ReSET

Regional Standardization of Equipment & Training

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Trench Rescue Technician

Curriculum Manual

January 2023

Trench Rescue Course

This manual is the updated version of the material that was originally written in 2018 by the ReSET Trench Rescue Curriculum Committee (a subcommittee of the Heavy Rescue Committee). This manual has been updated to the current 2021 version of NFPA 1006. Portions of this material are the product of previous work done by technical rescue specialists in the years leading up to the organization of this document. The remainder of the material was the work of the committee members with input from various sources including rescue professionals from the region and from outside organizations and relies heavily on the influence of the Michigan Urban Search and Rescue group (MUSAR).

Purpose

This curriculum is not meant to cover all methods acceptable for trench rescue operations. The purpose is to standardize those methods taught during this trench rescue course. All the learning material in this document is intended to cover the Knowledge, Skills, and Abilities (KSA) for the trench rescue student.

Scope

The organization of the knowledge, skills and abilities (KSA's) within this curriculum is designed to follow the Job Performance Requirements (JPR) outlined by the National Fire Protection Association (NFPA) 1006 – Standard for Technical Rescuer Professional Qualifications 2021 edition. Standardized organization following NFPA 1006 is intended to allow the rescuers training to be consistent with other emergency response organizations. Each JPR will be accomplished by using techniques specified in this curriculum, and adopted by RESET as the authority having jurisdiction.

Pre-Requisites: ReSET General Rescuer or NFPA Rope Operations Equivalent

Instructor Obligation

It is the responsibility of all instructors delivering any part of this curriculum to cover all of the learning material covered in the lesson plans. No instructor has the authority to delete, omit, or otherwise leave out any content within the curriculum. Anyone assigned the task of covering any part of this curriculum should build his/her class in such a manner that optimizes instructor style while at the same time maximizing the learning for the students.

Trench Curriculum Committee Participants (2018)

John Collins
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Trench Curriculum Committee Participants (2022)

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NFPA 1006

12.1 Awareness Level

12.1.1

Interview any witness or "competent person" given a specific trench collapse incident, so that potential for rapid, nonentry rescue or victim self-rescue is recognized

A. Requisite Knowledge: Need to secure "competent person" or witness; signs and evidence of victim involvement, number and locations
B. Requisite Skills: Determine severe environmental conditions with implications for secondary collapse and victim survivability; interview techniques

12.1.2

Facilitate a non-entry rescue or victim self-rescue, given a trench collapse incident, tools used for self-rescue, and the rescue area and general area are made safe, so that the non-entry and self-rescue tactics can be initiated

A. Requisite Knowledge: Understand mechanics and extent of collapse effects; need to brief rescuers criteria for rapid, non-entry rescues
B. Requisite Skills: Ability to implement nonentry rescue and self-rescue tactics; select and deploy tools used to facilitate non-entry and self-rescue; reduce imposed loads at or near the lip of the trench.

12.1.3

Identify hazardous areas specific to a trench environment, given a trench collapse incident, so that the scene is secured, hazards are managed, and an approach path to the trench is identified.

A. Requisite Knowledge: Areas at risk for increased likelihood of a collapse, general collapse patterns of trenches, methods of bridging and weight distribution, securing of scenes, and tactics for approaching the trench while minimizing the likelihood of collapse.
B. Requisite Skills: Ability to identify areas of high risk for additional collapse, select and deploy tools or materials for bridging or weight distribution, communicate high-risk areas to other responders.

12.1.4

Size up a trench rescue incident, given background information and applicable reference materials, so that the scope of the rescue is determined, the number of victims is identified, the last reported location of all the victims is established, witnesses and reporting parties are identified and interviewed, resource needs are assessed, primary search parameters are identified, and information required to develop an initial incident action plan is obtained.

A. Requisite Knowledge: Types of reference materials and their uses, availability and capability of the resources, elements of an incident action plan and related information, relationship of the size-up to the incident managements system, information gathering techniques and how that information is used in the size-up process, and basic search criteria for trench rescue incidents.
B. Requisite Skills: The ability to read technical rescue reference materials, gather information, use interview techniques, relay information, and use information gathering sources.

12.1.5

Recognize Incident hazards and initiate isolation procedures, given scene control barriers, personal protective equipment (PPE), requisite equipment, and available specialized resources, so that all hazards are identified; resource application fits the operational requirements; hazard isolation is considered; risks to rescuers, bystanders and victims are minimized; and rescue time constraints are taken into account.

A. Requisite Knowledge: Resource capabilities and limitations; types and nature of incident hazards; equipment types and their use; isolation terminology methods, equipment, and implementation; operational requirement concerns; common types of rescuer and victim risks; risk/benefit analysis methods and practices; hazard recognition, isolation methods, and terminology; methods for controlling access to the scene; and types of technical references.
B. Requisite Skills: The ability to resource capabilities and limitations, identify incident hazards, assess potential hazards to rescuers and bystanders, place scene control barriers, and operate control and mitigation equipment.

12.1.6

Recognize the need for technical rescue resources at an operations – or technician-level incident, given AHJ guidelines, so that the need for additional resources is identified, the response system is initiated, the scene is secured and rendered safe until additional resources arrive, and awareness-level personnel are incorporated in the operational plan.

A. Requisite Knowledge: Operational protocols, specific planning forms, types of incidents common to the AHJ, hazards, incident support operations and resources, and safety measures.
B. Requisite Skills: The ability to apply operational protocols, select specific planning forms based on the types of incidents, identify and evaluate various types of hazards within the AHJ, request support and resources, and determine the required safety measures.

12.1.7

Support an operations- or technician-level incident, given an incident, an assignment, an incident action pan, and resources from the tool kit, so that the assignment is carried out, progress is reported to command, environmental concerns are managed, personnel rehabilitation is facilitated, and the incident action plan is supported.

A. Requisite Knowledge: AHJ operational protocols, hazard recognition, incident management, PPE selection, resource selection and use and scene support requirements.
B. Requisite Skills: The ability to apply operations protocols, function within an incident management system, follow and implement an incident action plan, and report the task progress status to a supervisor or incident command.

12.2 Operations Level

12.2.1

Identify potential hazards to victims and rescuers in and around a trench excavation, given a trench collapse incident, a trench rescue toolkit so that potential areas of additional collapse in the trench are identified, utility lines are located, spoil piles are monitored, additional superimposed weight is identified, sources of atmospheric contamination are assessed, sources of water are identified, and environmental hazards are considered.

A. Requisite Knowledge: Method to distinguish soil types, collapse mechanics, and other contributing factors such as severe environmental conditions and other general hazards effects and hazards of collapse and rescue efforts on utilities at the incident site; jurisdictional and community resource lists and agreements; atmospheric monitoring; effects of additional superimposed weight and vibrations on trench walls; effects of water in and around trench.
B. Requisite Skills: The ability to interpret tabulated data information and tables; perform atmospheric monitoring; monitor spoil piles; assess and address the effects of water on trench stability.

12.2.2

Implement a hazard control plan given a trench collapse incident, hazard control plan and trench rescue tool kit so that provisions for ventilation, dewatering, energy control, air monitoring, and falls, and prevention of unplanned soil movement are accomplished.

A. Requisite Knowledge: Protocol on making the general area safe, criteria for a safe zone within the trench, atmospheric monitoring and ventilation, types of collapses and techniques to stabilize, emergency procedures, selection of PPE, and consideration of selected stabilization tactics on extrication and victim safety.
B. Requisite Skills: Employ hazard control plan to protect personnel inside and outside of the trench, establish safe zones, perform atmospheric monitoring and initiate ventilation as needed, initiate dewatering, provide energy control, ability to select and use PPE, apply fall prevention, and implement strategies to minimize unplanned soil movement.

12.2.3

Develop a shoring plan for a nonintersecting trench no more than 8 feet (2.4 m) deep, given a trench collapse incident and trench rescue tool kit, so that the methods of potential collapse are recognized, the mechanisms of entrapment are identified, areas of the trench that are blown out or undercut are addressed, related tabulated data is consulted, the weights and hazards associated with the soils are considered, and the location of the victim and projected path for removal are incorporated.

A. Requisite Knowledge: Shoring and shielding, tabulated data, strategies and tactics, protocols on making the general area safe, criteria for a safe zone within the trench, types of collapses and techniques to stabilize, emergency procedures, selection of personal protective equipment, and consideration of selected stabilization tactics on extrication and victim safety.
B. Requisite Skills: Determine shoring strategies, designate cut station location, and material and equipment needs; establish safe zones; ability to pre-brief team on shoring strategies, victim release, and projected path for removal.

12.2.4

Implement a trench shoring plan for a nonintersecting trench no more than 8 feet (2.4 m) deep, given a trench collapse incident, trench shoring plan, and a trench rescue tool kit, so that the victim is protected from additional collapse, the trench walls are supported, prior areas of collapse are addressed, shoring team members work from protected areas, and shoring systems are installed so they perform their intended function.

A. Requisite Knowledge: Shoring and shielding, criteria for a safe zone within the trench, types of collapse and techniques to stabilize, emergency procedures, selection of personal protective equipment, and consideration of selected stabilization tactics for extrication and victim safety.
B. Requisite Skills: The ability to place shoring and shielding systems, install supplemental shoring, use protocols, choose methods to stabilize, establish a cut station, use personal protective equipment, anticipate extrication logistics, and create systems in trenches 8 feet (2.4 m) deep. (See Annex I.)

12.2.5

Release a victim from soil entrapment in a nonintersecting trench of 8 feet (2.4 m) or less in depth, given a trench collapse incident and a trench rescue tool kit, so that hazards to rescue personnel and victims are minimized; considerations are given to the victim's injuries, crush injuries related to compartment syndrome, and other injuries; techniques are used to enhance patient survivability; and techniques do not compromise the integrity of the existing trench shoring system.

A. Requisite Knowledge: Identification, utilization, and required care of personal equipment; general hazards associated with each type of trench collapse; methods of evaluating shoring systems and trench wall stability; compartment syndrome protocols; identification of collapse characteristics; causes and associated effects of trench collapse; potential signs of subsequent collapse; selection and application of rescue tools and resources; risk/benefit assessment techniques for extrication methods; and time constraints.
B. Requisite Skills: The ability to select, use, and care for PPE; operate rescue tools and stabilization systems; identify crush injuries related to compartment syndrome; and complete risk/benefit assessments for selected methods of rescue and time constraints.

12.2.6

Remove a victim from a trench, given a disentangled victim, a basic first aid kit, and victim packaging resources, so that basic life functions are supported as required; the victim is evaluated for signs of compartment syndrome; methods and packaging devices selected are compatible with intended routes of transfer; universal precautions are employed to protect personnel from blood-borne pathogens; and extraction times meet time constraints for medical management.

A. Requisite Knowledge: Medical protocols, available medical resources, transfer methods and time needed to execute, universal precautions protocol, rope rescue systems, high-point anchor options, and patient ladder raise removal techniques
B. Requisite Skills: The ability to select and use personal protective equipment, provide basic medical care and immobilization techniques, identify the need for advanced life support and compartment syndrome management, and use a removal system that matches logistical and medical management time frame concerns.

12.2.7

Disassemble support systems at a trench emergency incident, given personal protective equipment, trench tool kit, and removal of victim(s), so that soil movement is minimized, all rescue equipment is removed from the trench, sheeting and shoring are removed in the reverse order of their placement, emergency protocols and safe zones in the trench are adhered to, rescue personnel are removed from the trench, the last supporting shores are pulled free with ropes, equipment is cleaned and serviced, reports are completed, and a post-briefing is performed.

A. Requisite Knowledge: Selection of personal protective equipment, equipment used and its location, shoring and shielding tactics and order of placement, shoring removal protocols, criteria for a "safe zone" within the trench, personnel accountability, emergency procedures, manufacturer's recommended care and maintenance procedures, and briefing protocols.
B. Requisite Skills: The ability to use personal protective equipment, remove equipment and protective systems, use trench safety protocols, clean and service equipment, and perform an incident debriefing.

12.2.8

Terminate a technical rescue operation, given an incident scenario, assigned resources, and site safety data, so that rescuer risk and site safety are managed; scene security is maintained and custody transferred to a responsible party; personnel and resources are returned to a state of readiness; record-keeping and documentation occur; and post-event analysis is conducted.

A. Requisite Knowledge: Incident command functions and resources, hazard identification and risk management strategies, logistics and resource management, personnel accountability systems, and AHJ-specific procedures or protocols related to personnel rehab.
B. Requisite Skills: Hazard recognition, risk analysis, use of site control equipment and methods, use of data collection and management systems, and use of asset and personnel tracking systems.

12.3 Technician

12.3.1

Develop a shoring plan for an intersecting trench, given a trench collapse incident and trench rescue tool kit, so that the methods of potential collapse are recognized, the mechanisms of entrapment are identified, areas of the trench that are blown out or undercut are addressed, related tabulated data is consulted, the weights and hazards associated with the soils are considered, and the location of the victim and projected path for removal are incorporated.

A. Requisite Knowledge: shoring and shielding, tabulated data, strategies and tactics, protocols on making the general area safe, criteria for a safe zone within the trench, types of collapses and techniques to stabilize, emergency procedures, selection of PPE, and consideration of selected stabilization tactics for extrication and victim safety.
B. Requisite Skills: Determine shoring strategies; designate cut station location and material and equipment needs; establish safe zones; pre-brief team on shoring strategies, victim release, and projected path for removal.

12.3.2

Implement a trench shoring plan for intersecting trench, given a trench collapse incident, trench shoring plan, and a trench rescue too kit, so that the victim is protected from additional collapse, the trench walls are supported, prior areas of collapse are addressed, shoring team members work from protected areas, and shoring systems are installed so they perform their intended function.

A. Requisite Knowledge: Shoring and shielding, criteria for a safe zone within the trench, types of collapses and techniques to stabilize, emergency procedures, selection of PPE, and consideration of selected stabilization tactics on extrication and victim safety.
B. Requisite Skills: Ability to place shoring and shielding systems, install supplemental shoring, use protocols, choose methods to stabilize, establish a cut station, use personal protective equipment, anticipate extrication logistics, and create shoring systems in trenches 8 ft (2.4 m) deep. (See Annex H.)

12.3.3

Develop a shoring plan for a trench more than 8 ft (2.4 m) deep, given a trench collapse incident, and trench rescue tool kit, so that the methods of potential collapse are recognized, the mechanisms of entrapment are identified, areas of the trench that are blown out or undercut are addressed, related tabulated data is consulted, the weights and hazards associated with the soils are considered, the location of the victim and projected path for removal are incorporated.

A. Requisite Knowledge: Shoring and shielding, tabulated data, strategies and tactics, protocols on making the general area safe, criteria for a safe zone within the trench, types of collapses and techniques to stabilize, emergency procedures, selection of PPE, and consideration of selected stabilization tactics on extrication and victim safety.
B. Requisite Skills: Ability to determine shoring strategies; designate cut station location and material and equipment needs; establish safe zones; pre-brief team on shoring strategies, victim release, and projected path for removal.

12.3.4

Implement a trench shoring plan for a trench more than 8 ft (2.4 m) deep, given a trench collapse incident, trench shoring plan, and a trench rescue tool kit, so that the victim is protected from additional collapse, the trench walls are supported, prior areas of collapse are addressed, shoring team members work from protected areas, and shoring systems are installed so they perform their intended function.

A. Requisite Knowledge: Shoring and shielding, criteria for a safe zone within the trench, types of collapses and techniques to stabilize, emergency procedures, selection of personal protective equipment, and consideration of selected stabilization tactics on extrication and victim safety.
B. Requisite Skills: Ability to place shoring and shielding systems, install supplemental shoring, use protocols, choose methods to stabilize, establish a cut station, use personal protective equipment, anticipate extrication logistics, and create systems in trenches more than 8 ft (2.4 m) deep. (See Annex H.)

12.3.5

Support an intersecting trench as a member of a team, given size-up information and an action plan, a trench tool kit, and an assignment, so that strategies to minimize the further movement of soil are implemented effectively; trench walls, lip, and spoil pile are monitored continuously; rescue entry team(s) in the trench remains in a safe zone; any slough-in and wall shears are mitigated; emergency procedures and warning systems are established and understood by participating personnel; incident-specific personal protective equipment is utilized; physical hazards are identified and managed; victim protection is maximized; victim extrication methods are considered; and a rapid intervention team is staged.

A. Requisite Knowledge: Shoring and shielding, tabulated data, strategies and tactics, types of intersecting trenches and techniques to stabilize, protocols on making the general area safe, criteria for safe zones in the trench, types of collapses and techniques to stabilize, emergency procedures, selection of personal protective equipment, and consideration of selected stabilization tactics on extrication and victim safety.
B. Requisite Skills: The ability to interpret tabulated data information and tables, place shoring and shielding systems, identify type of intersecting trench, use trench rescue protocols, identify types of collapse and methods to stabilize, identify hazards in a trench, use personal protective equipment, and anticipate extrication logistics.

12.3.6

Install supplemental sheeting and shoring for each 2 ft (0.61 m) of depth dug below an existing approved shoring system, given sizeup information, an action plan, and a trench tool kit, so that the movement of soil is minimized effectively, initial trench support strategies are facilitated, rescue entry team safe zones are maintained, excavation of entrapping soil is continued, victim protection is maximized, victim extrication methods are considered, and a rapid intervention team is staged.

A. Requisite Knowledge: Shoring and shielding, tabulated data, strategies and tactics, methods and techniques to install supplemental sheeting and shoring, protocols on making the general area safe, criteria for safe zones in the trench, types of collapses and techniques to stabilize, emergency procedures, selection of personal protective equipment, and consideration of selected stabilization tactics on extrication and victim safety.
B. Requisite Skills: The ability to interpret tabulated data information and tables, place shoring and shielding systems, identify supplemental sheeting and shoring, use all trench rescue protocols,

identify types of collapse and methods to stabilize, identify exposure to hazards within the trench relative to existing safe zones, select and use personal protective equipment, and anticipate extrication logistics.

12.3.7

Utilize spot shoring techniques to support soil without incorporating uprights or panels as part of the shoring plan, given a trench incident, trench rescue toolbox, tabulated data, and trench shoring plan, so that the soil is prevented from collapse.

A. Requisite Knowledge: Shoring and shielding, tabulated data, strategies and tactics, methods and techniques to install supplemental sheeting and shoring, protocols on making the general area safe, criteria for safe zones in the trench, types of collapses and techniques to stabilize, emergency procedures, selection of personal protective equipment, and consideration of selected stabilization tactics on extrication and victim safety.
B. Requisite Skills: The ability to interpret tabulated data information and tables, place shoring and shielding systems, identify supplemental sheeting and shoring, use all trench rescue protocols, identify types of collapse and methods to stabilize, identify exposure to hazards within the trench relative to existing safe zones, select and use personal protective equipment, and anticipate extrication logistics.

12.3.8

Construct load stabilization systems, given an assignment, personal protective equipment, and a trench tool kit, so that the stabilization system will support the load safely, the system is stable, and the assignment is completed.

A. Requisite Knowledge: Different types of stabilization systems and their construction methods, limitations of the system, load calculations, principles of and applications for stabilization systems, and safety considerations.
B. Requisite Skills: The ability to select and construct stabilization systems, evaluate structural integrity of the system, determine stability, and calculate loads.

12.3.9

Lift a load, given a trench tool kit, so that the load is lifted the required distance to gain access; settling or dropping of the load is prevented; control and stabilization are maintained before, during, and after the lift; and operational objectives are attained.

A. Requisite Knowledge: Lift a load, given a trench tool kit, so that the load is lifted the required distance to gain access; settling or dropping of the load is prevented; control and stabilization are maintained before, during, and after the lift; and operational objectives are attained.
B. Requisite Skills: The ability to evaluate and estimate the weight of the load, operate the tools correctly, operate a lever, and apply load stabilization systems.

12.3.10

Coordinate the use of heavy equipment, given personal protective equipment, means of communication, equipment, operator, and an assignment, so that operator capabilities and limitations for task are evaluated, common communications are maintained, equipment usage supports the operational objectives, and hazards are avoided.

A. Requisite Knowledge: Types of heavy equipment; capabilities", application, and hazards of heavy equipment and rigging; operator training; types of communication; and methods to establish communications
B. Requisite Skills: The ability to use hand signals, use radio equipment, recognize hazards, assess operator for skill and calm demeanor, assess heavy equipment for precision of movement and maintenance, monitor rescuer and victim safety, and use personal protective equipment.

12.3.11

Release a victim from entrapment by components of a collapsed trench, given personal protective equipment, a trench rescue tool kit and specialized equipment, so that hazards to rescue personnel and victims are minimized, considerations are given to compartment syndrome related to crush injuries and other injuries, techniques are used to enhance patient survivability, tasks are accomplished within projected time frames, and techniques do not compromise the integrity of the existing trench shoring system.

A. Requisite Knowledge: Identification, utilization, and required care of personal equipment; general hazards associated with each type of trench collapse; methods of evaluating shoring systems and trench wall stability; compartment syndrome protocols; identification of collapse characteristics; causes and associated effects of trench collapse; potential signs of subsequent collapse; selection and application of rescue tools and resources; risk/benefit assessment techniques for extrication methods; and time restraints.
B. Requisite Skills: The ability to select, use, and care for personal protective equipment; operate rescue tools and stabilization systems; identify crush syndrome clinical settings; and complete risk/benefit assessments for selected methods of rescue and time constraints.

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1000-1100	Stabilization and Lifting (Brown) NFPA JPR 12.3.8, 12.3.9, 12.3.10				
1100-1200	Lunch	Lunch	Lunch	Lunch	Lunch
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1300-1400	Equipment Familiarization (All) NFPA JPR 12.3.8, 12.3.9, 12.3.10		Replacement Shoring (Brown) NFPA 12.1.3, 12.1.5, 12.1.6, 12.2.1, 12.2.2, 12.2.7, 12.2.8		
1400-1500	Shoring non-intersecting < 8' trench (Rogers) NFPA JPR 12.1.3, 12.1.4, 12.1.5, 12.1.6, 12.1.7, 12.2.1, 12.2.2, 12.2.3, 12.2.4	Straight Trench > 12' (Haddock) NFPA JPR: 12.1.3, 12.1.4, 12.1.5, 12.1.6, 12.1.7, 12.2.1, 12.2.2, 12.2.3, 12.2.4, 12.2.5, 12.2.6, 12.2.7, 12.2.8	Alternate Shoring (Rogers) NFPA NFPA 12.1.3, 12.1.5, 12.1.6, 12.2.1, 12.2.2, 12.2.7, 12.2.8, 12.3.7		
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1600-1700	Shoring non-intersecting > 8' Trench (Haddock) NFPA JPR 12.1.3, 12.1.4, 12.1.5, 12.1.6, 12.1.7, 12.2.1, 12.2.2, 12.2.3, 12.3.3, 12.3.4, 12.3,6				

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Trench Rescue Course

Class Title:
Standards, Definitions and Hazards

NFPA 1006 JPR's:
12.1.3 – Identify hazardous areas specific to a trench environment
12.1.4 – Size up a trench rescue incident
12.2.1 – Identify potential hazards to victims and rescuers in and around a trench excavation

Time:
1.5 hours

Objectives:
- Implement the NFPA Standards applicable to Trench Rescue
- Define Terms used in Trench Rescue
- Identify classes of soil
- Identify Trench types and methods of shoring
- Establish Hot, Warm and Cold Zones
- Identify Trench Collapse patterns and causes
- Recognize standard construction practices, site considerations and heavy equipment

Standards:

- NFPA 1006: Standard for Technical Rescue Personnel Professional Qualifications
  - Chapter 12: Trench Rescue
- NFPA 1670: Standard on Operations and Training for Technical Search and Rescue Incidents
  - Chapter 11: Trench Search and Rescue
- OSHA 1926.650-652 Subpart P – Excavations

Terms/Definitions

Accepted engineering practices those requirements which are compatible with standards of practice required by a registered professional engineer.

Active Soil the ability of the soil to contain energy as it relates to movement

Aluminum Hydraulic Shoring a pre-engineered shoring system comprised of aluminum hydraulic cylinders (cross-braces) used in conjunction with vertical rails (uprights) or horizontal rails (wales). Such system is designed specifically to support the sidewalls of an excavation and prevent cave-ins.

Angle of Repose the angle at which loose particulate products will support their own weight, and which can be expected not to flow from a standing position

Bell-bottom pier hole a type of shaft or footing excavation, the bottom of which is made larger than the cross section above to form a belled shape.

Benching (Benching system) a method of protecting employees from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near-vertical surfaces between levels.

Cave-in the separation of a mass of soil or rock material from the side of an excavation, or the loss of soil from under a trench shield or support system, and its sudden movement into the excavation, either by falling or sliding, in sufficient quantity so that it could entrap, bury, or otherwise injure and immobilize a person.

Competent person one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

Cross braces the horizontal members of a shoring system installed perpendicular to the sides of the excavation, the ends of which bear against either uprights or wales.

Deep Trench trenches over 10 feet in depth but not greater than 20 feet. Trenches over 20 feet in depth present extreme forces that require engineered protective systems.

Excavation any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal.

Faces or sides the vertical or inclined earth surfaces formed as a result of excavation work.

Failure the breakage, displacement, or permanent deformation of a structural member or connection so as to reduce its structural integrity and its supportive capabilities.

Hazardous atmosphere an atmosphere which by reason of being explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen deficient, toxic, or otherwise harmful, may cause death, illness, or injury.

Kickout the accidental release or failure of a cross brace.

Lip the lip of the trench is the top two feet of the trench wall extending back from the edge two feet

Plasticity the property that allows the soil to be deformed or molded without appreciable change in volume

Protective system a method of protecting employees from cave-ins, from material that could fall or roll from an excavation face or into an excavation, or from the collapse of adjacent structures. Protective systems include support systems, sloping and benching systems, shield systems, and other systems that provide the necessary protection.

Registered Professional Engineer a person who is registered as a professional engineer in the state where the work is to be performed. However, a professional engineer, registered in any state is deemed to be a "registered professional engineer" within the meaning of this standard when approving designs for "manufactured protective systems" or "tabulated data" to be used in interstate commerce.

Sheeting the members of a shoring system that retain the earth in position and in turn are supported by other members of the shoring system.

Shield (Shield system) a structure that is able to withstand the forces imposed on it by a cave-in and thereby protect employees within the structure. Shields can be permanent structures or can be designed to be portable and moved along as work progresses. Additionally, shields can be either pre-manufactured or job-built in accordance with 1926.652(c)(3) or (c)(4). Shields used in trenches are usually referred to as "trench boxes" or "trench shields."

Shoring (Shoring system) a structure such as a metal hydraulic, mechanical or timber shoring system that supports the sides of an excavation and which is designed to prevent cave-ins.

Sides. See "Faces."

Sloping (Sloping system) a method of protecting employees from cave-ins by excavating to form sides of an excavation that are inclined away from the excavation so as to prevent cave-ins. The angle of incline required to prevent a cave-in varies with differences in such factors as the soil type, environmental conditions of exposure, and application of surcharge loads.

Spoil Pile: The dirt taken out of the trench and piled along the side of the trench. The spoil pile must be set back at least two feet from the trench lip.

Stable rock natural solid mineral material that can be excavated with vertical sides and will remain intact while exposed. Unstable rock is considered to be stable when the rock material on the side or sides of the excavation is secured against caving-in or movement by rock bolts or by another protective system that has been designed by a registered professional engineer.

Strong Back: a dimensional piece of lumber measuring 2”x12”x 12’. Strong backs are used in conjunction with panels to provide additional support to the panel and distribute the forces implied from the shores to the trench wall.

Support system a structure such as underpinning, bracing, or shoring, which provides support to an adjacent structure, underground installation, or the sides of an excavation.

Tabulated data tables and charts approved by a registered professional engineer and used to design and construct a protective system.

Trench (Trench excavation) a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench (measured at the bottom) is not greater than 15 feet (4.6 m). If forms or other structures are installed or constructed in an excavation so as to reduce the dimension measured from the forms or structure to the side of the excavation to 15 feet (4.6 m) or less (measured at the bottom of the excavation), the excavation is also considered to be a trench.

Trench box See "Shield.

Trench shield See "Shield."

Uprights the vertical members of a trench shoring system placed in contact with the earth and usually positioned so that individual members do not contact each other. Uprights placed so that individual members are closely spaced, in contact with or interconnected to each other, are often called "sheeting."

Wales horizontal members of a shoring system placed parallel to the excavation face whose sides bear against the vertical members of the shoring system or earth.

Trench Terminology

- Lip- top two feet of the trench walls and two feet back from the edge
- Wall (Faces or Sides) – the sides of the trench
- Toe – the bottom two feet of the trench walls to the floor
- Floor – the bottom of the trench
- Ends – end walls of the trench
- Spoil Pile
- Belly – The space between the Lip and the Toe, also referred to as the wall

Types of Trenches

- **Straight Wall Trench:** a narrow excavation in relation to its length made below the surface of the ground. In general, the depth is greater than the width, but the width is not greater than 15 feet.
- **L- Trench:** The "L" Trench can be described as two trenches that intersect at their ends and for a right angle. This type of trench presents a difficult scenario for rescuers because advanced techniques are required to protect the inside and outside corners of the "L" .
- **T- Trench**: The "T" Trench is composed of two trenches that meet at the end of one trench and intersect mid-span of the opposing trench, creating the formation of a "T". The "T" trench can be described as a very unstable trench with two inside corners which are most prone to failure.

Soil Classifications (excerpted from OSHA 1926.651)

- **Definitions**
  - **Cemented soil** a soil in which the particles are held together by a chemical agent, such as calcium carbonate, such that a hand-size sample cannot be crushed into powder or individual soil particles by finger pressure.
  - **Cohesive soil** clay (fine grained soil), or soil with a high clay content, which has cohesive strength. Cohesive soil does not crumble, can be excavated with vertical side slopes, and is plastic when moist. Cohesive soil is hard to break up when dry, and exhibits significant cohesion when submerged. Cohesive soils include clayey silt, sandy clay, silty clay, clay, and organic clay.
  - **Dry soil** soil that does not exhibit visible signs of moisture content.
  - **Fissured** a soil material that has a tendency to break along definite planes of fracture with little resistance, or a material that exhibits open cracks, such as tension cracks, in an exposed surface.
  - **Granular soil** gravel, sand, or silt (coarse grained soil) with little or no clay content. Granular soil has no cohesive strength. Some moist granular soils exhibit apparent cohesion. Granular soil cannot be molded when moist and crumbles easily when dry.
  - **Layered system** two or more distinctly different soil or rock types arranged in layers. Micaceous seams or weakened planes in rock or shale are considered layered.
  - **Moist soil** a condition in which a soil looks and feels damp. Moist cohesive soil can easily be shaped into a ball and rolled into small diameter threads before crumbling. Moist granular soil that contains some cohesive material will exhibit signs of cohesion between particles.
  - **Plastic** a property of a soil that allows the soil to be deformed or molded without cracking or appreciable volume change.

- **Saturated soil** a soil in which the voids are filled with water. Saturation does not require flow. Saturation, or near saturation, is necessary for the proper use of instruments such as a pocket penetrometer or sheer vane.
- **Soil classification system** for the purpose of this subpart, a method of categorizing soil and rock deposits in a hierarchy of stable rock, Type A, Type B, and Type C, in decreasing order of stability. The categories are determined based on an analysis of the properties and performance characteristics of the deposits and the characteristics of the deposits and the environmental conditions of exposure.
- **Stable rock** natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.
- **Submerged soil** soil that is underwater or is free-seeping
- **Unconfined compressive strength** the load per unit area at which a soil will fail in compression. It can be determined by laboratory testing or estimated in the field using a pocket penetrometer, by thumb penetration tests, and other methods.
- **Wet soil** soil that contains significantly more moisture than moist soil but in such a range of values that cohesive material will slump or begin to †ow when vibrated. Granular material that would exhibit cohesive properties when moist will lose those cohesive properties when wet.

- **Soil Type**

  - **Type A** means cohesive soils with an unconfined, compressive strength of 1.5 ton per square foot (tsf) (144 kPa) or greater. Examples of cohesive soils are clay, silty clay, sandy clay, clay loam, and, in some cases, silty clay loam and sandy clay loam. Cemented soils such as caliche and hardpan are also considered Type A. However, no soil is Type A if one of the following conditions exists:
    1. The soil is fissured.
    2. The soil is subject to vibration from heavy traffic, pile driving, or similar effects.
    3. The soil has been previously disturbed.
    4. The soil is part of a sloped, layered system where the layers dip into the excavation on a slope of four horizontal to one vertical (4H:1V) or greater.
    5. The material is subject to other factors that would require it to be classified as a less stable material

- **Type B** means one or more of the following:

  1. **1.** Cohesive soil with an unconfined compressive strength greater than 0.5 tsf (48 kPa) but less than 1.5 tsf (144 kPa)
  2. **2.** Granular cohesion-less soils including angular gravel (similar to crushed rock), silt, silt loam, sandy loam, and, in some cases, silty clay loam and sandy clay loam
  3. **3.** Previously disturbed soils except those that would other- wise be classed as Type C soil
  4. **4.** Soil that meets the unconfined compressive strength or cementation requirements for Type A but is fissured or subject to vibration
  5. **5.** Dry rock that is not stable
  6. **6.** Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less steep than four horizontal to one vertical (4H:1V), but only if the material would otherwise be classified as Type B

- **Type C** "Type C" means one or more of the following:

  1. **1.** Cohesive soil with an un-confined compressive strength of 0.5 tsf (48 kPa) or less
  2. **2.** Granular soils including gravel, sand, and loamy sand
  3. **3.** Submerged soil or soil from which water is freely seeping
  4. **4.** Submerged rock that is not stable
  5. **5.** Material in a sloped, layered system where the layers dip into the excavation or a slope of four horizontal to one vertical (4H:1V) or steeper

Test Equipment and Methods for evaluating soil type

- Each soil and rock deposit shall be classified by a competent person as Stable Rock, Type A, Type B, or Type C in accordance with the definitions set forth in paragraph (b) of this appendix.
- The classification of the deposits shall be made based on the results of at least one visual and at least one manual analysis.

- **Visual tests.** Visual analysis is conducted to determine qualitative information regarding the excavation site in general, the soil adjacent to the excavation, the soil forming the sides of the open excavation, and the soil taken as samples from excavated material.

  1. Observe samples of soil that are excavated and soil in the sides of the excavation. Estimate the range of particle sizes and the relative amounts of the particle sizes. Soil that is primarily composed of fine-grained material

is cohesive material. Soil composed primarily of coarse-grained sand or gravel is granular material.

2. Observe soil as it is excavated. Soil that remains in clumps when excavated is cohesive. Soil that breaks up easily and does not stay in clumps is granular.

3. Observe the side of the opened excavation and the surface area adjacent to the excavation. Crack-like openings such as tension cracks could indicate fissured material. If chunks of soil spall off a vertical side, the soil could be fissured. Small spalls are evidence of moving ground and are indications of potentially hazardous situations.

4. Observe the area adjacent to the excavation and the excavation itself for evidence of existing utility and other underground structures, and to identify previously disturbed soil.

5. Observe the opened side of the excavation to identify layered systems. Examine layered systems to identify if the layers slope toward the excavation. Estimate the degree of slope of the layers.

6. Observe the area adjacent to the excavation and the sides of the opened excavation for evidence of surface water, water seeping from the sides of the excavation, or the location of the level of the water table.

7. Observe the area adjacent to the excavation and the area within the excavation for sources of vibration that may affect the stability of the excavation face.

- **Manual tests**. Manual analysis of soil samples is conducted to determine quantitative as well as qualitative properties of soil and to provide more information in order to classify soil properly.

    1. Plasticity Mold a moist or wet sample of soil into a ball and attempt to roll it into threads as thin as 1⁄8-inch in diameter. Cohesive material can be successfully rolled into threads without crumbling. For example, if at least a two inch (50 mm) length of 1⁄8- inch thread can be held on one end without tearing, the soil is cohesive.

    2. Dry strength If the soil is dry and crumbles on its own or with moderate pressure into individual grains or fine powder, it is granular (any combination of gravel, sand, or silt). If the soil is dry and falls into clumps which break up into smaller clumps, but the smaller clumps can only be broken up with difficulty, it may be clay in any combination with gravel, sand or silt. If the dry soil breaks into clumps which do not break up into small clumps and which can only be broken with difficulty, and there is no visual indication the soil is fissured, the soil may be considered un-fissured.

    3. Thumb penetration The thumb penetration test can be used to estimate the unconfined compressive strength of cohesive soils. (This test is based on the thumb penetration test described in American Society for Testing and

Materials (ASTM) Standard designation D2488—''Standard Recommended Practice for Description of Soils (Visual—Manual Procedure).'') Type A soils with an unconfined compressive strength of 1.5 tsf can be readily indented by the thumb; however, they can be penetrated by the thumb only with very great effort. Type C soils with an unconfined compressive strength of 0.5 tsf can be easily penetrated several inches by the thumb, and can be molded by light finger pressure. This test should be conducted on an undisturbed soil sample, such as a large clump of spoil, as soon as practicable after excavation to keep to a minimum the effects of exposure to drying influences. If the excavation is later exposed to wetting influences (rain, flooding), the classification of the soil must be changed accordingly.

4. <u>Other strength tests</u> Estimates of unconfined compressive strength of soils can also be obtained by use of a pocket penetrometer or by using a hand-operated shear vane.

5. <u>Drying test</u> The basic purpose of the drying test is to differentiate between cohesive material with fissures, un-fissured cohesive material, and granular material. The procedure for the drying test involves drying a sample of soil that is approximately one inch thick (2.54 cm) and six inches (15.24 cm) in diameter until it is thoroughly dry:

    - (A) If the sample develops cracks as it dries, significant fissures are indicated.

    - (B) Samples that dry without cracking are to be broken by hand. If considerable force is necessary to break a sample, the soil has significant cohesive material content. The soil can be classified as an un-fissured cohesive material and the unconfined compressive strength should be determined.

    - (C) If a sample breaks easily by hand, it is either a fissured cohesive material or a granular material. To distinguish between the two, pulverize the dried clumps of the sample by hand or by stepping on them. If the clumps do not pulverize easily, the material is cohesive with fissures. If they pulverize easily into very small fragments, the material is granular

<u>**Soil Physics**</u>

Once a trench has been dug the trench walls are subject to the unyielding forces of gravity, the earth will always try to heal itself and it is just a matter of time before the unsupported walls of a trench cave in and fill the void. There are several factors that will contribute to the speed at which that happens, some factors help prolong the time frame while others will shorten it.

At rest and undisturbed a given unit of soil will be pushing in every direction with equal force while the adjacent units of soil are pushing back with the same force. This balancing act is how the ground stays stable.

Pushing and pulling forces are often opposed by resistant forces. For a trench wall gravity is a constant pulling force. An unbraced soil wall's resistance to the pulling force is the **soils internal strength**. The soil's internal strength includes friction, cohesion, and moisture content. Gravity and the soil's internal strength create a direction and magnitude called a vector (resultant). The resultant represents the lateral force of an unbraced trench wall. When the lateral force overcomes the soils internal strength, the soil will begin to move (accelerate), and the wall will collapse.

If the internal strength of the soil is greater than the lateral force, movement will not occur, and the trench wall will remain standing. That soil is considered to be "at rest". Soil that has been "at rest" may being to move as changes (water content, surcharged loads, vibrations, etc.) occur. When the lateral force overcomes the resistant forces, the soil will become "active", and the wall will eventually collapse.

Soil friction contributes to a soils "internal strength". Friction adds resistance. Angular shapes have more friction than rounded shapes. Soils with angular shaped particles are stronger than soils with rounded shaped particles because of the amount of friction. Dry sand will form a cone shaped pile when poured on a table. That is because the angular shape of the grains does not allow the particles to roll freely past each other.

Cohesion is an attractive force between like molecules. It is what makes clays "sticky". The shape and structure of its molecules which makes the distribution of orbiting electrons irregular when molecules get close to one another, creating electrical attraction that can maintain a macroscopic structure. Clay is the only soil type capable of electrical attraction (cohesion). The strength of clay is determined by the amount of water within the soil.

Moisture- under certain conditions, the presence of water can add strength to some soils, however, those conditions do not exist with open excavations. For trench walls, as the presence of water increases the strength of the soil will decrease and eventually the soil will behave as a fluid and "flow" into the trench. The presence of moisture compounds the hazards of trench failure as not only does the probability of failure increase but so does the unit weight of the soil.

Soil is made up of rock based material (grains), minerals, water (moisture), organic material and air. Since soil is made up of such diverse materials it is often divided into three basic types based on the size of the particles it contains. The basic types are sand, silt and clay. Most soils have a combination of clay, silt and sand. Sand has the largest particles and clay has the smallest. Sand particles can be seen by the naked eye. Clay and silt particles may only be seen with a microscope.

Soil is a multi-phase system composed of soil particles, air and fluid. The ultimate strength (resistance) of soil depends on the interaction of these phases or components. Typically, the more fluid (water) in the soil the weaker (lower the resistance) it is and the heavier it becomes. The heavier the soils is the larger the potential lateral force (typically) at failure. Clay material is typically lighter in weight than sandy soils but can yield larger failure surfaces along a trench face.

Although the range of soil weight can vary from about 80-150 pounds per cubic foot, a typical **unit weight of soil** is 115-120 pounds per cubic foot (pcf). That means that one cubic yard (27 cubic feet) of "typical" soil weighs about 3,240 pounds. Worst case scenario soil that can be found at a trench rescue (collapse) can weigh 135 pcf and a cubic yard can weigh 3,645 pounds.

In unbraced excavations the lateral earth pressure is the amount of downward pressure that is translated into a horizontal force. Factors that determine the lateral earth pressure include:

- Weight of the soil in pounds per cubic foot (pcf)
- Internal friction angle
- Cohesion
- Moisture Content
- Surcharged loads
- Strut activation forces

When rescuers shore trench walls, they need to know the maximum force that the soil could exert on the shoring. That force is best determined by using the worst case soil pressure (pounds per cubic foot) and multiplying it by the number of cubic feet of soil that each section of shoring will support.

The amount of lateral pressure exerted on the un-shored wall is about one third of the total force as measured on the bottom of any cubic foot. In a 6' deep trench, the force at the 4' level would be approximately 400 psf of vertical pressure. The lateral forces that could be expected would be approximately 132 psf. The distribution of lateral pressure occurs on about a 45 degree angle from the bottom of any given plane. When these lateral forces are released during a trench wall collapse, they result in a rotational failure, which is the most prevalent type of collapse.

- The most dangerous portion of the trench wall is the area about one fourth of the way up from the bottom. Although the pressure is greater at the bottom, the approximately 90-degree angle present at the bottom oat the trench wall provides a measure of stabilization.

Trench Collapse Causes

The reasons and indications of initial and secondary collapse of trenches and excavations are usually related to one or more of the following site characteristics:

1. Unprotected trench (lack of protection systems)
2. Static loads
3. Standing water or water seeping into the trench
4. Intersecting trenches
5. Vibrations (from vehicles, nearby roads, airports, etc)
6. Previously disturbed soil
7. Exterior cracking of trench walls

Trench Collapse patterns

Trenches fail in 7 ways

1. Spoil Pile collapse- where the excavated earth piled on the side of the trench slides into the trench
2. Slough-in collapse- where a below grade section of the trench collapses, leaving the potential for the collapse of an overhanging ledge
3. Shear wall collapse- where one side of the trench shears away from the wall of the trench
4. Toe failure- a slough failure that occurs at the bottom of the trench where the floor meets the wall.
5. Rotational failure- The result of a scoop shaped collapse that starts back from the trench lip and transmits itself to the trench wall in a half moon shape.
6. Wedge failure- failure of an angle section of earth at the inside corner of two intersecting trenches.
7. Bell bottom pier failure- slough failure that occurs at the bottom of the trench where the floor meets the wall, on both sides of the trench, leaving a bell shape. The lip is now a hazardous location to work with no support at the bottom of the trench.

Many conditions can ultimately lead to a trench collapse. While evaluating these factors, keep in mind that they can work synergistically to generate a very serious collapse situation. There is no definitive way to determine which one condition, or set of multiple conditions will cause a collapse.

- Water- The addition of water can add tremendous weight to soil. The effect water has on the soils ability to maintain its strength is critical. Some soils initially gain strength with the introduction of water, but then at some point get saturated and become weak.
- Freestanding Time – after a trench is cut it is subjected to environmental factors such as drying, wind and water. The freestanding time also is a ticking time bomb with respect to compressive forces that the trench can withstand. The longer the trench is open, the closer you are to natures attempt to fill it back in.

- Varying soil profiles- Because multiple layers of different materials demonstrate different strengths and friction coefficients, it is often difficult to state with any reasonable certainty how they will react in a specific incident
- Water Table
- Disturbed Soils

Trench Rescue Hazards (site safety considerations)

General hazards associated with search and rescue operations at trench and excavation collapses can present uniquely challenging situations. The most common hazards and the OSHA safety measures associated with trench and excavation sites include:

1. Collapse (cave in)
    - Any time a competent person encounters conditions where this is a potential for a trench collapse, protective systems are improperly installed or hazardous conditions are suspected, all employees must be removed from the area until the problems can be safely mitigated
    - No worker can enter a trench 5 feet deep or greater until proper protection is installed, or the trench walls sloped to proper back-slopes or steps and are declared safe by a competent person.
2. Struck by objects
    - Ensure that materials, equipment, and excavated soil is securely placed at least 2 feet back from the lip of the trench. Materials, such as pipes, should utilize restraining devices, or even better, be placed at 90 degrees to the trench axis to prevent pipes from rolling into the trench.
    - Anytime that materials are being lowered into a trench, the worker must place themselves away from the work so the load cannot fall on them or pin them against a wall or other materials in the trench.
    - High visibility vests should be provided for and worn by all employees that are working near areas of traffic and roadways should be completely closed if traffic cannot be safely re-routed around the trench area.
3. Underground utilities (natural gas, water, sewer, electrical, etc)
    - Utility identification and marking services should be engaged in advance of the digging to mark the location of utilities in the area of the planned trench. The utilities could include communications, electrical, natural gas, oil pipelines, water mains and sanitary sewers
    - Determine the exact location of utilities using hand digging, non-metallic probing, hydro excavating, or other safe methods
    - Remove, support, or protect any utilities that are within excavation to protect employees from the hazards they could present

4. Injured by falls
    - Trip hazards must be monitored and removed from the trench work zone.
    - Fall protection is not required unless the excavations are not readily seen because of plant growth or other visual barrier

5. Hazardous atmospheres (carbon monoxide, hydrogen sulfide, explosive and oxygen deficient air)
    - Air quality in trenches must be tested and monitored when to ensure safe levels of oxygen when issues could be reasonably expected to exist. This would be typically in or near landfills, contaminated ground or where substances are stored that could sink into the trench. Determination of the need for air monitoring is a key responsibility of the competent person.
    - Immediately upon the competent person determining that hazardous atmospheres could or do exist, the trench should be evacuated until the issues can be mitigated to ensure safety
    - Atmospheres with less than 19.5% oxygen are hazardous and require precautions to be taken to avoid employee exposure. Proper ventilation and air supplies would be methods to provide protection per subparts D and E of this standard
    - Atmospheres with flammable gases in concentrations measuring 20% of the lower flammable limit will require precautions, like ventilation with fresh air, to protect employees
    - It is important to provide continual air testing when controls are used to mitigate hazardous atmospheric contaminants
6. Hazardous materials (commonly gasoline, diesel fuel, solvents fluids) whether unearthed during the dig or brought into the trench by workers, it is better to assume that a hazardous material is present until proven otherwise.
7. Physical hazards (construction and rescue equipment around the trench lip)
    - Machines and other entrapping mechanisms could be a danger to rescuers.
        i. Just as in confined space lock-out/tag-out procedures, make sure you bring everything to a zero mechanical state meaning that you eliminate any possibility that any activation could occure.
    - The spoil pile and other material must have a 2 foot setback from the lip
    - Keep heavy equipment away from trench walls
    - Provide easily accessible means of ingress and egress for people entering protected trenches
        i. Trenches 4 feet or greater in depth must have a means of egress – via stairway, ladder, or ramp – every 25 feet maximum.
8. Water
    - Water can be a hazard at the scene of a trench collapse, whether in the form of groundwater or rain.

- If rain is imminent, start thinking about building a cover for the trench and establishing a method to divert incoming rain.
- The bottom line is to get existing water out of the trench, and do your best to see that no additional water gets in it. Have dewatering equipment on site.
- The addition of water can add tremendous weight to soil, the absorption rate will ultimately determine the total weight for any given volume of soil. Some soils initially gain strength with the introduction of water, but then at some point get saturated and become weak.

Safety Zones

Hot Zone: All spaces inside the trench and within a body's length from the trench lip.

Warm Zone: The area around the trench out to 50', access to this area needs to be controlled

Cold Zone: Everything from 50' out to 300', stop or detour any traffic within this space to limit or prevent any vibration.

The rescue area is that area immediately surrounding the trench and/or excavation site. Making the rescue area safe includes, but is not limited to, the following actions (however, specific actions should be based on both the type of collapse and the soil type):

1. Prohibiting entry into an unsafe trench/ excavation
2. Making the trench/ excavation safe for entry
3. Placing ground pads at the lip of the trench/ excavation
4. Ventilating the trench and monitoring its atmosphere
5. Utilizing sheeting and shoring to stabilize trench/excavation walls
6. Safely undertaking disentanglement operations in the trench/excavation
7. Dewatering
8. Supporting any unbroken utilities
9. Proving a helmet and goggles for a victim, if possible
10. Prevent the touching or operating of heavy equipment until its safety has been established

Components of Shoring

Sheeting and Shoring

- Shoring (struts)- the horizontal component of a trench shoring system
    - Timber: Timber posts can be used for struts and there is still tabulated data for shoring systems made from timber. The downside to timber shoring systems is that it is a time consuming process and there is no way to tell how much force is being applied to the trench walls from the cut to fit timbers.

- Screw Jacks: Ellis screw jacks can also be used in the construction of shoring systems, these are a little better than just straight timber but there is still no clear way to determine how much force is being imposed on trench walls when tightening the screw jacks.

- Aluminum Hydraulic (Speed Shore): Hydraulic shoring components are widely used in the construction industry. Depending on the soil type and conditions Speed shores can be used directly against the face of the trench without the need of FinnForm panels, unless there are signs of raveling and sloughing soil. Hydraulic shores do not have a collar that locks the strut into position after being charged and rely solely on the hydraulic system maintain the pressure, thus the pressures needed for hydraulic shoes are much higher than pneumatic, timber or screw jacks. These high pressures are very effective on trench walls that are intact and have stable soil conditions.

- Aluminum Pneumatic (Paratech)- Pneumatic struts use air pressure to extend the piston inside the cylinders to create pressure against the strong backs, panels and wales positioned on the trench walls. With pneumatic struts, once the desired air pressure is achieved, the struts must be mechanically locked.

- Sheeting

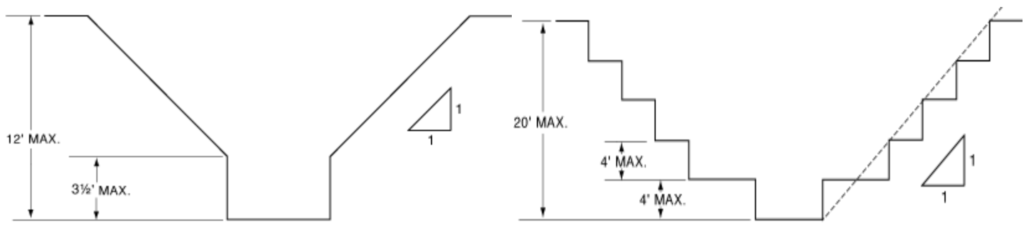
    - Finn Form- A composite plywood panel placed against the trench wall that keeps the wall from sloughing into the trench and helps distribute the force applied from the struts.

    - Plywood- Plywood has also been used in the same manner as Finn Form but recent tests have shown that plywood is significantly weaker than Finn Form panels and provides a false sense of security to rescuers in the trench.

- Wales: larger dimensioned lumber that is used to span large areas of trench walls without intermediate struts
    - Timber
    - LVL
    - Aluminum

Standard Construction Practices

Sloping/Benching: Sloping is referred to as cutting soil back to the maximum allowable slope, the point where the material can support its own weight and is not expected to flow. Sloping at a trench rescue scene should be at least 1 ½:1. Benching is creating a stair step effect on the trench wall with the rise over run cut back in accordance with the type of soil present.



OSHA Sloping Requirements		
Soil Type	**Slope**	**Angle (Degrees)**
A	3/4H:1V	53°
B	1H:1V	45°
C	1½H:1V	34°

Trench Boxes: The criteria for use are based on the manufacturer's data and the analysis of a competent person. If using a trench box at a trench rescue scene, the following issues need to be considered:

- Installation of a trench box may cause additional collapse. The issues of surcharged (backhoe/crane) loads, vibrations (heavy equipment) and collision of the trench box with the trench wall must be considered and resolved.
- Lowering or dragging a trench box, which can weigh several tons, into the area of a trench containing a victim may cause additional trauma. The rescue team must have strong indications that the trench box insertion will stay clear of the victim's position and location.
- The gap between the trench wall and the trench box sides should be **6 inches or less**. Backfill (e.g., airbags, backshores, and timber/soil) may be required to resolve larger gaps.
- The top of the box must either extend above the lip of the trench at least **18 inches** and any soils above the trench box must be cut back to their angle of repose (or otherwise be protected).
- The bottom of the trench max may be a maximum of **2 feet** from the bottom of the trench, and only if a competent person determines the soil will stand with o possible loss from behind or below the shield.

- The box must be **4 feet** longer than the rescue work area.
- Rescuers may never be outside the protection of the trench box or other protected area of the trench.

Interlocking Sheet piles: A common construction practice, panels can be easily maneuvered around existing utilities and they can be pushed into the ground at a depth that is appropriate for the type of soil and depth of excavation.

Soldier Pile and Lag Shoring: consists of sets of horizontally installed wales held in place by vertically installed piles.

Coordinating the use of heavy equipment

As a trench rescuer you must be capable of coordinating the use of heavy equipment at a rescue or recovery incident, which includes evaluating the capabilities and limitations of the operator and the equipment and establishing and maintaining communication with the equipment operator.

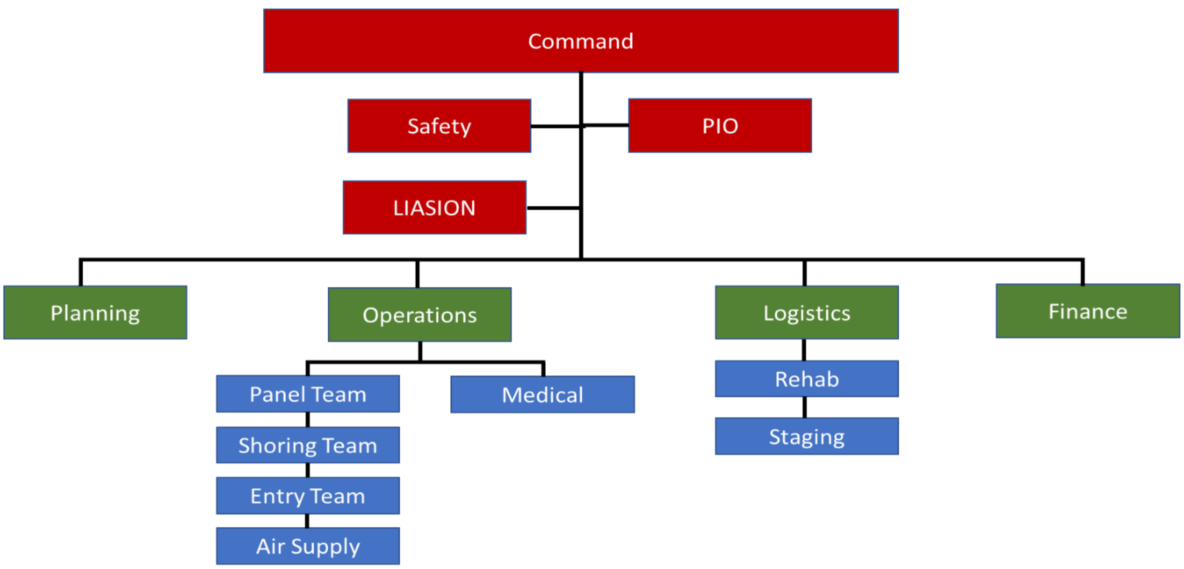
Once these components are in place, you can establish tactical objectives for the use of the equipment and for recognizing and avoiding related hazards, such as the pivot or swing areas, which are the radius around which the rotating cab can reach.
Equipment capabilities and limitations are objective and easy to determine based on the size and design of the machine. You can find this information by checking with the operator, looking at the chart in the cab, reviewing the operators manual (if on site) or measuring the components to determine the length (reach) of the boom/stick and the capacity (amount of dirt) of the bucket.

Determining the ability and limitations of the operator is much more subjective. Start by discussing the rescue plan with the operator. Determine the operator's emotional state and mental sharpness by giving him or her a chance to talk. If the operator is emotional (angry, fearful, etc.), cannot stay focused, or does not offer constructive suggestions to the plan, he or she should not be used. If the operator is calm and helpful, ask how many years of experience he or she has on that piece o equipment and how many times he or she has performed the objective (sloping, installing a trench box of sheeting, etc.) at hand.

Operations around a construction site are often noisy and hectic. When you add to that an emergency situation where people are often yelling and excited, the scene becomes especially challenging, noisy and stressful. Situations like this are common, where the various construction and rescue equipment we use, along with normal emergency radio traffic, can make it difficult to communicate on scene. This is especially true when you are dealing with construction workers who are operating equipment at a distance, making face-to-face communications impossible or impractical. In such situations, you must either establish radio communications and verify that there is no language barrier, or communicate through well-established hand signals.

ICS

The **Incident Command System** (ICS) is used by most fire departments to handle local emergency incidents. ICS was developed in the 1970s to deal with interagency responses to large-scale fire incidents. The incident management system (IMS) was later developed as part of the National Incident Management System (NIMS) of FEMA's National Response Plan. These systems were all developed to provide a coordinated interagency response to emergency incidents. With any command system, there will always be strategic, tactical and task levels. Someone will need to be in charge and other personnel will need to follow directions. Having a clearly defined approach to incident scene responsibilities and authority is critical to the safety of both victims and rescuers. In this class we will focus on the Task level functions of the Panel Team, the Shoring Team and the Entry Team



Task Level Teams

Panel Team

- Lip Safety
- Panel Placement
- Void Management
- Wale Installation
- Equipment removal
- Equipment Readiness

Shoring Team

- Ladders into the trench (as soon at the lip protection is in place)
- Trench Measurement
- Shoring Placement
- Shoring Removal
- Equipment Readiness

Entry Team – enters the trench to disentangle the victim(s) this may include digging below the installed shoring system and installing supplemental shoring components

- Recon (site assessment)
- Zoning
- Hazard Control
- Patient Stabilization
- Patient Extrication
- Lifting and Stabilizing Heavy Objects
- Equipment Readiness

Trench Rescue Course

Class Title:
Equipment and PPE

NFPA 1006 JPR's:
12.1.7 – Support an operations- or technician-level incident

Time:
1 hour

Objectives:
At the end of the lesson the rescuer should:

- Be familiar with common terminology for equipment used in the trench rescue environment.
- Demonstrate proficiency in the use and operation of Speed Shore shoring equipment.
- Demonstrate proficiency in the use and operation of Paratech shoring equipment.
- Demonstrate proper use of dewatering equipment.

There is a broad spectrum of equipment used in the trench rescue environment. This chapter will explore the various pieces of equipment used and offer some insight into the why and how the equipment is used. While each piece of equipment has its own function within the system the central purpose of each piece of equipment used in the trench rescue environment is to create a safe working space for rescuers and to protect the patient(s). This starts with dispersing loads at the lip of the trench with edge protection and bridging to bracing the walls of the trench to prevent or halt further collapse. Furthermore we try to mitigate environmental conditions inside the trench space by monitoring air quality, delivering fresh air when conditions warrant and pumping water out of saturated trenches.

There is a lot of assumed risk in the rescue world, but risk can be mitigated or assessed and assumed safely by knowing the equipment, how it operates and its working limitations. Let’s explore some of the equipment that is available within the R-E-S-E-T program that will more than likely be available on scene of a trench rescue.

Personal PPE

This section really doesn’t need more than a brief overview but as a rescuer working in and around the trench you should have at a minimum some sort of footwear that offers toe protection be it steel toe or composite toe caps with a steel shank to prevent sharp debris from penetrating the bottom of the boot. Long pants as well as long sleeves are necessary to prevent abrasions to the rescue as well as eye protection from debris and a helmet or hardhat to prevent head injuries. Lastly, gloves to protect your hands.

Trench Equipment

Air Monitoring

Trench falls under the umbrella of confined space and as with an industrial confined space incident we should be concerned about hazardous atmospheres in and around the trench. The first equipment around the trench should be air monitoring equipment that can look for any harmful vapors or hazardous gases above as well as inside of the trench. If air quality is bad then introduce clean air with a confined space blower fan.

Lip Protection

The first matter of protection at the trench site is to secure the lip of the trench with edge protection. The lip of the trench tends to be fragile and prone to sloughing into the trench, laying 2x8 or 4x8 sheets of plywood will disperse the rescuers weight and help to mitigate edge failures while rescuers evaluate the scene and perform general operations around the trench. 2’ x 8’ plywood may be necessary where there is not enough room to lay a full sheet of plywood but if room is available then the full sheet of plywood is the optimal choice. There may be instances where a spoil pile will not allow even the half width sheet of plywood to be laid down, in this case rescuers can place 2x12 lumber down and as the spoil pile is cleared away additional 2x12s can be laid down adjacent to the first to create a wider platform to stand on and in front of the first pieces placed until the lip is protected the length of the trench.

Trench Egress

Once the lip of the trench has been secured we need to place some ladders into the trench (unless there are already ladders in place). At a minimum ladders should be placed within 25 feet of persons working inside the trench.

Bridging

Following with increasing access in and around the trench Girders (made of LVL or dimensional lumber 6x6 or larger) should be laid across the trench, raised up on cribbing to help disperse the weight. Once the girders are set place scaffolding bridges parallel to the trench on top of the girders. This bridging can be moved to facilitate access to the trench at the lip and directly over the trench space.

Sheeting

Securing the trench walls is a matter of containing them with some form of sheeting and then applying a force against them to resist the trench walls urge to collapse in on itself. The most prevalent option for sheeting is Finn Form, in the past CDX plywood has also been an option and in some industry applications struts and rails can be placed on bare walls, depending on the soil type. In ReSET we will use Finn Form with Strongbacks glued

and screwed. Tests performed by the Michigan Urban Search and escue (MUSAR) have shown this to be the strongest configuration.
[All capacities listed below have been provided by tests conducted by the MUSAR group]

Strength Break Down for Various Forms of Sheeting

	Material	**Strength Rating**
Panel	CDX Plywood	1,100 lbs.
	Finn Form (14 ply artic birch)	3,800 lbs
Strong-back	2x12 sawn lumber	2,600 lbs.
	2x12 LVL (laminated veneer lumber)	7,400 lbs.

There are two methods of attaching strong-backs to the panel, the first would be to simply screw the strong-back onto the panel, the second and better option is to screw and glue the strong-back on. The introduction of glue creates a composite connection that significantly strengthens the bond between the two in turn drastically increasing the strength rating of the system as a whole.

Attachment	Panel Type	Strong-back	Capacity
Non-composite	¾" CDX	2x12 Sawn	3700 lbs.
Non-composite	¾" Finn Form	2x12 Sawn	6400 lbs.
Non-composite	¾" Finn Form	2x12 LVL	11,200 lbs.
Composite	¾" CDX	2x12 Sawn	18,100 lbs.
Composite	¾" Finn Form	2x12 LVL	48,600 lbs.

As stated earlier ReSET prescribes to the use of Finn Form with a composite LVL strong-back with a capacity of 48,600 lbs, this is to resist the lateral forces of soil which can reach up to 20,000 lbs and maintain a 2:1 safety factor.

Shoring

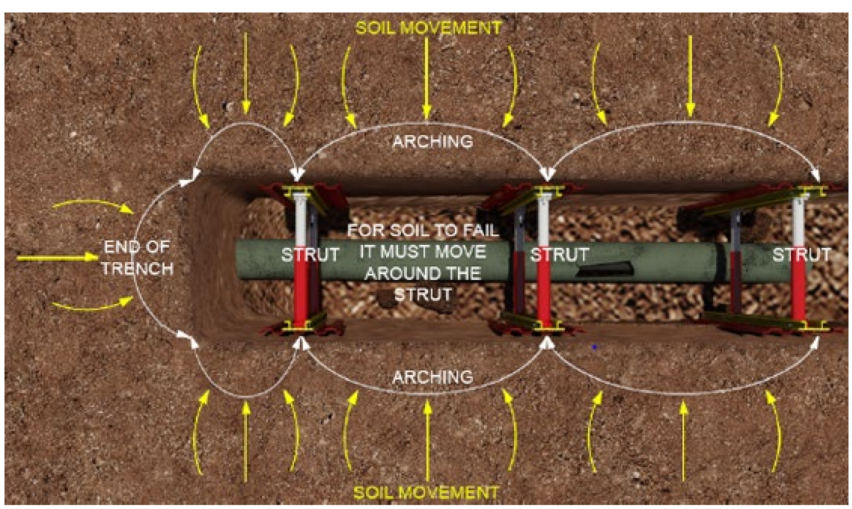
Panels are not self-supporting, there needs to be some form of shoring or bracing that will hold the panels tight against the trench walls. Shoring can be timber braces, hydraulic or pneumatic shores. Timber can be cut to fit and wedged into the trench against the panels or it can be cut short and held in place with a screw jack. We tend to steer away from the use of timber as there is no way to adequately measure the amount of force that is applied to the panels from the cut timber or the screw-jacks.

There are two types of shoring in the ReSET cache. They are SpeedShore Hydraulic Shores and Paratech Pneumatic Shores. Hydraulic shores are most commonly used in the construction industry and you are very likely to see them on a job site.

Speed Shore

Speed Shore hydraulic shores are quick and relatively simple to use. The shores consist of a hydraulic reservoir and pump that connect to a piston, when fluid is pumped the piston extends the cylinder a predetermined length. The extension cylinders can be traded out for longer or shorter pieces depending on the width of the trench. The extension pushes the rail bases out and against the panel. The cylinders are competent to a minimum of 23,000 lbs. axial loading with a 1.5:1 safety factor.

It is common on jobsites to see the rails set against bare soil with no panel in between, this is an acceptable practice on job sites when the soil conditions are known, and the cut is fresh. Hydraulic shores operate on the principle of soil arching meaning that in competent soil when a force is applied against the face of a cut the pressure exerted on the soil will create an arc of pressure behind it, when struts are spaced and appropriate distance apart from each other the arcs work to hold the soil in place, sort of like a pressure induced fence. When there has been a trench collapse the soil no longer has the integrity to maintain the pressure in the shape of an arc therefore panels must be placed against the trench wall to prevent sloughing or further collapse.



Speed shores operate in the pressure range of 750-1500 psi which helps induce the arcing. When a hydraulic shore is charged to 750 psi the force exerted on the trench wall is 2,355 lbs and at 1500 psi the force exerted on the trench walls is 4,710 lbs.

ReSET uses the Rescue Shores from Speed Shore, these are different from the ones used in industry on jobsites, and the only difference is that our rail bases can pivot up to 15 degrees to account for trench walls that are not straight, the industry bases do not pivot. The shores are split into two categories based on the stroke length of the pistons of either 12 inches or 30 inches with 4 different lengths of cylinders per stroke length.

Trench Rescue Shore Table TRS-1									
Model	Extension In.	Length		Cylinder Stroke In	Shore Spacing		Max Depth Ft	Over Sleeve	Close Sheeting Required
		Min In	Max In		Horizontal Ft	Vertical Ft			
VTR-1.5-36	None	24	36	12	4	4	20	Alum.	Yes
	11	35	47	12	4	4	20	Alum.	Yes
	22	46	58	12	4	4	20	Alum.	Yes
	33	57	69	12	4	4	20	Alum.	Yes
VTR-1.5-84	None	54	84	30	4	4	20	Alum.	Yes
	24	78	108	30	4	4	20	Alum.	Yes
	42	92	126	30	4	4	15	Alum.	Yes
	56	110	140	30	4	4	13	Alum.	Yes

Using Speed Shores

1. Measure the width of the trench and then select the appropriate shore
    a. Remember to account for the Finn Form and Strong-back, then subtract that from the measured width.
2. To switch Cylinder lengths
    a. Pull the pin holding the current cylinder
        i. The shores are stored in their shortest configurations which connects the inner sleeve to the rail base. Any extension will need two pins to connect the inner sleeve and the cylinder to the rail base.
    b. Insert the piston into the new extension
    c. Pin the cylinder to the inner sleeve
    d. Pin the cylinder to the rail base

3. Connect the hydraulic hose the pump and cylinder
    a. It's not a bad idea to leave the pressure valve open in case the shore needs to be compressed when inserting into the trench and then close it when it is time to extend the shore.
4. Lower the shore into the trench with the hook tools
5. Charge the shore to a the green range on the gauge between 750-1500 psi
6. Remove the hydraulic hose from the shore
7. Connect the hose to the next shore and repeat the installation process until the appropriate number of shores are set (according to the trench depth and the number of panels installed)

Paratech Struts

Paratech struts are also a versatile option for shoring. Similar in concept to the Speed shore struts in the sense that they transfer the load from one trench wall to the other yet different in that they use pneumatic pressure instead of hydraulic pressure to extend the strut. There are also a few other key differences that separate the two systems. By using pneumatic pressure instead of hydraulic there is a lower activation pressure exerted on the trench wall by the paratech struts somewhere in the range of 980- 1200 lbs vs 2300-4700 with the speed shore. In addition to the exerted pressures, Speed Shores don't have an option to lock the strut in place once charged, the integrity of the system depends on the system maintaining hydraulic pressure, where-as with the Paratech struts, there are locking collars to ensure that the struts will not collapse once charged.
There are two versions of the struts, the Acme Thread struts which are grey in color and the Longshore Struts which are gold in color. The grey struts are 3 inches in diameter while the gold struts are 3 ½" in diameter.
The grey struts can support a maximum of two extensions for a total length of 3 feet between the two and the charging pressure for the grey struts is a max of 250 psi. Grey struts are labeled based on their length in inches

Grey Struts	
Strut	**Extension**
12-15	6
19-25	12
25-36	24
37-58	36
56-88	

Grey Struts		
Length	**Load Rating 2:1**	**Load Rating 4:1**
2’	43,500 lbs	21,750 lbs
4’	40,000 lbs	20,000 lbs
6’	28,250 lbs	14,125 lbs
8’	24,050 lbs	12,025 lbs
10’	10,750 lbs	5,360 lbs
12’	7,660 lbs	3,830 lbs

The gold struts can support only one extension up to a max of 6 feet long (unlike the greys with a max of 3 feet) and the charging pressure for the gold struts is a max of 175 psi. Gold struts are labeled based on their length in feet

Gold Struts			
Strut	**Length**	**Extension**	**Length**
203	26”-36”	135	12”
304	36”-50”	235	24”
406	48”-73”	435	48”
610	72”-116”	635	67”
1016	114”-198”		

Gold Struts		
Length	**2:1**	**4:1**
2	44,000 lbs	22,000 lbs
4	44,000 lbs	22,000 lbs
6	44,000 lbs	22,000 lbs
8	40,000 lbs	20,000 lbs
10	24,000 lbs	12,000 lbs
12	20,000 lbs	10,000 lbs
14	12,000 lbs	6,000 lbs
16	6,000 lbs	3,000 lbs

Using Paratech Struts

1. Measure the trench width and depth and then select the suitable shore.
    a. Remember to account for the Finn Form and Strong back and to subtract that distance from the overall measurement
    b. When selecting struts and extensions the user must account for the the bases add. Optimal choice is to use a swivel base on each end to account for irregularities in the trench wall, next would be a single swivel and a solid base and last option would be two straight bases. When straight bases are used take into consideration that they may not seat flush against the panel, this lessens the surface contact and increases the loading point the panel,

shims should be placed to help disperse the load and ensure that solid contact is retained throughout the base plate and Finn Form connection.

Base	Length
Solid Base	1” each
Swivel Base	1 ¾” each
Swivel and Swivel	3 ½” Total
Swivel and Solid	2 ¾” Total
Solid and Solid	2” Total

c. After struts and extensions have been selected, connect the air hose to the strut and lock the collar.
d. Secure a rope on each base end to lower the strut into the trench.
e. Lower the strut to its working point and then soft charge to 50 psi
f. Increase psi in 50 psi increments until the set pressure of 175 for golds or 250 psi for greys is attained.
g. Spin the collar to lock the strut
h. Release the air pressure and remove the air hose from the controller end, leave the air hose connected to the strut but tie it off to the Finn Form along with the ropes used to lower the strut into the trench.
i. Repeat the process until enough struts have been placed to satisfy the needs of the trench.

Wales

Wales are horizontal members used to span a large areas of trench walls, this could be at the end of intersecting trenches where there is no direct strut support directly across from the panel or to cover voids in a trench wall. Wales can be dimensional lumber, LVL lumber or metal plate systems specific to each of the strut manufacturers.

De-Watering Equipment

There are times when the trench will have an accumulation of water that needs to be removed be it from rain or if the trench is below the water table. A trash pump will be the best option for removal.

For best performance, place the pump near the water level, and use hoses that are no longer than necessary; this will allow the pump to produce the greatest output with the least self-priming time.

Discharge head capacity is always greater than suction head capability, so it is important for suction head to be the shorter part of total head. The maximum suction head will vary based on the operating conditions, however, the suction head can never exceed 26 feet and should always be kept as low as possible.

Pump Operation

1. Install the suction hose to the intake side of the pump and ensure that the strainer is securely attached. Place the strainer into the trench where water needs to be removed (Never operate the pump without the strainer installed)
2. Connect the discharge hose to the outlet side of the pump and lay out hose in such a way that water will not redirect back into the trench.
    a. If the discharge hose must be run across a roadway, the hose should cross perpendicular to traffic flow and have heavy boards placed next to it for the vehicles to drive over.
    b. Driving over a discharge hose with the pump is running could cause pump case failure.
3. Prime the pump – before starting the engine, remove the filer cap from the pump chamber and completely fill the pump chamber with water (almost 4 gallons). Reinstall the filler cap and tighten it securely.
    a. Operating the pump dry will destroy the pump seal. If the pump has been operated dry, stop the engine immediately and allow the pump to cool before priming.
4. Starting the Engine
    a. Move the fuel valve to the on position
    b. Move the choke to the appropriate position
        i. Closed if the engine is cold
        ii. Open if the engine is warm
    c. Move the throttle from SLOW to about $1/3^{rd}$ of the way toward FAST
    d. Turn the ignition to ON
    e. Pull the starter cord
    f. If the choke was closed then move it to the open position
    g. Move the throttle lever to the FAST position for self-priming and check the pump output
    h. Pump Output will be controlled by the engine speed

Trench Back Fill

Often times the face of the trench will slough off creating a void space. In order for our shoring to be the most effective the void space needs to be filled. The fundamental process of shoring unstable soils is to Collect, Transfer, Distribute and Resist the Loads, there must be a continuity of load transfer from one trench wall to the other thus the void must be filled. There are several methods used to address the void spaces:

1. Duffage- this involves throwing excess spoil dirt and cribbing behind the panel to eat up space, while this does indeed fill the void it is difficult to compact from the trench lip, when the shores are charged into the panel the soil will compress but

will still allow for movement and this method does not really create a solid interface between the panel and trench wall. If wood is used, it is important to create a minimum 24” x 24” contact area between the panel and the existing wall directly behind the strut.

2. Airbags- The void can be filled with low pressure airbags, the bag is placed behind the panel and charged slowly until the panel is pushed slightly into the trench, a shore is then charged against the panel slowly until the panel registers movement back toward the face of the trench. From this point the airbag and shore are feathered until the shore reaches it set pressure.

3. Back-Shores- are a method of bracing the panel from behind, usually midface or a little higher. Struts run from the back wall of the trench up against the back of the panel so that when the face of the panel is charged the load makes a complete transfer from wall to wall.

4. Buttress Shores- are a method of bracing a panel from behind. Struts brace off a wale that is set outside of the trench and run to the back of the panel near the top.

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Trench Rescue Course

Class Title:
Strategies, Initial Actions and Approach

NFPA 1006 JPR's:
12.1.1 – Interview a witness or "competent person"
12.1.2 – Facilitate a non-entry rescue or victim self-rescue
12.1.3 – Size up a trench rescue incident
12.1.4 – Size up a trench rescue incident so that the scope of the rescue is determined and information required to develop an initial incident action plan is obtained
12.1.5 – Recognize incident hazards and initiate isolation procedures

Time:
2:00 hrs.

Objectives:
At the end of the lesson the rescuer should be able to:
- Describe the phases of a trench rescue operation
- Demonstrate proper size up of a trench rescue scene
- Describe initial actions to undertake prior to initiating trench entry
- Identify differences between non-entry rescue and entry rescue
- Perform atmospheric monitoring
- Identify proper PPE for trench entrants
- Identify and describe the organizational functions and the task at a trench rescue
- Demonstrate understanding of and implementation of an Incident Action Plan for a trench rescue

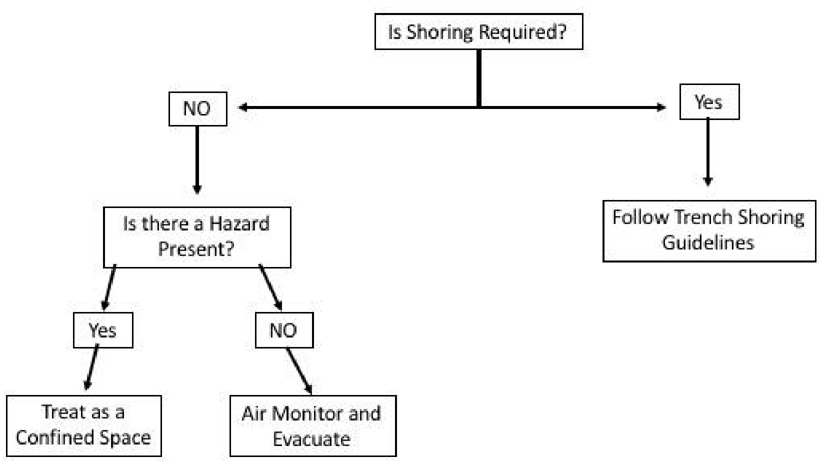
Type of Trench Emergency

- Is this a collapse in the trench fully or partially burying a patient(s)?
- Is this a medical/evacuation issue in a secured or stable/properly protected trench?

The type of trench emergency will drive the operation. The first trench emergencies are those where there is a collapse with partial or complete burial. If there is any collapse of the trench, this will lead to a trench shoring operation. The severity of the collapse, the estimated amount of material, and estimated depth of burial will all factor into the survivability of the event. These factors should be considered as the incident strategy (rescue vs recovery) is established and initial actions are being undertaken. It is important to consider a Risk Benefit Analysis. Some guidelines that may be used for the Risk/Benefit Analysis can be:

1) Incident Strategy (rescue vs recovery)
2) What is the risk to the rescuer
3) What is the benefit of a given action
4) Decisions must be made with your head over your heart (be analytical and not emotional)

The second type of trench emergency is when a patient has a medical emergency inside a trench without any failure of the trench. Often in these circumstances the trench is safe for entry without performing shoring operations. This will include those situations where the excavation does not require shoring, and those situations where shoring is already in place and deemed adequate after inspection.



Trench Rescue Decision Making

As rescue personnel evaluate the type of trench rescue operation, the above flow chart/decision making process can help in determining needed actions. As the evaluation is being performed, and no shoring is required to make patient access, if an atmospheric hazard is present Confined Space rescue procedures need to be followed. If no atmospheric hazard is found then proceed with entering the trench for patient evacuation.

Rescue Strategy

The Rescue Strategy is identified by those types of incidents where the patient is alive and requires assistance. The action plan will be formulated after the initial size up of what happened, what type of rescue operation is required, what are the injuries and number of victims, what are the available resources, and what resources are needed to successfully and safely complete the operation.

Recovery Strategy

The Recovery Strategy is identified by those types of incidents where the patient is deceased or time/conditions indicate survivability is highly unlikely. Recovery operations will need to be coordinated with Law Enforcement and notification of additional proper authorities. OSHA should be notified in the event of any emergency response to a trench incident. During Recovery operations there will be a more methodical approach and the sense of a hurried operation should not be present. Consideration should be given to utilize any trench boxes or onsite trench protection systems.

Confined Space Considerations

A Trench is considered a confined space. The knowledge, skills and abilities gained from being trained in confined space can come in handy. Working in a tight space, encumbered by PPE and obstacles in the work space and working while tethered (i.e. retrieval line) are just a few parallels. Additional familiar problems are typically restricted access and evacuation requiring mechanical advantage or rigging.
A conscious effort should be made to manage the rescue operation with a confined space mind set throughout the incident where it applies. Atmospheric monitoring, back up team, swapping out entrants (work cycles), high help are several related areas.

Common features of a confined space and trench are:

- Large enough and configured so a person can enter the space
- Limited means of Entry/Exit
- Not designed for continuous occupancy
- Has actual or potential hazardous atmosphere
- Material with potential to engulf the entrant
- Internally configured to trap or asphyxiate entrant due to converging walls, slopping/tapered floors
- Any other recognized serious safety hazard

Monitoring

Personnel should be assigned to monitoring the trench. Monitoring encompasses not only atmospheric monitoring but also monitoring conditions and hazards of the trench itself. The preferred method is to start away from the trench and walk toward the trench taking note of hazards, spoil pile location, soil conditions (cracks, class, moisture...), and ongoing trench conditions as shoring operations continue. When conducting air monitoring remember the Confined Space approach of:

A-APPROACH	(as you approach trench end)
A-ABOVE	(Above the trench, lighter than air)
B-BOTTOM	(Heavier than air)
C-CENTER	(Center/throughout middle area)

Air monitoring should be done prior to entry and every five minutes if necessary. The atmosphere should be monitored for Oxygen, Flammability, and Toxicity. Refer to the Confined Space Curriculum for atmospheric requirements and monitoring principles.

Monitor considerations:

1. Always assume there is something in the trench (an unknown)
2. Specific actions to take when a monitor reads certain levels
3. Notify Command/Operations/Safety with any change in monitor readings
4. Allow time for the air to draw through the tubing
    a. 5 seconds per foot of tubing
    b. Total tubing, not just length in the hole
5. Allow time for the sensor to react
    a. PID- 10 sec
6. Combustible Gas Detector (60Sec-4Min)
    a. Check the peaks/clear the peaks

The air readings will need to be recorded as part of the IAP throughout the operation, at five-minute intervals, until all personnel are out of the trench.

Personal Protective Equipment:

At a minimum all rescuers in the hot zone and warm zone be wearing a helmet and have gloves, eye protection and hearing protection available on their person. Support and Entry teams should be wearing long pants and long sleeve shirt/jacket to protect from abrasions and cuts. Sturdy boots will be worn. Additional PPE considerations should be dictated by air monitoring. I.E. SCBA, supplied air, N95

Personnel at cutting stations should be mindful to adhere to safe cutting practices and eye and hearing protection. The safety officer should be encouraged to monitor all functional task groups throughout the operation.

Travel Restriction

Travel Restriction should be considered when appropriate. Deep Trenches present a higher injury potential if a slip were to happen. Slippery or off camber working areas can also increase fall probability. In any of these situations it would be advised to consider travel restriction. However be mindful of adding trip hazards around the trench lip.

Initial Actions:

First units on scene will most likely be Regular Operations Fire units and other support agencies (police, EMS). Once a size up is given initial actions can begin to make the scene safe and prep for stabilization and entry. The following items need to be addressed:

- Identify the **Competent Person** or someone who can account for workers on scene.
  - Have the initial crew confirm it is a trench operation with a patient.
- **Approach** the trench from the end for initial size up
  - No entry should be made by initial response personnel if there is sign of a trench collapse and shoring is not adequate or present.
- The trench itself and a body length from the trench lip should be considered the **Hot Zone** and personnel should not spend time in this area unless secured from falling into trench
- Secure, lock out tag out, all machinery in the **Warm Zone** (50’ radius)
- Place a **ladder** in the trench for immediate egress. This should be at a stable location, end wall, or as near the pt as possible. OSHA dictates ladders be at any given time within 25’ of a person operating in a trench. Ideally you should try to have a ladder within 15’ of rescuers on either side of the trench rescue work area.

Additional Actions

- Protect the lip using ground pads or lip bridges
- Perform non-entry rescue if possible
- Utilize personnel to start establishing a Cold Zone of 300' with a focus on access corridor and appropriate location for staging and assembly areas.

Non-Entry Rescue Procedures

The preferred way of rescuing a patient from a trench is not putting us in the trench and in harm's way. Appropriate methods are:

- Direct the victim to self-rescue
- Ladders, ladder raise
- Cinch Collar
- PMI Harness (diaper)
- "Wristlets"
- Lower SCBA to the patient
- **ALWAYS** resist the urge to go into the trench
- **NEVER** attempt to pull a partially buried victim (must be able to see tops of feet)

By directing the victim to self-rescue they may be able to start digging themselves or others out if they are able. If coworkers are in the trench after a collapse they need to be directed out. Do not allow coworkers back into the trench and have police assist if help is needed to control co-workers at the scene. Self-rescue may be achieved by any of the options listed above or by thinking outside of the box.

Trench Size up:

Assess the Trench Lip
- Stable vs unstable
- Ground Pads vs Lip Bridges

Assess the Trench
- Measure Depth, Width
- Wall Angles
- Identify trench failures

Assess the Collapse Potential
- Impending collapse
- Undercut, Fissures, Bulging, Sloughing
- Surcharged Loads

Assess the Voids
- In order to identify best backfill technique identify:
  - Void size
  - Void Wall Angle
  - Open or closed lip void

Assess Patient Condition
- Rescue vs Recovery
- Undetermined

Assess Hazards
- Air Monitoring
- Water / Utilities
- Environmental

Ground Pads

- Best use of ground pads are when trench walls are stable

4’x8’ sheets of ¾” plywood are used to distribute the weight of rescuers on the lip. 2’x8’ sheets can also be used but do not offer the same distribution potential. 2” x12” lumber can be used on the spoil side of the trench while moving the spoil pile. Ground Pads help distribute the weight of rescuers but do not eliminate the load above weakened walls and offer little to no protection to those standing on them. Ground pads can cover up warning signs of impending collapse.

Lip Bridges

- Best use of Lip Bridges are whenever the walls are unstable or have collapsed resulting in significant voids in the walls

A bridge is built with decking (plywood), beams (ladders or lumber), girders (timber) and supports on ground pads (timber placed away from trench wall used to elevate the bridge). Bridges allow rescuers to work directly over the trench while placing shoring. Do not overload the bridges or girders with too many rescuers.

Division of labor on scene

Panel Team

- Lip Safety – ground pads and lip bridges
- Panel Placement
- Void Management
- Wale Installation
- Equipment Readiness
- Equipment Removal

Strut Team

- Ladder Placement
- Trench Measurements
- Strut Placement
- Equipment Readiness
- Strut Removal

Entry Team

- Recon (Site Assessment)
- Zoning
- Hazard Control
- Patient Stabilization
- Patient Extrication
- Stabilize / Lift Heavy Objects
- Equipment Readiness

Pre-Entry Briefing

Prior to entry into the trench there needs to be a pre-entry briefing. This should be conducted after a non-entry rescue has been ruled out. This should be simple, direct and brief. The point of the Pre-Entry Brief is to place every responder on the same page understanding the selected tactics to be implemented for the entry. Start from an outside view towards the trench. A brief overview of Who, What, Where, and specific tactical objectives to be completed (and by whom) is a good start. This allows the IC/RGS to verbalize the plan of action and hazards for others to understand the scope of the operation, their part of the operation and question openly.
In short, a brief summary of the incident with pertinent details (your Incident Action Plan). A Pre-Entry checklist may facilitate a timely and concise briefing.

An example of some items include:

- Collapse or no collapse
- Goal and mode of operation
- Air monitoring conditions
- Number and suspected condition of pt(s). (buried, partially buried, medical)
- Teams
- Protective system
- Safety and safety requirements
- Accountability (zones)
- Emergency procedures for back up team/RIT

Trench Rescue Course

Class Title:
Securing the Trench

NFPA 1006 JPR's:
12.2.1 – Identify potential hazards in and around a trench excavation
12.2.2 – Implement a hazard control plan given a trench collapse incident
12.2.3 – Develop a shoring plan for a non-intersecting trench no more than 8' deep
12.2.4 – Implement a shoring plan for a non-intersecting trench no more than 8' deep
12.2.7 – Disassemble support systems at a trench emergency incident
12.2.8 – Terminate a technical rescue operation

Time:
8 hours

Objectives:
At the end of the lesson the rescuer should be able to:

- Perform the necessary steps of the pre-entry check
- Perform placing ground pads or lip bridges
- Perform placing the side panels of the trench
- Demonstrate how to place Paratech struts inside the trench
- Demonstrate how to place Speed shore struts inside the trench
- Perform backfill and Back shoring techniques
- Perform setting Walers
- Perform removal of shoring

Pre-entry check

The steps of the pre-entry check are as important as the rescue itself. If we miss or skip steps in the trench environment it could easily result in one of our own getting hurt and further complicating the situation. Pre-entry checks act as the safety check prior to making entry into the hole and can be done as the site is getting set up by other team members. We need to make sure that the pre-entry check is completed but we do not have to stop operations to do so.

The site safety officer should be one of the first positions assigned by the IC. The safety officer is then responsible for completing the pre-entry check as part of their duties on scene. Some of the things the site safety officer will be responsible for are:

- Making sure safety measures are being followed throughout the rescue
- Confirm air checks inside the trench are within safe limits
- Filling out site safety form (not created yet)
- Keeping a clean work space inside the hot zone
- Use spray paint (when available) to mark areas of specific concern
- Meet with both the rescue group supervisor and the IC (if not the same person) to confirm overall strategy for rescue and removal of all people from scene
- Work with the medical division to set up rehab and treatment area

Panels

Panels are constructed with 1.75”x12” LVL lumber (strongbacks) glued and screwed to ¾” Finnform (4’x8’ treated birch panels). **Panels will always be carried by a minimum of 2 people.**

Finnform is used in conjunction with strongbacks in order to withstand the lateral forces of active soil. Panels must have a minimum of 2 struts with a maximum 4’ horizontal and vertical spacing, with the top and bottom strut being a max of 2’ from the lip and floor.

The placement of the first set of panels is going as close to the patient as possible. Once the first set of panels is in place and all struts properly charged we should be able to get a rescuer safely into the trench to begin working. Maximum of 2 people per panel set.

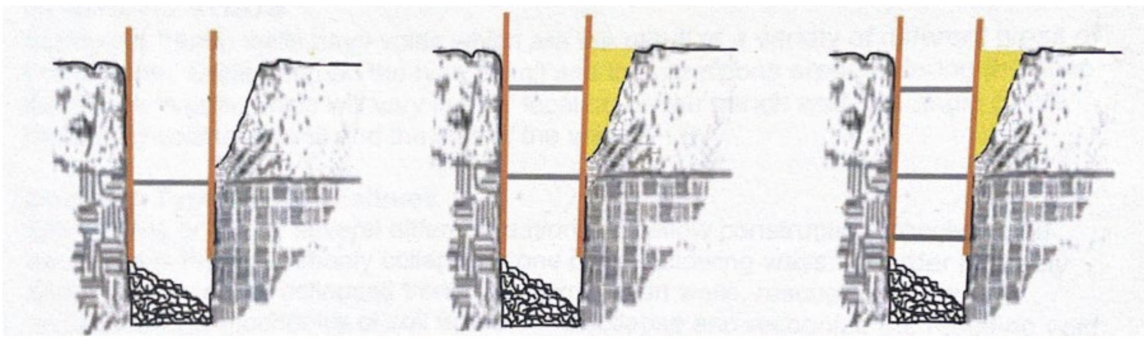
When determining how many sets of panels to place a good minimum rule to follow is to make our systems at least as long as the trench is deep. A better plan, if you have available resources, is to cover the minimum length and then add one more section. This will create a larger safe zone for our team members inside the trench and for our patient. When talking about the safe zone we are creating an understanding that the true safe zone will only be established after the panels have been fully pressurized by the struts.

Struts

The best practice is the use of struts that can be installed and removed without entering the trench, non-entry shoring. Struts should have adjustable lengths and controllable activation pressures. Activation forces of 1000-1250 punds. (Paratech gray @200-250 psi; Paratech Gold @150-175 psi). Speedshore to the green.

Shoring the area directly above a collapse is best accomplished by:

1. Install positioning strut- to hold panels on the trench walls
2. Install backfill strut – at a variable force and backfill the void
3. Install Compliance Strut – when necessary, to comply with strut spacing



Position Strut Backfill Strut Compliance Strut

The spacing of struts is 2-4-2. That means that the top strut is to be placed two feet down from the top, the next strut and each one after that four feet down from the first. The bottom strut will be placed no farther than two feet up from the trench floor. The bottom strut may be set closer than two feet above the bottom provided that it is not more than four feet from the above strut. For an 8-foot trench we would only need to place two struts. Note; while following the 2-4-2 method, nothing restricts the rescuer from adding additional shores as desired.

Strut Installation

When lowering the strut it is best to have one person at the end of the trench calling the commands. This person will direct each person holding the webbing/utility rope into the exact spot needed so it can be pressurized. We want them as close to horizontal as we can get.

When the person guiding the placement is ready we can pressurize the strut. We are not going to go to the full pressure of securing the strut all in one motion. It is recommended to use an initial pressure of 50PSI. As pressure is increased, it should be increased in increments of 50PSI, up to 200 psi as our final set pressure in this course. After the initial pressure is set on the strut we spin the collar to lock and then verify that everything is still correct. Ensure that nothing has slipped, moved, or otherwise gave us cause for concern when pressurizing the strut.

When we are tightening the collar on the strut is where a third rope or strut release tool would be helpful. You can use the tool to tighten the collar if you have one or if you have utility rope slung around it you can pull the rope in a manner that it spins the collar closed. This allows you to secure the collar from a safe location outside the trench.

Once all the struts are placed on a panel set, we will simultaneously charge all to 200 psi for their final pressure.

Primary Shoring

Panel Team

- Protect the lip of the trench using ground pads or lip bridges
- Place 1st set of panels (Primary) to protect the patient
- Begin void management

Shoring Team

- Place Ladder(s) in trench
- Size Up the trench
- Install 1st set of struts on the primary panel set
    - Backfill strut may be pressurized lower until backfill is ready

Secondary Shoring

Panel Team

- Install additional panels as to provide a safe zone to work in
- Minimum 3 panel set or as wide as the trench is deep

Shoring Team

- Install remaining struts on additional panels
    - Primary struts followed by backfill/compliance struts

Complete Shoring

- Nail all strut bases
- Finalize any supplemental shoring

Walers

- 6”x6” lumber or 7”x7” LVL beams
- Wales should extend 24” beyond struts
- Gaps between the wale and Finnform should be filled with spacers 12” long at the overhanging edges and at the seams of contiguous panel.

Back-Fill

Material and equipment that helps collect the load, distribute the load, and minimizes soil movement.

Air bags

- Best for voids between 18”-40”
- Open lip voids must have back wall angles between 90-70 degrees

Wood

- Best for voids accessible from the lip between 2”-12” beyond the trench wall
- No more than 2 pieces of wood stacked in the same direction.
- Wood should not be placed in the hole until one strut has pressurized the panel set
- Create a minimum 24”x24” contact area between the panel and existing wall directly behind the strut

Soil

- Best for voids accessible from the lip up to 18” beyond trench wall
- Soil from spoil pile may be shoveled into lip voids after the panels and at least one strut is in place
- Soil must be compacted

Backshores

- Best for shores accessible from the lip and greater than 40" or largest air bag
- Struts on the backside of panels or walers. They must have a near vertical surface 970-90 deg.) behind them with a minimum coverage of 24"x24" panel on the trench wall.

Buttress

- Best for large lip shear voids which have left low angled walls.
- Can be timber or aluminum struts
- Supports the back of a panel at the level of the lip. Used to resist the movement of opposite wall using the strut positioned 2 feet below the lip.

Ladders

Initially, during the placement of panels, one ladder shall be placed into the trench as an emergency egress. Now that all pieces of our trench are in place and secured the only thing left we have to do prior to entry is to ensure that a second ground ladder is placed on the opposite side of the first. We are always to have a minimum of two ladders inside the trench when our crew members go down to begin working. This will provide an emergency egress point on either end of our work space. All ladders will need to be within 25 feet of our rescuers working and if we are to continue setting panels down the length of the trench to where we exceed the 25 foot mark for our exit point, additional ladders will need to be placed accordingly.

Trench Rescue Shoring Plan

STEP 1 – Trench Size Up
STEP 2 – Primary Shoring
STEP 3 – Secondary Shoring
STEP 4 – Complete Shoring

STEP 1 – Trench Size Up

- Assess the lip – Install lip protection, ground pads and lip bridges
- Assess the trench – Measure depth and width of trench, determine wall angles. Identify trench failures.
- Assess collapse potential – Identify signs of impending collapse, fissures, water, surcharge loads, etc.
- Assess the voids – In order to identify the best backfill technique we must know void size, angle of void backwall and open or closed lip void.
- Assess the victim – Victim condition will dictate the calculated risk benefit analysis.
- Assess Hazards – Air Monitoring, Utilities, Environmental

STEP 2 – Primary Shoring

Install primary shoring in order to rapidly provide protection to the victim by stabilizing the trench that is most likely to collapse. Strut pressures are sometimes temporarily set lower until backfill can be installed.

STEP 3 – Secondary Shoring

Install secondary shoring to provide a safe sone for rescuers to work. We aim to build a minimum 3 panel set or as wide as the trench is deep.

STEP 4 – Complete Shoring

Maximize the safety of the rescuers and victim during removal operations. All struts are pressurized, all strut bases are nailed and supplemental shoring is in place.

Shoring Performance Assessment

Evaluate and adjust shoring to maintain safety. Inspect all shores every 30 minutes. Things to look for:

- Struts loosening – adjust strut activation mechanism
- Increased soil forces – Panels/wales bending. Having wood in your shoring provides warning signs (creaking, groaning, popping,etc.)
- When signs of loading appear, add struts between existing struts.
- Expand shoring to support adjacent trench walls that show moving.

Removal

Once all work has been completed in the trench and we are ready to begin to pack up a few things have to be kept in mind. The tear down portion of the trench is when people tend to get sloppy and cut corners. This will result in team members getting hurt unnecessarily. At this point in the scene everyone is tired and ready to leave but we cannot simply rip pieces out and pack up. We have to go step by step in removing the components in the reverse order in which they were placed.

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Trench Rescue Course

Class Title:
Straight Wall trench Shoring Greater Than 8’

NFPA 1006 JPR’s:
12.3.3 – Develop a shoring plan for a trench more than 8’ deep
12.3.4 – Implement a shoring plan for a trench more than 8’ deep
12.3.6 – Install supplemental sheeting and shoring for each 2’ of depth below an existing approved shoring system.

Time:
3 hours

Objectives:
At the end of the lesson the rescuer should be able to:

- Describe the concepts of shoring greater than 8 feet deep trenches
- Identify tabulated data for greater that 8 feet trench shoring systems
- Identify hazards specific to Greater than 8 Feet trenches
- Demonstrate and build a shoring system greater than 8 feet

Trenches Greater than 8 Feet

The hazards found in the 8' and deeper trenches include all those covered in the previous lesson. However, the deeper the trench the more likely the collapse, making deeper trenches more hazardous. The amount of exposed wall and the weight of the dirt are hazards that must be considered. Excessive lateral forces and deep vertical/near vertical walls can cause sudden wall failure.

Deep trench shoring relates to trenches deeper than 8 feet from the lip. A determination of trench depth must be part of the initial actions when safe to do so. Shoring below the 8' mark requires the panels to be placed in a "stacked" configuration. A 12 foot trench could require an 8' panel and a 4' x 4' panel above it or a 4'x8' panel placed sideways spanning two vertical panels. A 16' deep trench would require two "stacked" 8' panels. We can precede in this fashion to 20 feet. Any shoring deeper than 20 feet is out of our scope and an engineer approved design must be sought for the operation. All deep trench protection systems (shoring) should be as wide as the trench is deep. A 20' deep trench will require 5 panel sets that can reach 20 feet deep. [(20) 4 x 8' panels and an additional (4) 4' x 8' or (10) 4' x 4')]
In addition to "stacked" panel sets, the methods of supplemental shoring will be addressed.

In deep wall operations make sure there are pickets in place and plenty of rope is available for tying back equipment

The 2-4-2 system for placing struts may still be sufficient. However, the 2-3-2 system may be needed depending on depth and shoring equipment. This may be determined by looking at the shoring chart.

<u>Placing Deep Shore Procedures</u>

Precautions:

- Establish ground pads and bridging as needed
- Limit number of rescuers at lip with fall protection

Preparation:

- Hazards identified and mitigated
- Measure the trench depth, this is extremely important to establish the panel placement progression.
- Lip bridges should be a priority to assist in the placement of deep panels and preventing edge failure.
- Assign squads. Panel Team 1 (wall 1); Panel team 2 (wall 2); Shoring Team 1

PARATECH GRAY STRUTS

Total L	WIDTH <8	WIDTH 8'-10'
L-1	4'	4'
L-2	4'	4'
L-3	4'	4'
L-4	4'	4'
L-5	4'	4'
L-6	4'	4'
L-7	4'	4'
L-8	4'	4'
L-9	4'	4'
L-10	4'	**3'**
L-11	4'	**3'**
L-12	4'	**3'**
L-13	4'	**3'**
L-14	4'	**3'**
L-15	4'	**2'**
L-16	4'	**2'**
L-17	4'	**2'**
L-18	4'	**2'**
L-19	4'	**2'**
L-20	4'	**N/A**

<u>**Deep Wall Shoring Procedure**</u>:

Primary shoring is a panel column protecting the victim

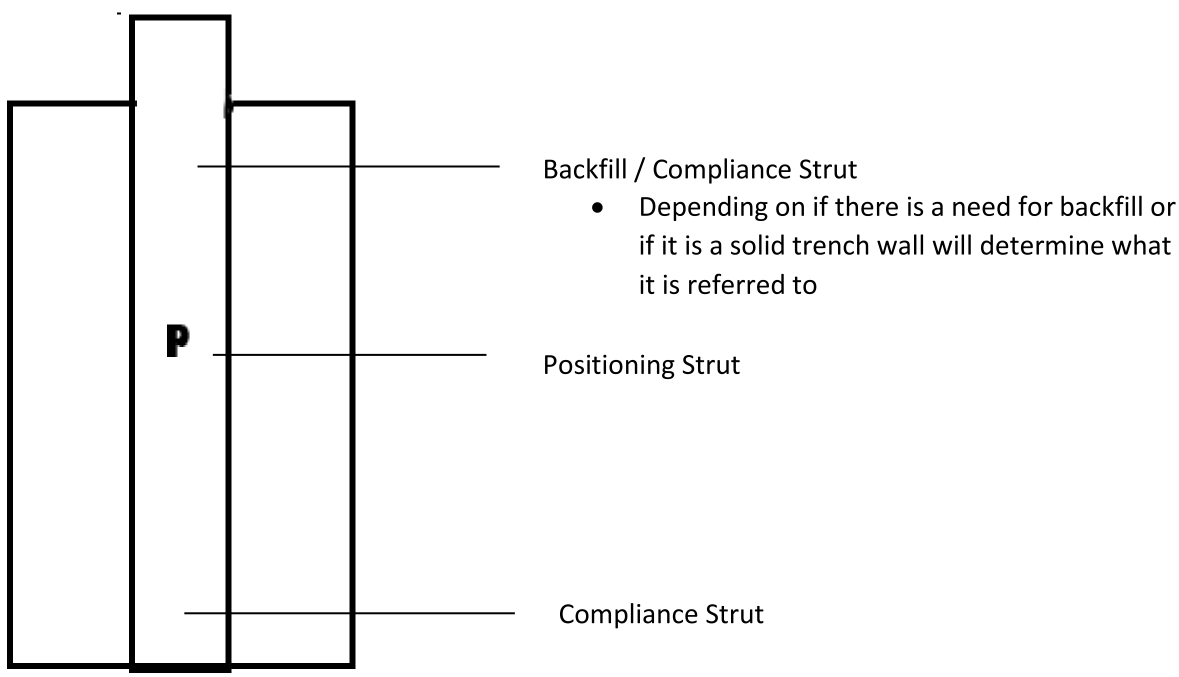
<u>**Bottom panel set**</u>

Panel Team:

- Mark victims location on ground pad/lip bridge
- Install 3 pickets on each side of the trench with the center picket in line with the patient's location. Other pickets should be 4 feet to either side of center picket. (Travel restrictions may be attached to these pickets for those on the edge.)
- Pickets should not be installed any closer than 4' from the lip of the trench or any failure point of trench wall such as a fissure.
- Installing picket on the opposite side of the spoil pile allows them to be set outside of the work area.
- Initiate backfilling techniques if needed
- Install panel set at the bottom on both sides at patient location or suspected location

Shoring Team:

- Install a strut near the center of the panels. This is the **PRIMARY** strut (**P** on the diagrams).
- If wall behind the strut is solid shoot @200 psi for greys & 175 for golds
- If a void is present behind the strut shoot @100-125 psi for greys and 100 for golds



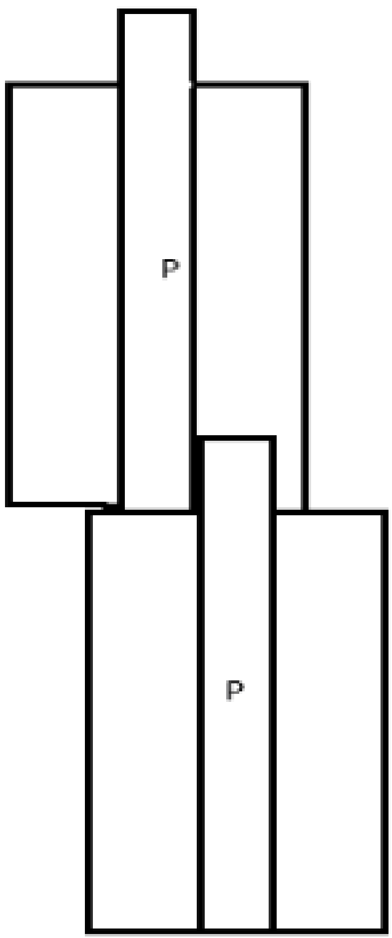
Primary shoring (Top Panel Set)

Panel Team:

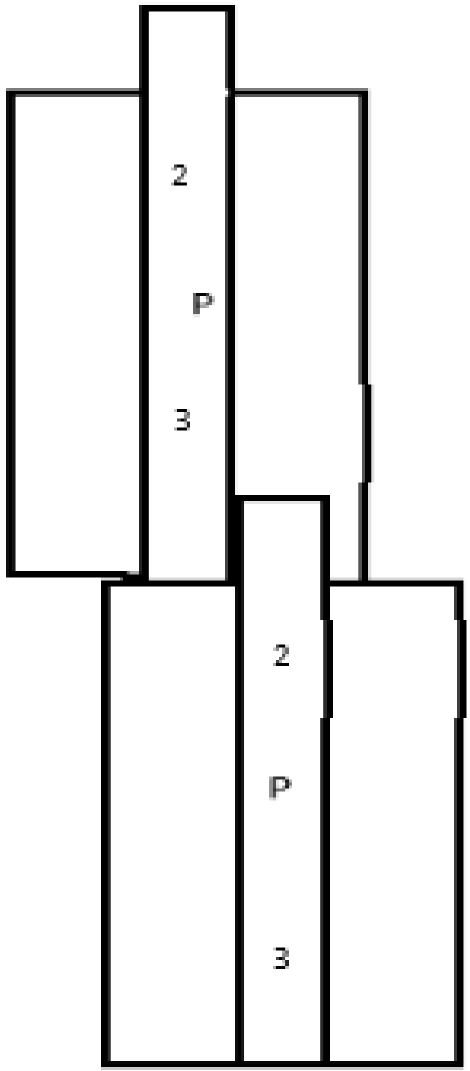
- Install top panel off set over bottom panel set where the two strong backs interlace
- Horizontal or half panel for trenches up to 12'
- Vertical for trenches 14' and deeper
- Prepare backfill (air bags, back shores, wales, cribbing as needed)

Shoring Team:

- Install a strut midway between the trench lip and the bottom and top panel. This is the **Positioning** strut on the primary panel set (**P** on the diagrams).



- Complete strut installation on primary panel set



SECONDARY SHORING- Step 1

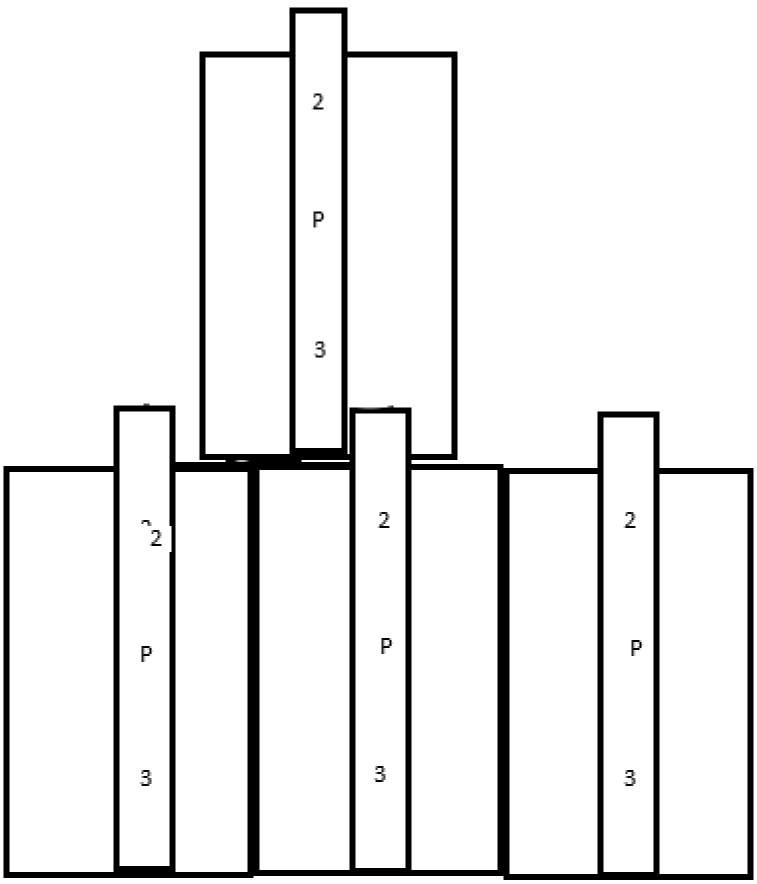
PANEL TEAM

- Install bottom panels on each side of the primary panels
- Install back fill as needed

SHORING TEAM

- Install a strut near the center on each bottom panel

WHEN INTALLING MORE THAN TWO STRUTS (ON A STRONG-BACK OR WALE) ALWAYS USE A WYE SO THAT ALL STRUTS ARE SHOT SIMUTANEOUSLY



SECONDARY SHORING- Step 2

PANEL TEAM

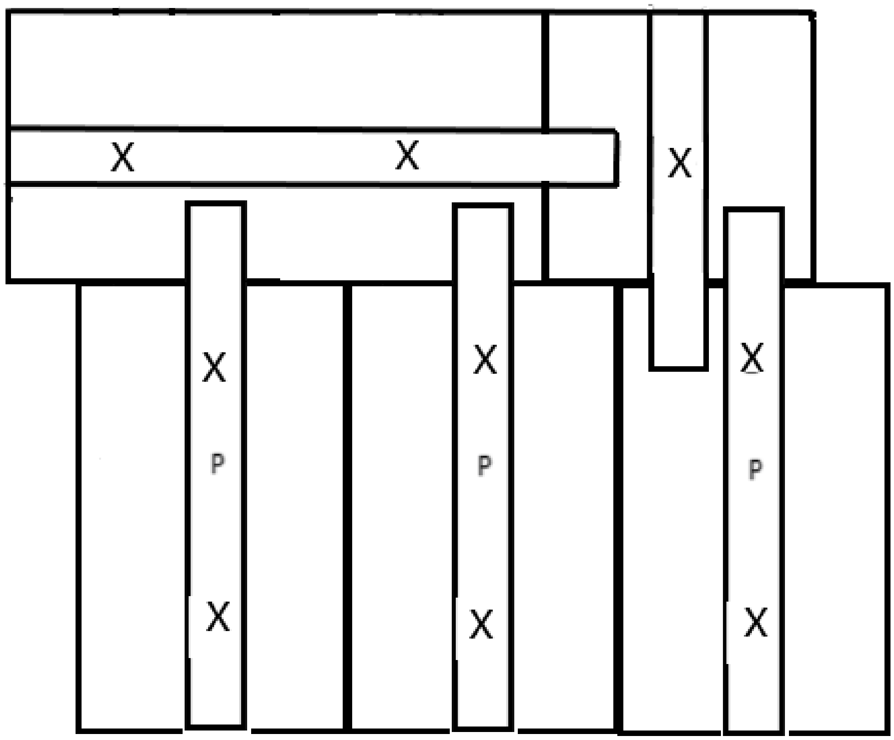
- Install top panels on each side of the primary panels
- Address backfill issues with appropriate technique

SHORING TEAM

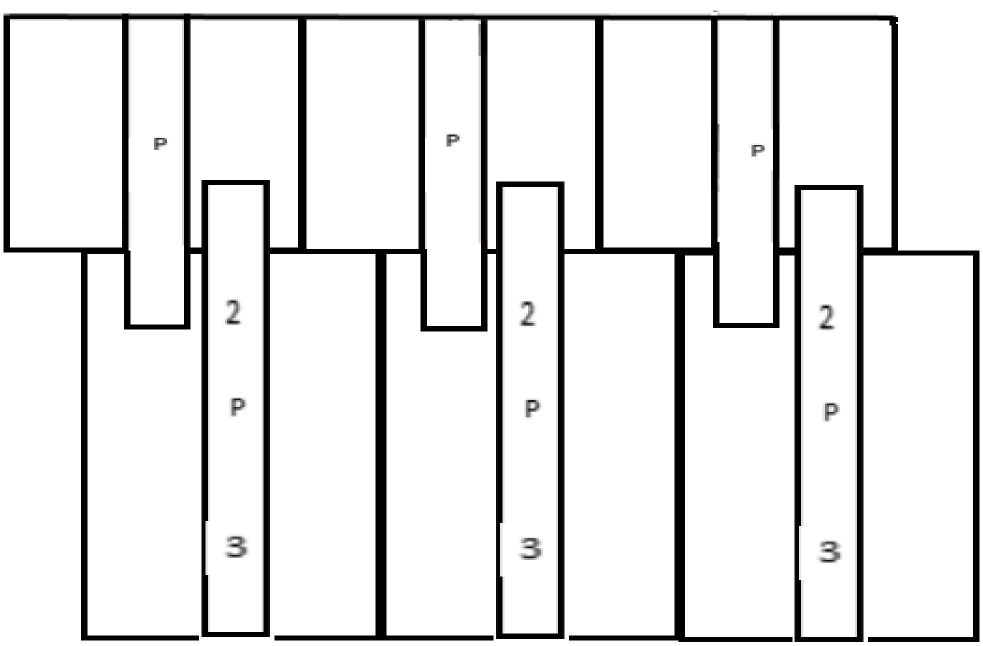
- Install a strut on each top panel set
- Install additional struts an all Secondary Shoring Panels. Maintain appropriate vertical spacing.
- Insure that all backfill is complete and all struts in the Secondary Shoring area are set at operating pressures.
- Enter the trench and nail the strut bases to the strong-backs in the secondary shoring area
- Police the area- Ensure that all trip hazards (panels, shore ropes etc.) are removed

SHORING COMPLETE

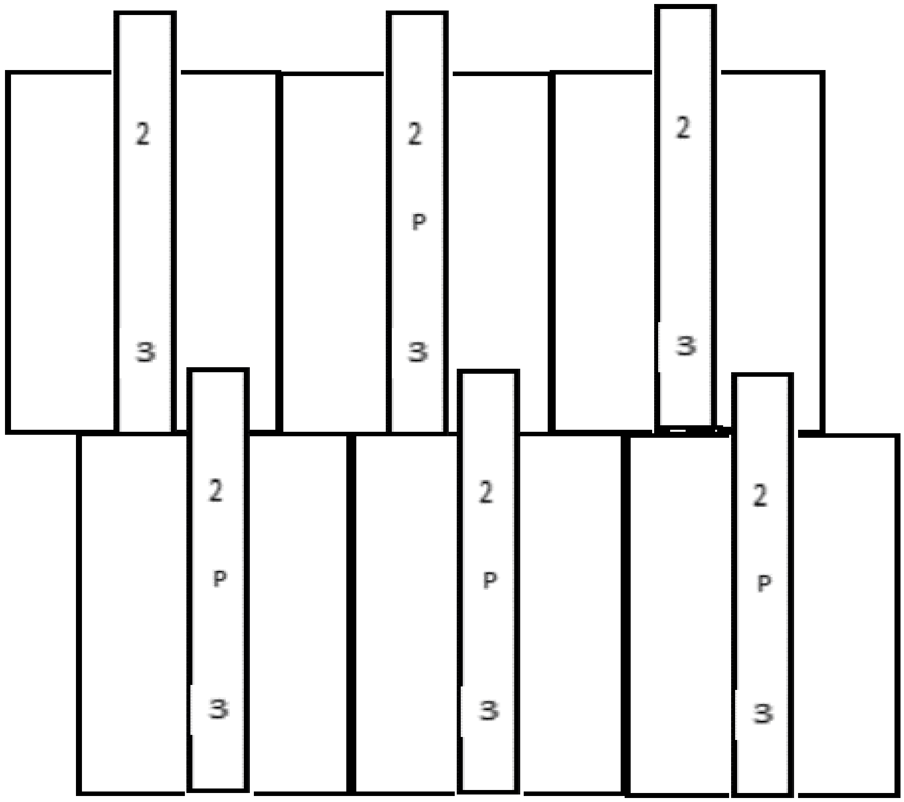
- Install additional panels and struts to complete a safe zone that is at least as wide as the trench is deep.
- Install supplemental shoring as needed.
- Ensure that all strut bases are nailed, backfill is complete and struts are set at recommended operating pressure and collars are locked.



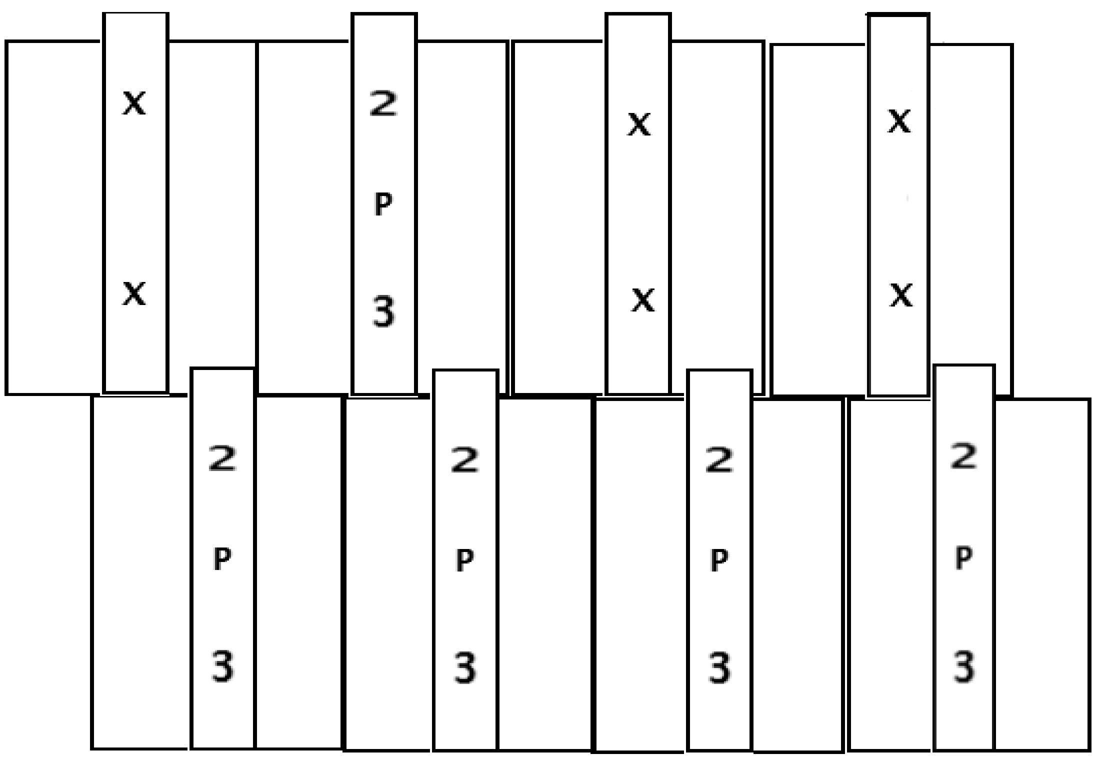
Alternate 12' shoring with Horizontal Panel



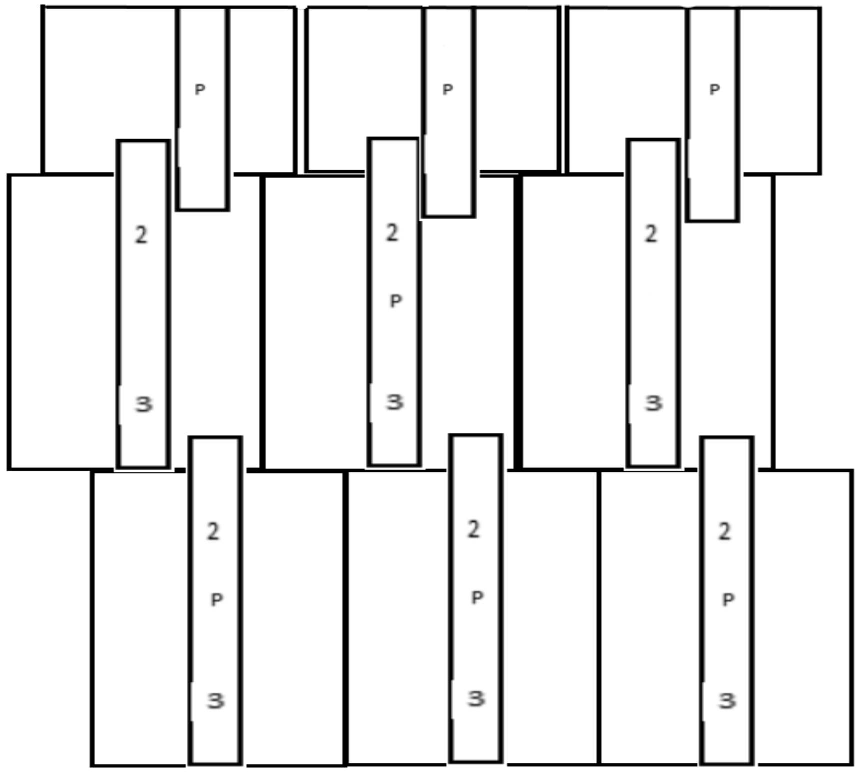
12' Completed shoring with Half Panels



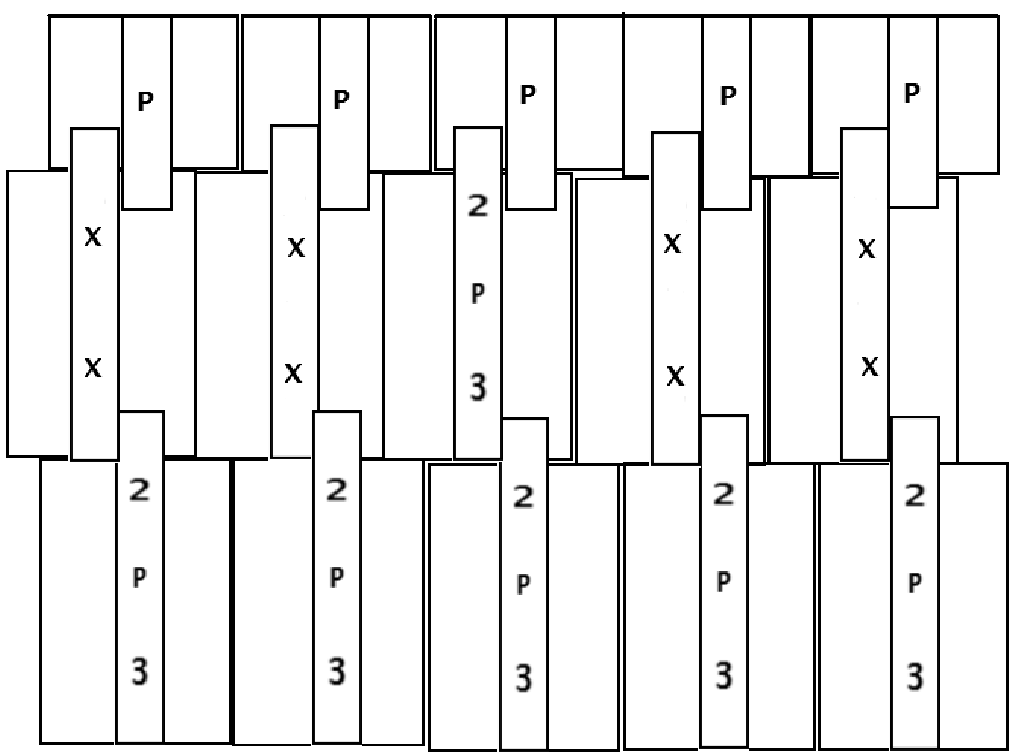
16’ Secondary shoring



16’ Completed shoring



20’ Secondary shoring



20’ Completed shoring

Digging Down

“Supplemental Sheeting & Shoring” is the term found in NFPA 1670 11.4.2 for additional shoring past the first 8 feet. Sheeting refers to the need for more Finn form and shoring refers to the additional struts needed.

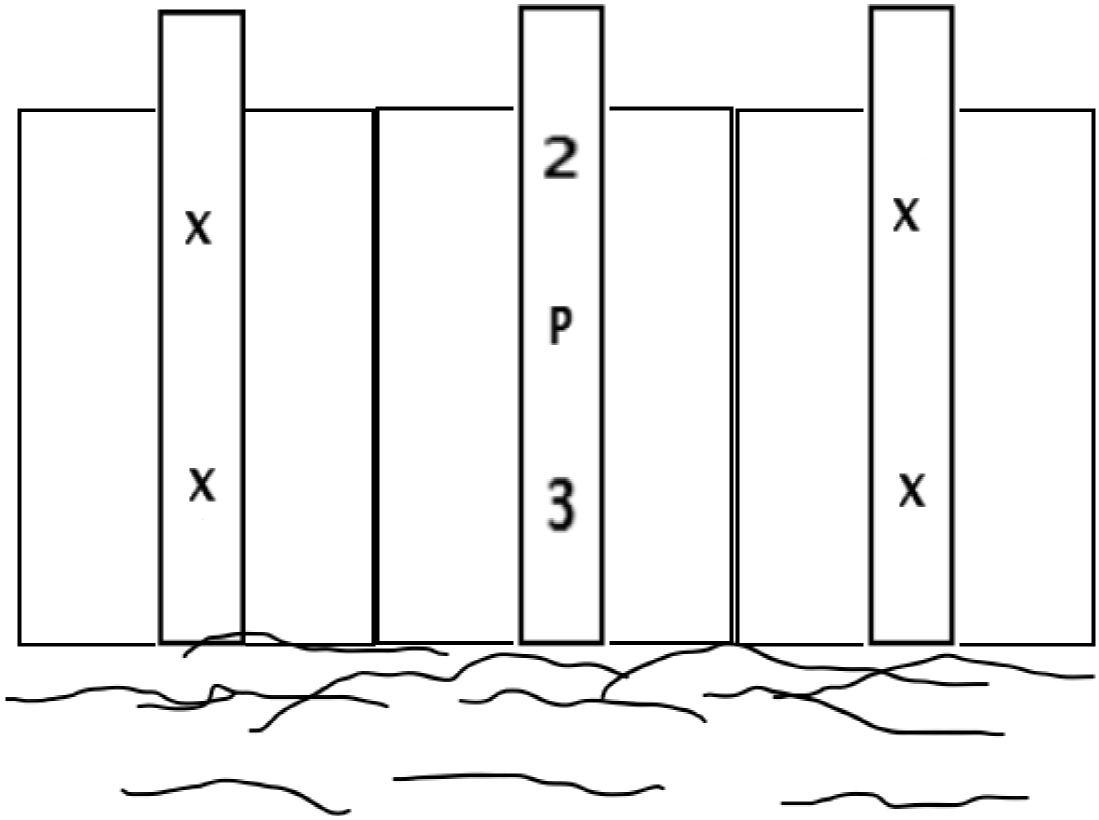
Once the PRIMARY PANEL SET IS PLACED AND ALL STRUTS ARE CHARGED the rescuers (or Entry Team) may enter the trench for patient care. This usually means digging and moving soil out of the trench. As rescuers go down the strut bases must be secured with (4) 16D nails to the strong-backs. Usually workers can accomplish this off ladders or the trench floor.

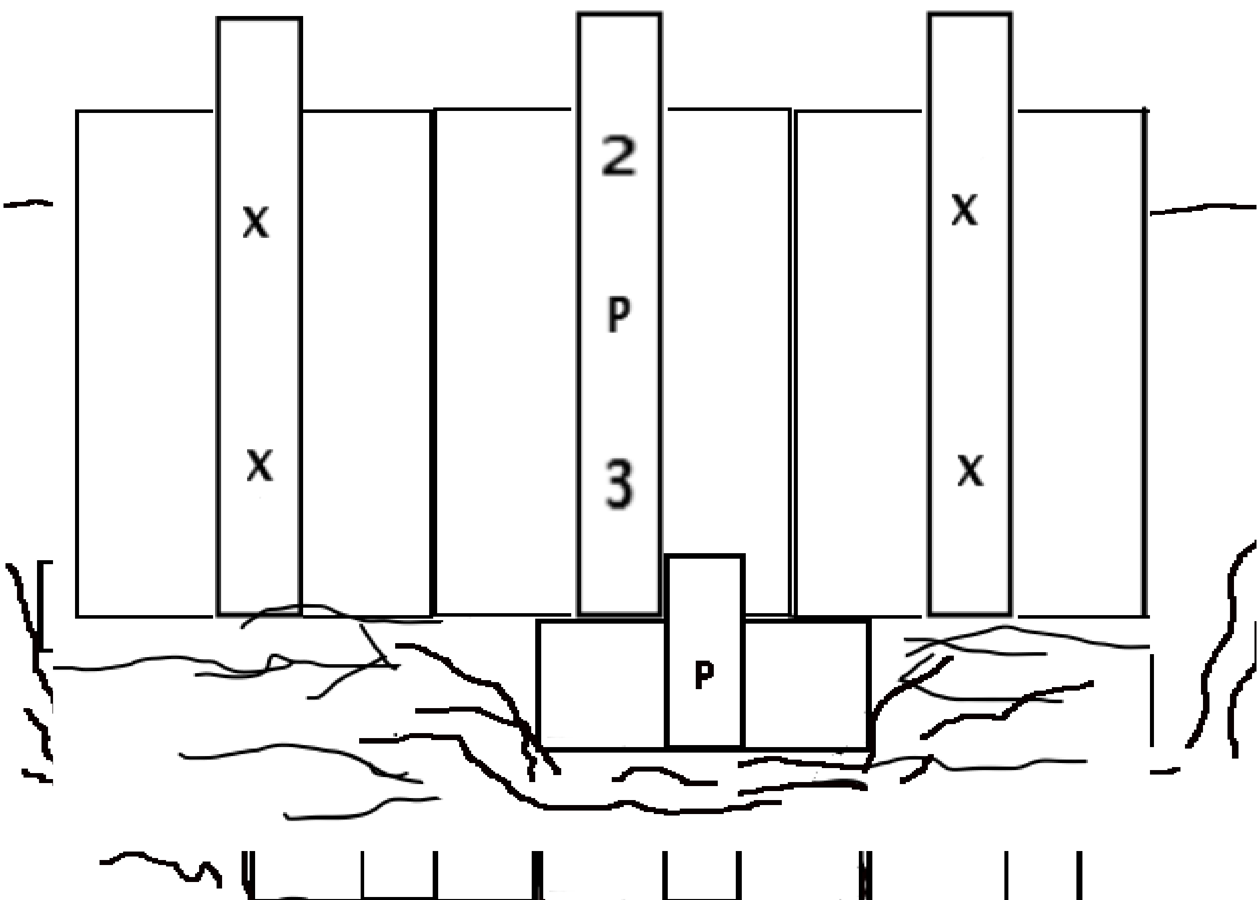
As progress is made removing the soil, more and more of the trench wall will become exposed and un-shored. Up to a two foot vertical distance is allowable. However, the walls should be shored if prolonged occupation of the trench and digging operations continue. Any exposed wall over two feet should be shored.

As the area is cleared, 2’ by 4’ panels with strong-backs can be sent in to shore the exposed wall. The 2’ X4’ are small enough to maneuver around the struts and can be managed by rescuers in the trench. Typically one strut will suffice. However, if in doubt place two struts accordingly, as needed.

DIGGING DOWN PANEL PLACEMENT:

- Trench wall are backfilled, panels set, struts charged and locked, base plates nailed in.
- Rescuers have exposed 2 feet or more of trench wall
- Supplemental 2’X4’ panels set into the wall below the original panel sets.
- Strut placed where necessary and charged to appropriate pressure
- Digging operations continue
- Place additional shoring when enough wall is exposed again.
- If excessive loading begins to occur on the supplemental shoring place additional struts

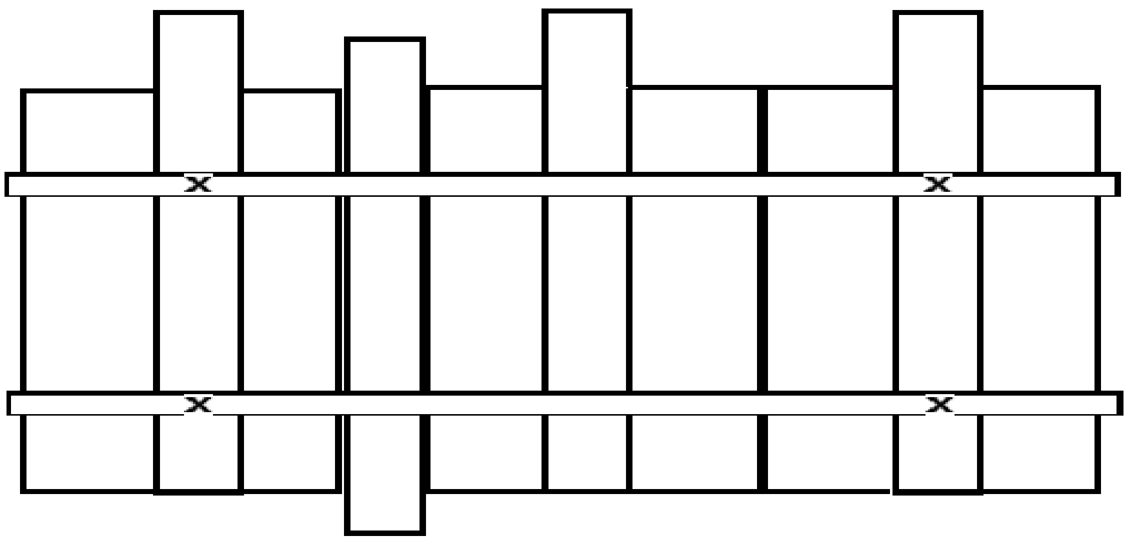




DIG DOWN AT 2 LEVELS 12’

VERTICAL SUPPLEMENTAL SHORING

Sectional sheeting must be used when gaps exist between panels. When installing shoring, effort should be made to keep any spacing between panels to less than 2". Flush to the next panel would be best practice if possible. Any gaps greater than 6" must be covered with supplemental vertical shoring. This will be the use of 2" x 6", 2" x 12' etc.so that the supplemental shoring is large enough to cover the exposed soil. Struts will then be placed in the same 2-4-2 or 2-3-2 pattern as the primary shoring.



EQUIPMENT REMOVAL PROCEDURE

The final phase of the operation is the termination phase. Extreme caution should be a primary concern and caution. Having a fresh crew or after rehab is worth consideration. The preferred method is the use of heavy equipment and trained operators. If this is not an option manual removal is necessary.

Preparation:

- Examine lip conditions under each ground pad.
- Evaluate the condition of the walls around the sheeting and shoring.
- If cracks, fissures, sloughing and other indicators of "active soil" are present do not attempt manual removal. Instead have heavy equipment brought to the site to make trench safe or remove the equipment.

Removal Procedure

1. Start with the last installed strut and work in reverse order
2. Connect hoses and ropes to all struts in a panel area (vertically)
3. Remove nails from strut bases.
4. Decrease pressure in air bags or back shores that are opposing struts.
5. Charge the hoses to loosen collars from a safe location out of the trench.

6. Slowly decrease pressure in struts and look for wall movement. If there is wall movement remove all personnel from the trench area and seek a new plan.
7. Release all air pressure from the struts and remove from the trench from bottom struts to top.
8. Pull up the panels and remove from the action area
9. Repeat this for all vertical sections until all equipment is removed.
10. NO NOT DROP SOMETHING INTO THE TRENCH!

This section has heavily utilized the MUSAR Trench Rescue training manual (May 2021) with much appreciation for their permission.

Trench Rescue Course

Class Title:
Intersecting Trenches

NFPA 1006 JPR's:
12.3.1 – Develop a shoring plan for an intersecting trench
12.3.2 – Implement a trench shoring plan for an intersecting trench
12.3.5 – Support an intersecting trench shoring plan for a trench more than 8' deep

Time:
2 hours

Objectives:
At the end of this lesson, the rescuer should:

- Perform the steps necessary to safely shore and enter for rescue an intersecting trench
- Demonstrate the placement and use of panels to capture the corners of "L" and "T" shaped trenches
- Demonstrate the use of inside wales to secure the long wall on a "T" shaped trench

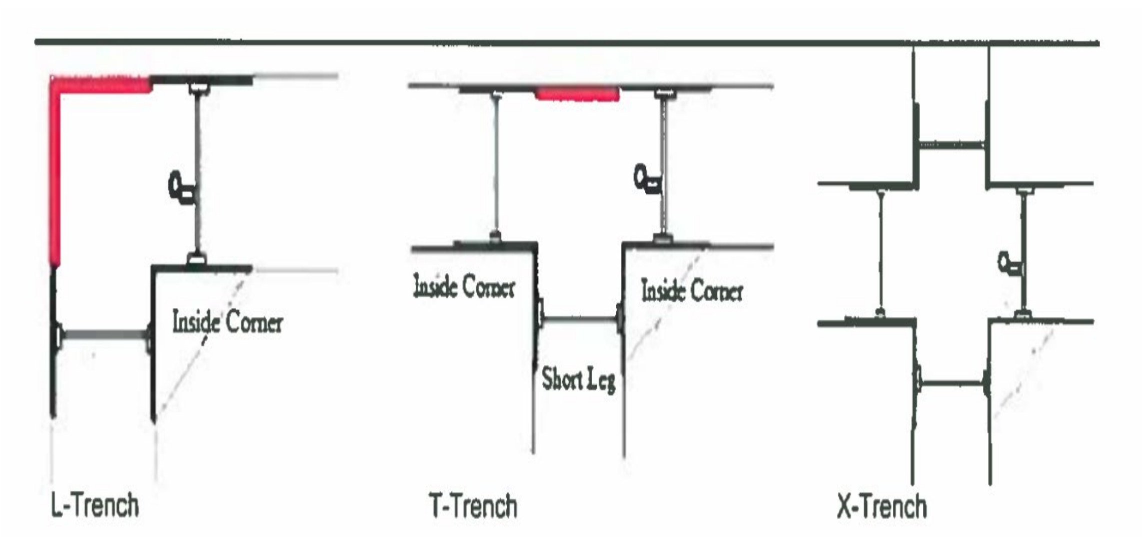
All of the same hazards exist when shoring intersecting trenches as with straight trenches however, there is an additional hazard with intersecting trenches, the corners. The portion of a trench most susceptible to collapse are the inside corners of the L and T shaped trenches. Outside corners meet at a 90 degree and each wall adds a little stability to the other. The inverse is true of the inside corners, which are two free standing walls that offer no stability to the other. The larger surface area of two surface walls on the protrusion of the corner maintains little stability and is quite prone to wedge style collapse where the whole corner shears off.

To make matters even more complicated, shoring one of the free standing walls without acknowledging the other further makes the second wall that much more prone to collapse, therefore care must be taken to capture both walls as evenly as possible so that neither are over pressured and remain intact until fully captured with shores on both walls.

Care should be taken to limit activity at the corners to prevent failure of the corner or injury to rescuers should the wall cave in. When assisting with panel placement from the inside corner, create a cantilever work platform with a ground ladder. Set the ground ladder on top of a ground pad and secure the back of the ladder with pickets. This process will be further explained later in the chapter.

ReSET no longer supports or encourages the method of shoring L trenches with corners shores and thrust blocks that rest on strongbacks. This process encourages the panels to slide out of place if too much pressure is applied from the diagonal struts. ReSET now employs a 2 panel set that forms a 90 degree angle by way of an angle bracket that holds the panels together, this allows for a complete capture of the corner piece of the trench wall.

It is essential when shoring corners in T and L shaped trenches that the process is a coordinated and simultaneous effort between the panel and shoring team so that one side of the corner is not overcharged before the other side can be contained.

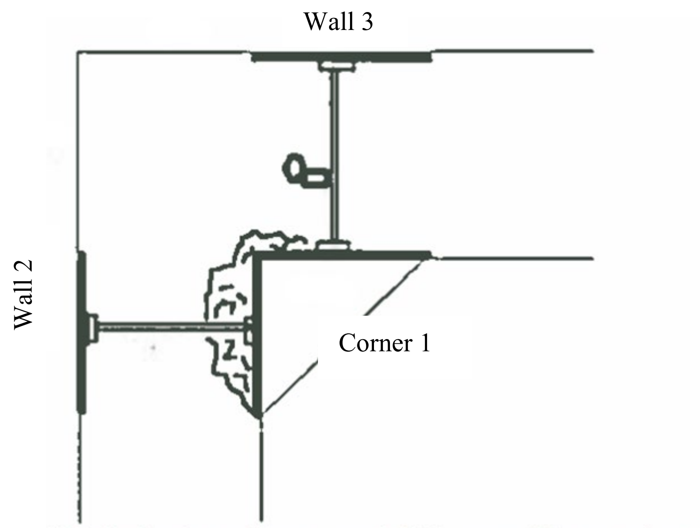


The areas highlighted in red (L- trench and T- trench) do not have any walls directly across from them that can be used to support struts. The X- shaped trench has opposing trench walls to shore all corner walls to.

Shoring Procedure for L Trench

Primary Shoring

Primary shoring must cover the area above the victim's head and chest to protect the victim from secondary collapse. This plan assumes that the most likely collapse will be a wedge collapse at the inside corner. If the victim is not trapped in the corner area then normal "straight wall" trench primary shoring procedures should be used.



Wall designations and Primary Shore plan.

Panel Teams

Panel Squad #1 (Corner)

1. Receive corner panels at inside corner
2. Begin installing backfill in the corner void after a minimum of one strut on each wall is in place

Panel Squad # 1 receiving the Corner Panel

Panel Squad # 1 positioning the Corner Panel

Panel Squad # 2 (Wall 2)

1. Position a wale on the trench floor of Wall # 2
2. Place (2) 6" x 6" x 6' runners on lip protection (pile side)
3. Place the Joined Corner Panels on the runners
4. Prepare back-fill and stage it near the inside corner
5. Insert 4 x 4 rails into the trench and cut flush with the trench lip
6. Slide Joined corner panels into the trench
7. Set Primary Panel on Wall # 2 directly across from the Joined Corner.

Panel Squad 2 on Wall 2 setting the Corner Panel onto rails to slide into the trench and place on Corner Wall# 1

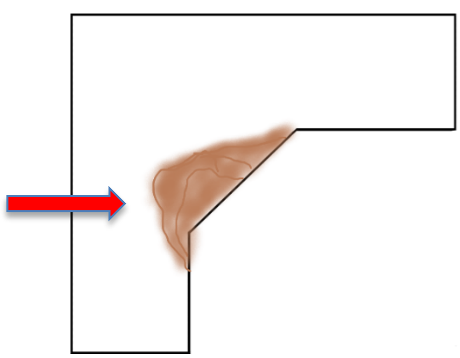
Panel Squad # 3 (Wall 3)

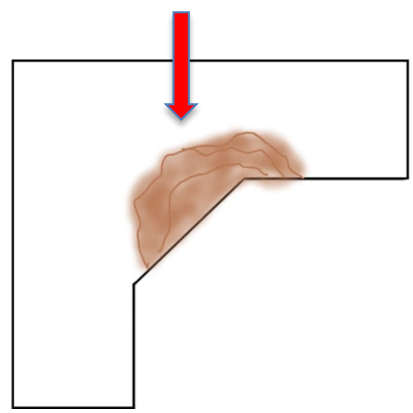
1. Position a wale on the trench floor of Wall # 3
2. Set Primary Panel on Wall # 3 directly across from the Joined Corner Panel

Primary Panel on Wall 3

Primary Panel on Wall 2

Primary Panels on Wall 2 & 3 are held in place with “Positioning Struts”





The Corner Panel should be set into the trench from the opposing wall face with the highest debris pile. This will set the panel at the high point which is easier to manage than setting the panel below the debris pile and trying to lift it up.

Shoring Team

1. Measure the trench
2. Place a ladder
3. Shore Corner # 1 panel to panel on Wall # 2 (Initial activation $\leq$ 0.5 kips) (100 psi for Grey Struts)
4. Shore Corner # 1 panel to panel on Wall # 3 (Initial activation $\leq$ 0.5 kips) (100 psi for Grey Struts)
   * [Place these first struts at the midpoint of the wall (depth) or at the strongest section of the remaining trench wall.]

Secondary Shoring

Panel Teams

Panel Squad # 1 and # 2 (Walls 1 & 2)

1. Set Panels into outside corner on Wall 2 & 3
2. Set 3rd Panel sets on walls 2 & 3
3. Position wale for 1st shoring tier
4. Position wale for 2nd shoring tier
5. Install backfill as needed

Panel Squad # 3

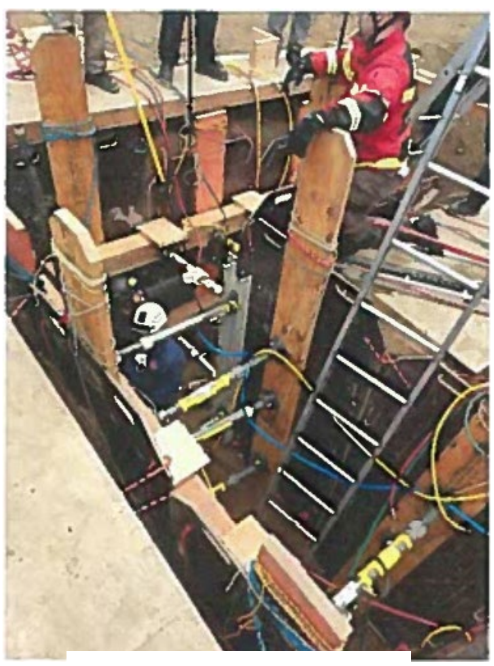
1. Install Backfill for inside corner
2. Install Panels on each side of corner
3. Backfill as needed

Shoring Team

1. Install Struts (1st Tier)
2. Install Struts (2nd Tier)

Note: Using a wye shoot both struts from the first wale to inside wall panels.

- Be sure to have the hose from the Primary Struts connected to the controller and pressurize it whenever the struts on the wale are shot
- Initially pressurize all struts @ ≤ 0.5 kips (100 psi for Grey Struts)
- Repeat on opposite side of corner
- Repeat this procedure for each additional tier of shores

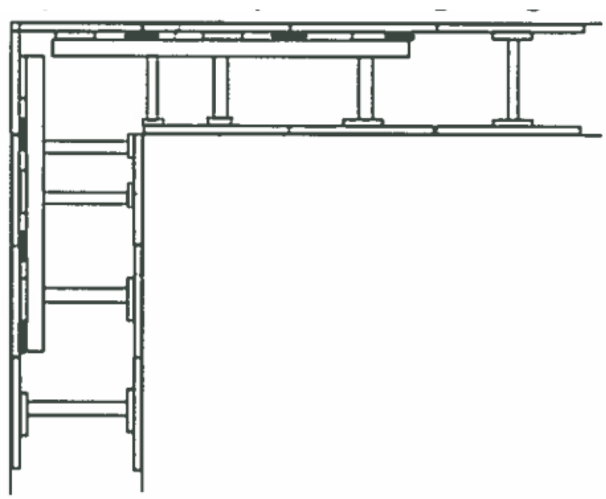


Secondary Shoring in Place

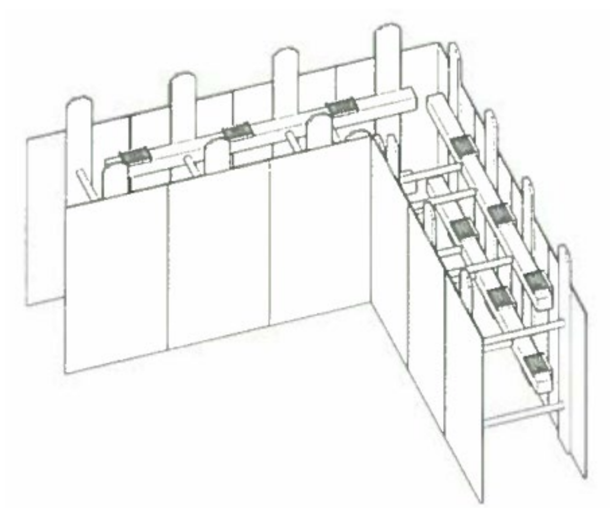
Safety Note: After backfilling has been completed increase the pressure in all struts (one tier at a time) to 1,000-1,250 lbs of force (175 on gold struts, 200 on grey struts)

Complete Shoring

1. Expand all safe zones with panels and shores as needed
2. Nail all strut bases
3. Install Supplemental Shoring as needed during extrication operations.



Overhead view of completed shoring



Side view of completed shoring

CANTILEVER WALE CHART 4' Maximum Vertical Spacing					
MAXIMUM TOTAL L for DISTRIBUTED LOADS					
Wale Type	Cantilever Length				
	3'	4'	5'	6'	8'
6"x6"	L-3	L-2	L-1	L-1	N/A
8"x8"	L-8	L-4	L-3	L- 2	L-1
7"x7" LVL	L-16	L-9	L-5	L-4	L-2
Paratech	L-10	L-5	L-3	L-2	L-1

NOTES:
*Length is the distance between the cantilever end of the wale and the nearest strut
*The cantilver end of the wale must be keep between 12"-18" from the outside corner of the trench to prevent overlapping wales
*Gaps between the wales and panels at the panel edges and both ends of the wales must be filled with spacers and/or wedges
*2' vertical Spacing will double the capacity (L Value) of each wale
*6"x6" and 8"x8" timber capacities are based on #1 Douglas Fir
* 7"x7" LVL capacity based on based on bending strength of 3,100 psi

This chart was created by MUSAR and incorporates their L system of load calculation. We don't dive into this information but this chart is an expression of the strength of various Wale materials and remains applicable to our shoring considerations.

<u>Equipment Removal Process</u>

This phase of the operations is known as the "Termination Phase". This is not the time to let your guard down. The trench walls were unstable before and now they have been subjected to lateral loading, that is about to be removed. Best practice would be to utilize heavy equipment and equipment operators to remove the shoring system. If heavy equipment is unavailable then rescuers will need to resort to manual removal of equipment.

Preparation

- Examine lip conditions under each ground pad and lip bridge
- Evaluate the condition of the walls around the sheeting and shoring
- If cracks, fissures, sloughing and other indicators of "active soil" are present, do not attempt manual removal. Instead have heavy equipment brought to the scene to remove rescue equipment

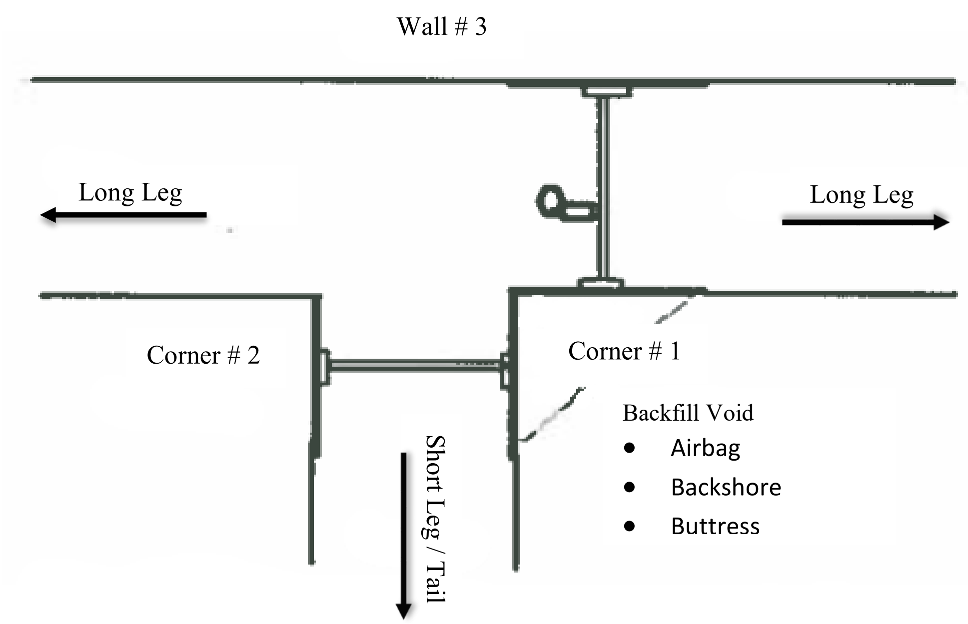
Manual Removal Procedure

- Remove struts in reverse order of installation
    - Connect hoses and ropes to struts
    - Remove nails from strut bases
    - Decrease Pressure on air bags or backshores that are opposing the struts being removed
    - Loosen collars with air pressure and spin collars from a safe zone
    - Slowly decrease air pressure in struts and look for any wall movement.
        - Caution: if any wall movement occurs remove all personnel from the trench and wait for heavy equipment to remove sheeting and shoring
    - Relieve all air pressure from struts and remove struts with ropes.
    - Repeat these steps for each tier of struts
    - Remove the wales and panels last.

Procedures for Shoring a T-Trench

Primary Shoring

This plan assumes the most likely T-Trench collapse which is an inside corner (most likely a wedge failure) collapse. Primary shoring must cover the area above the victim's head and chest. If the victim is not trapped in the corner area then normal "Straight Wall" trench primary shoring procedures should be used. The following procedure is used for shoring the corner area with a trapped victim.



Wall designations and primary panels and struts

Panel Team

Panel Squad # 1 (Collapsed Corner)

1. Install Panels
    a. Place rails from Wall # 3 to Corner # 1
    b. Slide panel on rails to inside corner and tie off
    c. Place and cut rails from Corner # 2 side
    d. Slide panel on rails to the inside corner and tie off
        i. Note: Joined corner panels can be used
2. Install Backfill
    a. Gather appropriate backfill (airbags, backshores, buttress, etc)
    b. Install backfill after panels are shored

Panel Squad #2 (Intact Corner)

1. Install Panel
    a. Install panel using "same side" set
    b. Position directly across from the panel on the collapsed corner

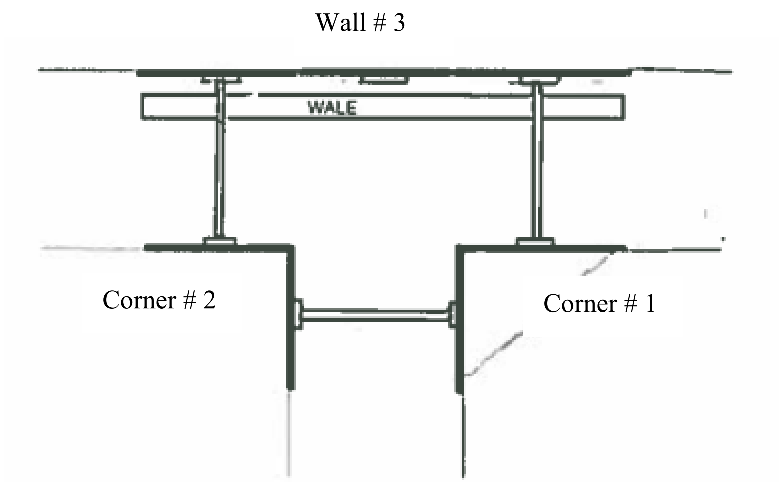
Panel Squad # 3 (Long Wall)

1. Place wale on trench floor (time permitting)
2. Set Primary Panel on Wall # 3 directly across from the corner panel [Primary panel will be located to protect the victim]

Shoring Team

1. Measure trench/ place ladder
2. Shore Corner #1 panel to panel on Wall #3 (initial activation ≤ 100 psi)
3. Shore Corner #1 panel to panel on Corner #2 (initial activation ≤100 psi)

Secondary Shoring (Part 1)



Panel Team

Panel Squad #1 (Collapsed Corner)

1. Continue to enhance Backfill Operations

Panel Squad #2 (Intact Corner)

1. Install Corner #2 panel facing Wall #3
2. Place wale hangers on outside panel across from Corner # 1 on the long wall side, after positioning strut is in place

Panel Squad #3 (Long Wall)

1. With a wale on the trench floor, install outside panels on Wall #3 directly across from the panel on corner #2
2. Install the Middle panel on the long wall

Shoring Team

1. Install strut in the middle of outside panels (Corner #1 to Wall #3 and Corner #2 to Wall #3)
2. Set Strut pressures at 100 psi at void area until backfill is complete

Secondary Shoring (Part 2)

Panel Team

Panel Squad #1 (Collapsed Corner)

1. Install additional panels on corner #1 wall as needed (Long leg and Short leg)
2. Assist Squad 3 and/or Shoring Team

Panel Squad # 2 (Intact Corner)

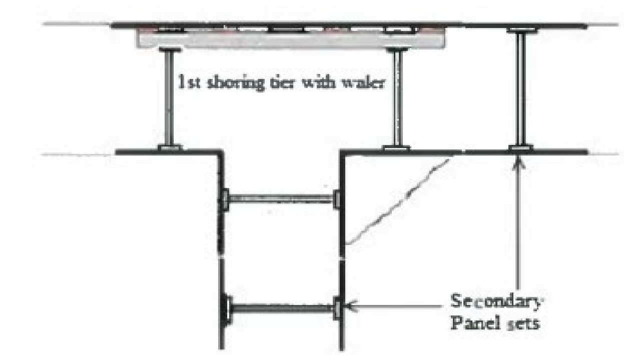
1. Install additional panels on Corner #1 as needed (Long Leg and Short Leg)
2. Assist Squad 3 and/or Shoring Team

Panel Squad #3 (Long Wall)

1. Hang wales on Wall #3 two feet from lip and two feet from floor (top or bottom first as dictated by soil conditions)
2. Assist Shoring Teams as needed

Shoring Team

1. Install a minimum of 2 struts (1st tier) from wales on outside walls to panels on inside corner walls. Use a wye to simultaneously pressurize struts from the Wale to the inside wall panels on each tier.

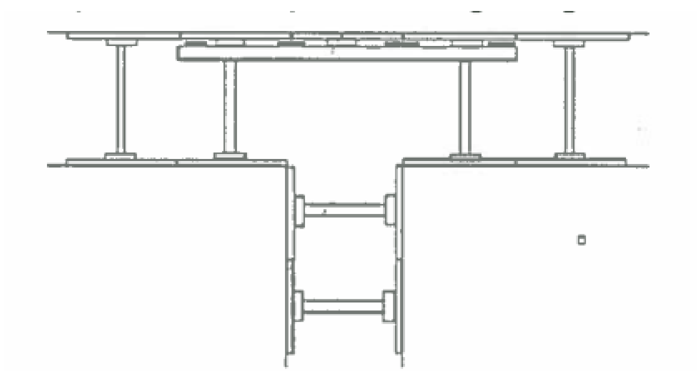


2. Be sure to have the hose from the Positioning Strut connected to the controller and pressurize it whenever the struts on the wale are shot. [This will prevent it from loosening and falling out during the secondary strut installation]
3. Initially pressurize all struts @ 100 psi
4. Repeat this procedure for each additional tier of shores
5. The number of tiers of shores and wales is dependent on the depth of the trench and the “Total L” calculation
6. After back-fill has been completed, increase the pressure in all struts (one tier at a time) to between 200 psi.

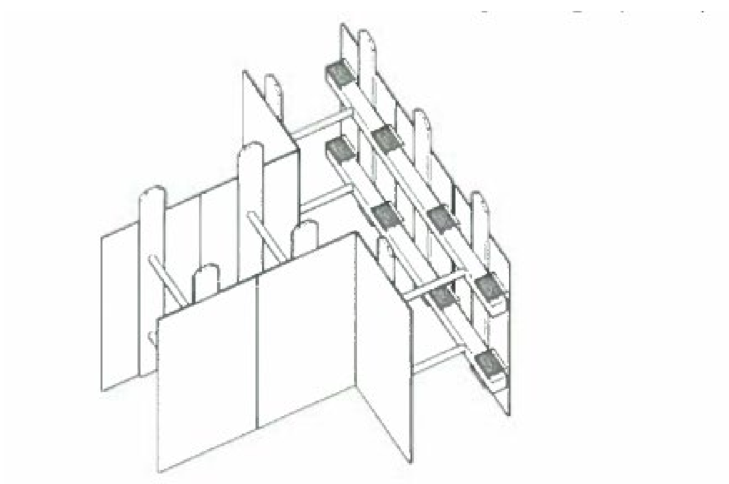
Complete Shoring

1. Bring all struts and airbags up to operating pressures
2. Expand all safe zones with panels and shores as needed
3. Nail all strut bases
4. Install supplemental shoring as needed during extrication

Top View of Complete Shoring Design



Side view of Complete Shoring Design (2 Tier)



Equipment Removal Process

This phase of the operation is known as the "Termination Phase". Exercise caution during this time. The preferred equipment removal method includes the use of heavy equipment and trained equipment operators. If heavy equipment and operators are unavailable then utilize the manual removal technique.

Preparation

- Examine lip conditions under each ground pad and lip bridge
- Evaluate the condition of the walls around the sheeting and shoring
- If cracks, fissures, sloughing and other indicators of "active soil" are present do not attempt manual removal. Instead have heavy equipment brought to the scene to remove rescue equipment

Manual Removal Procedure

- Remove struts in reverse order of installation
    1. Connect hoses and ropes to struts
    2. Remove nails from struts bases
    3. Decrease pressure on air bags or back shores that are opposing the struts being removed
    4. Loosen collars with air pressure and spin collars from a safe zone
    5. Slowly decrease air pressure in struts and look for any wall movement.
        i. Caution: If any wall movement occurs remove all personnel from the trench and wait for heavy equipment to remove sheeting and shoring
    6. Relieve all air pressure from struts and remove struts with ropes
    7. Repeat these steps for each tier of struts
    8. Remove the panels last

SUMMARY

In this module you learned about different types and methods of shoring intersecting trenches and their application considerations, discussed the precautions associated with these trenches, performed the preparation steps, and participated in the installation and removal of shoring system in intersecting trenches utilizing MUSAR procedures

ReSET
Regional Standardization of Equipment & Training
Serving the CAPCOG Region Since 2004

Trench Rescue Course

Class Title:

Lifting and Stabilization

NFPA 1006 JPR's:

12.3.8 – Construct load Stabilization system
12.3.9 – Lift a load
12.3.10 – Coordinate the use of heavy equipment

Time:

1 hour

Objectives:

- Demonstrate the ability to calculate estimated weights of various objects of different materials (concrete, reinforced concrete, steel, wood, earth)
- Demonstrate the ability to estimate the center of gravity on an object
- Perform cribbing and stabilization of an object in or around a trench
- Identify 3 classes of levers
- Identify rigging equipment and key features
- Identify the D/d ratio and how it affects the rigging capabilities

At a trench rescue incident, victim rescue may be as simple as having the injured person climb up a ladder for self-rescue or it may be a complex incident that requires extricating a victim from under a heavy load. In the event of the latter being the issue we, as technical rescuers, should be able to estimate the load of an object, account for load shift by estimating the objects center of gravity and know the capacities of our equipment to effect the lift and subsequent rescue as safely as possible.

Gravity, in mechanics, is the universal force of attraction acting between all matter. On Earth, all bodies have a weight, or downward force of gravity, proportional to their mass which Earth's mass exerts on them. This is the force that we have to overcome when lifting objects. Before we can consider the lifting or moving of an object we must first determine how much that object weighs. Fortunately, we have some quick formulas and generic weight estimations that can help us determine the weight of an object.

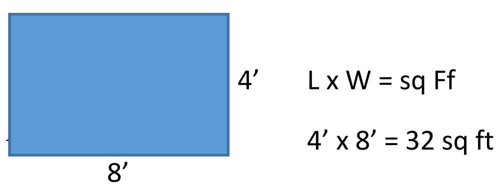
Weight is equal to the volume of an object multiplied by the density of material

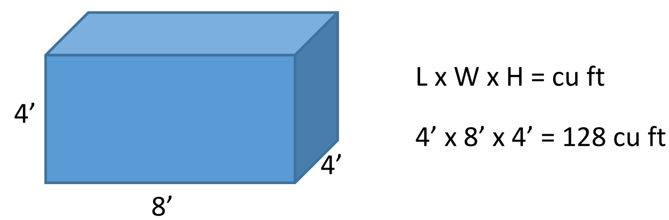
- W = V x Density of Material

Volume is the length of an object multiplied by its width and thickness

- V = L x W x Thickness

When calculating loads, it is important to know how to calculate square footage as well as cubic footage. Square feet will give you surface area while cubic feet provides volume. Square footage is determined by multiplying the length of an object by its width, cubic footage is determined by multiplying the length by the width and the depth of the object.



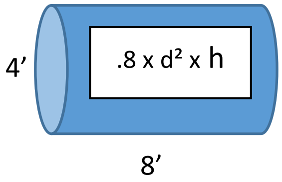


Solid Cylinders

Concrete pipes are a common hazard in trenches used primarily for sewage and water drainage. It would not be so shocking to have an incident in which a worker is entrapped in a trench by a section of pipe. Correctly calculating the area of a cylinder allows us to figure the actual weight of a hollow pipe.

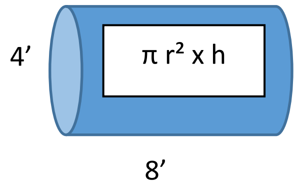
There are two methods for finding the area of a cylinder. The most common would be pi times the radius squared (πr^2) but one can also find the area using the diameter of the cylinder. In the field using the diameter may be a little easier.

Using the Diameter



$(\pi \div 4) \times d^2 \times h$
(3.14 ÷ 4 = .78)
$.8 \times 4^2 \times 8$
$.8 \times 16 \times 8$
= 102.4 cu ft.

Using the Radius

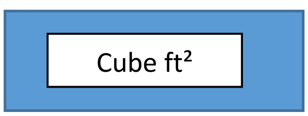


$\pi r^2 \times h$
$3.14 \times 2^2 \times h$
$3.14 \times 4 \times 8$
= 100.48

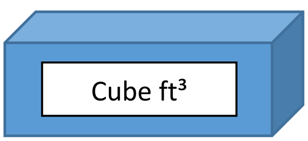
Why multiply by .8 when using the diameter but multiply by 3.14 when using the radius?

- Area = πr^2: the radius is just the diameter divided in half so $r = d \div 2$
- Therefore $A = \pi r^2$ which is the same as $A = \pi (d \div 2)^2$
- $A = \pi (d^2 \div 4)$ → $A = \frac{\pi}{4} \times \frac{(d^2 \div 4)}{4}$ → $A = \frac{\pi}{4} \times \frac{(d^2 \div 4)}{4}$ → $A = \frac{\pi}{4} \times d^2$ → $A = (\pi \div 4) \times d^2$
- $\pi = 3.14$ and $3.14 \div 4 = .785$ for simplicity with math round that up to .8
- And you end up with the equation of $A = .8 \times d^2 \times h$

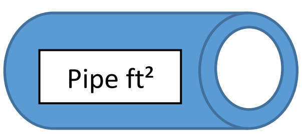
Calculating Weights (all dimensions are in feet) [dimension in inches will need to be converted to feet]



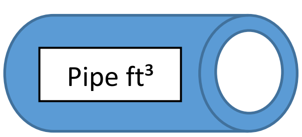
Length x Width x Weight (per square feet of material)



L × W × H x Material Weight

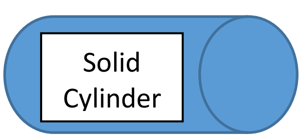


L × (π × d) × Weight per sq ft (based on thickness of pipe wall) [refer to weight estimations]



L x 3.14 x Wall Thickness × (Outside Diameter – Wall Thickness) × Material Weight

Outer volume – Inner Volume x Material Weight
(.8 x Diameter Outer ² x Length) – (.8 x Diameter Inner ² x Length) × Material



L × (d² x .08) × Material Weight

L × (r² x π) × Material Weight

Quick Reference for Measurements and Load Estimations

Inch to Feet Conversion Chart							
Inch	Feet	Inch	Feet	Inch	Feet	Inch	Feet
1”	.08	4”	.33	7”	.58	10”	.83
2”	.17	5”	.42	8”	.67	11”	.92
3”	.25	6”	.5	9”	.75		

Estimating Weights based on material type

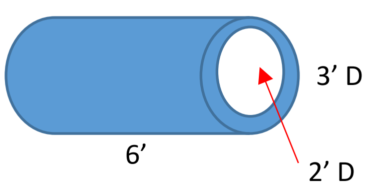
Steel Plate (per square feet)	
1/8”	5 lbs. / ft^2
¼”	10 lbs. / ft^2
½”	20 lbs. / ft^2
¾”	30 lbs. / ft^2
1”	40 lbs. / ft^2

Reinforced Concrete (per square feet)	
3”	40 lbs. / ft^2
4”	50 lbs. / ft^2
6”	75 lbs. / ft^2
9”	115 lbs. / ft^2
12”	150 lbs. / ft^2

Material Weight (per cubic feet)	
Concrete	150 lbs. / ft^3
Brick	120 lbs. / ft^3
Steel	480 lbs. / ft^3
Wood (oak)	45 lbs. / ft^3
Soil	125 lbs. / ft^3

Volume of a hollow cylinder

Calculating the volume of a hollow cylinder is basically the same as a hollow square or rectangle. Calculate for the whole volume and then subtract the volume of the hollow section.

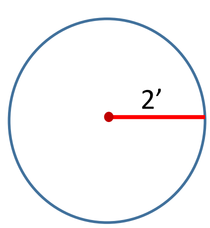


Cylinder Whole [πr^2]:
V = 3.14 x 1.5^2
V = 7.065 sq ft x 6’
V = 42.39 cu ft

Hollow Portion [πr^2]:
V = 3.14 x 1^2
V = 3.14 sq ft x 6’
V = 18.84 cu ft

Actual Volume:
42.39 cu ft – 18.84 cu ft
= 23.55 cu ft

Here is further examples of how the math works:



$A = \pi r^2$
A = 3.14 x 2^2
A = 3.14 x 4
A = 12.56

Divide the Diameter by 4

$A = \pi d^2/4$
A = 3.14 x $4^2/4$
A = 3.14 x 16/4
A = 3.14 x 4
A = 12.56

Divide Pi by 4

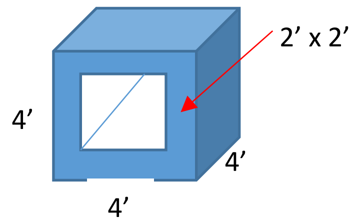
$A = \pi d^2/4$
A = 3.14 ÷ 4 x d^2
A = .785 x d^2
A = .785 x 4^2
A = .785 x 16
A = 12.56

Quick Field Math

A = .8 x d^2
A = .8 x 4^2
A = .8 x 16
A = 12.8

Volume of Hollow Objects

To determine the volume of hollow rectangular objects, first determine the volume as if the object were whole, then determine the volume of the hollow portion, subtract that volume from the whole volume to get actual volume.



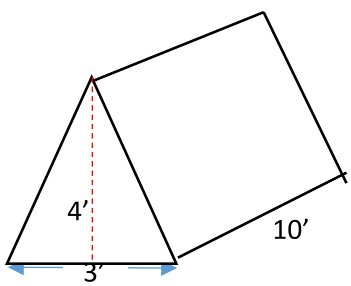
Volume of the Cube as a whole:
4’ x 4’ x 4’ = 64 cu ft

Volume of Missing Section:
2’ x 2’ x 4’ = 16 cu ft

Actual Volume:
64 cu ft – 16 cu ft = 48 cu ft

Triangular Shapes

The obtain the volume of a triangle you must first know the height and length of one of the triangle bases, find the area for that space and then you can multiply by the height/ length to get the volume.



First: Multiply the length of the base by the height and then divide that by 2.

3’ x 4’ = 12’ ⟹ 12’ ÷ 2 = 6 sq ft

Second: Multiply square footage by the length of the triangle

6 sq ft x 10’ = 60 cu ft.

Moving Objects

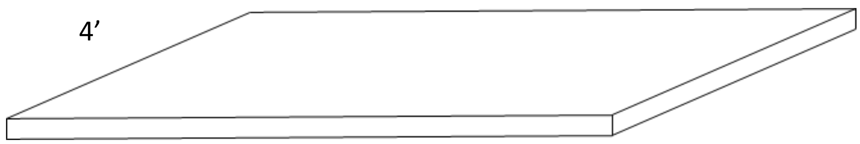
The weight of the object is not the only consideration when it comes to lifting and moving. We must also consider the effects of friction on the object and ways to reduce it. If feasible, lowering the amount of surface contact that the object is resting on will reduce the amount of friction when moving, i.e. using steel pipes as rollers under a concrete slab. Generally, reducing the amount of surface area between the two objects lessens the contact area, thereby decreasing the friction between the two objects.

Weight Calculations

There is no guarantee that the load encountered in the field will be of uniform shape or size, therefore it is important that the technician is able to calculate loads for uniform shapes as wells at atypical shapes.

Here are some examples and accompanying math to solve for various objects that could be seen in the field.

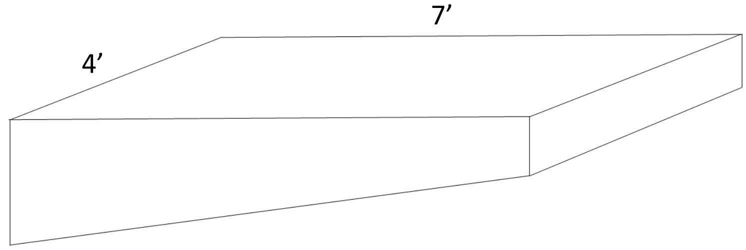
Typical Slab



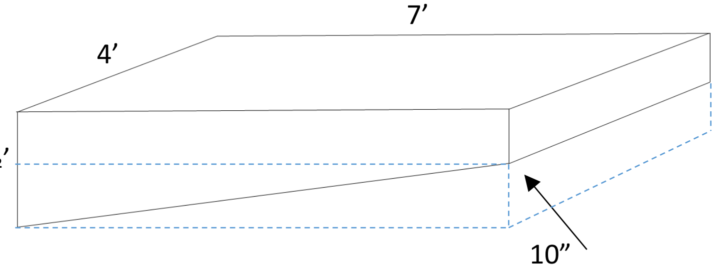
Area: 4' × 8' × 6" ⟹ 4'× 8' × .5' = 16 cu ft

Reinforced concrete weighs 150 lbs./cu. Ft. ⟹ 16 cu. Ft × 150 lbs. = 2400 lb. slab

Tapered Slabs



It is easiest to calculate the weight of this slab by making the top section solid and then solving the bottom section as a triangle.



Top Slab piece: 4' × 7' × .67' = 18.76 cu ft

Bottom Triangle:

- Area of the base: (H× B)÷2 (7' × .83') ÷ 2 = 2.91 sq. ft.
- Volume of the base: 2.91 sq. ft. × 4' = 11.64 cu ft.

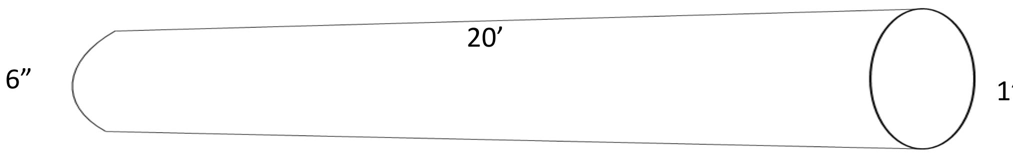
Add these together to determine the total volume

- 18.76 cu. ft. = 11.64 cu. ft. = 30.4 cu. ft.

Reinforced concrete weights 150 lbs./cu. Ft. so:

30.4 cu. Ft. x 150 lbs./cu. Ft. = 4,560 lbs.

Tapered Cylinders (think telephone pole)



For a tapered Cylinder there will be a difference in diameters from one end to the other, find the average diameter between the two.

6” + 12” = 18”, 18” ÷ 2 = 9” or .75 ft.

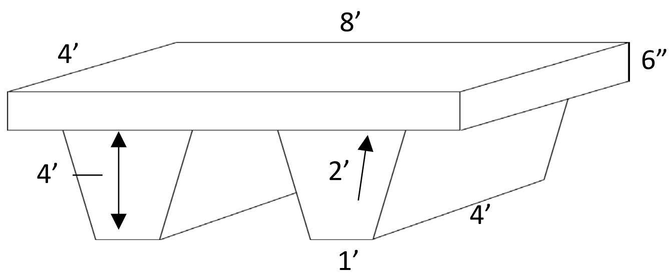
Now calculate the volume of the cylinder

.8’ × d² x l → .8 × .75² × 20 → .8 × .5625 × 20 = 9 cu. Ft.

Wood has an average weight of 40 lbs./ cu. Ft

9 cu. Ft. x 40 lbs./cu. Ft. = 360 lbs

Irregular Slabs (Concrete Double T)



Calculate for the top slab and separate the cone shapes then add all the pieces together for total volume.

Top Slab

4’ × 8’ × .5’ = 16 cu. ft. → 16 cu. ft. × 150 lbs. = 2400 lbs

Bottom Pieces

For trapezoidal shapes, much like the tapered cylinder, find the average width and then solve for the rest of the volume.

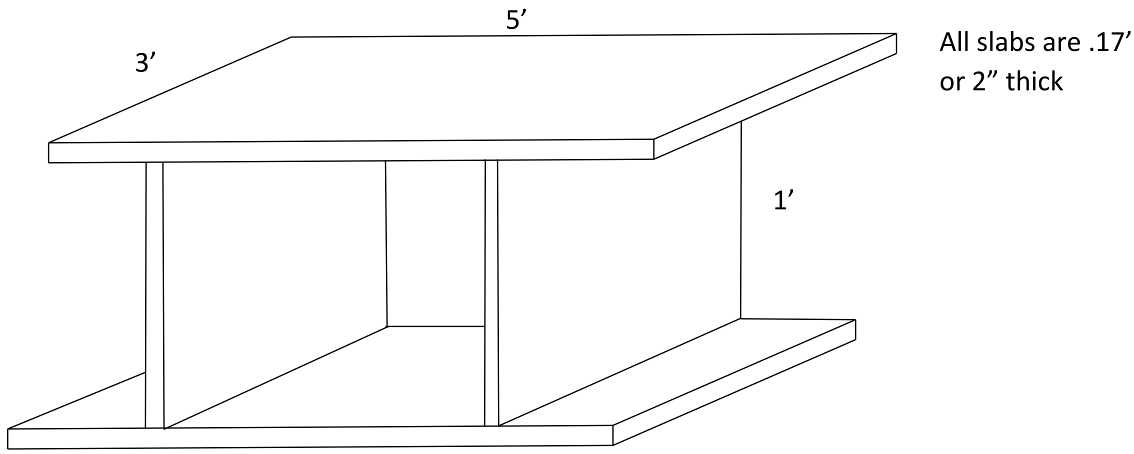
1’ + 2’ = 3’ ÷ 2 = 1 ½ ’

L × W × H → 4’ × 1.5’ × 4’ = 24 cu. ft → 48 cu. ft × 150 lbs = 3600 lbs

Total Volume

Top Slab = 2400 lbs, Both Bottom Pieces weight 7200 lbs → 2400 + 7200 = 9600 lbs.

More Irregular Shapes



Again, break the pieces up into individual pieces to solve for volume and then add them together at the end for the total weight of the object. Steel weighs 480 lbs./ cu. ft.

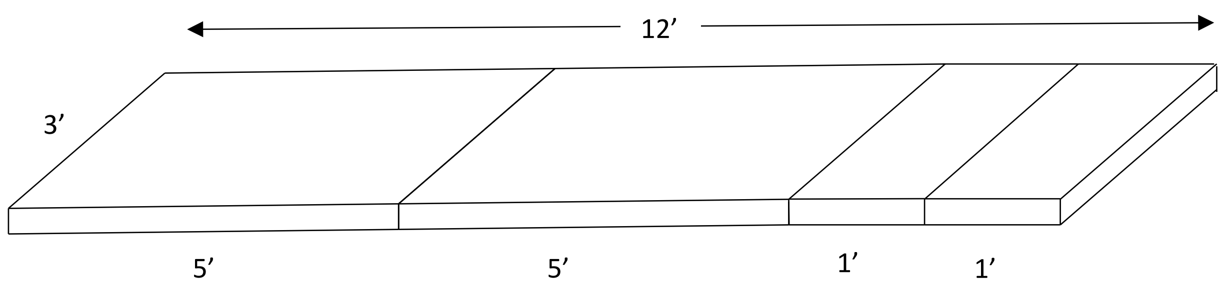
Top & Bottom: Center Sections:

3’ × 5’ × .17’ = 2.55’ 1’ × 3’ × .17’ = .51 cu. ft.

Total

(2.55 × 2) + (.51 × 2) = 6.12 × 480 lbs. = 2,937.6 lbs.

If it helps, visualize the structure as a individual slabs or as a single unit and figure the math that way.



12’ × 3’ x .17’ = 6.12 × 480 lbs = 2,937.6 lbs

Lifting Objects

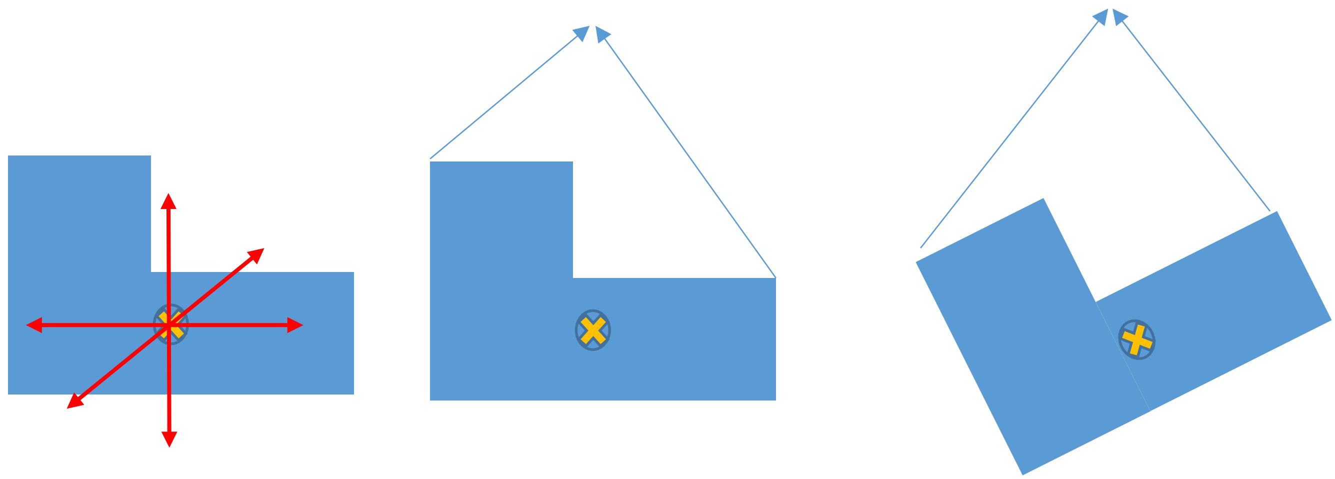
There are multiple options for lifting objects, it really depends on what equipment is on scene and how proficient the rescuer is with that equipment. When lifting and moving, perhaps the quickest method is with a lever or pry bar and some cribbing to adjust the height of the fulcrum as well as to capture the load at height as it is lifted. Other options include airbags, pneumatic struts or heavy machinery to facilitate over-head lifts. This chapter will primari8ly focus on load and weight estimation but it will also discuss some basics of using heavy machinery to accomplish overhead lifting when a competent operator is present.

A lever is a simple machine made of a rigid beam and a fulcrum. The effort (input force) and load (output force) are applied to either end of the beam. The fulcrum is the point on which the beam pivots. When an effort is applied to one end of the lever, a load is applied at the other end of the lever. This will move a mass upward. There are three classes of levers, each based on where the fulcrum rests.

Airbags are another option for lifting objects on scene. There are two versions of airbags that can be used in the trench rescue environment. The first would be high pressure bags, these bags come in a multitude of sizes and fit well into tight confined spaces. They are capable of lifting very heavy loads, weight rating is based on the size of bag, but they provide minimal height gain as their rated capacity is at 1 inch of lift, above this one inch the capacity of the bag declines significantly. The second type of airbag are low pressure bags. These are also capable of lifting heavy loads but they take up a lot more room, they are primarily used in trench rescue to fill voids in trench walls.

Lastly, our options for lifting would include some form of overhead support. That could be in the form of an adjustable tripod, a bipod rigged as a gantry or if available on scene heavy equipment with suitable connections.

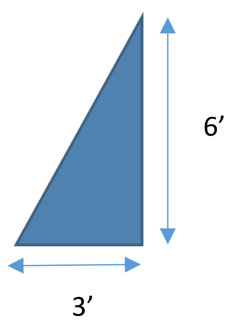
When it comes to lifting, the weight of the object is only part of the equation. In order to avoid the object from shifting, or at least be able to account for a shifting load, we need to find the objects center of gravity. Simply defined, the center of gravity (COG) is the point on a body around which the body's mass is evenly distributed. Consider the center of gravity as the point on a body where all forces of the earth's gravitational pull are equal. The center of gravity of an object is always at the junction of three axis. The horizontal, vertical and diagonal axis of an object will meet at a certain point that represents its absolute center, therefore, if you could attach to this point, you could lift the object straight up without a left/right correction.



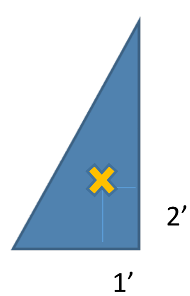
If the center of gravity is not accounted for during the rigging phase, the object will rotate until the center of gravity is located which could be catastrophic to the rigging equipment and potentially personnel on scene.

Let's look at the methods for finding the center of gravity for some basic shapes.

90° Right Triangle



The COG of a right triangle is found by measuring a distance 1/3rd the height from the base and 1/3rd the width from the vertical side.

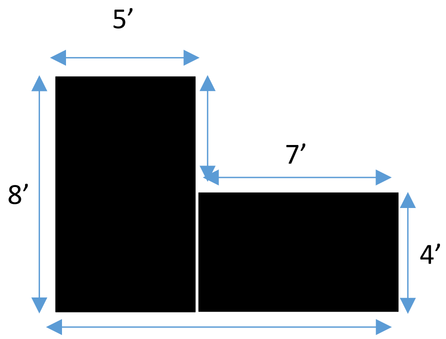


Vertical: 6 ÷ 3 = 2' up

Horizontal: 3 ÷ 3 = 1' in

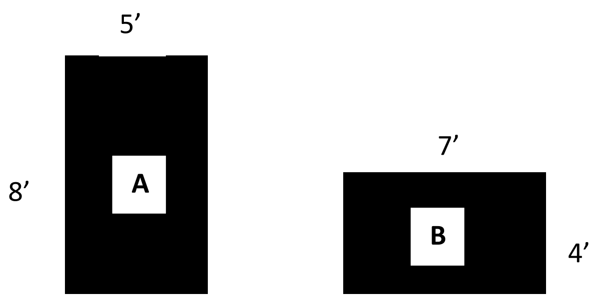
The COD is the point where these axes cross

Uniform Thickness Slabs



You have an L shaped section of 6”concrete.

6” concrete weighs 75 lbs/ sq ft



First: Divide the object into simple shapes

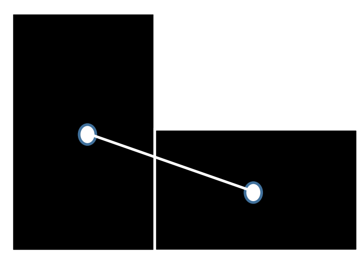
Second: Calculate the weight of each section.

A: 8’ x 5’ = 40 sq ft
  40 sq ft x 75 lbs = 3000lbs

B: 7’ x 4’ = 28 sq ft
  28 sq ft x 75 lbs = 2100 lbs

3000 lbs + 2100 lbs = 5100 lbs

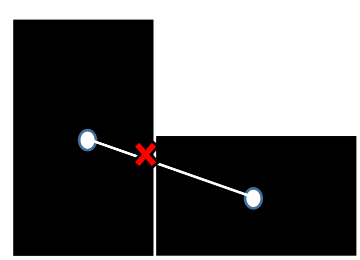
Third: Mark the COG for each object and connect them with a line.

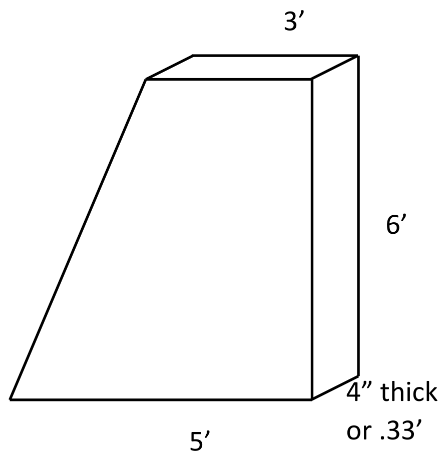


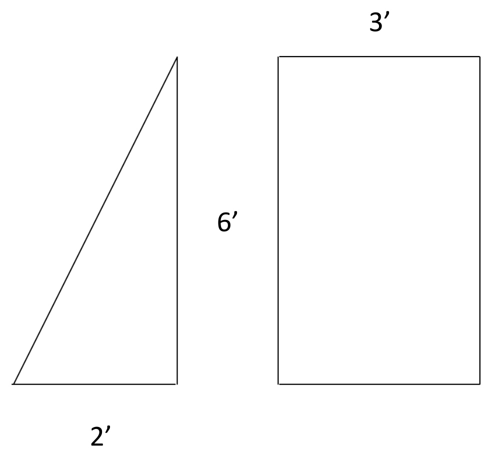
Fourth: To determine the COG for the object as a whole, calculate the proportion of the weight of the heavier piece to the weight of the whole unit.

3000 lbs ÷ 5100 lbs = .58

The COG will be 58% closer to the heavier object from the center point of the lighter object.







Solve individually as a triangle and a rectangle:

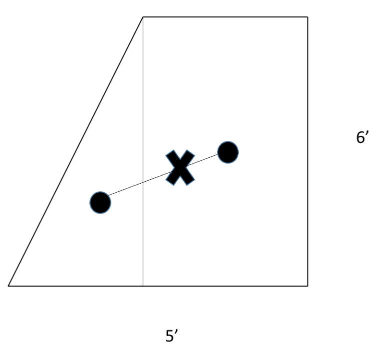
Triangle: (2’ × 6’) ÷ 2 = 6 sq. ft. → 6 x .33’ = 1.98 cu. ft. → 1.98 × 150 lbs. = 297 lbs.

Rectangle: 3’ × 6’ = 18 sq. ft. → 18 x .33’ = 5.94 cu. ft. → 5.94 x 150 lbs. = 891 lbs.

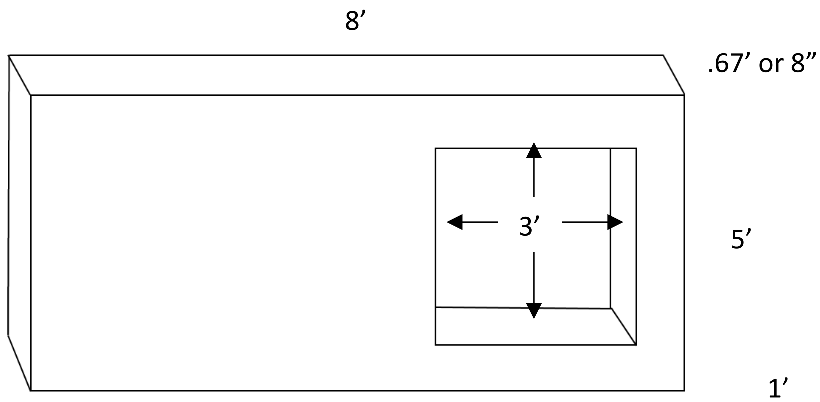
Total: 6 + 18 = 24 sq. ft. × .33’ = 7.92 cu. ft. × 150 lbs. = 1188 lbs.

Figure COG: Divide the heavier piece by the total weight for the percentage distance from the lighter toward the heavier object where the COG is located

- 891 ÷ 1188 = .75 or 75% toward the heavier object



Finding the CG of Objects with Missing Sections



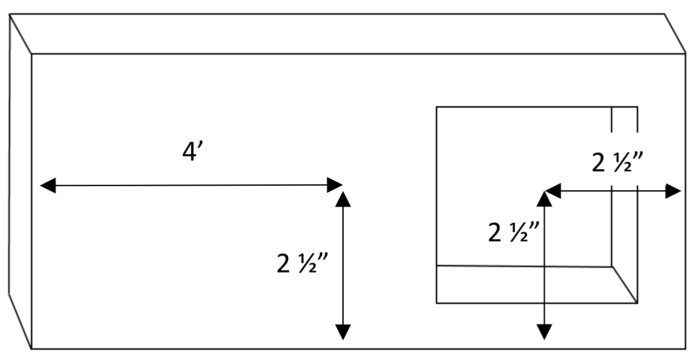
Solve for each piece separately:

Whole Slab: 8’ × 5’ × .67’ = 26.8 cu. ft. ⟹ 26.8 cu. ft. × 150 lbs. = 4020 lbs.

Hollow Section: 3’ × 3’ × .67’ = 6.03 cu ft. ⟹ 6.03 cu. ft. × 150 lbs. = 904.5 lbs.

Whole – Hollow = 26.8 cu. ft. – 6.03 cu. ft. = 20.77 cu ft

Actual Weight: 4020 – 904.5 = 3115.5 lbs



To obtain the COG we will approximate the weights of each section

Whole object: 4000 lbs.

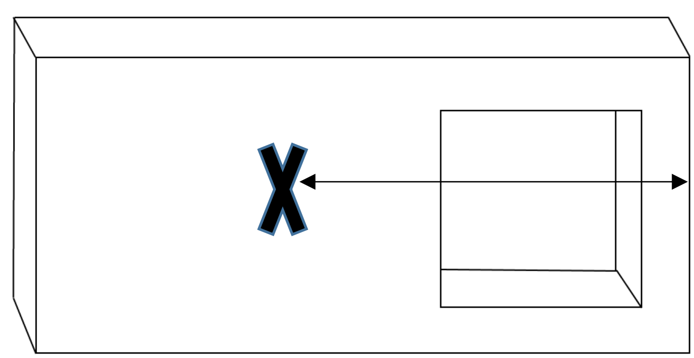
Cutout: 900 lbs.

Total Weight: 3100 lbs

(4000 x 4’) – (900 x 2.5’) =

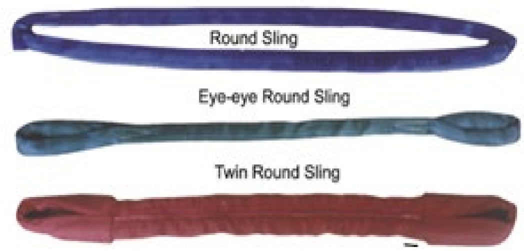
16000 – 2250 = 13,750 lbs

13,750 lbs. ÷ 3100 lbs. = 4.44 ft. from the bottom



The ability to correctly calculate the weight of the intended load is only part of the equation. The technician should also be familiar with the items in their cache that are used for lifting, what their capacities are in certain configurations and how the weight of the load is imposed on the lifting equipment based on the angles used when establishing the rigging.

Common items used in rigging are chains, wire rope slings and synthetic round slings. All of these have a rated capacity that can be increased or decreased depending on the manner in which they are secured to the load. Knowing these capacities or how to find them as well as understanding which piece in your cache is the weakest link helps the technician make informed choices on rigging methods.



Chain

Wire Rope Sling

Synthetic Round Sling

All Slings must have a Tag attached that provides critical information, without that tag the sling should be placed out of service. The tag will include the name of the manufacturer, the diameter or size of the sling and the rated loads for different hitches and angle those capacities are based on. For synthetic slings the tag will also list what type of synthetic material the sling is made of. Chain tags will include the chain grade.

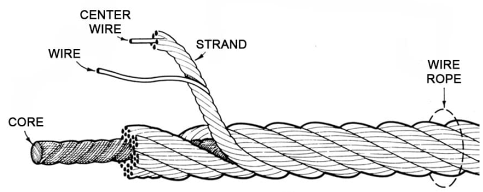
Chain

Chain is used in several aspects of rigging from binding and securing loads during transport to overhead lifting. Chains are rated by grade and grade is determined by the tensile strength of the base material, i.e. the ultimate breaking strength. The greater the breaking strength, the higher the grade. Chains with a grade of 80 and above (80, 100 & 120) are suitable for overhead lifting. Chains are ideal in high-temperature environments and for securing to rugged loads that could damage wire or synthetic slings.

The benefit of chains is that they are rugged and durable, they resist abrasion and are relatively resistant to corrosion and most chemicals. The downside of chains are that they are heavy, failure of a single link results in failure of the entire sling and there is no warning when they fail and they cannot be shock loaded. Prior to use check chain for the appropriate tag, excessive nicks, cracks, breaks or gouges, stretched, bent, or twisted links, or any other visible damage.

Wire Rope

Wire rope is the most frequently used material to make slings, it is strong dependable and economical option for most lifting applications.



Wire rope is made from several strands of high strength steel that are laid together to form a rope, usually around a central core. The core may be Fiber Core (FC), Independent Wire Rope Core (IWRC), or Wire Strand Core (WSC). The number of strands, the number of wires per strand, the type of material and type of core will depend on the use of the rope. Overall, the more wires and strands, the more flexible the rope.

Wire rope slings should be used where a variety of heavy loads and rugged conditions exist. When used, an object in the eye of a sling (i.e. the hook or a shackle) should not be wider than one half the length of the eye. Slings in contact with edges, corners or protrusions should be protected with a material of sufficient strength, thickness and construction to prevent damage to the sling, so edge protection anywhere on the load that impose a kink in the wire.

Prior to use wire rope should be checked for missing or illegible sling identification, sever corrosion, evidence of kinking, crushing, bird caging or any other damage resulting in damage to the structure of the rope. Check end attachments that they are not overly worn, cracked, or deformed.

Synthetic Slings

Synthetic slings are made from Nylon, Polyester, Aramid, Kevlar, Dacron, Polyethylene, or Nomex fibers. Synthetic slings are beneficial because they are lightweight, elastic, load hugging and non-spark producing. They are resistant to harmful chemicals depending on the construction material and are less prone to twisting or spinning the load, but they may stretch when loaded.

Synthetic slings are best used in situations where their stretch and flexibility are needed to mold to the shape of the object and grip the object securely. Some synthetic slings are round slings and others have end attachments. When an object is set in the eye of a synthetic sling (i.e a hook), it should not be wider than one third the length of the eye. And just as with wire rope, the synthetic sling should be protected from any sharp edges or highly abrasive surfaces to prevent damage to the sling.

Prior to use check the sling for missing or illegible identification, any chemical or heath related burns, broken or worn stitching, excessive abrasions or holes, tears or cuts. Check any end fittings and ensure that they are not broken, cracked, bent or twisted.

Rigging Considerations

Safety Factor is the structural capacity of a system beyond the expected or actual loads. It is a ration of the ultimate breaking strength of a lifting device to the actual working stress or safe working load when in use.

In the USAR world accepted working loads are as follows

- SF 5:1 for lifting applications
- SF 3:1 for other general uses
- SF 10:1 when lifting people

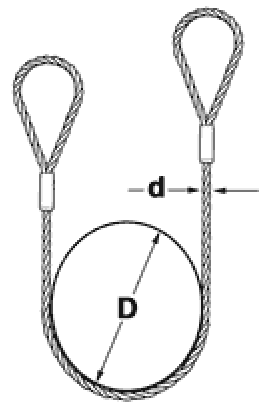
D/d Ratio

Obviously when rigging for lifting, at some point the sling will have to be placed into a hook, pulley or some other piece of hardware to accommodate that lift. It is essential to know the size of equipment in your cache as every connection, angle or influence on the sling has an impact on its load capacity.

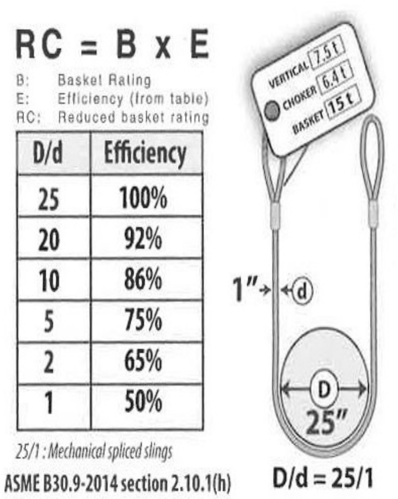
The D/d ratio is the diameter around which the sling is bent (D) divided by the body diameter of the sling (d). As you guessed, this affects the capacity of the slings.

Example:

- A ½" diameter wire rope is bent around a 10" diameter pipe
- The D/d ratio is 10" divided by ½" = 20:1

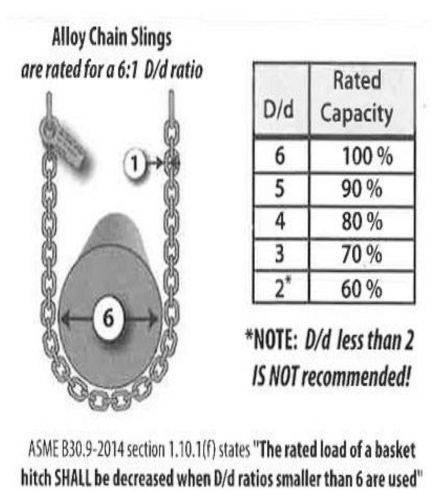


Wire Rope D/d



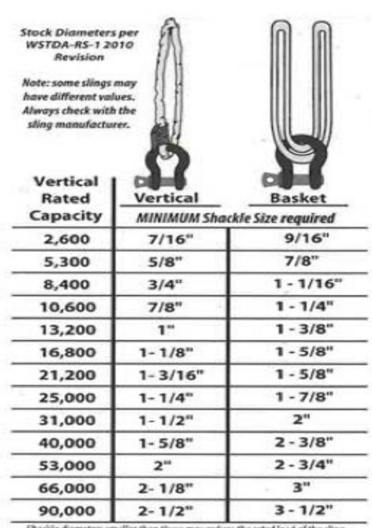
D/d	Efficiency
25	100%
20	92%
10	86%
5	75%
2	65%
1	50%

Chain D/d



D/d	Rated Capacity
6	100 %
5	90 %
4	80 %
3	70 %
2*	60 %

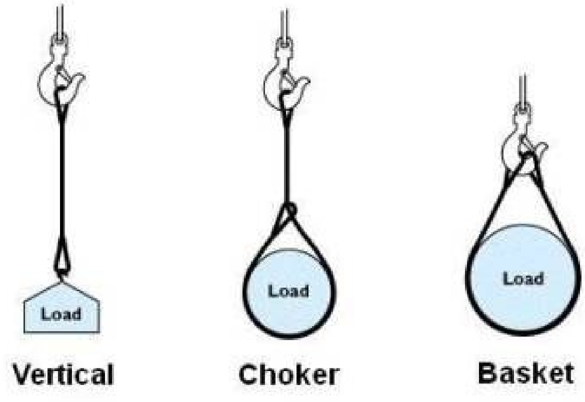
Round Sling D/d



Vertical Rated Capacity	Vertical (MINIMUM Shackle Size required)	Basket (MINIMUM Shackle Size required)
2,600	7/16"	9/16"
5,300	5/8"	7/8"
8,400	3/4"	1 - 1/16"
10,600	7/8"	1 - 1/4"
13,200	1"	1 - 3/8"
16,800	1- 1/8"	1 - 5/8"
21,200	1- 3/16"	1 - 5/8"
25,000	1- 1/4"	1 - 7/8"
31,000	1- 1/2"	2"
40,000	1- 5/8"	2 - 3/8"
53,000	2"	2 - 3/4"
66,000	2- 1/8"	3"
90,000	2- 1/2"	3 - 1/2"

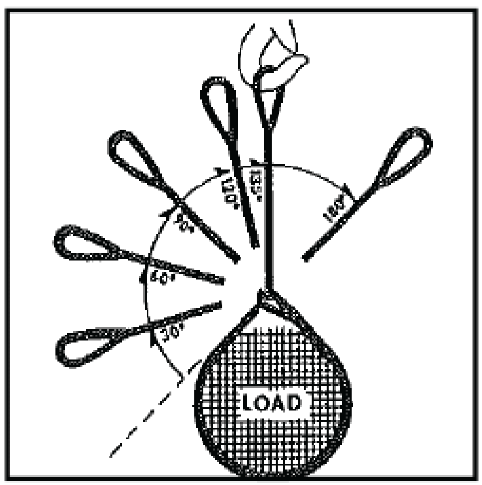
Shackle diameters smaller than these may reduce the rated load of the sling.

When connecting to a load there are three main methods of connection: Vertical, Choker and Basket.



Vertical: One eye of the sling is placed on the hook and the other eye is connected to the load. The Working Load Limit (WLL) of the sling will be 100% of the vertical sling capacity

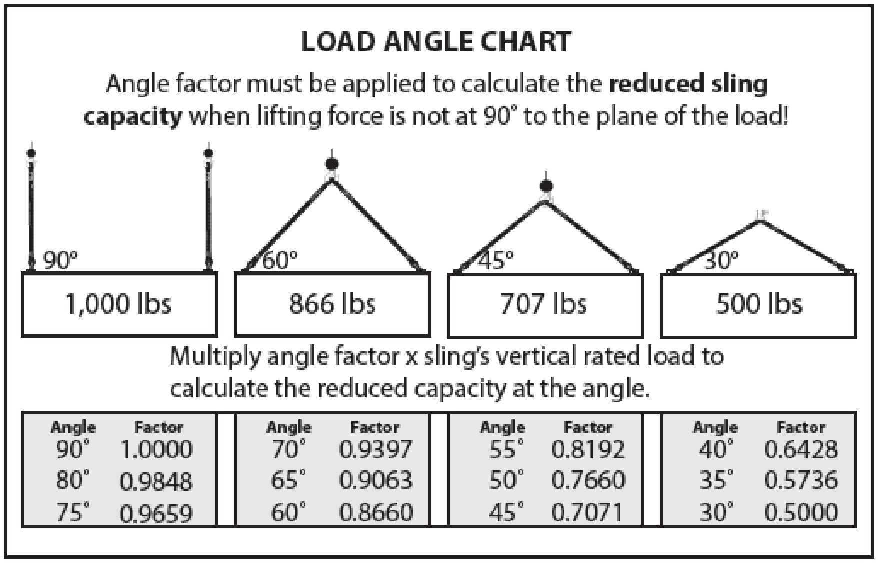
Choker: The sling is wrapped around the load and passes through one of the eyes or a shackle while the other eye is connected to the hook. The WLL of a choker hitch is about 75% of the rated capacity and that capacity will be reduced further depending on the angle of the hitch coming from the load.



Angle of Choke	Capacity % of Choker (ASME B30.9)	Capacity % of Vertical (ASME B30.9)
120°- 180°	100%	75%
90°- 120°	87%	65%
60°- 89°	74%	55%
30°- 59°	62%	46%
0°- 29°	49%	36%

Choker Hitch capacity reductions when angle of choke is less than 120 degrees.

Basket: The sling cradles the load with both eyes connected to the hook. More than one sling may be necessary for load control. The WLL of a sling in a basket hitch, with near 90 degree legs is 200% of the sling's vertical capacity. In order to use the full basket hitch to its rated capacity, the D/d ratio must meet the manufacturer's specifications.



Angle	Factor	Angle	Factor	Angle	Factor	Angle	Factor
90°	1.0000	70°	0.9397	55°	0.8192	40°	0.6428
80°	0.9848	65°	0.9063	50°	0.7660	35°	0.5736
75°	0.9659	60°	0.8660	45°	0.7071	30°	0.5000

The lifting capacity of each leg of the sling will be altered based on the angle of the sling from the load to the hook. The lower degree of the sling angle the less weight each leg will hold.

Sling Angle

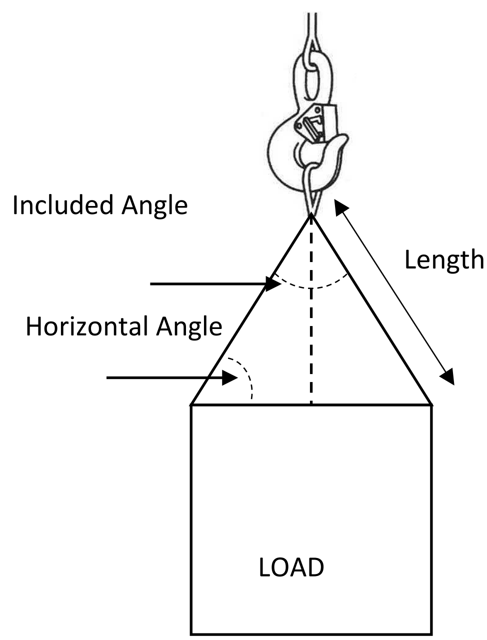
A Sling Angle is the angle formed between a horizontal line and a sling leg. The components of a sling angle are described below:

- Horizontal Angle: the angle formed between the top of the load and sling leg
- Included Angle: the angle formed between sling legs and the hook
- Length: the distance between the extreme bearing points of the sling

When the horizontal and included angles are added together, they will always equal 180 degrees.

When slings are configured so that the legs have a horizontal angle of less than 90 degrees, the force in the sling increases.

As the horizontal angle decreases, forces on that sling increase, and as the forces increase, the WLL of the sling decreases.



Calculating Load Angle Factors

The capacity of a sling depends on the sling material, hitch type and the sling angle. Most loads are not rigged at a 90 degree angle. The load imposed on each leg of a sling depends on the horizontal angle:

- 60 degree angles are preferable
- The angle should be at least 45 degrees

Try to avoid rigging at less than a 30 degree angle. Per ASME standards, sling angles less than 30 degrees shall not be used except as recommended by the sling manufacturer or a qualified person.

The load angle factor can be calculated by dividing the strap length by the height (L÷H).

An additional consideration is the placement of the attachment points. If the attachment points are at the same elevation (as shown in the example), it is called a symmetrical load. If the attachment points are at different elevations it is a non-symmetrical load.

If the straps are of different lengths (as found in non-symmetrical loads), then the load angle factor will be different for each leg.

If the sling angle is known then multiply the weight of the load to determine what each leg will see when lifting. It is not imperative to memorize every angle but it is a good rule of thumb to know load factors for 30, 45 and 60 degrees.

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Calculating the Sling Load

To calculate the sling load, four pieces of information are needed:

- WLL of each sling in the configuration you intended to rig (choker, basket, etc.)
- Weight (W) of the object to be lifted
- Length (L) of each strap from the hook to the connection point
- Height (H) above the load to the hook
- The number of sling legs

The procedure is as follows:

- Divide the strap length by the height (L÷H) (this gives the load angle factor)
- Divide the load weight by the number of sling legs (L÷ # of Legs) = Share of Load
- Multiple the load angle factor by Share of load
- Answer = Force exerted on each sling leg or Sling Tension

If the force exerted on the sling leg is higher than the WLL of the sling, do not use that sling for the lift!

Load Factor Chart

Leg Angle	Load Factor
90°	1.000
85°	1.003
80°	1.015
75°	1.035
70°	1.064
65°	1.103
60°	1.154
55°	1.220
50°	1.305
45°	1.414
40°	1.555
35°	1.743
30°	2.000

Example for 11’ Eye to Eye Synthetic Sling with WLL of:

- Vertical: 2600 lbs
- Basket: 5200 lbs
- Choker: 2100 lbs

Divide Strap Length by the Height

- 10 ÷ 8 = 1.25

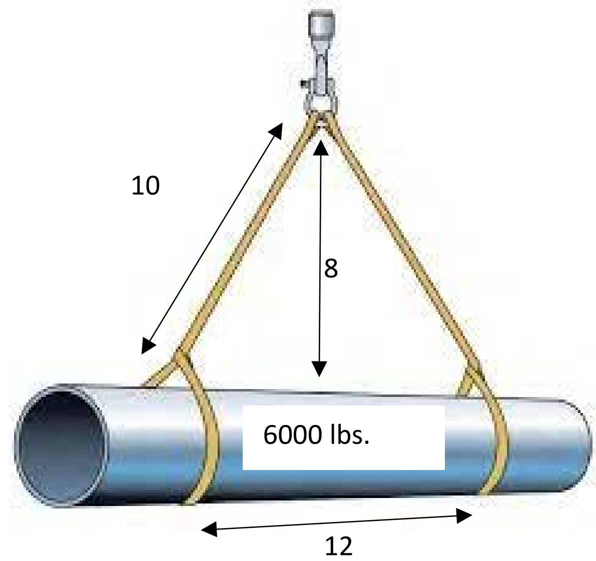
Divide the load weight by the number of sling legs

- 6000 ÷ 2 = 3000 lbs

Multiply the Load Angle Factor by the Share of Load

- 3000 × 1.25 = 3750 lbs

This sling in the choker configuration would not be suitable to lift this load.



Heavy Equipment

In order to utilize a piece of heavy equipment on scene, you must first have the equipment as well as an operator, and then you need to determine if that operator is competent enough to assist with the scene needs. To safely utilize the equipment and operator there must be a method of communication between the operator and whoever is running the operation.

Backhoes and Excavators are the two most likely machines to be on scene. As a rescuer you should be able to recognize the difference between the two and understand their capabilities as a machine, independent of the capabilities of the operator. This can be determined by speaking with the operator and referencing the load chart in the cab and reviewing the operator’s manual if on site and time permits.

Determining the ability and limitations of the operator is a little more subject. If they were present during the collapse and know the individuals trapped they are most likely not in the best frame of mind to be running the equipment. If the operator is calm and helpful ask how many years of experience they have and how many times they have performed the needed actions of sloping, benching, installing a trench box, etc.

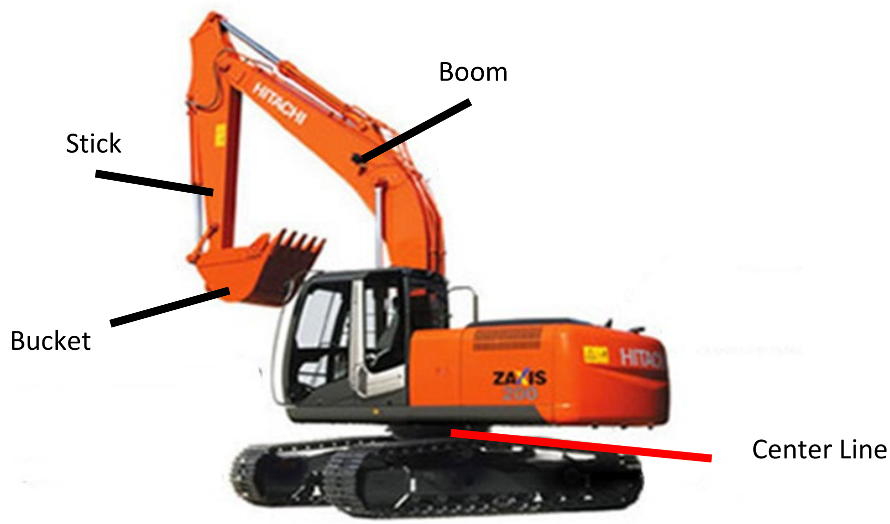
A clear line of communication should be established with the operator and those directing the rescue. If the scene allows for the use of radio traffic then provide one to the operator or keep personnel close to the operator to convey incident needs. Machines are loud and difficult to hear around therefore the rescuer should also be familiar with basic hand signals used around backhoes and excavators.

Hand Signals-Excavators

Heavy Equipment

Backhoe

Excavator



The rated lifting capacity of any hydraulic excavator is determined by two factors: hydraulic lift capacity and the tipping load. Hydraulic lift capacity is the point at which the excavator is limited by its hydraulic power to lift a load. Tipping load is the point at which the excavator begins to tip or lift off the ground when lifting a load.

Operators should factor in any lifting considerations that result from additional accessories or attachment variations, as these alternative items can reduce a machine's effective lifting capacity. For instance, the weight of slings, any auxiliary lifting device and the weight difference of any attachment heavier than the standard configuration must be subtracted from the rated lift capacity to determine the correct net lift capacity.

There may be several lift charts for a large or mid-range excavator, based on combinations of boom length, arm length, bucket size, counterweight size and track shoe width. According to Mike Stark, Doosan excavator product specialist, operators need to pay specific attention to whether the bucket weight is incorporated into the lift chart. This varies by manufacturer and can affect the operator's ability to determine the lift accurately because the bucket in use may not match the bucket weight used for the lift chart.

This chapter, while it covers quite a lot of material, is not an exhaustive collection of information related to lifting and moving. This provides a little more than the basics for load calculations but it is not intended to be an exhaustive resource. The student should look to a dedicated Heavy Rigging and Lifting Course for more a more comprehensive approach to load calculations. Information included in the chapter was referenced from TEEX as well as the MUSAR group.

Trench Rescue Course

Class Title:
Replacement Shoring

NFPA 1006 JPR's:
12.2.1 – Identify potential hazards to victims and rescuers in and around a trench excavation
12.2.2 – Implement a hazard control plan
12.2.3 – Develop a shoring plan

Time:
1 hour

Objectives:
At the end of this chapter the rescuer should be able to:

- Determine the need for replacement shoring
- Effectively replace substandard shoring components with appropriate shoring materials

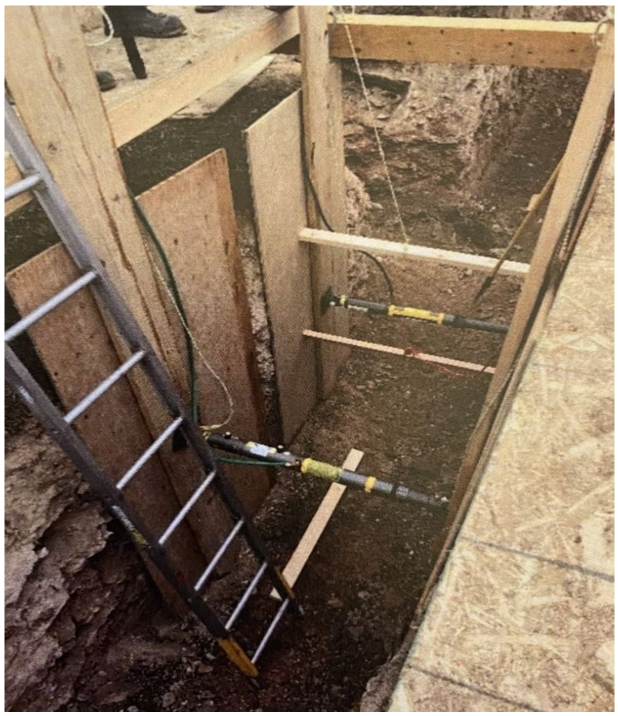
It is possible that on a trench rescue event, workers have placed temporary shoring in order to protect those inside the trench, substandard shoring will need to be replaced before rescuers can enter the trench. This must be done in such a way that we do not create a more dangerous situation for those already in the collapse. Whatever is in place may in fact be holding back a potential collapse and complete removal could be disastrous therefore we must be able to shore around the existing shoring.

Replacing or enhancing substandard sheeting and shoring should be done whenever the risk/benefit analysis concludes that the safety margin provided by the current (in place) sheeting/shoring system is inadequate for the entry of recuse personnel. This analysis would include, but not be limited to, the following:

- Wooden struts are not compliant with trench rescue shoring tabulated data
- Struts are placed in a fashion that does not provide axial loading, or are not perpendicular to the sheeting
- Struts are not adequately compressed or secured
- Sheeting is not compliant with trench rescue shoring tabulated data
- No sheeting (skip shoring or spot shoring)
- Inadequate back-fill of voids created by collapse
- Vertical/Horizontal spacing does not provide adequate safety factors
- Wall angles are less than 70 degrees

The first step in replacement shoring is to evaluate the scene, recognize and mitigate any present hazards. The next step would be to conduct a shoring size up, assess the size of the trench (depth, width and shape) as well as the condition of the lip. Look at potential collapse areas and voids around and behind the shoring. Once all this information has been taken into account a shoring plan needs to be developed and everyone needs to know the plan and their role. [Panel Team, Shoring Team and Entry Team] From there it will follow the same pattern as if the ad hoc shoring was not there: Primary Shoring for Pt protections, Secondary Shoring for Rescuer Protection and Complete shoring to extend the safe working area.

Step 1- Interim Shoring



Panel Team

- Place lip protection over the victim area on both long walls
- Position two 2x12 uprights per wall directly across the trench from each other. (If plywood is used as a panel in the substandard shoring system, install the uprights over the plywood.)
- The inside edges of the uprights must be between 4 ½’ (54”) and 5’ (60”) apart to allow panels to be placed between them at a later time.

Shoring Team

- Tie off substandard “struts” that are within 4 feet (both sides) of the pt [when the interim shoring is charged these will likely fall out and we don’t want them to hit our victim]
- Install 2 struts on each upright (for each 8 vertical feet) and slowly increase the strut pressure to 100 psi (greys) or 87 psi (golds) this is about 500 lbs of activation force.
    - Remove the substandard struts as they begin to loosen

Step 2- Primary Shoring

Panel Team

- Install primary panel in between the installed uprights to protect the victim's head and torso. [If plywood was used as a panel in the substandard shoring system, install the trench rescue panels over the plywood]
    - Depending on placement of uprights, two primary panel sets may be necessary to encompass and protect the victim
- Coordinate back fill with strut installation (if necessary)

Shoring Team

- Install at least 2 struts on each primary panel set
- If voids are present in the primary shoring area, follow the void shoring procedures
    - If voids are present behind the primary panels, begin with struts activation forces of 500 lbs and slowly increasing to 1,000 lbs of force. Stop adding air pressure if the panel bends and enhance back-fill before increasing the strut activation force.
- Place positioning struts (stop the crush)
- Place back fill strut
- Place compliance strut (as needed)

Step 3 – Secondary Shoring
Panel Team

- Install the panel sets on both sides of the victim (when possible, it may require placing more uprights and removing inadequate struts)
- Coordinate backfill installations for secondary panels with the installation of secondary struts

Shoring Team

- Install at least 2 struts on secondary panel sets
- Mitigate voids behind panels if present

Step 4 – Complete Shoring

- Expand the safe zone with panels and shores as needed
- Install Supplemental Shoring as needed during extrication operations