RESCUE SYSTEMS 2 Advanced Rescue Skills







INSTRUCTOR and STUDENT MANUAL

November 2009



Advanced Rescue Skills





Advanced Rescue Skills

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Credits and References



COURSE REFERENCES

Bob de Benedictis, Inc. *Bob's Rigging & Crane Handbook, 4th Edition*

California Department of Forestry & Fire Protection, Robert Tooker

Metal Cutting & Welding

California State Fire Training and Education

Rescue Systems One Manual Rescue Systems Two Manual

City of New York Fire Department *Torch Operations Manual*

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Rigger's Pocket Guide

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NFPA 1670 Operations and Training for Technical Rescue Incidents

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FEMA National Urban Search and Rescue Response System

Structural Collapse Technician Training Manual

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STATE FIRE TRAINING MISSION STATEMENT (SFT HAS THIS DOCUMENT)

REFERENCES – CREDITS – CONTRIBUTORS – TEXTS

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Topic 1-1: Administration and Introduction

Topic 1-1: Administration and Introduction

Terminal Objective: At the conclusion of this topic the student shall have received all information regarding course administration and operational requirements for successful completion.

Enabling Objectives:

- Students shall receive an introduction to all instructors and support staff.
- Students shall receive instructions on starting times and attendance requirements for successful completion of the course.
- Students shall receive information and the necessary paperwork to complete all administrative processes required for successful completion including:
 - 1. Access to course critiques
 - 2. Testing procedures
 - 3. Paperwork and process for injuries
- Students shall receive an overview of the criteria for successful completion of the course.
- Students shall receive an overview of the student manual and its contents.
- Students shall be broken into squads for operational periods. Squads shall be assigned to a division for rotation periods.
- Students shall have the opportunity to introduce themselves, if applicable.
- Students shall receive a schedule of events and rotation times, course agenda, and locations of specific events.

Administrative Matters

- A. Welcome and introduction of instructors and students
- B. Starting times, attendance requirements, and testing requirements
- C. Rotations and squad/division assignments
- D. Contact numbers for emergencies and review of emergency/medical plan
- E. Site rules and facility familiarity
- F. Paperwork requirements



Advanced Rescue Skills

Topic 1-1: Administration and Introduction



Course Overview and Requirements

- A. This course is designed to provide students with the knowledge, skills, and abilities they need to successfully obtain certification.
- B. Specific requirements must be met by each student in order to obtain a certificate of completion of the course curriculum.
 - 1. Show up on time, work as a team member, and remain safe.
 - 2. Successfully complete all practical station rotations.
 - 3. Successfully demonstrate all skills as outlined on the practical skills check lists.
 - 4. Obtain a passing grade on the comprehensive evaluation.
 - 5. Successfully participate in and complete the field exercise at each work station.
- C. Each student is continually evaluated during classroom and field sessions. Instructor observations coupled with specific passing criteria are all taken into account in evaluating a student's success.
- D. Certain prerequisites are required for the class:
 - 1. Low-Angle Rope Rescue
 - 2. Rescue Systems 1
- E. Additional knowledge, skills, and abilities (KSAs) that are necessary in gaining full competencies to respond to technical rescue incidents are outlined in NFPA 1670 Training and Operations for Technical Rescue.
 - 1. Confined space awareness, operations, and technician
 - 2. Trench rescue awareness, operations, and technician
 - 3. Water rescue awareness
 - 4. Hazmat operations
 - 5. ICS 100, 200, 700, 800



Advanced Rescue Skills

Topic 1-1: Administration and Introduction



Student Manual

- A. Each manual has been set up to provide students with the information they need to successfully complete this course.
- B. Each student shall be evaluated on skills at each work station. Final class evaluation will be completed per SFT requirements.

Safety Issues

A. Safety is the responsibility of the individual, the team, and the lead instructor. Practice safety at all times.

If at anytime a student, instructor, or safety officer sees an imminent safety hazard that may result in injury, the command or activity shall be <u>stopped</u>!

- B. Any injury, no matter how minor, shall be reported to the lead Instructor for the module for proper care and documentation.
- C. Students and instructors will wear all necessary personal protective gear during training evolutions, including but not limited to:
 - 1. Helmet
 - 2. Primary eye protection (when applicable)
 - 3. Long pants
 - 4. Long sleeves (recommended)
 - 5. Steel-toed boots
 - 6. Leather work gloves
 - 7. Hearing protection (when applicable)
 - 8. Respiratory protection (where applicable)
 - 9. Knee and elbow protection (where applicable)
 - 10. Dust masks (at least 10) or half-face APR
 - 11. Foul weather gehhand washing methods must be used.
- D. No smoking on site.
- F. Students and team leaders should ensure everyone stays hydrated.
- G. Students should always be aware of their surroundings including the following:
 - 1. The potential for tool movement and reaction
 - 2. The potential for concrete or steel movement
 - 3. Keeping hands and feet from pinch points



Advanced Rescue Skills

Topic 1-1: Administration and Introduction



- 4. Communicating with squad personnel to ensure operations are understood
- 5. Shifting or moving overhead loads
- 6. Flammable materials and products
- 7. Vehicular and heavy equipment movement on site
- 8. Electrical safety
- 9. Personal and team member fatigue
- 10. Fall hazards
- 11. Slip/trip/water hazards

Conclusion

- A. Questions?
- B. If you find yourself with any questions or concerns, please address them to your lead instructor.



Advanced Rescue Skills

Topic 1-2: Safety



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 (Lookouts, Communications, Escape routes, and Safe zones).
- Be able to perform a risk hazard analysis for a specific event and suggest actions to minimize risks and eliminate hazards.
- Understand issues related to personal and team security zones as a planning tool.
- Understand the importance of safety risk and hazard identification.

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 is vital to the accomplishment of that mission. Hence the reason for this course.

- Safety is a situation-dependent issue.
- Safety is most importantly an attitude. That attitude needs to be very positive 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 that 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, it will face the probability of many challenges and multiple rescues over extended periods of time. So, stay healthy, share lessons learned, and be safe.

Advanced Rescue Skills



Topic 1-2: Safety



Mission Response Operations

Risks and Hazards

Response team personnel conducting SAR 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 tripping hazards
- Falling material or flying objects
- Exposure to Hazmat
- Decontamination
- Exposure to smoke, dust, and other air pollutants
- Fire and explosion
- Excessive noise
- Electrical hazards
- Confined-space operations
- Oxygen-deficient atmospheres
- Contaminated air, water, and fuel
- Electrocution from damaged utilities
- Dangerous equipment
- Armed thieves and looters
- Fitness for duty
- Excessive fatigue, lack of sleep
- Food services
- Adverse weather
- Stress
- Security
- Safety equipment
- Escape routes
- Safety zones
- Personal hygiene
- Hydration



Advanced Rescue Skills

Topic 1-2: Safety



Safety Planning

Identify the Safety Officer

The Safety Officer for the operational period will be identified so as to leave no doubt who is filling that position. The Safety Officer will pass on information from the previous operational period from the Safety Officer being relieved.

The Safety Plan

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 and all team members must acknowledge those changes. Those changes affecting 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 signals for immediate evacuation, cease operations, and resume operations. It will also identify the area designated for assembly in case of emergency evacuation.

LCES

The multihazard Safety Plan is a guide to the basic elements of safety for a variety of incidents. The acronym is LCES, which stands for Lookouts, Communications, Escape routes, and Safe zones. In any operations scenario these areas must be addressed to ensure the safety and accountability of all response-team members.

 \blacksquare 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. The Safety Officer is free to watch over the entire operation, identifying potentially dangerous situations and mitigating them before they become disastrous.

- Several categories of Safety Officer exist.
- One is the overall Safety Officer for the response team.
- A second is a site-specific Safety Officer who may be a person or team assigned to a single location to monitor the existence of a special hazard. Examples of this are 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 upslope to serve as early warning 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 could limit their ability to be an 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 with this responsibility must resist the temptation to become involved in the tactical operation itself. This requires extreme self-discipline. Remember that the success of the mission depends upon the ability to counteract hazards before they become problems.

Advanced Rescue Skills



Topic 1-2: Safety



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 short blasts
 - Cease Operations 1 long blast
 - 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. During the safety briefing, before beginning to work, identify the specific methods of signaling that will be used at the work site should a problem arise during that operational period.

E - Escape Routes

An escape route is a preestablished 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 if often dynamic, constantly changing. This can occur as a result of external forces or the rescuer's action. The escape plan should be constantly updated to reflect changes in the 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 preestablished 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 for rescuers themselves.

- An example of this is when a victim is trapped inside a collapsed structure and rescuers crib and shore the immediate area. In this case, the proper response for rescuers would be to hold their position during an aftershock.
- 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 percent accountability in the event of an emergency.



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Topic 1-2: Safety



Risk Assessment Components

- Damaged infrastructure (including 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 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.
- Air Transportation
 - One method of travel that may be used by response teams is helicopter. A word of caution: Be sure to receive a preflight safety briefing before boarding and follow instructions furnished by the pilot or loading supervisor.
 - Remember, 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 team members can communicate during flight.

Ground Transportation

Response teams, in general, have a long way to go toward 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 team with assigned vehicle.
- Conduct maintenance checks each day.
- Maintain adequate fuel levels.
- Travel in convoy when possible.
- Properly identify vehicles.
- Red tag unsafe vehicles.

Secondary Collapse from Explosions

- With the constant threat of terrorist attacks, it is essential that response teams pay special attention to a new and potentially deadly threat. Secondary explosions are becoming common techniques, used to cause serious injury and possibly mass death 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.

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Topic 1-2: Safety



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 affected by such events and take necessary precautions while conducting their operations.
- Many injuries and deaths of first-responders could be prevented if more precautions against additional shock waves were taken.

Unfamiliar Surroundings

- Traffic directional signs and other landmarks may not survive the disaster impact. Traditional road maps might not be valid following a major disaster. Extra care must be taken to avoid accidents 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 the required safety gear when working in the affected area.
- An injury during the mission becomes a team liability, which may prevent the completion of the entire assessment task.

Fall or Tripping Hazards

Trip hazards are a common cause of falls resulting in injuries. This problem or hazard is commonly found in the Base of Operations (BoO) and work site. In most cases, these problems can easily be mitigated once identified. Some common trip hazards are:

- Downed wire
- Electrical cord
- Holes
- Uneven sidewalks/roads
- Protruding rebar

Falling Material or Flying Objects

- Displaced material may be everywhere—aftershocks or winds may cause displaced objects to become airborne.
- Eye and head protection is 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 aerial medical evacuation.
- Contact lens wearers are especially vulnerable. Responders with contact lenses should bringing an extra pair of glasses.

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Topic 1-2: Safety



Exposure to Hazmat

- There is a significant risk of exposure to hazardous material during a 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 of Hazmats are underground pipelines, 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.
- Protective equipment includes at least gloves, mask, and eye protection.
- 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.

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 things to consider are:

- Reenergizing power grids
- Improper electrical cord for current requirements
- Jury-rigged connective boxes
- No weather protection
- Power line backfeed (generators)

Confined-Space Operations

Oxygen-Deficient Atmospheres

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.
- Dangerous Equipment (i.e., cranes)

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Topic 1-2: Safety



Fitness for Duty

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

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 quickly.
- Special precautions for monitoring food stock have to be followed. There is nothing more dangerous than a stale sandwich made with 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 team members are prepared for any kind of weather change prior to leaving their point of departure. A weather change that the team is ill equipped to handle could jeopardize successful and timely completion of the mission.
- Gear for rain and cold weather, 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 assessment.

Security

- Don't count on a disaster area always 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. In these situations, uniformed personnel may be targeted by undesirables seeking to take advantage of the damaged infrastructure.



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Topic 1-2: Safety



- 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 potentially hostile situations.

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 victims can contract pneumonia as a result of inhaling these particles.

Doctors have calculated the danger of inhaling small amounts of toxic materials (i.e., asbestos) over a period of 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.

The following is the description, function, and limitations of the respiration protection devices available to the rescue specialist:

Dust Mask

A simple paper or cloth mask that fits over the mouth and nose to filter out nontoxic particles will NOT filter out toxic materials and cannot be used in toxic environments or in an oxygen-deficient atmosphere where the oxygen level is less than 19.5 percent.

Respirator

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

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. SCBA is bulky and can be difficult to use in confined spaces. When low on air, the bottle must be recharged or replaced. SCBA is portable to the rescue site and is not tied to an external air source.

■ Supplied-Air Breathing Apparatus (SABA)

SABA supplies air to the wearer for virtually unlimited amounts of time via an air source (large bottles or 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 air supply tank in case of emergency. This emergency supply is rated at 10 minutes, but may deliver only from 2 to 3-1/2 minutes of air, depending upon the exertion rate of the wearer.



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Topic 1-2: Safety



SABA is not as bulky as SCBA and is easier to use in confined space, but the rescuer is limited in distance by the length of line and, most importantly, by the time to escape in the event the emergency air supply is needed.

For confined space entries, SCBA or SABA will be used if atmospheres are toxic or the oxygen levels are below 19.5 percent. Rescuers 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.

Monitoring Devices

Ensure that appropriate monitoring equipment is available and used to support on-site operations including:

- Atmospheric monitoring devices for checking toxic and oxygen levels
- Structural stability monitoring equipment for determining movement of buildings

Rescue Tools And Equipment

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

- Personnel should use only tools 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 for only their designed purpose. Failure to do so will add a victim to the rescue and take a tool out of service.
- Anticipate the consequence 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. 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 operations. Whenever possible, rotate rescue tools to provide for on-site inspection and maintenance.
- Provide hearing protection to rescuers and victims to protect them from excessive noise levels (greater than 90 decibels). Provide victims with helmet, goggles, blankets, or other protection when necessary. Advise them of your operation before starting. This will help prepare them for what will follow. Allow victims to participate in their own rescue; do not treat them like a rescue mannequin. Do not be surprised if victims come 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.



Advanced Rescue Skills

Topic 1-2: Safety



Safety Equipment

- All response team members must take personal responsibility to ensure that when they are deployed they have appropriate safety equipment assigned to them.
- Rescuers are responsible for the accountability of such property. The response team equipment cache may have additional equipment and supplies for expendable items.
- The following items, at a minimum, should be with the team member at all times:
 - Safety boots
 - Respirator
 - Helmet/headlamp
 - Spare batteries
 - Ear and 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:
 - Providing feeding and hydration at the Base of Operations (BoO) and at the work site
 - Keeping sleep and rehab areas free of unnecessary negative health exposures
 - Establishing hand wash stations wherever possible
 - Establishing and enforcing canine relief and rehab areas

Hydration

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





Advanced Rescue Skills

Topic 1-2: Safety



Safety Concerns During Mobilization

Safety concerns during mobilization include:

- Current physical fitness assessment
- 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-hour, multiple-day operation soon leads to fatigue and increases the chances of injury to team members. Proper shift length needs to be enforced and appropriate rehab facilities should be provided, if possible. These facilities (i.e., tents, buildings) 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 and cell phones
- Aircraft overflights
- Public-address systems
- Noise from generators



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Topic 1-3: Survival



Topic 1-3: Survival

Terminal Objective: The student shall understand the phases of a large disaster and how the US&R resources are most commonly deployed to perform its initial tasks.

The following is a guide to survival for a 24- to 48-hour period. If for any reason an individual or small group is isolated from your support system, this information may aid in their safe return. It is not comprehensive, nor is it intended to be. There are many books on the subject of survival for further study.

Survival priorities are listed in descending order, with attitude topping the list.

Attitude

- The will to survive and a positive attitude are the most important attributes in survival. The key is not to panic when confronted with separation or isolation. Keep calm, assess the situation, and do something, anything, to positively affect your survival outcome.
- Address only ONE survival problem at a time. If you were to look at everything at once, the task of surviving could seem overwhelming.
- Conserve strength, fluids, and heat. Prepare emergency signals, make shelter, inventory supplies, ration all food. Guard against infection and intestinal disorders. Do not travel in adverse weather. View the experience as a challenge.

Shelter

- Shelter is the most critical necessity in a survival situation. You can live for days without water, weeks without food, but only a few hours exposed to a harsh environment. You can build a good shelter without the aid of knife, blanket, or anything but your bare hands almost anywhere on the continent.
- Look for these components:
 - Protection from weather—Select a place away from wind, rain, snow, and glaring sun. Locate your shelter on the lee side of incoming weather systems.
 - Protection from natural hazards—Keep an eye open for avalanche slopes, overhanging dead limbs, trees that might blow down in the wind, or rock formations that could collapse. Either break them down or select a new location.
 - Dry, well drained area—Locate your shelter away from valleys, washes, troughs, and depressions.
 - Open, southern exposure—Do not build in thick woods. Preferably build at the edge of a clearing with a southern exposure where the sun provides the longest-lasting heat and light.
 - Entryway facing east—Eastern exposure takes greater advantage of the warming rays of the sun.
 - Fire safety—Locate your shelter away from cooking or signaling fire.
 - Plant and animal hazards—Avoid everything from poison oak, to ant nests, to bear dens!
 - Abundance of materials—Pick an area with plenty of resources.
 - Comfort—Find an area free of sharp rocks or other debris.

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- Shelters are best built not too large. The main purpose of the shelter is to keep your body's internal fire burning with as little heat loss as possible. The smaller the shelter, the less energy it takes to keep it warm.
- Insulation between the ground and the body is essential for survival. Preventing heat from being conducted out of the body into the ground is important for anyone sitting or lying on the cold ground. Almost any light, dry, airy, soft debris laid out in a pile will do. Plastic sheeting can be used as a moisture barrier between the ground and the insulation.
- Any natural shelter will do to temporarily get you out of the weather. These are caves, rock outcroppings, or whatever you can squeeze into.
- The simplest shelter to build is the debris hut. Place one end of a large strong branch (ridgepole) on top of a tree stump, fallen log, or medium-size rock. Prop other gathered branches along both sides of the ridgepole to create a wedge-shaped ribbing effect. The space created in between should be large enough to accommodate your body, but steep enough to shed off moisture. Place finer sticks and brush crosswise to make a latticework that will keep junk from falling through the ribbing. Now heap on a pile of light, dry, airy, soft debris. To check thickness, work your arm through the debris to the ribbing. Debris should be to your armpit. In cold weather, add another foot or two of debris.

Outerwear

- Loose-fitting clothing improves insulation, ventilation, and circulation. You can add insulation to clothes by stuffing them with dry grass or leaves. Sleeping in your clothes holds moisture and chills the body. You will not freeze to death in your sleep; the cold will awaken you.
- Layering clothing is the best way to prepare for a variety of conditions. The three essential layers are underwear, insulation, and shell. Different combinations will enhance your comfort throughout changes in weather and exertion.
- The first layer is underwear. It should provide basic insulation and move moisture away from your skin, thus preventing chill when activity ceases.
- The second layer is insulation. These garments provide additional warmth. The weight of the material should be considered in relation to weather and activity.
- The third layer is the outer shell. This layer insulates against cold and protects against snow, wind, and rain. Shells can be wind- and rainproof, depending on need. Good fit is crucial. If you are wearing your shell in a cold climate, allow room for your insulating clothing layers underneath. If a parka is too big, heat loss can occur rapidly. Pay close attention to vents and closures, such as cuffs, hoods, and zippers. They should seal tight and open freely to allow you to adapt easily to changing conditions.
- Not all shells accomplish the same job. Coats made of Gore-Tex-type material laminated to durable nylon are then treated for water repellency and the seams are sealed. This type of shell is waterproof and allows your body to breathe by wicking moisture away from your skin but retaining body heat.
- Remember to plan head to toe. Pants are just as important as a jacket for total warmth, and a hat is crucial for staying truly warm. Gloves, neck gaiters, balaclavas, hoods, and headbands further insulate you from the cold.



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Water

You can survive ten days at 50°F. with no water. However, you need three to four pints a day to maintain good health. Most of this can come from food sources. There are a variety of additional sources where water can be found. In the desert at 120°F. in the shade, expected survival without water is only one to two days.

- Rainwater—Collect all you can. Set up plastic sheeting at an angle to catch rain and funnel to bottle, bucket, or cup. Spread out a blanket and wring it out. Set out cups, buckets, anything to catch whatever you can. Look for standing water in depressions of rocks, etc. Water can be collected from dew in a similar fashion.
- Snow/Ice—Eating raw snow can cause dehydration. Ice is preferable to snow. It takes 50 percent less fuel to melt ice. Snow can be melted by holding it in your hand or packed in a can over the fire.
- Tropics/Swamp—Standing water is usually unfit to drink and streams are too muddy. Dig a hole 1' to 6' from the shore, let the water filter in, strain and purify.
- Ocean—Saltwater kills from dehydration one to two days faster than no water at all. At the beach, dig a hole below the high tide line and use the first water seeping in—deeper water is salty.
- Arid Lands—Avoid a water hole where green vegetation doesn't grow. It is probably poison. Look for water where green vegetation does grow and low places in the outside bend of dry creeks (dig hole, wait two hours), at the base of cliffs, hills, mountains, canyon heads, rocky plates, and low places between dunes. All cactus in the world is safe. Mash the core to extract the liquid. Small barrel cactus and yucca are the best. PURIFY all arid land water.
- Solar Still—Select an open, damp place. Dig a hole 3' deep. Place a cup or container capable of holding water in the center of the hole. Cover the hole with a 6 x 6-foot piece of plastic sheeting. Seal the edges of the plastic sheeting with rocks and dirt from the hole. Place a rock in the center of the sheeting directly over the container. The sheeting should angle toward the container. Moisture from the ground is collected on the underside of the sheeting, runs toward the lowest point, and drops into the container. To help saturate the hole, add pieces of vegetation or urine. This method can collect about one quart in two hours. Make sure the container is large enough to collect all the liquid. The water collected in this manner is safe to drink without any further purification.
- Purification—According to the federal Center for Disease Control and Prevention in Atlanta, no surface water in the world is guaranteed free of the microscopic cysts responsible for the parasitic condition called giardiasis (giardia). It is not fatal in healthy adults, but it is an unpleasant and debilitating illness. Another parasite, crystosporidium, similar to giardia is highly resistant to chlorine. Symptoms of giardia are a sudden onset of explosive diarrhea, nausea, vomiting, lack of appetite, headache, and a low-grade fever. These occur seven to ten days after ingestion of the parasite
- Purification of collected water is a matter of your survival. Treat all backcountry surface water streams, lakes, and waterfalls. Headwaters of streams are not even safe. Even treat municipal drinking water in developing countries.
 - Boil water for 20 minutes and let stand for 30 minutes and strain. Boiling with charcoal helps remove the bad taste. It kills bacteria and cysts, but does not affect toxic chemicals or pesticides.
 - Good filtration systems remove harmful bacteria, cocci, protozoa, cysts, fungi, and parasites. They are small, lightweight, and effective.



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Fire

- Build fires away from grass, trees, and overhead snow. Clear duff to bare mineral soil. Start with tinder—shaved dry twigs, leaves, or needles. Once a flame is going, stack small fuels. As fire increases, place larger fuels on top.
- Build a small fire, sit close. To keep warmer, sit between fire and a reflective surface (e.g., a large rock).
 Sleep with your feet toward fire.

Travel

- Your best bet is to stay put. If you or your group is reported missing, the search will begin at your last known location.
 - Travel in the snow uses five to ten times more energy than staying put.
 - Travel in the desert during the day rapidly dehydrates your body. In the desert, stay in the shade during the day and travel only at night when temperatures are lower.
 - Travel in the tropics only during the day.
- Follow ridgeline trails and streams. But stay out of the streams—too many critters!
- Dense aerial canopy deadens sound, limits light, blocks radio waves, and renders signaling useless.
- Build shelters above ground.
- Straight-line travel is best. Traveling downhill along a watershed may triple the distance. The use of a compass will aid in this endeavor.

Orienting

- By Watch—Hold the watch level and point the hour hand at the sun. South is midway between the hour hand and the number twelve in the smallest angle. South of the equator, read with face down and the midline will point North.
- By Shadow—Put a long stick in the ground. Mark the tip of the shadow and mark the tip of the shadow an hour later. A line from the first point to the second points East.
- By Stars—Stars rise in the East and fall in the West. If a star is rising is on your right, you are facing North.

Signaling

- Mirrors—Reflection is seen long distances. Signal even though you do not hear aircraft or vehicles. It may be spotted.
- Fires—In the daytime, make your fire very smoky. Use fuel oil or wet fuels. In the nighttime, make your fire large and bright.
- Sound—Sound travels over great distances and farther at night. Use whistles or other methods of making noise rather than yelling. Conserve as much energy as possible. Sound direction can be confusing as it seems to come from several directions when reflected off natural barriers.

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Physical Considerations

- HYPOTHERMIA—Individuals suffering from hypothermia will tend to lose consciousness. Awareness becomes clouded as body temperature approaches 90°F. and unconsciousness generally occurs at 86°F. Pulse slows and becomes irregular. Skin is pale. Pupils are constricted and react poorly to light. Respiration is slow and labored. The victim may appear intoxicated. Shivering becomes severe. Delay in treatment may cost a life. Treatment consists of removing clothing, if wet, and replacing with dry clothes. Warm the victim rapidly, but do not burn or overheat. The victim should take nothing orally. Monitor respiration. Treat for shock. If available, administer intravenous fluids.
- HIGH ALTITUDE—The reduced amount of oxygen at high altitudes may have adverse effects on any preexisting medical problems. Acute Mountain Sickness or AMS is a syndrome that can range from mild headache to incapacitating illness. Although it generally occurs when one sleeps at altitudes above 8,000 feet, symptoms can develop in some people at the 6,000-foot level. Symptoms are headache, nausea, insomnia, fatigue, lack of appetite, and light-headedness. Generally, symptoms will improve with rest and fluids over 24 to 48 hours.
- DEHYDRATION—Dehydration occurs more frequently in areas where the humidity is very low. Dehydration depletes energy, causes headaches, and affects performance. The rule of thumb is to drink enough fluid to cause urination at least every three hours. Take frequent water or fluid breaks during vigorous activities.
- EXPOSURE—Avoid exposure to the cold resulting in frostbite and avoid exposure to the sun resulting in sunburn.
- FOOD—Since this document provides some survival strategies for 24 to 48 hours, food should not be a factor. However, if your predicament lasts considerably longer, ALL healthy mammals, birds, freshwater fish, and insects are edible. Be sure to cook all flesh.

List of Essentials

- Essentials to be carried in potential survival situations:
 - Water and emergency food
 - Map
 - Compass
 - Flashlight/headlamp with extra bulbs and batteries
 - Extra clothing (for season and location)
 - Sunglasses
 - First aid supplies
 - Knife
 - Waterproof matches or fire starter
 - Toilet paper
 - Whistle
 - Emergency space blanket
 - 50' of nylon cord
 - 6' x 6' sheet of plastic
 - Wet wipes



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- Other items to consider:
 - Sun screen
 - Bactine
 - Insect repellent
 - Medications (pain killer and antihistamine)
 - Signal mirror
 - Water purification filter
 - Moleskin
 - Eyedrops
 - Prescription glasses or magnifying glass
 - Plastic trash bags (large)

Rule of 3's in Survival

- You may die in:
 - 3 minutes without AIR
 - 3 hours without SHELTER
 - 3 days without WATER
 - 3 weeks without FOOD



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Topic 1-4: Search Capabilities



Topic 1-4: Search Capabilities

Terminal Objective: The student shall understand the recon strategies that should be employed to produce the best results for finding the most victims.

Introduction

- Search and Rescue operations in the urban disaster environment require close interaction of all task force elements for safe and successful victim extrications.
- Search operations will be initiated early in the mission and could continue until stand-down, since as the structure is accessed, parts removed, etc., re-searching will be required.
- Successful search requires that the victims be **detected** and then efficiently **located**. There are many methods and types of equipment that can be used in the search; many can perform both of these functions. However, some are more efficient at **detection** and some are most often used to **locate** victims.
- All US&R team members need to understand the advantages and disadvantages of each tool in order to enhance the functioning of all operations.

Search Strategy and Prioritization

- In the past, the search function has been used, at least partly, to initially prioritize a group of buildings. Since an adequate search may take several hours, it is essential to use some other logical method to prioritize the structures if a large number are involved.
- The current approach is to use a simple, commonsense, numerical method (triage) to sort the buildings so those that have the greatest chance of yielding positive results (most saves in the shortest time) will be given highest priority.
- This initial prioritization may have taken place prior to the arrival of US&R resources at a specified area.
- Triage may be performed by US&R members if they are assigned to an area that contains many collapsed structures or it may be used to sort the sections of a very large building complex.

Reconnaissance Team

- Once a priority has been established, the US&R teams would deploy a nine-person search and recon team, staffed as follows:
 - Search Team Manager (1) functions as search/recon team supervisor, sketches and records information, and communicates details and recommendations back to the Task Force Leader.
 - **Canine Search Specialists** (2) conduct canine search operations and redundant verifications of alerts.
 - **Technical Search Specialist** (1) conducts electronic search operations including acoustic/seismic listening devices and electronic viewing equipment.
 - **Medical Specialist** (1) provides medical treatment for search/recon team members and recovered victims.
 - **Structures Specialist** (1) provides advice regarding building stability, shoring, stabilization, access, victim location, and hazard assessment and marking.

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- **Hazardous Materials Specialist** (1) monitors atmospheres in and around voids and confined spaces; assesses, identifies, and marks hazardous materials dangers; works with Structure Specialist regarding hazard assessment and marking.
- **Rescue Specialists** (2) provide assistance to the search/recon team including drilling/breaching for electronic viewing equipment and deployment of listening arrays.
- The following operations should be conducted by the search and recon team:
 - General area/building search, reconnaissance, and evaluations
 - Structure I.D., structure/hazard evaluation and marking, search assessment and marking
 - · Assessment of general atmospheric conditions in/around confined spaces or voids
 - Primary Search, followed by more detailed Secondary Search, as appropriate for the given situation, including canines, electronic devices, search cameras, and physical search operations to provide detection and location of victims
 - Victim location identification and marking the exact location with International Orange spray paint or orange surveyors tape
 - Sketching the general search area and noting all significant issues
 - Communicating findings and recommending priorities back to the Command Post
- Specific equipment and materials are necessary to fully support a deployed search and recon team. This equipment should be segregated and receive priority consideration when a task force cache is being moved to an assigned location. It should be immediately available in order to deploy one or two search and recon teams in a timely manner. The following equipment and supplies are required:
 - Electric hammer-drills (preferably battery-operated; if not, then a small electric generator, fuel + cord)
 - Electronic viewing equipment (search camera, fiber optics)
 - Electronic listening devices (acoustic, seismic, etc.)
 - Atmospheric monitoring equipment (flammable, toxic, N.B.C.,oxygen-deficient)
 - Marking materials (orange spray paint/surveyors tape, fire line tape, etc.)
 - Alerting devices (bullhorn for hailing, aerosol horns for emergency signaling)
 - Medical pack (physician or paramedic backpack)
 - Personal gear (per person safety equipment, food, water, etc.)



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Topic 1-4: Search Capabilities

Review of Search Tools and Tactics

The following outlines the current tactics available for locating trapped victims (usually from collapsed buildings of reinforced concrete construction) and their corresponding advantages and disadvantages. No single tactic is sufficiently effective on its own to ensure that a complete search has been conducted. The most effective search strategy should blend all viable tactical capabilities into a logical plan of operation.

Physical Void Search (visual/vocal)

- In most incidents, a basic physical void search has been done by neighbors, passersby, or first-responders. To conduct a thorough physical search, US&R members should be deployed in a grid pattern over the collapse site. They should make separate visual assessments in voids and confined space areas for any indication of victims. They may also be used in a coordinated fashion as an array of listeners. A bullhorn or hailing device can be used to provide direction to trapped victims. The area is then quieted and the personnel listen and attempt to pinpoint the location of the noise.
- This operation is less exacting than the others and poses a significant risk to the personnel involved in the operation.
- Advantage: Does not necessarily require specialists, canines, or sophisticated electronic equipment. People could quickly be trained to support the effort.
- Disadvantages
 - Hampered by limited access to all voids in building
 - Requires proximity that may be dangerous to search personnel
 - Will not locate unconscious, physically weak, or very young victims

Audible Call-Out Method (rescue hailing method)

- Since frequently the voice of the victim cannot be heard, a method of calling out to them with a request for knocking may be successful. Again, an array of listeners in a grid pattern can be used to help pinpoint the victim's location.
- Advantages
 - Same as Physical Void Search
 - Can inform victim of expected response
 - Can be modified and used in conjunction with listening devices
- Disadvantages
 - Unconscious, physically weak, or very young persons cannot be detected
 - Sound of knocking possibly too weak for audible detection



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Fiber Optics

- Fiber-optic viewing equipment provides another, and more advanced, capability for the search tool box.
- The flexibility and the small diameter of the fiber-optic bundles make the flexible fiberscopes very appealing in extremely tight spaces. The technology has been advanced primarily for medical applications where fiber-optic systems are used to view an operation and the walls of the heart, veins, intestines, etc. The picture resolution is limited by the number of fibers in the bundle. Light can be brought in and the picture will return through the same bundle. Eyepieces, cameras, light sources, and articulation are all available. Most fiberscopes have four-way articulation of the tip. Diameters range from 2.4 to 13 mm. Long high-resolution fiber bundles can become very expensive.
- This equipment, especially when used in conjunction with concrete hammer/drills, is quite effective at pinpointing the exact location of victims. However, it may also be used for general void searches within collapsed buildings. Experience has shown that success is achieved when rescue personnel have drilled an array of holes (in a floor space, for example) and an operator subsequently follows with the fiber-optic device to make quick assessments through them.
- This equipment is convenient to use when cutting/breaching near a victim and offers ease of operation once personnel are fully trained. The most difficult aspect to master is the determination of which direction one is viewing when the instrument is inserted into a drill hole or void opening. This requires consistent training.
- Because of its actual visual indication of a victim, no redundant check is usually required. If the operator is required to move on for subsequent operations, the site should be marked with red tape to indicate a live victim. In addition, the specialist should sketch the general features of the structure/area being searched, noting any significant information on the sketch for future reference.
- Alternatives to flexible fiberscopes are rigid fiberscopes. These devices have been in use for a long time. As the name implies, they are used mainly to explore, through bored holes, mechanical devices such as aircraft engines, castings, and pipes. These devices consist of straight tubes with lenses, mirrors, or prisms on the ends. Because no fibers limit the resolution, picture quality is very high and cost is moderate. Limited articulation is available. Brightness, color, and resolution are excellent, especially when used with high-intensity light sources. Tactics are similar to fiber-optic search, since this tool is used mostly to locate victims.

Advantages

- Provides the general position and condition of the victim
- Can be used to verify other search tactics prior to commencing rescue operations
- Can be used to monitor victim during rescue operation
- **Disadvantage**: Extended or inaccessible voids (observation holes) cannot be viewed due to the inflexible nature of the fiber-optic cable and the limited light source.



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Search Cameras

- Recently, cameras have been designed specifically for search and rescue applications. Tactics make use of available holes and openings to look inside voids, or holes can be drilled to allow camera access. This item is a very important tool for close-in search. It can be used for **detection**, but is most often used to **locate**, communicate with, and assess to condition of the victim.
- Search CamTM is a pole-mounted, 1.75"-diameter camera specifically designed for urban search and rescue. The camera itself is remotely movable over a +/-90° angle. A CRT monitor, either black/white or color, displays a television-like picture in front of the operator. Typically, a 2" hole is drilled into a void. The very light sensitive CCD camera is placed into the hole. A built-in light source will illuminate the interior of the void. Turning the telescoping pole and using the articulation allows viewing in all directions. A microphone and speaker permit listening for sound and possible communications with a victim. Depending on the distance to the objects to be viewed, the light source has to be adjusted carefully so as not to wash out the picture. Unless there are obstructions that block the view, this is a very useful tool, not only during the search, but also during extrication, where it can guide cutting operations.
- SnakeEyeTM is a low-cost (\$2,000) alternative, featuring a 1¹/₄"-diameter CCD-type camera, mounted on a lightweight, rigid pole. While the SnakeEye has a built-in LED light source, it may need additional light. The display is a small (5") flat, high-resolution (960 x 234) rotatable color TFT-LCD. The camera head is mounted with a swivel that allows 90° vertical articulation, or the camera head may be removed from the wand, mounted on another device, or suspended by its cable. The camera head is waterproof and, therefore, may be submerged to the length of the cable (100' max.). The display, connected only to the opposite end of the cable, is rugged and portable.
- Other Cameras: Rescue teams may also have access to other cameras from local resources. A chimney inspection camera can be helpful in exploring shafts, pipes, or other voids, and cameras used in sewer or water pipe inspection may also be useful. These may all be available locally.
- Advantages
 - Easily understood
 - Possibility to record picture
 - Remote viewing
- Disadvantages
 - Size, cost, power requirement
 - Only straight line of sight

Infrared/Thermal Imaging

- A unique way of seeing through smoke and dust is infrared. An infrared imaging system was used successfully in the very smoky environment of the World Trade Center incident.
 - These cameras are fairly expensive.
 - Some models are helmet-mounted with a small TV display right in front of the eyes of the operator.
 - Infrared vision allows searchers to find hot spots inside walls and sources of fire in very smoky environments.
 - Resolution is poorer than on a typical black and white TV picture, but these systems are useful when maneuvering around in unfamiliar surroundings.



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- Advantages
 - Sometimes readily available with some responding local organizations
 - Can be used to survey large, open, dark areas
- **Disadvantage:** Unit cannot detect heat differential through solid mediums. Sources of heat other than persons buried under debris are also indicated, which creates confusion in a search application.

Electronic Listening Devices

- The advent of state-of-the-art electronic listening devices has added a new dimension to the search function. The latest electronic devices can extend the range of the search (in cases where the victim's scent may not reach the surface and is therefore inaccessible to canines) by detecting sounds from the victim.
- Electronic search operations are usually more site-specific and longer in duration than canine search operations. In addition, a sketch is produced of the general features of the structure/area being searched, noting any significant information for future reference.
- The general application of an acoustic/seismic device involves the deployment of an array of two or more pick-up probes around the perimeter of a building or void area. A bullhorn or other hailing device should be used to attempt to give direction to any conscious victim trapped within the structure. The victim should be directed to make a repetitive sound (i.e., knock five times repeatedly). The general area should be made as quiet as possible during this operation. The repetitive series will provide the operator with an identifiable sound to detect. If victims are **detected**, the different probes are assessed separately to determine which gives the strongest indication and should theoretically be closest to the source of the sound/victim. If necessary, the array of probes may then be redistributed (around the area of the original probe giving the strongest indication) to more precisely identify the victim's **location**.
- The distance between probes or sensors will depend on the material the structure or rubble pile is made of and in what sections of material the structure-borne sound is expected to travel. Also of influence will be the presence of interfering signals, which may lead to a further reduction in sensor spacing. In any case, the sensor spacing should not exceed 25'. Typically, a 15-foot spacing will cover the area well, even under more difficult circumstances.
- For **detection**, and as part of a hasty search, a single operator using one sensor may suffice. But for safety reasons, the search team should always be composed of at least two people.
- Pinpointing the location of a victim using only one sensor will be difficult because the signal amplitude and clarity would have to be remembered from sensor location to sensor location. Being able to compare several sensors, and to switch from sensor to sensor quickly, will allow the operator to identify the sensor with the largest or clearest signal. As a rule, if a signal is detected, it is advised to leave that sensor in its position and reposition the other sensors around it for more accurate determination of the location. The more sensors available, the larger the area that can be searched and the quicker a victim location can be pinpointed.
- Comparison of signals is meaningful only if the sensors are matched in sensitivity and are of the same type and construction, covering the same frequency range. This may not be the case with all listening devices. Some use two types of sensors: one for high and one for low (seismic) waves.
- If two sensors are available and a signal is heard, the louder sensor should be left in place. When the second sensor is moved step by step in a circular fashion around the first sensor, a direction toward the signal source may be obtained when the movable sensor shows maximum signal.

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• However, it should be kept in mind that the majority of collapsed sites will be made out of different materials: steel, concrete, brick, and wood may all be found on one site, with each material having a different sound transmission capability. There will be breaks and fractures, large and small pieces, and overall inhomogeneous materials. It will be more important to access the larger structural parts and to try to place the sensor on similar materials rather than work with theoretical search patterns and assume equal sound distribution and attenuation. The "Stereo Effect" is effective if homogenous materials are present. Eventually, some type of modified grid search should be used to verify that no section of the site is overlooked.

In the same manner as in searching with dogs, a second US&R member (or other member fully skilled in acoustic/seismic devices) should be used to confirm the initial find (certain brands of devices employ two separate headphones for this purpose). Should the second operator provide an indication of a find at the same location, this position should be marked with orange survey tape. This information is then passed on to the US&R team leadership and the technical search would continue.

Advantages

- Able to cover large search areas and sometimes triangulate on victim position
- Capable of picking up faint noises and vibrations
- Can be used in conjunction with other search devices to verify find

Disadvantages

- Cannot detect an unconscious person
- Intrusive ambient site noise
- Need for victim to create a recognizable sound pattern
- Limited range (acoustic 25', seismic 75')

Canine Search

- A well-trained canine search team can search large areas in a relatively short time. The dogs use their keen sense of smell to **detect and locate** victims buried under the debris. The primary function of the canine search is to find those victims who are alive. However, most canines will give subtle indications of the dead, and whenever possible these areas will be noted for future recovery.
- The search canine will indicate finding the scent of a buried human victim by focused barking and digging at the strongest scent source. The canine may also try to penetrate to the victim.
- A canine team consists of a canine search specialist and a search canine. Two of these canine search specialist teams, a technical search specialist, and a search team manager will be assigned to search a site. The search team manager monitors handler safety, may be an observer (spotter), keeps track of and maps alerts, and coordinates the search operations.

Canine Search Strategy

- The search team manager, technical search specialist, and the canine search specialists (handlers) will survey the site and decide the best search strategy for the operation.
- They will factor in the time of day, the temperature, size of the area to be searched, and the type of collapse.
- The site will usually be divided into small search sectors.



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The search team manager should sketch the general features of the structure/rubble area, labeling each search sector and noting all significant information (landmarks, etc.) on the sketch for future reference.

Canine Search Tactics

- From a safe zone the search specialist will deploy canine #1 to free-search the sector. If no alerts or areas of interest are indicated, the handler will then direct the canine in a fine-grid search of the sector. While canine #1 is searching, canine #2 is nearby and resting. However, team #2 handler and possibly the team manager will be observing (spotting) the canine #1 search. Each will watch from a different vantage point. These spotters provide the handler with important information on how well the area has been covered, areas that need to be researched, and any subtle alerts on possible dead bodies, etc.
- If canine #1 detects human scent and alerts, the handler will praise and reward the canine as they leave the area. The area must be noted on the map and no flagging will be placed at this time. Canine #2 will be deployed into the general area of the alert. If the alert is confirmed by canine #2, the area will be flagged and the search team manager will inform the US&R Team Leader of a find.
- If there are no finds, the canine teams will switch places after approximately 20 to 30 minutes of searching. Canine #2 will re-search the same sector. If possible, the handler will direct canine #2 to fine-grid the sector in a different direction than canine #1 worked, such as north to south or east to west.
- When a search sector has been completely searched by both canines, the next sector will be started, and so on, until the entire site has been searched. The canine team should continue to search around rescue operations that may be in progress, providing this doesn't endanger the rescuers.
- Scent channels around the solid slabs and large chunks of concrete, and canines will indicate where scent is emerging, not necessarily exactly where the victim is located. Scent tends to rise and flow relatively evenly through more broken rubble and lighter types of structures such as light-frame, URM rubble with wood floor planes, and badly broken reinforced concrete and precast concrete buildings. Therefore, the canines will tend to indicate a more precise location of the scent source/victim in these lighter, more broken structures.
- Continued re-searching of any structure, as it is penetrated by cutting and removal, is important in order to better locate the initial victim and provide information regarding additional victims. This is especially true for concrete structures with solid slabs, since the scent may be traveling back and forth across many solid layers/floor surfaces, and a true direction for victim location may not be indicated until the layer/ floor level on which the victim rests is reached.

Best Working Conditions

- Dawn and dusk when scent is raising
- Cool weather, light winds (up to 20 MPH)
- Stable rubble that doesn't slide as canine traverses
- Light rain

Difficult Working Conditions

- Hot weather (above 90°)
- Middle of the day when temperatures are above 80°
- Strong winds or no winds


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Topic 1-4: Search Capabilities



- Snow, when surfaces are more slippery or hidden and safe footing is unknown
- Firefighting foam and other chemicals

Advantages

- Can search large areas in a short period of time.
- Can traverse or gain access to voids and other opportunity sources
- Can detect and locate unconscious victims
- Disadvantages
 - Short work period of 20 to 30 minutes, rest for 20 to 30 minutes, ready to work, etc.
 - Two canines needed to search same area, to check/confirm
 - Varied performance according to individual handler/canine capabilities
 - Scarce resource

Electronic Devices Working in Combination with Canines

- Whenever possible, dogs and electronic search should be employed together.
- Canines can and have successfully located victims when electronic detection was first employed to sense structure-borne sound/vibration.
- In the Mexico City 1985 quake, relatively crude seismic sensors were used in the quiet of late night to determine if live/conscious victims were present in pancaked waffle slab structures. Canine teams were then deployed within the cavities of the building to pinpoint the **location** of victims, leading to the successful rescue.
- With the more sensitive electronic detection currently available, a more efficient interaction between canines and seismic sensors should be initiated.
- For large, multistory, pancaked concrete slab structures, the electronic detectors could initially indicate if conscious victims respond, even on which floor level they are trapped. Canines could then be more efficiently directed to search a specific floor area, even through relatively thin, unsafe voids.
- During hot daytime hours, the electronic devices could be deployed to **detect** numerous areas where victims are located. These areas would then be searched at dusk by canine teams to confirm and pinpoint location.
- In buildings with unconscious victims or poor vibration transmission, characteristic of badly broken structures of wood, brick, and even precast concrete, the initial search by canines may be the most effective.
- By contrast, in large concrete and steel structures, electronic **detection** should be the most effective initial search tool.
- When both of these area search tools are available, they should be used to check/verify the finds each other.



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Topic 1-4: Search Capabilities

Work Site Search Prioritization

- Depending upon the situation, it may not be necessary to deploy a full search and recon team.
 - Once a viable specific work area (i.e., group of buildings, single building, or separate section within a building) has been determined or assigned, the various search tactics should be determined.
 - In many instances, the canine search can provide the most rapid assessment of a work site area.
 - One canine search team can cover a significant area in short amount of time.
 - This capability might be used first to sweep an area for a general assessment of indications for victims.
 - The redundant check by the other canine should be used to ensure the greatest degree of credibility.
- The electronic search capability may be used effectively prior to, in conjunction with the ongoing canine search, or afterward.
 - The electronic search by its nature will usually be slower and more time consuming.
 - The selection of a specific electronic search site could result from the prior indications of the canine search teams or be based upon the types of construction/occupancies affected, as noted earlier.
 - Once again, a redundant check by a second operator should be made after an initial find is identified and should also be marked if necessary.
- Prior to the location of any viable trapped victims, the US&R personnel present a significant search resource.
 - They should be used to assist the canine and technical search personnel with safety assessments at collapse sites, gaining access to difficult areas, deploying equipment, etc.
 - They should also conduct physical search operations, either separately or in conjunction with the canine/electronic search operations.
 - Individual void inspections or combined listening operations can be conducted, as necessary.
 - These operations would be coordinated by the Rescue Team Manager in conjunction with the Rescue Squad Officers.
- Once a reliable indication of the general location of a victim is made, the use of the fiber-optic viewing equipment (in conjunction with the concrete hammer/drills, if necessary) may prove useful in precisely determining the exact location and orientation of the victims.
 - These tools may also prove to be the most effective method of performing a general sweep of a collapse area adjacent to an open, accessible area (such as an intact basement or floor above a collapsed area).
 - An array of inspection holes can be drilled and fiber-optic viewers can be inserted to make a general determination of the collapsed area.



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Topic 1-4: Search Capabilities



Summary

- When US&R resources arrive at an area severely affected by an earthquake, they could possibly be faced with hundreds of persons trapped beneath the rubble. Some may be alive, others dead, and many simple rescues may have already been accomplished by the community.
- The combined use of physical, canine, and electronic search tactics will enable the task force to better establish priorities and focus emphasis on the most important rescue activities.
- US&R resources will be assigned the most difficult rescue situations. Depending on the complexity of the search and rescue activity, a great amount of time may be spent on each live extrication. The search function must locate viable victims before committing rescue resources to any prolonged operation.
- Time should not be wasted in unproductive missions (such as removing bodies or finding trapped animals) while other live victims might still be saved.
- Accordingly, it is essential that all members understand the advantages and disadvantages of each search tool. The interdependence of the search and rescue function requires mutual respect and confidence, which can be best maintained by understanding that each has significant capability and limitations.
- US&R supervisors must ensure the close interaction of the Structures Specialists with the search and rescue personnel during search operations. The Structure/Hazards Assessment should include information regarding existing openings and probable victim location, in addition to evaluation of structure stability and hazard identification.
- Recurring assessments should be performed throughout the operations, since aftershocks and debris/ structure removal can expose new hazards and new search opportunities.



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Advanced Rescue Skills

STATE FIRE

Topic 1-5: Structure Triage and Recon

Topic 1-5: Structure Triage and Recon

The theme of US&R must be to save trapped victims while minimizing the risk to the victim and US&R personnel.

Terminal Objective: The student shall understand the most appropriate strategies to be used to effect rescues om various types of structures.

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



RESCUE SYSTEMS 2 Advanced Rescue Skills

Topic 1-5: Structure Triage and Recon



Phases of Large Disaster

CALIFORNIA STATE FIRE

- Initial Spontaneous Response by unskilled rescuers, neighbors, community response teams, and passersby. These will heroically help remove lightly trapped and 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 firefighters, 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 by local trained community response teams. Call-out and visual search would be used to locate and rescue the nonstructurally 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 by local emergency services rescue forces. Search personnel would help prioritize the site to make better risk vs. benefit judgments. Rescue would proceed using existing cavities, duct/ plumbing shafts, basements, and 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 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 & Rescue by trained US&R forces, aided by equipment. Site or sites would be reevaluated, re-searched, and prioritized for an effort of many days. 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.

Initial Information Gathering

Information-gathering techniques will be crucial to the efficient transition of the US&R 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 many-hour period of physically and emotionally draining work and 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 and 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. Information from others on structural safety issues should be recorded, but the Search Specialist should perform his own assessment, independently, as in any good check.

Typical First-Hours Deployment

There are many possible scenarios to which a US&R Task Force (TF) or a number of Task Forces could respond. However, our Operating System Description (OSD) envisions that, after initial setup, a decision needs to be made as to the most appropriate deployment of TF Structure Triage and Search & Recon components. Some initial questions that need to be answered are:

■ Is Structure Triage needed or have initial priorities been established by others?



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Topic 1-5: Structure Triage and Recon



- How many building have been assigned to the TF and does Search and Recon need to be carried out at one or more locations?
- How remote are the buildings assigned to TF?

Structure Triage, Structure/Hazards Evaluation, And Marking

In this section, we will discuss the following topics that involve structure marking and location as listed below:

- Identification of individual buildings
- Building triage (only if required)
- Structural/hazard evaluation and marking
- Initial US&R with search and rescue marking
- Example of search assessment and victim marking

These are important communication methods that are used to designate what operations have been performed. It is extremely important that these standards be followed so critical information can be shared with all responders who may be working the same incident. Standard nomenclature is critical for efficient US&R operations.

Identification of Individual Buildings

Standard system to locate building on any block:

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

Standard system for building layout:

- Sides are designated 1, 2, 3, and 4.
 - Start at street and go clockwise.
 - If more sides, use more numbers.
- Stories are designated: 1 (or Ground), 2, 3, 4, etc.
 - Make sure everyone understands where the first (or ground) floor is and if there are any basements.
 - There may be confusion if the street slopes.
- Basements are designated B1, B2, and B3.

Quadrants within a building:

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



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Topic 1-5: Structure Triage and Recon



Building Triage

Basic Assumptions for Use of Triage

- Triage will be necessary if there are three or more buildings assigned to a single task force.
- Triage should initially be done by a team of Structures Specialist and Hazmat Specialist as soon as possible upon arriving at the site and should be accomplished within no more than two hours. The remainder of the task force would be involved in camp setup, information gathering, etc., during this time period.
- No planned search operations should begin until initial triage is completed, in order to establish priority.
- The more detailed Structure/Hazards Evaluation and Building Marking should take place (along with the initial search) after structures are initially prioritized. One or more teams of Structures Specialist and Hazmat Specialist should accomplish Structure/Hazards Evaluation and Building Marking.
- Triage criteria should be reevaluated after initial search in light of locating live victims.
- If many buildings are involved, triage would probably be done by two teams, each consisting of one Structures Specialist and one Hazmat Specialist. It would, therefore, be imperative that the two teams compare assessment criteria before and after they do the triage work in order to ensure that uniform evaluations are obtained.
- The natural tendency of the Structures Specialist will be to stop at each building to "solve the problem" and not leave a structure where people might be known to be trapped. This tendency must be overcome by maintaining a predesignated time schedule of 5 to 15 minutes per building and frequent check-in with task force leadership.

Triage Criteria

- The following information needs to be considered in determining risk/benefit that will aid in prioritization.
- Occupancy: The type of activity done in the building, as well as the potential maximum number of occupants.
- Structural Type: The type of materials involved in order to help identify difficulty of access, type of collapse, potential hazard mitigation needs, etc.
- **Collapse Mechanism:** How the building failed in order to provide an indication of type of voids that might be available for victim survival.
- **Time of Day:** The time of the event that caused the collapse. This is a critical factor when combined with the occupancy type. For example, if an earthquake occurs at 2100 hours and collapses an office building and an apartment building, the apartment building would normally represent the higher potential for a successful rescue than would the office building. If the event occurred at 1000 hours, the opposite would be true.
- **Prior Intelligence:** Information from the general public, local authorities, first-responders, etc., relating to known trapped victims.
- Search and Rescue Resources Available: Does the particular building require resources beyond what is readily available to the TF (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?



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Topic 1-5: Structure Triage and Recon



Triage Scoring Factors

The following factors will be used to obtain a numerical score for each structure in a group of buildings. The higher the numerical score, the better the risk/benefit ratio.

- ZERO OCCUPANTS PROBABLE. A notation of "ZERO" should be written in the score column if the earthquake occurred at a time of day when the type of occupancy is such that the building would normally have been unoccupied (school rooms on Sunday, retail shops at 6 A.M., etc.). The triage team should then proceed to the next building.
- **TOTAL NUMBER OF POTENTIALLY TRAPPED VICTIMS.** This will be assessed knowing the type of occupancy, the floor area of the collapsed entrapping structure, the time of day the incident occurred, and the type of collapse. The following are the average total number occupants for various occupancies:

Based on units other 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

	Variation
1 per 70 SQ. FT.	50-100
1 100	80-150
1 200	100-300
1 100	50-200
1 150	100-200
1 25	10-050
1 125	100-150
1 200	100-300
1 600	400-900
	1 per 70 SQ. FT. 1 100 1 200 1 100 1 150 1 25 1 125 1 200 1 600

- The **Time of Day** that the incident occurred may indicate that there was very little possibility of a structure being occupied. The type of collapse (auto garage only, partial collapse) may also indicate that few occupants would remain entrapped even if many occupied the structure during the incident. All these factors should be considered when calculating Total Number of Trapped Victims.
- The numerical value of this criteria will vary from 1 to 50 as the number of potentially trapped victims varies from 1 to more than 200. Between 5 and 250, the value is the total number of possible trapped victims divided by 5.



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- **CONDITION OF VOIDS.** This criterion will attempt to assess the degree of survivability of the potentially trapped victims. Victims don't survive well in tightly compacted collapsed areas consisting of rubble masonry, badly broken cast-in-place concrete, and precast concrete. Hollow, survivable voids are often found under wooden floor panels that are collapsed into angular interlocking planes and in reinforced concrete structures where floors have projecting beam elements and parts of columns/walls and furnishings that hold the slabs apart. Partly collapsed structures may have large triangular voids or entrapped victims in large voids due to blocked exits, etc. These large voids have the best chance of having surviving entrapped victims. The value of this criteria will vary from 1 to 20.
- TIME REQUIRED TO ACCESS VICTIMS. This is an estimate of the time required to get to the first victim. It should include the time required to cut through floors or roofs, etc., and the time required to shore or brace the access route and appropriate adjacent structures. The numerical value will vary from 1, for more than one day, to 20 for taking only two hours.
- DANGER OF ADDITIONAL COLLAPSE DUE TO AFTERSHOCK. This criterion will be represented by a minus number from -1 for low probability to -20 for high probability of additional collapse, assuming the proposed shoring or bracing is installed from criteria 3.
- **SPECIAL OCCUPANCY INFORMATION.** Add 25 points if the occupancy is a school, day care center, hospital, or other occupancy that could involve children. In addition, 5 points should be added for each potential live victim that is confirmed by previous intelligence, search, etc.
- "NO GO" CONDITIONS. These 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 should be reevaluated when those conditions were mitigated, and some comment regarding this should be recorded on the form.

Recon Team

This group of TF members is composed of the NINE individuals listed in Topic 1-4. A TF can field two of these groups and might need to do so if they were faced with the task of locating victims in more than one building. The Rescue Specialist involved on the team could be asked to perform any of the following search functions (in addition to his normal rescue duties):

- Help set up and operate technical search equipment.
- Cut access holes for equipment and evaluation.
- Perform visual and vocal physical search.
- Help spot for canine search.
- Help with Hazmat assessment.

Recon Team—Initial Tasks

The initial tasks involve collecting the data that will help define the US&R problem.

- Where is it, what is it, and what are the details?
- What was the original configuration and has it reached a new state of equilibrium?
- What are our current problems? Define and evaluate the hazards.
- How do we best to remove victims without creating new ones?



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Topic 1-5: Structure Triage and Recon



Recon and Primary Search

It is best to proceed by taking nothing for granted. Do an independent search and evaluation. For large incidents, search may be done in two phases—Primary and Secondary.

- Primary Search is intended to, as quickly as possible, detect the presence of survivors.
 - Physical search with hailing would normally be tried first.
 - Canine and electronic detection may also be used.
 - Accessible voids would probably be searched.
- Secondary Search will normally include an extensive grid search, using all appropriate tools.
 - All available tools (Canine, Physical, Electronic, and Cameras) will be used to pinpoint the location of all survivors.
 - Cutting tools may be used to provide access, and redundancy will be used to confirm all locations.

Recon—Following First Building

Where numerous buildings are involved, after finding live victims in the first building a decision must be made by TF leadership regarding deployment of the Search & Recon Team. Should Recon proceed to determine victim viability in other structures or stay to aid rescue operations?

Other Options—Rapid Recon

- A segmented, rapid Recon Procedure was proposed in early 2005 in order to provide an additional deployment option for disaster situations where an individual US&R TF is overwhelmed by the number of structures that they are required to deal with.
 - The intent here is to speed up the processes of using triage to prioritize the affected structures, followed by deploying Recon (in the order of the highest triage score).
 - The assumption here is that the structures involved would be moderate in size and complexity. A large, complicated, multistory steel or concrete structure would be expected to require the full deployment of one or more task forces.
- The personnel from the two TF Recon Teams would be divided into three functional units. All three teams would carry only the equipment that is essential for their tasks in order to maximize mobility.
 - Rapid Triage and Assessment Team
 - Rapid Victim Detection Team
 - Victim Location Team
- The Triage/Assessment Team would be expected to rapidly assess and preprioritize the structures and feed back information to the Search Team Manager (STM) and the TF Leader.
 - The Hazmat Specialist would be expected to make the appropriate test that would allow normal Structure Assessment to proceed.
 - The Structures Specialist would be expected to use the triage forms to rapidly record appropriate data in order to develop a Relative Risk Number that could be compared to each structure as the Rapid Assessment Team moved from building to building.



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Topic 1-5: Structure Triage and Recon



• Frequent communication of interim results to the STM would allow for better use of the Victim Detection Team. The Victim Detection Team would, in turn, better define the highest priority structures.

This is just one of many options that have been considered. Thus far, except for Hurricane Response, all major incidents have had many Task Forces all focused on a single disaster site. However, it is probable that a great earthquake will overwhelm the US&R system and this type of deployment configuration would be considered.

Structure/Hazard Evaluation And Marking

Structural/Hazard Evaluation should take place AFTER a priority list of structures has been established by the leadership, using triage or just common sense if only a few structures are involved. The Structure/ Hazards Evaluation form has, deliberately, been made different from the ATC-20 Safety Assessment placards and forms. It should be assumed the US&R task force will be dealing with buildings that have or would have received a red tag (using ATC-20). The greatest area of concern is not with the fully collapsed structures, but with those that have partly collapsed. The Search Specialist and Hazmat

TASK FORCE BUILDING MARKING SYSTEMSTRUCTURE/HAZARDS EVALUATIONUHR-4

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:



STRUCTURE IS RELATIVELY SAFE FOR S&R OPERATIONS DAMAGE IS SUCH THAT THERE IS LITTLE DANGER OF FURTHER COLLAPSE.



STRUCTURE IS SIGNIFICANTLY DAMAGED. SOME AREAS MAY BE RELATIVELY SAFE, BUT OTHER AREAS MAY NEED SHORING, BRACING, OR REMOVAL OF HAZARDS. (MAY BE PANCAKED BLDG)



STRUCTURE IS NOT SAFE FOR RESCUE OPERATIONS. AND MAY BE SUBJECT TO SUDDEN COLLAPSE. REMOTE SEARCH OPERATIONS MAY PROCEED AT SIGNIFICANT RISK. IF RESCUE OPERATIONS ARE UNDERTAKEN, SAFE HAVEN AREAS & RAPID EVACUATION ROUTES SHOULD BE CREATED.



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



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)

Figure 1:2



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Topic 1-5: Structure Triage and Recon



Specialist should be prepared to fill out the US&R Structure/Hazard Evaluation Form, identifying structure type, occupancy, hazards, etc. In addition, the Search Specialist will generate notes and diagrams regarding search operations (locations of voids, shafts, shoring, etc.). It is anticipated, however, that in some cases the assessment will indicate only that the building is too dangerous to conduct US&R operations.

- The term "safe" should be understood by the Structures Specialist in a context very different from that of "safe for occupancy." All the structures will be damaged, and the value judgment of "safe enough for the risks of US&R" will need to be measured. It is strongly suggested that the Structures Specialist work with another person during this phase (just as engineers do in ATC-20-type assessment) for safety reasons as well as being able to have immediate access to second opinions on all critical decisions. The second person would ideally be the other Search Specialist; however, in larger incidents this may be impractical. Each Structures Specialist would, more probably, be paired with a Hazmat Specialist in order to evaluate all hazards during this evaluation (just as during triage).
- The Structure/Hazard Evaluation Marking is then placed on the building near each entry, etc.

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:	BUILDING MARKING: Date/Time of Evaluation: Date/Time of Catastrophe:			
Bldg ID:				
No. Stories: No. Basements:				
MATERIALS: Wood Concrete Steel URM PC Concrete Other:	TYPE OF COLLAPSE: Pancake Soft 1st Floor Wall Failure Torsion Middle Story Overturn Other: Other: Other:			
FRAMING SYSTEM: Shearwall Moment Frame Braced Frame Other:	LOCATION OF VOIDS: Between Floors Basement Shafts Other:			
OCCUPANCY: Hospital Police Station Emergency Operations Center Office Building School Public Assembly Industrial Hotel Apartment Retail Store Other: VICTIM & OTHER INFORMATION:	DESCRIPTION OF UNSAFE AREAS & HAZARDS:			

LUATADDO EVALUATION FODA

Figure 1:3



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Topic 1-5: Structure Triage and Recon



Search and Rescue Assessment Marking

Standard SAR assessment marking is designed to perform two functions:

- First, when SAR personnel enter the building or parts of the building, the initial diagonal line is drawn so others will be informed of **On-going Operations**. The TF identifier and entry time and date are marked in the left quadrant. The time, date, and I.D. information will inform others as well as provide critical data should there be a question regarding the TF's safety in the event of a secondary incident.
- Upon entering, the searchers should proceed to the right and always keep to the right in every room in the structure.
- When operations are completed in the building (or parts of the building), the crossing diagonal line will be drawn. At the main entry the information in the remaining three quadrants is added to indicate date and time of exit and what was found and accomplished. This will also indicate that the TF has exited safely.
- The finished mark can then indicate to other SAR forces the outcome of previous operations.

FEMA US&R BUILDING MARKING SYSTEM MAIN ENTRANCE SEARCH MARKING UHR-4B 02/05 DATE & TIME ARE MARKED 2-10-02 AS SEARCH TEAM EXITS 1400 SEARCH TEAM I. D., + DATE & TIME ARE MARKED WHEN PERSONAL CA-RTF-2 ENTERING STRUCTURE. RATS 2-10-02 (OR-1 is short for OR-TF1 HAZARDS and 1100 means 1100 hrs) 1100 1 - L CROSSING SLASH IS MADE 3-D AS THE TASK FORCE EXITS. THE RIGHT & BOTTOM INFO +EXIT TIME IS THEN ADDED NUMBER OF LIVE & DEAD VICTIMS LEFT THE FIRST SLASH IS MADE WHEN ENTERING STRUCTURE

Figure 1:4



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Topic 1-5: Structure Triage and Recon



Search Assessment Marking

A separate and distinct marking system is necessary to denote information relating to the victim location determinations in the areas searched. This separate Search Assessment marking system is designed to be used in conjunction with the Structure and Hazards Evaluation marking system. The Canine Search Specialists, Technical Search Specialists, and/or Search Team Manager (or any other Task Force member performing the search function) will draw an "X" that is 2' X 2' in size with International Orange paint stick, lumber crayon or color spray paint (note that K9 may be adversely effected by the Fumes from Spray Paint). This X will be constructed in two operations - one slash drawn upon entry into the structure (or room, hallway, etc.) and a second crossing slash drawn upon exit.



Single slash drawn upon entry to a structure or area indicates search operations are currently in progress. Upon entering a building or a separate wing of a large building, add the Search Team I.D., Date and Time (24hr) of entry. (Next to main entry)

Crossing slash is drawn as personnel exit from the structure or area.

Distinct markings will be made inside the remaining quadrants of the X to clearly denote the search status and findings at the time of this assessment. The marks will be made with carpenter chalk or lumber crayon. The following illustrations define the Search Assessment marks:





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US&R SHORING OPERATIONS GUIDE DISASTER SITE REFERENCE DATA

VICTIM LOCATION MARKING SYSTEM (cont.)



Make a large (2' x 2') "V" w/orange paint near the location of the known or **potential** victim. Mark the name of the search team as shown. An arrow may need to be painted next to "V" pointing towards the victims location is not immediately near where the "V" is painted. Show distance on arrow.



Paint a circle around the "V" when a potential victim has been <u>Confirmed to be alive</u> either visually, vocally, or by hearing sounds that would indicate a high probability of a victim. If more than one confirmed live victim, mark total number under the "V".



Paint a horizontal line through the middle of the "V" when a <u>Confirmed</u> victim is determined to be <u>deceased</u>. If more than one confirmed deseased victim, mark the total number under the "V". Use both live and diseased victim marking symbols when a combination of live and deseased victims are determined to be in the same location

Paint an "X" through the <u>**Confirmed**</u> victim symbol after <u>all victims</u> have been removed from the specific location identified by the marking.

 Paint new victim symbols next to additional victims that are later located near where the original victim(s) were removed. (assuming original symbol has been "X"ed out).

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Search Assessment and Victim Location Mark Example

Enter building, make first slash, TF I.D., time and date, and enter Rooms 1 and 2 after making single slash by each door.



Exit Rooms 1 and 2, draw second slash, and record findings. Then enter Rooms 3 and 4.





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Exit Rooms 3 and 4, draw second slash, and record findings.



Exit building, draw second slash, complete all data, and prepare to go to next building or assist Rescue at this building. If exit might be approached by another SAR unit without seeing the front entry, marks should be repeated at the exit location.





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Topic 1-5: Structure Triage and Recon



Basic Building Search and Rescue Plans

Basic Plan for Individual Building

- **Reconnoiter site**, collecting as much information as possible.
 - Determine structure type to better assess type of failure, type of hazards, ease of entry and cutting, etc.
 - Interview neighbors, survivors, and interested people (how many potential victims; where last seen; location of stairs, elevators, basement, etc.).
 - Obtain building plan or draw crude plan with special emphasis on probable location of voids, existing shafts, basement.
 - Search Specialists reassess building in detail to reidentify hazards.
- **Prioritize site** and use collected data to obtain best risk/benefit ratio.
 - Conduct call-out/listen search.
 - Plan shoring at access or use most efficient access.
 - Determine condition of basement.
 - Avoid falling hazards unless they can be removed or shored.
- In Initial Search, properly trained search dogs and electronic locators have been used successfully in US&R to locate deeply buried victims. Both have significant limitations, i.e., the dogs must be repeatedly trained in the rubble environment in order to effectively find human scent, to not be concerned about their own safety, and to ignore animal, food, and sewer gases. Even properly trained dogs may only be able to indicate the direction of scent, which is not necessarily the direction of the victim.

Electronic devices, even when operated by trained personnel, may be able to detect only victims who are very actively sending tapping signals.

- Use search dogs with "send out" as far as possible into structure. Check alerts with second dog/ observer/handler.
- Use listening/seismic finders, if available.
- Explore existing vertical shaft openings, if available.
- Explore horizontal openings with great care (send dogs in and keep people out, if practical).
- In general, search from safe, stable areas into unstable ones.
- Reprioritize site vs. location of potential live victims.

• Selected cutting and removal is based on priorities of initial search vs. probable hazards.

- Cut vertical openings and re-search, recheck with dogs and listening/viewing devices.
- Complete initial shoring for access.
- Avoid unshored overhead structures.
- Recheck all shoring after cutting and removal since loading can change.
- Continue process of cutting layers, re-searching, and reprioritizing.
- Stabilize area at victim to give medical aid.

Advanced Rescue Skills



Topic 1-5: Structure Triage and Recon



Secondary Search and Rescue

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

SAR Plan—Light-Frame Buildings

Search

- Call-out/listen search may be effective due to 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 scent through cracks in wood floors if they are not heavily covered.

Hazard Reduction

- Shut off gas (and electricity) and reduce other fire hazards. (This applies for all types of buildings.)
- Assess and refer chemical hazards. (What's in the typical kitchen?)
- Remove and avoid or topple leaning chimneys.
- Place vertical and lateral shores. Leaning multistory buildings may be shored using diagonal timbers.

Victim Access

- Use horizontal entry through cavities or through walls.
- Make vertical access through holes cut in roof or floor.
- Remove or shore hazards as required.

SAR Plan—Heavy Wall Buildings—URM and TU

Search

- Call-out/listen search may be effective due to 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 scent through cracks in wood floors if they are not heavily covered.

Hazard Reduction—URM

- Shore hazardous floors with vertical shores.
- Remaining uncollapsed URM walls are brittle—aftershock and wind falling hazards. Either avoid, remove, tie back, or raker shore them. There may be a need to shore in both IN and OUT direction.
- Beware of all falling hazards. Peeled, cracked, and split URM walls are very brittle, with a high potential for falling and collapse hazards.

■ Hazard Reduction—TU and Low Rise

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



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Topic 1-5: Structure Triage and Recon



■ Victim Access—URM

- Use horizontal entry through existing openings with great care.
- Vertical access through wood floors should be easy and least dangerous.
- Avoid cutting large beams and more than two joists in a row.
- Avoid cutting walls. Holes can greatly reduce strength of poorly cemented walls. Most are important bearing walls.
- Beware of roof and floor joists or 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 next stable position.
- Basements 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 wall may be removed by clamshell or other bucket with thumb—need to prevent parts from falling).

Victim Access—TU and Low Rise

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

SAR Plan—Concrete Frame Buildings

■ Search—Heavy Floor

- It is not likely to hear call out of victims through these floors due to high density of concrete.
- Seismic listening devices can be 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 direction of scent that may be flowing around large slabs, back and forth across the building. (Location of victim must be interpreted from conditions.) 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 scent is rising.

Hazard Reduction—Heavy Floor

- In a partly collapsed building (upper floors, etc.), it is very important to check floors that support debris load.
 - Read cracks to determine if more and progressive collapse is probable.
 - Multistory shoring may be the only safe procedure.
 - It normally takes at least two 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 or avoid badly cracked beams.
- Shore or avoid hanging slabs and beams.



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Topic 1-5: Structure Triage and Recon



- Shore heavily loaded flat slabs (beamless slabs)—punching shear.
- Beware of all falling hazards—parts of slabs, walls, etc., that may be hanging from exposed rebar. How well is rebar embedded?
- Monitor structure for lateral movement with theodolite or other tilt measuring device.

■ Victim Access—Heavy Floor

- Use any existing vertical shaft.
- Basement may be good access, but evaluate 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 midway between beams and columns.
- Check for thinnest slab area. Pan joist and waffle slabs have ribs spaced 3' or so with 3- to 4- inch-thick slab between.
- Do not cut columns—usually do not need to.
- Avoid cutting concrete/masonry walls. They may be bearing walls. If masonry infill wall in concrete frame, cutting is possible. Check first to see if frame is loading wall due to collapse.
- Remove concrete slabs with crane after all rebar is cut.

SAR Plan—Precast Concrete Buildings

■ Search—Precast Concrete

- Call-out/listen search may be effective. It depends on size of voids between larger pieces of concrete.
- 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 depending on compactness of concrete rubble.

Hazard Reduction—Precast Concrete

- Remove or avoid hanging pieces of 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.
- Partly collapsed buildings may have adjacent slabs or wall panels that have damaged connections that may break loose in aftershocks or if loading shifts.

■ Victim Access—Precast Concrete

- Cutting of cored slabs and tee slabs should be done at edges—through thinnest part of section and away from ribs. Cut half of hole in each of two adjacent precast pieces.
- Don't cut ribs in tees or walls and do not cut columns.
- Walls may be cut with care.
 - Cut holes at least 2' away from joints.
 - Consider problems of shoring vs. removal (removal may be more efficient).
 - Check wall welded joints for signs of movement.
 - Some walls may be infill URM and may be cut if not loaded by collapsed concrete pieces.



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Topic 1-5: Structure Triage and Recon



- Basements may not be good access unless basement walls and first-floor slab are cast-in-place concrete. Shoring may be required in any case.
- Use horizontal access through existing cavities with great care.
- Lift off loose concrete pieces with cranes or other equipment.
- Great care must be taken when lifting and shoring large concrete pieces since adjacent pieces may shift.
- Precast concrete will often weigh about 75 percent of normal (150 PCF) concrete. It also splits more easily.

Metal Detector

Handheld metal detectors should be used to locate rebar or prestress cables prior to cutting slabs and walls. This can prevent dulling bits and inadvertently cutting cables.

Metallescanner Pro by Zircon is a magnetic type that is small and can determine location of rebar as much as 4" deep. Cost is \$100. Other devices are available with costs from \$400 to \$2,000.

Cutting Post-Tensioned Concrete

Post-tensioned concrete contains steel cables ($\frac{1}{2}$ " dia.) enclosed in a long plastic casing (sometimes called 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-tensioning cables (P.T.) 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 P.T. cables need to be cut during US&R Ops, special care needs to be taken to deal with the tension force that will be released (normally 25,000 lb).
- Cables are most often placed in a draped configuration within the concrete. The cable is placed near the bottom of slab or beam near midspan and near the top where cables pass over supporting columns or beams.
- It is best to use a torch to cut the P.T. cables, since the tension can 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 the force can be gradually released, parts of the cable may violently project out of the concrete structure.
- Depending on where the cable is cut, it may project above the floor near the supports, below the floor near midspan, or out of the end or side of the concrete slab like a spear. Any of these occurrences can severely injure or kill.
- The TF 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' or barricaded to deal with the threat of the cable spear.

Do not attempt to cut a tensioned cable unless you have received proper training and under the direction of a Structural Engineer.



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Topic 2-1: Collapse Patterns Structural Engineering

Topic 2-1: Collapse Patterns Structural Engineering

Terminal Objectives

- The student will understand how building structures can be separated into specific types that exhibit unique collapse patterns when subjected to extreme forces due to earthquake, wind, and explosions.
- The student will be able to recognize the unique collapse patterns.

Enabling Objectives

- Understand how earthquakes, winds, and blasts produce unique effects on different types of structures.
- Understand how each of these produces unique and recognizable collapse patterns.
- Understand how this knowledge will allow us to recognize the difference between survivable and less-survivable voids.

Basic Collapse Patterns

Most building collapses occur due to loss of stability; that is, 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 and, therefore, the structure will rapidly continue to change until 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 or foundation. Basic collapse patterns can be summarized as follows:

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

The basic instability occurs when the gravity load is offset a distance (delta) that is large enough to overcome the shear capacity of walls at a particular level, usually the first story. The horizontal resistance required to maintain stability in the racked condition (parallelogram) is proportional to the percent of offset (i.e., when a 10-foot-high story is offset 1 foot, then 10 percent of the total gravity load above that level is required to keep the parallelogram from becoming flatter).

- **b. Inadequate beam/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.

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- The result of this type of collapse may be a pancaked group of slabs held apart by broken columns and building contents.
- **c.** Tension/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 very rapid loss of stability.
 - If the reinforcing steel in walls is inadequately proportioned or poorly embedded, it can fail in tension and result in rapid collapse of the wall by overturning.
 - A more common condition occurs when the tension causes the joints in a concrete moment frame to lose bending/shear strength. As previously discussed, a rapid degradation of the structure can result in partial or complete pancaking as in beam/column failure.
 - The failure of Pino Suárez Tower in Mexico City is an example of how poorly proportioned steel structures can catastrophically overturn due to a compression failure of the columns.
- **d. Wall-to-roof interconnection failure** is when stability is lost since the vertical support of the roof/ floor is lost as well as the horizontal out-of-plane support of the wall. This condition could be triggered by any of the destructive forces previously mentioned.
- e. Local column failure can lead to loss of stability and progressive collapse in a part of a structure and may, again, be caused by any of the previously mentioned forces. Precast concrete and structures that have wood floors tend to be more susceptible to a progressive-type failure due to the lack of continuity of these construction configurations.
- **f. Single-floor collapse** has occurred in earthquakes due to pounding or vertical irregularities that focus the damaging effects to a single story.

In summary, in almost all collapses (except cases when wind causes lifting), the driving force is the gravity load acting on a structure that has become unstable due to 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 uncollapsed adjacent bays as tension structures.

The issue in US&R is not the academic one of how the structure collapsed in order to improve future construction, but what additional collapse is possible and how stable is the existing configuration.

Earthquake Collapse Patterns

The Basic Principals

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



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Basic Building Types

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

LIGHT-FRAME: Mostly wood frame

HEAVY WALL: URM, Tilt-up (TU), and other low-rise buildings with concrete and masonry walls

HEAVY FLOOR: Concrete frame buildings and highway bridges

PRECAST CONCRETE BUILDINGS: With fairly heavy floors and some heavy walls

STEEL-FRAME BUILDINGS: Mostly diagonally braced steel buildings

Light-Frame Collapse Patterns

- Collapse usually occurs when lower walls have insufficient strength to resist the lateral forces and rack (become parallelograms).
- If there is a sufficiently heavy load on these walls, they can completely collapse as the wall top moves sideways a distance equal to its height.
- This causes the structural collapse to be in the form of part or all of the building being projected away from its original foundation by the height of the story walls that fail.
- When the bottom story of a multistory light-frame structure fails in this way, additional stories can also collapse due to the impact of the first story hitting the ground.
- This type of collapse usually leaves many voids that are fairly easily accessible.
- There is great danger of fire due to the combination of broken gas (or other fuel) lines and the combustible debris.

Heavy Wall Collapse Patterns

- Collapse is usually partial and is strongly related to the heavy, weak bearing walls falling away from the floors.
- In URM buildings the walls normally fall away from their original position, but, most often, don't 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' 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.
- However, in collapse due to failure of interior columns or to fire, it is possible to have the very precarious situation of multistory heavy walls that are left standing without any laterally supporting floors or roof. For this case, it is probable that the walls could fall in such a way that they extend their full height along the ground.
- When the wood roof and/or floors collapse, many easily accessible voids can be created.
- Areas adjacent to the walls where the heavy debris falls often contain badly injured or dead victims.
- The combination of broken gas lines and debris can lead to fire.
- The falling walls can cause the roof and floors that they support to collapse in patterns of Lean-to, V-Shape, Pancake, and Cantilever.

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- Lean-to can be formed when one exterior wall collapses, leaving the floor supported at one end only.
- V-Shape occurs when an interior supporting wall or column fails.
- **Pancake** can occur when all vertical supporting members fail and most of the floors collapse on top of one another. This is more common in heavy floor buildings.
- **Cantilever** is a pancake collapse where some of the floor planes extend out as unsupported members.
- Walls in tilt-up buildings also 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.
 - The adjacent section of roof will then collapse, although it may still be supported at its far end.
 - There will be tension forces imposed on the roof system; therefore, all beam-to-beam and beam-to-column connections may be damaged or pulled out.



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URM W/WOOD FLOOR COLLAPSE PATTERNS

LEAN-TO FLOOR COLLAPSE

Formed when one wall collapses, leaving other end in hazardous condition May also occur in TU, Heavy Floor and Precast Conc.



V-SHAPE FLOOR COLLAPSE

and the second

Occurs when interior support fails. More common in urban decay/overloaded column failure

May also occur in Heavy Floor and Precast Conc. bldgs



PANCAKE FLOOR COLLAPSE

Occurs when most all vertical supporting members fail and allow floors to collapse on top of each other.

More common for Heavy Floor and Precast Conc. bldg.



CANTILEVER FLOOR COLLAPSE

(pancake with extended floors)

May also occur in Heavy Floor Precast Concrete buildings.

Figure 2:1

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Heavy Floor Collapse Patterns

- Collapse can be partial to complete. It is usually caused when columns or walls, weakened by quake motion, are unable to support the heavy floors.
- The collapse patterns can be those shown in the accompanying figures, and almost all share the pattern of thin void spaces forming within the original plan area of the building.
- These heavy floor structures usually fall on themselves, but they can project laterally as they fall if the columns or walls are strong enough to not fracture. That is, the columns can fail due to hinging at the top and bottom and then the collapse looks more like the light-frame type.
- The voids can be very difficult to access, since even though the heavy floors can have dropped tens of feet, they are still usually well interconnected with reinforcing steel.
- The height of remaining voids between floors in pancaked buildings will depend on what projections the slabs originally had (beam stems, flat slab drops) and partly crushed contents.
- Tall moment frame structures, where tension-to-compression reversal causes an almost explosive failure of exterior columns, may overturn, but more often they will collapse within their plan boundaries due to high gravity forces.
- Many partially collapsed concrete-frame structures will contain parts of slabs and walls that are hanging off an uncollapsed area. This has been observed in corner buildings when only the street-front bays collapse due to torsion effects and in long buildings or those with several wings, where some bays do not collapse.
- Torsion Effects occur in concrete-frame structures when URM infill is placed in exterior, property line walls for fire resistance. These walls become stiffer than all other parts of the building and cause a temporary, eccentric condition, which can lead to a collapse of the columns on the opposite side of the building.
- **Overturned**, normally taller structures with shear walls will often fail due to tension/shear failure at the base. In this case, the structure can project sideways by its full height.
- **Soft First-Story Collapse** occurs in buildings that are configured so they have significantly less stiffness (much fewer walls or no walls) in the first story than in the stories above.
 - This configuration may occur in wood as well as concrete structures.
 - The collapse is often limited to the one story only, as the building becomes one story shorter.
- Midstory Collapse can occur when a midstory is configured with much different stiffness than the stories above and below:
 - When a story has no walls and the ones above and below have significant walls
 - When a story has stiff, short columns and the ones above and below have longer, more limber columns.
- Pounding can cause a midstory collapse, leaving a difficult problem to assess due to remaining floors being overloaded, etc.
 - 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 will cause the collapse of the adjacent building's column when they collide.
- Fire is usually not a problem for heavy floor buildings unless the contents are particularly combustible.

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Precast Collapse Patterns

- Collapse is usually caused when the precast parts become disconnected from each other and the structure very rapidly loses stability.
- The collapse normally contains numerous layers of broken and unbroken pieces of slabs, walls, beams, and columns.
- It is dificult to predict how far the parts can be projected away from the original structure's position, but gravity normally will drive them downward without projecting them laterally away from the building.
- The voids can be difficult to access, but the slab, etc., can be removed, layer by layer, since interconnections are normally poor to nonexistent.
- Precast parking garages have performed particularly badly.
 - They may be very large and as much as eight stories tall.
 - Outside of California most do not have a cast-in-place floor topping to help tie the structure together.
 - The most common failure is a column collapse caused by unintended shear overstressing columns near ramps or at girder connections.

Steel-Frame Collapse Patterns

- Collapse is usually caused when columns are not proportioned so they are capable of receiving the combination of structure weight and all the vertical component of the quake load that can be delivered by the diagonal braces connected to them.
 - In this case, the affected column or columns can buckle, causing a catastrophic, overturning failure.
 - This effect contributed to the catastrophic failure of the Pino Suárez, a 20-story tower in Mexico City in 1985.
- 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 rollover of beams.
- This type of failure rarely causes collapse, but damage can be caused to nonstructural elements such as rigid wall panels, stairs, and interior finishes.

Windstorm Collapse and Damage Patterns

Windstorm Basics

- Windstorms often produce flooding and the damage to structures by both is similar.
 - Initial flooding may occur due to tidal surge and may produce very high forces on structures.
 - Additional flooding may involve coastal rivers that have been fed by high-volume rainstorms.
- Windstorms normally affect light, poorly, or nonengineered structures and generate static and dynamic pressures on the exterior surfaces as well as impact forces from missiles and debris.
- Well-engineered structures are designed to resist wind forces by elastic action (as contrasted to the inelastic response that is assumed in earthquake design) and, therefore, it is unusual to have this class of buildings sustain significant wind damage.

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STATE FIRE

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- Water surge, especially that 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 of 2004 caused damage to freeway bridges and concrete apartments as well as lighter structures.
- Tornados, with winds above 200 MPH, can damage all but the most well engineered and well constructed buildings.
 - The most destructive tornados have lifted structures as large as 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 designed as a shelter.
 - In some cases, tornado warning can be given, but the warning is only that the conditions are present in a general area and not the precise location where a tornado will occur.

Most Common Wind Collapse

- Part or all of light roof is blown off and walls collapse due to lack of lateral support.
- Very tall walls are blown in or out, causing the roof to collapse.
- Light metal buildings collapse after loss of cladding due to buckling or bending failure of long-span roof beam/frame or pull out of base connection.
- Missiles penetrate glass openings or doors blow in, structure changes from "closed" to "open," roof and/ or leeward wall are blown out. Exterior walls may even be masonry or concrete tilt-ups in this scenario, and light interior walls can also be badly damaged.
- Structures can be designed to resist the 95 to 155 MPH wind speeds that are generated during hurricanes, including all types of engineered structures. Lighter structures require especially competent engineering and well-supervised construction to adequately resist hurricane winds.
- The types of structures that are seriously damaged by hurricanes usually fall into three categories:
 - **Preengineered 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.
 - **Unengineered Buildings** might be as homes and apartments.

Common Wind Damage can create structural hazards:

- Partial removal of roof and/or wall skin in light-frame buildings; partial loss of lateral load resisting system
- Peeling of outer layer of multilayer, 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 destructive missiles)

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Topic 2-1: Collapse Patterns Structural Engineering



Flood Collapse and Damage Patterns

Common Flood Collapse Problems

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

Common Flood Damage Problems

- The 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 roves 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 and can cause severe health problems.
- Flooding may also lead to many Hazmat problems.

Explosion Effects on Buildings

Basic Explosion Effects

The pressures exerted on buildings by explosions may be many orders of magnitude higher (5,000 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 frames 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 collapse of at least part of the structure.



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Explosion Effects on Specific Buildings

The following is a brief description by type of the most predictable blast damage:

WOOD FRAME: The light wall and roof planes can be blown away and/or shredded. Leveling of all or at least a significant part of the structure can occur.

STEEL FRAME: 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 post blast, but beams may be twisted with large areas of the floor diaphragm missing.

LIGHT METAL: The light metal roof and wall panels can be easily blown away leaving a bare, poorly braced frame.

- Roof, purlins, and wall girts 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).

CONCRETE FRAMES: Lift pressures have had devastating effects on concrete slabs in gravity-type designs.

- One-way slabs hinge up due to the lack of top reinforcing at midspan and continuity splices in bottom bars at supports.
- A critical location for flat slabs occurs at columns when the uplift pressure fails the slab column joint in upward punching shear, followed by a combination of gravity and positive overpressure that tends to drive the already damaged slab downward.
- The remaining structure may contain columns that are standing exposed for several stories without the lateral bracing that the collapsed floors used to provide.
 - In both the World Trade Center and Murrah Federal Building in Oklahoma City, large areas of several floors collapsed, leaving columns that extended as far as six stories without lateral support.
 - These columns were still loaded with hundreds of thousands of pounds of load from the uncollapsed floors above, but were standing without the lateral support previously provided by the collapsed floors.
 - Lateral bracing was then provided using steel tubes.
- In concrete frames, the URM infill is also particularly vulnerable to blast pressure—large areas, very little resistance to the lateral pressure.



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Topic 2-1: Collapse Patterns Structural Engineering



PRECAST CONCRETE In precast 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 multistory precast structure.
- In box-type structures (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 multicellular character of these structures made from closely spaced bearing walls, however, will tend to limit the collapse damage to those areas where the bearing capacity of wall panels is lost.

POST-TENSIONED CONCRETE: If the unbonded cables are damaged, becoming untensioned 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 gravity weight of the structure.
- The floor slabs or beams may also have some rebar, but these bars are placed at the bottoms of slabs near midspan and at the top near supports (as in a normal gravity design) and will not be affected in resisting the upward pressures from blasts.
- This is a very vulnerable and dangerous post-blast structure.

HEAVY WALL BUILDING—TU, RM, 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 due to loss of vertical and/or lateral support.
- For blasts initiated outside the building, the near walls may be shattered or blown in. This can be followed by having roof sections lifted, then dropped, as well as having sections of the far side blown out.

In summary, the effects of explosions can be compared to a very short term, very high velocity wind. There may be special effects at corners and other discontinuities and shading of one part of a structure by another or one building by another.

Review of Learning Objectives

In this section we have discussed the various Collapse Patterns that have occurred that will give us some insight as to how structures will behave in future disasters.

This should make us more effective in assessing the dangers at a disaster site as well as recognizing the difference between survivable and less-survivable voids.



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Topic 2-2: Structural Hazard Identification and Building Monitoring



Topic 2-2: Structural Hazard Identification And Building Monitoring

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 that have been used to mitigate them.

Enabling Objectives

- Discuss how concrete and masonry crack and how these cracks can be "read" to predict future performance of these structures.
- Identify the most common hazardous conditions that will occur in the four types of buildings.
- Discuss the various tools and methods that are currently available to monitor buildings.

Cracks in Reinforced Concrete and Masonry

A favorite statement in building design and construction is "**If it's not cracked, it's not concrete**," since cracks must form in concrete for the reinforcing steel to be stressed in tension. Most normal concrete develops cracks that are narrow (hairline) as a result of shrinkage, temperature change, and predictable structural behavior.

Shrinkage Cracks

- Usually cracks occur in slabs, beams, walls, and even in columns within 60 days of the pour, after the concrete is allowed to dry out.
- Diagonal cracks will originate from most reentrant corners in slabs and walls, i.e., window, door, and floor openings.
- Straight cracks (more or less) occur often at 5' to 20' on center in long wall 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.

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) and, therefore, it cracks and the reinforcing steel attempts to hold it together.
- Reinforced concrete structures will, obviously, have more observable temperature/shrinkage cracking when subjected to the winter cold.

Tension Cracks

These most often occur in concrete slabs and beams when bending-caused tension forces stretch the reinforcing steel.

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Topic 2-2: Structural Hazard Identification and Building Monitoring

- Cracks must form in the concrete in order to transfer the force to the steel, but the cracks normally are 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 hairlike, the structure is behaving normally.

Diagonal Tension Cracks

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

Cracks in Reinforced Concrete Walls

- The stability of concrete box buildings will probably depend on the postcracked strength of the shear walls. Even with unsightly diagonal cracking, a shear wall may still have significant strength.
- 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 also act as dowels.
- Both these resistive actions are lessened when there is enough shaking or continued reshaking due to aftershocks that the crack widens, concrete chunks fall out, and the rebar can be seen in an offset curved condition. In this later degraded condition, a shear wall has become unreliable and must be evaluated accordingly.

Cracks in URM Walls and UR Concrete Walls

- Shrinkage, temperature, and diagonal tension/shear wall cracks also occur in URM and UR concrete walls. In these walls, however, cracking indicates a significantly degraded structure.
- Diagonal tension cracks form in these walls between openings, as they do in reinforced concrete walls due to 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. This is 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. That is, the crack follows the weaker mortar, rather than going through the bricks. This results in cracked surfaces that are smoother than those in reinforced concrete.
- Masonry walls with significant diagonal tension cracks must be considered to be capable of a sudden, brittle failure. There is some clamping force on the horizontal steps of the cracks due to the gravity force, but no vertical bars 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 quakes. They tend to break apart in pieces, defined by whatever crack pattern existed prior to and/or by the original pour joints.

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Topic 2-2: Structural Hazard Identification and Building Monitoring

DIAGONAL TENSION CRACKS







HAZ-DTEN



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Topic 2-2: Structural Hazard Identification and Building Monitoring

SHEARWALL CRACK PATTERNS HAZ-CK





URM SHEARWALL • UNREINFORCED CONCRETE = SIMILAR

Figure 2:3

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Topic 2-2: Structural Hazard Identification and Building Monitoring

Cracks in Reinforced Concrete and URM Shear Walls

Hazard Identification

- In damaged, partly collapsed, and collapsed structures we can identify three types of hazards:
 - Falling, where part of the structure or its contents are in danger of falling
 - **Collapse**, where the volume of 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 (discussed in Hazmat 1st Responder Course)
- Falling and collapse hazards will be discussed here. The degree of hazard in both cases is strongly related to mass and how additional failure may occur. Brittle, sudden failure potential must be recognized as contrasted to structures where 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 such as bad, very bad, and deadly. We must consider that:
 - Judgments cannot be precise.
 - We must try to identify brittle vs. ductile behavior.
 - Partial collapse is very difficult to assess.
 - The cause of the condition is very important input (i.e., earthquake with expected aftershock, windstorm, etc.).
- In evaluating, if a specific structure is at rest, one could state, on the positive side, that the structure that was moving had enough resistance to stop moving and achieve at least temporary stability. However, the damaged structure is difficult to assess, weaker, and more disorganized than the original.
 - Try to identify the load path and visualize what could happen 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.

Light-Frame Building Hazards

Principal weakness is in lateral strength of walls and connections.

Check Points (HAZ-LF)

- Badly cracked or leaning walls
- Offset residence from foundation
- Leaning first story in multistory buildings
- Cracked, leaning masonry chimney or veneer
- Separated porches, split-level floors/roof



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Topic 2-2: Structural Hazard Identification and Building Monitoring



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Topic 2-2: Structural Hazard Identification and Building Monitoring

Light-Frame Building Hazards

In structures of less than three stories, additional collapse is unlikely due to 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.



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Heavy Wall Building Hazards

Principal weakness is in lateral strength of walls and their connections to floors/roof.

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



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Heavy Wall Building Hazards—TU

Low-rise reinforced masonry wall buildings with light roof are similar. Principal weakness is in connections between wall and floor/roof.

Check Points (HAZ-TU)

- Connection between floor/roof and exterior wall
- Connection between beams and columns, both exterior and interior
- Badly cracked walls and/or columns
- Connection failure will often be brittle. Wall/column failure and shear failure may be more ductile, but single curtain wall reinforcing provides little confinement.



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Topic 2-2: Structural Hazard Identification and Building Monitoring

Heavy Floor Building Hazards—Concrete Frames

Principal weakness is lack of adequate column reinforcing that can properly confine the concrete and inadequate connection between 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 nonstructural, unreinforced masonry walls (infill walls)
- Cracks in concrete shear walls and/or stairs
- Ductile behavior may still be possible if the concrete remains confined by reinforcing steel and the reinforcing has not been badly distorted.



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Topic 2-2: Structural Hazard Identification and Building Monitoring

Precast Building Hazards

Principal weakness is in interconnection of parts: slabs to walls/beams; beams to columns; walls to slabs, etc. It is very difficult to make connections adequate to transfer the strength of parts, which is 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 with broken welds, cracked corbels
- Column cracking at top, bottom, wall joints
- Wall panel connections
- Shear wall connections at floors, foundation
- Badly cracked walls
- These structures are often made from lightweight concrete, which 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 the collapse, many falling hazards may be present.



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Topic 2-2: Structural Hazard Identification and Building Monitoring

Heavy Steel-Frame Building Hazards

Principal concerns are the potential for building cladding to become falling hazards and the cracking of welds in the principal 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, stair, and nonstructural damage—as clues to potential structure damage
- Main beam-column connections—may need to remove finishes or fireproofing
- Broken or damaged floor beam connections and, if present, broken precast slab connections

HEAVY STEEL FRAME - HAZARDS HAZ-HS



Figure 2:10

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Topic 2-2: Structural Hazard Identification and Building Monitoring

Post-Tensioned Concrete Slab Hazards

- There are many types of structures that have floor slabs that are reinforced by height strength cables (250ksi ult) 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 almost always exhibit brittle behavior. The most common examples of structures where P.T. slabs may be found are:
 - Multistory parking garages
 - First floors of apartment houses that are built over parking
- Since the cables often extend the full length of these slabs, if the slab 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 US&R Incident, to cut through a P.T. slab that still has stressed cables. With the proper care, a limited amount of cutting can be done.

Summary of Hazard Identification

The problems of identifying hazards after structural collapse are extremely difficult.

- Buildings are often complicated and there are many different types and configurations.
- It is important to assess what remains after the triggering event may have come to rest, but the danger of further collapse and falling objects is often present.
- A qualified engineer who understands the basic behavior of structures should identify these hazards.
- Brittle conditions pose the greatest threat due to the probability of sudden failure.
- As many hazards as possible should be identified and probable risk factors assigned to them.
- Measures to avoid or mitigate the danger can then be factored into the overall search and rescue effort.

Hazard Assessment for US&R

Based on the previous section on hazard identification, we need to add some additional considerations for US&R, since staying out of the structure is normally not an option.

- 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.
- Know what are global vs. local hazards.
- Look up first! Small, nonstructural elements may be 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:
 - Is there brittle or ductile behavior?
 - What redundancy is present?

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Topic 2-2: Structural Hazard Identification and Building Monitoring



- Can the hazards be mitigated to an acceptable level? What is the risk during the mitigation?
- Check for potential instabilities. Consider building stability and rubble stability.
- What caused the collapse? Has the structure collapsed to a stable condition?
- What if there is an aftershock?
 - What is the plan?
 - What are the escape routes and/or safe havens?
- Before changing the existing configuration, evaluate the effect of the change on the load path.

Methods to Monitor Stability

The fundamentals of structural monitoring for SAR include: a **Monitoring Plan**; effective **Emergency Communication Plan**; **Monitoring Tools**; and **Trained Monitoring Personnel**.

- Monitoring Plan: Similiar to a design performance memorandum, the monitoring plan establishes the expected performance levels for the structure being monitored.
- Emergency Communication Plan: Effective monitoring must use 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).
 - US&R Command 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.
- Monitoring Tools: The following indicators have been used to monitor damaged structures in an attempt to warn of change in stability:
 - Engineer's transit or theodolite
 - Electronic tilt-meter systems
 - Electronic levels—SmartTool and SmartLevel
 - Laser pointers or level
 - Plumb bob
 - Crack measuring device
- Theodolites and surveyor's transits 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 resetup of the instrument.

This may be problematical following earthquake aftershocks when many structures and ground surfaces have been moved and possibly disrupted.



Advanced Rescue Skills

Topic 3-1: Basic Shoring



Topic 3-1: Basic Shoring

Terminal Objectives

- The student will understand the function and capacity limitations of the shoring used in US&R to support damaged structures.
- The student will understand why and how shores are constructed.

Enabling Objectives

- Determine weights to be supported.
- Determine the appropriate shore to be constructed.
- Understand the sequence of construction to minimize risk.
- Understand how to inspect constructed shores.

Basic Definition and Principals

Shoring is normally the temporary support of structures during construction, demolition, reconstruction, etc., in order to provide the stability that will protect property as well as workers and the public.

Shoring for US&R is the temporary support of only that part of a damaged, collapsed, or partly collapsed structure that is required for conducting search and/or rescue operations at reduced risk to the victims and US&R forces.

A shoring system is like double funnel. It needs to collect the load with headers or sheathing, deliver it into the posts and struts, and then distribute it safely into the supporting structure below. A heavily loaded wood post can punch through a concrete slab, etc.

Shoring should be built as a system that has the following:

- Header beam, wall plate, other element that collects load
- Post or other load-carrying element that has adjustability and positive end connections
- Sole plate, bearing plate, or other element to spread the load into the ground or other structure below
- Lateral bracing to prevent the system from racking (becoming a parallelogram) and buckling
- Built-in forgiveness—will give warning before failure

Minimum level of lateral strength in any vertical support system should be at least 2 percent of vertical load, but more is desirable where aftershocks are expected. A Structural Engineer (Structures Specialist) should be consulted regarding extra lateral support.

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Topic 3-1: Basic Shoring



Considerations for Design WEIGHTS OF COMMON BUILDING MATERIALS

- Concrete = 150 pcf = 168 per cubic ft
- Masonry = 125 pcf psf = lbs per square ft
- Wood = 35 pcf psi = lbs per square inch
- Steel = 490 pcf
- Conc/Masonry Rubble =10 psf per inch (of thickness)
- NOTE that heavily reinforced concrete beams and columns can weigh more than 150 PCF (up to 200 PCF and more).
- Another way to quickly calculate the weights of concrete and steel members is to find the area of the cross section and multiply it by the weight per square inch of a foot-long piece:
 - For concrete beams and columns use 1.2 psi per ft of length. Example: 16"x16" column weighs: 16 x 16 x 1.2 = 307 lbs per ft
 - For steel sections use 3.4 psi per foot of length.
 Example: ³/₄" round bar (steel cable weighs about 70% of bar)
 ³/₄ x ³/₄ x .785 (for round shape) x 3.4 = 1.5 lbs per ft
- Concrete floors weigh from 90 to 150 psf.
- Steel beam with concrete-filled metal deck = 50 to 70 psf.
- Wood floors weigh from 10 to 25 psf (floors with thin concrete fill are 25 psf or more).
- Add 10 to 15 psf for wood or metal stud interior walls, each floor level.
- Add 10 psf or more for furniture/contents each floor (more for storage, etc.).
- Add 10 to 20 psf for rescuers.
 - 10 psf on large slab that spreads out load
 - 20 psf on wood floors to allow for concentrations

Example: 20' x 30' slab

Total for 8" concrete slab, 6" of debris, allowance for lights and ceiling, and 10 psf for rescuers = 105,000 lbs

(In this case, the 10 psf allows for 24 250 lb rescuers, which seems to be reasonable.)



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Topic 3-1: Basic Shoring

Shoring in Multistory Structures

- For existing, sound, wood structures, the excess live load capacity in an undamaged floor will usually be enough to support the weight of a damaged floor. This assumes that the damaged floor is not highly loaded with debris from exterior walls, etc. Also, the undamaged floor is assumed to not be heavily loaded with storage of books or other material, and no occupants (other than rescue forces) would be present.
- For existing steel-frame structures, it would take **at least** two undamaged floors to support one damaged floor (with the same assumptions of loading as for wood floors).
- For existing cast-in-place concrete (CIP), it would take **at least** three undamaged floors to support one damaged floor (again, with the assumptions of loading as for wood floors).
- For precast concrete (PC) and all concrete parking structures, all shoring should be extended to the ground or a "base slab" that has been designed to support the impact forces of a progressive collapse. Unfortunately, due to the competitive nature of many structures of this type, one must approach them with extra caution.
- Special caution needs to be practiced when structures under construction have become a partially collapsed US&R incident. This would also apply to existing structures that collapse unexpectedly (due to no apparent cause).
 - Since the cause of the collapse may involve an inadequacy in the original design or construction, US&R operations should proceed with great caution and only after review by a knowledgeable Structural Engineer (Structures Specialist).
 - For CIP concrete structures, the age of underlying floors and "reshoring" scheme would need to be considered in deciding if undamaged floors could safely share any additional load.
 - PC concrete and concrete parking structures have proven to be vulnerable to secondary collapse and must be approached only after careful evaluation. Risk of further collapse must be weighed against to possible reward of live recoveries. Deconstruction may be the only viable option.

Since these structures may contain unconnected elements that may also bear on narrow corbels, any shoring system must be complete enough to reduce the possibility of both vertical and lateral progressive collapse.

Sequence Considerations

■ When shoring is placed in a multistory incident, one should begin the shoring directly below the damaged floor. This should be done in as safe a manner as possible, but the intent is to "share the load" of the damaged floor, as soon as reasonable.

Once the upper level of shoring has been accomplished, then all succeeding levels should be added, in line with the shores immediately above.

■ To minimize risk, the normal strategy is to shore from outside (in the Safe Zone) into the more hazardous area. Safe havens plus access/egress corridors need to be established in order to place the shoring with minimized risk.

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Topic 3-1: Basic Shoring



Selection Considerations

Condition of structure to be supported: Is the floor constructed with concrete beams, solid concrete slab, broken slab, etc.? Does the floor have to support masonry rubble? Does the shoring system need to contain an elaborate spreading system or need one only to support the main beams? Are we supporting a solid concrete slab/wall or is it a broken masonry wall that needs more of a spreader system?

- In wood floors we can normally place our shoring header directly against the bottom of 2x10 or 2x12 joist, but if the floor or roof is constructed using deep, thin trusses, I-joist, or truss-joist, that may be problematical.
- Deep, thin members should not be shored from the bottom without doing something to keep them from tipping over. A solution to this problem is to somehow shore from the top of this type of member or to provide some way of keeping the members from tipping.
- In steel floors beams can be directly shored from the bottom, but steel bar joists present the same problem as wood trusses.
- In PC concrete floors the configuration of the members will dictate the shoring layout. Members like the T and double T will need major support under the T stems, but for very deep Ts, stability will also have to be considered.

Condition of foundation/support of shoring: Solid or soft ground, slab on ground, floor over basement below, rubble, number of undamaged stories below all determine extent of system.

Availability of shoring materials: Consider preplan, local contractors, foreign location. For collapsed structures you want a light, portable, adjustable, reliable, and forgiving shoring system.

Damaged/Collapsed buildings often contain lateral as well as vertical instability.

Buildings that are out of plumb due to cracked (damaged) walls and/or columns require lateral support in proportion to the slope of the offset story.

- This is easily calculated as illustrated in adjacent figure.
- Wood buildings have been found that were racked at a slope of as much as 2' in one 10-foot story (20 percent slope).
- It would be rare to find damaged but uncollapsed masonry walls that are racked at more than 5 percent (6" in 10').
- If the structure is partly supported by a tension structurelike system, horizontal forces are often induced in the remaining structure.
- Collapses that have large remaining pieces can be extra dangerous. Interconnected pieces may depend on each other for support—a complicated balancing act to be wary of.
- Collapsed structures containing sloped surfaces are especially difficult, since loads are vertical due to gravity, but contact surfaces are sloped and, therefore, vertical and lateral forces induced in shoring are both very large.
- Total load of structure above can be relatively easily calculated, but where individual load concentrations are being applied, it is often difficult to determine. A shoring system that will give warning of overload is therefore most desirable.







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Topic 3-1: Basic Shoring



- It is difficult to decide on the design load when a damaged structure is at rest, but of questionable stability.
 - Should vertical shoring support the weight of the damaged but currently stable floor or only the weight of rubble resting on it?
 - A four-story wood building that is offset one foot in ten in the lower story will require a 10 percent stabilizing force, but what additional force should be allowed for wind or aftershock?

Using the Desirable Properties of Wood to Advantage

- As previously stated, a most desirable property for emergency shoring is to have a system that will give a warning when it is becoming overloaded, so one can mitigate the situation. Wood has a built-in (or more accurately, grown-in) property that can be used in our systems to give a noisy indication of high stress. This is a useful "Structural Fuse."
- Most commercial timber grows in a way that produces softer spring fibers and harder summer fibers. By configuring a shoring system such that the longitudinal grain bears on the cross grain of wood, and the vertical piece is kept short enough that it won't buckle, we can cause the cross grain to crush.
- We can hear and observe this crushing that will occur when the bearing stress is somewhere between 500 and 700 psi, depending on species of timber.
- We, therefore, want to proportion our posts so crushing of the header or sole will occur as the failure mode, not the sudden failure mode of buckling. In order to do this we need to keep the length to width ratio (L/D) of a wood post to less than 25 (for the most common lumber used).

Example: 4x4 length for L/D of 25 = 25x3.5 = 88'' = 8ft 6x6 length for L/D of 25 = 25x5.5 = 138'' = 12ft

- One can use posts and other compression members that have L/D ratios up to 50. We would do this only for bracing members or if we were sure that our loading was very light and predictable.
- The strength of a wood post shoring system is governed by:
 - Perpendicular to grain bearing on the header or sole plate (allowable bearing stress varies from 300 psi to 700 psi depending on wood species)
 - Vertical capacity of the posts
 - Strength of header beam and/or sole plate
 - For most US&R vertical shoring systems, posts are kept 4' on center in order to keep the header size to 4x4 or 6x6.
 - Often the supported structure is stiffer than the header.
 - Strength of ground or structure below sole plate

As noted, US&R shoring is proportioned to give warning of failure by crushing the softer cross grain at the bearing of the post on the header and cupping of the wedges at the sole.



Figure 3:2



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Topic 3-1: Basic Shoring



Shoring Systems

We will now discuss the following shores:

- Vertical shores
- Lateral shores
- Sloped floor shores
- Raker shores and tieback systems—built when walls are too high for raker shores

Vertical Shores

- Almost all these systems use wood wedges to provide for adjustability. Wedges also provide an ideal "structural fuse" since they will deform and "cup" when the posts are loaded to about 1.5 to 2x allowable bearing load (about 1,000 to 1,200 psi). Wedges should be checked at least twice a day and after any significant change in loading, including aftershocks.
- All wood post systems should have diagonal wood bracing, in northsouth and eastwest directions, if possible. Bracing should be designed for at least 2 percent of the vertical capacity of the shoring system.



Figure 3:3

Class I spot shore is constructed from a single vertical post with a header plate and sole plate to collect and redistribute the load.

Double T Shore

- This type shore may also used for initial stabilization of dangerous areas.
 - It provides temporary support of damaged floors and is much more stable than the T shore.
 - With a 3-foot header and the posts placed 24" outside to outside, most of the load would be centered between the posts.
 - Due to its limited width of 3', this shore is not as desirable as the 2- or multipost vertical shores, but its portability allows it to be installed with minimum exposure of rescue workers.
 - For shore height less than 6', you may omit midheight gusset.
 - For heights over 11', midheight gussets should be placed at 1/3 height and 2/3 height. Maximum height of shore is 12'.
- The capacity of the 4x4 posts depends on length as in vertical shores (one 8'-long 4x4 safely supports 8k, 10'-long = 5k).



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Topic 3-1: Basic Shoring



They need to be installed with wedges, sole plate, and half-gusset to spread the load and tighten the shore against the load.

Two-Post Systems

- This shore is preferred by engineers for constructing a vertical shore using wood posts.
 - Prefabricate the two posts, header, and upper diagonal and horizontal braces. This is a two-dimensional, Class 2 shore, same as a three or more post vertical shore.



- After positioning the prefabricated part, the sole, wedges, lower diagonal, and half-gussets would be installed.
- An additional 2-post system could later be placed in an adjacent location in order to form the stable, three-dimensional laced post system—a Class 3 shore.
- For a full-height 2-post shore, the diagonal bracing is best configured as shown. Posts should be spaced 4' maximum on center for 4x4 and 5' maximum for 6x6.
 - Maximum height using 4x4 posts is 12' (6x6 is 20'). If the 2-post shore becomes a part of a laced post, the height may be greater (see laced post information).
 - The 2x diagonals are configured the same as a laced post, so their L/D is small enough to allow them to resist both compression and tension.
 - Diagonals should not be greater than 7'6"-long from end to end (6.5' clear between posts on diagonal).
 - The safest way to build this shore is to prefabricate as discussed above, then the sole, wedges, half-gussets, and lower diagonal can be added in the Collapse Zone.
- For heights from between 11' and 17', two horizontal braces and three diagonals should be used.
- For conditions in Collapse Zones where shoring heights are 6' and less, the short, 2-post vertical shore may be used.
 - In this case, again, the 2x diagonal brace is short enough so it can resist compression and tension and, therefore, X bracing is not required.
 - Cribbing may be the best choice at heights 3' and less (to be discussed later).

It is preferred by engineers, since it can be converted from a Class 2 shore into a Class 3.



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Topic 3-1: Basic Shoring



header

Wood Post Systems (2 or More Post to Make Systems)

- Figure 3.5 illustrates the construction and capacity of a **3-post wood post, vertical shore.**
 - Connections at top and bottom of posts are nailed gussets. For 4x4 and 6x6 headers, a single-sided half-gusset may be used at the top; however, half-gussets should be placed each side at the bottom to prevent wedge popout in aftershocks.
 - Diagonal braces are nailed to each post and also provide top and bottom connections for exterior posts.

Vertical Shore - Important Joints

- 2x6 diagonal needs to be carefully positioned
 - to provide a competent load path
 to fit 5-16d to header, post & sole
 May use 3-16d to post at bottom
 - to confine wedges and reduce roll over at bottom
- over at bottom post
 For most long-incidents, need to add gusset on opposite side of diagonal brace to protect against sole roll-over & wedge pop-out
 Figure 3:5 sole
- It is difficult to provide lateral stability in the "out of plane" direction for these **two-dimensional** (Class 2) shores.
- The connection at the top and bottom of exterior posts is of special interest, since the diagonal must be carefully positioned to transfer the lateral load. The diagonal must also be nailed to the header, post, and sill and also confine the wedges. A half-gusset needs to be placed on the opposite side of posts at the bottom to reduce risk of sole rollover and wedge pop-out. Also, a half-gusset should be added on the opposite side at the top when the header is deeper than their width (rollover).
- The following gives design values for two systems (4x4 and 6x6 posts) based on post design strength for various lengths (height).
 - Header size is specified as 4x4 and 6x6 minimum based on the following:
 - The maximum post spacing for 4x4 is 4' (6x6, 5'), and posts are aligned under floor beams and/or joists.
 - Use when concrete slabs and/or beams are being supported and the concrete is not badly cracked and therefore capable of spanning between the posts.
 - When the conditions for the 4x4 and 6x6 headers cannot be met, a Structures Specialist will need to design a larger header, based on required bending and shear resistance. Taller headers will require that double half-gusset plates are used at the header to post connection, in order to prevent rollover.

2-Post Vertical Wood Shores





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Topic 3-1: Basic Shoring

- The headers of vertical shores may slope as much as 6" in 10' or 5 percent (about 3°). For slopes that are greater, one should use a sloped floor shore, discussed later in this section.
- The 3-post wood system has been built for many years, but it has several shortcomings.
 - Because of its length, it is often difficult to prefabricate.
 - It is only a two-dimensional system; therefore the posts can only be braced in the plane of the X bracing. Thus, the effective length of the posts cannot actually be reduced.
 - To assure stability, the header would need to be connected to the load at the top. If it is not connected, it could shift sideways during an aftershock.
 - The sole plate should also be restrained from moving sideways.



Figure 3:7



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Ellis Clamp - Wood Post Systems



Figure 3:8



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Topic 3-1: Basic Shoring

Ellis Clamp—Wood Post Systems

- 4x4 posts can be assembled with Ellis Clamps that give them adjustable length. The failure mode of these assemblies is usually indicated by the crushing of the wood under the clamps (if shores are 10' or less in height). This gives the system some forgiveness.
- These shores use more lumber than single posts, but they can be very useful when working with short 4x4s.
- Metal adjustable post feet for 4x4 and 6x6 are made by Ellis and called screw jacks. The foot base plate has nail holes for positive attachment. The capacity of the screw jacks is 15,000 lb for 4 x 4 screw jacks, and 30,000 lb for 6 x 6 screw jacks.

SCREW JACK by ELLIS

- Adjustable metal foot for 4x4 and 6x6 wood posts
- 6 inch adjustment set half way to get 3 in. up & down
- Metal Foot is stronger than wood post
- Use sill beam to spread load

Figure 3:9





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SHOR L PA

Laced Posts

- Four posts may be placed in a square pattern and laced together with 2x4 or 2x6 horizontal and diagonal bracing.
 - The spacing of posts is 4' maximum for 4x4 (5' for 6x6) so the length of the 2x diagonal braces will be 7'6" maximum to allow them to resist compression as well as tension forces.
 - The maximum height with 4x4 posts is 17' (20' for 6x6).
 - 2x4 diagonals, 3-16d each end, are used with 4x4 posts.
 - 2x6 diagonals, 5-16d each end, are used with 6x6 posts.

Laced Posts - Class 3

- 4x4 Posts=4ft max o.c.
 6x6 Posts = 5 ft max.o.c.
- Increase long post capacity due to short effective length
- Add 2x4 lacing, 3-16d @ end
 3 bays bracing if over 11ft high
 Use K layout or any other
- 2x6 lacing, 5-16d at 6x6 Posts
 Need Header & Sole
- Connections like Vert Shore
- Height NOT exceed 4x o. to o.
- Can use as Safe Haven
- Design Load

 4 4x4x17"- 0"max. = 32,000#
 - 4 4x4x17"- 0"max. = 32,000#
 4 6x6x20'- 0"max. = 80,000#
 - Based on 660psi bearing

Figure 3:10

- The connections between diagonals and header/sole need to be made with as much care as for the vertical post shore, since the 2x diagonals must be nailed properly to header, post, and sole and confine the wedges as shown in the adjacent slide. A half-gusset is, again, useful opposite the diagonal to sole connection to guard against rollover and wedge pop-out.
- The strength of each post may then be calculated on the basis of the length/height between the horizontal braces (8K for 4x4 and 20K for 6x6).
- Header beams and sole plates are usually required to collect and distribute the load, as for vertical shores.
- The surface that is being supported may have a slope of 6" in 10' in any direction, as in other vertical shoring systems.
- Use sloped floor shores for larger slopes.
- The space inside the laced posts may be useful as a safe haven, since it is relatively strong and one may climb in relatively quickly.
- The safest and most effective way to construct laced posts is to first build two 2-post vertical shores and then lace them together. The 2-post vertical shores should be prefabricated, without their sole plates, and then assembled in the Collapse Zone.
- The most common configuration of the laced post has one midpoint horizontal brace and two sets of diagonal braces. These should be used for shoring heights between 6' and 11'.
 - For heights from 11' to 17', there needs to be a horizontal brace at one-third points and three sets of diagonal braces.
 - For heights below 6', in limited-height areas, one can build a short, braced shoring system that is essentially a half-height laced post.

The configuration of the diagonals is discussed above-right. The K configuration is easy to teach and remember.



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NAIL PATTERNS FOR RAKER AND OTHER SHORES



Figure 3.36



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Topic 3-1: Basic Shoring

Window and Door Shores

- They are used mostly in URM buildings to confine and support loose masonry over openings in the URM walls.
 - They are quite complicated if all corners are properly connected and wedges are confined.
 - They may also be used in wood or other buildings where door or window headers have been damaged.
 - They have been used in badly racked wood buildings as diagonal bracing (use 4x or larger compression diagonals that are on same plane as header, sole, and posts).
- The capacity of the wood posts (which are usually short) usually depends on the cross grain bearing strength (between 300 and 700 psi depending on wood species).

Alternate - Window / Door Shore



used

Pre-construct as box-frame, 1 1/2" min. less than opng.

Add wedges at bottom and one side at top & bottom

Add diag. Braces if wall is racked, & access isn't regd.

- A rule of thumb for header size is to make the depth the same in inches as the opening width in
- feet.
- The header width should be 6" for thick URM walls, but may be 4" for thinner walls such as wood and hollow concrete block (cinder block).
- A simpler, preconstructed configuration uses 2x wedges under sole over and at one side.
 - It can be built in the safe area and possibly reused.
 - It can support as much vertical load as the standard window shore, but may not be practical for badly racked openings.

Lateral Shoring Systems

- Principles of trench shoring may sometimes need to be applied to US&R, where pulverized masonry rubble tends to cave into an otherwise accessible space. As previously discussed, pneumatic shores may be used in vertical applications since they have positive locking devices.
- There are several systems used as lateral shores, such as
 - Wood horizontal shores •
 - Hydraulic shores
 - Pneumatic shores ٠
 - **Tieback** systems •
 - Drilled-in solid or pole systems

The design of these systems is competently presented in the CALTRANS Trenching and Shoring Manual.



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Topic 3-1: Basic Shoring

Wood Horizontal Shores

- These wood shores have been used by firefighters in URM and other damaged buildings to support bulging walls.
- Since the horizontal wood posts (struts) are usually short, their capacity is normally based on cross grain bearing strength (300 to 700 psi).
- Wall plates are used to spread the load from two or more posts.
 - Wedges are used to tighten the horizontal struts.
 - Bracing and cleats are added to complete each shore (box in wedges and interconnect all members).
 - The normal X braces may need to be eliminated to allow for access and, in that case, corner plywood gussets are added to help connect corners and brace the shore.
 - The shores are normally spaced at 8' on center, depending on the situation.



Hydraulic Trench Shore



- These are frames made from aluminum hydraulic rams with continuous side rails.
- They are intended to be dropped into open trenches from the top and pressurized with a 5-gallon hand pump to between 500 and 1,000 psi.
 - Plywood panels are added against the soil to spread the load and confine soils.
 - There is no locking device as for pneumatic shores; therefore, **hydraulic shores are not recommended** for supporting vertical loads.
- Hydraulic shores can have a single ram with 2-foot-long rails or double rams with rails up to 12' long. Standard double ram frames have rails in 3.5-foot, 5-foot, and 7-foot lengths.

Other Trench Shores (All have same capabilities as in vertical application)

- Trench jack (screw jack)
- Post screw jack
- Pneumatic shore



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Topic 3-1: Basic Shoring

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 psf).
- Bracing frames (like double rakers) may be placed 4' on center.
 - Use 30° or 45° slope with 4x4 or 6x6 members, depending on height.
 - Sheathing between frames may need to be 3x or 4x.
 - Anchor system is very important.
 - Perpendicular bracing needs to be installed.

Vertical Shores on Sloped Surfaces

- In normal sloped roof construction, sloped rafters are fabricated with horizontal bearings cut-in, so the vertical gravity load can be directly transferred into the supporting structure.
- When attempting to shore a damaged, sloped floor, however, the vertical gravity load is transferred from structure to shoring through a sloped surface where two forces are generated.
 - A force that is perpendicular to the sloped surface and
 - A force that will act down the slope—slope force
- In many cases, especially for reinforced concrete slabs, the slope force may be assumed to be resisted by:
 - The connection of the sloped floor to the remaining structure at the top, or
 - The sloped floor is firmly embedded in rubble at the bottom.
 - When this is the case, **the perpendicular to slope method** shores may be used to successfully support the sloped floor.
- When the sloped floor is connected to the remaining structure or is embedded in rubble, the perpendicular method shore should be used. This may be built on concrete, paving, or soil and uses cleats nailed to the sole, which is, in turn, anchored. This will be called a Type 2 sloped floor shore (may be used on concrete, paving, or soil). See Figure 3.13.
- When the sloped floor is not reliably connected to the remaining structure or is embedded in rubble, the **sloped friction method** shore should be used. This will be called a **Type 3** sloped floor shore (may be used on concrete, paving, or soil). See Figure 3.13.
 - In this case, the perpendicular and slope force are combined within the system to allow the shore posts to be placed in a vertical alignment.
 - Since the reliance on friction, especially during aftershocks, may be problematical, the header should be positively attached to the sloped floor, especially if floor is sloped greater than 5 percent.
 - Small bars (½" to ¾" in diameter) could be carefully drilled into bottom of slab (through predrilled holes in header) and held in place with epoxy (or by interference fit).
 - Shore could bear on sides of beams or other protrusions.



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Topic 3-1: Basic Shoring

Vertical Shores on Sloped Surfaces

- All sloped floor shores should be built as three-dimensional, Class 3 systems.
 - Construct systems as a minimum of two 2-post shores—4x4 posts spaced 4' maximum and 6x6 posts spaced 5' maximum.
 - Diagonal bracing (X bracing) should be placed in the plane of the shore. Bracing should be designed for 10 percent minimum weight of supported structure.
 - Bracing between shores should be configured as lacing (laced post shores) if shores are kept within 5' on center. However, if shores are spaced more than 5' but less than 8' on center, they should be laterally braced using horizontal and X bracing as for raker shores.
 - When the height of the shorter end of the shore gets as small as 3', a 12"- to 24"-wide strip of ³/₄" plywood should be used between shores instead of X bracing. Nail plywood with 8d at 3" on center staggered each end.
 - 6x6 shore posts should be used where heavier concrete floor systems are encountered.
- Well-braced systems using normal vertical shores may be used when floors are sloped less than 5 percent (6" in 10'). Again, use the shores in pairs with either lacing or horizontal plus X or V bracing in between shores as for rakers.

Vertical Shores on Sloped Surface – Cribbing

- For conditions where the shore height is less than 3', cribbing can be used to support sloped floors, as shown in Figure 3.13.
 - Slope for crib-supported floor should not exceed 30 percent (3' in 10', approximately 15°).
 - Cribs can be built into the slope, but care must be taken to properly shim the layers in order to maintain firm, complete bearings. These will be called **Type 4** sloped floor shores.
 - Notches, nails, or metal clips could be used to interconnect crib members so they would better transfer lateral loads.
- Summary for Sloped Floor Shores
 - Sloped floor shores are complicated. No one solution will work for all conditions.
 - One needs to carefully assess the situation to determine which way the floor will move.
 - To shore sloped wood floors, the header needs to be placed perpendicular to the joist.
 - Very adequate bracing is required in an attempt to better resist the forces that may not be accurately predicted.



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Type 2 ON SOIL SURFACE





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SHORES FOR SLOPED FLOORS • CRIBBING • TYPE 4



MORE RESISTANT TO HORIZ FORCES BY NOTCHING 6x INTO EACH OTHER



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Topic 3-1: Basic Shoring

Raker Shores

- Raker shores are useful in bracing URM and other heavy walls that have cracked (especially at corners) and/or are leaning away from building.
- They 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 it will bear on the opening head.
- The required horizontal force may be less than 2 percent of the wall weight, since URM walls are seldom left standing very far out of plumb. However,



Figure 3:14

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.

- Rakers should be built away from the dangerous area next to wall and then carried or walked into place.
 - Rakers should be spaced at 8' maximum on center.
 - When the insertion point is greater than 8', the raker needs to be configured with a midheight brace.
- Rakers may be configured using the full triangle method (called fixed raker) or as a flying raker (friction raker).
 - Full triangle rakers may be configured as solid sole or split sole rakers.
 - The preferred solid sole raker may be built on concrete, paving, or soil.
 - The split sole raker may also be built on concrete, paving, or soil. Since the sole/bottom brace may be sloped, this raker may be constructed in locations where some rubble is present next to the base of the wall.



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US&R SHORING OPERATIONS GUIDE CONSTRUCTING VERTICAL SHORING SYSTEMS

BRACING BETWEEN PAIRS of SLOPED FLOOR SHORES

(When shores are spaced 5'-0" o.c. maximum.)





- 1. When Sloped Floor Shores are spaced a no more than 5'-0" o.c., brace the two sections together, same as in Laced Posts.
 - a. Do this at both posts to tie the two sections together.
 - b. You may use a wide piece of 3/4" plywood (12" to 24" wide) if shore height is 3ft or less. Nail plywood with 8d nails as shown.
 - c. The 2x6 horizontals and diagonal should be nailed each end with 5-16d. 2x4s may be nailed with 3-16d.



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Topic 3-1: Basic Shoring

DIAGONAL (RAKER) SHORES




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RAKER SHORE SYSTEMS



All systems using 4x4 members over 11ft long should be braced in two directions in order to limit L/D to 25[±]

Its better to have a 2x6 continuous at top, mid, & bottom w/ X-braces every forty ft or so than what is shown here.



RAKER SHORE FRAMES Must be braced

4x & 6x Rakers may be spliced using 36" long plywood strips x full width of Raker, placed each side. Splice needs to be located near intersection of lateral braces with raker. 8-8d in 5 nail pattern to each Raker, each side. Use 1x material, same size as plywood if ply not available (with same nailing as ply)



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RAKER SHORE CONNECTIONS



• AFTER FABRICATION, THE RAKERS NEED TO BE CARRIED OR WALKED TO THE WALL, AND ADJUSTED FOR TIGHT FIT.

Figure 3:16



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US&R SHORING OPERATIONS GUIDE CONSTRUCTING LATERAL SHORING SYSTEMS





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Raker Angle

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

- If the angle is 30°, the horizontal force applied to the wall is 87 percent of the force in the diagonal, and the upward force that needs to be resisted at the wall face is only 50 percent of the diagonal force. Limited access normally prevents using 30°.
- When the angle increases to 60°, the horizontal is 50 percent and the vertical is 87 percent.
- At 45°, the two are equal at 71 percent of diagonal force.



Figure 3:17

- Disaster "field" conditions, such as need for access, available timber length, and/or clearance, normally limit the choice to either 45° or 60°.
 - The simplest to build are 45° (1 to 1) and 60° (1.7 to 1). Both are extensively used in US&R.
 - The 60° angle is preferred for the split sole raker, since the soil has better resistance to a more vertical load.

Raker Shore Construction

- The design strength of individual, single, full triangle rakers is in the range of 2,500 lbs (2.5k). This is normally sufficient to brace most masonry or concrete walls up to about 20' high.
 - This is the capacity based on the horizontal load of the wall. (The force in the sloped raker member may be as much as twice the horizontal load.)
 - The 2,500 lbs is based on the cleat nailing of 14-16d nails plus some friction between the raker and its bearings.
 - The design strength of flying rakers is about 1,000 lbs (1.0k) based on a 4x4 raker that must resist bending plus compression. This value may be increased if the bottom brace is sloped down to intersect the raker near the U-channel.
- The full triangle rakers can be configured with a split sole plate (Figure 3.21), which is most useful for bearing on ground. This example shows how a 4x4 lumber x 20' long can be used to brace a 20-foot wall.
 - Lateral bracing is required at midheight of the 4x4 in each direction.
 - Overall lateral bracing is required to stabilize the system of rakers, especially during aftershocks.
 - A second configuration of full triangle raker is shown with solid sole plate (Figure 3.22). This is most useful where paving is found next to the wall. It has the same L/D and overall bracing requirements as the split sole type.
 - Full triangle rakers should always be built in groups of two or more, with lateral bracing systems connecting them together.
 - The split sole raker may also be built on concrete, paving, or soil. Since the sole/bottom brace may be sloped, this raker may be constructed in locations where some rubble is present next to the base of the wall.



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Raker Shore Systems

Raker Shores

- The capacity of rakers is usually limited by the nailed cleat connections and/or the connection to the ground.
 - U-channels may be used to connect the shore to earth for flying and split sole rakers. An 18" sq ft base is added for the split sole. This base does require rescuers to dig in the base, within the wall's Collapse Zone.
 - A trough base may be used along with a sole anchor for split sole rakers that bear on paving or hard soil. This base also keeps the rescuers farther from the Collapse Zone during its installation. See Figure 3.19.
- It is difficult to obtain lumber over 20' long, but splices may be made in rakers as long as they are located near where the diagonal and lateral braces connect. Use ³/₄-inch plywood x (width of raker) x 3' each side of splice, nailed with 8-8d each side each end. Also 1x4x3' may be used to splice the raker, with same nailing as for plywood (more splitting may occur).
- Flying rakers can be configured to restrain a wall that has rubble piled up near its base (without removing it). However, flying rakers have some disadvantages.
 - Unless the bottom brace intersects the raker just above the U-channel base, the force in the bottom brace will cause bending stresses in the raker and tend to push the base out of the ground.
 - These disadvantages can be minimized by sloping the bottom brace so it will connect to the raker as near to the top of the U-channel as possible.
 - Flying rakers are recommended for use to initially stabilize a wall and/or building (especially one with rubble piles next to the wall) so the rubble can be more safely removed and a full triangle system can then be built.
- Lateral bracing consists of continuous horizontal struts (capable of resisting compression and tension) and diagonal bracing (in either V or X configuration). When the height of raker requires a midbrace, horizontal struts are placed at the bottom, middle, and top of the raker.
- Solid sole rakers can be built into tall multiraker configurations using 4x4 members with lateral bracing to bring the L/D ratio to between 35 and 40.
- Multiraker is fairly complicated, but shows how the smaller timbers can be used in a system to stabilize a two-story wall. Note that the bracing needs to be placed in two mutually perpendicular directions.

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 Airshore and Paratech, as well as base plate and bracing connections.



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PNEUMATIC STRUTS USED AS RAKERS

- INDIVDUAL 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



Tilt- Up Wall Braces

- These can be used to brace concrete tilt-up walls and other reinforced masonry walls. They are available for rent from concrete supply companies such as Burke Concrete Accessories.
- The walls would need to be pretty well intact and only in need of bracing, due to connection failure. (Spreading of the load would induce bending moments in the wall.)
- Connection of braces to the wall could be by drill-in anchors, and anchorage at the base could be to a wood curb/pad or slab on grade with a drill-in. These braces act in tension and compression.



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Topic 3-1: Basic Shoring



Tiebacks

- When URM walls are more than 30' tall, it is probably impractical to attempt to brace them with raker shores.
- Vertical and/or horizontal strong backs could be placed on the face of a hazardous wall and tied across the structure to a floor beam or the opposite sidewall. (See Figure 3.24)
- The strong backs could be made from double 2x6 wood members with the tie being placed between them. Solid 4x or 6x members could also be used.
- The ties that have been placed by contractors were steel rods with turnbuckles, bearing washers, etc. Cables with come-along could also be used as well as utility rope, chain, etc. One may need to be creative to obtain an adequate tie, but climbing rope used by firefighters should be considered only as a last resort. (Climbing rope is considered unreliable with the rough treatment of this type of application and would be discarded.)



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FULL HEIGHT RAKER . SOLID SOLE TYPE





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Shoring Systems Used In US&R

Stabilize Wood Apartment

The house moving contractor, R. Trost, provided emergency shoring after the 1989 Loma Prieta Quake for 25 buildings in the San Francisco Marina District. The three- and four-story wood buildings were out of plumb in the first story as much as 2'. Trost provided lateral stability by placing 6x8 diagonal shores from the inside of the street curb to the second floor and added 6x6 diagonals in doorways. They later placed story-high cribbing and large steel beams to provide better vertical support and allow for later straightening of the buildings. One must carefully consider where this type of bracing is connected to the structure in order for it to effectively obtain a vertical reaction while it is providing the horizontal resistance.

Stabilize Tall Highway Structures

At the Highway 880 collapse, Loma Prieta Earthquake, shoring contractors used 12x12 vertical posts to support the concrete frames in first stories that were damaged by the collapse of the second story. The 20-foot height was too great for cribbing, and a spreader system was used to interconnect the posts at the ground level. Diagonal bracing was added to same locations of those rows of posts, but it was very light for the potential load.

Use of Nontraditional Shoring Devices

Large backhoe/excavator or bucket-loader vehicles have been used to provide lateral (raker) support to leaning walls and buildings at several disaster sites—a very good idea for an emergency condition.

Shoring for Specific Building Types

Shoring for Light-Frame, Multistory Buildings

- Multistory frame with leaning first story needs lateral/diagonal shoring that acts against the floor plane.
- Wood buildings with crawl space that have moved off foundation have normally come to rest, but roof and upper story floors may also be offset/cracked and need vertical shoring.
- Brick veneers on wood-frame walls are often falling hazards in aftershocks and may need to be shored, or protective tunneling-type structure may be required to protect access.

Shoring for URM Buildings (Heavy Wall)

- URM walls may be cracked (especially at corners) or peeled and need diagonal/raker shores.
- Cracked URM walls may also require shoring of openings.
- When URM exterior walls have collapsed, the remaining wood floors may require vertical shoring.
- Floors often collapse into the following patterns: (See Figure 3.25)
 - **LEAN-TO:** Shoring is usually required under the suspended floor and possibly on the outside wall, opposite where the floor is still connected. Victims might be found under the suspended floor and on top of this floor at the lowest end.
 - **V-SHAPE:** Shoring is usually required under the two suspended floor pieces and possibly on the outside walls, opposite where the floors are still connected. Victims might be found under the two suspended floor pieces and on top of the floor in the middle of the V.

Advanced Rescue Skills



Topic 3-1: Basic Shoring



- **PANCAKE:** Shoring is usually required under the floors. Victims might be found under the floors. Voids are formed by building contents and debris wedged between floors.
- **CANTILEVER:** This type of collapse is similar to the pancake pattern with the added problem of some of the floor planes extending unsupported from the debris pile. Shoring is usually required under and above the floors, starting at the lowest level. Victims might be found under the floors as in the pancake condition.

Shoring for Reinforced Concrete Buildings

- Reinforced concrete buildings will often have fairly unbroken planes that can be easily shored with vertical shores.
- When floors have beams and girders intersecting at the columns, diagonal tension and shear cracks will give indication of potential failure.
- In flat slab (beamless) floors that are heavily loaded with debris, a punching shear (rapid) failure is possible. Since the cracking that indicates this type of overload usually is best seen from the top of the slab (covered by debris), it is very difficult to assess.
- If concrete floor plane is badly broken, a system with sheathing, spreaders, and safe haven areas may be needed.
- Lean-to, V-shape, and pancake collapse patterns may be found in heavy floor buildings (especially pancake).
- In floors where post-tensioned cable reinforcing is present, a double hazard may exist. If the cables are loose, then the collapse will contain a mass of closely spaced, unreinforced pieces that are difficult to shore. If the cables are still tensioned, they can become lethal missiles.

Shoring for Precast Concrete Structures

- Collapses of this type will normally contain large pieces of lightweight concrete. Shapes like single and double Ts are difficult to shore.
- Lean-to, V-shape, and pancake collapse patterns may be found in precast concrete buildings (especially lean-to).
- Shoring of sloped surfaces will probably be required. Large pieces may be lightly interconnected and there will be the potential of their shifting.
- Using cranes to remove critical pieces may be the best strategy to access voids.

Inspection of US&R Shoring

- Following its installation, US&R shoring should be periodically inspected. The Structures 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
- Properly proportioned shoring with adequately braced posts should be considered as a crude "load cell."



Advanced Rescue Skills



Topic 3-1: Basic Shoring

URM WALL/WOOD FLOOR COLLAPSE PATTERNS SHOWING POSSIBLE SHORING LOCATIONS



Advanced Rescue Skills



Topic 3-1: Basic Shoring



- When the posts are braced so buckling is limited, a slow failure can be achieved. In order to achieve this, the effective L/D should be limited to between 20 and 25 for each post (in each direction).
- Signs of overload should be able to be seen at approximately 150 to 200 percent of design load.
- One should then be able to observe:
 - The cupping of wedges
 - Crushing of the header under its contact with the post
 - Splitting of the ends of the header

Note that header-end splitting is caused by the catenary action of the longitudinal wood fibers that are trying to resist the vertical forces applied by the post. As these fibers are crushed, they indent and form the catenary that then induces longitudinal tension forces in the bottom 1" or so of the header. The tension forces then cause the header to split along a soft spring-wood plane.

- Take appropriate action when any sign of overload is observed. Appropriate action could include:
 - Adding shores in line with the existing ones or at a location that will reduce or share the load
 - Reevaluating the entire situation, since the structure may be responding differently than expected
 - Reassessing the original design to check for errors in assumptions and/or calculations

Summary for Emergency Shoring of Structures

- Shores need to be strong, light, portable, and adjustable and reliably support the structure as gently as possible.
- Systems should be used that are positively interconnected, laterally braced, and have slow, predictable failure mode.
 - A typical shoring scenario would begin with the placement of spot shores (Class 1) to initially stabilize, followed by
 - Individual multipost shore systems with in-plane bracing (Class 2), followed by
 - Pairs (or greater numbers) of multipost shores that are X-braced together as two-dimensional systems. These are called Class 3 shores (three-dimensional). As just discussed, periodic inspection of US&R shoring is essential. It should be made part of the everyday checklist.
- Braced wood post systems and cribbing are desirable since they can be constructed to have the following properties:
 - Made from light pieces that are adjustable and can be built into almost any conceivable situation including sloped surfaces
 - Are relatively wide and stable; will spread the load
 - Can be proportioned to have slow failure mode that will give warning
- Testing of rakers, laced posts, paired double Ts, and cribbing has been done as a part of Advanced Structures Specialist Training (StS2) starting in September 2004. These tests have indicated that, as long as the sole anchors are adequate, properly braced rakers can resist up to five times the allowable load before failure.
 - Twelve raker pairs have been tested by end of 2005.

Advanced Rescue Skills



Topic 3-1: Basic Shoring



- The high safety factor is justified, since it is very difficult to calculate what lateral force rakers will be subjected to during the term of an incident.
 - Since rakers are designed and constructed to resist lateral forces, earthquake aftershocks may apply very high loads to rakers. So what may appear to be excess capacity may turn out to be important protection for rescuers.
- Laced posts normally fail at just above three times allowable load. Cupping of wedges can normally be observed as soon as the load exceeds 1.5 times allowable load. Horizontal splits often form in the ends of the header overhang when load exceeds two times allowable.
 - Failure occurred when individual posts were broken and diagonal braces came free from their connections.
 - Twelve laced posts have been tested by end of 2005.
 - Therefore, the wedges can be observed as a good indication of shore overload—a structural fuse.
- Paired double T failed at about 85 percent of the load at which laced posts failed. However, only two have been tested by end of 2005. More tests are planned.
- Two tests of cribbing have been done by end of 2005.
 - Tests indicated that 6-foot-high cribs (4x4x48" pieces in a 2x2 lay-up) crushed 6" when loaded to about 1.5 times allowable load.
 - This performance indicates that cribbing installations will have significant deflection.
 - This "softness" would indicate that cribbing needs to be proportioned so it is capable of carrying all the vertical load in a specific location, instead of being able to assume the remaining structure could "share" in resisting some of the load.

See USACE Structures Specialist (StS) FOG and US&R SOG used by the FEMA US&R Task Forces. Electronic copies can be obtained from the DisasterEngineer.org website.

Final Summary

In a disaster we need to consider any viable system based on availability of material, special contractors, and special equipment. The basic principles of engineering will always apply, but creative thinking and cooperation between all members is essential.



Figure 3:21

FEMA StS Deployment **Ck-Lists & Forms**



Advanced Rescue Skills

Topic 3-2: Shoring Construction



Topic 3-2: Shoring Construction

Terminal Objective

The student will learn how to maintain the integrity of all structurally unstable elements and learn how to properly transmit or redirect the collapse loads to stable ground.

Enabling Objectives

- Understand how to conduct a proper shoring size-up.
- Identify locations for proper shoring placement.
- Understand shoring team concepts and identify positions and purpose.
- Understand different types of shoring components and equipment.

There are many other types and methods to construct shoring. However, it is important that all rescue personnel within this program learn to efficiently construct these systems. They have been engineered as well-braced, reliable systems that can be rapidly constructed in emergency conditions.

Mitigation Basics

- Avoid It: Put barrier tape around a hazardous area preventing access.
- Remove It: Pull down a cracked or leaning brick chimney.
- Shore It: Construct shoring and bracing systems.
- Monitor it: Set up monitoring with a warning system and preplanned escape and evacuation plan.

Shoring Size-Up

- The shoring size-up provides a survey of structural damage and potential victim locations in buildings identified during the initial building triage and structure and hazards evaluation process.
 - Identify structural hazards, damage, and potential victim locations.
 - Determine best method to mitigate the structural hazards and damage. Avoid, remove, shore, or monitor.
 - Determine the type and placement of shoring systems in relation to structural hazards, damage, and potential victim location.
 - The shoring size-up should be performed by at least a Structures Specialist and US&R member.
 - The shoring size-up must be extensive, be accurate, and continue throughout the rescue operation.



Advanced Rescue Skills

Topic 3-2: Shoring Construction



The Vertical Shore

- The main purpose of the vertical shore is to stabilize damaged floors, ceilings, or roofs. It can also be used to replace missing or unstable bearing walls or columns.
- The two sizes of lumber most commonly used in vertical shoring are 4x4 and 6x6 Douglas fir (or Southern pine). The estimated weight of the floor and its contents will help determine the size of shoring materials and their spacing.
- Businesses and commercial occupancies with heavier structural elements and greater floor height and/ or loading may require 8x8 or even 12x12 lumber. The Structures Specialist should be used to help determine the correct size and placement of shoring materials.
- Structural Components of the Vertical Shore
 - The **Sole Plate** provides a foundation for the shoring system by supporting the weight being transferred from above and distributes it over a wider area.
 - The Header collects the weight from above and spreads it throughout the shoring system.
 - The **Posts** support the weight being collected by the header or spreader beam and transfer it to the sole plate where it is distributed.
 - The Sole Plate, Header, and Posts should be the same width for a more secure attachment.
 - Wedges are two wooden incline planes married together and placed under the bottom of the post. They are simultaneously tapped together until the shoring system is under compression and resists the weight of the structural materials above. 2x wedges are more stable than 4x wedges. 2x wedges do not allow for as much adjustment, but they are preferred due to their better stability.
 - **Diagonal Braces** double as connections and bracing for the vertical shore. They should be long enough to span its entire length and be attached to the header, each post, and the sole plate to lock the entire shore together as one unit to support against possible eccentric loads applied to it. 2x6s nailed on both sides of the shore in opposite directions of each other resist lateral deflection from either side.
 - **Midpoint Braces** are needed when 4x4 posts are greater than 8' long or 6x6 posts greater than 12' long.
 - A 1x6 or length of ³/₄" plywood at least 6" wide nailed to the midpoint of the posts on both sides takes deflection out of the post.
 - If 1x6 or ³/₄" plywood is not available, 2x4 or 2x6 may be used as midpoint braces. This is the least desirable midpoint brace, since it must be installed after the diagonal braces. Also, 2x4x18" cleats need to be added to the sides of the end posts to provide a step out.
 - To increase the posts' bearing capabilities, midpoint bracing must be in both directions with diagonal braces long enough to connect the header to the sole plate or two shorter diagonal braces, one connecting the header to the midpoint braces and the other connecting the midpoint braces to the sole plate.
 - Half-Gusset Plates are 6"x12"x³/₄" plywood nailed to the top and bottom of posts to ease shore placement and secure the posts to header and sole plate. You may use 2x4x18" cleats, but they require 16d nails and may tend to split.
 - As previously discussed, the configuration of gussets and bracing may vary depending on the stability of the structure and the length of time involved in the rescue.



Advanced Rescue Skills

Topic 3-2: Shoring Construction



The Double T Shore

- The double T shore may also be used to initially stabilize damaged floors, ceilings, or roofs.
- The double T shore is much more stable than the T spot shore.
 - Since it has two posts with only small header overhang, the load is more likely to be applied between the posts.
 - The double T is about 25 lbs heavier than the T and a little more difficult to carry through a window.
 - The midheight plywood gusset acts as a stiffening brace as well as keeping the posts aligned as the shore is being carried into place.
- The size of lumber most commonly used for the double T shore is 4X4 Douglas fir. The estimated weight of the floor and its contents will help determine the number of shores that will be required.
- Structural components of the T shore are the same as for the T spot shore except that top connection uses double gussets each side that are $12"x24"x^{3/4}"$. There is a midheight gusset, which may be omitted for heights less than 6'.

How to Construct the Double T Shore

- 1. Determine height and cut header, post, and sole as for T shore.
- 2. Prefabricate double T shore as follows:
- Nail posts to header spaced 18" to 24" outside to outside and centered on header.
- One post may be tacked to header and temporarily configured to meet other post at bottom for access.
- Place upper double gusset plate over joint and nail as noted below $(12"x24"x^{3/4}")$ double gusset).
- The header will get 14 nails and each post will get 5 nails.
- Place midheight, single plywood gusset and nail eight 8d to each post.
- Flip over and nail the second upper gusset in position.
- 3. Place double T in position, centered under the load. If one post has been configured on slope for access, straighten it and complete nailing of double gussets.
- 4. Slide sole plate under double T and wedge each post in position. Length of sole plate needs to be at least as long as header.
- 5. Check shore for straightness and stability and tighten wedges.
- 6. Install bottom half-gussets and nail four 8d each post and sole. 2x4x18" cleats may be used with three 16d each end (second choice).
- 7. Anchor the shore to the floor beams above and nail sole plate into the floor below.



Advanced Rescue Skills

Topic 3-2: Shoring Construction





Figure 3:22



Advanced Rescue Skills



Topic 3-2: Shoring Construction

How to Construct the 2-Post Vertical Shore

- 1. Determine where to erect the 2-post vertical shore and the condition of the supporting structure and/ or ground.
 - If practical, this shore should be partially prefabricated, same as for the laced post.
 - If using 4x4 posts, space them 4' maximum on center. 6x6 posts may be 5' maximum on center. If access is limited, post spacing may be reduced to 3' on center.
 - The intent is to support the damaged structure as quickly and safely as possible and be able to later convert two adjacent single 2-post vertical shores into a laced post for better stability.
- 2. Measure and cut the posts to the proper height. Remember to deduct for header, sole, and wedges when cutting posts. Also, cut the midbrace and diagonals to proper lengths.
 - Header will have a 12" overhang each end.
 - Nail the header, posts, midbrace, and upper diagonal together outside the damage zone, if practical.
 - Use half-gussets at post to header. Remember to shift the half-gusset so its outside edge is flush with outside of post.
- 3. Cut the sole and wedges. Sole is same length as header.
- 4. Place 2-post shore in position, centered under the load.
- 5. Slide sole plate under shore and tap wedges into position.
- 6. Check for straightness plus stability, then tighten wedges.
- 7. Install bottom half-gussets (or cleats) and nail properly. Outside face of half-gusset should be placed flush with outside face of posts.
- 8. Anchor the shore to floor above and sole to floor below, if practical.



Advanced Rescue Skills



Topic 3-2: Shoring Construction

Two-Post Vertical Shores

- The limited height area, 2-post vertical shore is constructed the same as a half-high, single side of a laced post shore.
- This 2-post vertical shore is constructed the same as single side of a laced post shore.



Figure 3:23



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Topic 3-2: Shoring Construction





Figure 3:24



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Topic 3-2: Shoring Construction



How to Construct a 3-Post Vertical Shore

- 1. Determine where to erect the vertical shore.
 - After initial temporary shoring has been installed as needed, clear the area of debris down to the floor, removing thick carpeting, if necessary. A clearance of 3' to 4' wide is usually adequate.
 - If the vertical shore is to bear directly on soil, examine the ground for stability. If the earth is soft, additional supports should be installed under the sole plate to transfer the load over a wider area (2x8 or 2x10 under sole or, if very soft, three 2x6x18" placed perpendicular under sole at each post).
- 2. Lay the sole plate on the floor or ground directly under and in line where the header will be installed. The sole plate should be as level as possible.
- 3. Measure and cut the posts to the proper height.
 - Place the header on top of the sole plate.
 - With the end of the tape measure on top of header where the posts are to be installed, slide the tape up to the bottom of the structural element to be shored and measure in at least three places, deducting the width of the wedges.
- 4. If possible, anchor the header to the area that is to be shored, square and in line with the sole plate. Secure it at the lowest point and shim the structural elements down to the header to keep it as level as possible.
- 5. Install the posts between the header and sole plate under each structural element to be supported.
 - The first two posts are installed at opposite ends at least 12" from each end of the sole plate.
 - Keep the posts in line and plumb with header and sole plate.
- 6. Install a set of wedges under the bottom of each post and tap them together simultaneously until the posts are under compression and tight. Nail behind the wedges to secure them in place.
- 7. Attach the diagonal braces to each side of the vertical shore.
 - Midpoint braces, when needed, should be installed prior to the diagonal braces (except when 2x material is used; then the midpoint braces are placed over the diagonals).
 - The diagonal braces should be long enough to span the entire length and be attached to the sole plate and header and each post.
 - If possible, diagonal braces should be installed in an X pattern on opposite sides of the system.
 - Vertical shoring systems that span a long area may require several sets of diagonal braces to connect multiple posts.
- 8. Attach 6"x12" half-gusset plates to at least one side of the header and posts and nail in place if not done previously.
- 9. Attach half-gusset plates to at least one side of the sole plate and posts and nail in place (2x4x18" cleats may be used.) Half-gussets should be placed both sides to confine the wedges in all cases where any type of vibration or shock loading might occur.



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Topic 3-2: Shoring Construction





Figure 3:25



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Topic 3-2: Shoring Construction

The Laced Post Shore

- The main purpose of the laced post shore is to stabilize very heavy damaged floors, ceilings, or roofs.
 - It can also be used to provide a safe haven.
 - It is a very stable system, since each vertical post is braced in each direction.
- The two sizes of lumber most commonly used as laced posts are 4x4 and 6x6 Douglas fir. The estimated weight of the floor and its contents will help determine the size of shoring materials and their spacing.
- The structural components of a laced post shore are very similar to the vertical shore.
 - A laced post is essentially two 2-post vertical shores that are constructed separately and then laced together.
 - Use one midbrace and two diagonals per side up to 11' high and two midbraces + 3 diagonals over 11' high.
 - You need only one diagonal and no midbrace under 6' high.
 - When 4x4 posts are used, the diagonal braces and center or midpoint braces are constructed using 2x4 lumber for most cases. Nail 2x4s with three 16d each end, and take care not to split the 2x or post.
 - When 6x6 posts are used, the diagonals and center braces should be 2x6 lumber, using five 16d each end.
 - The diagonals in a laced post system may be configured in a parallel or a K configuration.
 - The diagonals are less than 7'6" long, and, therefore, they can resist both tension and compression forces and may be placed in any diagonal direction.
 - The preferred configuration is four K, as shown in Figure 3:31. It is also easy to remember.

In order to reduce the potential for torsion failure, it was stated in previous manuals that at least one side of each laced post should have its diagonals configured opposite the other three sides. That can lead to having too many members nailed to a 4x4 post in a single location and splitting. That layout of diagonals is no longer recommended above any other.



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Topic 3-2: Shoring Construction

How to Construct a Laced Post Shore

- 1. Survey area and determine load displacement and structurally unstable elements.
- 2. Clean area to be shored. Install temporary spot shores if required (prior to clearing).
- 3. Determine the length of the shore.
 - Cut the header and sole plates 24" longer than width of the shore to allow for 12" overhang on each end.
 - Use 6-foot-long header for typical 4' outside to outside of posts.
- 4. Nail posts to the header with toenails. Check to see if posts are straight. If not, set so both with bow out (to be corrected later with mid horizontal brace).
- 5. Make posts square to the header.
 - Do overall check by making X measurements. (Outside top right to outside bottom left should be same as outside top left to outside bottom right.)
 - Nail a half-gusset plate to one post/header joint. (Outside face of half-gusset is flush with outside face of post.)
 - Nail the midpoint brace(s) in position and recheck X measurement. If posts bow out, pull them in with midpoint brace(s).
- 6. Measure and install the top diagonal. It must overlap the post and tie into the header. Use the proper nail patterns.
- 7. Fabricate the second section using first as template.
- 8. Have the horizontal tie-in braces precut for ease of assembly.
- 9. Bring both sections and the sole plates into position and place the prefabricated units on top of the sole plates.
- 10. Install wedges under each post, and check post spacing.
- 11. Nail the horizontal braces to the two sections on both sides.
- 12. Measure for all the diagonals and install them in a K or other configuration as dictated by access.
- 13. At the sole plate, make sure the bottom diagonal extends past the post and nail into the sole plate. Place a half-gusset plate on the opposite side of this post and to each side of the other posts at the base (outside edge of half-gusset is flush with outside of post).
- 14. Anchor the shore to the ceiling and the floor, if appropriate. Make sure all wedges are snug and the proper nail patterns are done.



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Topic 3-2: Shoring Construction





Figure 3.31







Window and Door Shore

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- The main purpose of the window and door shore is to stabilize a window, doorway, or other access way. An extensive collapse can generate a tremendous amount of debris that blocks the primary entrances into a building and sometimes requires a window entry.
- The window and door shore is usually installed in entry points intended for use by rescue personnel to hold up or stabilize loose headers or lintels that have lost their integrity.
- Additional load stress is usually exerted from above and, therefore, this shore is constructed similar to the vertical shore. If additional load stress is exerted from the side, the window and door shore is constructed similar to the horizontal shore.

Structural Components—Window and Door Shore

- The **Sole Plate** provides a foundation for the shoring system by supporting the weight being transferred from above and distributing it over a wider area.
- The **Header** collects the weight from above and spreads it throughout the shoring system.
- The **Posts** support the weight being collected by the header and transfer it to the sole plate where it is distributed.
 - The sole plate, header, and posts should be the same width for a more secure attachment.
 - Buildings with large structural elements or openings greater than 4' usually require lumber larger than 4x4 for the sole plate, header, and posts.
- **Triangular Gusset Plates** and **Cleats** are 12"x12"x³/₄" plywood cut on diagonal (triangular gusset plates) and nailed short pieces of 2x4 (cleats) to both ends of the posts and struts to ease in the placement and securing the posts to the header and sole plate.
- Wedges are two wooden incline planes married together and placed under the bottom of the posts or struts and simultaneously tapped together until the shoring system is under compression and takes the weight of the structural materials.
- Diagonal Braces are the last items to be installed on the window and door shore when the opening is not used for access or egress.
 - The diagonal braces should be long enough to contact the top of the posts on one side and the bottom of the posts on the other to lock the entire shore together as one unit and support against possible eccentric loads applied to it.
 - A 2x4 or 2x6 is nailed on both sides of the shore in opposite directions of each other to resist lateral deflection from either side.
- The **Built-up Header** is used when additional support is needed or if the opening is more than 6' wide and only 4x4 material is available. Prior to installation of header, cut two 4x4s to proper length for header and set them one on top of the other. Place 6"-wide plywood strips (as long as the headers) on each side to join the two pieces and nail 8d at 3" on center from each strip of plywood to each 4x4.
 - Total nailing will be 4 rows of 8d spaced 3" on center.
 - Header will be 7" high, almost equivalent to a 4x8.



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Topic 3-2: Shoring Construction

How to Construct the Window and Door Shore

- 1. Determine where to erect the window and door shore. After initial temporary shoring has been installed, clear the area of debris or remaining framing material.
- 2. Measure and cut the sole plate to the proper length, deducting the width of the wedges to be used.
- 3. Measure and cut the header to the proper length, deducting the width of the wedges to be used. Prefabricate a built-up header as noted above, if required.
- 4. Measure and cut the posts to the proper height.
 - Place the header on top of the sole plate.
 - With the end of the tape measure on top of the header where the posts are to be installed, slide the tape up to the bottom of the structural element to be shored on both sides, deducting the width of the wedges to be used.
 - Use the shorter of the two measurements
- 5. Install the sole plate with a set of wedges at one end and tap them together simultaneously until the sole plate is under compression and tight. The sole plate should be as level as possible. Use shims as necessary under the sole plate.
- 6. Install the header with a set of wedges at the opposite end of the sole plate and tap them together simultaneously until the header is under compression and tight. The header should be as level as possible. Use shims as necessary above the header.
- 7. Install the posts between the header and sole plate and against the sides of the opening.
 - Install the first post under the wedge side of the header to prevent accidental movement if the header wedges loosen up.
 - Keep the posts in line and plumb with header and sole plate.
 - A set of wedges is installed **under** each post, on top of the sole plate. The wedges are then tightened to lock the shore in place.
- 8. Attach cleats and triangular gusset plates to at least one side of the header and posts and nail in place.
- 9. Confine the wedges by placing a cleat against the inside face of each post at the bottom and nail them in place with three 16d to each post and two 16d toenails to the sole plate. Nails may need to be duplex for future adjustment of the wedges.
- 10. Install diagonal braces on the window and door shore when the opening is **not used** for access or egress.
- 11. Window and door shores may also be preconstructed.



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Construct in Place Method









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Topic 3-2: Shoring Construction



Alternate - Window / Door Shore



The Horizontal Shore

The main purpose of the horizontal shore is to stabilize a damaged wall against an undamaged wall in hallways, in corridors, or between buildings.

Structural Components of Horizontal Shore

- The **Wall Plates** provide a foundation for the shoring system by collecting the weight being transferred laterally and spreading it throughout the shoring system.
- The **Struts** support the weight being collected by one wall plate and transfer it to the other wall plate. The wall plates and struts should be the same width for a more secure attachment.

Cleats or Half-Gusset Plates

- Cleats are short pieces of 2x4 nailed under the struts to ease in their placement and prevent the struts from being dislodged.
- Half-gusset plates are 6"x12"x³/4" plywood nailed on at least one side of the wall plates and struts to prevent struts from being dislodged.
- Wedges are two wooden incline planes married together and placed under one end of the strut, simultaneously tapped together until the shoring system is under compression and takes the weight of the structural materials.
- Diagonal Braces are the last items to be installed on the horizontal shore when the hallway or corridor is not used for access or egress. They should be long enough to contact both the top and bottom of the wall plates and all the struts to lock the entire shore together as one unit and support against possible eccentric loads applied to it.
 - 2x4s or 2x6s are nailed on both sides of the wall plates in opposite directions of each other to resist lateral deflection from either side.



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Topic 3-2: Shoring Construction



How to Construct the Horizontal Shore

- 1. Determine where to erect the horizontal shore.
 - After initial temporary shoring has been installed as needed, clear the area of debris.
 - A clearance of 3' to 4' wide is usually adequate.
- 2. Measure and cut the wall plates to the proper length.
- 3. Measure and cut the struts to the proper length.
 - Place both wall plates against the walls.
 - Measure between the wall plates where the struts are to be installed, deducting the width of the wedges to be used.
- 4. Place both wall plates next to each other and attach cleats to the wall plates just below where the struts will be installed.
- 5. Place the wall plates in the area that is to be shored, square and in line with each other and as plumb as possible by shimming any void spaces behind the wall plates.
- 6. Install the struts between the wall plates. Keep the struts in line and plumb with the wall plates.
- 7. Install a set of wedges behind one end of each strut and tap them together simultaneously until the struts are under compression and tight.
 - Secure the wedges by placing the back of a shim on top of the wedges and nail it to the wall plate or toenail the wedges to the wall plate.
 - Nails may need to be duplex for future adjustment of the wedges.
- 8. Attach cleats or half-gusset plates to at least one side of the wall plates and struts, where aftershocks, vibrations, or other shock loading may occur.
- 9. If possible, attach the wall plates to the walls.
- 10. Attach the diagonal braces to each side of the horizontal shore when **not used** for access or egress.
 - The diagonal braces should be long enough to span entire length and be attached to both wall plates and each strut.
 - When used, diagonal braces should be installed in an X pattern on opposite sides of the system.



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HOW to CONSTRUCT a <u>TYPE 2</u> SLOPED FLOOR SHORE on PAVING or SOIL SURFACE (Type 1 is not recommended)

- 1. Survey area and determine load displacement and structurally unstable elements, and clean area to be shored.
 - a. Install temporary, spot shores if required.

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Sloped Floor Shores

- The main purpose of the sloped floor shore is to stabilize damaged floors, ceilings or roofs that have collapsed into a sloped configuration. Vertical shores may be used to support floors with a slight slope, which are slopes up to 5 percent (6" in 10').
- This shore is essentially a 2-post vertical shore system, constructed with the posts placed perpendicular to the sloped surface or placed vertical. (See discussion below)
 - These shores should be built in pairs and laterally braced in two directions, to make them Class 3 Shoring Systems.
 - Posts in each shore should be 3' to 5' feet on center, and the shores may be spaced from 4' to 8' ft on center.
- The two sizes of lumber most commonly used in vertical shoring are 4x4 and 6x6 Douglas fir. The estimated weight of the floor and its contents will help to determine the size of shoring materials and their spacing.
- Components of this shore are similar to the vertical shore.
- Sloped floor shores can be configured in two ways:
 - The **perpendicular bearing method** is used when shoring a floor slab that is hinged off remaining structure or otherwise restrained from sliding. Type2 is constructed on hard surface like concrete or paving, but also on soil if 2x6 flat is placed under Sole.
 - The **sloped friction method** is used when floor slab is free to slide and one type is used for on soil or hard surfaces.
- Cribbing may also be constructed to support a sloped surface. The crib is built into the slope by adding nailed, full width shims in various layers, so the top crib members end up flush and tight against the sloped surface
- Horizontal and diagonal bracing should be placed between pairs of Sloped Floor Shores, same as for Laced Posts for shores spaced not more than 5' on center. Where shores are spaced more than 5' but less than 8' on center, the lateral bracing should consist of horizontals plus X or V bracing as for raker shores.
- When these shores are not over four feet tall, one may use ³/₄" plywood strips (12" to 24" wide x 5' long) as the lateral bracing between pairs of shores. The plywood should be nailed to the Sloped Floor Shore posts as shown in adjacent slide, and the plywood should extent to within about 12" of the top and bottom of shore.
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How To Construct a Type-2 Sloped Floor Shore (On Concrete, Paving or Soil Surface)

- 1. Survey area and determine load displacement, and structurally unstable elements.
- 2. Clean area to be shored. Install temporary spot shores, if required.
- 3. Determine length and width of shore and post locations.
 - Headers must overlap at least 12".
 - The sole plate is at least 24" longer at the base of the back post. Add 2x6 or 2x8, 16d @ 8", under sole if on soil.
 - These shores should be built in pairs, spaced no more than 8' on center (5' if using lacing type bracing).
 - Install the header and sole plates, and anchor header.
- 4. Measure and install the two posts.
- 5. Anchor to the header.
- 6. Nail down the bottom cleats with the proper nail patterns. Place wedges in position. (Wedges optional.)
- 7. Anchor down the sole plate, and pressurize the wedges.
 - Anchor sole using drilled-in anchors or large rebar to anchor to concrete or paving, based on Structure Specialist recommendations.
 - Alternate sole anchor using sole plate anchor system is shown with rakers.
- 8. Measure for the diagonal braces inside and outside each section.
- 9. Install the 2x6 braces in position and nail into posts, header, and sole plate.
 - Place half-gusset plate (or use 2x cleats) the opposite side of the posts, top, and bottom, using the 4 and 4 nail pattern.
 - Place half-gussets to clear horizontal and diagonal braces (installed next) or use 2x cleats instead of half-gussets.
- 10. Brace the two sections together, same as in laced posts or raker shores (depending on spacing).
 - Do it at both posts in order to tie the two sections together.
 - You may use a wide piece of 3/4" plywood (12" to 24" wide) if shore is too short to fit X braces. It's usually easier to place the plywood on the inside of the posts
 - Make sure the shore is attached to the floor and ceiling, if possible.



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TYPE-2 SLOPED FLOOR SHORE ON HARD SURFACE OR ON SOIL



Note: For conditions on very soft soil, you may need to use 2x8 under sole, or add minimum of two 2x6x18" crosswise under sole at each post.



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How To Construct A Type-3 Sloped Floor Shore (On Concrete, Paving or Soil Surface)

- 1. Survey area and determine load displacement, and structurally unstable elements
- 2. Clean area to be shored. Install temporary spot shores if required.
- 3. Determine length and width of shore and post locations.
 - Headers overhang is 12" on lower end, but should be increased to 24" at high end.
 - The sole plate should extend 12" beyond each post (add 2x6 or 2x8, 16d at 8", under sole if on soil)
 - These shores should be built in pairs, spaced no more than 8' feet on center. (5' if using lacing type bracing)
 - Install the header and sole plates, and anchor header.
- 4. Measure & install the two posts. Make sure posts are vertical.
- 5. Anchor to the header.
- 6. Install one 18"cleat for each post on underside of header with eleven 16d nails (pre-install one or more of these cleats on header, when practical, to reduce nailing in Collapse Zone). Wedges optional.
- 7. Place wedges in position and only snug up, then place a half-gusset one side of each post, but only nail to post.
- 8. Attach header to ceiling with at least two 1/2" bar or rebar, embedded at least 3".
- 9. Anchor the sole plate, if required, and pressurize the wedges.
- 10. Measure for the diagonal braces inside and outside each section.
- 11. Install the 2x6 braces in position and nail into posts, header, and sole plate.
 - Place half-gusset plate (or use 2x cleats) the opposite side of the posts, top and bottom, using the 4 and 4 nail pattern.
 - Place half-gussets to clear horizontal and diagonal braces (installed next) or use 2x cleats instead of half-gussets.
- 12. Brace the two sections together, same as in laced posts or raker shores (depending on spacing).
 - Do it at both posts in order to tie the two sections together.
 - You may use a wide piece of 3/4" plywood (12" to 24" wide) if shore is too short to fit X braces. It's usually easier to place the plywood on the inside of the posts.
 - Make sure the shore is attached to the floor and ceiling, if practical.



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US&R SHORING OPERATIONS GUIDE CONSTRUCTING VERTICAL SHORING SYSTEMS

BRACING BETWEEN PAIRS of SLOPED FLOOR SHORES

(When shores are spaced 5'-0" o.c. maximum.)





- When Sloped Floor Shores are spaced a no more than 5'-0" o.c., brace the two sections together, same as in Laced Posts.
 - a. Do this at both posts to tie the two sections together.
 - You may use a wide piece of 3/4" plywood (12" to 24" wide) if shore height is 3ft or less. Nail plywood with 8d nails as shown.
 - c. The 2x6 horizontals and diagonal should be nailed each end with 5-16d. 2x4s may be nailed with 3-16d.

US&R SHORING OPERATIONS GUIDE CONSTRUCTING VERTICAL SHORING SYSTEMS

BRACING BETWEEN PAIRS of SLOPED FLOOR SHORES (When shores are spaced 8'-0" o.c. maximum.)



- 2. When Sloped Floor Shores are spaced more than 5'-0" but no more than 8'-0" o.c., brace the two sections together, same as in Raker Shores.
 - a. Do this at both posts to tie the two sections together.
 - b. The 2x6 diagonals should be placed so that one nails to the vertical posts, and the other nails to the horizontal braces (just beyond the nailing from horizontal to post.
 - c. All 2x6 should be nailed with a 5-16d nail pattern.
 - d. The diagonals should be internailed with at least 3-16d where they cross.



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TYPE-3 SLOPED FLOOR SHORE





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Topic 3-2: Shoring Construction

The Raker Shore

The main purpose of the raker shore is to support leaning or unstable walls and columns by transferring additional weight down the raker to the ground or other structural supporting members and away from the wall or column.

- Raker shores must always be installed in series; at least two must be erected in any given situation and braced together with a recommended separation of 8'.
- Two general styles of raker shores are the (flying) friction raker shore and the (full triangle) fixed raker shore. As indicated below there are two configurations of full triangle.
- The (Flying) Friction Raker Shore—Spot Shore
 - This type of shore may be considered for initial temporary shoring due to its ease of construction and need for fewer shoring materials when followed with a group of well-braced (full triangle) fixed raker shores.
 - Attaching the wall plate directly to the wall to reduce or eliminate slippage and shifting increases stability.
 - The strength and stability of the shore may be significantly increased if the bottom brace is sloped down to meet the raker as close to the top of the U-channel base as possible.
- (Full Triangle) Fixed Raker Shore—Class 3 (with bracing)
 - All of the structural elements are tied together, making the shore one integral unit and providing the best method of anchoring and bracing, but requiring the most shoring material.
 - The shore itself is stable and, because of its ability to stay together, this style of shoring is most often recommended for rescue situations.
- The two types of (full triangle) fixed raker shores are the solid sole plate and the split sole plate.
 - The **solid sole plate** (full triangle) fixed raker shore is used in locations where concrete or asphalt cover the ground or when there is open ground.
 - The **split sole plate** (full triangle) fixed raker shore is used in locations where rubble is piled up against the wall and would be dangerous to remove.
- Raker Shore Support Point: The support point at which the raker shore should intercept the building's load is within 2' below the center of the floor or roof joist. Rounding off the height of the raker shore support point to the nearest foot will make it easier to measure and cut.
- The two most common angles used are 45° and 60° .
 - 60° angle is the maximum recommended angle.
 - 60° angle is preferred for split sole rakers with U-channel base (better for capacity of soil).
 - 45° angle is most often used for solid sole rakers and may be used for split sole with trough base.
 - 30° angles have been used to brace some large structures when adequate space was available.
- Determining the height at which the raker shore needs to intersect the wall will identify the angle that works best with the available lengths of lumber. A 45° angle raker shore requires longer lumber than a 60° raker shore to reach the same insertion point.

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- The length of a 45° angle raker shore is the height of the raker shore support point in feet multiplied by 17, which will give the length of the raker, tip to tip, in inches. (8 ft x 17 = 136" or 11' 4" and horizontal distance is 8')
- The length of a 60° angle raker shore is the height of the raker shore support point in feet multiplied by 14, which will give the length of the raker, tip to tip, in inches. (8 ft x 14 = 112" or 9'4" and horizontal distance is 8 x 7" = 56" or 4'8")

Raker Dimensions Table (Based on Info Above)

This section contains General Information, Graphics and Detailed Explanations of how to construct FEMA Horizontal Shoring – arranged as follows:

- How to construct Horizontal Shores
- Raker Shore Design Information
- How to construct Raker Shores
 - Flying Raker Spot Shore
 - Solid Sole Raker
 - Split Sole Raker
- Raker Shore Design Examples
- Tiebacks and Alternate Raker Systems
- Horizontal & Raker Shoring Systems using Pneumatic Struts

Insertion Point, Ft	45° Raker L Inches / Feet	60° Raker L Inches / Feet	60º Horizontal Dist. Inches / Feet
3	51" / 4'- 3"	42" / 3'- 6"	21" / 1'-9"
4	68" / 5'- 8"	56" / 4'- 8"	28" / 2'-4"
5	85" / 7'-1"	70" / 5'- 10"	35" / 2'-11"
6	102" / 8'- 6"	84" / 7'- 0"	42" / 3'-6"
7	119" / 9'- 11"	98" / 8'- 2"	49" / 4'-1"
8	136" / 11'- 4"	112" / 9'- 4"	56" / 4'-8"
9	153" / 12'- 9"	126" / 10'- 6"	63" / 5'-3"
10	170" / 14'- 2"	140" / 11'- 8"	70" / 5'-10"
11	187" / 15'- 7"	154" / 12'- 10"	77" / 6'-5"
12	204" / 17'- 0"	168" / 14'- 0"	84" / 7'-0"
13	221" / 18'- 5"	182" / 15'- 2"	91" / 7'-7"
14	238" / 19'- 10"	196" / 16'- 4"	98" /8'-2"
15	255" / 21'- 3"	210" / 17'- 6"	105" / 8'-9"
16	272" / 22'- 8"	224" / 18'- 8"	112" / 9'-4"
17	289" / 24'- 1"	238" / 19'- 10"	119" / 9'-11"
18	306" / 25'- 6"	252" / 21'- 0"	126" / 10'-6"
19	323" / 26'- 11"	266" / 22'- 2"	133" / 11'-1"
20	340" / 28'- 4"	280" / 23'- 4"	140" / 11'-8"



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Topic 3-2: Shoring Construction

Structural Components of the Raker Shore

- The **Wall Plate** provides a foundation for the shoring system by collecting the load being applied laterally (horizontally) and spreading it into the shoring system.
- The Sole Plate receives the load being transferred both vertically and horizontally and distributes it into the ground and other structural supporting members.
- The **Raker** supports the load being collected by the wall plate and transfers it to the sole plate.
 - The wall plate, sole plate, and raker should be the same width for a more secure attachment.
 - Buildings with heavy structural elements or support points taller than 16' may require lumber larger than 4x4 for the wall plate, sole plate, and raker (or spliced 4x).
- The **Top Cleat** is a piece of 2x lumber nailed to the top of the wall plate to keep the raker from riding up the wall plate.
 - Use 2x4, 24" long, with fourteen 16d for 4x4 rakers at 45° angles or less.
 - Use 2x4, 30" long, with twenty 16d nails for 4x4 rakers at 60 °angles.
 - See Figure 3.39 for others.
- The **Bottom Cleat** is a two-foot piece of 2x lumber nailed to the top of the sole plate to keep the raker from riding back on the sole plate (fourteen 16d for 2x4, at both 45° and 60° angles). If possible and practical, the bottom cleat and sole on the solid sole plate raker shore should be made long enough to return back to a solid object, such as an adjoining wall.
- Wedges are two wooden incline planes married together and placed against the back end of the raker and the bottom cleat.
 - They are simultaneously tapped together until the shoring system is under compression and takes the weight of the structure.
 - 2x wedges are more stable than 4x and are preferred.
- **Gusset Plates** are 12" x 12" pieces of ³/₄" plywood nailed on both sides of the wall plate and sole plate connection and the top and bottom of the raker to prevent them from being dislodged. Split sole raker shores require gusset plates on both sides of the wall plate at the top of the raker only.

■ Midpoint Braces increase the strength of the raker by reducing the L/D ratio.

- These braces should be long enough to reach from the wall plate and sole plate connection to near the midpoint of the raker.
- On the solid sole raker shore, a 2x6 or two 2x4s are nailed to both sides of the wall plate and sole plate connection and midpoint on the raker.
- On the split sole raker shore, a 2x6 or two 2x4s are nailed to both sides of the wall plate and just above the bottom braces connection and midpoint on the raker.
- **Bottom Braces** on split sole raker shores are a 2x6 or two 2x4s nailed just above the ground and attached as close to the bottom of the raker as possible and the bottom of the wall plate with a fill block near the middle for additional stability. They are placed at the bottom of the wall plate and along the raker above the ground on the (flying) friction raker shore.



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- The U-Channel is used to provide a foot for the friction and split sole raker when bearing on soil.
 - It is nailed to three 2x6x18" (or two layers of 18" sq x ³/₄" plywood) to provide better proper soil bearing for the split sole.
 - It may be placed directly against soil for the flying raker.
- The **Trough** is used to provide a foot for the friction and split sole raker when bearing on paving or hard soil. It needs to be anchored against a sole anchor with pickets and existing curb or some other reliable object. On paving, drilled-in metal anchors may be used.
- Horizontal Braces horizontally connect the raker shores together near the top and bottom of the raker to provide additional stability to the raker shore system.
 - Horizontal braces attached to the midpoint of the raker increase the strength of the raker by reducing L/D ratio.
 - Splice the horizontal brace at center of raker and cover splice with half-gusset, as shown in adjacent slide.
- X and V Braces connect the raker shores in an X or V pattern near the bottom and middle of the raker, depending on access needs and available lumber.
 - They provide additional stability to the raker shore system and decrease the lateral movement when at least a pair are used at the beginning and end of the raker shore system.
 - This bracing should be placed no farther than 40' on center for a multiraker system.
- **Backing Material (Optional, Only if Needed)**
 - Plywood (full and half sheets) requires a minimum of ³/₄" or two ¹/₂" sheets of plywood nailed together.
 - Use 2x lumber (2x8, 10 and 12).
 - Nailed to the back of the wall plate, it can help distribute the weight of the wall over a wider area and prevent the wall plate from pushing through an unstable wall.
 - It is very useful on unreinforced masonry (URM).
 - Nailed to the back of the sole plate, it can help distribute the weight of the wall over a wider area and prevent the sole plate from pushing into soft or muddy soil.
 - Backing material must contact the wall at the raker support point and at the bottom of the wall plate.
 - Shims may be needed to fill void spaces.
 - Backing material can be used to attach the wall plate to the wall or sole plate to the ground.
- Splicing the Raker Shore
 - If available length of 4x4 or 6x6 is insufficient to extend to the required insertion point, the raker may be spliced.
 - The splice should be constructed where midbrace and mid horizontal lateral brace intersect. The splice may be most necessary for the double raker.



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Topic 3-2: Shoring Construction

How to Construct a Flying Raker Shore

All wood shoring should be **prefabricated** as much as possible to **minimize the exposure of rescue personnel to risk.**

- 1. The areas to be supported by raker shores should be considered extremely dangerous. Temporary (flying) friction raker shores may need to be erected prior to building more permanent (full triangle) fixed raker shoring systems. Determine where to erect the raker shores and the height of its support points. Determine height of insertion point.
- 2. Flying rakers can be erected against the wall without removing the debris that may be piled up against it.
 - a. They may be used as single spot shores or may be built in pairs with horizontal and X bracing added between pairs.
 - b. Flying rakers should be prefabricated, fit into their U-channel or trough base, wedged and/or shimmed, and then attached to the wall with drill-ins.
 - c. In some cases, the drill-ins may be omitted if the top of the wall plate can bear against a protrusion in brick or concrete wall.
 - d. Or, at brick or concrete wall, the raker may be built at one edge of a window, with a single or double 2x4 (24" minimum length with fourteen 16d nails) prenailed to the wall plate so it will bear on the bottom of window header (only if header is not badly cracked).
- 3. In order to prefabricate, cut raker, wall plate, and bottom brace to proper length and perform angle cuts on raker.
 - a. Lay out wall plate, raker, and bottom brace at selected angle and toenail raker to wall plate.
 - b. Nail on top cleat, then nail gusset to one side of this joint.
 - c. Nail one bottom brace to wall plate in position to clear debris, but only tack-nail it to raker.
 - d. Turn shore over and nail on other gusset plus other bottom brace (nailed to wall plate, tack to raker).
- 4. Dig in U-channel (or anchor trough), then carry the partly assembled raker into place. Snug up the wedges and complete the nailing of bottom brace to raker.
 - a. Make whatever connection to wall that is selected, as indicated above, and retighten the wedges.
 - b. A trough base is used to reduce the risk of digging adjacent to the Collapse Zone or on hard paving.



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Topic 3-2: Shoring Construction

How to Construct a Solid Sole Raker Shore

All raker shores should be prefabricated as much as possible to minimize the exposure of rescue personnel to risk.

- 1. Determine where to erect the raker shore and the height of its support points. Determine height of insertion point.
 - a. After initial temporary shoring has been installed as needed, clear the area of debris.
 - b. For each raker clear 3' wide and at least the height of the support point out from the wall.
- 2. Select angle of raker, then measure and cut the wall plate, sole plate, and raker to the proper length.
 - a. Sole plate and wall plate must extend at least 24" from where the raker intersects them to allow for the cleats to be nailed.
 - b. Both ends of the raker are to be angle-cut with 1 1/2" return cuts for full contact with the wall plate, top cleat, sole plate, and wedges.
- 3. Prefabricate wall plate, raker, and sole.Toenail sole to base of wall plate, square inside to 90°, and secure with bottom, full-gusset plate, one side.
 - a. Lay out raker at selected angle, intersecting with wall plate and sole. Then install top cleat and nail on gusset one side of this top joint.
 - b. Nail one sole gusset to raker, but not to sole at this time, since raker may need adjusting when moved to wall.
 - c. Mark the sole for the approximate position of the bottom cleat, allowing for the wedges.
 - d. Flip raker shore over and nail full-gussets on opposite side, but remember to nail the raker-to-sole gusset to raker only, not to sole to allow for later adjustment.
- 4. Carefully move the partially prefabricated raker shore in place at the wall and make sure it is plumb.
 - a. With raker shore placed against the wall, the sole should be carefully driven in so the wall plate is snug against the wall, and the bottom cleat should be completely nailed, allowing space for the wedges.
 - b. Full contact must be maintained between the wall plate and the support point of the raker and between the base of the wall plate and the wall. If the wall has bulged out, shims may need to be added near bottom of wall plate.
- 5. After anchoring the sole plate as noted in step 10, install wedges between the bottom cleat and the base of the raker and tighten them slightly. After adjusting the shims/spacers (if any) between the wall plate and the wall being shored to ensure full contact, as in 4a above, finish tightening the wedges and complete nailing of gusset plates on each side.
- 6. With raker shore erected, prevent it from sliding up the wall.
 - a. Attach wall plate directly to a concrete/masonry wall.
 - A minimum of two 1/2" drill-in anchors, lag screws, or rebar should be placed through the wall plate or four 1/2" drill-in anchors through two 9"-long channel brackets attached with two on each side of the wall plate near the middle.



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- On concrete walls, if backing material is needed, then attach to wall plate and use at least five 3" powder charge pins with washers through the backing material on each side of the raker (you may also use three 3/8x4" concrete screws each side).
- b. Attach the wall plate directly to a wood framed wall.
 - A minimum of two 1/2" lag screws should be placed through the wall plate directly into the wall studs.
 - When plywood backing material is attached to the wall plate, use at least eight 16d nails through the backing material into wall studs, each side of raker.
- c. Another method is to attach an engineered ledger (2x6 minimum) to the wall above the wall plate.
- 7. Attach midpoint braces (required if 4x4 raker is longer than 11' and/or 6x6 raker is longer than 16'). One 2x6 is nailed to both sides of the wall plate/sole plate connection and midpoint on the raker. (If 2x6 is not available, 2x4 may be used).
- 8. Attach horizontal braces.
 - a. Connect raker shores together near the top and bottom of the raker with at least 2x6 material or two 2x4s.
 - b. For insertion point greater than 8', a horizontal brace should be placed near midpoint of the raker, near where the midpoint braces intersect.
- 9. Attach X or V braces.
 - a. All raker shore systems must be connected with either X or V bracing near the top and bottom of the raker between at least two raker shores with 2x4 or 2x6.
 - b. Attach the first brace to the rakers near the top and bottom between the upper and lower horizontal braces.
 - c. Attach the second brace to the upper and lower horizontal braces near the rakers.
- 10. After the solid sole raker shore is assembled, prevent the sole plate from sliding back away from the wall.
 - a. To attach the sole plate directly to concrete, asphalt, or dirt, drill a minimum of two 1" holes through the sole plate, concrete, or asphalt and drive 1"x48" steel pickets or rebar directly into the ground. You need at least four 1"x48" diameter pickets if driven directly into ground, but it may be more practical to use a sole anchor as in 10c below.
 - b. Attach the sole plate to concrete and masonry.
 - A minimum of two 1/2" drill-in anchors, lag screws, or rebar should be placed through the sole plate or four 1/2" drill-in anchors through two 9"-long channel brackets attached with two on each side of the sole plate.
 - On concrete only, when backing material is attached to the sole plate, the use of at least five 3" powder charge pins with washers through the backing material on each side of the sole plate is acceptable.



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- c. An anchor can be secured to the ground or floor behind the sole plate to prevent the sole plate from backing away from the wall.
 - Timber anchors should be as least 4x4 size lumber (6x6 is better). Place four 1"x48" pickets, spaced about 12" on center, directly behind anchor on soil. Two pickets may be used into paving.
 - Steel anchors or channel brackets should be at least 1/4" thick.
 - Concrete curbs, walls, and other nearby secure structures may also be used.



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Topic 3-2: Shoring Construction

How to Construct a Split Sole Raker Shore

- 1. Determine where to erect the raker shore and the height of its support points. Determine height of insertion point.
 - a. After initial temporary shoring has been installed as needed, clear the area of debris.
 - b. For each raker clear 3' wide and at least the height of the support point out from the wall.
- 2. Select angle of raker, then measure and cut the wall plate, raker, and bottom brace to the proper length.
 - a. If there is rubble next to wall, wall plate will not extend to the ground, and bottom brace should be attached 6" from bottom of wall plate and slope down to base.
 - b. Raker angle should be 60° if U-channel base is used, but may be 45° or 60° if trough base is used.
 - c. If trough base is used, both ends of the raker are to be angle-cut with 1 1/2" return cuts for full contact with the wall plate, top cleat, and trough cleat.
 - d. For U-channel base, one end of raker will be angle cut.
- 3. In order to prefabricate, cut raker, wall plate, and bottom brace to proper length and perform angle cuts on raker.
 - a. Lay out wall plate, raker, and bottom brace at selected angle and toenail raker to wall plate.
 - b. Nail on top cleat, then nail gusset to one side of this joint.
 - c. Nail one bottom brace to wall plate 12" from bottom or in position to clear debris, but only tacknail it to raker.
 - d. Turn shore over and nail on other gusset plus other bottom brace to wall plate.
 - e. Tack-nail bottom brace to raker so it can be moved into place at the wall. If there is rubble against the wall, the bottom brace should slope down from the wall to the raker base and intersect as close to the base as possible.
- 4. Carefully move the partially prefabricated split sole raker shore in place at the wall and make sure it is plumb.
 - a. U-channel base requires a willow hole dug at a 30° to 45° angle for the raker bearing.
 - b. Place the wedges on the top of the 4x4x18" bottom piece of the U-channel and drive them slightly.
 - c. When a trough base is used, after securing the sole anchor, drive wedges slightly against the trough.
 - c. Full contact must be maintained between the wall plate and the support point of the raker and between the base of the wall plate and the wall. If the wall has bulged out, shims may need to be added near bottom of wall plate.
 - d. After adjusting the shims and spacers (if any) between the wall plate and the wall being shored to ensure full contact, finish tightening the wedges and/or complete nailing of the bottom brace on each side.
- 5. With split sole raker shore erected, prevent the raker shore from sliding up the wall. See solid sole raker shore.
- 6. Place the midbrace, if required by length of raker, and erect the horizontal and X bracing.
- 7. Anchor the sole anchor when trough is used, same as for solid sole raker sole anchor.



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Topic 3-2: Shoring Construction



Figure 3.38

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Topic 3-2: Shoring Construction

Other Preconstructed Raker Shores

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

Raker Shore Connections

Pre-constructed Vertical Shoring Systems

All wood shoring should be prefabricated as much as possible in order to minimize the exposure of rescue personnel to risk.

The vertical shoring systems to preconstruct are:

The T and Double T Spot Shores

- Assemble header and post by nailing the upper gussets on both sides.
- Sole plate, wedges, and half-gussets are added after shore is positioned (as previously discussed).
- Vertical Shore with two posts, diagonal braces, and half-gusset plates or cleats connecting the header to the posts
 - Assemble entire system except for bottom diagonal brace.
 - After moving shore into position, tighten wedges, add bottom diagonal brace, add and nail bottom half-gussets.
- **Ellis Shores** used as a T shore with adjustable post
 - Ellis Clamp positions on posts (use two nails at each clamp, eight per post).
 - Slide the upper post under the clamps and manually raise to proper height and pull down on the top clamp.
 - Attach the shore-jack to the lower post under the upper post and lift on the handle.
 - While pressure is being applied to the shore-jack, tap downward on the unsecured end plate of the top clamp and then tap downward on the unsecured end plate of the bottom clamp with a hammer to lock the clamps in place.
 - Assemble header and post by nailing the upper gussets on both sides.
 - Sole plate, wedges, and lower cleats are added after shore is positioned.
- Post Screw Jack, with one or two posts with gusset plates or cleats connecting the header to the posts
 - Metal foot should be nailed to sole.
 - Diagonal braces should be added to multipost system as for vertical shores.
- **Pipe Shores**, with one or more shores
 - Metal ends should be nailed to header and sole.
 - Diagonal braces cannot be attached unless a special metal fitting is provided by manufacturer.
 - Capacity of 2" pipe is similar to 4x4 wood post and is dependent on height.
 - Special pipe frames are available that are assembled as a group of four columns with cross bracing, similar to a laced post system.



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Topic 3-2: Shoring Construction



- Pneumatic Shores, with one or more shores with wood or metal rail header
 - Metal ends should be nailed to header and sole.
 - One manufacturer sells a clamp fitting that allows for nailed 2x6 X bracing to be installed.
 - Pneumatic shores are best used as temporary shores.
 - Some manufacturers provide a header rail that may be preassembled with two or more struts to provide a preconstructed 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 handtightened.**
- Window and Door Shores, preconstructed
 - They should be made at least 1 1/2" less than opening in each direction and then tightened with wedges at one side and on bottom. If header is badly damaged, great care should be taken while inserting the shore and the shims.
 - They may not be practical in racked or otherwise deformed openings.
 - For large openings, they may be too heavy to carry up to locations above ground floor.
 - Their main advantage is allowing preconstruction away from the dangerous wall or Collapse Zone.

Measuring Notes

The following points explain how to measure shoring materials while deducting for wedges, the proper use of wedges, and maximum thickness while maintaining full contact with perpendicular shoring materials.

- When possible, round off shoring material measurements to the nearest 1/2" for ease in marking and cutting.
- When using 4x4x18" wedges, deduct the thickness of one wedge from the length of the shoring material being measured.
- When using 2x4x12" wedges, deduct the thickness of one wedge from the length of the shoring material being measured.
- 4x4x18" wedges can be moved together to a thickness of 6" while still maintaining full contact with a perpendicular 4x4.
- 2x4x12" wedges can move together to a thickness of 2 1/4" while still maintaining full contact with a perpendicular 4x4.

Supplies and Equipment

The use of the same dimension lumber for the headers, wall plates, sole plates, posts, and struts will ease the construction of the shoring systems and make the braces more effective.

(The use of duplex 16d and 8d nails during training will assist in the dismantling of the shoring systems and reduce the amount of destroyed shoring materials during the dismantling process.)

- Cleats should be 2x4x12" minimum (18" for less splitting).
- Plywood gusset plates should be $12"x12"x^{\frac{3}{4}"}$ thick.
- Pairs of 18" sq x ³/₄" ground pads are used under the U-channel for raker and sloped floor shores bearing on soil.



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Topic 3-2: Shoring Construction

- Smaller gusset plates can easily be formed by cutting the larger square gusset plates in half, making four 6"x12" gusset plates.
- Triangle gusset plates (12"x12"x17") can be easily formed by cutting a 12"x12" full-gusset plate in half from one corner to the opposite diagonal corner.

Using the Steel Framing Square for Raker Shores

- The **Tongue**, shorter, narrower part that is usually 16" long and 1 1/2" wide
- The **Body** (blade), usually 24" long and 2" wide
- The **Heel**, the point where the tongue and the body meet on the outside edge
- The Face
 - The side with the manufacturer's stamp
 - The side that is visible when the body is held in the left hand and the tongue in the right hand
- The **Back**, opposite of the face

The Scales and Tables

- There are seven different scales and tables on the steel framing square. Four of the seven scales and tables may be used for rescue shoring.
- The Rafter Table
 - Found on the face of the square, on the body
 - Used to determine the lengths of common, hip, valley, and jack rafters and the angles at which they must be cut to properly fit ridge board/top plates for roof framing
 - Can be used to determine the length of the raker
 - Remember that rafter table is based on the run (horizontal distance)
 - Rakers based on the insertion point (vertical distance up the wall)
- The Brace Table
 - Found along the center of the back of the tongue, giving lengths from 24" to 60" forming 450 angles
 - Determine the length of short rakers/corner bracing
- The Hundredths Scale
 - Found on the back of the tongue, near the heel
 - Consists of 1" divided into one hundred parts
 - Useful to convert lengths given in hundredths
- The Inch Scale
 - Found on both the body and the tongue along the inside and outside edges of the square
 - Used for measuring inches and graduations of an inch

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- The Steel Framing Square
 - It may be used to scribe the cut angles for rakers
 - Place the square on the raker with heel pointing up and the body on the left side and the tongue on the right. (Although it may be body at right and tongue at left.)
 - For a 45° raker, position it so the number 12" on the body and 12" on the tongue are aligned at what will become the top of the raker (actually any pair of equal numbers from 6 to 12 may be used, 6"-6", 7" 7", etc.).
 - Scribe a line on the slope at the right.
 - Slide the framing square to the far end of the raker the required distance. (Use one of the methods given below.)
 - Then realign the 12'' 12'' to the edge of the raker and scribe a line at the left.
 - Finally, make a 1 1/2" perpendicular cut.
 - For a 60° raker, position it so that the number 12" on the body and 7" on the tongue are aligned at what will become the top of the raker.
 - Scribe a line on the slope at the right. This will become the wall end of the raker.
 - Slide the framing square to the far end of the raker the required distance.
 - Realign the 12" 7" to the edge of the raker and scribe a line at the left. Make the 1 1/2" perpendicular cut.
- There are two methods to determine the length of a raker using the steel framing square:
 - The Diagonal Method
 - The Step-Off Method
- The Diagonal Method
 - This is the least accurate of the two methods.
 - Use the tongue to simulate the wall and the body to simulate the floor.
 - Use the inch markings on the outside edges as "foot measurements."
 - Place the tape measure tip on the outside inch mark simulating the support point on the wall and lay it across the square until it intersects the outside inch mark on the body simulating the contact point on the floor.
 - The length of the tape measure when it is intersecting the outside tongue and body inch marks will be the length of the raker from tip to tip.
 - Example: 9' high support point on the wall, 9' back from the wall will be a 12'9"-long raker.
- The Step-Off Method
 - Place the square on the raker with heel pointing up and the body on the left side and the tongue on the right.
 - Use the tongue to simulate the wall and the body to simulate the floor.
 - Use the inch markings on the outside edges as "foot measurements."



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- Align the tongue outside edge inch mark representing the height in feet of the support point on the wall with the bottom edge of the raker.
- Align the outside edge inch mark on the body representing the length in feet away from the wall the contact point on the floor with the bottom edge of the raker.
- Scribe a line, which will be the top cut of the raker along the outer edge of the tongue.
- Mark the point where the outer edge inch mark of the body contacts the bottom edge of the raker.
- Hold the square with the outer edge inch marks remaining constant and "step" over the pencil mark to the left and place outer edge inch mark of the tongue next to it.
- Realign the same outer edge inch marks as before and mark the point where the outer edge inch mark of the body contacts the bottom edge of the raker.
- Repeat this step as many times as there are feet in the length away from the wall.
- On the last step scribe a line along the outer edge of body for the bottom cut of the raker.
- Example: 9' high support point on the wall, 9' back from the wall will be a 12'9"-long raker.
 - The 9" mark on the outer edge of the tongue and the 9" mark on the outer edge of the body is "stepped" over these marks twelve times.
 - Measuring the distance covered after 12 steps is 12'9" tip to tip.



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Topic 3-2: Shoring Construction



How to Cut Wedges

- Cutting 4x4x18" wedges
 - Mark a full length 4x4x8 ft every 18".
 - This will make five pair of wedges with a 6" piece left to secure the last pair while being cut.
 - Mark a diagonal line from the top edge of one 18" line to the bottom edge of the opposite 18" line every 18 inches.
- Cutting wedges with a rotary saw
 - Score the line with the blade 1/2" deep.
 - Second pass cut halfway through.
 - Third pass cut all the way through.
 - Cut the other half of the wedge off the remaining 4x4 at the 18" line.
- Cutting wedges with a chainsaw
 - Align the blade with the diagonal line on the 4x4 with the tip of the saw pointing toward the cutting table.
 - Start cutting with the tip of the saw bar approximately 2" past the edge of the 4x4.
 - Once the tip of the saw bar is through the full thickness of the 4x4, start to drag the saw toward the opposite end of the diagonal line.
 - Once the heel of the saw is past the end of the 4x4, flatten the saw and cut the remaining part of the 4x4 with the full bar.
 - Cut the other half of the wedge off the remaining
- Cutting wedges with a circular saw
 - This is difficult to do unless the saw has at least a 10 1/4" blade.
 - Circular saws with blades 10 1/4" or larger need only one pass from corner to corner along the diagonal line.
 - Circular saws with blades less than 10 1/4" require marking and cutting on both sides and do not always align correctly.

How to Cut the Top End of the Raker at 45° and 60°

- Mark the end of the raker to be cut.
- $4x4 = 3 \frac{1}{2}$ " from the end for 45°
- 4x4 = 6" from the end for 60°
- $6x6 = 5 \frac{1}{2}$ " from the end for 45°
- 6x6 = 9" from the end for 60°
- Mark a diagonal line from the upper end of the lumber to the mark on the lower edge of the lumber and cut the end off at this angle.
- Measure 1 1/2" wide on the tapered end and mark a line on the cut side for the relief cut to make full contact with the end of a cleat.

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Topic 3-2: Shoring Construction



- Cut this line from the cut side with a circular saw.
- The Cutting Team will mark and cut the end of a raker at 45° and after cutting the angle end cut off the raker, they will cut the end of the raker at 60°.

How to Determine Length of Raker and Wall Plate

Length of Raker: Insertion Point in feet, times the factor, equals length of raker in inches.

Factors: 45° Raker = 17

 60° Raker = 14

Length of Wall Plate: Insertion Point in feet, plus the cleat length, equals length of wall plate.

Factors: 45° Raker = 24" cleat 60° Raker = 30" cleat

How to Cut the Bottom End of the Raker at 45° and 60°

- Mark the end of the raker to be cut.
- $4x4 = 3\frac{1}{2}$ " from the end for 45°
- 4x4 = 2'' from the end for 30°
- $6x6 = 5\frac{1}{2}$ " from the end for 45°
- 6x6 = 3" from the end for 30°
- Mark a diagonal line from the upper end of the lumber to the mark on the lower edge of the lumber and cut the end off at this angle.
- Measure 1 1/2" wide on the tapered end and mark a line on the cut side for the relief cut to make full contact with the end of a cleat.
- Cut this line from the cut side with a circular saw.
- The Cutting Team will mark and cut the end of a raker at 45° and after cutting the angle end cut off the raker, they will cut the end of the raker at 60°.

How to Notch Lumber for Added Stability

- How to Notch Cribbing (Not Recommended)
 - Mark 4" from the end of the cribbing to prevent the end piece from splitting off.
 - From the 4" mark, make a second mark the true thickness of the lumber being used for cribbing.
 - $4x4 = 3 \frac{1}{2}$ " and $6x6 = 5 \frac{1}{2}$ ".

Speed Square: The speed square resembles a triangle and can be made of metal or plastic. It is used to ensure that shoring components are square at 90° angles. It is also useful to determine the angle of a raker.



Figure 3.41



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Topic 3-2: Shoring Construction

- Adjust a circular saw to the depth of 1/2" and cut the two lines and then between the two lines every 1/2" to 1".
- Ensure saw is unplugged while adjusting blade depth.
- Hit the sliced pieces of lumber with a hammer toward the remaining cribbing to break off the pieces.
- Clean out the notch with the claw end of the hammer until smooth.
- Have one of the squad members repeat this process on the opposite end of the cribbing.
- Notches should be made only on each side of the cribbing to provide full interlock of each piece in each direction.

Steel Pipe Systems

- Pipe capacity depends on buckling strength.
- $\blacksquare \quad \text{Design Load} = \text{Fc x Area}$
 - Fc (Allow. Compression Stress) given in Sect 7 StS FOG
 - Fc is dependent on L/r (L = length in inches; r = radius of gyration = average radius of pipe)
 Example: Design Capacity of 2" diameter standard pipe x 8' long
 - (2.375" O.D., Area = 1.07 sq in, from Sect 7 StS FOG
 - L/r = 96"/.787 = 122; from StS FOG, Fc = 10ksi
 - Design Capacity = 10ksi x 1.07 sq in = 10.7 kips = 10,700 lbs (The author uses about 90 percent of this value, based on the manufacturing tolerances of pipe.)
- Retractable pipe shores are normally adjustable by screw end and/or sleeve and pin. They may have square steel feet that may even have slope adjustment and nail holes for attachment.
- Pipe shores used for bracing tilt-up concrete walls come in lengths up to 30' and have rated capacities listed in tables supplied by rental companies.
- Pipe systems are often used with wood spreader beams and sills, which could limit their capacity. Engineers should be used to design these systems.
- Pipe systems normally fail by buckling and are, therefore, less desirable than well-braced wood systems that can be proportioned to initially fail by crushing of wood.

Trench Jacks

- Trench jacks vary from about 2' to more than 8' long and normally have a rated capacity. They are intended to support the opposing sides of a trench with the addition of spreaders and sheathing. They should be Schedule 40 pipe.
- They may be used as initial unbraced shoring to permit building of a more stable system, not first choice.
- They could be used as a 2- or 3-post system, nailed to header and sole. Diagonal X bracing would need to be nailed only to the header and sole.



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Topic 3-2: Shoring Construction

Diagonally Braced Metal Frames

Steel and aluminum tubular frames are available in design capacities up to 50,000 lb per 2-post frame. They have adjustable height and spreader systems. They may be stacked and guyed to reach great heights and have diagonal bracing members.

Aluma Beams

- These are light-gauge, shaped aluminum joist or beams that are normally used as shoring for wet concrete.
- They have been used to construct shelters from falling debris, as plywood sheathing can be placed between the Aluma Beams and nailed to them to provide a surface that is quite flexible but strong.
- The flexibility of the aluminum (three times that of a similar steel structure) is ideal for catching falling objects, since the flexibility reduces the strength required for the catch structure.

Pneumatic Shores (Struts)

- These are lightweight aluminum pneumatic piston/ram shores, which are highly adjustable with ranges up to 16'. They can be configured with various end connections (see slide).
 - Airshore manufactures 3 1/2"-diameter struts in seven ranges of length (from 2' to 16').
 - Paratech manufactures 3"-diameter struts in four ranges of length (from 2' to 8'), dark grey anodized color.
 - Paratech also makes a 3 1/2"-diameter long strut, in three ranges of length (from 6' to 16'), gold anodized.

Pneumatic Shores

- 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 collar, the safe working load can range from 20,000 lbs for a 6-foot shore to 3,000 lbs for a 16-foot shore.
 - Load charts for the two manufacturers are listed in the US&R Structural Specialist FOG, Sect 7. Loading is based on using swivel end connections.
- When used in US&R, 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 50 psi maximum due to accident potential.
 - The sleeve nut or steel pins are used to adjust length.
 - They may be included in a system with headers, sole plate, and bracing, but are considered best as temporary shores that allow braced systems to be installed at reduced risk.
- The manufacturers also make simple aluminum tubing extensions in lengths from 1' to 6'.
 - Extensions should be used only when other alternatives are not available.
 - Only one extension should be used with each strut



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Topic 3-2: Shoring Construction



Specialty Shores

- **AIRBAGS:** Airbags are a lifting device, not shores. They are tough neoprene bags that come in sizes from 6" to 36" square.
 - They are pressurized to lift very heavy objects a short distance and are helpful in releasing an entrapped victim.
 - They can be punctured by rebar, and objects that are lifted must be laterally restrained by other means since the bags have little lateral strength.
- STEEL OR REINFORCED CONCRETE CULVERT: These sections could be used as a protection device for entry through an area where protection from smaller falling hazards was required.
- SHORING AT COLUMN/SLAB CONNECTIONS: The danger of a punching shear failure occurring at a flat slab/column joint is often present due to heavy debris loading on slabs that do not collapse initially.
 - Since most of the cracking that warns of this type of collapse hazard is on the top of the slab and may be covered by the debris, it may be prudent to increase the column's periphery by adding vertical shoring on all four sides.

Shoring consisting of vertical posts that are tied around the column could be used. All the normal problems, i.e., what's the load, supporting system, etc., need to be considered.

Summary

We have discussed how to size-up and what considerations need to be made in order to select the appropriate type, size, and location of emergency shoring.

In addition, we have discussed the different types of shores and given step-by-step procedures for how to build each type.

The Structures Specialists FOG from the US Army Corps of Engineers and the Shoring Operations Guide (SOG) both have diagrams and instructions for constructing these shores.

Both guides are available in electronic form on the following web site: www.DisasterEngineer.org.

Advanced Rescue Skills





Topic 4.1: Breaching, Breaking, Cutting, and Burning

Topic 4-1: Breaching, Breaking, Cutting, and Burning

Terminal Objectives:

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

Enabling Objectives:

- Correctly identify types of concrete and their components. •
- Identify concrete components and their importance to systems design. •
- Understand their importance during collapse rescue operations.
- Identify concrete construction types. ٠
- Understand the properties, strengths, and weaknesses of concrete and its components.
- Correctly select tools or tool packages for rescue operations. ٠
- Identify functional parts of an exothermic torch. •
- Identify functional parts of an oxyacetylene torch.
- Effectively troubleshoot each tool as needed.

Concrete as a Material

History

- Initially, the Romans used a cement to make concrete. They used Pozzolan cement made from volcanic ash, sand, and lime. These raw materials were simply ground together to make the cement and they mixed their cement with broken stone and brick to produce concrete.
- In 1824 Joseph Aspidin, a brick mason from Leeds, England, took out a patent on a material he called Portland cement. Aspidin is generally credited with inventing a method for proportioning limestone and clay, burning the mixture at a high temperature to produce clinkers, then grinding the clinkers to produce a hydraulic cement very similar to that used today.

Hydration

- When cement and water are mixed, they form a paste. It is this paste that binds particles of aggregate (sand and stone) together to form concrete.
- The reaction of cement and water is exothermic; heat is generated during the reaction. Depending on the type of structure, heat can be an advantage (thin concrete) or a disadvantage if excessive (thick concrete). This hydration reaction can last for years if the concrete is very thick and has moisture, i.e., Hoover dam. Generally, however, a slab or driveway of concrete will cure to its rated strength in about 28 days.

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Topic 4.1: Breaching, Breaking, Cutting, and Burning



Concrete, Mortar, and Grout

- When cement and water are mixed together with sand, broken rock, or gravel (aggregate), we have concrete.
 - Mortar is usually made by mixing Portland cement and water with sand and lime. The lime makes the mix take on a buttery texture, which is especially helpful when bonding blocks and bricks together.
 - Grout is a mixture of Portland cement and water with sand, and sometimes pea gravel. Grout is usually proportioned to be quite fluid when it is used for filling voids, but may be made to be more buttery (without pea gravel) when used in grouting tile.

Types of Concrete

- People often misuse the words cement and concrete. Cement is a fine gray powder and once mixed with water, sand, gravel, or stone becomes concrete. The strength and durability of concrete depend chiefly on the amount of water used. If too much water is used, the cement paste will be too weak to hold the aggregates together. Generally, within limits the less water used, the stronger the concrete.
- There are a variety of concrete types. These depend on the aggregate used, the amount of water added, and ultimately the end use required of the concrete. In all instances, the concrete will be constructed and designed in accordance with what it is expected to accomplish. This may mean the addition of reinforcing mechanisms and may include a variety of engineering options. Note: Contractors have been known to cut corners with regard to the specific engineering requirements of the concrete.

Types of Concrete Construction

- Concrete can be used in a variety of structural members. The strength of the member is dependent upon construction. Obviously, if you are expecting a portion of concrete to be used as a load-bearing member, it had better be engineered for the job. Depending upon the US&R mission, you may be faced with a variety of different construction formats. Knowing how to identify each, knowing what the properties of each are, and establishing a best-method scenario to breach and break provides you with a tactical edge.
- There are two types of reinforcement used in concrete systems— rebar and steel cable.
 - Reinforcement systems are a composite material of steel (rebar) or steel cable and concrete. Steel provides the tensile strength that concrete alone lacks. Steel may also be used to provide compressive strength.
 - You must remember that, if the bond or anchorage is broken between the steel and the concrete, the structural strength ceases to exist.
 - Reinforced concrete examples include columns, floors, walls, beams, double Ts, and practically every concrete-bearing structural member.



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Topic 4.1: Breaching, Breaking, Cutting, and Burning



- Concrete construction can be broken down into the following two types of formats.
 - **CAST-IN-PLACE:** This is concrete that has been molded in the location in which it is expected to remain. This could be a patio porch, a foundation for a house, or a cast floor for a high-rise structure. Castin-place concrete will often have rebar used as the reinforcing steel. However, it may be constructed using post-tensioned cables, explained as follows: High tensile strength steel cables or bars are encased in tubing (casing) and greased to prevent adhesion between steel and concrete. The steel is 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. Note that the grease also provides protection from rust, etc.
 - **PRECAST:** This is concrete that has been cast at a location other than the place it is to remain. These could be tilt-up walls, which are made on site or are brought onto site, or double T floor sections (joists) that are hauled in and connected together. Precast concrete may be constructed with rebar or **pretensioned reinforcing** (or



Figure 4:1



Figure 4:2

both). For pretensioned reinforcing, high tensile strength steel strands (cable) are stretched inside the concrete member. Concrete is placed into 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. Examples may include double Ts or certain floor slabs for large concrete buildings.

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 - Each of these types of concrete has a specific place in the construction industry.

Advanced Rescue Skills



Topic 4.1: Breaching, Breaking, Cutting, and Burning



Properties of Concrete

Weight

- A basic understanding of concrete weights and calculations is critical to rescue personnel, both operationally and for your own safety. Understanding the weights you are dealing with will greatly affect your decisions at times when breaking and breaching becomes necessary.
- Generally, a cubic foot of reinforced concrete weighs about 150 lb (145 for concrete and 5 for rebar). Knowing this basic information provides the rescue team with the ability to quickly calculate how much weight is to be moved from a certain piece of concrete. This becomes important not only during shoring and lifting operations, but is also critical when performing lift-out operations, which require surgical precision. It should be understood that many concrete beams and columns have a greater concentration of rebar than the 5 pounds a cubic foot (pcf) allowance. These members may weigh up to 175 pcf. This must be taken into account when planning to lift the concrete, especially with a crane. The US&R Structures Specialist should be asked to calculate the weight of these members.

Strengths and Weaknesses

- Like all building materials, concrete has its strengths and weaknesses. Knowing these and taking advantage of the weaknesses while avoiding concrete's strengths will enable you to speed your breaching times and enable you to apply techniques suited to type of concrete you will be faced with.
- There are three basic "forces" that we should be concerned about when dealing with concrete: tension, shear, and compression.
- As discussed earlier, concrete is actually 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.
- 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 sledgehammer (placing it is 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.

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Topic 4.1: Breaching, Breaking, Cutting, and Burning



Effects of Environment and Chemicals on Concrete

- Any number of factors can affect concrete. Under these conditions concrete may be subject to early failure or weakening:
 - A harmful reaction between minerals in the aggregates
 - Exposure to groundwater, seawater, or industrial chemicals
 - Repeated cycles of freezing and thawing
 - Inferior concrete resulting from inferior materials, high water-cement ratio, low cement content, inadequate agitation, compaction, and lack of curing

Definitions

Concrete often involves the discussion of the component parts associated with the makeup, failure, or construction of any given system. For this reason, certain definitions are standard within the industry.

- Cement: A fine gray powder, it is mixed with water and aggregates to form concrete.
- Portland cement: The most commonly used cement, called hydraulic cement, which means it hardens after the addition of water.
- Concrete: Fire-retardant, watertight, and comparatively cheap to make.
- Aggregates: Materials, fine or coarse, mixed with cement to make concrete.
- Fine aggregates: Usually sand.
- Coarse aggregates: Crushed stone, gravel, cinders, shale, lava, pumice, vermiculite, etc.
- Spalling: The loss of surface material when concrete is subject to heat or the force of breaking and breaching. It is due to the expansion of moisture in the concrete.
- Explosive spalling: The violent projection of concrete caused by heat or a portion of the concrete being "sheared" by a tool.

Rebar and Reinforcing

General Steel Properties

- 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 size from 3/8" to 1 3/8" in 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 in Concrete Structures

Rebar is generally located in specific locations in certain types of construction. We can predict not only the location but also the size and thickness of the rebar associated with each type of structural member.

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- WALLS
 - Walls up to 8" thick 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 more than 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" in diameter.
- ONE-WAY SLABS
 - These normally span 8' to 16' between parallel beams and are from 6" to 10" thick. Normally, bars near top and bottom of the slabs occur about 1" clear in each case. 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 bars 1/2" or 1" in diameter. 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" or so apart and are 1/2" clear from the top.
- TWO-WAY SLABS—FLAT SLABS (two-way slabs supported by beams)
 - Normally, these bars are similar to one-way slabs except some top bars may extend throughout the slab and will vary.
 - Bars are usually 1" clear from the top and bottom of the slab. Bottom bars range from 1/2" to 3/4" in diameter with spacing from 4" to 12".
 - Top bars are most closely spaced over columns and placed each way.
- TWO-WAY SLAB—WAFFLE SLAB
 - 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 36".
- BEAMS AND GIRDERS
 - These usually are 12" to 18" wide and up to 18" to 24" deep.
 - There are usually two to six bottom bars that are from 3/4" to 1 1/4" in diameter and placed within 2" of the bottom. More bottom rebar occurs in the mid two-thirds of the span.
 - There may be two to eight top bars, also 3/4" to 1 1/4" in diameter, placed in the slab above the beam and parallel to it (usually 4" or so apart). Most top rebar will be within 5' of the support.
 - 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 that usually occur about 1" from the surface and are 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.
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• Tie sizes range from 3/8" to 5/8" in diameter and the tie spacing is 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 four to eight vertical bars, but there may be as many as eighteen verts in very large columns.

Tensioning Cables vs. Steel Rebar

- As previously discussed, in some instances concrete will be prestressed by using high-strength steel cables. Prestressing places engineered stresses in architectural and structural concrete to offset stresses that occur in the concrete when it is placed under load.
 - The concrete may be precast and pretensioned, 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.
- Consider a row of books side by side. As a "beam" such a row will fail of its own weight without any superimposed 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 tensile stress 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.
- Special high-strength cables, similar to those used in suspension bridges, or alloy steel bars are used. They are called "tendons," "strands," or "cables."
- These cables need to be identified early to ensure the rescue team can recognize the difference between the cables and rebar. Cutting of cables can result in the immediate failure of slabs or structural members in precast, pretensioned concrete and cast-in-place, post-tensioned concrete.

Cutting Cast-in-Place, Post-Tensioned Structural Members

Do not attempt to cut a tensioned cable unless you have received proper training and under the direction of a Structural Engineer.

- 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 lb 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 untension if cut or one of the anchorages comes loose. Posttensioned cables can be found in beam and slab floors, flat slabs, and joist and girder floors. 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.





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- Generally, rescue teams should not cut post-tensioned cables or should cut them only under the direction of a Structural Engineer. If you decide, for whatever reason, to cut a cable, you should use a torch or carbide saw to cut one strand at a time to provide for slow detensioning.
- To minimize the risk of cutting tensioned cable during US&R 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', within 10' of the centerline of the cable, and/or a barrier should be built at the end of the slab to stop the cable's projection.
 - No more than three adjacent tendons should be cut in each direction unless the structure has been collapsed and is being supported more or less uniformly.

Cutting of Precast, Pretensioned Structural Members

- These members usually consist of beams, single and double Ts, and slabs. The steel is bonded to the concrete, but the stresses are usually very high near the steel. The following is a guide to cutting pretensioned members. Discuss with your Structural Engineer.
 - AVOID cutting pretensioned beams or the stems of Ts unless they have collapsed and are supported as part of the rubble pile. Even in that case, AVOID cutting near the ends.
 - One may cut slabs, including the very thin slabs of Ts. Since these members are usually only about 4' 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.

Types of Tools and Uses

- Tools for breaching and breaking must be used in a "systems" approach. No tool will accomplish the task of breaching and breaking by itself. In order to accomplish any breaching and breaking task, a team must identify the tools it will need in advance. Once identified, they must be used in the appropriate manner to accomplish the operation as quickly and safely as possible.
- These tools operate from a variety of power sources. They may be pneumatic, hydraulic, fuel driven, battery, electric, or manually operated.
- For our purposes we will categorize tools in the following manner:
 - Cutting
 - Breaking
 - Breaching
 - Torches
 - Support

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Cutting Tools

- These are tools that are used to cut concrete, steel, wood, or reinforcing bars. They come in a variety of forms and sizes, with certain tools best suited for specific jobs. The following are tools that you will encounter during this course:
 - Circular saws with diamond segmented blades
 - Diamond-tip chainsaws
 - Wizzer saws, electric or pneumatic
 - Reciprocating saws, electric or pneumatic
 - Chainsaws (electric and fuel)
 - Rebar cutters, manual and hydraulic
 - Hacksaws, bolt cutters, chisels
 - Hydraulic rescue tools

Breaking and Breaching Tools

- These tools are used to remove a large or small section of concrete by removing it under tension or shear. Breaking and breaching tools are most effective when some method of compression relief is provided for the concrete, such as relief cuts or stitch drilling. They include:
 - Hydraulic breakers
 - Manual mauls and sledgehammers
 - Pneumatic chipping hammers
 - Electric rotary hammers
 - Electric demolition hammers
 - Feather and wedge sets



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Torches

- These devices are used most appropriately to cut steel reinforcing plates, beams, or cables. They come in a variety of sizes and operate from a variety of different power sources. These may include the following:
 - Oxyacetylene/Mapp torches
 - Exothermic torches
 - Oxy-gasoline torches



Figure 4:1 Oxyacetylene



Figure 4:2 Oxy-Gasoline



Figure 4:3 Plasma



Figure 4:4 Exothermic

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Support Tools

- These tools include all the accessories you will need to accomplish your breaching and breaking. Without these tools your operation may not be as effective or safe. These may include:
 - Ventilation fans
 - Generators •
 - Atmospheric monitors ٠
 - Hand tools •
 - Water cans, sprayers
 - Bolts ٠
 - Lights and accessories ٠
 - Cribbing ٠
 - Fuel and repair tools ٠
 - Webbing
 - Extinguishers ٠
 - Mechanical advantage systems and rope systems

Other Optional Equipment

- There are other tools on the market or in the trades that can be used effectively at a rescue site. They may include the following:
 - Plasma cutters •
 - Exothermic torches
 - Gasoline-powered breakers ٠
 - Electric chipping hammers ٠
 - Pneumatic breakers •

Methods to Defeat Concrete Properties

In order to effectively breach and break 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 that, used together, will enhance your operational capabilities.



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RELIEF CUTS (Tension vs. Shear): These cuts are usually made with saws and provide the concrete that is being broken the ability to be taken out of compression. These may be square relief cuts, triangular, or X-shaped. The gap created by the relief allows you to attack an inherent weakness of concrete, which is its poor structural stability when placed in shear or tension.



Figure 4:5

■ BEVEL CUTS: These are angled cuts that are 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.

BEVEL CUT





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• STEP CUTS: These are cuts that are used during a "lift out" operation when the slab is thicker than what 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.





Figure 4:7

Figure 4:8



Figure 4:9



Figure 4:12



Figure 4:10



Figure 4:11



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Topic 4.1: Breaching, Breaking, Cutting, and Burning

STITCH DRILLS: These are bore holes that 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 shear or tension when applying a breaker.



Figure 4:13

- BOLTING: Bolting can be used in a variety of situations. Bolts can be permanent or reusable. In most instances, they are placed in the concrete as anchors to support 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.
- BURNING AND CUTTING: Cutting with a torch is an art and it requires experience to become an accomplished burner. Oxyacetylene/Mapp and oxy-gasoline require 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 takes only 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 ensure you are not in or creating a hazardous atmosphere.

The most common method of cutting is to place the tip of the flame halfway over the edge, with the preheat flames 1/16" to 1/8" from the surface to be cut. When the flame starts to produce an orange color, the metal has reached its kindling point; slowly squeeze the oxygen-cutting lever and the process will begin. Once the cut has been started, the torch is moved with a smooth and steady motion maintaining a constant tip-to-work-surface distance. Move the torch with a speed that will produce a light ripping sound and a smooth, steady stream of sparks.



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Topic 4.1: Breaching, Breaking, Cutting, and Burning



Figure 4:14

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 use all appropriate Personal Protective Equipment (PPE) for the task at hand. During breaching and breaking operations, you may be confronted with a variety of hazards that may affect your operations. These may include, but are not necessarily limited to the following:
 - Exposure to heat
 - Shifting or movement of large weights
 - Deficient or dangerous atmospheres
 - Confined spaces
 - Tool reaction
 - Materials reaction
 - Sharp objects, tools, and blades
 - Trip and fall hazards

Other Issues

- Concrete movement during tool use: The rescuer must be aware of the ability of slabs to shift vertically, lift-out sections to fall, and concrete in large or small pieces to move 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 of and prepared for saw kickback and blade movement. During operations you must also be aware of your environment and fellow rescuers to ensure you do not strike them with a running saw.



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Topic 4.2: Tool Applications and Assessment

Topic 4-2: Tool Applications and Assessment

Terminal Objective: At the conclusion of this section, the student will demonstrate proficiency in the inspection, operation, maintenance, and safe use of all power tools.

Enabling Objectives:

- Understand the operator's influence on tool performance.
- Understand electrical power sources, the electrical loads, and tool safety.
- Understand the tool assessment criteria.
- Be able to perform a pre-use inspection of all gas, fuel, pneumatic, hydraulic, and electric power tool systems.

Tool System Application and Assessment

Systems Approach to Tool Selection and Operation

Generally, in the fire service we do not use complicated tool systems or, if one is used, it is either preconnected or stored as a "system" and easy to deploy. In the US&R system we don't have that luxury. Our tools are stored in small boxes that allow only parts of a tool system to fit, then they are transported to an unknown location and stacked for possible use. This system of deployment does not make for quick or easy tool acquisition or deployment, but it is the system that we must live with.

Imagine if the preconnected hose on your pumper were broken down into the following parts: nozzle, hose, washers, outlet valve, pump, water tank, intake valve, supply hose, hydrant adapter, and hydrant wrench, and then they were all stored in separate boxes that were mixed in with 200+ other boxes. It would take a lot of thought and preparation to bring that system together. That is the system we live with.

US&R members must know that and think in these terms. They cannot rely on the Logistics team members to provide a complete tool system when requested. There are just too many items in the cache for Logistics to remember every complete tool system that could be requested by Search, Planning, Rescue, Hazmat, Rigging, or anyone else on the team. You will be using the tool system and you are responsible for making sure it is all there when you leave the Base of Operations (BoO). Many times, the rescue site will be miles from the tool cache, and a missing part can place the whole operation in jeopardy and make the difference between a rescue or a recovery.

Let's look at all the parts needed for a Stanley DS11 Concrete Chainsaw operation to place a hole in a slab for entry:

Stanley power unit, unleaded gasoline, motor oil, hydraulic hose (3/4 and 1/2), DS11 chainsaw, spare chain, wrench (chain changing), screwdriver (chain tensioning), garden hose, water pressure booster pump (depending on chain and water pressure), 1 1/2" to garden hose adapter, fire hose 1 1/2" (to bring water from remote source), hydrant adapter 2 1/2" to 1 1/2", possible adapter from local standard to NST carried by task force, hydrant wrench.



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That is one complete system for the cutting operation. Many of those parts are carried in separate boxes and no part is more important than the next. You can set up the whole system but nothing can happen if you are missing the 1 1/2" to garden hose adapter. It seems like a small part, but the whole rescue operation waits while it is requested, picked up, and brought to the scene. Depending on the situation at hand, that could take hours. Think about it being delivered by helicopter to a remote rescue location and you may never get it.

These tools or parts must be identified on the cache list to find box numbers, and the boxes must be located among the 200+ others at the BoO. The boxes must be opened and tools/parts collected and delivered to rescue site. One problem with just identifying the needed boxes and taking them is that they may have parts from another tool system inside, and removing them from the BoO could place that tool system in jeopardy of missing some items.

Now think about the system and tools that will be needed to control and lift out that slab of concrete once you have cut it out with your saw. Imagine this whole evolution happening at night and the tool system needed to provide power for lights and electric tools.

Rescue Tool System Application

The goal is to assemble, operate, and maintain rescue systems to efficiently extricate victims. Inability to do this will result in further pain and suffering for the trapped victim. The professional rescuer needs to be proficient and capable of quickly determining the proper application and safe operation our rescue tool systems.

When your "Rescue System" is not working, typically there will be only one thing wrong. Most troubleshooting analysis operates from this premise. The most efficient way to trace the problem will be to start at one end (usually the power source) and work toward the tool, inspecting/isolating/testing each component. It's usually something simple. This way, even if there are multiple problems, you are likely to find them. Resist starting in the middle of your system; this will often result in your going back and forth looking for the problem and, if there are multiple problems, you will quickly be frustrated, not to mention that the rescue process will be losing irreplaceable time.

Experience has taught us that many times the issue is one of application or operation. We must choose the right tool for the job or, when forced to use an alternative tool/system, know its limitations. Sometimes this is dictated by environment or proximity to the victim—excessive noise produced by a pneumatic breaker may aggravate the situation. If you need to cut steel but have a concern about heat transfer, you may need a colder cutting technique than a torch, i.e., a reciprocating saw or electric rebar cutter. Working in confined spaces often limits what kind of tools we can use. Inherent system inefficiencies such as friction loss can limit our tool operation (Stanley Tool 1/2" hose) or even workplace regulations like the 300' OSHA limit on SABA lines. When operating gas engines, plan for and predict the accumulation of carbon monoxide; always monitor the atmosphere.

Therefore, within these confines we apply our tools and techniques. Some basic operating principles can help maintain an efficient rescue operation.



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Topic 4.2: Tool Applications and Assessment



1. Know the cache.

Do not become overly dependent on others knowing where and how your tools are stored. Many of our systems can be useless without a single adapter or other seemingly minor component. Ensure that when leaving the BoO you have an adequate size-up of what you are to do, that you know where the boxes are, and know what is in them. A couple of minutes verifying the inventory and in-service status will save time once you are deployed to the field and then find out, for example, the extension cords are in a separate box. Think *"Systems"*—know that when you finish the floor breech, ropes/ladders may be needed to make entry. Anticipate tool packages and have them staged for use; stay ahead of the rescue operation.

2. Use proper application and operation of tool systems.

As an example, our diamond saws/cores will not cut cured, engineered concrete at the same rate some of us may be used to with the "training" concrete often used in US&R training classes. Blades, bits, torches, cores, etc., have specific applications; make sure you have matched the tool system to the work piece.

Speed/Feed Rate of Tool

A good rule of thumb when running a saw, drill, or jack, either electric, hydraulic, or gas powered, is to not load or apply so much pressure on the tools so as to slow the RPMs down more than 15 percent of full speed. Keep the saw cutting at full speed. Keep in mind that you will run into situations that will require full speed all the time or require you to start off in a slower speed to begin the cut and then increase RPMs. If the operator of the tool is pressing too hard and slowing the tool down too much, typically the motor/pumps and saw blades will overheat, further compromising performance. If the tool cannot cut "fast" enough, assess if you are using the right tool/bit/blade or get multiple tools in operation. By maintaining 80 to 90 percent of full speed RPM or BPM, the tool/bit will cut/grind as efficiently as it can. Heat, one of the by-products of our systems, must be controlled. Overheating the working ends of our drills and saw bits can cause irreparable damage. Diamond segments (grinding) will mushroom, cutting edges will round off, and motor insulation will break down.

- 1. Some techniques to keep your blades/bits cool:
 - a. Ensure adequate lubrication—water or oil.
 - b. If dry cutting, pull tool blade/bit out of cut every 10 to 20 seconds to run in ambient air to cool.
 - c. Make sure a properly dressed sharp bit/blade is in the power tool.
- 2. If the motor is too hot to touch, you may need to switch it out or change tool systems.
- 3. Anticipate long-term operations and plan for replacement of consumables.
- 4. Keep conductors of energy as short as possible—air hoses, electric extension cords, and hydraulic lines.
- 5. Particularly when operating pneumatic and hydraulic systems with long hoses, consider jogging the tool against the work piece to counteract the friction loss in order to prevent out-running the system's ability to keep up with energy consumption.
- 6. Consider what type of force you wish to apply to your work piece. Attack the barrier in its weakest mode, i.e., concrete in shear, not compression. If you can locate the rebar and cut these first, you remove concrete's ductile capability. This consideration can also be applied to choice of hand tools vs. power tools, such as a dirty breech executed with sledgehammers in lieu of heavy power tools. Take





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time to thoroughly size up the barrier and develop a coordinated plan (with backup) to get through it. Make sure the tool and technique are matched to the material being worked on.

- 7. Anticipate the action/reaction of the tool and the barrier. Be prepared to deal with rubble, weight of the cut out, and the speed of the release.
- 8. Continuously assess the working end of your tool. Keep the bits dressed and sharp. Inspect diamonds for any deformation and integrity. Ensure bits/blades are compatible with the barrier and the desired result, i.e., the bull point of a jackhammer will create circular lines of force (general demolition), a chisel bit will create linear lines of force for a more precise/predictable break.
- 9. Listen for pressure relief valves venting. The tool system may be overloaded.
- 10. Stay within the operating envelope of your tool package. When you have questions or problems, refer to your supervisor and the operating manuals.

General Tool Operation Safety Considerations

When operating power tools, always wear the appropriate PPE—gloves, ear protection, safety glasses, helmet, respiratory protection, and work uniform. Do not wear loose-fitting clothing or other items that could get entangled in the power tool. Prepare to mitigate any hazard your tool operation may produce—dust, dirty water runoff, exhaust fumes, etc. All tools require a general inspection prior to use checking for loose, cracked, or broken components. Check for loose fasteners, proper lubrication, blocked vents, cord damage, and proper operation. Never operate power tools when too tired or under the influence of drugs. A moment of inattention could result in serious injury. When operating tools, try to maintain a firm and balanced body position, and try not to overreach. Keep your work area as well lighted as possible. If your tool is not operating properly, place an "Out of Service" tag on it and turn it in for repair.

There are no perfect or trouble-free tool packages. The rescuers' ability to keep their Rescue Systems working in the field will be directly proportional to safe and successful rescues.

Urban Search and Rescue is a young and evolving program. Part of the evolutionary process is a constant evaluation of tools and equipment. Who better to evaluate the tools and equipment in the cache than a US&R member?

When assessing the tools' effectiveness, it is important to form your opinions when the tools are being operated in a manner for which they were designed. Oftentimes, in a rush to complete a rescue, we tend to operate our equipment outside the parameters for which it was designed. This would not produce an accurate assessment of the tools' true effectiveness.

Operators' Influence on Tool Performance

- No other factor will influence the tools' performance more than the level of training and experience of the operator.
 - Cutting large sections of concrete with new equipment and equipment that we just don't use every day is a relatively recent addition to the fire service.
 - As a result, operators are inexperienced and tools are not being properly operated. The result is poor performance and increased maintenance.
 - Proper assessments must take this into account and resist the tendency to blackball a piece of equipment due to operator inexperience.



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Assessment Criteria

The following is a list of equipment evaluation criteria that will assist in the assessment process.

- Field performance: Does the tool perform in field situations as well as in training?
- Weight: Does the weight of the equipment restrict its transportability when compared to like equipment? Is the equipment too heavy to operate in confining spaces or on poor footing?
- Power source
 - Can the power sources be anything from battery-powered to propane, gasoline, etc.?
 - What is the duration, ease of recharging, and availability of batteries?
 - What is the type, capacity, and transportability of fuel? Does the fuel type restrict locations where the tool can operate and is that a hindrance?
- On-scene maintenance
 - Can the equipment be serviced and maintained on the rescue site?
 - How often does maintenance need to be performed?
 - Is special equipment required to perform the maintenance?
- Operating conditions: Can there be any other condition that may affect tool performance or how the tool impacts on the operator?
 - Environmental
 - Hazards
 - Confined space
 - CO
 - Noise
 - Fire
 - Atmosphere
 - User interface
 - Ease of operation
 - Day/night
 - Number of personnel required to operate
 - Technical skill required to operate
 - Specialized training
 - Certification
- Make notes on tool and operator performance during incidents and training activities. After the incident is over, put these notes in memo form to be given to your US&R program manager.



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Topic 4.2: Tool Applications and Assessment



General Operating Principles and Tool Maintenance

Operating Principles of Two-Cycle and Four-Cycle Engines

- The key to any successful US&R operation is a thorough knowledge of the tools. The US&R member must not only be able to select the appropriate tool to accomplish the task quickly and safely, but also be able to troubleshoot minor tool problems and make the necessary on-site repairs.
- Unfortunately, the US&R system is not overly abundant with tools, small tool mechanics, or personnel to shuttle tools back and forth from the work site to the BoO. This requires the US&R member to pick up the slack and make the minor tool repairs.

Two-Cycle Engines

- The predominant engine used for most gasoline-powered rescue tools is the 2-cycle engine. The 2-cycle engine has many advantages over the conventional 4-cycle engine for rescue work, but requires distinct starting and maintenance considerations.
- By understanding the operating characteristics of a 2-cycle engine, the Rescue Specialist can better prepare for and troubleshoot maintenance issues.
 - The 2-cycle engines have no oil sump. The gasoline-oil mixture provides the fuel and lubricating oil. This allows the 2-cycle engine to be operated at almost any angle without loss of lubrication. It is important to mix and maintain the proper fuel/oil mixture. A 2-cycle engine run on a fuel/ oil mixture too rich in oil may end up fouling the spark plug and may smoke excessively when operated. But an engine run on too lean an oil mixture can permanently damage the engine.
 - Two-cycle engines operate at a higher RPM than 4-cycle engines. The higher RPMs generate higher operating temperatures. After periods of running under load and at high RPM, the engine should be allowed to cool before shutting off. Allow the engine to run for 10 to 15 seconds at idle. This slows cooling, reducing the chance of mechanical damage.
- With every down stroke of the piston, the fuel/oil mixture is drawn into the cylinder. This makes the 2-cycle engine more susceptible to flooding than the 4-cycle engine. To reduce the possibility of flooding, the following guidelines should be used when starting a cold 2-cycle engine.
 - Turn the on/off switch to the *on* position and close the choke.
 - Pull the starter cord briskly until the engine starts.
 - If the engine fires but will not start, open the choke and attempt to start again.
- If repeated attempts to start have failed, the engine is probably flooded. Remove the spark plug and dry. Replace and repeat the above procedure. If the engine still fails to start, check the maintenance items listed below.
- The maintenance and troubleshooting of all 2-cycle engines no matter what the applications are very similar. The three areas where the US&R member may be required to perform maintenance are replacing air filters, cleaning spark plugs, and clearing fuel systems.
 - Clogged airs filter can result in loss of power and prevent starting. Air filters should be checked after every tankful of fuel or more often in dusty conditions. Before removing any air filter, always close the choke. This will reduce the possibility of dirt getting into the engine and causing damage.

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- Spark plugs can become fouled from too rich of an oil mixture or when the engine idles too long. If an engine fails to start or quits during operation, check to see if the spark plug has fouled.
- The fuel tank on 2-cycle engines is most often vented with a one-way valve to let air in and prevent fuel from leaking when operated at different angles. If, after starting, the engine runs only to stall 10 or 15 seconds later, the one-way valve may have become clogged. Open the fuel tank cap slowly and listen for a rush of air to enter. This is a telltale sign of no fuel tank venting.

Four-Cycle Engines

These engines, which use straight gasoline, typically for US&R run electric generators. They have an oil sump or crankcase that circulates oil within the engine to provide the lubrication that is done with the gas and oil mixture for 2-cycle engines.

This means that 4-cycle engines, unless otherwise specified (pressurized oil crankcase), must be upright to run properly. Aside from this, 4-cycle engines operate similarly to 2-cycle engines.

Gasoline-Powered Chainsaws

- The chainsaw is one of the most frequently used tools and may be one of the most dangerous to operate. The large exposed cutting surface requires the operators to be skilled at using a chainsaw, for their safety as well as the victim's safety. It is therefore important to know not only about the maintenance aspects of the saw, but also the possible reactive forces involved in cutting.
- Before every use, the chainsaw should be inspected for fuel, chain oil, chain tightness, and operation of the chain brake. Most chainsaws will allow for the fuel tank to run dry before the chain oil reservoir is emptied. For this reason, don't be fooled into thinking that, because chain oil remains in the reservoir after a tank of fuel, chain oil does not need to be added. Always refill your chain oil reservoir after each tank of fuel.
- Before beginning work, check to make sure the chain is receiving oil. Point the tip of the chainsaw toward the ground and run the engine at half to three-quarters throttle. You should begin to observe a darkening of the ground underneath the tip of the guide bar. This indicates the chain is receiving lubrication and cutting can begin. The absence of chain lubrication can destroy the guide bar and chain.
- If no oil appears on the ground, check the chain oil reservoir to make sure the reservoir has not run dry. If that is not the problem, next check the inlet hole in the guide bar for blockage.
- The chain brake should be checked while running the saw at an idle. Engage the chain brake by pushing the hand guard forward, then squeeze the trigger for no longer than a few seconds. The chain should not rotate.
- There are three main reactive forces the operator may encounter during cutting. They are pushback, pull-in, and kickback.
 - A pushback occurs when the chain on top of the guide bar gets pinched, which suddenly stops the chain movement. The saw will tend to push back toward the operator.
 - The opposite of this is a pull-in, in which the chain on the bottom of the guide bar gets pinched and the saw is pulled into the work.
 - The kickback occurs when the tip of the bar comes in contact with a solid object or when movement is restricted. Kickback can happen in an instant with explosive force.



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- When cutting wood that may be under stress, a relief cut should first be made in the area of the wood that is under compression. The deepness of the cut depends on the thickness of the material to be cut. For example, a 2x4 may just have to be nicked and a large log may require a cut of several inches. In either case, you do not want the wood to begin to flex from this cut. Your next cut will then be on the tension side of the material, completing the cut. Use the "Chipper Chain" when cutting trees; the carbide-tipped chain will not clear the kerf. The carbide chain works better on kiln-dried lumber and mixed layered, i.e., asphalt, roof coverings.
- Working in areas of blown down trees or in collapsed structures is very dangerous. Always work in pairs, plan your cuts, and keep the nose of the guide bar away from solid objects.
- The rescuer may be required to complete three main maintenance or repair items on site. They are:
 - Inspecting and changing of the air filter and spark plug
 - Inspecting and replacing the chain and/or guide bar
 - Tensioning the chain and replacing fluids
- A clogged air filter can reduce engine performance and increase fuel consumption. Most chainsaws have two sets of filters, a prefilter to remove the larger dirt and wood chips and a fine filter.
 - The prefilter should be cleaned after every tankful of fuel. This is accomplished by brushing away the dirt with a small brush or by blowing the filter clean with a stream of air.
 - The fine filter can either be a mesh material or a paper filter similar to that found in automobiles. The mesh-type filter may be reused after cleaning so long as there are no holes in the filter material. The paper-type filters should be discarded when dirty. Mesh filters should be cleaned at least once a day and more often in dusty areas. For this reason, spare filters should accompany the saw to any cutting site.
- Although the methods for replacing air filters vary according to the brand of saw, all manufactures recommend that before the fine filter is removed brush away any dirt near the carburetor and close the choke to prevent dirt from entering the engine.
- If deployed to an area of significantly higher altitude than you typically work in and you experience sluggish performance from your saws, the carburetor may need to be tuned to the elevation.
- Chainsaw chains should be replaced or sharpened when the operator must force the saw to cut or the wood begins to smoke when cutting. A dull chain increases fatigue on the operator and increases the risk of kickback. Since sharpening the chain is time consuming and can involve complex angles, the US&R member should plan to replace the chain on site.
 - To do this, remove the side cover covering the chain sprocket. Relieve the tension on the chain. Once the chain tension is released, remove the chain from the tip of the guide bar. The chain and guide bar can then be removed.
 - Once the guide bar is removed, examine the ridges on which the chain rides for uneven wear. If one side of the ridge is higher than the other, a file must be used to level the ridges. During the course of normal operation, the nose and underside of the guide bar will wear faster than the top. For this reason, every time the saw chain is sharpened or replaced, turn the guide bar over.
 - Reverse the removal procedures when reinstalling the guide bar and chain, but tighten only finger-tight the nuts that hold the sprocket cover in place.

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- Now that the chain has been replaced, pull the guide bar nose up and out at the same time as turning the tensioning nut. The chain is properly tensioned when the chain is resting on the underside of the guide bar and can be easily pulled along the bar. Run the saw for two or three minutes, then readjust the chain tension as necessary.
 - Chains that are overly tight will increase guide bar wear and engine strain.
 - Chains that are too loose run the risk of being thrown off the guide bar and injuring the operator.

Cutoff Saw

- The rotary blade power saw goes by many names—cutoff saw, K-12, or Cutquik—but whatever you call it, these saws all have a circular blade driven by a V-belt attached to a 2-cycle engine. These saws can be used to cut wood, concrete, or steel, depending on the type of cutting wheel attached to the saw.
- Before using, check the cutting wheel for any nicks, cracks, or missing segments that could cause the blade to be out of balance and shatter during use. Check the V-belt tension.
- Always place the wheel guard in a position to protect the operator.
- Operators should always stand to the left of the cut to protect themselves in the event of cutting wheel failure or to prevent being hit by thrown material.
- During wet concrete cutting, the slurry created can cause slick footing. Make sure you have a stable base and work in pairs.
- The following are general guidelines the US&R member can use when replacing the cutting wheel. Refer to your owner's manual for specific details.
 - To replace the cutting wheel, switch the engine off and prevent the cutting wheel from turning by placing the locking pin through the spoke in the V-belt pulley.
 - Remove the nut holding the thrust washer in place and remove the thrust washer. The cutting wheel can now be removed.
 - Reverse the sequence when installing the new cutting wheel. Always make sure blade rotation corresponds to the rotation arrow on the cutting wheel.
- In the field, the rescuer may be required to clean and replace the air filter and spark plug and replace and tension the V-belt.
 - Filters for rotary blade power saws are similar to that of chainsaws. There is a prefilter that is usually a reusable foam filter and a fine filter of mesh or paper. The prefilter should be cleaned after every tankful of fuel. This element can be cleaned by with a soft brush or by blowing the filter clean with air.
 - The fine filter should be cleaned daily or more often in dirty and dusty conditions such as in cutting concrete. Nonreusable paper filters should be discarded when dirty.
- Remember to close the choke and wipe away any dirt near the filter housing before removing any filter.
- The V-belt or drive belt should be inspected before every use. Look for fraying or any damage to the belt that could cause it to break.

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- Most V-belts are replaced in a similar manner. Unscrew the screws holding the arbor bearing and wheel guard in place. Next, remove the screws holding the drive arm in place. Place the new V-belt on the drive pulley and reassemble.
- To tension the V-belt, loosen the screws holding the arbor bearing/guard in place. Either tighten the eccentric adjuster or turn the tensioning screw (depending on the manufacturer) until the V-belt can be depressed slightly. Overtightening of the V-belt may cause premature arbor bearing failure.

Cutting Wheels

- Cutting wheel is a generic term for any number of cutting blades whether they are diamond blades, abrasive blades, or carbide-tip blades. These blades can be grouped according to the material they are designed to cut. Concrete or masonry blades can be either diamond or abrasive cutting blades. The concrete abrasive blades are composed of a silicon oxide matrix. Metal-cutting blades are almost exclusively the abrasive types composed of an aluminum oxide. Lastly, wood-cutting blades are made of steel and may or may not be carbide tipped.
- Abrasive cutting wheels, no matter what the material they are designed to cut, are subject to the same type of wear and use considerations.
- Abrasive blades are particularly susceptible to chipping and cracking. For this reason, blades should not be transported attached to the saw.
- Before using an abrasive blade, inspect it for chips, cracks, and uneven wear. If any are found, replace and discard the damaged blade. Uneven blade wear is characterized by a thinning of the blade toward the outer edge.
- If water is to be used during cutting, make sure the blade is compatible for use with water. Not all blades are designed for wet cutting and the application of water could result in blade failure.
- Wet cutting has several advantages over dry cutting.
 - Water helps keep the blade cool, which will prolong the blade life.
 - Water will reduce the air-borne by-products of cutting, which can clog air filters and breathing respirators.
- When using water, make sure both sides of the blade receive nearly equal amounts. Unequal water coverage can cause greater wear on one side of the blade resulting in thinning and eventual blade failure.
- After completing your cut, shut the water off first, allowing the abrasive blade to spin and remove excess water.
- Abrasive blades should only be stressed radially and never torsionally by twisting or bending. This could result in sudden blade failure, seriously injuring the operator.
- The diamond cutting wheel is composed of a steel wheel, called a core, on which a diamond and steel cutting matrix, called a segment, is welded. Although diamond blades are not as susceptible to chipping and cracking as abrasive blades, other problems can arise with diamond blades, which, when recognized and corrected, will help extend blade life and shorten cutting time.
- The first and most important step to prolong blade life is selection of the proper wheel. Wheel segments (the diamond and steel matrix) vary in hardness according to the material they are designed to cut. Some blades are designed for cutting cured concrete, while others may be designed to cut asphalt or lightweight concrete. The blades we should be primarily concerned with are those designed to cut cured concrete.

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- After the proper blade is selected, the blade must be broken in on the material being cut. Allow the blade to begin cutting by exerting only slight pressure. This exposes the cutting diamonds without generating excessive heat. Cutting can now begin using the back and forth motion. This cools the blade by exposing it to air.
- During cutting operations, periodically examine the cutting wheel for the following problems:
 - Cracked or missing segments can occur due to stresses from twisting or jamming of the blade in the cut or by blade overheating. A telltale sign of segment loss due to overheating will be a discoloration of the core just underneath the missing segment. To prevent overheating, expose the blade to air more frequently, cool with water.
 - Check for glazing.
- Glazing appears as a shiny, smooth surface on the segment. The first sign that glazing has occurred is lack of cutting progress. Glazing can occur at any time during the cutting process from contact with rebar, overheating, or cutting a material too hard for the diamond segment. Once glazing has occurred, cutting progress will be slowed and overheating will result until the blade is reconditioned. To recondition or dress a diamond blade, the operator must find a material softer than the material being cut. Operate the saw in the softer material as you would for the break-in period with light pressure.
- Just as abrasive blades can have uneven wear, diamond segments can also wear unevenly. The most common cause of uneven segment wear is lack of adequate water coverage to one side of the segment, which results in one side of the segment wearing faster than the other.
- The third blade we should be familiar with is the carbide-tipped cutting blade. Designed to cut primarily wood, the main advantage of a carbide-tipped blade is the long life of the cutting edge when compared to conventional blades. The blades work best at high RPM. Slower RPMs can result in carbide tip loss.

Rescue Tool Power Sources and Operating Principles

Hydraulic Operating Principles

Hydraulic rescue systems have three basic components: power unit with a gasoline engine, hydraulic fluid pump, and reservoir with associated valves to control direction and pressure. The hoses transmit the pressurized fluid to the tool, spreaders, and jackhammer, etc. This is a closed system, as opposed to a pneumatic (open) system that vents/consumes its power transfer medium. Hydraulic systems have a pressure port (output of the pump) and a return port (hydraulic fluid flowing back into the reservoir). For best operations, the fluid temperature should be between 60 and 140°F.

Pressure is applied in all directions within the containers. The hydraulic fluid is mostly incompressible, but may contain up to 10 percent air. The action that creates the mechanical advantage depends on Pascal's Law, which explains that a force or pressure on a small surface can be transferred to a larger surface, amplifying the force. Think of the small piston attached to the pump handle of a hydraulic bottle jack and reference that to the larger piston or the column that rises as you pump the handle. The small force you create by pumping the small piston with the lever (handle) transmits the force (the pressure in psi) to a larger area (the square inches in psi). This is why by simply jacking this pump by hand you can lift several tons. This is a positive displacement pump, which means that, if it pumps against a closed head for very long, the pressure will build until something relieves the strain.

System operating pressure is directly related to the load applied, ultimately relieved by internal overpressure valves automatically or by decreasing the load on the working end tool. Think of a vehicle rescue

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system ram pushing against a vehicle component. The tool system will load up and build pressure until the object is displaced, the operator releases the tool, or the relief valve kicks in.

The Stanley system also has a GPM measure, which is critical. This is because we use tools such as saws and jackhammers with this system. These tools reciprocate and spin, not just push a piston. The GPM of the pump relates directly to the speed at which the tool runs.

When hoses are left in the hot sun or on pavement, the fluid will expand, building up pressure in the hose, which can prevent coupling or uncoupling of hoses. There are two ways to relieve this pressure.

- 1. When the hoses are connected to the pump or a tool, you can relieve the pressure back through the system by cycling the tool control valve or the flow control on the power unit.
- 2. When the hoses are not connected and the couplings become "locked up," you must carefully loosen the threaded connection between the coupling and the hose. This will allow a small amount of fluid to leak out, lowering the pressure and allowing the connection to be made. Remember to tighten the connectors once the connection has been made.

Safety Issues

- Pressures in hydraulic systems can be 2,000 to 40,000 psi, always assume under pressure.
- Treat as "hot" work; have an extinguishing capability handy.
- Always wear PPE.

Pneumatic Operating Principles

Pneumatic tools weigh less, are very portable, and have many excellent applications. Air tools, with the exception of air bags, are often measured not only in operating pressure but also CFM, cubic feet per minute. This is the amount of air the tool uses to work. The speed of the air is expressed as FPS, or feet per second. These factors can be affected by the friction losses in the hoses. The air in these containers when static represents potential energy and needs to be relieved safely. Cracking valves or couplings may blow O-rings and launch projectiles. Drain your pneumatic system appropriately.

Our class D breathing air will dry out the system O-rings and cause premature failure. Oil regularly by adding a couple of drops into the tool. Extend your usable air supply by jogging your tool to counteract the friction losses in the system. The air consumption of the tool can exceed the ability of the regulator and hoses to deliver the needed CFM especially when the SCBA bottle is getting low on pressure.

Safety Issues

- Control bleeding off of pressure.
- Use a pressure relief valve with air bags.

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Electric Operating Principles

Electric tool systems have three general parts: power generation, transmission, and tool. It is our responsibility to understand the operation of each part and know where it fits in the operational envelope. It is also important to understand some terms and units of measure concerning electricity. This information is often displayed on the tool. One helpful way to think of these parameters is to liken them to fire ground hydraulics. Volts is the pressure the pump creates to flow the water; amperage compares to GPM of the water flowed. Alternating Current (AC) is like our house outlets; Direct Current (DC) is battery power. Voltage is the pressure or amplitude of the energy of the electricity. Watts is the amount of energy consumed by the tool. You can calculate the amount of watts by multiplying amps and volts.

All appliances have a specific amount of amperage required to make them work efficiently. The operator can influence the amount of amps or load that the tool draws. For example, if you push your reciprocating saw until it bogs down and stalls in the cut, the amps will increase, probably causing a circuit breaker or similar protection device to trip or shut the tool off.

Generation of Power

Generally, we get our electric power from an outlet supplied by the electric company. This serves us well at home, but in the field we need to make and distribute electricity by our own means. Portable generators are the "life blood" in the US&R environment, with the Honda 5000w and 6500w being the generators of choice. These Honda generators produce 110 and 220 volts and approximately 41 to 54 amps, respectively. The electrical system is protected by circuit breakers, and you are protected by Ground Fault Interrupters (GFI).

Generator Issues

- 1. Operating with a gasoline motor can cause problems in itself. Honda generators use regular unleaded gas with a recommended minimum octane rating of 86. They also have an oil sensor that will shut down the motor or refuse to let it start if it senses that the oil is low. This sensor is good for the motor, but can cause undue problems if its operation is overlooked. The oil does not have to be very low for this sensor to operate.
- 2. Anytime you are going to transport the generator, be sure to shut off the fuel valve. If left on, gasoline may get into the crankcase and dilute the oil. If the generator is going to be stored for more than two months, drain the fuel from the carburetor float bowl, drain the fuel from the sediment cup, and add fuel stabilizer to the fuel left in the tank.
- 3. Electrical production is accomplished when the motor turns a set of windings. In a 110/220v generator, there are two of them. Each one of these windings is rated at half the total load of the generator. In 120v mode, each winding supplies certain portions of available outlets. In the 120/220v mode, they supply the 120v outlets and they are combined at the 220v outlet to supply its needs.

It is important to understand this theory and look at the wiring arrangement for your model. Some of the Honda EB models have two duplex outlets, each one fed from a different winding. This is important to know when plugging in tools and equipment because you have the opportunity to spread the load out between the windings.

4. Instead of overloading one winding with the draw of two big tools, you can opt to split that load between the two windings and allow the generator to operate better with less chance of breakdown.



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- 5. All generators have two output ratings. Their labels usually reflect the Max output (marketing value). The rated output is what we should follow; it is the amount of power the generator can produce over an extended period of time without damage. The Max rating is for peak periods of short duration like tool startup.
- 6. Circuit breakers protect the generator and specific outlets from overload. Honda EB model generators generally have a main breaker to protect the windings from accumulative overload and outlet specific breakers to protect each circuit individually. They also have a GFI circuit protector that is designed to protect humans from shock. The GFI compares the amount of electricity sent out on the hot wire to the amount received back on the neutral wire; if there is a 5mv difference, it will trip and stop the electric flow. This should be quick enough to stop personnel from electrocution, but it is also enough to cause muscle reflex that could be dangerous.
- 7. Most generators have an "auto idle" switch. When turned on, this mode allows the generator to go to idle speed when it senses that there is no electric draw from any of its outlets. This idle mode saves fuel and generator wear and tear. When electricity is requested (by turning on a light or pulling the trigger on a tool), the generator will come up to full speed and supply the requested energy.

Power Transmission

- 1. Once the generator is running, it is our job to get the power to the tool. This is accomplished with extension cords and splitter boxes. All cords are size-rated to electrical standards, the smaller the number the bigger the wire. This wire size is something we need to be cognizant of because it determines the ability of our tools to operate. Electric wire has resistance that relates directly to wire size (similar to friction loss in fire hose). It is important to keep our wire length as short as possible and our wire size as big as possible. All this relates directly to the power needs of our end user, the tool. If we are only powering a 500-watt light, then 100' of 12 gauge cord will work fine, but if the end user is a 60-lb electric breaker that draws 2,000 watts at startup and 1,600 to 1,700 watts during operation, then a 10 gauge cord as short as possible is a must. The matching of cord or wire size to the tool is important to keep the tool operating correctly and to keep it and the wire from overheating and melting.
- 2. The standard cache rescue section lists 10/3 and 12/3 wire with 20 amp twist lock connectors in 50- and 100-foot lengths. It is important to note that the twist lock connector on a Honda EB generator is a 30-amp twist lock. A 20-amp twist lock looks like it will fit and if pushed hard enough it will come close but it will not twist or lock in place; this is not a safe operation. We must be sure to match 20-amp male to 20-amp female plugs.
- 3. Having to push connectors or bend outlet prongs to make them fit should not happen. All the tools in the standard cache have regular house plugs, so it is important for the rescuer to get all the needed adapters from the cache before leaving the BoO and heading to a job site. The need for male and female house to male and female 20-amp twist lock along with splitter boxes cannot be overlooked.



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Electric Tools

- 1. Electric tools require a predetermined amount of electricity to operate correctly. Supply less voltage or amperage because of wire mismatch, resistance, or length and the tool will not be able to do its job. Most tools used by the rescue team have an electric motor somewhere inside the housing. Electric motors require a much greater amount of electricity (amperage and voltage) to start than to run. This can be seen when you start a tool and the lights dim or the motor on a generator bogs down to accommodate the required draw. Once the tool is up to speed, its electrical requirements generally fall to those listed on its housing. This initial startup draw can cause circuit breakers to blow if the circuit is near its rated capacity. It can also cause a GFI to operate or trip because of voltage leakage in the tool.
- 2. All tools have an operating envelope that meets their design criteria. Trying to make a tool work faster by forcing it into a cut, pushing it harder into concrete or steel, and overloading its blade will only cause it to heat up internally and in the long run fail. If we overdrive and force it to work outside its normal operating range, it will work slower, heat up, and in the end stop working. This would leave the whole rescue team and its entombed victims with one hammer drill to get the job done. Working a tool with the right amount of force can be learned only during training. It is important to understand this theory and work to find the correct operating forces for all the tools in the cache.
- 3. Generator auto idle was discussed in the generator section, but needs a quick review here. The auto idle mode is good when there is a lot of stand-around time or very little tool use, but when tools are constantly being cycled on and off and the generator is running up and down, it can cause undue tool damage. This damage is caused when the trigger is pulled and the tool motor starts to turn. Since the generator is idling, it is producing very low voltage and amperage and the tool is requesting normal voltage and high amperage to get the motor turning. This delay can cause heat to build up in the tool. Anytime you are using the auto idle you should let the tool and the generator come up to full speed before putting the tool to work. If there will be a lot of on/off cycles, it is best to turn off the auto idle and allow the generator to run at full speed all the time.

Operating Principles—Cutting Torches

Description of Process

- Oxy-fuel cutting is a process whereby a metal is heated to its kindling temperature (temperature below the melting point) by an oxy-fuel gas flame and then burned rapidly by a regulated jet of pure oxygen. Cutting torches, whether handheld or machine operated, are used for this operation.
- The cutting process is a chemical reaction between iron and oxygen. When iron is heated to a temperature in excess of 1,600°F. (870°C.) and then exposed to a stream of high-purity oxygen, the iron oxidizes rapidly and produces a mixture of molten oxides and iron called slag. When cutting, a narrow slot called the kerf is formed as a result of the loss of metal by the cutting oxygen jet.
- The oxy-fuel cutting process is generally used on materials ranging from 1/32" to a thickness in excess of 100". The majority of oxy-fuel cutting is done on materials ranging from ¹/₄" to 2" in thickness.





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Equipment and Supplies

- In order to perform oxy-fuel flame cutting, the following equipment is required as a minimum:
 - Oxygen
 - Fuel gas (acetylene, propane, or Mapp gas)
 - Pressure regulators
 - Hoses and fittings
 - Torch
 - Cutting tips
 - Tip cleaners
 - Strikers
 - Protective clothing and safety equipment meeting ANSI-Z49.1

Oxygen

- Oxygen of high purity (99.5 percent minimum) is required to perform the operation of oxy-fuel flame cutting. This can be supplied in a variety of high-pressure cylinders or in bulk liquid tanks. CAUTION: Oxygen supports combustion! Improper use can result in fires or explosions. Never use oxygen in pneumatic tools, to clean equipment or parts, or to blow dust off clothing.
- Oxygen Safety Precautions
 - Do not permit smoking or open flames in area where oxygen is stored, handled, or used.
 - Liquid oxygen at -297°F. can cause freeze burns to the eyes and skin if it comes in contact with them.
 - Keep materials such as oil, grease, wood, kerosene, cloth, tar, and coal dust away from contact with oxygen.
 - Do not place liquid oxygen equipment on asphalt or surfaces with grease or oil deposits.
 - Remove all clothing that has been saturated with oxygen gas. Such clothing is highly flammable and should not be worn for at least 30 minutes.

Fuel Gas

- Many different fuel gases are available for oxy-fuel cutting. They include acetylene, propane, methylacetylen-propadiene (Mapp), natural gas, propylene, hydrogen, and several propane or propylene base mixtures. Each of these fuel gases will produce different flame characteristics.
- Acetylene cylinders contain porous filler that is used to absorb acetone. The acetylene in these cylinders is then dissolved into the acetone. This is done to prevent acetylene from being drawn faster than the acetone will release it. The maximum safe rate for being withdrawn from the cylinder is 1/7th of the cylinder's capacity per hour. If this rate is exceeded, acetone will be drawn from the cylinder producing a flame with a purple color.
- Acetylene Safety Precautions
 - Acetylene is not to be used at pressures above 15 psig in free form.
 - Concentrations of acetylene between 1 percent and 99 percent by volume in air are easily ignited and may result in an explosion.

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- STATE FIRE
- Keep cylinders away from overhead welding or cutting. Hot slag may fall on a cylinder and melt the fusible plug.
- Fusible plugs on acetylene cylinders will melt at 212°F.
- Acetylene forms readily explosive compounds with copper, silver, and mercury. Acetylene must be kept away from these metals, their salts, compounds, and high-concentration alloys.
- Adequate ventilation is required. Acetylene gas produces a strong garlic odor. Acetylene may displace air in a poorly ventilated area; atmosphere that does not contain at least 18 percent oxygen may cause dizziness, unconsciousness, or even death.
- Leave the hand wheel, wrench, or key on the cylinder for emergency shutoff.
- Always store acetylene cylinders in an upright position. If the cylinder had been laid down on its side, put it in the upright position for at least three hours before using.

Pressure Regulators

- Regulators are pressure-controlling devices that reduce high pressures to a desired working pressure. A pressure-adjusting screw adjusts these regulators. Regulators may be single- or two-stage.
- Regulator Safety Precautions
 - Keep contaminates such as oil, grease, dust, and dirt away from all inlet and outlet connections on regulators.
 - Never use oil on any threads or fittings on any regulator.
 - Before attaching an oxygen regulator to a valve, check to make sure that the regulator meets the pressure requirements of the supply.
 - All regulators should have the pressure-adjusting screw backed out before opening the cylinder or station valve.
 - Never use acetylene above 15 psig.
 - Never stand in front of a regulator when the cylinder valve is being turned on.

Hoses and Fittings

- Oxygen hoses in the United States are always color-coded green. The fittings have right-hand threads and a smooth outside surface.
- The fuel gas hoses are always color-coded red. The fittings have left-hand threads and a notch on the outside.
- These fittings are designed to form a gas-tight seal with the application of very little mechanical pressure.
- The use of undersized or excessively long hoses can cause pressure drops that can result in a low flow rate. Insufficient flow rates can cause overheating of torches and backfires.
- Hose and Fittings Safety Precautions
 - A fuel gas hose should never be used to transfer oxygen or vice versa.
 - Hoses should be checked for kinks, cuts, burns, and other signs of damage before use.
 - Tape or other temporary repairs should never be used to repair leaks; this could lead to fires and serious injury to personnel.
 - Use only approved leak-detecting solutions and equipment when checking connections.

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Torches

- There are basically three different types of cutting torches. However, these torches come in many different styles and shapes.
 - Hand torch: A torch equipped with a one-piece body with valves to control the flow of preheated oxygen and fuel gas, a spring-loaded valve for the cutting oxygen, and tubes carrying the gases to the head that accepts the cutting tip
 - Combination hand torch: A welding torch equipped with valves to control the flow of oxygen and fuel gas to which cutting, welding, or heating attachments may be attached
 - Machine torch: A torch equipped with valves controlling oxygen, fuel gas, and cutting oxygen, with tubes encased in a body with a head to accept the cutting tip
- Torches are classified as being either a positive pressure or an injector-type (low pressure). In the positive pressure torch, both the oxygen and the fuel gas are supplied at pressures high enough to sustain sufficient flow of both gases. In the injector-type torch, the fuel gas is supplied at a low pressure, relying on the high pressure of the oxygen to pull the fuel gas to obtain the correct flow of gases.
- Torch Safety Precautions
 - A fire extinguisher should always be at hand when flame cutting for use if an emergency arises.
 - Always extinguish a torch whenever it is not in your hand.
 - If a torch backfires, shut it down, find the trouble, and remedy it before continuing to use the torch.
 - Be careful that a torch is not being directed at another person when lighting.
 - Be sure that the area where the cutting/welding is to be performed is clear of any hazardous or flammable materials.



Figure 4:15



Advanced Rescue Skills

Topic 4.2: Tool Applications and Assessment



Cutting Tips

- All oxygen-cutting tips have preheat flame ports (orifices) that are commonly arranged in a circle around the cutting oxygen port. The size of these ports will determine the thickness of the materials to be cut as well as the amount of gas supplied.
- Tips for use with acetylene are usually one piece in design and flat on the flame end. Tips for use with Mapp and propane gas are usually two pieces in design with milled spines.
- Of all the items needed to perform the oxy-fuel cutting process, besides oxygen itself, the cutting tip has the greatest effect on the quality of the cut.
- During cutting procedures slag will form around the preheat and oxygen cutting ports. This will disrupt the preheat flame as well as the oxygen cutting jet, resulting in poor performance and quality cut. When this occurs, the tip should be removed and cleaned.

Tip Cleaners

- Cleaning is done by means of tools called tip cleaners. There are different types of tip cleaners available to clean the surfaces of oxy-fuel cutting tips.
 - Tip drills and wire broaches (normally called tip cleaners) are designed to clean the ports of the cutting tip.
 - Refacing tools are designed to keep the face of the tip flat, providing preheat flames of the same length.

Strikers

When lighting your cutting torch, it is important to use an approved spark lighting device. The use of lighters and matches can lead to personnel injury as well as injury to others around you.

Protective Equipment

- Appropriate protective clothing and equipment is required at all times when using oxy-fuel cutting equipment. As cutting operations vary so will the required protective clothing and equipment; size and the location of cutting will determine this. Some or all of the following may be required:
 - No. 4 or 5 lens tinted goggles or face shields
 - Welding cap or hard hat
 - Safety glasses
 - Leather gloves suited for oxy-fuel cutting
 - Flame-resistant clothing
 - Appropriate respirator for type of fumes that will be produced

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Topic 4.2: Tool Applications and Assessment



Start-Up and Shutdown Procedures

- Secure the cylinders to cart or a substantial support.
- Attach regulators to the valves; ensure valves are free from oil, dust, and obstructions. Tighten inlet connection nuts firmly with a close-fitting wrench.
- Inspect the hoses for cuts, burns, and kinks. Have them repaired or replaced, if damaged.
- Connect hoses to proper regulators (green oxygen, red fuel gas).
- Attach hoses to the correct torch inlet.
- Before opening either of the cylinder valves, check to make sure that the regulator adjusting screw is backed out, so no pressure is being exerted on the adjusting screw. This is done to protect the regulator parts from damage due to high-pressure surges.
- Open the oxygen cylinder valve very slowly to allow pressure to increase slowly into the regulator. Warning: Do not stand in front of or behind the regulator when opening the valve. After the pressure in the regulator has equalized, open the oxygen cylinder valve completely so the valve will seal. Oxygen cylinder valves are designed to seal when fully opened and fully closed.
- Fuel cylinders equipped with a hand wheel should be opened no more than 1½ turns. Acetylene cylinders equipped with a valve that requires a key or wrench should be opened no more than ¾ turn. Fuel gas valves on cylinders should never be opened completely. This is done to allow the valves to be turned off quickly in case of an emergency.
- With the torch and tip directed in a safe direction, open the oxygen valve located on the torch body. Turn the adjusting screw on the oxygen regulator and adjust to the recommended pressure for the tip being used. Allow the oxygen to flow for at least five seconds for every 50' of hose. Close the inlet oxygen valve on torch body.
- Next, open the fuel gas valve on the torch body. Turn the adjusting screw on the fuel gas regulator and adjust until recommended pressure is obtained. Allow the fuel gas to flow for at least five seconds for every 50' of hose. Close the fuel gas inlet valve on the torch body.
- The recommended procedure for lighting acetylene is to open the fuel gas valve on the torch body slightly (usually 1/8 to 1/4 turn) and light with a striker. Adjust the fuel gas valve until the acetylene produces a semi-smokeless flame. Open the oxygen valve slightly to produce a neutral flame.
- To extinguish the flame, turn off the fuel gas valve first, then the oxygen valve. This is done to prevent the flame from burning back into the torch body and producing a flashback.
- After the flame has been extinguished, close both the fuel gas and oxygen valves on the cylinders.
- Open the torch fuel gas valve and bleed off the fuel gas from the regulator, hose, and torch. Back out the regulator adjusting screw and close the torch fuel gas valve.
- Open the torch oxygen valve and bleed off the oxygen from the regulator, hose, and torch. Back off the regulator adjusting screw and close the torch oxygen valve.



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Topic 4.2: Tool Applications and Assessment



Flame Adjustment

■ The flame adjustment is a critical factor in attaining satisfactory torch operation. The amount of heat produced by the flame depends on the type of fuel gas, intensity of flame, and the type of flame used.





Advanced Rescue Skills





Advanced Rescue Skills

Topic 4-3: Metal Burning Operations



Topic 4-3: Metal Burning Operations

Terminal Objectives

- The student will understand the technology, capabilities, and characteristics of each different metal burning system.
- The student will be able to recognize different types of metals and their characteristics.
- The student will be able to determine which metal burning system is best suited for a particular job or assignment.

Enabling Objectives

- Discuss and understand the functions that need to be performed by the burning teams.
- Understand the advantages and disadvantages of the various types of metal burning equipment.
- Understand the different and most expedient methods to be used with each cutting or burning system to safely accomplish the assigned task.

Safety

- Cutting and burning operations require strict compliance to safety guidelines.
- The two biggest 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 and 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 be on the lookout for potential hazards and make sure the burner is aware of them.
- Always pay strict attention to what you are burning through or into. Flammable or explosive material may be on the other side.
- Always inspect cutting and burning equipment for leaks and proper setup before use.
- Rehydrate often. Because of the heavy protective clothing and the heat generated from the equipment and hot material, burning operations can be very hot work.
- Pressurized or hand pump water extinguisher will be on site at all times.
- Use Proper PPE



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Topic 4-3: Metal Burning Operations



- Tinted eye protection
- Respirator
- Helmet
- Gloves
- Long sleeves
- Leather or heavy fire-resistive jacket and chaps, if needed
- Accessory Equipment
 - Crescent wrench
 - Marking paint
 - Tip cleaners
 - Side cutter pliers
 - Water extinguisher
 - Exhaust and ventilation equipment, if needed
- CAUTION! Using Chlorinated Solvents
 - 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! When using metals that have been painted or plated, remember the following:
 - Always inspect metal for protective surfaces finishes such as paint or plating before welding or 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 below will require proper respiratory protection:
 - Antimony
 - Arsenic
 - Barium
 - Beryllium
 - Cadmium
 - Chromium
 - Cobalt
 - Copper
 - Lead
 - Manganese
 - Mercury
 - Nickel



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Topic 4-3: Metal Burning Operations



- Ozone
- Selenium
- Silver
- Vanadium
- Internet safety articles
 - www.cdc.gov/niosh/elcosh/docs/d0300371/dooo371.html
 - www.cdc.gov/niosh/elchos/docs/d0100/d000026/d000026/html
 - <u>www.cdc.gov/niosh/elcosh/docs/d0100/d000100/sec10.html</u>
 - <u>http://msds.pdc.cornell.edu/msds/msdsdod/al151/m75300.htm</u>
 - <u>www.osha-slc.gov/outreachtraining/htmlfiles/weldhlth.html</u>
 - <u>www.msha.gov/S&HINFO/HHICM10.HTM</u>
 - <u>www.ccohs.ca/oshanswers/safety_haz/welding/fumes.html</u>
 - <u>http://www.esab.com/eu/literature/F15-660_English_Safety_Instructions.pdf</u>

Estimating the Weight of Steel

- Burning operations are often 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 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 a very simple way to calculate the weight per foot of any steel cross section when one realizes that a one square inch bar of steel that is one foot long weighs 3.4 lbs.

Therefore the **General Rule** to remember is: **Steel weighs 3.4 lbs per square inch, per foot of length.** (A 1" x 1" square steel bar, 12" long weighs 3.4 lbs.)

Example 1:

The weight of a 1" thick x 12" steel plate is ? 1" x 12" x 3.4 lbs per sq in per ft of length = 12 sq in x 3.4 = **40.8 lbs per ft** (same as 12 1" sq bars x 1' long)



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Example 2:

What does a 1 1/2" diameter X 20 ft long round steel bar or steel cable weigh? **Answer 2:** 1 1/2" x 1 1/2" x .78 (for round shape) x 20' x 3.4 = 1.77 sq in x 20' x 3.4 = 120 lbs

Example 3:

What is per ft weight of a fabricated, square steel tube column that is made from a pair of 36" x 2" plates and a pair of 12" x 2" plates?

Answer 3: $(2 \times 36" \times 2" + 2 \times 12" \times 2") \times 3.4 =$ (144 sq in + 48 sq in) x 3.4 = 192 sq in x 3.4 = 653 lbs per ft (plf)

If this column was 36 ft long, it would weigh 653 plf x 36 ft = 23,500 lbs = 12 tons

Types of Burning Equipment

There are many different types and brands of equipment used for metal burning. Each one has its strengths and weaknesses and is best suited for a particular task and location. They are as follows:

- Oxygen/Acetylene
- Gasoline/Oxygen
- Exothermic
- Plasma Arc

Oxy/Acetylene

Oxy/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.

Benefits

- A wide range of torches, accessories, and gases is available from most welding and gas suppliers.
- It is the industry standard used by most fabrication shops and at most construction or demolition sites.

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 guidelines 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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Topic 4-3: Metal Burning Operations



Gasoline/Oxygen

This technology has been around for many years, but was not perfected until oxy/acetylene had cornered the industry market.

It is similar to oxy/acetylene in many ways, except that welding cannot be done with this technology—**only burning of carbon steel.**

Benefits

- Compared to oxy/acetylene, gasoline/oxygen technology burns much cleaner and more completely with almost no slag.
- Gasoline is readily available almost anywhere and has a much narrower flammable limit than acetylene, which makes it much safer.
- When steel thickness exceeds 2", this process is much faster, more efficient, and economical.
- Gasoline vapor is four times heavier than acetylene vapor and the burning process carries through the steel much better.
 - Even though acetylene burns at a higher temperature, it does not give up its BTUs as fast as gasoline.
 - Because of this, there are some types of cuts that can be made with the gasoline/oxygen process that cannot be done with acetylene.
- With a special torch tip collet this system can also be used under water.

Disadvantage

• Equipment is not readily available from welding suppliers.

Exothermic

The exothermic technology came to us from the US Navy. They designed this equipment for burning through bulkheads in submarines.

- This technology uses oxygen pushed through consumable alloy rods, which burn at 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).

Benefits

- 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



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Topic 4-3: Metal Burning Operations



Disadvantages

- The main disadvantage is Fire!
- This system throws large amounts of molten material.
- The operator must be wearing full protective clothing 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 batteries should not replaced with lead acid automotive batteries because the latter may give off hydrogen gas and can explode.

Plasma Arc

This technology uses an electric arc in conjunction with compressed air. It works very well, but is best suited for fabrication work.

Benefits

- Plasma systems do an excellent job and can burn through both ferrous and nonferrous metals including stainless steel.
- They make very clean burns with almost no slag and very light sparks.

Disadvantages

- Only small units that are limited to burning light-gauge metals are portable.
- The larger systems that can burn thicker material are very large and heavy and require at least 220 volts to operate.

Common Fuel Gases

The following types of gases are used in industry:

- Acetylene
- Propane
- Mapp gas

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 a gaseous state above 15 psig.
- 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.

POROUS FILLER 8% to 10% The filler, which completely occupies the steel shell, is 90% to 92% 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 150° F.

Figure 4:16



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Topic 4-3: Metal Burning Operations



- 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.

Example 1: An acetylene cylinder with a total volume of 300 cubic ft may be withdrawn only at a rate of about 42 cubic ft per hour to not withdraw the acetone.

Example 2: Very small cylinders (such as 10 cubic ft, which we have in our US&R cache) may be withdrawn only at a maximum rate of 1.42 cubic ft per hour.

■ When not in use or while being transported in a vehicle, acetylene cylinders must be capped and secured.

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 where pure oxygen may be present.
- Oil and grease can ignite and burn violently in the presence of pure oxygen.

Liquid Oxygen Tanks (Dewars)

- Dewars are large cryogenic tanks. Many times at 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.
 - One K-Style compressed gas cylinder holds 249 cubic feet of product.
 - So, one GP45 is equivalent to about 18 K-Style cylinders. A manifold can be attached to the Dewar that will supply oxygen to many torch sets.
 - This can save a lot of time and energy that would be wasted moving and changing out compressed gas cylinders.
- Dewars must be secured and handled with caution; they are heavy and if knocked over can be damaged.

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.







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Topic 4-3: Metal Burning Operations



- 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 regulator. This 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.
- Regulators
 - The purpose of the regulator is to reduce the high pressure within the cylinder to a usable working pressure.
 - Before attaching regulator to cylinder, inspect 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 counterclockwise until it turns freely. This places the valve seat of the regulator in a closed position.



Figure 4:18 Oxy/Acetylene

- When opening the tank cylinder valve, always stand to the side of the regulator and gauges to avoid injury.
- If a gauge or other component of the regulator should malfunction or fail, it 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.
- Do the same procedure with the **Fuel Gas Cylinder Valve**, but open the cylinder valve only 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 case of fire or other problems with the system.



Figure 4:19 Regulator



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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.
- Check Valves: They 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 torch.
- 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.

Torches

- Torches come in a variety of brands, models, and sizes, including 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 awkward and heavy, causing additional fatigue to the operator.
- Short torches are lighter and more maneuverable, especially in confined spaces.



Figure 4:20

- Remember, it is not the size of the torch that determines the thickness of the steel that can be burned; it is the size of the tip.
- Some newer-style torches have antireverse flow check valves built into the main torch body, so 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 you are using an older-style torch or a brand not having one-way check valves, you should install them.



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Topic 4-3: Metal Burning Operations



- **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.
 - Use a tip chart to select. ٠
 - Remember, you can withdraw only 1/7th of the • total volume of an acetylene cylinder per hour.
 - If you are using a small acetylene cylinder, the size ٠ of the tank will dictate or limit the cutting tip size that can be used.

Cutting Tip Cutting tips are available in a wide variety of configu keep the preheat gas mixture and cutting oxygen stream characterstics needed for a particular cutting application the thickness of metal they can cut. For instance, a num metal 1/16⁺ to 1/8⁺ in thickness, and a number 00 tip y thickness. Charts are available to assist operator with tip



Figure 4:21

Metal Thickness	Tip Size	Cutting Oxygen		Pre-heat	Acetylene		Snood	Vart
		Pressure*** PSIG	Flow *** SCFH	Oxygen* PSIG	Pressure PSIG	Flow SCFH	IPM	Width
1/8"	000	20-25	20-25	3-5	3-5	6-11	20-30	.04
1/4"	00	20-25	30-35	3-5	3-5	6-11	20-28	.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	9-16	16-22	.06
3/4"	1	30-35	80-85	4-7	3-5	8-13	15-20	.07
1"	2	35-40	140-160	4-8	3-6	10-18	13-18	.09
2"	3	40-45	210-240	5-10	4-8	14-24	10-12	11
3"	4	40-50	280-320	5-10	5-11	18-28	10-12	.12
4"	5	45-55	390-450	6-12	6-13	22-30	6-9	.15
6"	6**	45-55	500-600	6-15	8-14	25-35	4-7	.15
10"	7**	45-55	700-850	6-20	10-15	25-35	3-5	.34
12"	8**	45-55	900-1050	7-25	10-15	25-35	3-4	.41

TYPES 1-101, 3-1-1 & 5-101 (Oxy-Acetylene)

*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.

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.

Figure 4:22



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Topic 4-3: Metal Burning Operations



- Brass Fittings and Attachments
 - All gas-welding components use brass compression-type fittings.
 - When assembling welding components, remember to not overtighten 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 and heating attachment, multiflame, or Rosebud). If damaged O-Rings are found, do not use the torch until they are replaced.
 - When mating attachments to the main torch body, tighten them only hand tight. Overtightening with a wrench will only damage the O-rings and cause them to fail.
- Cylinder Safety
 - Compressed gas cylinders must be secured at all times. Always cap cylinders when not in use or while being transported to protect the discharge valve from being sheared off or damaged.
 - 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. The types of pressure relief devices include fusible plugs, rupture disks, rupture disks with fusible metal backing, and spring-loaded relief valves.
 - Never totally drain all 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.



1. Cylinder Specification

- DOT-Department of Transportation, which is the regulatory body that governs the use of cylinders
- Specification of the cylinder type of material of construction (e.g., 3AA).
- Service or working pressure in pounds per square inch (e.g., 2,265 psi)
- 2. Cylinder Serial Number
- The letters SG precede the serial numbers for Specialty Gas cylinders.
- Registered Owner Symbol

 Symbol used to indicate the original owner of the cylinders.
 APROINC is a Registered Owner Symbol for Air Products.
- 4. Date of Manufacture • This date (month-year) also indicates the original hydrostatic test.

Figure 4:23

- 5. Neck Ring Identification
 - The cylinder neck ring displays the name of the current owner of the cylinder.
- 6. Retest Markings
 The format for a retest marking is:
 - The format for a retest marking is: Month–Facility–Year–Plus Rating–Star Stamp.
 The + symbol (Plus Rating) indicates that the
 - cylinder qualifies for 10% overfill. • The * symbol (Star Stamp) indicates that the
- cylinder meets the requirements for 10-year retest.
- 7. CytinderTrak[™] Bar Code Label
 The CylinderTrak bar code label provides a unique cylinder identifier and is used by computer systems to track cylinders throughout the fill process. As an optional service, we have the capability of tracking cylinders to and from customers.

8. Cylinder Manufacturer's Inspection Marking

- 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 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.

^{9.} Cylinder Tare (Empty) Weight



Advanced Rescue Skills

Topic 4-3: Metal Burning Operations



- 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.
- Welding Cart
 - 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 proper size to accommodate and contain cylinders safely.
 - There should also be a place to store safety goggles, spark lighter, tip cleaners, wrench, and extra torch attachments.

Important Rules to Remember

- Always use
 - Proper protective clothing
 - Gloves
 - Proper eye protection
 - Extinguisher
- In addition
 - Keep flame away from combustibles.
 - Always have good ventilation.
 - Use proper fuel gas and oxygen regulator settings.
 - Use proper size tips according to tip chart.
 - Have a safety person watch the area for fire or other hazards while torch is in use.
- Never
 - Use oil or other organic compounds around pure oxygen or oxidizers.
 - Use pure oxygen to blow off clothing.

Setup and Starting Torch for Cutting Operations

- 1. Start by checking all the components in the system. Give them a visual inspection to make sure they are in good working order. Make sure all brass fittings are snug and all valves on the torch are closed.
- 2. Next, open the main valve on the oxygen cylinder remembering to stand off to the side of the regulator. Open the valve slowly until it registers the full pressure in the cylinder. Once the pressure has stabilized, continue to open the valve until it is fully open, then turn it back toward the closed position about a half a turn so the brass valve is not jammed against the stop.
- 3. Slowly open the main valve on the acetylene cylinder while standing off to the side. Open the valve a maximum of one turn.



Advanced Rescue Skills

Topic 4-3: Metal Burning Operations



- 4. Next, set the desired pressure settings on the regulators corresponding with the recommendations on the tip flow chart. Turn the adjustment screw in until you reach the desired pressures, i.e., tip size 0 oxygen setting 35 psi/ acetylene setting 5 psi. Once pressures have been set, listen for any leaks in the hoses, torch fittings, or valves.
- 5. There are two oxygen adjustment valves on the cutting torch. One is on the main torch body and the other is on the cutting torch attachment. Turn the oxygen valve on the main torch body all the way open. Separately open and close both the acetylene valve and the oxygen valve on the cutting attachment for two to three seconds in order to purge the air out of the hoses and torch.





6. Then open the acetylene valve 1/8 turn until you can lightly hear gas coming out of the torch tip and ignite the gas with a spark lighter. Adjust the acetylene until you get a moderate flame and then open the oxygen valve on the cutting attachment until you reach a neutral flame. Let the flame stabilize five to six seconds and then depress and hold the oxygen lever on the cutting torch attachment while fine-tuning the oxygen adjustment valve again until you get a neutral flame. Then let up on the oxygen lever and torch is ready for use.



Advanced Rescue Skills

Topic 4-3: Metal Burning Operations



Recommended Procedure t Efficient Flame Cutting of Stee





Start to preheat tip at angle on edge

Rotate tip to upright position





Figure 4:25



Advanced Rescue Skills

Topic 4-3: Metal Burning Operations



Shutting Down Torch and Securing Until Next Use

- 1. Shut down torch by closing the acetylene fuel gas valve and then closing the oxygen valve. This may also be done in the reverse order.
- 2. Next, close the oxygen and acetylene fuel gas cylinder valves.
- 3. Then open the acetylene fuel gas valve at the torch and bleed off the gas from the regulator, hose, and torch. Watch to make sure that both gauges are completely zero at the regulator. Then do the same with the oxygen.
- **4. Important**: Back off the regulator diaphragm adjustment screw until it turns freely. Do not back it off too far or it will fall out and get lost during transport. Backing off the diaphragm adjustment screw does two things:
- 5. It takes the strain off the diaphragm and its spring.
- 6. It closes the regulator diaphragm so gas cannot pass through to the hose and torch in the event that someone accidentally opens the cylinder valve or it develops a leak during storage.
- 7. If the welding equipment is to be transported in a vehicle or stored for a long period of time, the regulators and hoses should be removed from the cylinders. The cylinder valves should be checked for leaks by spraying with a mild soapy water solution and then cylinders should be capped.

Gasoline/Oxygen Operation

- The gasoline/oxygen system operates somewhat differently than its oxy/acetylene cousin that most torch operators are accustomed to.
 - It uses all 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 operates.
- The 2.5-gallon ASTM certified gasoline 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 shut-off valve should be opened slowly when setting up the torch for operation so the fast-flow check valve will not engage and shut off the fuel.
- The tank pressure should normally be between 10 and 20 psig during normal operations when using the hand pump. Higher pressures may be employed when using the optional compressed air carry tank.



Advanced Rescue Skills

Topic 4-3: Metal Burning Operations



- Lighting the torch
 - First turn on the oxygen and the gasoline tank valves and set the proper and pressures.
 - Then open the preheat oxygen valve at the torch until a light flow is established.
 - Next, 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.
 - Then readjust and you are ready to burn.
- To shut down the torch
 - First shut off the gasoline, then the oxygen at the torch.
 - Then close the valves at the tanks and back off the oxygen regulator pressure adjustment.
- The tip sizes are a little different than oxy/acetylene tips. Refer to the gasoline/oxygen tip chart in the operator's manual.



Advanced Rescue Skills



Topic 5-1: Lifting and Moving

Topic 5-1: Lifting and Moving

Terminal Objectives

- The student will size up objects that have entrapped people and efficiently apply a variety of machines and power to safely move these objects to free trapped people or gain access for search and rescue.
- The student will understand the basic physics, material behavior, and mechanics necessary to accomplish the above.

Enabling Objectives

- Demonstrate an understanding of basic physics as it relates to weight, gravity, center of gravity, and friction and resistance force.
- Demonstrate the use of mechanical advantage to move heavy objects.
- Demonstrate the effective use of air bags.
- Demonstrate proper load stabilization techniques.
- Demonstrate the use of a wedge anchor and eye nut.
- Calculate the weights of common materials.
- Use proper safety protocols.

Introduction

A company officer on an engine was once asked why he ordered the engineer to drive the 30,000-pound fire apparatus on a road that had a bridge with a 10,000-pound load limit. The officer responded by saying that "it was an emergency." Rescue personnel often think that the physical laws of the universe do not apply when there is "an emergency." Gravity is one of the laws of the universe that applies to all earthly (rescue) environments. Rescuers deal with gravity every time they lift a patient, every time they move an object, and every time they lower themselves on a rope.

Rescuers need to understand the relationship of gravity to basic tactical evolutions such as lifting, lowering, moving, and stabilizing loads. Today, even with the availability of powerful cranes, strong hydraulic winches, and high-pressure air bags, there is a need for knowledge of the basic concepts of leverage and gravity. It is the ability of the rescuer to make effective size-ups in confined areas of collapsed buildings that often means the difference between life and death.

This training module for Rescue Systems 2 will look at gravity, friction, and mechanical advantage in relation to lifting, moving, and stabilizing heavy objects.

Advanced Rescue Skills





Topic 5-1: Lifting and Moving

Prime Rule of Lifting and Moving

One should only lift and move an object if there is no other viable alternative. Once in motion, it is more dangerous.

Universal Gravitation and Center of Gravity

Principle

- The Earth's gravity exerts a force on all objects on its surface called "weight."
 - Gravity can help us move and/or stabilize objects.
 - Gravity can be used as a movement engine.
 - There is no exception to gravity.
 - All objects seek a state of equilibrium.
 - Gravity affects such evolutions as:
 - Lifting
 - Lowering
 - Moving
 - Stabilizing

Center of Gravity and Position Changes

- Center of gravity is the:
 - Point at which the whole weight of an object is acting vertically downward
 - Balance point
- A load's weight is perfectly balanced or distributed around the center of gravity.
- If a load is suspended at its center of gravity, it can be turned in any direction with little effort.
- If a load is lifted to the right or left of its center of gravity, it will tilt at an angle.
- If a load is lifted below its center of gravity, the weight of the load will be above the lifting point and the load will tip over.
- The center of gravity of a solid object is located in three planes or directions:
 - X axis
 - Y axis
 - Z axis



Advanced Rescue Skills



Topic 5-1: Lifting and Moving

Example of Center of Gravity

A solid piece of concrete that is 10 ft long x 4 ft wide x 6 ft high has its center of gravity at a point that is 5 ft from the end, 2 ft from the front, and 3 ft from the bottom.



Weight

■ Force of the Earth's gravity on a mass sitting on its surface is called its "weight." The weight of the same mass on the moon would be 1/6 as much.

Equilibrium

Principle

• Every object resting on Earth is said to be "at rest" and in a state of static equilibrium. All objects seek a state of equilibrium.

Changing Equilibrium

- A small outside force or effort at the highest point on the object can change its condition from static to unstable equilibrium.
 - The wind or a gentle push can move the object out of this "balance point" of static equilibrium.
 - When force is applied to the object, it may change to a state of unstable equilibrium.
 - The object will move or fall over into another position of static equilibrium.

Friction and Resistance Force

Principle

- Friction and resistance force is found in the location of the contact between two surfaces.
- This force acts parallel to those surfaces in a direction opposing the relative motion between them.
- The greater the weight (force of gravity) of an object, the greater the friction force.



Advanced Rescue Skills

Topic 5-1: Lifting and Moving



Basic Concepts Related to Friction

- The smoother the two contact surfaces, the less the friction between those surfaces.
- Liquids can reduce the friction between two surfaces unless too much surface tension is developed.
- Materials with rounded surfaces that break the contact between objects will generally reduce friction.
- Reducing the size of the surface area between two objects may reduce the amount of friction present, especially if the contact surfaces are rough.
- Lifting operations often involve lifting only one side of the object, which reduces the weight on the contact surface and consequently decreases the friction force.

Friction and Equilibrium

- Friction may be the outside force acting on an object creating equilibrium.
- The rescuer can change the amount of friction holding an object in place and allow the force of gravity to overcome the forces of friction by:
 - A rocking motion
 - Making the contact surface area smaller (tilt or lift)
 - Reducing the weight on the contact surface
- Friction holding an object in place can be overcome by the force of gravity when an object is on an inclined plane.

Overview of Mechanical Advantage

- Mechanical advantage is the ratio between the output force a machine exerts and the input force that is furnished to that machine to do work.
- Mechanical advantage defines how efficient and effective a machine is.
- Mechanical advantage greater than one means that the output force delivered by the machine exceeds the input force supplied to the machine.
- Mechanical advantage less than one means that the output force delivered by the machine is smaller than the input force supplied to the machine.
- Mechanical advantage is applied to the relationship between the weight of a load being lifted and the power of the force required to lift, push, or hold that load.
- The efficiency of a machine is determined by calculating the theoretical mechanical advantage and subtracting friction. In pulley systems, the friction factor may be around 10 percent. That requires a 110 lb force to lift a 100 lb object.

The difference between theoretical and actual mechanical advantage is "friction."



Advanced Rescue Skills



Topic 5-1: Lifting and Moving

Simple Machines

- Simple machines are rigid or resistant bodies that have predefined motions.
- They are capable of performing work.
- Energy is applied to these mechanisms by a source that causes these mechanisms to perform useful motion.
- It is more efficient to perform work with machines than with muscle force only.
- Simple machines that can give us mechanical advantage are:
 - Inclined planes
 - Levers
 - Pulleys

Inclined Planes

- Gain effectiveness of energy used based on distance traveled—mechanical advantage
- Use a gradual slope—less force needed to move an object a certain distance
- Percentage of load based on slope and grade:
 - When an object comes to rest on a slope, the rescuer must determine the percentage of the load's weight that needs to be managed during the stabilization process.
 - To estimate the load percentage, first determine the amount of resistance the load surface has in relation to the object.
 - In discounting friction, refer to the table on the following page for approximate weight based on slope.

Slope/Grade	% of Load's Weight
45 degrees	71%
30 degrees	50%
20 degrees	34%
10 degrees	17%

- However, the friction force associated with sliding objects up ramps may be as high as 35%:
 - The force that is required to move the object up the ramp may be greater, as shown above.
 - Friction may be used as a brake to keep the object from sliding back down the ramp when the slope is less than about 20°.

Levers

"Give me a place to stand and I will move the world." ~Archimedes

- Application of levers
 - Moving a load that is heavier than can be moved by manpower alone
 - Pulling and hauling
 - Raising



Advanced Rescue Skills

Topic 5-1: Lifting and Moving



- Leverage—the means of accomplishing work with levers
 - Transfers force from one place to another
 - Changes the force's direction

Pulleys

- Application related to loads
 - Lifting
 - Pulling
 - Moving
 - Changing direction
 - Achieving mechanical advantage
 - Reducing friction

Compound Machines

- Combination of two or more simple machines
- Compound machines that can give us mechanical advantage
 - Screw-type machines
 - Jacks
 - Come-alongs

Screw-Type Machines

These machines are a combination of a lever and an inclined plane.

Air Bags

- There are several different manufacturers of air bags and many different terms used to refer to them. Other terms that may be found:
 - High-pressure air bags
 - High-pressure lifting bags
 - High-pressure rescue bags
 - High-pressure heavy lifting bags
 - Lifting bags
 - Air lifting bags
 - Low-pressure air bags
 - Low-pressure heavy lifting bags
 - High-lift air bags
 - Low-pressure cushions
 - Rescue air cushions



Advanced Rescue Skills



Topic 5-1: Lifting and Moving

This course will use the terms high-pressure air bags and low-pressure air bags in keeping with the ICS-US&R-120-1 equipment description.

High-Pressure Air Bags

- Characteristics
 - Neoprene/butyl rubber reinforced with six layers of Kevlar
 - Variety of sizes
 - Outer layer textured to reduce slippage
 - Capacity calculated at 1" of lift
 - At maximum height, usable capacity typically reduced to 50 percent of the rated capacity
- Precautions
 - Regulator can be damaged from shock and opening high-pressure air source too fast.
 - Hoses are susceptible to heat, sharp objects or edges, chemicals, and dirt particles.
 - Controller can be damaged from shock and dirt particles.
 - Relief valves can be damaged from shock and dirt particles.
 - Air bags are susceptible to damage from heat, sharp objects, and chemicals and air inlet damage from dropping on end.
- Application
 - Stacking bags
 - Maximum stacking is two high (bag centers must align).
 - Lifting capacity is that of the smaller bag.
 - Lift height is increased.
 - Ensure that the smallest bag has the capacity for the lift.
 - Place the large bag on the bottom.
 - Bags in tandem
 - Use bags side-by-side or at two points under a load.
 - Maximum working capacity is each bag added together.
 - Consider lift height as well as load weight.
- Working area
 - Ensure surface area is flat.
 - Put solid layer of cribbing under bag.
 - Establish safe zones.
 - Pressurize bags slowly and watch for load shift.
 - If load is uncontrolled, stop the lift and reevaluate.
 - Use cribbing or wedges under the load to stabilize.
 - See manufacturer's manual for additional information.



Advanced Rescue Skills

Topic 5-1: Lifting and Moving



- Calculating lifting capabilities
 - Calculate surface area contact (smaller than bag dimensions).
 - Determine maximum working pressure of bag.
 - Maximum working capacity is the maximum surface contact area of the bag (always smaller than bag dimensions) times the maximum working pressure.
 - As the air bag lifts and "pillows," surface contact is reduced and the lift capacity is decreased.



Example

- A 10" x 10" air bag is 100 sq in of total area. The maximum working pressure is 118 psi, and 100 sq in times 118 psi equals 11,800 lbs of lift (5.9 tons) if full bag area is in surface contact. However, identification tag lists actual lifting capacity at 4.8 tons.
- Check bag for identification tag that lists maximum pressure, load, and lift height data.

HIGH PRESSURE AIR BAGS I.D. Tag is right on Bag



Figure 5:5



Advanced Rescue Skills

Topic 5-1: Lifting and Moving



Low-Pressure Air Bags

- Characteristics
 - 3-ply Neoprene/coated belt—working surface
 - Heavy coated Neoprene nylon fabrc—side wall
 - Variety of sizes
 - Capacity calculated at maximum lifting height
- Precautions
 - Regulator can be damaged from shock and opening high-pressure air source too fast.
 - Hoses are susceptible to damage from heat, sharp objects or edges, chemicals, and dirt particles.
 - Controller can be damaged from shock and dirt particles.
 - Air bags are susceptible to damage from heat, sharp objects, and chemicals and air inlet damage from dropping on end.
- Application
 - Do not stack air bags.
 - Ensure the side walls are folded inward and that the upper working surface is "square" with the lower by reference to the web loops placed at quadrant positions.
 - There is no stability at lower heights.
- Working area
 - They may be used on soft or uneven surfaces.
 - Establish safe zones.
 - Pressurize bag slowly and watch for load shift.
 - If load is uncontrolled, stop the lift and reevaluate.
 - Use cribbing or wedges under the load to stabilize.
 - See manufacturer's manual for additional information.

Mechanics of Load Stabilization and Movement

- Functions that need to be addressed before any load is stabilized, lifted, or moved
 - Center of gravity, lifting, hinge, and cribbing points
 - Load stabilization including
 - Shims
 - Wedges
 - Cribbing
 - Estimating load weight



Advanced Rescue Skills



Topic 5-1: Lifting and Moving

Center of Gravity, Lifting, Hinge, and Cribbing Points

- Center of gravity
 - The load's lifting points and hinge points will be on opposite sides of the center of gravity.
 - Loads will seek to have their center of gravity below the point of support.
 - A narrow base of support can rapidly become a fulcrum (pivot point) for the load.
 - The higher the center of gravity is located in the load, the wider and more stable the base of support needed to maintain static equilibrium.
 - A load with a relatively high estimated center of gravity and narrow base of support must be considered to be in a state of unstable equilibrium. The force of the load's own weight (or external force) can cause the load to move into a state of equilibrium (i.e., fall over).
- Lifting points
 - Where fulcrums can be built and lifting crews are positioned to safely perform their job
 - Where air bags are placed to safely lift an object
- Hinge points
 - Point or points at which the object will hinge opposite the lifting force
 - Often indicate the direction the load may shift
- Cribbing points
 - Points at which the crib beds will be built to support the load
 - Points at which the crib beds will be built to support air bags used to lift the load
 - Points at which the crib beds will be built to provide stable hinge points
 - Must not block access/egress to the victim

Load Stabilization

- Widen and extend the load's base of support when:
 - The distance from the base of support to the estimated center of gravity is greater than the width of base of the support. Loads showing any signs of rocking or swaying are in a state of unstable equilibrium. Consider that the center of gravity may change.
 - The base of support shifts.
 - Wind or shaking from an earthquake (external force) can move a load with a high estimated center of gravity and narrow base of support.
- Use for shims (single wedge)
 - Stabilizing
 - Creating inclined plane
 - Taking up void space
 - Changing direction
 - Braking



Advanced Rescue Skills

Topic 5-1: Lifting and Moving



- Use for wedge sets (always use married pairs)*
- Use wedge sets to snug up or tighten load.
- \blacksquare 2x wedges are more stable than 4x.
- For shoring, wedges will start to cup when the load reaches about 1.5 times the allowable load. This converts to a pressure of about 1,000 psi. This provides an overload indicator for shoring.
 - If cupping of wedges occurs when moving objects, the process must be stopped immediately since it is too dangerous.
 - * It is always best to place the wedge pairs so their cut surfaces are in full contact with each other when moving objects. There will be more friction and more complete contact. The ends will also be square for better driving.
- When used for moving objects, the center of gravity of the supported load must be within the middle 1/3 of the crib bed.
 - The angle of the slope allowed when moving loads needs to be limited to 10 percent (1 ft in 10 ft, same as 6°).
 - When using cribbing as shoring to support sloped slabs of structures, the angle is limited to 30 percent (3 ft in 10 ft, same as 15°).
- Failure is slow and noisy because of the crushing of softer spring wood fibers, which make this system very desirable for unknown loading of US&R work:
 - Heavily loaded cribbing can crush so it will lose from 10 to 20 percent of its height.
 - Solid levels can be placed within the crib bed to support an air bag or spread the load at ground level.

Estimating Load Weights

- Weight for material in pounds per cubic foot (pcf)
 - Reinforced concrete weighs 150 pcf.**
 - Steel weighs 490 pcf (use 500).
 - Earth weighs 100 pcf.
 - Wood weighs 40 pcf.
 - ** This assumes that the concrete weighs 145 pcf and the reinforcing steel adds 5 pcf. However, concrete beams and columns are often more heavily reinforced and may weigh as much as 175 pcf. This can be very important to know when lifting with a crane.
- Solid objects = Length x Width x Height x pcf = Weight
- Solid cylinder = Length x 0.8 x Diameter x Diameter x pcf = Weight
- Hollow pipe = Length x 3 x Diameter x Thickness x pcf = Weight



Advanced Rescue Skills

Topic 5-1: Lifting and Moving



Lifting and Moving Devices

Anchor Bolts

- Wedge anchor
 - This is a torque controlled anchor. It has an undercut shaft that is inserted into the hole. The wedge expands as a cone at the bottom of the shaft as the shaft is pulled through it when the fastener is tightened.
 - It **cannot** be safely used in hollow concrete block.
 - Correct hole size (not too large) is very important since the wedge must develop great friction against the sides of the hole.
 - It will develop more friction as it is loaded in tension, since more expansion occurs as the pull on the shaft causes the cone to spead the wedge 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 uncracked concrete.
 - A wedge anchor should not be used in badly cracked concrete.



Expansion anchors require clean, proper sized holes and need to be set with a torque wrench.



They have a reduced capacity in cracked concrete Figure 5:6



Advanced Rescue Skills

Topic 5-1: Lifting and Moving



- Application: Anchor spacing and edge distance
 - Minimum spacing between anchors is 12 times the diameter of the anchor.
 - Minimum distance to the nearest concrete edge is 6 times the diameter of the anchor (9 times if load is acting toward the edge).
 - 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.
- Installation
 - Drilled holes should be the proper size and depth. Dull bits produce oversized holes that can lead to premature pull-out.
 - Holes need to be cleaned of all loose material.



- Min. edge distance = 6 x dia. (9 x dia. better)
- Min. spacing = 12 x dia.
- Min. depth = 6 x dia. (9 x dia. better)





STRENGTH REDUCERS

Overlapped cones – spacing too close

Figure 5:8

Eye Nuts

- Eye nuts are drop forged and galvanized devices that can be attached to the exposed threads of an installed anchor bolt to produce a lifting or moving device.
- They have a holding capacity slightly greater than the tension capacity of a wedge anchor, provided that the direction of the pull is vertical or within 15° of vertical, loading the anchor primarily in tension.

Teamwork and Leadership

- Teamwork is critical to a safe and efficient operation and requires a strong leader. The leader sets the tone of how well the objective is met. Leadership involves:
 - Developing a plan of action and implementing the plan by coordinating work through others
 - Adapting and overcoming problems
 - Ensuring overall safety of the operation and personel involved

EYE NUTS

- Attach over nut of installed wedge anchor
- Load in tension only (within 15 deg.)
- Use 3/8", 1/2", or 3/4"
- Capacity determined by anchor
- Tightened eye to nut
- 1/2" in FEMA Cache

Figure 5:9





Advanced Rescue Skills





Rescue Team Position Descriptions

- Squad Leader
 - Develops and implements the action plan
 - Calls commands
 - Maintains safety
- Assistant Squad Leader(s)
 - Fills this position when a squad of 10 to 12 students is divided in two to form "A" and "B" squads
 - Assists the Squad Leader with developing and implementing the action plan
 - Is also responsible for squad safety
- Safety Officer (If the squad is large enough, the Squad Leader can designate a Safety Officer.)
 - Maintains overall safety of squad members
 - Monitors stability of heavy objects, crib beds, and air bags
 - Can terminate any operation deemed unsafe
- Air Bag Attendant
 - If more than one air bag is being used independently, acts as an Assistant Squad Leader (identified by color of hose connected to air bag)
 - Is responsible for air bag selection and placement
 - Is responsible for crib bed to support air bag
- Controller Operator
 - Assembles air bag components (air source, regulator, controller, air hoses, and any appliances)
 - Operates controller to inflate or deflate air bags
 - If two air bags are being used, ensures that each air bag has a different color hose
 - Monitors air supply and air bag pressure
- Bars
 - Operate pry bars to raise, hold, lower, and move heavy objects
- Cribbers
 - Construct crib beds to support and stabilize heavy objects
 - May also assist air bag attendant to construct crib bed for air bag
- Feeders
 - Supply Cribbers, Air Bag Attendant, and Bars with materials to construct crib beds and fulcrums



Advanced Rescue Skills

Topic 5-1: Lifting and Moving



Standard Commands

Verbal commands are used to prevent rescuer injury and develop safe, deliberate movement of heavy objects. Clear text should be used. The following are commonly used commands for lifting and moving operations:

Squad Leader	"READY TO RAISE" "READY TO LOWER"
	"READY TO MOVE OBJECT"
	All assigned positions will respond with "READY"
Squad Leader	"RAISE"
	"LOWER"
	"MOVE OBJECT"
	The Bars or Controller Operator will take action as commanded.
	If two air bags are being used with hoses of different colors, the Squad Leader will use hose color to identify the action that should be taken by the Controller Operator.
Example	"RAISE ON RED"
1	"LOWER ON YELLOW"
Squad Leader	"HOLD"
	This command is used to hold the object until the Cribbers have completed the crib beds to support the load.
Cribbers	"CRIBS SET"
	This states when the crib bed is completed.
Squad Leader	"LOWER OBJECT"
	"LOWER ON RED"
	The Bars or Controller Operator will lower the object until it is supported solely by the crib beds.
Any Squad Member	"STICK"
	This emergency command can be given by any squad member. It is an immediate request for the Cribbers to support the object. The Bars may have lost their purchase point or control, or there is undesired movement or instability.
Cribbers	"CRIBS SET"
	This command is given when the load is secure.

A heavy lift operation takes a lot of people and a lot of equipment. If the team is to be successful, everyone must work within their assigned positions and follow commands as given to maintain safety.



Advanced Rescue Skills

