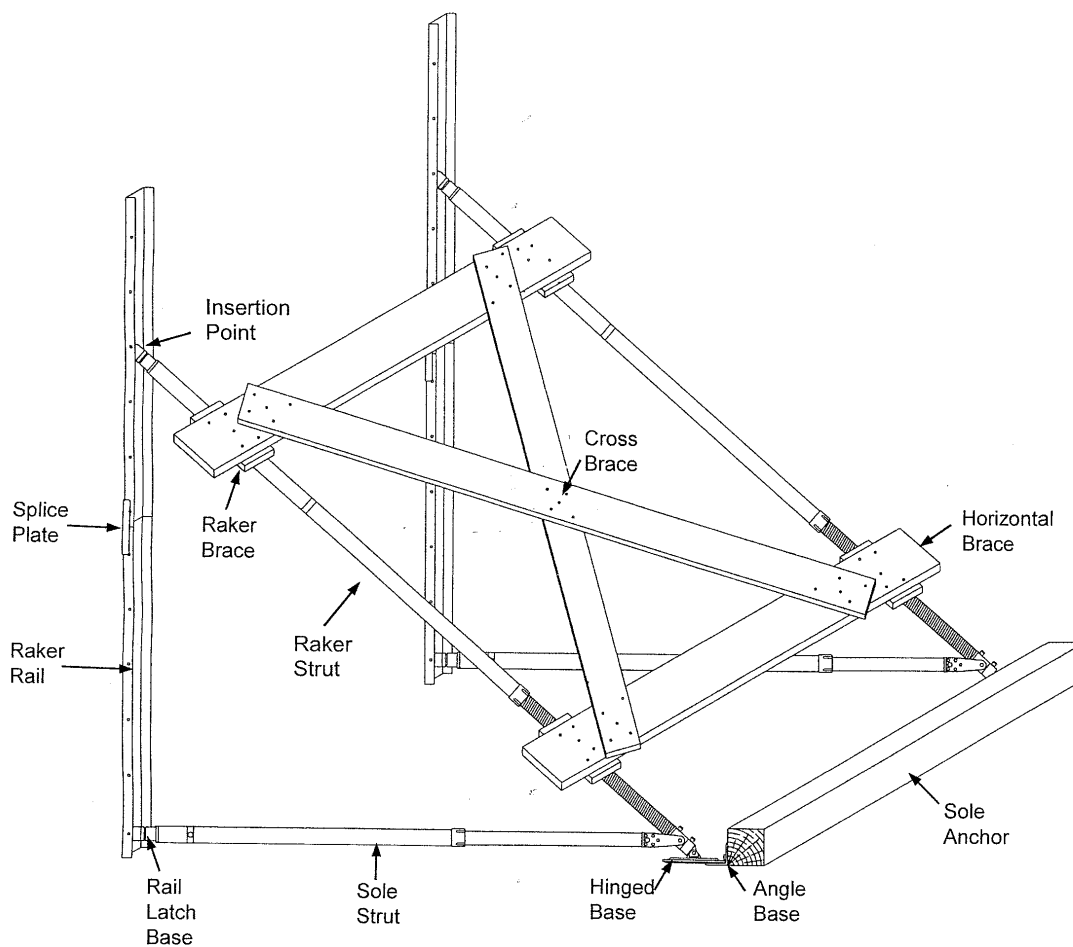
Paratech Raker Shore Components



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

Raker Shore (set) w/ Horizontal & Cross Bracing



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

PARATECH RESCUE SHORING INSTALLATION

RAKER SHORES

STEP-BY-STEP “RAKER” SHORE FABRICATION AND ERECTION

1. Select a suitable spot close to the area to be shored, but away from any possible collapse danger. A safe area must be available to pre-construct the raker shore out of the way of any damaged or leaning wall. The safety of rescue personnel is the top priority. The area must be large enough and relatively level to help speed the assembly and make it easier to assemble the components. An area approximately 20 ft. by 20 ft. would be sufficient.
2. Determine the raker insertion point. This will determine the length of the raker rail. The raker rail should extend at least 12” above the raker strut insertion point. The raker shore should contact the floor beams or be no more than 2 feet below them.
3. Lay out the raker rails in line with each other and parallel with the wall to be shored. This will make it easier to pick-up and erect the pre-assembled raker shore. To splice the raker rails together, pull out the lock pin assembly knobs on the splice to retract the lock pins, fully engage the splice and raker rails and release the knobs. Check the connections and make sure they are positively locked into position.
4. Determine the hole locations in the raker rails where the raker rail latch bases will be installed. One set should be at the raker strut insertion point and the other set should be either at the bottom set of holes or one set higher to accommodate the sole strut. Place the raker rail latch bases between the channel legs of the raker rail locating and engaging the bases in the predetermined holes. The raker latch base should be slid in on an angle keeping the lock pin assembly up for easier engagement. The lock pin assembly is spring loaded and will retract as the raker rail latch base is slid into position and then extended into the raker rail holes.
5. Refer to the chart to determine the recommended safe working load and maximum height to the raker strut insertion point for raker shores with 45° and 60° raker angles. Determine the size of the raker struts and the extensions that will be utilized. Do this for both the sole strut as well as the raker strut. Any extension should be installed directly into the rail latch base connected to the raker rail. Place the extension, if used, in the raker strut latch base first. Align it to the approximate angle of the raker strut. Then place the sole strut extension in the sole strut rail latch base and align it to the approximate angle of the sole strut.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

6. Insert the sole and raker struts into the extension pieces. To lock together, pull out the lock pin assembly knob on each extension, fully engage the extension with the sole and raker struts and then release the knobs to lock the components together. Place the longer strut into the raker strut extension. Make sure the strut pistons (inner threaded shaft) are facing away from the extensions to facilitate attachment to the raker junction base.
7. Extend the sole and raker struts (pull the inner threaded shafts outwards) with the sole strut perpendicular to the raker rail as much as possible, until the ends almost meet. The assembly should now be in the shape of a tri-angle.
8. Place the raker junction base onto the sole and raker struts. Pull the lock pin assembly out when making the assembly, and when fully engaged, release the knob. Make sure the lock pin assemblies are locked in position. The swivel end of the raker junction base must be assembled onto the raker strut, and the fixed end onto the sole strut.
9. Place the hinged base plate onto the swivel end of the raker junction base. Pull the lock pin assembly, and when fully engaged, release the knob. Make sure the lock pin assembly is locked in position.
10. Tilt up the assembled raker shore. It is now ready to be placed into position.
11. Place the assembled raker shore in position against the wall. Make sure that the raker rail contacts the wall at the base and at the raker shore insertion point. If necessary shim the wall to accomplish this.
12. Set the hinged base plate flat on the ground. Turn the collars up the threaded shafts until they contact the outer tubes in order to lock the struts in their extended positions.
13. Anchor the assembled raker shore to the ground at this time using at least two (2) 1" diameter pickets driven through the holes at the back of the hinged base plate. Slide an angle base under the hinged base plate engaging the slots in the angle base with the pickets driven through the hinged base plate.
14. If required, place a 6" x 6" x 10' or 8' x 8' x 10' wooden sole (deadman) directly behind the angle bases. Secure the deadman into the foundation or ground with at least 8 pickets behind the deadman or through holes drilled in the deadman (four (4) behind each angle base).
15. Anchor the raker to the wall utilizing the holes provided in the raker rail.
16. At this time re-hand tighten the collars on the struts as necessary. The struts should be under compression and tight.

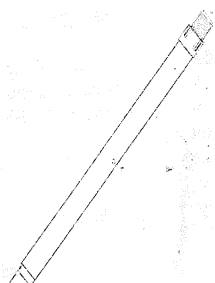
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

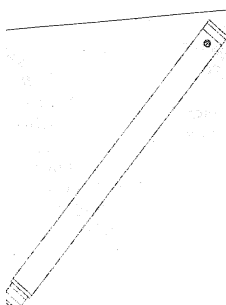
17. Repeat steps 1 through 16 to assemble and install the second raker shore.
18. After the second raker has been assembled and installed (no more than 8ft. on center from the first raker), it will be necessary to cross brace the rakers.
19. To cross brace the rakers four raker braces (nailing pads) will need to be installed. Place two nailing pads on each raker strut, one approximately 12" down from the raker insertion point and the second approximately 12" up from the hinged base plate on the threaded shaft.
20. Repeat step 19 on the second raker.
21. Using 2" x 6" lumber, place one piece horizontally across the top pair of nailing pads and one piece across the bottom pair of nailing pads. Nail the lumber to the nailing pads using five 16d nails at each connection point .
22. To complete the bracing, cross brace the rakers using 2" x 6" lumber and securing to the horizontal braces with five 16d nails at each connection point.

Paratech Pneumatic Window / Door / Vertical / Horizontal

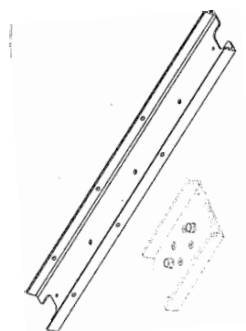
Components



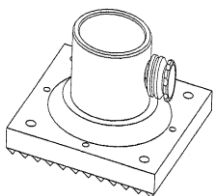
Shore Strut



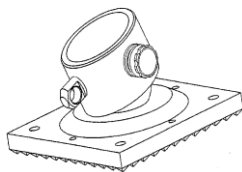
Strut Extension



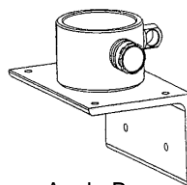
Raker Rail & Splice



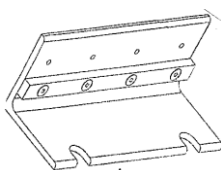
Rigid Base



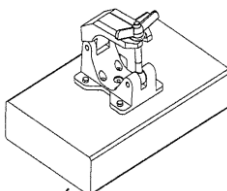
Swivel Base



Angle Base



Angle Base Plate

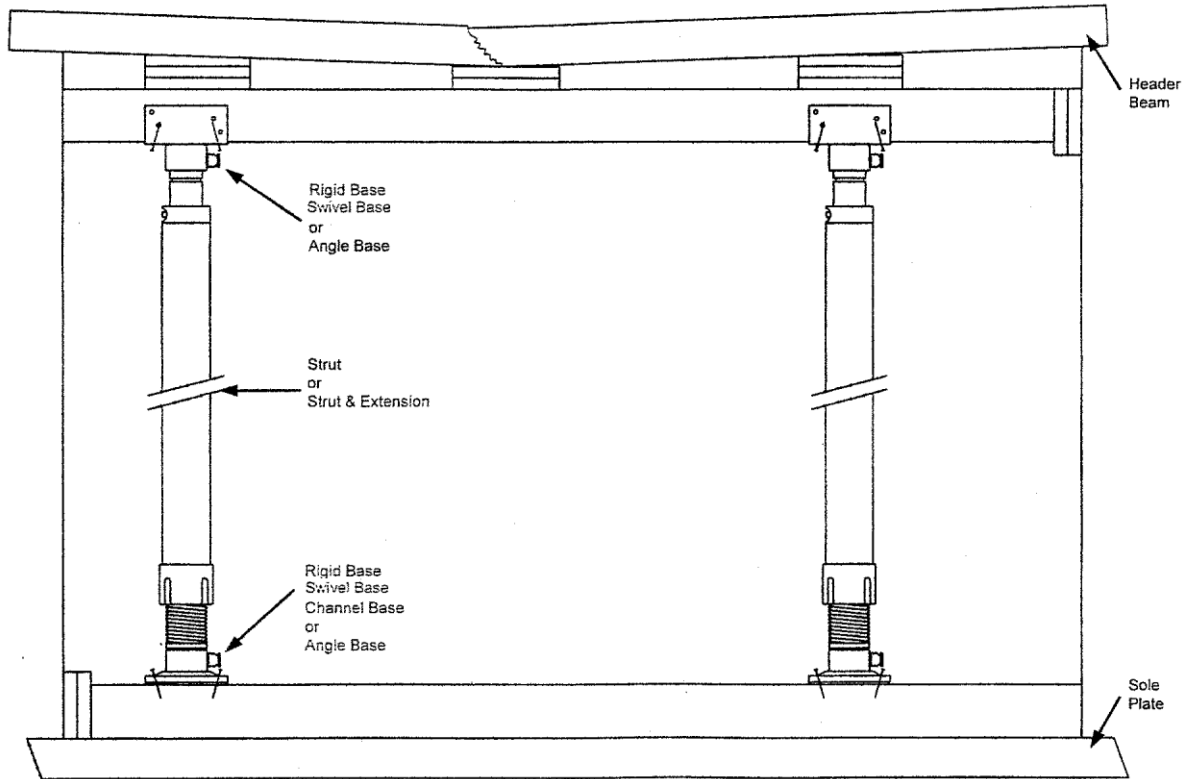


Nailing Plate / Bracket

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

Window / Door Pneumatic Shore



Step-by-Step Window or Door Shore Fabrication and Erection

1. Refer to the tables for the maximum buckling strength values and the recommended safe working values to determine the specific strut and strut length to be used during the stabilization effort.
2. Place a rigid base, swivel base, ground plate, channel base, or angle base onto the designated strut piston (threaded shaft) and outer tube. Lock together by pulling out each lock pin assembly knob, and fully engaging the strut and then releasing the knob.

RESCUE SYSTEMS 3

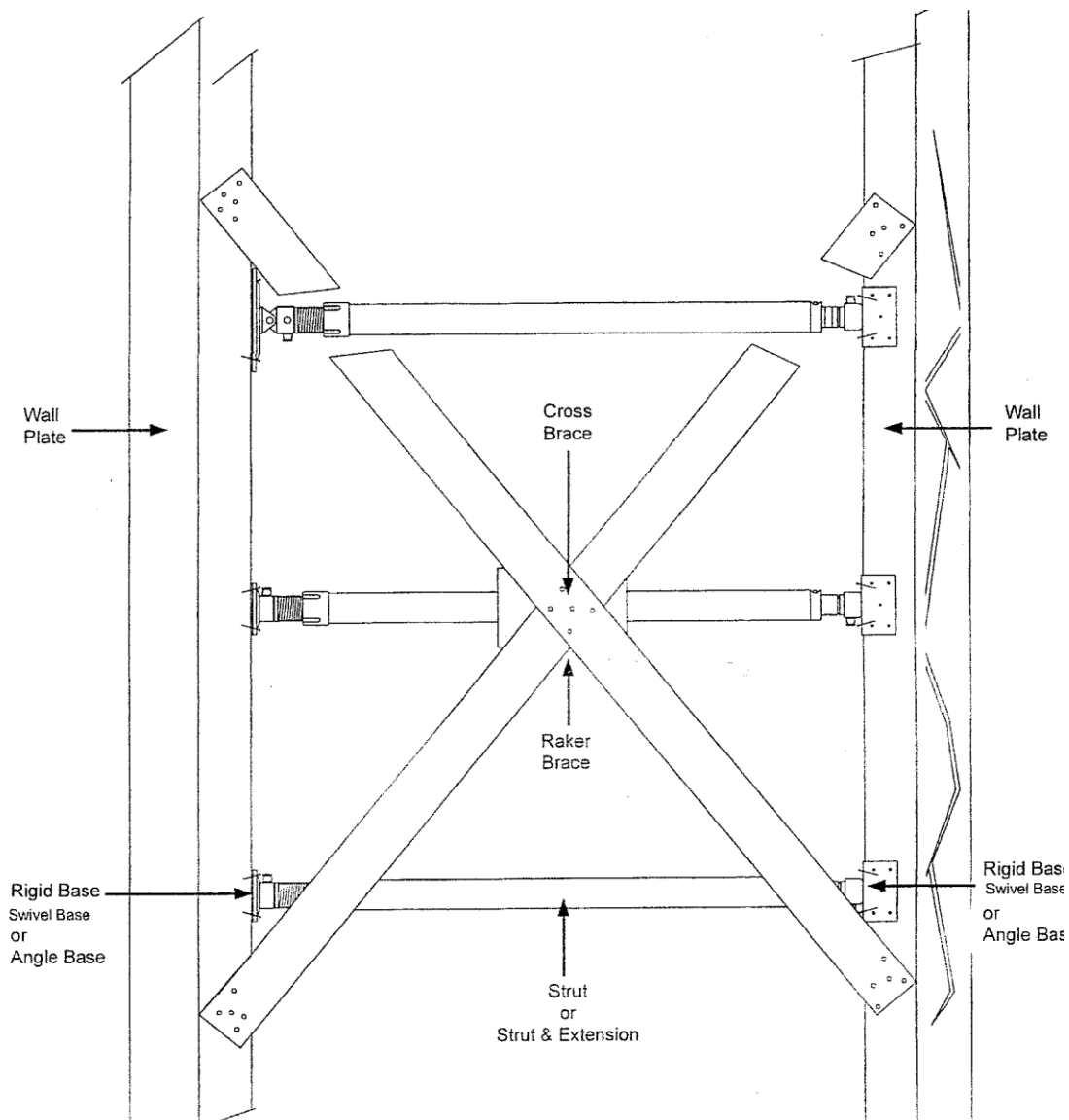
STRUCTURAL COLLAPSE TECHNICIAN

3. Position the assembled strut in the opening requiring stabilization with the strut piston (threaded shaft) facing down to provide easy access to the collar. Shim the “sole” plate as required until it is as level as possible and secure in position with nails.
4. Position the “header” and shim until it is as level as possible and secure with nails. With the strut assembly(s) resting on the “sole” plate, slide the outer tube up slightly and then turn the collar until it contacts the outer tube. Repeat this process until the upper portion of the shore contacts the “header”.
5. Repeat steps 2 through 4 to assemble and install additional window or door shores as required. The quantity of shores required and the spacing depends upon the strut length and recommended working load.
6. Secure all rigid bases, swivel bases, ground plates, channel bases, or angle bases to the “header” and “sole” plates with nails.
7. Fully tighten the collar on each shore until a safe condition exists through stabilization. The window or door shore should be under compression and tight.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

Horizontal Pneumatic Shore



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

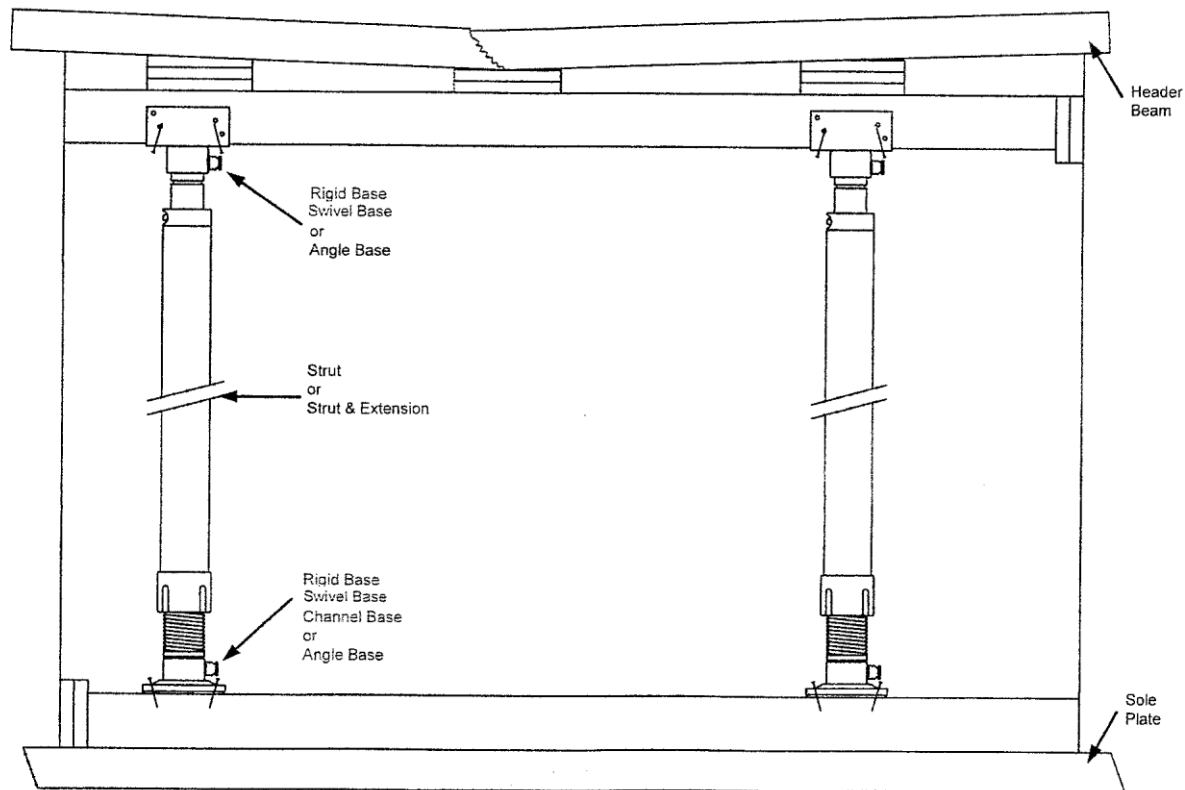
Step-by-Step Horizontal Pneumatic Shore Fabrication and Erection

1. Refer to the tables for the maximum buckling strength values and the recommended safe working values to determine the specific strut and strut length to be used during the stabilization effort.
2. Place a rigid base, swivel base, ground plate, channel base, or angle base onto the designated strut piston (threaded shaft) and outer tube. Lock together by pulling out each lock pin assembly knob, and fully engaging the strut and then releasing the knob.
3. Shim the “wall” plates as required until they are as plumb and parallel as possible to each other and then secure them in position with nails. Position the assembled strut horizontally between the wall plates in the opening requiring stabilization.
4. With the assembly resting against one solid “wall” plate or other foundation, slide the outer tube until the assembly comes in contact with the opposite “wall” plate. Turn the collar until it comes in contact with the outer tube.
5. Repeat steps 2 through 4 to assemble and install additional horizontal shores as required. The quantity of shores required and the spacing depends upon the strut length and recommended working loads.
6. Secure all rigid bases, swivel bases, ground plates, channel bases, or angle bases to the “wall” plates with nails.
7. Fully tighten the collar on each shore until a safe condition exists through stabilization. The horizontal shore should be under compression and tight.
8. To further stabilize the horizontal shores, they may be cross braced as necessary.
9. To cross brace the horizontal shores, it is necessary to place a “nailing pad” at the center of each alternate horizontal strut.
10. Place 2” x 6” or 2” x 8” lumber diagonally across the “wall” plates with the center contacting the nailing pad. Nail the lumber to the “nailing pad” and “wall” plates using a 5 spot nailing pattern.
11. Repeat steps 9 and 10 installing a “nailing pad” on each alternate horizontal strut and cross brace.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

Vertical Pneumatic Shore



Step-by-Step Vertical Shore Fabrication and Erection

1. Refer to the tables for the maximum buckling strength values and the recommended safe working values to determine the specific strut and strut length to be used during the stabilization effort.
2. Place a rigid base, swivel base, ground plate, channel base, or angle base onto the designated strut piston (threaded shaft) and outer tube. Lock together by pulling out each lock pin assembly knob, and fully engaging the strut and then releasing the knob.

RESCUE SYSTEMS 3

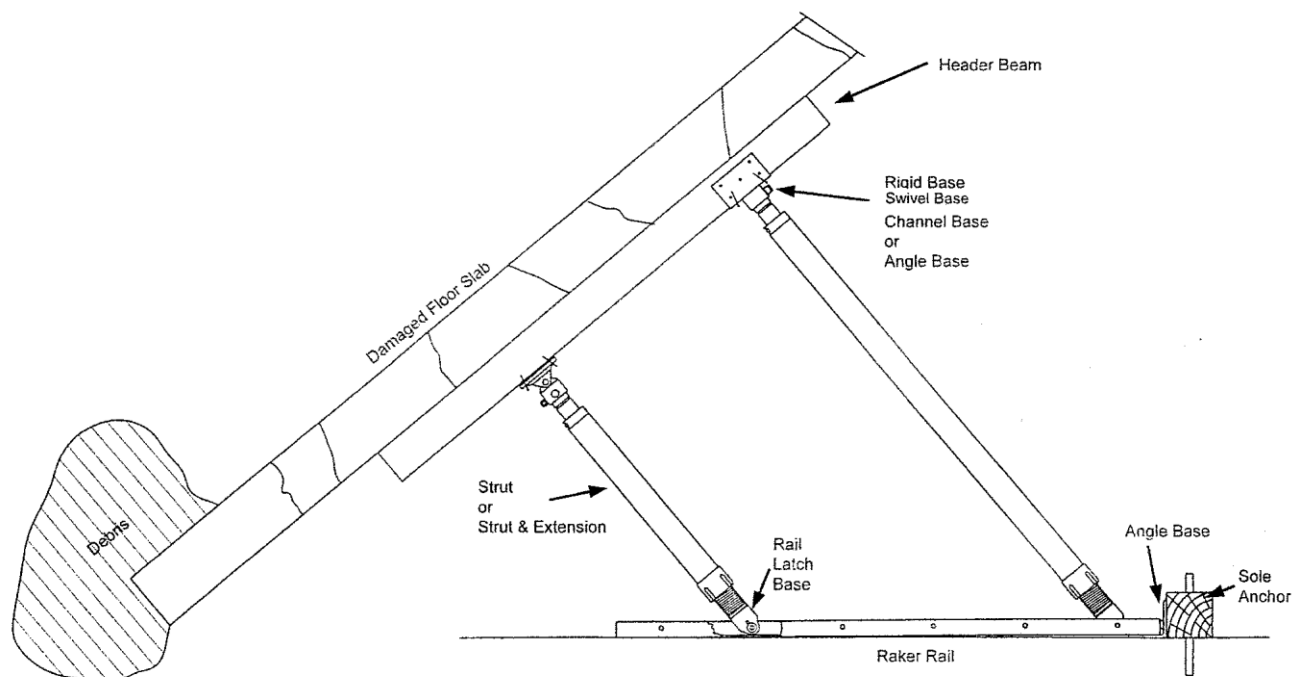
STRUCTURAL COLLAPSE TECHNICIAN

3. Position the assembled strut in the opening requiring stabilization with the strut piston (threaded shaft) facing down to provide easy access to the collar. Shim the “sole” plate as required until it is as level as possible and secure in position with nails.
4. Position the “header” and shim until it is as level as possible and secure with nails. With the strut assembly(s) resting on the “sole” plate, slide the outer tube up slightly and then turn the collar until it contacts the outer tube. Repeat this process until the upper portion of the shore contacts the “header”.
5. Repeat steps 2 through 4 to assemble and install additional vertical shores as required. The quantity of shores required and the spacing depends upon the strut length and recommended working load.
6. Secure all rigid bases, swivel bases, ground plates, channel bases, or angle bases to the “header” and “sole” plates with nails.
7. Fully tighten the collar on each shore until a safe condition exists through stabilization . The vertical shore should be under compression and tight.
8. To further stabilize the vertical shores, they may be cross braced.
9. To cross brace the vertical shores, it is necessary to place a nailing pad at the center of each alternate vertical strut.
10. Place 2” x 6” or 2” x 8” lumber diagonally across the “header” and “sole” plate with the center contacting the nailing pad. Nail the lumber to the nailing pad, “header” and “sole” plate using a 5 spot nailing pattern.
11. Repeat steps 9 and 10 installing a nailing pad on each alternate vertical strut.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

Sloped Floor Pneumatic Shore (Hard Surface)



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

Step-by-Step Instruction for Sloped Floor Shore (On Hard Surface) Fabrication and Erection

1. If necessary, use debris to prevent the sloped floor from sliding before attempting to install a sloped floor shore.
2. Install temporary spot shores as required until a sloped floor shoring system can be erected.
3. Position and shim the header as required and secure in place with nails or fasteners.
4. Select a suitable spot close to the area to be shored, but away from any possible collapse danger. A safe area must be available to preconstruct the sloped floor shores out of the way of any damaged or leaning floor slab.
5. Determine the strut quantity and spacing to adequately support the sloped floor. Lay out one or two raker rails in line with each other. To splice raker rails together, pull out the lock pin assembly knobs on the splice to retract the lock pins, fully engage the splice and raker rails and release the knobs. Then check the connections and make sure they are positively locked into position.
6. Determine the hole locations in the raker rails where the latch bases will be installed. One set should be either at the bottom set of holes or one set higher to accommodate one strut and the other set should be at the approximate location determined in step 5 to maintain the proper spacing between the struts to support the load. Place the rail latch bases between the channel legs of the raker rail locating and engaging the bases in the predetermined holes. Each rail latch base should be slid in on an angle keeping the lock pin assembly up for easier engagement. The lock pin assembly is spring loaded and will retract as the rail latch base is slid into position and then extend into the raker rail holes.
7. Refer to the tables to determine the recommended safe working load and maximum height of the struts. Determine the size of struts and the extensions if any, that will be utilized. Position the strut with the strut piston (threaded shaft) facing the rail latch base to provide easy access to the collar.
8. Insert the struts into the strut rail latch bases first and the extension pieces onto the struts outer tube. To lock together, pull out the lock pin assembly knob on each strut and extension, fully engage the struts into the rail latch bases and the extension with the struts, and then release the knobs to lock the components together.
9. Place a rigid base or swivel base onto the strut outer tube. To lock together, pull out each lock pin assembly knob, fully engage the strut and then release the knob.

RESCUE SYSTEMS 3

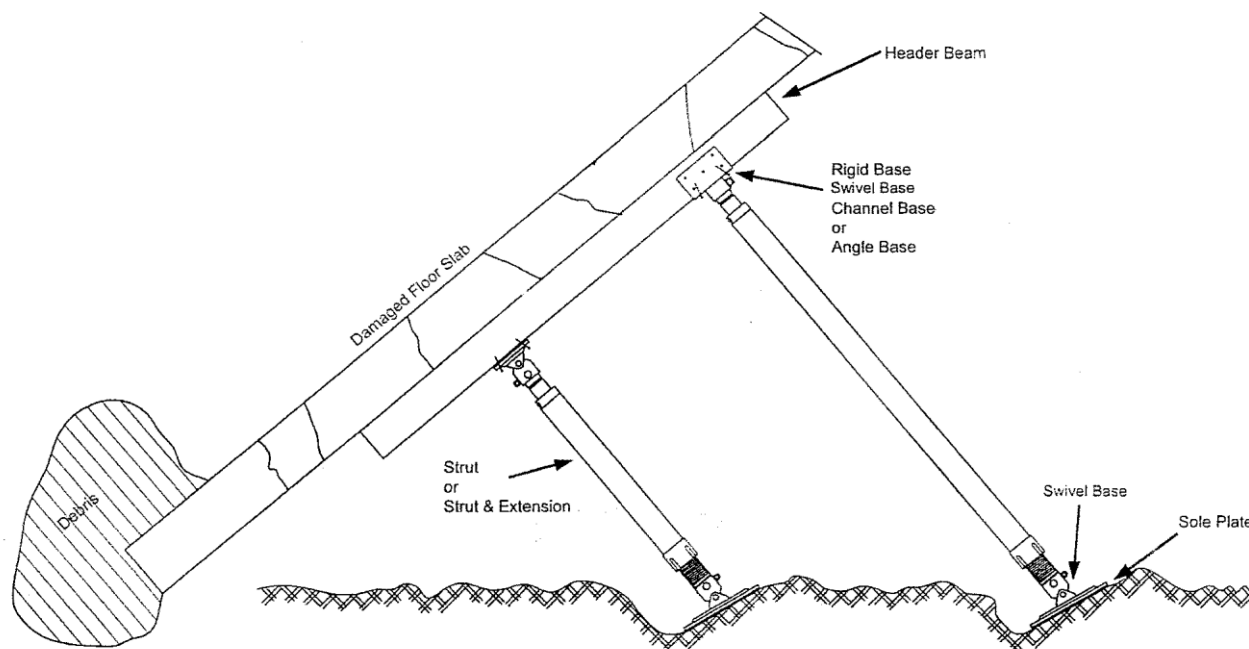
STRUCTURAL COLLAPSE TECHNICIAN

10. Slide the assemblage under the sloped floor and extend the struts until they contact the header. The struts should be as perpendicular to the header as possible.
11. Turn the strut collars until they contact the outer tubes in order to lock the struts in the extended position.
12. Slide an angle base under the end of the raker rail. If necessary, as a result of foundation instability, use a 6" x 6" or 8" x 8" wooden sole / deadman anchor directly behind the angle base. Secure into the floor / foundation with 1" diameter steel pins (reinforcing bars or equal). The pin length will be determined by the type of floor / foundation they are driven into. Also secure the angle base to the wooden sole / deadman anchor.
13. Anchor the sloped floor shore to the floor / foundation utilizing the holes provided in the raker rail. The attaching nails, pins, etc. will depend upon the floor / foundation material.
14. Retighten the collars on the struts as necessary. The struts should be under compression and tight.
15. Repeat the instructions in steps 5 through 14 to assemble and install a second sloped floor shore no more that 8 ft. from the first installed sloped floor shore. One may not be laterally stable enough to do the job.
16. After the second sloped floor shore has been assembled and installed, it may be necessary to cross brace the sloped floor shores.
17. To accomplish this it is necessary to use four nailing pads; two each on the longer strut of each sloped floor shore approximately 12 inches from the end of the struts and extensions, if used. Lock the nailing pads in position onto the struts or extensions with the nailing surface facing up.
18. Using 2" x 6" or 2" x 8" lumber, place one piece horizontally across the top pair and one piece horizontally across the bottom pair of nailing pads. Nail the lumber to the nailing pads using a 5 spot pattern.
19. To complete the sloped floor shores, cross brace the two sloped floor shores with 2" x 6" or 2" x 8" lumber and secure to the nailing pads.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

Sloped Floor Pneumatic Shore (Natural Surface)



Step-by-Step Sloped Floor Shore (On Earth Surface) Fabrication and Erection

1. If necessary, use debris to prevent the sloped floor from sliding before attempting to install a sloped floor shore.
2. Install temporary spot shores as required until a sloped floor shoring system can be erected.
3. Position and shim the header as required and secure in place with nails or fasteners.
4. Select a suitable spot close to the area to be shored, but away from any possible collapse danger. A safe area must be available to preconstruct the sloped floor shores out of the way of any damaged or leaning floor slab.
5. Refer to the tables to determine the recommended safe working load and maximum height of the struts. Determine the size and the extensions if any, that will be utilized.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

6. Excavate the ground at the anticipated location of the struts so that the bearing surface is parallel to the sloped floor. Position a sole plate measuring 18" square and 2" thick in the excavation.
7. Assemble an extension piece onto the outer tube of the strut, if needed. To lock together, pull out the lock pin assembly knob, fully engage the strut and the extension and then release the knob.
8. Place a 12" swivel base onto the strut piston (threaded shaft). Place a rigid base or swivel base onto the strut outer tube or extension if used. To lock together, pull out each lock pin assembly knob, fully engage the components and then release the knobs. Repeat steps 7 and 8 for the second strut.
9. Slide each sloped floor shore under the sloped floor with the 12" square hinged base toward the sole plate to provide easy access to the collar and the rigid base or swivel base toward the header.
10. Extend the strut until it contacts the header. Turn the collars until they contact the outer tubes in order to lock the struts in their extended position. The struts should be under compression and tight. The struts should be as perpendicular to the sole plate and header as possible. Secure shore in position with nails.
11. After the second sloped floor shore has been assembled and installed no more than 8 ft. from the first sloped floor shore, it may be necessary to cross brace the sloped floor shores.
12. To accomplish this it is necessary to use four nailing pads; two each on the longer strut of each sloped floor shore approximately 12 inches from the end of the struts and extensions, if used. Lock the nailing pads in position onto the struts or extensions with the nailing surface facing up.
13. Using 2" x 6" or 2" x 8" lumber, place one piece horizontally across the top pair and one piece horizontally across the bottom pair of nailing pads. Nail the lumber to the nailing pads using a 5 spot pattern.
14. To complete the sloped floor shores, cross brace the two sloped floor shores with 2" x 6" or 2" x 8" lumber and secure to the nailing pads.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

Takedown

1. Take down and repositioning is accomplished by removing the load pressure and then manually turning the strut collar down the inner shaft. If during release, a load shift begins to forcibly collapse the strut, simply releasing the collar will again lock the strut in that extended position where the collar was released.
2. On occasion, load pressure may prevent either one or more struts from being taken down. When this occurs, an evaluation must be made to determine the safety of such removal. Before removing a bound strut, determine whether the bound strut can be replaced with a more permanent strut (timber / metal beam). If so, and if safety will not be compromised, cut a permanent strut to the proper replacement size. Install the permanent strut next to the strut to be removed and turn the strut collar down the inner shaft until the load rests on the permanent strut. Continue to turn the collar down the inner shaft until the strut can be removed. Repeat this procedure for each bound strut.
3. At the conclusion of use, perform the after use maintenance.

Cleaning and Maintenance

1. Keep the exterior of all components clean of all dirt, grit, oil and grease accumulation. Wipe exterior surfaces with a lint free towel dampened with clean water. Then dry the surfaces thoroughly with a lint free cotton towel of low pressure compressed air.

Maintenance Schedule

Frequency	Maintenance Requirement
After Use	Clean all dust, oil and grease from the Rescue Strut Support System components and attachments.
Quarterly	When not used periodically for training or collapse incidents, the full complement of equipment should be field tested to ensure its integrity and flawless operational capability.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

Inspection

1. Do not paint any part of the Rescue Strut or components. Check for cracked or deformed parts that may fail during their next use.
2. If during the last three months struts and components have not been used for training or collapse incidents, they should be field tested and visually inspected to ensure that they are in full operational condition.

Lock Pin Assembly Replacement

1. To replace the lock pin assembly, pull up and turn the locking pin knob to expose the bonnet. Use a wrench on the bonnet hex and unscrew the defective lock pin assembly. Thread in by hand the replacement lock pin assembly, then pull up and turn the locking pin knob to expose the bonnet and use a wrench on the bonnet hex to fully tighten the lock pin assembly.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

TOPIC 2-2: POWDER ACTUATED TOOLS

TERMINAL OBJECTIVE

- The student will understand the function and capacity of powder actuated fasteners used in Urban Search and Rescue to support damaged structures.
- The student will understand how to safely operate powder actuated tools.

ENABLING OBJECTIVES

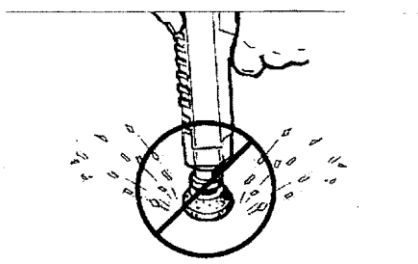
- Understand how to safely handle and operate powder actuated tools.
- Understand the appropriate materials in which powder actuated fasteners can be installed.
- Know how to perform a "Center Punch Test" of materials.

PREPARATION

ACCEPTABLE BASE MATERIALS

- Powder actuated fastening is suitable for use in the following base materials only:
 - Poured Concrete
 - Structural Steel
 - Masonry Joints

Never attempt to fasten into any other type of material. Fastening into other type material can cause blindness or other serious injury.



NEVER FASTEN INTO VERY HARD OR BRITTLE MATERIALS



NEVER FASTEN INTO SOFT MATERIALS SUCH AS DRYWALL

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

UNACCEPTABLE BASE MATERIALS

- Never attempt to fasten into very hard or brittle materials such as cast iron, tile, glass, or rock of any type.
 - These materials can shatter, causing the fastener and / or base material fragments to fly free and cause serious injury to the tool operator and others.
- Never fasten into soft base materials, such as drywall or lumber products.
 - These materials may allow the fastener to travel completely through and out the other side, endangering those in the path of the fastener.
- Never fasten into any base material that does not pass the Center Punch Test.
 - Failure to assure the suitability of the base material can result in serious injury to the eyes or other body parts.

CENTER PUNCH TEST

- **ALWAYS WEAR SAFETY GOGGLES WHEN PERFORMING THIS TEST.**
- Always test the material being fastened into for hardness before attempting any fastening operation.
- Using a fastener as a center punch, strike the fastener against the work surface using an average hammer blow and check the results.

CENTER PUNCH TEST RESULTS

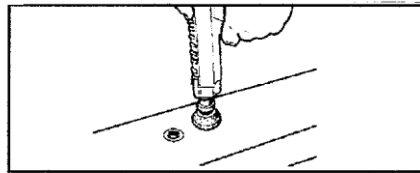
- If the fastener point is flattened, the material is too hard for powder actuated fastening.
- If the fastener penetrates the the material easily, the material is too soft.
- If the material cracks or shatters, the material is too brittle.
- If the fastener makes a small indention in the material, the material is suitable for fastening.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

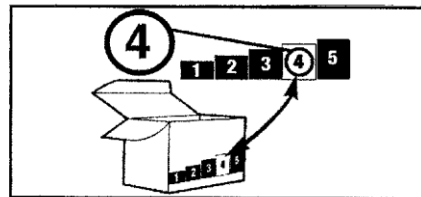
LOADS AND LOAD SELECTION SAFETY

- Always make a test fastening after being sure that the base material is suitable for powder actuated fastening.
 - Failure to determine the correct power level to be used may result in the use of excessive power, allowing the fastener to pass completely through the work material, causing serious or fatal injuries to others who may be in the path of the fastener.



ALWAYS MAKE A TEST FASTENING

- Color-blind operators must always select loads by number to prevent use of an incorrect for the same reason as above.



COLOR-BLIND OPERATORS MUST
ALWAYS SELECT LOADS BY NUMBER

WORKPLACE SAFETY

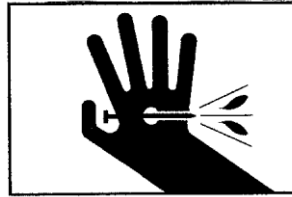
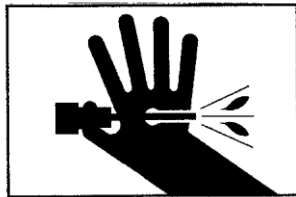
- Operators and bystanders must always wear approved eye protection and approved hearing protection.
 - Failure to do so may result in blindness or serious eye injury from flying debris and loss of hearing from constant or repeated unprotected exposure to fastening noise.
- Always keep the work area clear of unnecessary bystanders and unnecessary materials that could interfere with safe tool operation.
 - Operating the tool in a congested or cluttered area may affect your ability to operate the tool safely.
- Never operate the tool if flammable or explosive materials are nearby.
 - Powder loads burn and create sparks when fired and could ignite these materials or vapors.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

TOOL HANDLING SAFETY

- Always make sure that the tool is operating properly before attempting to use.
- Always load tool using a strip load selected directly from a box indicating the power load type and number. Never attempt to use a strip that could be mis-identified.
- Never carry loose loads in pockets with pins or other hard objects.
- Never load a tool unless you intend to immediately make a fastening.
 - Loading a tool and leaving it unattended in the work area can result in the tool being accidentally discharged by others.
- Never place your hand or any other body part over the fastener loading end of the tool.
 - Serious hand injury could result from being struck by either a fastener or if the tool should be accidentally fired.



Never close tool with hand over fastener loading end of the tool.
A serious hand injury from penetration by the piston or a discharged fastener could result.

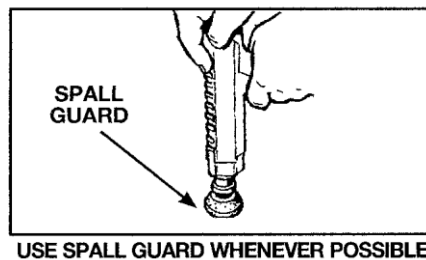
- Always store the tool unloaded and keep the tool and the loads secured in an appropriate storage container.
- Always keep the tool pointed away from yourself and others.
- Never carry a loaded tool around the work area.
- Never allow anyone not trained to use the tool.
- Never engage in horseplay with the tool.

RESCUE SYSTEMS 3

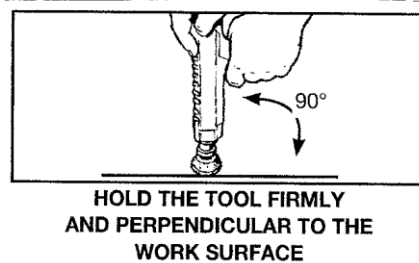
STRUCTURAL COLLAPSE TECHNICIAN

FASTENER DRIVING SAFETY

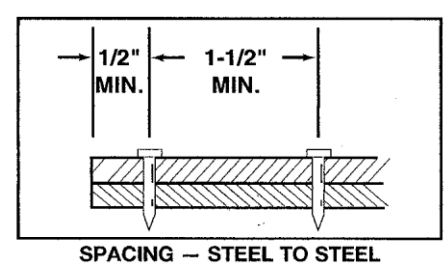
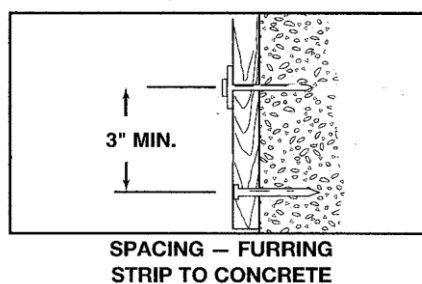
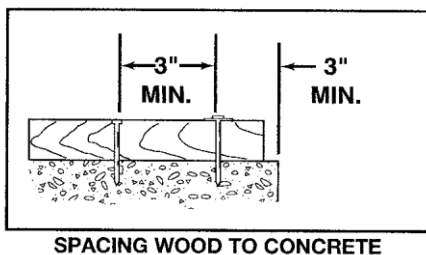
- Only use the tool for fastening into a suitable base material.
- Never fire a tool without a fastener.
 - Firing a tool without a fastener will cause the piston to strike the work surface, and may cause serious injury to you and others in the work area.
- Always use the spall guard whenever possible to minimize flying particles or debris.



- Always hold the tool perpendicular to and firmly against the work surface when making a fastening.
 - Failure to do so could allow a fastener to ricochet.



- Never attempt to drive a fastener close to an edge or to another fastener..



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

FASTENER DRIVING SAFETY (Continued)

MISFIRE PROCEDURE

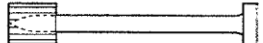
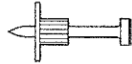
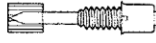
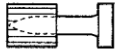



- If the tool does not fire after the normal firing sequence, continue to hold the depressed tool against the work surface **for at least 30 seconds**. Then carefully lower the tool, remove the strip load, and put it in a can of water or other non-flammable liquid. Never carelessly discard a strip with live loads into a trash container.
- If the tool becomes stuck or jammed with a live powder load, *keep the tool pointed in a safe direction, and immediately tag it, “**Danger – Defective – Do Not Use**”*. Lock the tool in a tool box and call your local tool distributor for assistance.

FASTENERS / LOADS

DANGER

Never use any other types of fasteners or strip loads in the Ramset SA270 Tool. Use of other types of fasteners or loads may cause unintentional load discharge, damage to the tool, cause poor fastening performance, or create a risk of serious injury to the operator or bystanders.

FASTENERS

<p>.300 HEAD PLASTIC FLUTED DRIVE PINS</p>  <p>.145 Shank Diameter in Shank Lengths from 1/2" to 2-1/2"</p>	<p>.300 HEAD PLASTIC FLUTED DRIVE PINS WITH 7/8" WASHER</p>  <p>.145 Shank Diameter in Shank Lengths from 1" to 3"</p>
<p>1/4" - 20 THREADED STUDS</p>  <p>.145 Shank Diameter in Shank Lengths of 1/2" and 1" and Thread Lengths of 1/2", 3/4" and 1"</p>	<p>.300 HEAD POWER POINT PLASTIC FLUTED DRIVE PINS</p>  <p>.150 Straight Shank in Shank Lengths from 1/2" to 7/8" .150/.180 Step Shank in Lengths from 1" to 1-7/8"</p>
<p>8 mm HEAD TOP-HAT DRIVE PINS</p>  <p>.145 Shank Diameter in Shank Lengths from 1/2" to 1"</p>	<p>CEILING CLIP ASSEMBLIES</p>  <p>Ceiling Clip with 1" or 1-1/4" premounted .145 Shank Pin and Ceiling Clip with 1" or 1-1/4" Premounted .150/.180 Shank Pin</p>
<p>CONDUIT CLIP ASSEMBLIES</p>  <p>For 1/2" and 3/4" Diameter Conduit with 1" Premounted Fastener</p>	

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

LOADS

- Ramset RS27 strip loads are specially made for use in the Ramset SA270 Tool.
- The power level of the load is indicated by the number marked on each box, and the color on the tip of each load. As the number increases, the power level also increases.

Ramset RS27 strip loads are specially made for use in the Ramset SA270 Tool.



RS27 10 SHOT STRIP LOAD

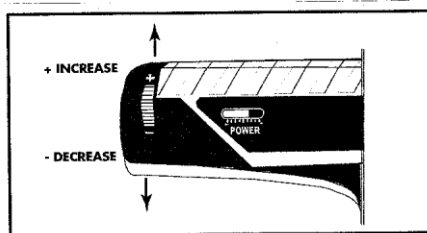
POWER LEVEL	CATALOG NUMBER	LOAD COLOR	CASE COLOR
2	2RS27	Brown	Brass
3	3RS27	Green	Brass
4	4RS27	Yellow	Brass
5	5RS27	Red	Brass

The power level of the load is indicated by the number marked on each box, the color of the box, and the color on the tip of each load. As the number increases, the power level also increases.

Always perform the center punch test described on page 3 to test the base material.

Always make a test fastening using the lowest power level first. If more power is required to set the fastener, use the next higher power level until the powder level necessary to drive the fastener is reached.

- Always perform the Center Punch Test to test the base material.
- Always make a test fastening using the lowest power level first. If more power is required to set the fastener, use the next higher power level until the powder level necessary to drive the fastener is reached.



POWER LEVEL ADJUSTMENT

FASTENING APPLICATIONS

The Ramset tool can be used for a wide range of fastening needs in a variety of base materials. Reading and following these important fastening guidelines will help you get the best results from your tool, fasteners, and powder loads, as well as help you perform these fastening operations safely and effectively. Powder actuated fastenings are permanent fastenings and attempting to remove a fastener from concrete or steel may result in serious injury.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

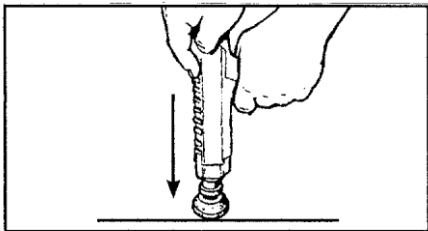
FASTENING TO CONCRETE

- When fastening into concrete, always maintain a minimum spacing of 3" between fastenings and 3" from any free edge. Concrete thickness should be at least three (3) times the intended penetration depth into the concrete. The primary exception to the 3" edge distance can occur in a sill plate application where by necessity, the edge distance is reduced.
- Driving fasteners too close to an edge or too close to each other can cause the concrete edge to fail or fasteners to fly free.
- Fastening to **Concrete Block** or to **Masonry Walls**.
 - While this application is not recommended, when used, it is necessary to take care to observe a 3" edge distance to avoid cracking the block and over penetration of the fastener to avoid loss of holding value. Fastening may be made into the horizontal joint but not into the vertical joint.

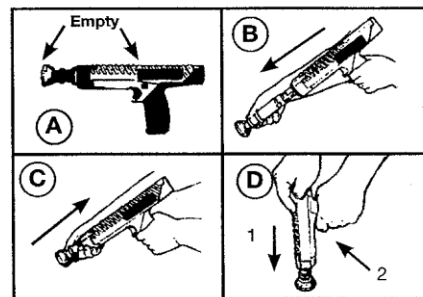
TOOL OPERATION

DAILY FUNCTION TEST

- Always test the tool first to make sure that it does not contain a strip load or fastener.
 - Test the tool several times by depressing the muzzle bushing fully on a hard surface and pulling the trigger. You should hear an audible click as the firing pin releases. Let up on the tool and check to be sure that the barrel has opened to the semi-open position.



PERFORM THE FUNCTION TEST WITH EMPTY, UNLOADED TOOL



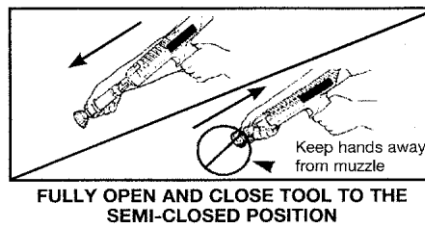
ALWAYS DO A DAILY FUNCTION CHECK BEFORE LOADING TOOL

RESCUE SYSTEMS 3

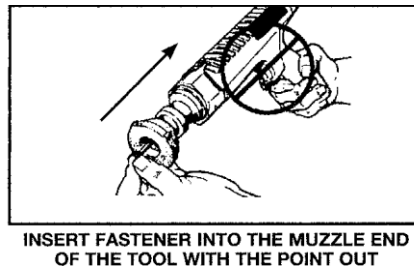
STRUCTURAL COLLAPSE TECHNICIAN

OPERATING THE RAMSET SA270 TOOL

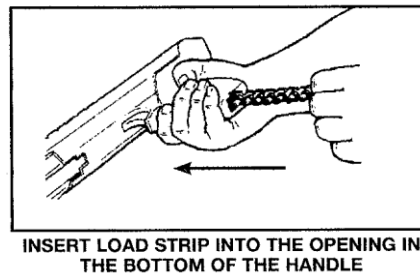
- After checking to be sure that the tool is not loaded, point it in a safe direction and be sure that the barrel is fully extended and then close the tool to the semi-closed position. This assures that the piston is in position for the next fastening. Use the spill guard every time possible to minimize the risk of being struck by flying debris.



- With finger off the trigger, place the fastener, point out, into the muzzle end of the tool until the point end is inside the muzzle. **NEVER** load a fastener with your finger on the trigger. **DO NOT** use excessive force when inserting a fastener. **STOP** immediately if excessive force is required, inspect the barrel to find out why the fastener is not entering the muzzle freely. **DO NOT** continue loading unless the problem is corrected.



- With the tool pointed in a safe direction and finger away from the trigger, insert a load strip into the bottom of the handle and push it in until your finger is in firm contact with the handle recess.

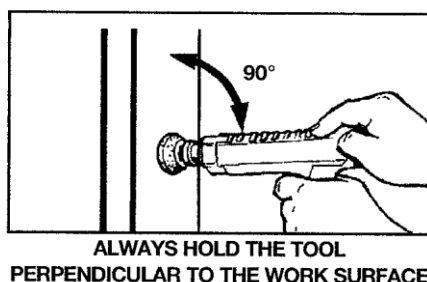


RESCUE SYSTEMS 3

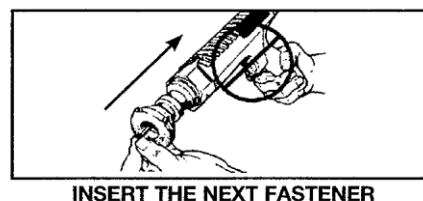
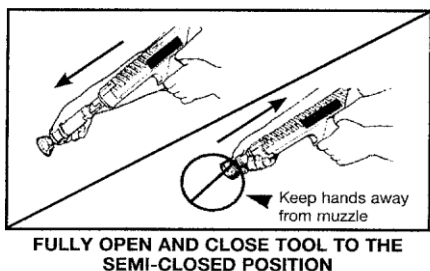
STRUCTURAL COLLAPSE TECHNICIAN

OPERATING THE RAMSET SA270 TOOL (Continued)

- Hold the tool perpendicular (90°) to the work surface with both hands and press firmly to fully depress the tool. Maintain firm downward pressure on the tool with both hands and pull the trigger to drive the fastener. **DO NOT DEPRESS THE TOOL AGAINST ANYTHING OTHER THAN THE INTENDED WORK SURFACE.** Holding the tool firmly in place will produce more consistent fastening quality and minimize tool wear or damage.



- After making the fastenings, fully open and then close the tool to the semi-closed position. This resets the piston and indexes a new load into place for the next fastening.



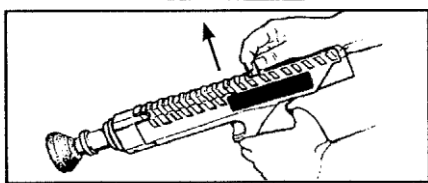
- Insert another fastener in the muzzle end of the tool as before and the tool is ready for the next fastening. Keep your finger off the trigger until the tool is in position to drive the fastener.

RESCUE SYSTEMS 3

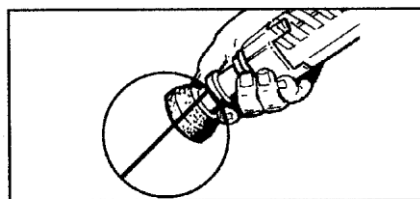
STRUCTURAL COLLAPSE TECHNICIAN

OPERATING THE RAMSET SA270 TOOL (Continued)

- To remove a used or partially used strip load from the tool, pull the strip out from the top of the tool. **DO NOT** try to remove the strip by pulling it out from the bottom of the handle. **NEVER** try to remove a jammed or stuck load strip. Should a “jammed” load strip occur, call your local distributor for technical assistance.



REMOVE THE LOAD STRIP ONLY FROM
THE TOP OF THE TOOL



NEVER PLACE HANDS OR BODY OVER
MUZZLE OPENING

POWER ADJUST

- The power level on the SA270 may be adjusted for varying base materials by turning the power adjust wheel located at the rear of the tool.

ONLINE TRAINING

Prior to using and being certified as an authorized operator of the Ramset SA270 Powder Actuated Tool, an online study course and test must be completed. The online course typically takes between 15 and 20 minutes to complete.

COURSE INFORMATION

Go to the the Ramset website at www.ramset.com.

Click on Powder Actuated Tool Test and Licensing.

Click on begin the course. Read the course material. At the end of this section, a list of online manuals for Ramset Powder Actuated Tools will appear.

Click on the SA270 manual and read the contents.

Take the exam and pass the color test.

Fill out your information and print out your certificate.

YOU WILL NOT BE ALLOWED TO OPERATE A RAMSET POWDER ACTUATED TOOL UNLESS YOU HAVE AN ONLINE COURSE CERTIFICATE OF COMPLETION.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

TOPIC 3-1: BREAKING - BREACHING

TERMINAL OBJECTIVE

- The student will properly break and breach to gain access through concrete, steel or other structural components during rescue operations in heavy floor, heavy wall, steel and concrete structures.

ENABLING OBJECTIVES

- Identify concrete components and their importance to systems design.
- Understand their importance during collapse rescue operations.
- Identify concrete construction types.
- Understand the properties, strengths, and weaknesses of concrete and its components.
- Correctly select tools or tool packages for rescue operations.
- Understand how to minimize risk to rescuers.

Why Do We Breach, Break, Cut And Burn?

- To gain access to entrapped victims
- During search operations to create openings
- For rigging slabs
- For debris removal
- For anchoring operations
- To create voids and pathways
- For construction of needed items (welding, burning, etc.)

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RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

TYPES OF CONCRETE CONSTRUCTION

- Concrete can be used in a variety of structural members. The strength of the member is dependent upon construction. Concrete to be used as a load bearing member had better be engineered for the job. You may be faced with a variety of different construction techniques. Knowing how to identify each, what the properties of each are, and determining the most efficient method to defeat each provides you with a tactical edge.
- There are two types of reinforcement used in concrete systems. Rebar and steel cable. This is a composite material of steel (rebar) or steel cable and concrete. Steel provides the tensile strength that concrete lacks. In some cases, steel can add some compressive strength.
 - Rebar
 - ◆ Low carbon steel bars that are similar to structural steel (beams, angles, etc). The bars have deformations that enhance the bond between the bar and concrete. The bond is essential for the rebar and concrete to work together to resist loads.
 - High strength cable (usually in a 7-wire twisted configuration)
 - ◆ Bonded to the concrete.
 - Pre-cast, pre-tensioned applications.
 - ◆ Un-bonded to the concrete.
 - Cast-in-place, post-tensioned applications.

Two Types Of Reinforcing

- **Deformed Bars = Rebar**
 - Low carbon steel, similar to steel in beams, angles, etc.
- **High tension steel cables**
 - Usually 7 wire, twisted cable
 - One center, king, wire with 6 smaller around it in helical twist

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RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

TYPES OF CONCRETE CONSTRUCTION (continued)

- Concrete construction can be broken down into the following two types:

- **Cast in place**

- ◆ This is concrete that has been poured in the location in which it is expected to remain. This could be a patio porch, a foundation for a house, or the complete structure for a multi-story concrete building. For concrete buildings, the concrete is poured in stages; walls and columns, then floor slabs and beams. This sequence is repeated at each story on multi-story construction. Cast in place concrete will often have rebar used as the reinforcing steel, but may be constructed using post-tensioned cables.

- ◆ **Post-tensioned**

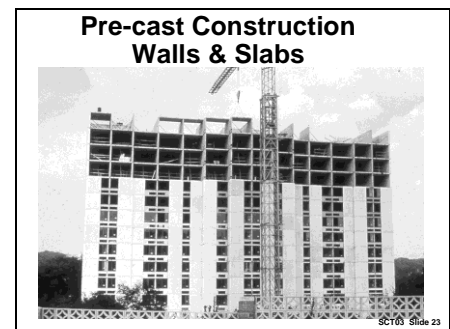
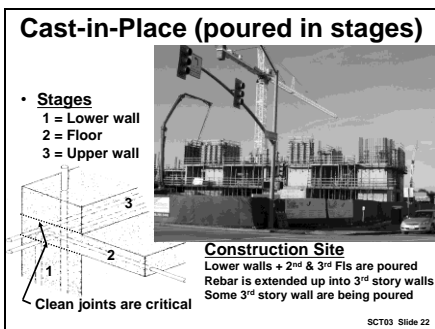
- High tensile strength steel cables or bars are encased in tubing (casing) and greased to prevent adhesion between steel and concrete, positioned in the forms, and then the concrete is poured. After the concrete is set and reaches a specified strength, the steel is stretched and anchored at the ends of the slab or structural member. Examples include floor slabs in concrete high-rise buildings and parking structures. The grease also provides protection from rust.

- **Precast**

- ◆ This is concrete, which has been cast at a location other than the place it is to remain. These could be at the construction site, as in tilt-up walls, or could be cast at an off-site pre-casting facility, and then trucked to the construction site. Precast concrete may be constructed with rebar, pre-tensioned reinforcing, or both.

- ◆ **Pre-tensioned**

- High tensile strength steel strands (cable) are stretched inside the concrete member. Concrete is then placed into these very strong steel forms built around the strands. As the concrete sets, it bonds to the tensioned steel. Pretensioning is done in a plant and the completed unit is shipped to the job site.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

STRENGTHS AND WEAKNESSES

Like all building materials, concrete has its strengths and weaknesses. Knowing these and taking advantage of the weaknesses while avoiding the strengths will enable you to more efficiently apply the proper techniques for the type of concrete you will be faced with.

- There are three basic "forces" which we should be concerned about when dealing with concrete:
 - **Tension, compression, and shear.**
- Concrete is a mixture of materials. This mixture provides its strengths and enables us to use it in different forms of construction. Concrete is strong in compression but weak in tension and shear. These general characteristics explain the need to add reinforcement to load bearing concrete components.

Basic Forces Applied To Concrete

- **Shear**
- **Tension**
- **Compression**

Strengths & Weaknesses Of Concrete

- **Strong in compression but weak in shear or tension**
 - Consider a flat slab patio and the forces applied to it. What happens if you place the slab on blocks off the ground and jump on it?
 - Consider load bearing walls, columns, and beams, how do they maintain their strength?

- A backyard patio made of concrete, with limited reinforcement, perhaps just wire mesh, holds up well under the wear and tear of parties, lawn furniture and even dropped items. This form of concrete is strong in its current form for several reasons. Primarily, it is not load bearing and secondarily it remains in compression, with the static loads it is exposed to pressing down on top and ultimately to the ground. If we were to take that same slab and lift it up on blocks (off the ground) and jump up and down on it or strike it with a sledge hammer (placing it in shear) it would fail.
- Concrete used in load bearing walls, floors, or columns requires the addition of materials, (typically rebar), to provide tensile strength and the ability of the concrete to withstand the forces of shear. If you were to remove or damage the reinforcement(s) you would effectively have nothing but dead weight. In this case, both elements are equally important. Failure of any element or removal of any element results in system failure.
- An example of using this knowledge to effectively breach, is using a saw to create relief cuts or a breaker / drill to create "stitch" drill holes.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

REBAR AND REINFORCING

GENERAL PROPERTIES OF STEEL

- Steel rebar and a variety of other steel products are used to provide reinforcing strength to concrete structures. Deformed round bars are the most common types to be found and range in sizes from 3/8" to 2 1/4" diameter.
- Rebar is found in almost all concrete used in construction as a method to provide shear and tensile strength. Failure or breaking away of the rebar by either mechanical forces or natural forces will result in failure of the concrete.

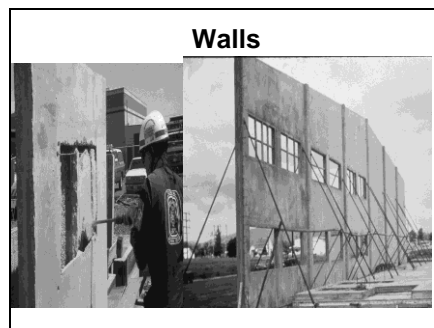
Placement of Rebar Depends on type of Structural Member

- Walls
- One way slabs
- Pan joists
- Flat Slabs – (beamless slabs)
 - Two way slabs on columns
 - Usually have Drop Panel* at columns (* thickened slab)
- Beams and Girders
- Columns

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PLACEMENT OF REBAR IN CONCRETE STRUCTURES

- Rebar may generally be located in specific locations in certain types of construction. Not only can we predict the location but also the size and thickness of the rebar associated with each type of structural member.
- **Walls**
 - Thickness up to 8" will have one layer of bars, which will occur at the center of the wall. Spacing usually occurs from 8" to 16" each way (vertical and horizontal). Bigger bars are normally added adjacent to the openings and will extend beyond edges of openings. There may even be diagonal bars at corners of openings.
 - Walls over 8" thick should have two layers of rebar, each about 1" clear of the surface. Spacing of each layer is 8" to 16" each way. Each bar will be 3/8" to 3/4" diameter.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

PLACEMENT OF REBAR IN CONCRETE STRUCTURES (continued)

■ One-Way Slabs

- These normally span 8' to 20' between parallel beams and are from 6" to 10" thick. Normally bars are near the top and bottom of the slab and clear about 1" from the surface. Bars may vary from 1/2" to 3/4" in diameter. Bottom bars extend throughout the slabs each way. In the short direction they are spaced between 4" to 12". In the long direction they are spaced 10" to 18".



■ Pan Joists

- These are deep concrete ribs that are usually about 6" wide and are spaced 24" to 36". The bottom bars may be two 1/2" or 1" diameter bars. The top bars are two or four 1/2" to 3/4" bars placed in the slab above the rib and parallel, these run about 4 inches or so apart and are 1/2" clear from the surface.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

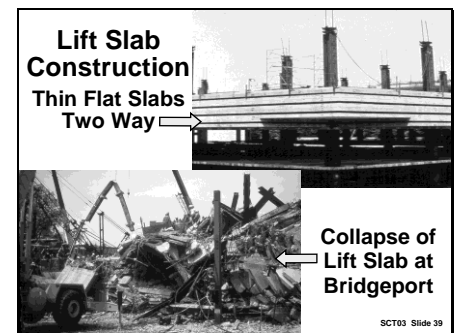
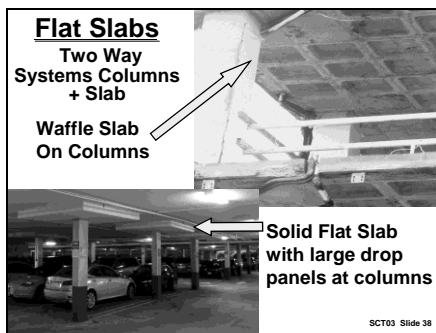
PLACEMENT OF REBAR IN CONCRETE STRUCTURES (continued)

■ Two-Way Slabs (Flat Slabs)

- Solid, two way slabs supported only by columns (beamless slab).
 - ◆ These most often have a drop panel section of thicker concrete at each column in order to reduce punching shear stress.
 - ◆ Normally the bars are similar to one way slabs except some top bars may extend through out the slab and will vary. Bars are usually 1" clear from the top and bottom surface of the slab. Bottom bars range from 1/2" to 3/4" diameter with spacing from 4" to 12". Top bars are more closely spaced over columns and have the same spacing in each direction.

■ Two-Way Slabs (Waffle Slabs)

- Concrete that is poured over square, steel voids so that ribs are formed. The voids are omitted at and near the columns in order to allow the full thickness of the concrete to resist punching shear stresses.
 - ◆ These are the same as two-way flat slabs except the bottom bars are found only within the ribs and about 1" from the bottom. The ribs are typically 6" wide and spaced between 24" and 48".



■ Two-Way Slabs (Lift Slabs)

- Concrete that is uniformly thick with no vertical projections.
 - ◆ This type of construction has lost favor since a spectacular collapse in 1987.
 - ◆ The slabs are all poured in a stack on the ground floor slab, cured, and then lifted into place by a series of jacks (one placed on each column).
 - ◆ These slabs most often were post-tensioned and the cables drape from near the top of the slab over the columns to near the bottom at mid-span.

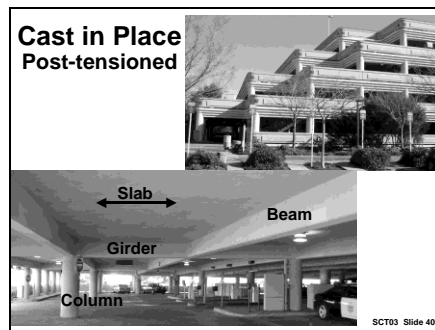
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

PLACEMENT OF REBAR IN CONCRETE STRUCTURES (continued)

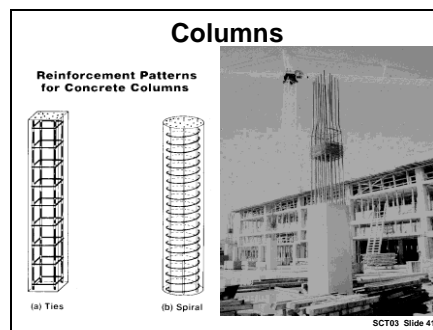
■ Beams and Girders

- These usually are 12" to 24" wide and 18" to 36" deep. There are usually two to six bottom bars that are from 3/4" to 1 1/4" diameter and placed within 2" of the bottom. More rebar is placed in the middle of the span. There may be two to eight top bars, also 3/4" to 1 1/4" diameter placed in the slab above the beam and parallel to it (usually 4" or so apart). Most top rebar will be within 10 feet of the support column. You will also find vertical bars called stirrups, which extend from the top to the bottom of the beams. These range in size from 3/8" to 1/2" in diameter.



■ Columns

- These are round, square or rectangular support members. Within these columns are horizontal ties which usually occur about 1" from the surface and are usually shaped the same as the column. (Spiral for round columns and individual square ties for square columns, but you can find spiral ties in square columns).
- Tie sizes range from 3/8" to 5/8" in diameter and the tie spacing of 2" to 6" for spiral and 6" to 18" for horizontal ties. Vertical rebar is usually placed more or less evenly around the periphery of the column. These "Verts" range in size from 5/8" to 1 1/4" in diameter. You will normally find from 4 to 8 vertical bars, but there may be as many as 18 Verts in very large columns.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

TENSIONED CABLES AND STEEL REBAR

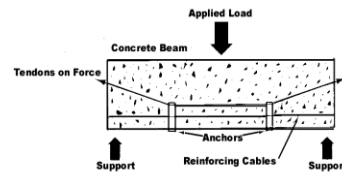
- Concrete can be pre-stressed by using high strength steel cables. Pre-stressing places calculated stresses in architectural or structural concrete to offset the tension and shear stresses, which occur in the concrete when it is placed under load.
 - The concrete may be precast and pre-tensioned, where the steel is bonded to the concrete, or
 - The concrete may be cast in place and post-tensioned, where the steel is not bonded to the concrete.
- High-strength cables, similar to those used in suspension bridges are called “tendons”, “strands,” or “cables”.

Tensioning Cables vs. Rebar

- Pre-cast concrete may be pre-stressed using cables
 - or may have rebar reinforcing steel, in one or more layers
- Pre-stressing places engineered stresses in concrete to offset stresses which occur in the concrete when placed under load.

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Pre-tensioned Cables Bound to Concrete Not as large a cutting problem



Pretensioned Tendons in Draped Position

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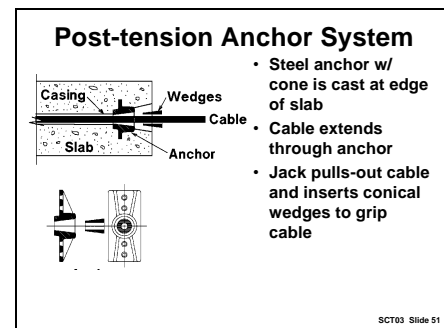
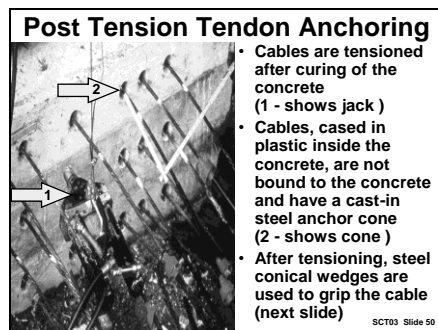
- Consider a row of books side by side. As a "beam", such a row will fail because of its own weight without any added load due to the lack of shear resistance between the books. Drill a hole through the row of books laterally, pass a wire through the books and tighten the wire against the end books. The row of books would be compressed by putting tension in the wire and compression in the books.
 - This "beam" could be placed across two chairs and stood on. The beam has been prestressed sufficiently to counteract the stresses placed on it by the load.
 - The prestressed cables are normally placed in a draped configuration. The cables are proportioned so that they “balance” the weight of the structure they support.
 - ◆ This is similar to the way a suspension bridge cable is draped to carry the load of a large span.
 - In precast, prestressed concrete the cables are “harped” (held down in two places) since this is the only way the pretensioned bar will not straighten.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

TENSIONED CABLES AND STEEL REBAR (continued)

- Tensioned cables need to be identified early. The rescue team must recognize the difference between the cables and rebar. Cutting tensioned cables can result in the immediate failure of slabs or structural members in both precast, pre-tensioned concrete and cast-in-place, post-tensioned concrete. The Structures Specialist should be consulted to help with this identification.
- When post-tensioned cables are installed, they have at least one end that must be stressed (pulled) using a special hydraulic jack.
 - After the cable is stressed and the conical wedges are inserted to “capture” the cable in the anchor cone, the cable is cut-off and a circular void space, about 3” deep is left in the edge of the concrete. This void space is normally filled with dry-pack grout, and one may “read” the difference in texture of the grout finish from the surrounding, cast-in-place concrete.
 - A way to recognize post-tensioned flat slabs is by checking the drop panels (thickening of slab at column head). If they are 3’ or less, square, or no drop is found, the slab is probably a post-tensioned slab.



I.D. of Post-tensioned Concrete

- Consult your Structures Specialist
- Can often I.D by shape of flat slab systems
 - Thin slab with small or no drop panels at columns
- May see projecting tendons in damaged structure
- May be able to detect the circular pattern left by grouting the anchors
 - May be difficult due to placement of finish materials



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RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

CUTTING POST-TENSIONED STRUCTURAL MEMBERS

- This type of reinforcing cable usually consists of a greased, seven strand, 1/2" diameter wire in a plastic casing that is cast into the concrete. After the concrete is properly hardened, the cable is tensioned to about 25,000 lbs. and then anchored at the exterior edges of the slab. Except in some bridges, the cable is not bonded to the concrete and will rapidly un-tension if cut or one of the anchorages comes loose.
- Post-tensioned cables can be found in beam and slab floors, flat slabs, and joist and girder floors.

Guidelines For Cutting Post-tensioned Systems

- Avoid cutting if at all possible.
- If cutting is necessary, be sure you consult your US&R Structures Spec.
- Tendon's reaction might be predictable based on where the cable is cut.
- Slab / beam location, damage, applied forces will impact tendon's reaction to cutting.

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Potential Tendon Cutting Scenarios Both Bad

- After cut, the cable may pop out of the top or bottom of the slab within the structure, forming a lethal loop.
(as high as three and as long as five feet)
- Or, the cable may exit either (or both) end of the slab as a lethal spear
(Anywhere from a few inches to many feet)
- Both scenarios could occur after only one cut

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- The following is known about cutting post-tensioned cables:
 - When the cable is cut near or at the end of the slab, the cable may pop out of the slab surface (above or below the slab) in the form of a loop that may be as high as 3' and as long as 5' or more.
 - When the cable is cut in the middle of the slab it will usually pop out of each end of the slab. It may extend only a few inches, but in extreme cases it may be propelled beyond the building.
 - In general, the distance the cable is propelled is relative to the amount of tension, how tightly the plastic casing (sheath) is fitted around the cable, and how much grease was used.
 - It is possible that cables could pop out of the slab surface, as well as exit the end of the slab.

More Tendon Cutting Scenarios

- In general the distance the cable is propelled is relative to the amount of tension, how well the tendon was greased, and how tightly the plastic casing (or sheath) is fitted around the cable.
 - The easier they can slide inside their casing, the farther they will go.

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Safety When Cutting Post-tension Tendons

- Use a cutting torch to slowly de-tension the tendon by heating and cutting one strand at a time.
- Create a safety zone that extends ten feet each way from the Tendon centerline, and that extends 100 feet from each end of the slab or beam
- Cut no more than 2 adjacent tendons in any one slab – consult the US&R Structures Specialist (StS)

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RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

CUTTING POST-TENSIONED STRUCTURAL MEMBERS (continued)

- Generally rescue teams should not cut post-tensioned cables, unless absolutely necessary or:
 - Cut them only under the direction of a USAR Structures Specialist (StS). The StS should be able to determine the location and type of cable, and if it is fully stressed.
 - To cut a tensioned cable there are two generally accepted methods. After the concrete around the cable has carefully been removed, and its casing has been removed, locally:
 - ◆ **Method one** would be to use a torch to slowly heat the cable so it will stretch and relax the tension stress.
 - ◆ **Method two** would be to use a carbide saw to cut one strand at a time to provide for slow de-tensioning.
- To minimize the risk of injury from cutting tensioned cable during USAR operations, proceed as follows.
 - An area within 10' each way of the centerline of the cable should be evacuated within the building.
 - The area outside the building at each end of the slab should be evacuated for a distance of 100', and / or a barrier should be built at the end of the slab to stop the cable's travel.
 - No more than two adjacent tensioned cables should be cut in each direction unless the structure has collapsed and is being supported more or less uniformly.
 - One normally may cut a few cables in several separate locations in a post-tensioned slab, however the StS should always be involved with making the decision.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

CUTTING PRE-TENSIONED STRUCTURAL MEMBERS

- These members usually consist of Beams, Single and Double Tees, and Slabs. The steel is bonded to the concrete, but the stresses are usually very high near the steel.
- To minimize the risk of injury from cutting tensioned cable during USAR operations, proceed as follows.
 - **Avoid** cutting pre-tensioned Beams, or the Stems of Tees unless they have collapsed and are supported as part of the rubble pile. (Even in that case, **avoid** cutting near the ends).
 - You may cut slabs, including the very thin slabs of Tees. Since these members are usually only about four feet wide, it is best to cut access holes centered on the joint between two adjacent pieces. In this way most of the steel can be avoided.

Guidelines For Cutting Pre-cast, Pre-tensioned Systems

- If cutting is necessary consult StS
- Avoid cutting Beams and Stems of Single & Double Tees.
 - May carefully cut these when collapsed and are part of rubble pile.
 - Avoid cutting near the ends (all cases)
- May cut Slabs, including Slabs of Tees
 - Cut access holes, centered on the joint between two adjacent members

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RESCUE SYSTEMS 3

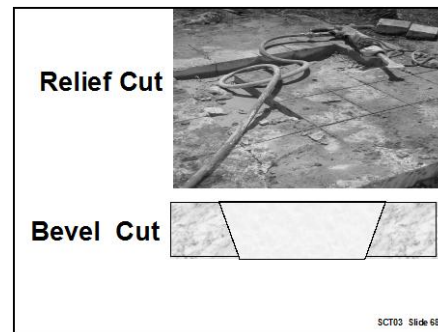
STRUCTURAL COLLAPSE TECHNICIAN

METHODS TO DEFEAT CONCRETE

In order to effectively break and breach concrete, you must know how to apply your tools using specific techniques. These techniques are designed to defeat the structural strengths of concrete based on its construction type. Listed below are several techniques, which used together, will enhance your operational capabilities.

■ Relief cuts

- These cuts are usually made with saws to prevent the concrete from acting in compression. These relief cuts may be square, triangular, or "X" shaped. The gap created by the relief cut allows you to attack an inherent weakness of concrete, which is its poor structural stability when placed in shear or tension.

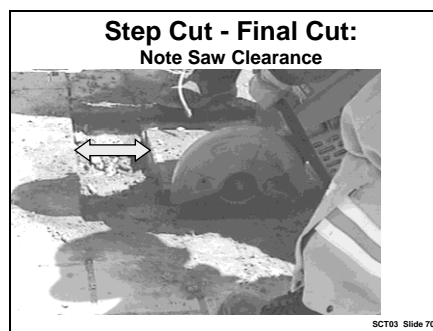


■ Bevel cuts

- This is an angled cut which is made during a "lift out" operation. The bevel cut allows the rescue team to cut deep within the concrete while limiting the possibility that the cut section will slip through the hole. These types of cuts are critical when cutting over the top of a victim(s).

■ Step cuts

- This is a cut which is used during a "lift out" operation when the slab is thicker than what can be cut with one pass of the saw. Two cuts are made parallel to one another, the width of the saw blade guard. The concrete is then chipped out between the two cuts forming a trench. This allows the saw to complete the cut through the full depth of concrete.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

METHODS TO DEFEAT CONCRETE (continued)

■ Stitching

- These are holes which are partially or completely drilled thorough the concrete in a close stitch pattern within a predetermined area. These holes act very similar to the relief cut, allowing you to place the concrete in sheer or tension when chipping with a breaker.



■ Bolting

- Bolting can be used in a variety of situations. Bolts can be permanent or re-usable. In most instances they are placed in the concrete as anchors to support either the slab portion being removed or to support a tool.

■ Wetting

- The application of water from tool attachments or from manual spray devices is often critical when using diamond saws. The application of water keeps blades and chains cool and lubricated, which keeps the diamonds from becoming polished and ineffective. This also keeps down dust.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

SAFETY ISSUES

- The safety of the rescuers and support crews is critical to a successful operation. It is the responsibility of the Rescue Specialist to utilize all appropriate personal protective equipment (PPE) for the task at hand. During breaking and breaching operations, you may be confronted with a variety of hazards which may effect your operations. These may include but are not necessarily limited to:
 - Shifting or movement of heavy weights.
 - Tool reaction.
 - Materials reaction.
 - Sharp objects, tools, and blades.

OTHER ISSUES

- Concrete movement during tool use.
 - Rescuers must be aware of the ability of slabs to shift, the vertical lift out section to fall, and the movement of concrete in large or small pieces as a result of tool reaction. You must also be aware of and anticipate tool reaction/ torque during operation. The rescuer should be prepared for violent tool reactions during breaching and cutting operations.
- As in any cutting operation you must be aware and prepared for saw kickback and blade movement. During operations you must also be aware of your environment and fellow rescuers to assure you do not strike them with a running saw.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

TOPIC 3-2: BURNING - CUTTING

TERMINAL OBJECTIVE

- The student will properly cut, and burn to gain access through steel during rescue operations in heavy floor, heavy wall, steel and concrete structures.
- The student will understand the capabilities and limitations of all types of burning equipment that can be used in USAR operations.

ENABLING OBJECTIVES

- Correctly select tools or tool packages for rescue operations.
- Understand safety practices associated with the different metal burning equipment.
- Identify hazardous situations found when cutting and burning on a debris pile.
- Understand how to minimize risk to rescuers.
- Understand the use and setup of the various types of metal burning equipment based on safety, material type, and thickness.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

CUTTING POST-TENSIONED STRUCTURAL MEMBERS

- This type of reinforcing cable usually consists of a greased, seven strand, 1/2" diameter wire in a plastic casing that is cast into the concrete. After the concrete is properly hardened, the cable is tensioned to about 25,000 lbs. and then anchored at the exterior edges of the slab. Except in some bridges, the cable is not bonded to the concrete and will rapidly un-tension if cut or one of the anchorages comes loose.
- Post-tensioned cables can be found in beam and slab floors, flat slabs, and joist and girder floors.

Guidelines For Cutting Post-tensioned Systems

- Avoid cutting if at all possible.
- If cutting is necessary, be sure you consult your US&R Structures Spec.
- Tendon's reaction might be predictable based on where the cable is cut.
- Slab / beam location, damage, applied forces will impact tendon's reaction to cutting.

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Potential Tendon Cutting Scenarios Both Bad

- After cut, the cable may pop out of the top or bottom of the slab within the structure, forming a lethal loop.
(as high as three and as long as five feet)
- Or, the cable may exit either (or both) end of the slab as a lethal spear
(Anywhere from a few inches to many feet)
- Both scenarios could occur after only one cut

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- The following is known about cutting post-tensioned cables:
 - When the cable is cut near or at the end of the slab, the cable may pop out of the slab surface (above or below the slab) in the form of a loop that may be as high as 3' and as long as 5' or more.
 - When the cable is cut in the middle of the slab it will usually pop out of each end of the slab. It may extend only a few inches, but in extreme cases it may be propelled beyond the building.
 - In general, the distance the cable is propelled is relative to the amount of tension, how tightly the plastic casing (sheath) is fitted around the cable, and how much grease was used.
 - It is possible that cables could pop out of the slab surface, as well as exit the end of the slab.

More Tendon Cutting Scenarios

- In general the distance the cable is propelled is relative to the amount of tension, how well the tendon was greased, and how tightly the plastic casing (or sheath) is fitted around the cable.
 - The easier they can slide inside their casing, the farther they will go.

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Safety When Cutting Post-tension Tendons

- Use a cutting torch to slowly de-tension the tendon by heating and cutting one strand at a time.
- Create a safety zone that extends ten feet each way from the Tendon centerline, and that extends 100 feet from each end of the slab or beam
- Cut no more than 2 adjacent tendons in any one slab – consult the US&R Structures Specialist (StS)

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RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

CUTTING POST-TENSIONED STRUCTURAL MEMBERS (continued)

- Generally rescue teams should not cut post-tensioned cables, unless absolutely necessary or:
 - Cut them only under the direction of a USAR Structures Specialist (StS). The StS should be able to determine the location and type of cable, and if it is fully stressed.
 - To cut a tensioned cable there are two generally accepted methods. After the concrete around the cable has carefully been removed, and its casing has been removed, locally:
 - ◆ **Method one** would be to use a torch to slowly heat the cable so it will stretch and relax the tension stress.
 - ◆ **Method two** would be to use a carbide saw to cut one strand at a time to provide for slow de-tensioning.
- To minimize the risk of injury from cutting tensioned cable during USAR operations, proceed as follows.
 - An area within 10' each way of the centerline of the cable should be evacuated within the building.
 - The area outside the building at each end of the slab should be evacuated for a distance of 100', and / or a barrier should be built at the end of the slab to stop the cable's travel.
 - No more than two adjacent tensioned cables should be cut in each direction unless the structure has collapsed and is being supported more or less uniformly.
 - One normally may cut a few cables in several separate locations in a post-tensioned slab, however the StS should always be involved with making the decision.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

CUTTING PRE-TENSIONED STRUCTURAL MEMBERS

- These members usually consist of Beams, Single and Double Tees, and Slabs. The steel is bonded to the concrete, but the stresses are usually very high near the steel.
- To minimize the risk of injury from cutting tensioned cable during USAR operations, proceed as follows.
 - **Avoid** cutting pre-tensioned Beams, or the Stems of Tees unless they have collapsed and are supported as part of the rubble pile. (Even in that case, **avoid** cutting near the ends).
 - You may cut slabs, including the very thin slabs of Tees. Since these members are usually only about four feet wide, it is best to cut access holes centered on the joint between two adjacent pieces. In this way most of the steel can be avoided.

Guidelines For Cutting Pre-cast, Pre-tensioned Systems

- If cutting is necessary consult StS
- Avoid cutting Beams and Stems of Single & Double Tees.
 - May carefully cut these when collapsed and are part of rubble pile.
 - Avoid cutting near the ends (all cases)
- May cut Slabs, including Slabs of Tees
 - Cut access holes, centered on the joint between two adjacent members

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BURNING AND CUTTING

- Cutting with a torch is often an art and requires experience to become an accomplished burner. Oxy-acetylene , and Oxy-gasoline requires the most knowledge while exothermic cutters can be used after only a few minutes of instruction and practice. **ALWAYS!!! Wear proper burner's goggles.** It only takes one piece of slag to end a career. In some instances cutting with a torch provides the most controllable method of cutting cables and rebar. When using any torch you must be aware of the fire hazard. You must also be aware of radiant heat transfer. **Before and during operations you must monitor the atmosphere to assure you are not in, or creating a hazardous atmosphere.**

Torch Safety

- Always wear proper burner's goggles, one piece of slag can end your career
- Always be aware of the potential fire hazard
- Always be aware of heat transfer
- Monitor the atmosphere before, and during use

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As A Cutter You Should:

- Understand the different torch functions
- Understand fuel and oxygen supply
- Understand torch heads and handle
- Select cutting tips
- Set up and cut using proper application
- Understand exothermic systems
- Set-up and cut with rods

SCT03 Slide 74

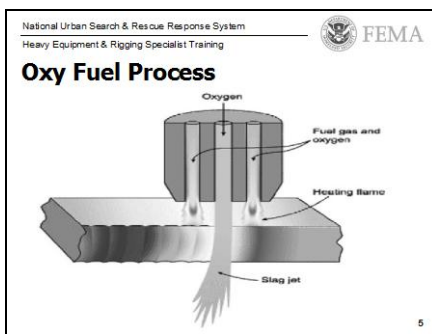
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CUTTING TORCHES

THE OXYGEN / FUEL PROCESS

- Cutting with a torch is the process of burning metal with oxygen to effect separation. Wrought iron, steel, and cast iron are the metals cut by this process. Aluminum, brass, bronze, nickel, monel, and the other non-ferrous metals and alloys cannot at present be cut by the torch process.
- In cutting iron, steel, and cast iron with oxyacetylene, the metal is heated to the ignition temperature with preheating flames burning at the end of the tip. The preheating flames, usually four, are spaced around the cutting orifice in the center of the tip.
- When the metal to be cut is heated to a bright red, the high-pressure oxygen jet is turned on, and the metal in the path is cut or burned away. Progressive movement of the torch results in cutting a narrow kerf similar to that made by a metal saw.
- Acetylene is the most common fuel gas for the preheating flame. Oxygen is required both to burn the acetylene in the preheating flames and to effect cutting. However, the recently developed Petrogen System uses gasoline as the fuel gas, in combination with oxygen.




SAFETY

- Metal burning operations require strict compliance with safety guidelines.
- The two major causes of injury during burning operations are; burns caused from hot materials or ultraviolet rays, and injuries caused from breathing toxic materials and gases that can attack internal organs or the respiratory tract.
- Full Personal Protective Equipment (PPE) must be worn at all times.
- Respirators and air handling equipment should always be used in confined spaces or when material surface finishes such as paint or plating have been applied to metal.
- Whenever possible, two person teams should be assigned to burning assignments. One person should operate the burning equipment while a second person tends hoses and equipment. It is the second person's responsibility to look out for potential hazards and make sure the burner is aware of them.

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General Safety Guidelines

- Metal burning requires strict compliance with all manufacturer's safety guidelines
- Biggest causes of injury
 - Burns from hot material or ultraviolet rays
 - Breathing toxic materials
- Wear full PPE at ALL TIMES
 - Wear UV rated eye protection
 - Use proper respiratory protection
- Work in 2 person teams

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General Safety Guidelines (contin.)

- Inspect all equipment prior to use for damage and leaks
- Have a fire extinguisher or small hose line available for spot fires
- Hydrate often
- Consider the reaction of your actions before and while cutting a piece of steel or cable

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- Always pay strict attention to where the burning / cutting is directed (into or through). Flammable or explosive material or victims may be on the other side.
- Always inspect cutting and burning equipment for leaks and proper setup before use.
- Re-hydrate often. Because of the heavy protective clothing and the heat generated from the equipment and hot material, burning operations can be very hot work.
- A pressurized or hand pump water extinguisher shall be on site at all times.
- In order to minimize the chance for injury, it is imperative to deploy a Safety Person that will have no other responsibility than the area where metal burning / cutting is taking place.
 - This individual should watch for fires and other hazards that may be created, and be aware of any other equipment that may be working in the area.
- The metal burning team should be a minimum of two persons, so that there is a second pair of eyes that are focused on the immediately surrounding area. The second person would observe the progress of the cut, and anticipate when and where to cut piece or pieces will fall.


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PERSONAL PROTECTIVE EQUIPMENT

- In addition to “normal” USAR PPE, the metal cutting personnel must wear additional protection. This may vary, depending on what type of metal is being cut, but in most cases the cutter should be protected from the metal burning process.
- Coatings such as paint and galvanizing can create harmful gasses from which protection is needed.

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Proper PPE

- Tinted eye protection
- Respirator (organic vapor)
 - Consider PAPR
- Helmet
- Leather gauntlet gloves
- Long sleeves
- Leather or heavy fire resistive jacket and chaps if needed

Level of protection will depend on Situation and type of Metal to be cut

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Personal Equipment

- Crescent wrench
- Striker/spare flint
- Tool belt, Tape Measure & Soapstone
- Spare Tips & Tip cleaners
- Marking paint
- Side cutter pliers
- Water extinguisher
- Exhaust and ventilation equipment if needed

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PERSONAL ACCESSORY EQUIPMENT

- Metal burn cutting requires specialty equipment and a tool belt to carry them.
- Extinguishing and ventilation equipment may be provided for an entire area of cutting operations, but should be immediately available for all that are involved .

SPECIAL CAUTIONS WITH METAL BURNING

- Do not operate welding or cutting equipment in the vicinity of chlorinated solvents or hydrocarbons.
 - The heat or arc rays can react with the chlorinated hydrocarbons to form phosgene or hydrogen chloride, which are highly toxic irritant gases.
- **CAUTION! Using Painted or Plated Metals**
 - Always inspect metal for protective surface finishes such as paint or plating before cutting.
 - Metals that have been painted may contain lead or cadmium.
 - Metals that have been plated may contain zinc (galvanize) or cadmium.
 - Stainless steel contains nickel and chromium.
 - Welding, cutting, and heating operations that involve or generate any of the substances listed, require proper respiratory protection.

◆ Arsenic	Beryllium	Chromium
◆ Cobalt	Copper	Lead
◆ Manganese	Mercury	Nickel
◆ Ozone	Selenium	Silver
◆ Vanadium	Zinc	

RESCUE SYSTEMS 3

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OXYGEN / ACETYLENE BURNING EQUIPMENT

Oxygen/acetylene has been the most widely used metal burning technology in the industry for many years. It is very versatile and can be used for brazing, welding, and cutting carbon steel.


ADVANTAGES

- There are a wide range of torches, accessories, and gasses available from most welding and gas suppliers.
- It is the industry standard used by most fabrication shops and at most construction or demolition sites.
- It can be used to weld items, unlike other systems that can only be used to cut.

DISADVANTAGES

- Acetylene has one of the widest flammable limits of any fuel gas (2.5 percent to 81 percent) and is extremely hazardous at pressures exceeding 15 psig.
- Acetylene gas requirements for proper handling, use, and storage must be followed at all times.
- The oxy/acetylene burning operation can create large amounts of molten slag when cutting thick steel.
 - This slag can fuse back into the cuts and cause problems for the burner if clean cuts are not made.
 - Slag will also ignite spot fires and can be a hazard to the burner.

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Oxy/Acetylene

- Benefits
 - Commonly used in many industries
 - Wide variety of available accessory equipment
 - Industry standard for shops and field
- Disadvantages
 - Wide flammable limits
 - Limited to withdrawal rate of 1/7 per hour
 - Extremely hazardous above 15 psig
 - Requires proper handling and storage
 - Can create large amounts of molten slag

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Oxy-Acetylene - Safety Practices

- Do not operate Acetylene above 15 PSIG
- Do not withdraw more than 1/7 of the cylinder contents per hour
- Do not drain all of cylinder contents
- Keep components and area clear of grease, oil and other oxidizers/flammables
- Do not operate without Flashback Arrestors and reverse flow check valves
- Always perform a mechanical check for leaking components

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OXY/ACETYLENE SAFETY PRACTICES

- There are many safety practices to be followed, when using oxy/acetylene.
- Limit the pressure, limit the withdrawal rate, limit contaminants, use flashback arrestors and reverse flow valves, and perform checks for leaking components.


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ACETYLENE FUEL GAS CYLINDERS

- Acetylene cylinders are considered to be low pressure (200 to 250 psi).
- Acetylene is a compound of carbon and hydrogen (C₂H₂). It is produced when calcium carbide is submerged in water or from petrochemical processes.
- Acetylene becomes unstable when compressed in its gaseous state above 15 psig.

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Acetylene Gas Cylinders

- Open cylinder 1 to 1 1/4 turns
- Acetylene cylinders are 200 to 250 psig
- Gas becomes unstable when compressed in gaseous state above 15 psig
- Requires special porous core cylinder
 - Acetylene gas is absorbed by acetone in cylinder core to keep it stable under pressure
 - Must be stored and used in upright position to keep liquid acetone contained
- Maximum delivery pressure is 15 psig


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Oxy Acetylene Equipment

Acetylene cylinder



POROUS FILLER 8% to 10%
The filler, which completely occupies the steel shell, is 80% to 90% composed of millions of interconnected pores.

ACETONE 42%
Acetone equal to 42% of the internal volume is dispersed throughout the filler.

ACETYLENE GAS 36%
The acetylene gas is uniformly absorbed by the acetone. The resulting mixture occupies 78% of the internal volume.

RESERVE VOLUME AT 70° F 10% to 12%
Since acetone and acetylene gas will expand as temperature rises, a safety reserve must be present even at 70°F.

Must be stored & operated in upright position

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- Acetylene gas requires a special cylinder; it has a porous core that is saturated with liquid acetone.
 - Acetylene gas is pumped into the cylinder and is absorbed by the acetone, which keeps the gas stable while under pressure.
- Acetylene cylinders must always be stored and used in an upright position to keep the liquid acetone properly contained.
- The maximum safe delivery pressure for acetylene is 15 psig. **Never exceed regulated pressures above 15 psig or the acetylene gas will become very unstable.**
- Only 1/7th of the total capacity of an acetylene cylinder should be withdrawn per hour. This is controlled by the tip size being used and regulated fuel gas pressure.
 - If more than 1/7th of the total capacity is withdrawn from the cylinder, it may also withdraw the liquid acetone.
- When not in use or being transported in a vehicle, acetylene cylinders must be capped and secured.
- Most cylinders are equipped with pressure relief devices to prevent rupture of a normally pressurized cylinder when it is inadvertently exposed to fire or high temperatures.

RESCUE SYSTEMS 3

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ACETYLENE FUEL GAS CYLINDERS (continued)

- Never completely drain all of the gas out of the cylinder.
 - Always change out your cylinders before they are completely empty, leaving some measurable amount of gas product in the cylinder.
 - If you completely drain the cylinder, you may run the risk of contaminating the cylinder with mixed gases.
 - Completely draining the cylinder may allow gas to travel down through the hose into the mixing chamber of the torch and then back down through the other hose into the empty cylinder, thereby contaminating it.
 - ◆ If this goes unnoticed by the welding gas supplier, the next time the tank is filled, the cylinder will contain mixed gases that may be explosive.
- Friction generated during filling or opening the high-pressure cylinder may cause the cylinder to explode. This is the reason for using one-way check valves and flashback arrestors on the regulators and torch.

COMPRESSED GAS OXYGEN CYLINDERS

- Compressed gas oxygen cylinders are considered high pressure since they are rated at 2,250 psi.
- They must be secured at all times. By law, they must be capped while being transported in a motor vehicle, or when not in use.
- Grease and oil must never come in contact with any component of an oxygen system, cylinder, regulator, hose, or torch. They can combust and burn violently in the presence of pure oxygen.

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Compressed Gas Oxygen Cylinders

- High pressure—rated at 2,250 psi
- Must be secured at all times
 - By law must be capped to transport in motor vehicle or not in use
- Grease and oil must not come in contact with component of oxygen system
 - They can combust and burn violently in presence of pure oxygen

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Alternate Oxygen Sources (Liquid Oxygen - Dewars)

- GP45 Dewars can evaporate 4500 Cu. Ft. of gas from a liquid contained in cylinder
 - External evaporator may be needed
 - Must be kept in an upright position
- The Green, K-Stile compressed gas cylinder holds about 250 cu ft of oxygen
- Both these tanks must be secured and handled with caution

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LIQUID OXYGEN TANKS (DEWARs)

- Dewars are large cryogenic tanks.
- For large jobs, these liquid oxygen tanks (called Dewars) will be used instead of compressed gas oxygen cylinders.
 - One GP45 Dewar holds 4,500 cubic feet of product, and One k-size compressed gas cylinder holds 249 cubic feet of product.
- A manifold can be attached to the Dewar that will supply oxygen to many torch sets.
- Dewars must be secured and handled with caution. They are heavy, and if knocked over, can be damaged.


RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

OXY/ACETYLENE USE AND SAFETY

- Equipment Set Up
 - Oxygen/cylinder, hose, and torch threads are right hand.
 - Acetylene/cylinder, hose, and torch threads are left hand.
- Main Cylinder Valves
 - Inspect the cylinder valve seating surfaces and threads for dirt or damage.
 - If you notice the presence of oil or grease on the oxygen cylinder valve, do not use the cylinder, inform your gas supplier immediately.
 - Always crack the valve before attaching a regulator; doing so helps remove any loose dirt or debris that might be in the valve.
 - ◆ Always stand to the side of the valve port and make sure nobody else is standing directly in front of the valve port when you crack it.


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 **Oxy/Acetylene – Use and Safety**

- Equipment setup
 - Oxygen—cylinder, hose, and torch threads are Right-Hand
 - Acetylene—cylinder, hose, and torch threads are Left-hand
- Main cylinder valves
 - Regulates gas down to working pressure (15psi max.)
 - Inspect cylinder valve seating surfaces and threads for dirt and damage
 - Always crack valve before attaching regulator—helps remove any loose dirt or debris
 - Stand to side of valve port and make sure no one is standing in front of it when you crack it

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 **Oxy/Acetylene – Regulators**

- Before attaching to cylinder, inspect for damaged threads and seating surfaces + dirty filter, dirt, oil, and grease
- Before opening cylinder, release tension on regulator diaphragm by turning screw counterclockwise until it turns freely—places regulator valve seat in closed position
 - Stand to side of regulator and gauges to avoid injury
 - Components of regulator usually fail while opening cylinder valve, thereby releasing high-pressure gas
 - Start opening oxygen cylinder valve by slowly cracking it until max pressure is indicated on high-pressure gauge, then continue opening valve until it is opened completely

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REGULATORS

- The purpose of the regulator is to reduce the high pressure within the cylinder to a usable working pressure.
- Before attaching the regulator to the cylinder, inspect it for damaged threads, seating surfaces, dirty filter, or the presence of dirt, oil, or grease.
 - Regulators are attached to the cylinder or manifold by their inlet connections.
 - All inlet connections conform to specifications and standards set by the Compressed Gas Association (CGA) and are marked with an identifying CGA number.
- Before opening the cylinder, release the tension on the regulator diaphragm by turning the pressure adjustment screw counter clockwise until it turns freely. This places the valve seat of the regulator in a closed position.
 - When opening the tank cylinder valve, always stand to the side of the regulator and gauges to avoid injury.
 - If a gauge or other components of the regulator should malfunction or fail, they will usually do so while opening the cylinder valve and thereby release the high-pressure gas.
- Start opening the oxygen cylinder valve by slowly cracking it until maximum pressure is indicated on the high-pressure gauge, then continue opening the valve until it is opened completely.


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FUEL GAS CYLINDER VALVES

- Do the same procedure with the **fuel gas cylinder valve**, but only open the cylinder valve a maximum of 1 to 1 1/2 turns.
 - Some acetylene cylinders use a regular hand wheel knob to open the cylinder and others use a special removable wrench or key.
 - If a removable wrench or key is used to open the valve, leave it attached to the cylinder valve so the fuel gas can be shut off quickly in the case of fire or other problems with the system.

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Oxy/Acetylene – Fuel Gas Cylinder Valves

- Use similar to prior procedure to open fuel gas cylinder valve except only open cylinder valve 1 to 1½ turns
- Some acetylene cylinders use hand wheel knob to open; others use special, removable wrench or key
- If removable wrench or key is used to open valve, leave it attached to valve for quick shut off

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Oxy/Acetylene – Connection Parts

- Check valves
 - Permits gas to flow in only one direction—from regulator to torch
- Quick connectors
 - Can be installed on regulators, hoses, and torch
 - Make extending or changing equipment more efficient
 - Quick connectors have check valve built-in
- Flashback arrestors
 - Designed to stop flame from flashing into hose and regulators

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CHECK VALVES

- Check valves permit the gas to flow in only one direction (from the regulator to the torch).

QUICK CONNECTIONS

- Quick connections can be installed on regulators, hoses, and torches.
- They make setup plus extending and/or changing equipment more efficient.
- Each quick connect has a check valve built into it.

FLASHBACK ARRESTORS

- Flashback arrestors are designed to prevent the flame from flashing into the hose and regulators.


RESCUE SYSTEMS 3

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Hoses

- Make sure the hoses are rated for the fuel gas being used and that they are large enough to deliver the required volume for the tip size that has been selected.
- Welding hoses are often exposed to severe abuse and must be inspected for cracks, crushed areas, burns, cuts, and other damage.
- They must be kept clean and free of oil or grease and should be repaired or replaced if found to be damaged.
- The hoses are color-coded and threaded differently:
 - (Oxygen—green with right-hand threads),
 - (Fuel gas—red with left-hand threads),
 - The fuel gas hose nuts also have a V groove on the outside to indicate left-hand threads.
- Purge both hoses at about 3 psi to clear any foreign objects before attaching torch.


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 **Oxy/Acetylene – Hoses**

- Hoses are color-coded and threaded differently
 - Oxygen is green with Right-Hand threads
 - Fuel gas is red with Left-Hand threads
 - Fuel gas hose nuts have a V-Groove on outside to indicate Left-Hand threads
- Make sure rated for gas being used and tip size
- Hoses often exposed to abuse and must be inspected for cracks, burns, etc.
- Keep clean and free from oil or grease
- Purge both hoses at about 3 psi to clear any foreign objects before attaching torch

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 **Oxy/Acetylene - Torches**

- Many models and sizes
- Long ones work well for extended reach and when cutting thick steel
 - May be awkward and cause operator fatigue
 - Size of tip determines thickness that may be cut
- Some newer torches have anti-reverse flow check valves built-in to main torch body
 - Marked OC or FC with arrow to indicate flow direction

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TORCHES

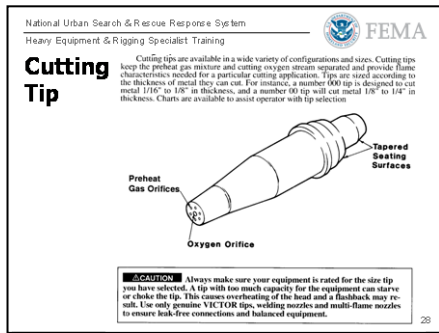
- Torches come in a variety of brands, models, and sizes.
 - There are one piece and universal two piece styles.
- Long torches work well when the burner needs extended reach or is burning thick steel with a large size tip and needs extra distance from the heat.
- Long torches can be very awkward and heavy, which cause additional fatigue to the operator.
- Short torches are lighter and more maneuverable, especially in confined spaces.
- The size of the tip determines the thickness of the steel that can be burned, not the size of the torch.
- Some newer style torches have anti-reverse-flow check valves built into the main torch body. Therefore, additional accessory check valves may not be necessary.
 - The valves are marked OC or FC with an arrow to indicate the direction of flow.
- If using an older style torch or a brand not having one-way check valves, they should be installed.

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CUTTING TORCH TIPS

- Cutting tips are available in a wide variety of configurations and sizes.
- Cutting tips keep the preheat gas mixture and cutting oxygen stream separated and provide flame characteristics needed for a particular cutting application.
- Select the proper size torch tip to match the make and model torch you are using and the thickness of the material you will be burning.
- Selection of the proper size tip can be aided by using a tip chart.
 - Remember, you can only withdraw 1/7th of the total volume of an acetylene cylinder per hour.
- If using a small acetylene cylinder, the size of the tank will dictate or limit the cutting tip size that can be used.



Metal Thickness	Tip Size	Cutting Oxygen		Pre-heat Oxygen		Acetylene		Speed (IPM)	Kerf Width
		Pressure (PSIG)	Flow (SCFH)	Pressure (PSIG)	Flow (SCFH)	Pressure (PSIG)	Flow (SCFH)		
1/8"	000	20-25	20-25	3-5	3-5	6-11	20-30	.04	
1/4"	00	20-25	20-25	3-5	3-5	6-11	20-30	.05	
3/8"	0	25-30	55-60	3-5	3-5	6-11	18-26	.06	
1/2"	0	30-35	60-65	3-6	3-5	6-16	16-22	.06	
3/4"	1	30-35	88-85	4-7	3-5	8-13	15-20	.07	
1"	2	35-40	140-160	4-8	5-6	16-18	15-18	.09	
2"	3	40-45	210-240	5-10	4-8	18-24	16-12	.11	
3"	4	40-50	280-320	5-10	5-11	18-28	16-12	.12	
4"	5	45-55	390-450	6-12	6-13	22-30	6-9	.15	
6"	6**	45-55	500-600	6-15	6-14	25-35	4-7	.15	
10"	7***	45-55	700-850	6-20	10-15	25-35	3-5	.14	
12"	8***	45-55	900-1050	7-25	10-15	25-35	3-4	.41	

*Applicable for 3-hose machine cutting torches only. With a two hose cutting torch, preheat pressure is set by the cutting oxygen.

**For best results use ST 1600C-ST 1900C series torches and 3/8" hose using tip size 6 and larger.

***All pressures are measured at the regulator using 25' x 1/4" hose through tip size 5, and 25' x 3/8" hose for tip size 6 and larger.

WARNING: At no time should the withdrawal rate of an individual acetylene cylinder exceed 1/7 of the cylinder contents per hour. If additional flow capacity is required, use an acetylene manifold system of sufficient size to supply the necessary volume.

BRASS FITTINGS AND ATTACHMENTS

- All gas-welding components use **brass** compression type fittings.
- When assembling welding components, do not over tighten them, or you will destroy the brass seating surfaces and threads.
 - You should only have to tighten them snugly with a short wrench.
 - If they leak after being tightened with moderate pressure, check for damage or defects and repair or replace.
- Always inspect O-rings before assembling welding and cutting attachments (welding tips, cutting attachment and/or heating attachment, multi-flame or rose bud).
 - If damaged O-Rings are found, do not use the torch until they are replaced.
- When mating attachments to the main torch body, only tighten them hand tight.
 - Over tightening with a wrench will only damage the O-rings and cause them to fail.

RESCUE SYSTEMS 3

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WELDING CART

- The welding cart should be of sturdy construction and be well balanced.
- Pneumatic rubber tires 8" tall or larger with bearings or bushings should be used to ensure ease of movement on broken or uneven ground.
 - Small hard rubber or steel wheels will stop or bind when used on rough or rocky surfaces.
- The cart should be of the proper size to accommodate and contain cylinders safely.
- There should also be a place to store safety goggles, spark lighter, tip cleaners, a wrench, and extra torch attachments.

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Oxy/Acetylene – Welding Cart

- Should be sturdy and well-balanced
- Use 8" minimum pneumatic tires and wheel bearings or bushings
- Need to safely contain cylinders
- Need place to store goggles, lighter, tip cleaners, wrench, and extra torch attachments

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OXYGEN / GASOLINE (PETROGEN)

The Petrogen gasoline/oxygen system operates somewhat differently from its oxy/acetylene cousin that most torch operators are accustomed to.

- It uses all of the same oxygen components and safety guidelines.
- The torch looks and operates in much the same way on the outside but is totally different on the inside.
- The gasoline stays liquid throughout the system until it reaches the cutting tip where it is heated and turned into a vapor in much the same way a Coleman stove or lantern does.

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Oxy/Gasoline - Petrogen

- Has been available for many years
- Similar to oxy/acetylene, but only for burning
- Benefits
 - Can cut steel up to 14" thick
 - Will cut through various sized air gaps
 - Less likely to fuse itself back together
 - Burns cleaner and with little slag
 - Not limited by fuel cylinder size
 - Gasoline is readily available and is safer
 - Can be used under water with special tips

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Oxy-Gasoline - Petrogen

- Disadvantages:
 - Equipment is not available locally
 - Rescuers must understand that the Petrogen torch setup, tuning and usage is different than the oxy-acetylene setup
 - Failing to understand the differences will produce poor cutting results

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RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

PETROGEN SAFETY PRACTICES

- As with all burn cutting, the use of Petrogen equipment entails significant and special risks.
- Fuel leaks are critical.
 - Perform leak checks after assembly and prior to lighting.
 - Look for liquid fuel on the ground and at couplings.
 - Secure fuel tank in the upright position, since the fuel cannot flow with tank on its side.
- A flashback arrestor should be used on the oxygen line, but one is not required for the fuel line.

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Petrogen Safety Practices

- Always perform a check for leaks
- When checking for a fuel leak look for liquid fuel on the ground and couplings
- Secure fuel tank in the upright position
Fuel cannot flow with tank on its side
- A flashback arrestor should be used on the oxygen line.
 - One is not required for the fuel line
- Do not operate fuel tank below 10 psi

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Petrogen Equipment – Fuel Tank

- 2.5 gal ASTM-certified tank is equiv to 250 c.f. acetylene tank
 - Has fast-flow, check valve inside tank shut-off valve
 - ◆ Designed to shut off fuel if hose is cut
 - ◆ For valve to operate, tank pressure should not drop below 10 psi
 - ◆ Shut-off valve should be opened slowly so fast-flow check valve will not engage
 - Keep tank pressure between 10 and 20 psi when using hand pump
 - ◆ Higher pressure may be used when using optional compressed air carry tank
- Use freshest fuel available

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PETROGEN FUEL TANK

The 2.5 gallon ASTM certified Petrogen fuel tank is equivalent to a 250 cubic foot acetylene tank.

- It has a fast-flow check valve located inside the tank shut-off valve that is designed to shut off the fuel in the event that the fuel hose is ever cut or severed.
- For the fast-flow check valve to operate properly, the pressure in the gasoline fuel tank should never be allowed to drop below 10 psig.
- The tank shutoff valve should be opened slowly when setting up the torch for operation so that the fast-flow check valve will not engage and shut off the fuel.
- The tank pressure should normally be between 10 to 20 psig during normal operations when using the hand pump.
- Higher pressures may be used when using the optional compressed air carry tank.

PETROGEN TORCHES

- Torches come in various configurations.
 - Torches are available in 14", 20", 27", 36", and 48" lengths.
 - Available head angles are 75, 90 and, 180 degrees.
- The size of the tip, and not the torch length determines the thickness of the cut


RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

PETROGEN TORCH TIPS

- The tip is a 2-piece assembly, with an inner brass core and an outer copper shell. The liquid fuel is vaporized, directed down to the base of the core, and then re-directed out the tip through the flutes of the core.
 - As gasoline changes from liquid to vapor, its volume increases almost 200 times. This rapid expansion provides a large force to the pre-heat flame.
 - Because gasoline vaporizes inside the tip, and evaporation is a cooling process, the tip runs cool.

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Petrogen Equipment Torch Tips

- Tip has two pieces
- Fuel enters the tip as a mist /atomized gasoline oxygen mixture
- Has oxygen and pre heat ports similar to Oxy-Acetylene
- If tuned properly, fuel entering tip should keep tip cool as it vaporizes

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Petrogen Equipment Tip Chart

- Serves as a basic starting point
- Settings will depend on operator experience
- You are not limited by the 1/7 per hour rule
- Tip does not need to be as clean as a oxy-acetylene tip

INCHES STEEL	TIP NO.	POUNDS/INCH ² GASOLINE OXYGEN
0-1/4	0	10-20
1/4-1	1 & 81	17-25
1-2	2	25-35
2-4	3 & 83	35-40
4-6	4	40-50
6-8	5	50-60
8-10	6	70-80
10-12	7	80-100
12-14	8	120+

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PETROGEN TIP CHART

The chart shows the cutting range of each tip, and suggests gasoline and oxygen pressures.

- The range of each tip is extended by higher pressures, but the quality may be reduced.
- The best combination of tip and pressures depends on operator technique, type and size of steel, desired cutting speed, and quality of cut.

LIGHTING THE TORCH

- Lighting the torch is done by first turning on the oxygen and the gasoline tank valves and setting the proper pressures.
- Open the pre-heat oxygen valve at the torch until a light flow is established.
- Open the gasoline valve until you see a very light mist.
- Using a spark lighter, light the torch and adjust the flame.
- Place the torch tip against the steel to heat the tip.
- Readjust the torch.

SHUTTING DOWN THE TORCH

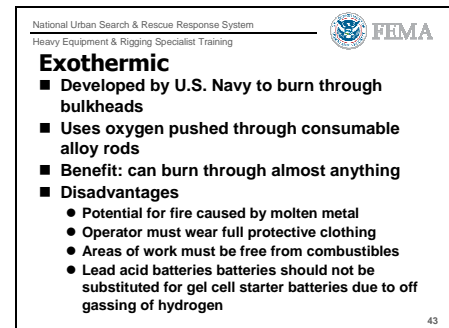
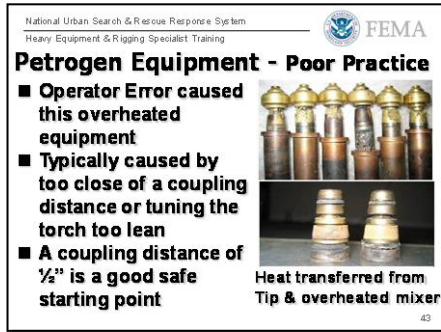
- Shut off the gasoline, then the oxygen at the torch.
- Close the valves at the tanks and back off the oxygen regulator pressure adjustment.

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PETROGEN POOR PRACTICES

- Damage to torch tips can be caused by operator error.
 - This type of damage is usually caused by having the coupling distance too short, or
 - By turning the torch too lean.
 - One should start with a coupling distance of $\frac{1}{2}$ ".



EXOTHERMIC CUTTING TORCH

The exothermic technology came to us from the U.S. Navy. They designed this equipment for burning through bulkheads in submarines. This technology uses oxygen pushed through consumable alloy rods, which burn at a very high temperature. The arc is started by shorting out the consumable rod, which is attached to a gel-cell battery and to a grounding plate (or by using a burning punk).

ADVANTAGES

- This system can burn through almost anything, including:
 - Ferrous and nonferrous metals
 - Stainless steel
 - Concrete
 - Glass
 - Cast iron
 - Just about anything else you can think of.

DISADVANTAGES

- The main disadvantage is fire!
 - This system throws large amounts of molten material.
 - The operator must be wearing full PPE to prevent serious burns.
 - The area where the work is performed must be free from combustible materials, and water extinguishers must be available at all times.

Gel-cell starter batteries should not be substituted for lead acid automotive batteries because they may give off hydrogen gas and can explode.

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BASIC TORCH HANDLING


- As with any physical task that will last for significant time, one needs to assume a reasonably comfortable position.
- Use a longer torch rather than reaching with a shorter one.
- It is best to balance the torch on a pivot point like a pool cue.
- It is worth the time to set-up the work space in order to remove stress from the arms and back.

ESTIMATING THE WEIGHT OF STEEL

Often burning operations are needed when large steel beams and columns are present in a collapsed structure. Since these heavy objects will need to be moved, some of the first things to consider are the lifting capability of the available equipment, based on the distance to the object's initial and final positions. The information regarding maximum lifting capacity will determine where to mark and cut the heavy steel members so that the weight requirements are met. Most metal suppliers offer booklets that give information about the weight of steel by thickness, shape, and dimension, usually on a per-foot basis.

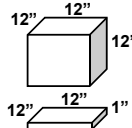
- There is an easy way to quickly estimate the weight of steel, by remembering that a one square foot, one inch thick steel plate weighs 40.8 pounds per square foot (psf). The 40.8 psf is based on the fact that steel weighs 490 pounds per cubic foot (12"x12"x12"). Twelve one inch slices, one square foot each, from a cubic foot.
 - Therefore, a 1" thick, sq ft plate weighs $490/12=40.8$ lbs.
- In order to easily remember, we round off to 40 and use the following weights for one sq ft steel plates:
 - 1" thick = 40 psf
 - $\frac{3}{4}$ " thick = 30 psf
 - $\frac{1}{2}$ " thick = 20 psf
 - $\frac{1}{4}$ " thick = 10 psf

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Estimating Steel Weight - Area Method

- Steel weighs 490 lbs per cubic ft
- Steel 1" thick weighs $490\text{pcf} / 12" = 40.8$ psf
- For steel weight per square foot use:
 - 1" thick Use 40 lbs
 - $\frac{3}{4}$ " Use 30 lbs
 - $\frac{1}{2}$ " Use 20 lbs
 - $\frac{1}{4}$ " Use 10 lbs



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RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

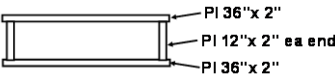
AREA METHOD EXAMPLE 1

- The weight of the steel “box section” can be easily calculated by noting that a 2” thick plate would weigh 80psf.
 - Since the total area of 2” plate is 8 sq ft per ft, the section weighs $8 \times 80 = 640$ pounds per foot (plf).
 - Total weight if the section is 36ft long is 23,040 lbs.
- This is only 2% less than the exact weight

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Area Method Example - 1

- What is weight of this 36ft long steel section?
 - 2” Steel = $2 \times 40 \text{ psf} = 80 \text{ psf}$
 - Area per ft = $2 \times 3 \text{ sq ft} + 2 \times 1 \text{ sq ft} = 8 \text{ sq ft}$
 - Weight per ft = $8 \times 80 = 640 \text{ plf}$
 - Total weight = $640 \times 36 = 23,040 \text{ lbs}$
- Exact weight = 652.8 plf (only 2% off)

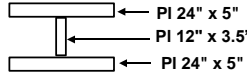


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Area Method Example - 2

- What is weight of this 20ft long steel section?
 - 2 Flanges $40 \text{ psf} \times 5'' \times 2 \text{ ft} \times 2 = 800 \text{ plf}$
 - Web $40 \text{ psf} \times 3.5'' = 140$
 - Weight per ft = $800 + 140 = 940 \text{ plf}$
 - Total weight = $940 \times 20 = 18,800 \text{ lbs}$
- Exact weight = 958.8 plf (only 2% off)



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AREA METHOD EXAMPLE 2

- An additional example, using a built-up so called W shape.
- The calculation is simple and the error is the same 2%.
- The 2% is the difference between the exact 40.8 psf and the easier to remember 40 psf for the 1” x one square foot steel plate.


AREA METHOD FOR ROUND TUBE / PIPE SHAPES

- For round tubes, imagine a flat plate made from cutting the tube lengthwise and laying it flat.
- The width of this imaginary plate is the circumference of the round shape, which is the diameter x 3.14 (Phi).
- The easy to remember value is 3, which is about 5% less, but close enough.

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Area Method – Round Tube Shapes

- Get area by: Circumference x Length
 - Either Measure distance around w/ tape or
 - Multiply Diameter x 3 (exact is 3.14)
 - Think - cut & unfold tube
- Weight per ft is 3 x Diameter x Wt. per sq ft
 - Wt. per sq ft depends on thickness
 - 1" thick Use 40 lbs
 - ¾" Use 30 lbs
 - ½" Use 20 lbs
 - ¼" Use 10 lbs



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RESCUE SYSTEMS 3


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OTHER CLUES TO THE WEIGHT OF STEEL

In order to identify steel sections and aid with erection, the steel mill, and/or shop may paint on indications of the section/s weight.

- The standard method is:
 - First numbers are the section depth
 - Second number is the weight per foot
 - Third number is the approximate length in feet
- One may or may not be able to find these numbers for any specific piece, since it may be cut from something longer, and/or may be covered by some sort of primer or finish paint/coating.

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Other clues for Steel Weight

- Numbers painted on steel at the Mill/Shop
 - First number is Depth in Inches
 - Second is Weight Per Foot in Pounds
 - Third is Length in Feet
- Usually located near the end
 - May be covered with other paint

24X76X46

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Shipping & Storage Methods

- All torches & hoses purged of combustible fuel
- Remove quick disconnects if used to completely remove fuel
- Store Petrogen torches, hoses & fuel tanks in a ventilated shipping box
- Regulators are fragile and should be stored in protective oil free hard case
- Refer to IATA and local guidelines for shipping compressed gases
- Acetylene torches can be stored in a oil free hard case

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SHIPPING AND STORAGE METHODS

- To be stored, all torches and hoses must be completely purged of fuel. In order to do this, one must remove quick disconnects.
- Acetylene torches should be stored in an oil free, hard case.
- Petrogen torches, hoses, and fuel tanks must be stored in ventilated shipping boxes.
- Since regulators are relatively fragile, they should be stored and/or shipped in oil free, padded hard cases.
- Refer to IATA and local guidelines for shipping compressed gas

CYLINDER SAFETY

- Cylinders must be secured and capped during transport and when not in use.
- Since most cylinders are equipped with pressure relief devices, there is little chance of rupture, due to high temperature.
- Never drain all gas out of a cylinder due to the risk of contaminating it.

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TOPIC 4-1: LIFTING - MOVING

TERMINAL OBJECTIVE

- Size-up objects that have entrapped people and efficiently apply a variety of machines and power to safely move these objects.

ENABLING OBJECTIVES

- Understand and use mechanical advantage to lift and move a heavy object.
- Understand the use of anchor systems, anchor failure considerations, and proper anchor spacing.
- Understand the proper use of a swivel hoist ring and steel angle brackets.

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ADVANCED LEVERAGE APPLICATIONS ("A" Frame Gantry)

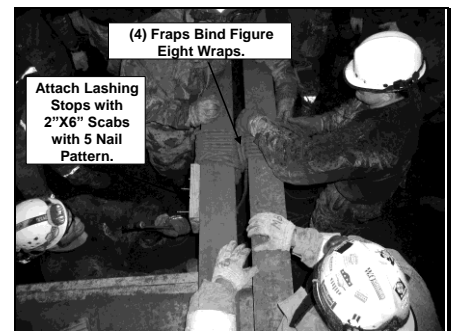
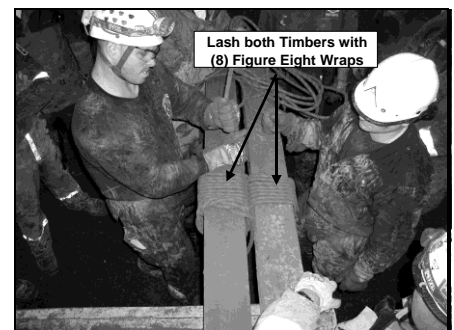
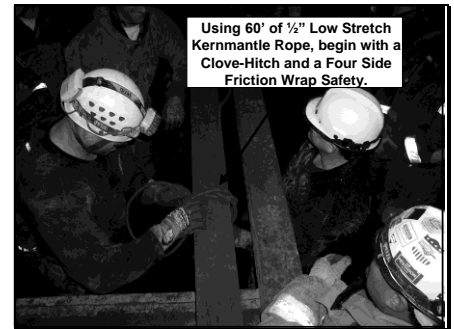
- The "A" Frame Gantry is a fairly complex application of leverage that involves floating an object in air between two horizontal points.
- The application for the "A"-Frame Gantry is most practical during collapse situations involving the movement of objects where there are no suitable overhead anchor points and crane access is not practical.

The "A" Frame

- The A-frame provides method for lifting and/or stabilizing heavy loads using simple and readily available materials.
- The A-frame crosses many technical rescue disciplines by allowing rescuers to establish elevated anchor attachments for rope rescue systems, or for use in confined space rescue.
- The simple addition of a third leg makes a stand along tripod. The A-frame reinforces the cognitive ability of being able to improvise when more common rescue tools are not available.

SCT04a Slide 108

- The "A" Frame may be made from two 6"x 6"x 14' timbers that are lashed together at the top, or by using a pair of 12', aluminum rescue struts with special connections at the apex and feet.
 - The two lower ends of the "A" Frame must be connected together, just above the ground, using a rope, webbing, or chain.
 - The legs should be spaced from 10' to 12' apart at the ground.
- A 15:1 or 20:1 compound mechanical advantage system is used for swinging the "A" Frame Gantry. It is attached to the apex of the "A" Frame and anchored to an appropriate anchor.
- The object (load) is attached to the apex of the "A" Frame using a short rigging strap.
- A lowering control rope is connected opposite the mechanical advantage system.
- As the "A" Frame Gantry is tensioned and elevated, the load starts to rise. A hoist or Come-A-Long may also be used to initially suspend the load.

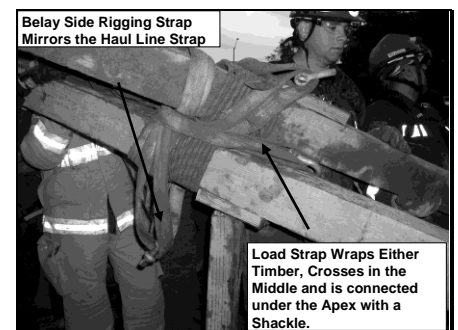
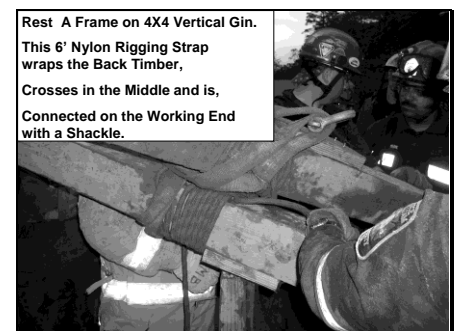


RESCUE SYSTEMS 3

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ADVANCED LEVERAGE APPLICATIONS ("A" Frame Gantry) (continued)

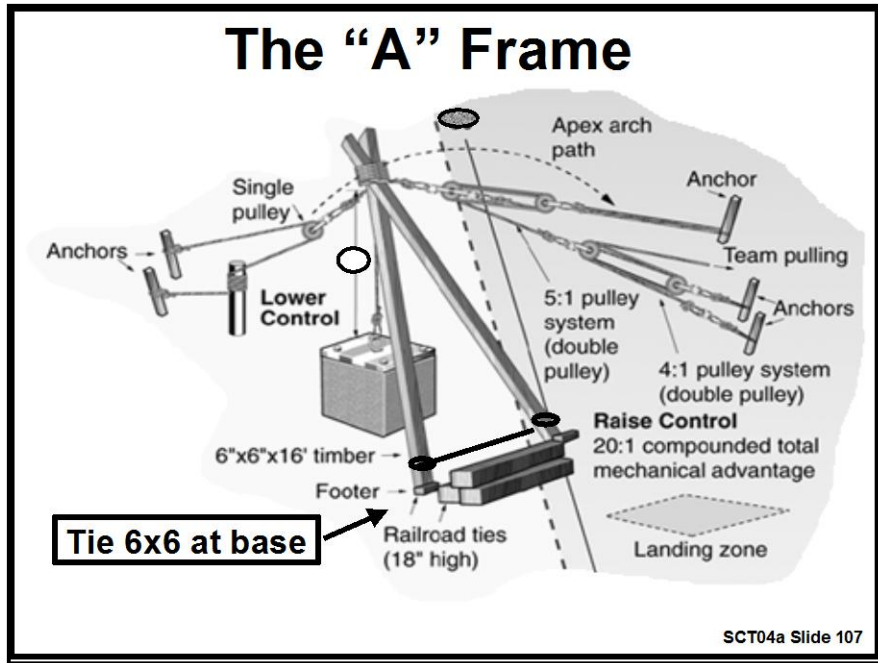
- The apex of the "A" Frame must be rotated to be centered over the load, but the angle between the ground and the "A" Frame should not be less than 45 degrees.
 - At this angle, the initial force on the hauling system is about 25% greater than the load itself, assuming that the anchors are placed at least 30' from the base of the "A" Frame legs.
 - The force in each of the A-Frame legs will be about equal to the load as the lifting begins.
- As lifting begins, forces are generated in the "A" Frame legs.
 - The horizontal force tending to move the base of each of the "A" Frame legs away from the load will be about 2/3 of the load.
 - There will also be a vertical load directed into the ground at the "A" Frame base that is about equal to this horizontal force.
 - These forces need to be resisted by the ground, and / or some type of restraint system.
- In most cases, it is necessary to provide a footing / baseplate for each leg of the "A" Frame Gantry.
 - In very firm ground, a shallow hole may provide enough resistance to the compression forces that are exerted when the "A" Frame legs rotate.
 - ◆ The forces at the edges of the 6"x 6" will dig into the ground and create their own bearing surfaces.
 - In softer ground, it may be necessary to use a pair of 12" square plywood gussets to spread the load. Neoprene pads will be helpful in providing shaped bearings for the edges of the 6"x 6" as it rotates.
 - On concrete surfaces, it will be necessary to restrain the 6"x 6" from slipping.
- As the "A" Frame is arched over, the load elevates until the Gantry is straight up and the object being lifted is directly beneath apex.
 - As the load moves past 90 degrees, the mechanical advantage system becomes useless, and the lowering system take over the controlled lowering of the load.



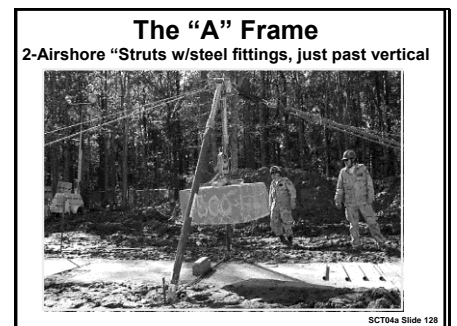
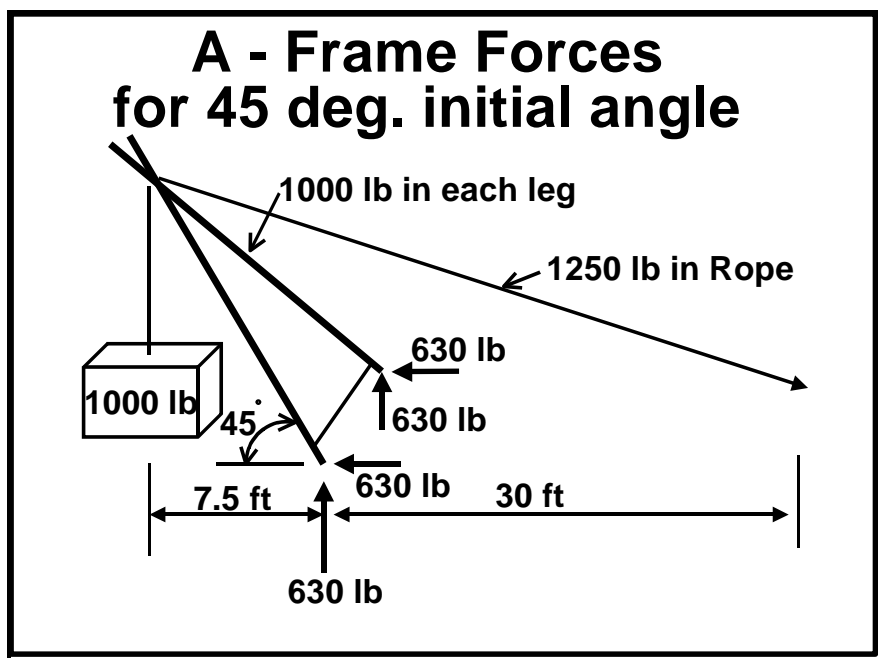
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"A" FRAME GANTRY (4000 lb. maximum suggested load)



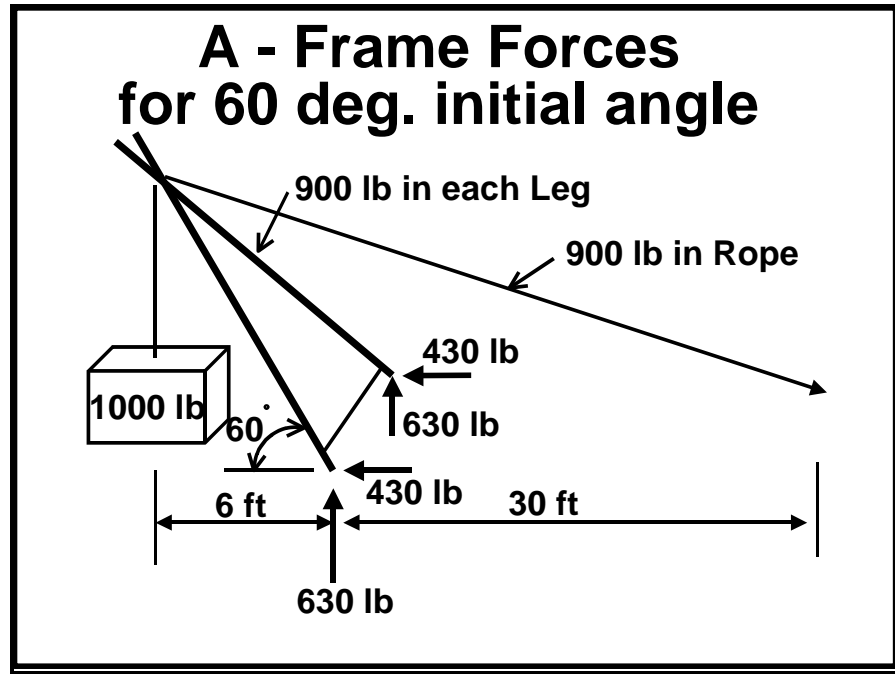
"A" FRAME GANTRY FORCES AT 45 DEGREES



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"A" FRAME GANTRY FORCES AT 60 DEGREES



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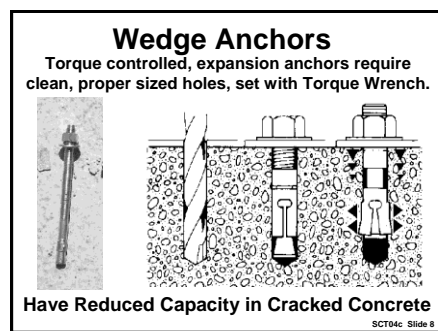
CONCRETE ANCHOR SYSTEMS

INTRODUCTION

The purpose of this section is to provide information about safe and practical methods of anchoring to concrete when some other method (such as cable loops or chokers) is not available.

WEDGE ANCHORS

- Are torque controlled anchors. They have an undercut shaft that is inserted into the hole and a wedge device that expands, as a cone at the bottom of the shaft is pulled through it, when the fastener is tightened.
- Correct hole size (not too large) is very important since the wedge must develop great friction against the sides of the hole.
 - The hole size is the same as the anchor ($\frac{1}{2}$ " hole for $\frac{1}{2}$ " anchor).
- These anchors will develop more friction as they are loaded in tension, since more expansion occurs as the pull on the shaft causes the cone to spread the wedges with greater force against the side of the hole.
- Applying a setting torque with a calibrated wrench is essential to the reliable performance of this type of anchor, since doing so actually tests the installation.
- The proper failure mode for this type of anchor is either pull-through (where the conical part of the shaft pulls through the wedge) or pull-out of a concrete cone.
 - The diameter of concrete cone that can be pulled out is usually more than two times the depth of the embedment of the anchor, however, this assumes un-cracked concrete.
- Anchors of this type should not be used in badly cracked concrete.
- Expansion anchors may be used to anchor Raker shores and in tieback systems, provided that the concrete into which they are set is relatively crack free.

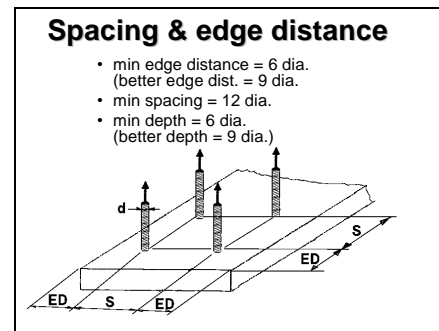


RESCUE SYSTEMS 3

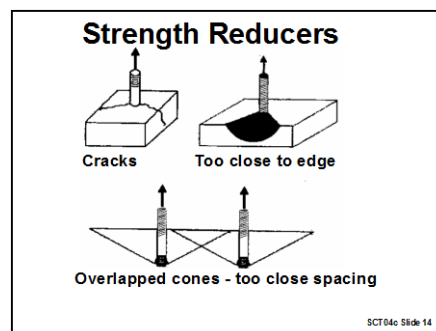
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ANCHOR APPLICATIONS

- Anchor spacing and edge distance.
 - The minimum spacing between anchors is 12 times the diameter of the anchor.
 - The minimum distance to the nearest concrete edge is 6 times the diameter of the anchor (9 times if the load is acting towards the edge).
 - The minimum anchor depth in concrete is 6 times the diameter of the anchor.
 - Anchor depth should be increased to 9 times the diameter of the anchor, since at ultimate load a more gradual failure will occur.



- Tension values can be increased, especially in lower strength concrete (2000 PSI), by increasing embedment and spacing to as much as double the minimum listed strength values.



RESCUE SYSTEMS 3

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INSTALLATION OF ANCHORS

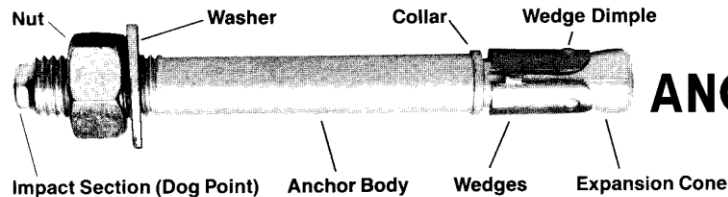
- Drilled holes should be the proper size and depth. Dull bits produce oversized holes which can lead to premature pull-out.
- A metal detector should be used to locate existing rebar, so that it can be avoided.
 - Hitting rebar with the bit will cause oversized holes, and a dull bit, which will continue to produce oversized holes.
- Holes need to be cleaned of most loose material.
 - One method to accomplish this is to drill the hole about one inch deeper than the insertion length, so that some of the loose material will drop to the bottom. In thin slabs, one may drill completely through.
 - The pile of concrete powder that collects around the drill bit at the top of the slab should be carefully swept away.
 - In addition, one should lift-out the loose material by quickly pulling out the drill bit as it is rotating.
 - One may use air to blow out the hole. Do not allow anyone to inhale any concrete dust because it is very damaging to the lungs.
- Wedge Anchors need to be tightened with a calibrated torque wrench.
 - This tests and “preloads” the anchor, giving one reasonable confidence in the installation.
 - Hole size is same as anchor size ($\frac{1}{2}$ ” hole for $\frac{1}{2}$ ” anchor)

RESCUE SYSTEMS 3

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ALLOWABLE WORKING LOADS FOR WEDGE ANCHORS

**SAFE
WORKING
LOADS**



ANCH-6S

WEDGE ANCHORS • *Kwik Bolt, Wedge-All or Trubolt*

Allowable Tensile Loads (lbs)

Dia- meter	Embedment	Required Torque (ft-lb)	$f'_c =$ 2000 psi	$f'_c =$ 3000 psi
3/8"	1 5/8"	20	530	605
	2 1/2"	use 25	1130	1210
	4 1/4"	25	1200	1230
1/2"	2 1/4"	40	870	970
	3 1/2"	use 50	1750	2000
	6"	65	1970	2170
5/8"	2 3/4"	85	1430	1690
	4"	use 100	2170	2670
	7"	110	3000	3270
3/4"	3 1/4"	150	1850	2180
	4 3/4"	use 225	2750	3630
	8"	235	3750	4630
1"	4 1/2"	250	2930	3650
	6"	use 350	4000	5310
	9"	450	6070	7070

Allowable Shear Loads (lbs)

Dia- meter	Embedment	$f'_c =$ 2000 psi	$f'_c =$ 3000 psi
3/8"	1 5/8"	930	970
	$\geq 2 1/2"$ **	1100	1100
1/2"	2 1/4"	1810	1840
	$\geq 3 1/2"$ **	1840	1840
5/8"	2 3/4"	2880	2880
	$\geq 4"$ **	3140	3140
3/4"	3 1/4"	3880	3880
	$\geq 4 3/4"$ **	4220	4220
1"	4 1/2"	6620	7120
	$\geq 6"$	8620	8620

INCREASE TENSION & SHEAR VALUES 1.33x
FOR WIND & EARTHQUAKE LOADING

TEN + SHEAR: $(P/P_{allow})^{5/3} + (V/V_{allow})^{5/3} \leq 1$

SLEEVE ANCHORS

Carbon Steel Allowable Working Loads in Concrete (lbs.)

Sleeve Anchor Diameter	Bolt Diameter	Embedment Depth	Required Torque (ft-lb)	2000 PSI		4000 PSI	
				Tension	Shear	Tension	Shear
1/4"	3/16"	1"	5	275	235	275	240
5/16"	1/4"	1"	5	275	410	380	420
3/8"	5/16"	1 1/4"	10	425	680	580	945
1/2"	3/8"	1 1/2"	30	820	960	820	1340
5/8"	1/2"	2"	50	960	1270	960	1410
3/4"	5/8"	2"	90	1270	1900	1270	2350

Carbon Steel Allowable Working Loads in Hollow Concrete Block* (lbs)

Sleeve Anchor Size	Bolt Diameter	Tension (lbs)	Shear (lbs)
1/4"	3/16"	300	490
5/16"	1/4"	330	670
3/8"	5/16"	420	930
1/2"	3/8"	610	930

*ASTM Specification C90, Grade N, Type II.

ANCH-6S 03/02

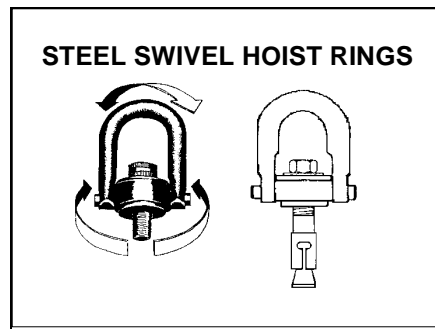
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

LIFTING DEVICES

SWIVEL HOIST RINGS

- These are devices that can be attached to concrete using a Wedge Anchor.
- Since the ring's loop pivots 180 degrees and the ring's base swivels 360 degrees, the load will always be applied directly through the bolt into the concrete.
 - There is also no danger of the swiveling ring applying a de-torquing twist to the properly tightened Wedge Anchor.
- These rings are available in sizes from 5/16" to 3". The 1/2" size is suggested as a minimum size, and it has a 2500 lb allowable working load, which is greater than the 2000 lb of a 1/2" Wedge Anchor with 6" embedment.
 - The 1/2" Swivel Hoist Rings and Wedge Anchors are included in the FEMA USAR Cache List.
- For larger loads, it is recommended that the 3/4" size be used. It has a 5000 lb allowable working load. A 3/4" Wedge Anchor with 8" embedment has 4500 allowable working load. It is not in the FEMA USAR Cache.
- The proper way to install the Swivel Hoist Ring is by using a 1/2" x 7" Wedge Anchor.
 - The hole may be cleaned by just lifting out the concrete dust with the bit a few times if the hole is made 1" deeper than the required 4 1/2" embedment.

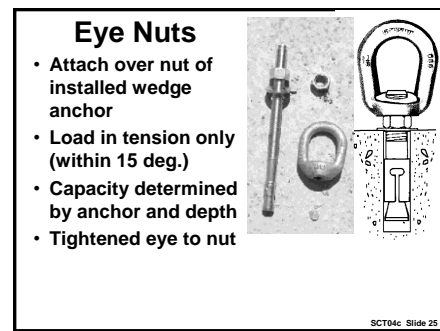


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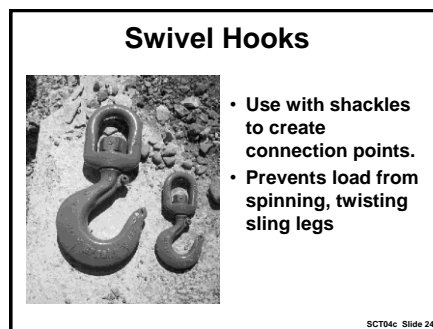
EYE NUTS

- These are drop forged and galvanized devices that can be attached to the exposed threads of an installed Wedge Anchor to produce a lifting device. ½" Eye Nuts are in the FEMA USAR Cache.
- They have a lifting capacity slightly greater than the tension capacity of a Wedge Anchor, provided that the direction of the load is vertical (or within 15 degrees of vertical), thereby loading the anchor primarily in tension.
 - The Wedge Anchor needs to be installed first; driven 4" into the ½" hole (with double nuts w/ washer just above the top end); then one of the nuts is removed, so the lower nut may be torqued to 50 ft-lb against the concrete; then the Eye Nut is tightened on top of the bolt.
- The ½" Eye Nut with a ½" Wedge Anchor has an allowable working load of about 2,000lb for a vertical pull.



SWIVEL HOOKS

- These devices may be used to attach to a shackle, however most often a sling will be used between the load anchors and the crane hook.
 - If these are used, the load must be kept from spinning, and / or the sling be kept from twisting.

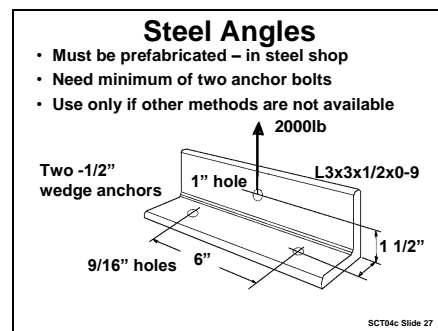


RESCUE SYSTEMS 3

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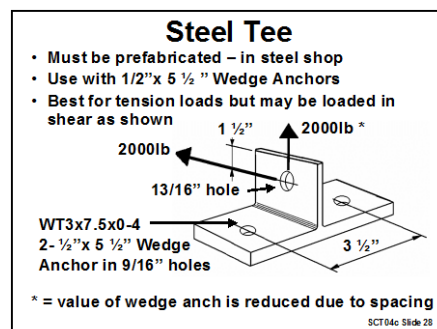
STEEL ANGLES

- May be pre-fabricated to be used with wedge anchors, however, if not sized properly will cause the failure of the lifting system.
- To be useful, an angle must be of sufficient thickness and length. A minimum of two bolts must be used with a single angle in order to assure that it will not spin.
- Due to the prying action of the vertical leg of the angle, it takes two wedge anchors to produce the same allowable working load as one wedge anchor when used with the hoist ring.
- Use this angle only if a hoist ring is not available.



STEEL TEES

- May be pre-fabricated to be used with 1/2" Wedge Anchors (if hoist rings are not available).
- The "T" must be a sufficient size to allow for the required spacing of the fasteners, and have the thickness necessary to resist the bending stresses. For tension forces, there is no prying action.
- When the "T" is loaded in shear (parallel to the concrete surface) the T stem needs to be aligned with the direction of the pull. Use a 5/8" (min) shackle to connect to rigging



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

TOPIC 4-2: CRANES - RIGGING

TERMINAL OBJECTIVE

- Size-up objects that have entrapped people and efficiently apply a variety of machines and power to safely move these objects.

ENABLING OBJECTIVES

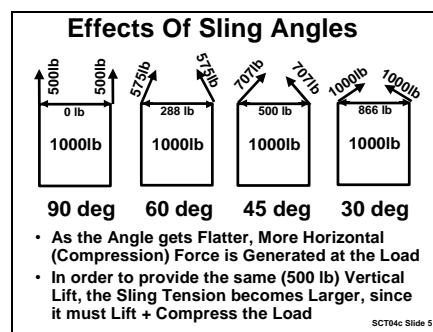
- Understand the proper use of wire ropes, wire rope fittings, end terminations, and tighteners.
- Use slings and sling arrangements for rigging and lifting.
- Use chains for rigging and lifting.
- Understand and determine the effects of critical angles as they relate to lifting and moving objects.
- Identify and describe the advantages and disadvantages of the different types of cranes.
- Understand considerations for crane use, and demonstrate basic crane signals for rescue operations.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

CRITICAL ANGLE CONSIDERATIONS

- The angle of a rigging strap / cable attachment in relation to the lifting point greatly effects the vertical and horizontal forces placed on the anchor attachments as well as the forces in the strap / cable.
 - These forces are easily calculated, based on the properties of the triangle that is created.
- A circle can be divided into three 120 degree sections.
 - If the angle of the rope system is equal to 120 degrees, the force in the rope and it's attachment is equal to the supported load.
 - If the angle becomes greater by pulling the load line tighter, a greater force is placed on the rope and the anchors.
 - If the angle is less, the force in the rope is less.
 - In lifting systems the angle should be as small as possible, but a 120 degree angle, which translates to a 30 deg angle, measured up from the horizon, is the largest angle that is allowed.
- Applying this concept to rigging can be done by using the triangle system.
 - The higher the point of attachment is over the objects center of gravity the lesser the forces on the sling and it's attachments.
 - The flatter the angle, the greater the forces.
 - ◆ As the angle gets flatter, compression forces on the top of the load increase.
 - ◆ In some cases, lifting a fairly light object with a flat lifting angle will create forces substantial enough to break the sling and / or blow-out the anchor points.



RESCUE SYSTEMS 3

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RIGGING TOOLS

SLINGS

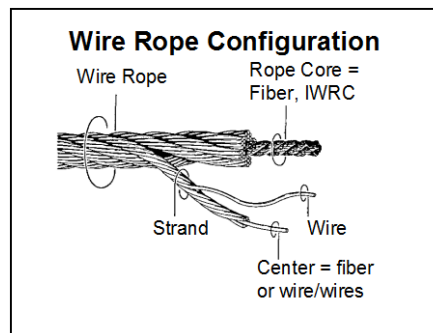
Commonly used material for the manufacture of slings:

- Wire rope
- Chain
- Synthetic Fibers

Rigging is defined as a length of rope, chain, or webbing attached to a load and / or an anchor for the purpose of stabilizing, lifting, pulling, or moving objects.

■ Wire rope

- Very strong and well suited for USAR environment.
- Strength depends on size, grade, and core.
- Resistant to abrasion and crushing.
- Must keep from bending or kinking.
- Sharp bends and edges can cause damage.
- Wire rope components
 - ◆ Core (Fiber core or independent wire rope core)
 - ◆ Strand
 - ◆ Wire
 - ◆ Center



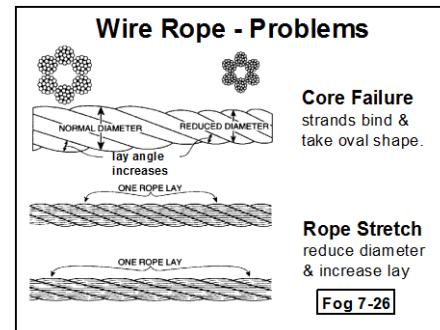
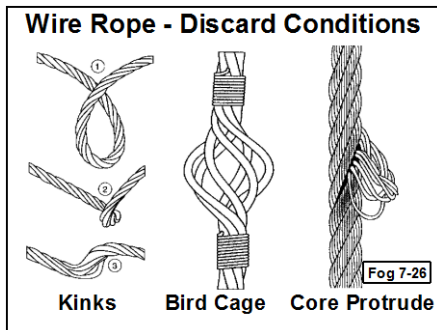
- Wire rope safety factors:
 - ◆ Wire rope sling (5:1)
 - ◆ Lifts with personnel (10:1)
 - ◆ Elevators (20:1)
 - ◆ Mobile crane (3:1 for standing ropes)
 - ◆ Slings have greater factor of safety than for wire rope used on cranes due to the likelihood of rough usage and wear.

RESCUE SYSTEMS 3

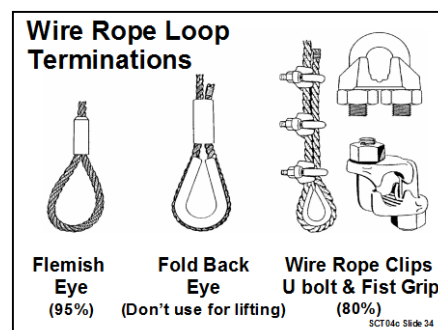
STRUCTURAL COLLAPSE TECHNICIAN

SLINGS (Continued)

- Wire Rope inspection should be done on a regular basis.
 - ◆ Wire rope discard conditions:
 - Kinks
 - Bird cage
 - Core protrusions



- Wire rope fittings and terminations are available in many designs.
 - ◆ Swaged and Spelter Sockets:
 - These sockets are normally found connecting the standing lines (wire rope lines that do not move) on a crane.
 - ◆ Wedge socket:
 - If properly manufactured and installed, will only reduce capacity by 10%.
 - These normally occur at the connection of the Ball to the Whip Line of a crane. (Whip Line is a single part line that extends from the crane boom tip, just beyond the main sheaves).
 - ◆ Flemish eye:
 - Most reliable and efficient termination. Must be done in a shop, and it does not reduce load capacity.
 - ◆ Fold back eye:
 - Unreliable, do not use it.

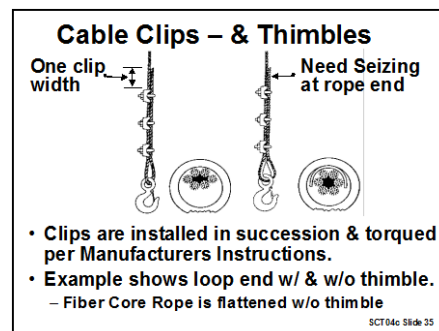
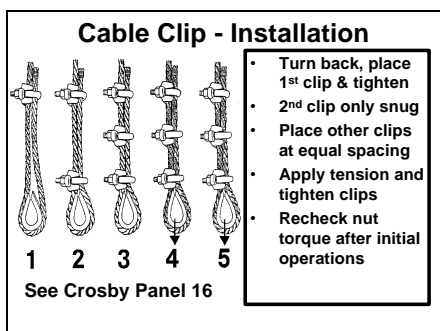


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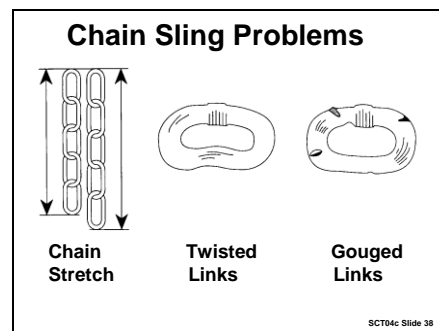
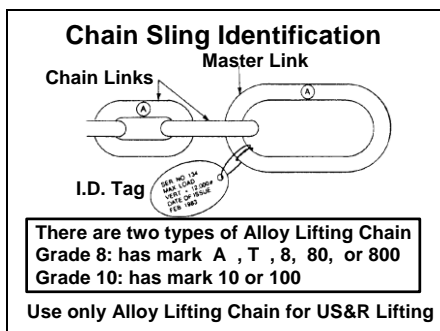
SLINGS (Continued)

- ◆ Cable clips:
 - During past USAR incidents, it has been necessary to construct cable terminations using these clips.
 - All rescue personnel should become familiar with how to position and tighten these useful devices.
 - Reduces capacity by 20%.



Chain

- Limited use due to weight.
- Links can break without warning.
- Requires padding between the chain and load to create a better gripping surface.
- Should not be exposed to cold temperatures for long periods of time.
- Avoid kinking and twisting while under stress.
- Load must be seated in the hook.
- Avoid sudden jerks in lifting / lowering the load.
- Use padding (planks, heavy fabric) around sharp corners on the load to protect the links from being cut.
- Cannot use for overhead lifting unless tagged by manufacturer.



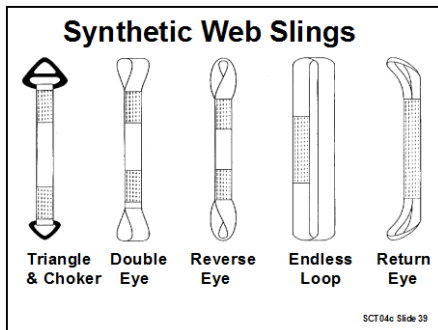
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

SLINGS (Continued)

■ Synthetic slings

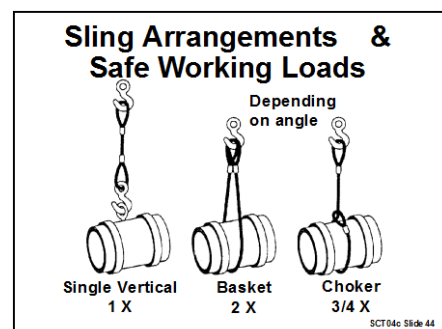
- Tends to mold around the load adding additional holding power.
- Will not rust and are non-sparking.
- Are light weight, making it easier and safer to rig and carry on the rubble pile.
- Have no sharp edges, thereby reducing injury potential.
- Are more elastic than chain or wire rope and can absorb a shock loading better.
- Are not effected by moisture and are resistant to many chemicals.
- Are very susceptible to abrasion and catastrophic failure, especially in the collapse structure environment.



BASIC SLING ARRANGEMENTS

■ Single vertical / horizontal hitch

- Supports the load with a single leg of rope, chain, or webbing.
- The full load is carried by a single leg (one straight piece of Chain, rope, or webbing).
- Should not be used when:
 - ◆ The load is hard to balance.
 - ◆ The center of gravity hard to establish.
 - ◆ Loads are loose.
 - ◆ The load extends past the point of attachment.



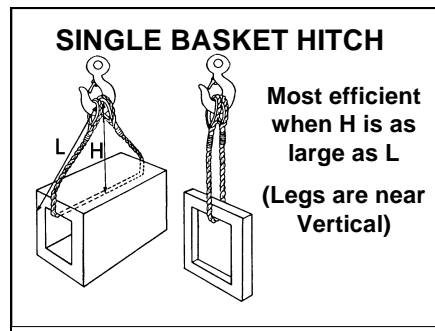
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BASIC SLING ARRANGEMENTS (Continued)

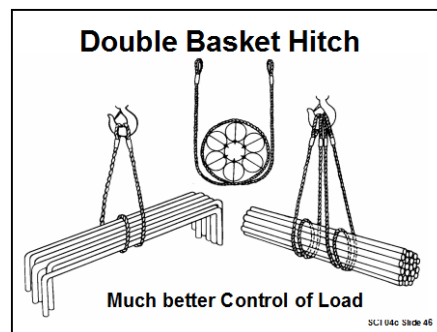
■ Basket hitch

- Supports the load by attaching one end of the sling to a hook.
- The other end of the sling is wrapped around the load.
- That end is then attached to the same hook as the other end of the sling.
- Presents problems related to keeping the load balanced or stabilized.



■ Double basket hitch

- Is more stable than single basket hitch.
- Uses two slings wrapped at separate locations on the load in the same manner.
- Able to position the attachment hook over the estimated center of gravity.
- Slings are wrapped on either side of the center of gravity.
- Can use a "double wrap" basket hitch, which makes contact all the way around the load surface, for increased securing of loads (good for cylindrical loads).



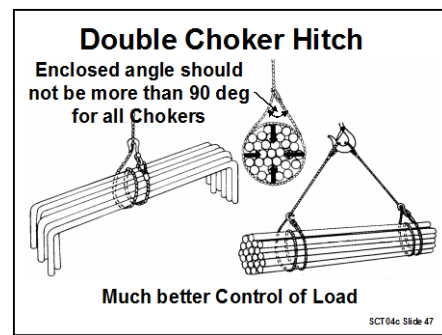
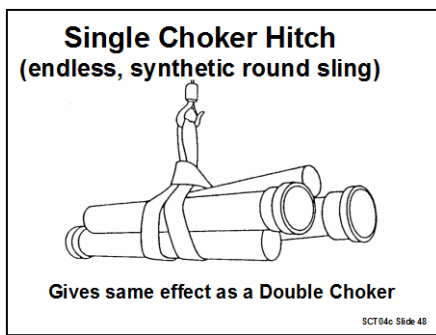
RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

BASIC SLING ARRANGEMENTS (Continued)

■ Single choker hitch

- Loop a strap / rope around the load.
- Pass 1 eye through shackle attached to the other eye.
- Pass that same eye over the hook.
- The sling should be wrapped around the load.
- The sling is secured back onto itself.
- Has the potential for having stability problems.
- Creates a vise-like grip on the load.



■ Double choker hitch

- Consists of two single choker hitches spread apart on the load.
- Does not make full contact with the load surface.
- Can be double wrapped to help control / hold the load.
- A double choker hitch provides for better lifting, pulling, stabilizing, and moving than a single choker.
- When using straps in pairs, the hooks should be arranged on the straps so that they will pull from the opposite sides. This provides for better gripping action.
- Creates a vise-like grip on load.

■ Bridle hitch

- Uses 2, 3, or 4 single slings. Each sling is called a "LEG".
- The slings are secured to a single point. This is usually in line between the center of gravity and the anchor (lifting point).
- Can allow for very stable lifting, stabilizing, moving, and pulling due to the distribution of the load onto multiple slings.
- Sling lengths must allow for an even distribution of the load.

■ Basic guideline for sling formations

- Make sure that the slings are protected at all actual or potential sharp corners in contact with the load.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

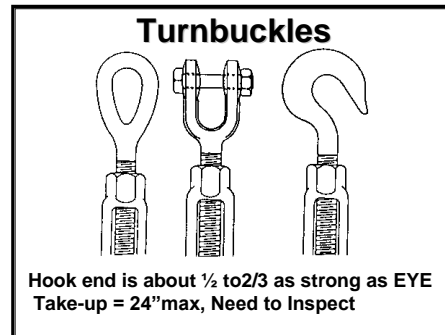
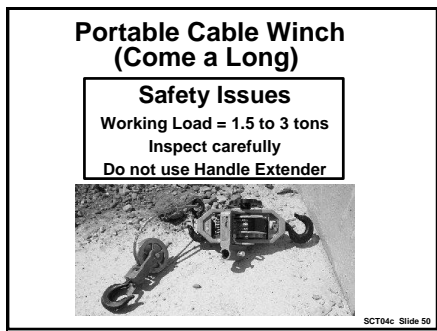
TIGHTENERS

■ Wire rope tighteners

- They have been required during many USAR incidents.
- They may be used for lifting light loads as well as tightening cable tiebacks and other rigging.
- Care needs to be taken to not overload them. **DO NOT ADD CHEATER BARS TO THE HANDLES.**
- They are available in several configurations, and are included in the FEMA USAR Cache.

■ Come-A-Long

- The length of the handle and the strength of one person provides the overload limit. **DO NOT ADD TO THE LENGTH OF THE HANDLE.**
- Take care in re-winding the cable, it can foul.
- These devices are 2' to 3' long, therefore their use may be limited in confined spaces.



■ Turnbuckles

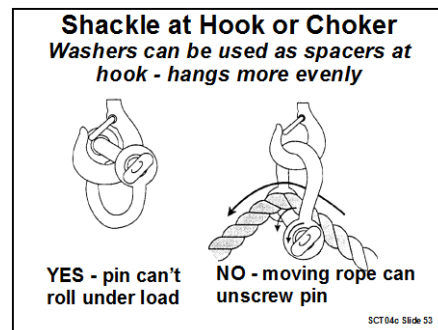
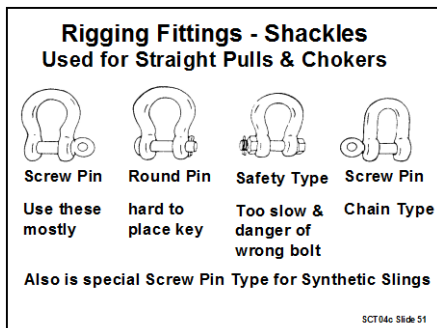
- Commonly used tightening device, and are in the USAR Cache.
- Can be used to do final tightening of tiebacks, and liberate a Come-A-Long so that it can be used for other jobs.
- The maximum take-up can vary from 8" to 24", depending on what type is purchased.
- They may be difficult to tighten at high loads, so keep the WD-40 handy.
- **Hook** ends are only 2/3 as strong as **eye** or **jaw** ends.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

RIGGING FITTINGS

- Ring, hook, and shackle components of slings should be made from forged alloy steel.
- Basic components:
 - Hook
 - Shackle
 - Eye
- Provide for a means of hauling (lifting) loads without directly tying to the load.
 - Can be attached to wire or fiber rope, blocks, or chains.
 - Used when loads are too heavy for hooks to handle.
 - Hooks need a latch or mouse closing / securing device.
 - ◆ **Mousing**
 - The process of closing the open section of a hook to keep slings / straps from slipping off the hook.
 - Use rope yarn, seizing wire, or shackle.
 - **Shackle**
 - ◆ Check the rating stamp and Working Load rating.
 - ◆ Pins are not interchangeable with other shackles.
 - ◆ Screw the pin in all the way and back off $\frac{1}{4}$ turn before loading.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

CRANES USED FOR STRUCTURAL COLLAPSE RESCUE

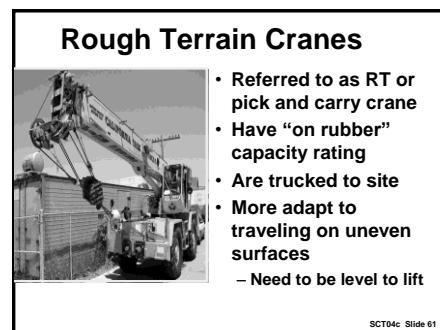
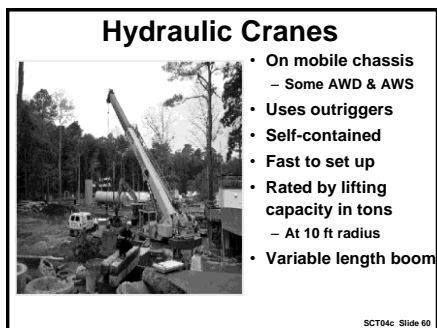
PRE-INCIDENT INFORMATION

- Develop and maintain a listing of businesses with crane resources including; crane equipment, crane operators, and crane rigging equipment.
- Develop a telephone call-up list for crane resources listed.
- Develop an identification and vendor call-back system for; verification of incident needs and projected response time to the incident scene, and confirming on scene contact person and their location.

TYPES OF MOBILE CRANES

■ Hydraulic Cranes

- Mounted on a mobile chassis. Some have AWD and AWS.
- Have outriggers, which need to be set on firm bearings, and some have “on rubber” lifting capacities.
- They are self-contained, except for 120 tons and greater.
- Are relatively fast to set up.
- They are rated by lifting capacity, in tons, at a distance of about 10 ft from the center of the crane .
- The variable length boom makes them very useful in a USAR incident.



■ Rough Terrain (RT) Cranes

- Are normally trucked to the site.
- They have “pick and carry” capabilities (driving with loads).
- Are rated for “on rubber”.
- More adaptable to rough terrain, but must be leveled to lift.

RESCUE SYSTEMS 3


STRUCTURAL COLLAPSE TECHNICIAN

TYPES OF MOBILE CRANES (Continued)

■ Lattice Boom Cranes (Sometimes called conventional)

- Lattice Boom Cranes may be **truck mounted** or **crawler mounted**.
- Normally require more than one truck to haul the boom components, counter weights, and rigging.
- Crawler mounted cranes usually require several trucks, since the crawlers may be trucked separately.
- Have a longer set-up time than the hydraulic crane.
- Rated by lifting capacity, in tons, at a distance of about 10 ft from the center of the crane .
- Require more set-up area than the hydraulic crane.
- Need to find a place to park all the trucks.

Lattice Boom Cranes (conventional)



- Components usually hauled on several trucks
 - Rigging
 - Jib
 - Counterweight
 - Boom
- Determine boom length at initial setup
- May be Truck or Crawler

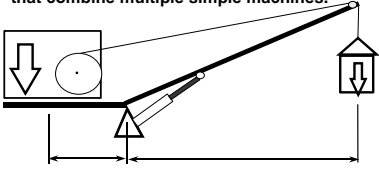
SCT04c Slide 62

■ LIFTING CAPACITY

- The lifting capacity of all cranes is reduced the farther away the center of the cranes is from the load.
- The '**Rated Load**' is what can be lifted at 10' to 12' from the crane "**Pin**" (the center of rotation).
- They are, essentially a very complicated 1st class lever

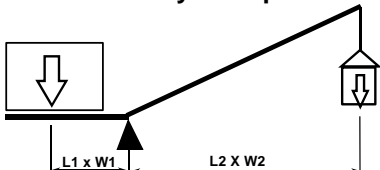
Crane is Complex Machine - Internally

- Maximum lifting capacity is reduced the farther the crane is from the load.
- Cranes are considered complex machines that combine multiple simple machines.



SCT04c Slide 61

Crane Stability - Simple Lever



$L1 \times W1$ $L2 \times W2$

Big Weight x Small Dist. = Small Load x Big Dist.
 (Resisting Moment) (Load Moment)

SCT04c Slide 62

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

AREAS OF OPERATION

- All Cranes are required to carry load charts on board.
- Cranes may have different capacities for different quadrants of operation.
- Some cranes may lift “on rubber”, but most require their out riggers to be fully extended in order to operate safely.
- Crawler Cranes are an exception to the statement above, but some crawlers do have extendable tracks for greater lifting capacity.

Lifting Quadrants

- Front, Sides, Rear
- May have different ratings
 - Some are same 360 deg
- Cranes ability to counter balance
- Similar to a Load Chart for Aerial Ladder Truck

Over Front
Over Side
Over Side
Over Rear
On O.Riggers
Over Front
Over Side
Over Side
Over Rear
On Rubber
SCT04c Slide 65

Many Cranes have both Main Block & Whip Line

- Main/Traveling Block is Rigged as a 4:1 = 4 Part Line
- Whip Line = Single Line
- Operator must take care so Single Line does not get tangled around Main Lines
 - Can be caused by Rapid Swing of Boom

SCT04c Slide 70

CRANE RIGGING

- Most cranes have two separate hook / systems that they can lift from.
 - The **Main Block** will have more than one sheave, so its hook has the greatest capacity.
 - It may have several “parts of line” which multiplies the strength of the wire rope that is connected to the drum for lifting.
 - Often the capacity of each part of line is determined by the strength of the brakes on the drum, however, the capacity of the wire rope must not be exceeded.
 - The **Ball (Headache Ball) and Hook** normally drops over a single sheave at the tip of the crane boom.
 - It most always has one “part of line”, but the load moves much faster on this “Whip Line”.
 - The capacity of this line is often determined by the strength of the brake at the drum.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

LOAD MOVING TACTICS

- Secure the load
 - The type of load, it's weight, and center of gravity must be known.
 - When cranes are lifting near their maximum reach, have a very small safety factor for tipping.
- Adjust the rigging
 - Check all slings, hooks, and connectors.
 - All should be aligned and without twists.
 - The load should be slowly lifted a short distance off the ground.
 - Check the balance and that all slings appear to be tight.
- Check the center of gravity (C.G.)
 - If the load does not come up level, it means that the rigging has not been correctly placed (not centered on the C.G.).
 - The load will rotate until its center of gravity is directly under the lifting hook.
 - ◆ The load will then need to be set down, and the rigging will need to be shifted towards the side of the load that came up last.
- Sling Leg Adjustment
 - You may need to change the position of the slings, or type of hitch, in order to properly center the load.
 - In some cases, a pair of slings may not be able to be positioned so the load can be lifted without tilt.
 - ◆ In such a case, another connection devise may need to be added, such as a chain hoist that is connected to the load using an anchored swivel hoist ring or eye nut.

Rules of Thumb

- Leg of Sling 30 deg to flat, double the load
- Leg of Sling 45 deg to flat, 1 ½ time the load
- Choker de-rates sling 25%
- Lose 50% rating of rigging when bending rope around of equal or less than diameter
- Figure Multi-leg bridles to lift on no more than 2 legs
- Chains too brittle below 32 deg F
- Work from top to bottom, trace out Load Paths
- Crib around the victim
- 20 Feet from Electric wires

SCT04c Slide 77

Common Considerations

- Double "T"
- Wood Trusses
- No Rapid Swinging
- Using Rigging as Shoring
- Obtaining a gap for slings
- Don't Move a disaster from one spot to another, block load when landed

SCT04c Slide 78

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

REQUESTING THE APPROPRIATE CRANE

- Prepare for a crane request by using standard USAR forms.
- Be sure to describe potential load weights and load materials so that the right size crane, the right rigging equipment, and the right personnel can be matched and sent to the incident.
- Reach distance should be calculated from a suitable crane lifting location or locations.
 - This assessment should be completed by identifying suitable location(s) that would accommodate aerial ladder operations.
 - ◆ Distance is measured from the center pin on the crane turntable to the center of gravity of the load.
 - Generally, the larger of either the load capacity or reach, the longer the response time, and a larger area is required for effective operation.
 - Conventional cranes may require an area as large as 35ft x 200ft for boom assembly, adjacent to lifting area.
- Ensure sufficient access to the area before the crane's arrival:
 - Access road condition and width.
 - Overhead clearance (including power lines near site).
 - Room and conditions to maneuver around the site.
- Rescue personnel must be assigned to facilitate crane operations:
 - To communicate with the crane operator.
 - To assist the crane operator and riggers.
- Rescuers should prepare for crane operations:
 - Anticipate the best location for crane operation and setup.
 - Initiate clearing activities prior to the arrival of the crane.
 - Is surface sloped or level?
 - Is surface hard or soft?
 - Obstacles and hazards:
 - ◆ Buildings
 - ◆ Walls
 - ◆ Wires

Safety Rules

- | | |
|---|--|
| • Know Weight | • Allow low D/d for wire rope |
| • Know C.G. | • Reduce ratings for chokers |
| • Know Rigging Ratings | • Only use Grade 8 or equal chain |
| • Inspect Before Use | • Use Tag Lines as needed |
| • Use Softeners | • Stay Clear of Lift |
| • Allow for increased Tension when loaded | • Lift a couple of inches and re-check |
| • Once a Choker is loaded do not force hitch down | • Start & Stop Slowly |

SC704c Slide 82

More Rules

- Watch for Obstacles
- Only One Person Signals
- Use known Hand Signals
- Know Swing Radius of Crane
- Keep Lift Line Vertical
- Allow for Wind Loading, No Lifts if Wind greater than 35mph (Special Care over 25mph)
- Respect your Gut Feeling
- Keep Alert

SC704c Slide 83

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

20 QUESTIONS TO ANSWER WHEN ORDERING A CRANE

When you contact a rental source of heavy lift equipment, they will start asking questions to permit them to give you what you need. If you can have answers to their questions ready beforehand, you will speed the process considerably. If you have answers to the following questions, you will be well prepared for the rental agent's questions.

1. Who are you and what are you doing?
2. How quickly do you want a machine?
3. What do you intend for this machine to do?
 - Pick and swing
 - Pick and carry
 - Lift large objects at small distance
 - Lift small objects at large distance
4. Will multiple machines be needed? (Second machine to set up primary machine).
5. What are the capabilities of the onsite crew? (Are they qualified to assist with set up?).
6. If this machine is for a single task, what is the load weight and what is the load radius?
7. If this is for multiple tasks, what are several combinations of load and distance?
 - Max load / min distance, max distance / min load, possible mid load / mid distance?
8. Will this task require pick and carry capability?
9. What are the limits of room available for operation of the machine?
 - Overhead clearance, tail swing clearance, underground obstructions?
10. Is there a place to assemble boom (if lattice) and crane (counterweights)?
 - Including room for assisting crane?
11. Are there limitations on delivery of crane or parts?
 - Posted bridges, low clearances, underground utilities?
12. What areas of operation are anticipated?
 - Over rear, Over side, Over front, On rubber?
13. Are two crane (simultaneous) picks anticipated?
14. Will work be performed on a continuous (24 hr) basis? Is auxiliary lighting available?
15. Will radio communication be required to control load? Are dedicated radios available?
16. How much boom is required? Are special boom features (offset, open-throat) needed?
17. What size hook block is needed? Are shackles to fit hook available?
18. Will jib be needed? Jib length? Offset? Load?
19. Are additional rigging components needed?
 - Load cell, lift beams, slings, shackles?
20. Who is the contact person and who is the person directing the rigging operations?

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

USAR CRANE USE FORM CU-1

This form is intended to act as a check-list when ordering or planning for the use of a crane. One form may be used for each crane. The sketch should show the approximate position of crane and setup area, as well as where trucks for removal of debris should be staged. Also need to show locations of overhead and underground hazards. **Get form on Disasterengineer.org.**

US&R Crane Use/Order Form CU-1

By: _____

Date: _____

Page _____

of _____

Situation Name: _____		Date and Time of Lift: _____	
Rigging Task: _____		Task Force Name: _____	
Weather Conditions: _____		Task Force Leader: _____	
Load Description:		Crane Operator: _____	
Load Weight: _____		Crane Make & Model: _____	
Block Weight: _____		Crane Serial No: _____	
Rigging Weight: _____		Boom Length: _____	
Jib Weight: _____		Jib Length: _____	
Jib Ball Weight: _____		Jib Position: <input type="checkbox"/> Stowed <input type="checkbox"/> Retracted <input type="checkbox"/> Offset at _____	
Hoist Line Weight: _____		Size of Counterweights Installed: _____	
Other Weight: _____		Front Outrigger Installed: Yes No	
Total Weight: _____		Setup On: <input type="checkbox"/> Crawlers <input type="checkbox"/> Outriggers <input type="checkbox"/> Tires	
Lift will be On: <input type="checkbox"/> On Main Block <input type="checkbox"/> On Jib		<input type="checkbox"/> Extended <input type="checkbox"/> Retracted <input type="checkbox"/> Other	
Max. Intended Working Radius	Boom Angle:	Rated Capacity:	Percent of Capacity : (Total Load / Rated Capacity)
Over Rear: _____	Over Rear: _____	Over Rear: _____	Over Rear: _____
Over Side: _____	Over Side: _____	Over Side: _____	Over Side: _____
Over Front: _____	Over Front: _____	Over Front: _____	Over Front: _____
Hazards: <input type="checkbox"/> Electrical <input type="checkbox"/> Fire <input type="checkbox"/> Underground <input type="checkbox"/> Other _____			
Are Crane Mats, Blocking Req'd: _____			
SKETCH			
<div style="border: 1px solid black; width: 100%; height: 100%; position: relative;"> <!-- Grid lines --> <div style="position: absolute; top: 0; left: 0; right: 0; bottom: 0; background: repeating-linear-gradient(45deg, transparent, transparent 2px, black 2px, black 4px); background-size: 20px 20px;"></div> </div>			



USAR RIGGING ACTION PLAN - RAP

It is intended to be the planning tool and record of rigging operations during one operational period. It can then serve to hand-off the info to the on-coming shift. A copy should also get back the the TF and/or IST Plans Unit.

The HERS should number all significant loads, give dimensions and weight, indicate load radius, indicate where the load is intended to go, and check-off if moved by end of shift. One page will work for 12 loads. Use as many pages as necessary. This form works best if a copy machine is located at the forward BoO. **Get form on Disasterengineer.org.**

US&R Rigging Action Plan - RAP **Task Force:** **Date:** **Op Period** **Page** **of**

[illegible]

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

CRANE HAND SIGNALS

Rescue personnel must have a basic knowledge of hand signals normally used to communicate with the crane operator.

<h2>CRANE SIGNALS</h2> <p>ALWAYS STAND IN CLEAR VIEW OF YOUR CRANE HOIST ENGINEER</p> <p>BE SURE TO STAY A SAFE DISTANCE FROM HOOK, BLOCK OR BOOM</p> <p>Published by SPECIALIZED CARRIERS & RIGGING ASSOCIATION In accordance with the American National Standards Institute</p>		<h3>HOIST</h3> <p>HOIST: With forearm vertical, forefinger pointing up, move hand in small horizontal circles.</p>	<h3>LOWER</h3> <p>LOWER: With arm extended downward, forefinger pointing down, move hand in small horizontal circles.</p>
<h3>USE MAIN HOIST</h3> <p>USE MAIN HOIST: Tap fist on head, then use regular signals.</p>	<h3>USE WHIP LINE</h3> <p>USE WHIP LINE: (Auxiliary Hoist) Tap elbow with one hand; then use regular signals.</p>	<h3>RAISE BOOM</h3> <p>RAISE BOOM: Arm extended, fingers closed, thumb pointing upward.</p>	<h3>LOWER BOOM</h3> <p>LOWER BOOM: Arm extended, fingers closed, thumb pointing downward.</p>
<h3>MOVE SLOWLY</h3> <p>MOVE SLOWLY: Use one hand to give any motion signal and place other hand motionless in front of hand giving the motion signal. (Hoist slowly shown as example)</p>	<h3>RAISE THE BOOM AND LOWER THE LOAD</h3> <p>RAISE THE BOOM AND LOWER THE LOAD: With arm extended, thumb pointing up, flex fingers in and out as long as load movement is desired.</p>	<h3>LOWER THE BOOM AND RAISE THE LOAD</h3> <p>LOWER THE BOOM AND RAISE THE LOAD: With arm extended, thumb pointing down, flex fingers in and out as long as load movement is desired.</p>	<h3>SWING</h3> <p>SWING: Arm extended, point with finger in direction of swing of boom.</p>
<h3>STOP</h3> <p>STOP: Arm extended, palm down, move arm back and forth horizontally.</p>	<h3>EMERGENCY STOP</h3> <p>EMERGENCY STOP: Both arms extended, palms down, move arms back and forth horizontally.</p>	<h3>TRAVEL</h3> <p>TRAVEL: Arm extended forward, hand open and slightly raised, making pushing motion in direction of travel.</p>	<h3>DOG EVERYTHING</h3> <p>DOG EVERYTHING: Clasp hands in front of body.</p>
<h3>TELESCOPING BOOM TWO HANDS</h3> <p>EXTEND BOOM BOTH FISTS IN FRONT OF BODY WITH THUMBS POINTING OUTWARD</p>	<h3>TELESCOPING BOOM TWO HANDS</h3> <p>RETRACT BOOM BOTH FISTS IN FRONT OF BODY WITH THUMBS POINTING TOWARD EACH OTHER</p>	<h3>TELESCOPING BOOM ONE HAND</h3> <p>EXTEND BOOM ONE HAND SIGNAL: ONE FIST IN FRONT OF CHEST WITH THUMB TAPPING CHEST</p>	<h3>TELESCOPING BOOM ONE HAND</h3> <p>RETRACT BOOM ONE HAND SIGNAL: ONE FIST IN FRONT OF CHEST, WITH THUMB POINTING OUTWARD AND HEEL OF FIST TAPPING CHEST</p>

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

APPENDIX A: COURSE SYLLABUS

ONLINE TRAINING

STRUCTURAL ENGINEERING SYSTEMS LECTURE (Prerequisite)

Go to the United States Army Corps of Engineers website at www.disasterengineer.org

Click on Links

Click on SCT01c Structural Engineering Systems - Web Version

This will take you to the menu

There are five parts, exam, and student manual

Start with part one and view all five parts

You can start, stop, and go back, as you wish

Viewing all five parts will take about four hours

After you have viewed all five parts, take the exam

Click on exam

Take the twenty question multiple choice exam

You must get a score of at least 70% to pass

Upon successful completion of the exam, fill out the information and print out your certificate

If you would like a certification card sent to you from the USACE, follow the information provided in the instructions

POWDER ACTUATED TOOLS (For students being certified to use the SA 270 Powder Actuated Tool)

Go to the Ramset website at www.ramset.com.

Click on Powder Actuated Tool Test and Licensing.

Click on begin the course. Read the course material. At the end of this section, a list of online manuals for Ramset Powder Actuated Tools will appear.

Click on the SA270 manual and read the contents.

Take the exam and pass the color test.

Fill out your information and print out your certificate.



RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN



This class is designed as a three day, 24 hour course. It is divided into six, 4 hour modules. It can be taught as a three day course over three consecutive days or in a modular format over several days.

<u>TOPIC</u>	<u>TIME</u>
ADMINISTRATION - SAFETY Welcome - Introductions - Administration - Safety	2 HOURS
GROUND SCHOOL Powder Actuated Tools Rigging	2 HOURS
SHORING (PNEUMATIC SHORES ONLY) Spot Shore Vertical Shore Horizontal Shore Window Shore Door Shore Raker Shore Sloped Floor Shore	4 HOURS
BREAKING - BREACHING Gallows Coring Tool Stanley Hydraulic Tool	4 HOURS
BURNING - CUTTING Cutting A Tensioned Cable Plunge And Line Cut With All Torches	4 HOURS
LIFTING - MOVING "A" Frame Gantry "O" Course	4 HOURS
CRANES - RIGGING Crane Operations Vertical Rigging And Lifting	4 HOURS

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

APPENDIX B: WORK STATION SET-UP

POWDER ACTUATED TOOLS (1 HOUR)

If students are being certified in the use of powder actuated tools, station 1 and station 2 can be combined into one station.

STATION 1

CENTER PUNCH TEST

■ Objectives

- Understand the purpose and use of powder actuated tools.
- Understand how to perform the center punch test.
- Understand proper safety techniques.

■ Site Requirements

- 20' x 20' minimum working area.
- Poured concrete 4" minimum thickness.
- Pieces of structural steel.
- Concrete / masonry blocks.

■ Equipment List

- Ramset SA270 powder actuated nail gun
- Ramset fasteners
 - ◆ Enough for the instructor to shoot one fastener into each type of material for each group.
- Ramset RS27 10 shot strip loads
 - ◆ Enough for the instructor to shoot one fastener into each type of material for each group.
- Hammer

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

STATION 2

POWDER ACTUATED NAIL GUN (Certification Only)

ONLINE TRAINING

Go to the Ramset website at www.ramset.com.

Click on Powder Actuated Tool Test and Licensing.

Click on begin the course. Read the course material. At the end of this section, a list of online manuals for Ramset Powder Actuated Tools will appear.

Click on the SA270 manual and read the contents.

Take the exam and pass the color test.

Fill out your information and print out your certificate.

Students must present certificate of completion of online training.

■ Objectives

- Demonstrate the proper operation of powder actuated tools.
- Receive certification in the use of specific powder actuated tools.
- Demonstrate proper safety techniques.

■ Site Requirements

- 20' x 20' minimum working area.
- Poured concrete 4" minimum thickness.
 - ◆ Enough for each student to shoot at least one fastener into the material.
- Pieces of structural steel.
 - ◆ Enough for each student to shoot at least one fastener into the material.
- Concrete / masonry blocks.
 - ◆ Enough for each student to shoot at least one fastener into the material.

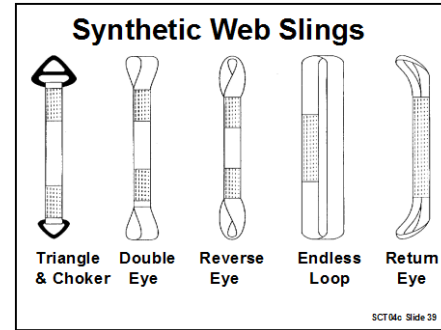
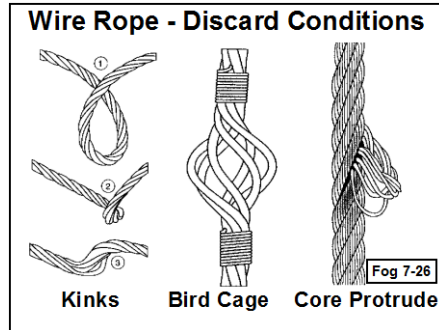
■ Equipment List

- Instructor(s) able to certify students on powder actuated tools being used.
- Printout of online certificate of completion from each student.
- Ramset SA270 powder actuated nail gun
 - ◆ 1 for every 24 students minimum
- Ramset fasteners
 - ◆ Enough for each student to shoot at least one fastener into each type of material.
- Ramset RS27 10 shot strip loads
 - ◆ Enough for each student to shoot at least one fastener into each type of material.
- Any other powder actuated tools and accessories that the agency needs to certify members in the use of.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

RIGGING (1 HOUR)



STATION 1

RIGGING EQUIPMENT

- Objectives
 - Identify different types of rigging equipment.
 - Understand the purpose and use of rigging equipment.
 - Understand effects of critical angles on rigging equipment.
 - Demonstrate the inspection of rigging equipment.

- Site Requirements
 - 20' x 20' minimum working area.

- Equipment List
 - Wire rope slings
 - Synthetic slings
 - ◆ Different sizes and types
 - Lifting chains
 - Shackles
 - Concrete wedge anchor
 - Swivel Hoist Ring
 - Turnbuckle

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

SHORING (4 HOURS)

The Shoring module is divided into four or five stations, depending on how the instructor wants to set it up.

STATION 1

STATIC DISPLAY

■ Objectives

- Identify the components of pneumatic shores.
- Understand the purpose and use of pneumatic shores.
- Understand the limitations of pneumatic shores.
- Understand how to construct a spot shore.
- Understand how to construct a window shore.
- Understand how to construct a door shore.
- Understand how to construct a sloped floor shore (optional if students will construct in this module).

■ Site Requirements

- All shores will be preconstructed and on display.
- Structure(s) adequate for operations of interior and exterior shoring systems that is of sound and safe engineering design.
- Spot Shore
 - ◆ 20' x 20' minimum working area with an 8' minimum ceiling height.
- Window Shore
 - ◆ 36" x 36" minimum window opening.
- Door Shore
 - ◆ 36" wide minimum door opening.
- Sloped Floor Shore (set-up optional if members construct during this module)
 - ◆ 20' x 20' minimum working area with a 12' wide x 12' long sloped surface.
 - ◆ Configured so that the sloped surface is no shorter than 3' in height at the low end.
 - ◆ Slope angle to be at least 6" in 10' (3 deg, 5%) to a maximum of 120" in 10' (45 deg, 100%).
 - ◆ Earth or hard surface

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

■ Equipment List

- 4 x 4's
- 8d Duplex nails
- Hammer
- Shims (optional)
- Pneumatic shoring components for a spot shore.
- Pneumatic shoring components for a window shore.
- Pneumatic shoring components for a door shore.
- Pneumatic shoring components for a sloped floor shore (optional).
- Nailing pads (optional)
- 16d Duplex nails (optional)
- 2 x 6 or 2 x 8's (optional)
- 6 x 6 or 8 x 8 deadman (optional)
- Sledge hammer (optional)
- Pickets (optional)

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

STATION 2

VERTICAL SHORE

- Objectives
 - Construct a vertical shore.
 - Demonstrate proper safety techniques.
- Site Requirements
 - Structure(s) adequate for operations of interior shoring systems that is of sound and safe engineering design.
 - 20' x 20' minimum working area with an 8' minimum ceiling height.
 - Area with simulated or actual joists to set one vertical shore with two posts.
 - Cutting station
 - ◆ 20' x 20' minimum working area.
- Equipment List
 - 2 x 6 or 2 x 8's
 - 4 x 4's
 - 8d Duplex nails
 - 16d Duplex nails
 - Hammers
 - Tool Belts
 - Shims (optional)
 - Pneumatic shoring components for a vertical shore.
 - Cutting table
 - Generator
 - Electrical cord
 - Adapter
 - Circular saw

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

STATION 3

HORIZONTAL SHORE

- Objectives
 - Construct a horizontal shore.
 - Demonstrate proper safety techniques.
- Site Requirements
 - Structure(s) adequate for operations of interior shoring systems that is of sound and safe engineering design.
 - Hallway or door opening with vertical walls that are at least 36" wide.
 - Cutting station
 - ◆ 20' x 20' minimum working area.
- Equipment List
 - 2 x 6 or 2 x 8's
 - 4 x 4's
 - 8d Duplex nails
 - 16d Duplex nails
 - Hammers
 - Tool Belts
 - Shims (optional)
 - Pneumatic shoring components for a vertical shore.
 - Nailing pads (for three post shore only)
 - Cutting table
 - Generator
 - Electrical cord
 - Adapter
 - Circular saw

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

STATION 4

RAKER SHORE

- Objectives
 - Construct a raker shore.
 - Demonstrate proper safety techniques.
- Site Requirements
 - Structure(s) adequate for operations of exterior shoring systems that is of sound and safe engineering design.
 - 20' x 20' minimum working area.
 - 16' x 16' minimum wall.
 - Cutting station
 - ◆ 20' x 20' minimum working area.
- Equipment List
 - 2 x 6 or 2 x 8's
 - 16d Duplex nails
 - Hammers
 - Tool Belts
 - Nailing pads
 - Shims (optional)
 - Pneumatic shoring components for a raker shore.
 - 6 x 6 or 8 x 8 deadman (if required)
 - Pickets
 - Sledge Hammer
 - Cutting table
 - Generator
 - Electrical cord
 - Adapter
 - Circular saw

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

STATION 5

SLOPED FLOOR SHORE (optional)

■ Objectives

- Construct a sloped floor shore on an earth or hard surface.
- Demonstrate proper safety techniques.

■ Site Requirements

- 20' x 20' minimum working area with a 12' wide x 12' long sloped surface.
- Configured so that the sloped surface is no shorter than 3' in height at the low end.
- Slope angle to be at least 6" in 10' (3 deg, 5%) to a maximum of 120" in 10' (45 deg, 100%).
- Earth or hard surface.
- Cutting station
 - ◆ 20' x 20' minimum working area.

■ Equipment List

- 4 x 4's
- 8d Duplex nails
- Hammers
- Tool belts
- Shims (optional)
- Pneumatic shoring components for a sloped floor shore.
- 6 x 6 or 8x 8 deadman (if required)(hard surface only)
- Pickets (hard surface only)
- Sledge Hammer (hard surface only)
- Cross bracing (optional)
 - ◆ 2 x 6 or 2 x 8's
 - ◆ Nailing pads
 - ◆ 16d Duplex nails
- Shovel (earth surface only)
- Sole plate (18" square and 2" thick minimum)(earth surface only)
- Cutting table
- Generator
- Electrical cord
- Adapter
- Circular saw

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

BREAKING - BREACHING (4 HOURS)

STATION 1



GALLOWS

■ Objectives

- Use rotary hammer to breach a 2" minimum inspection hole.
 - ◆ Drill several holes.
 - ◆ Change rotary hammer bit while suspended by rope system.
- Breach concrete while suspended by a rope system.
- Construct a rope system consistent with Rescue Systems 1.
- Identify safety concerns when breaching concrete.
- Demonstrate proper safety techniques.

■ Site Requirements

- 20' x 20' minimum working area.
- Concrete slab 6" minimum thickness.
 - ◆ 1 square foot per student.
 - ◆ Secured perpendicular to the ground.
 - Suitable frame or other method to secure the concrete slab.
- Suitable anchors to support the operation.

■ Equipment List

- Rotary hammer
- 1/2" or 3/4" carbide bits
- Chisel ormoil point bits
- Generator
- Electrical cord
- Adapter
- Hardware and software to construct a two line rope system.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

STATION 2



STANLEY TOOL

■ Objectives

- Set up and operate the Stanley hydraulic power unit.
- Use the hydraulic chainsaw.
 - ◆ Demonstrate a bevel cut for a "lift out".
- Use the hydraulic circular saw.
- Use the hydraulic breakers.
- Identify safety concerns when breaching concrete.
- Demonstrate proper safety techniques.

■ Site Requirements

- 20' x 20' minimum working area.
- Concrete slab 6" minimum thickness.
 - ◆ Four square feet per student.

■ Equipment List

- Stanley hydraulic concrete breaking / breaching system
 - ◆ Power unit
 - ◆ Chain saw
 - Spare chains
 - ◆ Circular saw
 - Spare blades
 - ◆ Breakers
 - Various bits
 - ◆ Hoses
 - Hydraulic
 - Water
 - Adapters
 - ◆ Water supply
 - ◆ Fuel
 - ◆ Oil

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

STATION 3



CORING TOOL

- Objectives
 - Drill 2" core hole in concrete.
 - Use the concrete coring tool.
 - ◆ Gas and electric.
 - Identify safety concerns when breaching concrete.
 - Demonstrate proper safety techniques.
- Site Requirements
 - 20' x 20' minimum working area.
 - Concrete slab 6" minimum thickness.
 - ◆ One square foot per student.
- Equipment List
 - Gas coring tool
 - 2" bits
 - Wrench
 - Gas / oil mix
 - Water supply
 - Electric coring tool
 - Generator
 - Electrical cord
 - Adapter

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

BURNING - CUTTING (4 HOURS)

STATION 1



CUTTING TORCHES

- Objectives
 - Use the oxy/acetylene cutting torch.
 - Use the oxy/gasoline cutting torch.
 - Use the exothermic cutting torch.
 - Demonstrate the proper technique for a piercing / plunge cut with each cutting torch.
 - Demonstrate the proper technique for a line cut with each cutting torch.
 - Demonstrate the proper technique for cutting a tensioned cable or wire rope.
 - Cut a hole in steel for a sling attachment (optional).
 - Demonstrate proper safety techniques.
- Site Requirements
 - Various sizes and shapes of steel.
 - 1/2" wire rope or cable.
 - ◆ Set up in tension
 - ◆ Suitable anchors to set up tensioned cable prop.
- Equipment List
 - Oxy/acetylene cutting torch
 - ◆ Accessories to the oxy acetylene cutting torch
 - Rosebud
 - Oxy/gasoline cutting torch
 - ◆ Accessories to the oxy/gasoline cutting torch
 - Exothermic cutting torch
 - ◆ Accessories to the exothermic cutting torch
 - Cable or wire rope tensioing device

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

LIFTING - MOVING (4 HOURS)

STATION 1



"O" COURSE / "A" FRAME GANTRY



Objectives

- Use levers to lift, move, and lower a heavy object.
- Use pipes as rollers to move a heavy object.
- Use wood timbers as rails.
- Use an inclined plane.
- Use crib beds to lift and stabilize a heavy object.
- Construct a mechanical advantage system with rope and pulleys.
- Construct an "A" Frame Gantry.
- Use proper staffing and commands.
- Demonstrate proper safety techniques.



Site Requirements

- 50' x 50' minimum working area with 20' clear area on each side.
- 3' x 3' x 3' concrete cube.
- Suitable anchors for the "A" Frame Gantry.
- 5' x 8' x 6" minimum concrete slabs.
- 30" high minimum concrete barriers.

RESCUE SYSTEMS 3

STRUCTURAL COLLAPSE TECHNICIAN

LIFTING - MOVING (4 HOURS)

STATION 1



CRANE OPERATIONS / VERTICAL RIGGING AND LIFTING

- Objectives
 - Accurately calculate load weights.
 - Find the center of gravity of different size loads and irregular shaped objects.
 - Use different methods to rig wire rope slings on a load.
 - Use different methods to rig synthetic slings on a load.
 - Properly use shackles in rigging a load.
 - Rig loads of different sizes and shapes.
 - Become familiar with different types of cranes.
 - Understand how to set up a crane.
 - Demonstrate proper crane hand signals.
 - Demonstrate proper safety techniques.
- Site Requirements
 - Two (2) working areas of 30' x 30' minimum.
 - 14 ton crane minimum
 - Concrete cube
 - Concrete slab
 - Solid concrete cylinder
 - Irregular shaped objects
- Equipment List
 - Cribbing
 - Wedges
 - Wire rope slings
 - Synthetic slings
 - Shackles