



# Field Guide for Building Stabilization and Shoring Techniques

BIPS 08 / October 2011



Homeland  
Security

Science and Technology



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Science and Technology

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## Background

Collapse rescue operations are dangerous, rapidly evolving efforts focused on finding and extracting trapped and entombed victims, while avoiding harm to the rescuers and further harm to the victims. Stabilization of damaged structures is an integral part of building collapse rescue operations.

Over the past 20 years, first responders and structural engineers (Structures Specialists) in the Department of Homeland Security Federal Emergency Management Agency (DHS/FEMA) and the US Army Corps of Engineers (USACE) Urban Search & Rescue (US&R) programs have been rigorously trained and have gained invaluable experience at actual building collapse incidents and in building stabilization.

The building stabilization state of practice has evolved based on experience at disaster responses, full-scale testing of stabilization methods, and the evolving development of tools and techniques to monitor the stability of damaged structures.

## Overview of Contents

This guide is a field reference book for vertical shoring, lateral shoring, and in-situ rapid strengthening and/or repair of damaged building components. This guide refines and expands on the information provided in the existing US&R Structures Specialist Field Operations Guide (FOG).

This guide includes concise information - including descriptive graphics – on the current FEMA developed built-in-place shoring systems, newly designed and tested built-in-place shoring systems, the results of the most recent testing of built-in-place shoring systems, and a system by system discussion of the relevant characteristics of Manufactured Shoring and Repair and Strengthening techniques that may be able to be adapted to rescue operations. Also included in this Guide is expanded information on Building Size-Up and new Shoring Size-up information.

Information contained in this guidebook is based on experience, experimental testing, engineering analysis, and common sense. However, all rescue scenarios are unique

and the stabilization techniques contained herein must be applied with judgment, considering the specifics of the operations underway. In many instances, additional input from a qualified engineer is required.

### **Intended Audience**

This Field Guide has been developed with a number of different audiences in mind.

- **First Responders:** Local agencies responding to initial/everyday incidents. Engine companies, truck companies, police, etc.
- **Special Operations and Technical Rescue Teams:** Department based units, companies or teams that have more specialized training and equipment than the First Responders.
- **County and Regional Response Teams:** County and regional based teams with specialized training and equipment.
- **State & National Response Teams (FEMA US&R and SUS&R teams):** Highly trained, advanced equipment.
- **Disaster Engineers:** Trained engineers who may respond as a component of any of the above categories.

While the highly trained Technical Rescue teams may already have the information on the Built-In-Place shoring systems, this book has added a few newly tested shores (Plywood Laced Post systems) and it is the only place where the in-situ Repair and Strengthening techniques are presented with respect to their performance requirements and their possible applications in a rescue environment.

## Approach

This document has been produced by the Department of Homeland Security, Science and Technology Directorate, Infrastructure Protection and Disaster Management Division.

Much of the base content for the Guidebook has been drawn from the US&R Structures Specialist Field Operations Guide (FOG), the US&R Shoring Operations Guide (SOG), and the student manuals for the USACE US&R Program's Structures Specialist I and II classes. These original documents were prepared as resources and training tools for the rescue community.

Shoring designs included in this Guide build on the established shoring designs used in the FEMA Urban Search & Rescue system and adds information learned from experience in field situations regarding stabilization of buildings.

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## **Training and Preparation**

The importance of training and preparation cannot be emphasized enough. Search and rescue operations are chaotic and fast-moving with judgment and decisions needing to be made rapidly. Arriving on a scene without prior training and preparation can be dangerous.



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# 1 Stabilization Concepts and Size-up

## 1.1 Stabilization: Philosophy, Principles, Characteristics

The three primary characteristics of a full or partial building collapse that should be addressed by rescue personnel are:

- Viable void potential.
- Structural hazards.
- Hazard mitigation measures.

### 1.1.1 Viable Void Potential

The primary focus for search & rescue teams is rescuing live victims. This means finding and accessing voids in which live victims are entombed – viable voids. In assessing the potential for viable voids, there are two aspects that must be considered: the physical potential for voids and the viability of any victims in those voids.

Void potential is a function of

- Total energy released (during the initial event and any secondary events).
- Structure type and configuration.
- Collapse patterns.
- Building contents.
- Other contributing factors.

In addition to the physical presence of voids, the viability of potential victims in those voids must also be considered. A physical void that initially protects a victim from crushing may become non-viable due to various secondary events such as fire, smoke, temperature extremes, aftershocks, flooding, chemical exposure, and time.

### 1.1.2 Structural Hazards

While the first inclination may be to assume that progressive collapse of the remaining structure is of the greatest concern, experience has shown that this is not usually the case. While secondary collapse cannot be ignored, other structural hazards are often a more immediate concern.

The predominant hazards of immediate concern are:

- Falling of loose debris.
- Shifting of the debris pile.
- Shifting/sliding/dropping of elevated failed components.

- Local shear/flexural failure of beams/slabs.
- Local crushing/buckling of walls/columns.

The significance of these hazards often changes over the course of rescue operations and must be re-evaluated on a continuing basis. The changing conditions may include external events such as aftershocks, secondary detonations, and weather; or they may be operations related changes such as debris removal, vibrations from operations and load changes due to rescue personnel and equipment.

### 1.1.3 Risk Management

Managing risk in a hazardous environment involves evaluating, at least qualitatively, risk versus reward. Operations naturally accept higher risk when the reward involves rescuing live victims. When the probability of live rescue is low, the acceptable level of risk should be proportionally lower. Managing the relative risk is accomplished through a Hazard Mitigation Plan.

### 1.1.4 Hazard Mitigation Measures

Once potential viable voids and structural hazards have been identified, mitigation measures can be planned and implemented to manage the risk during operations. There are no pre-set, cookie-cutter solutions to hazard mitigation, rather the rescue team must assess the situation and apply a combination of the following five basic mitigation strategies based on the premise of risk versus reward:

#### 1.1.4.1 Avoidance

If there is no immediate need to be in a specific dangerous area, that area is cordoned off and personnel are not to enter. An example would be to cordon off the front of a building where there is collapse debris that could slough off the building or a parapet that is subject to falling.

#### 1.1.4.2 Exposure Time Reduction

When time is critical, or other hazard reduction methods are not justified, the risk can be reduced by minimizing exposure of personnel to a dangerous area. This can be accomplished by:

- Minimizing the number of rescue personnel going into a hazardous area.

- Minimizing the time rescue personnel spend in a hazardous area.

For instance, if a large building is racked laterally, shoring that building would require much time, effort and materials. If there are live victims in the structure, rescuers can minimize exposure by sending in the minimum number of required personnel for as short a time as possible.

#### 1.1.4.3 Removal

One of the most dangerous situations for rescuers is falling debris or objects from overhead. In these cases, removing the object removes the hazard.

An example is a leaning, non-load-bearing wall or a leaning, brick chimney. After considerations of the effects on the overall structure, possible victims, and the surrounding debris, the wall or chimney can be pulled down, removing the fall hazard in the operational area.

#### 1.1.4.4 Monitoring

Monitoring the time dependent movement of a structure as operations continue comes in many forms including

- Surveying equipment to monitor building movements.
- Strain gage indicators to monitor crack widths.
- Digital levels to monitor plumbness or rotations of walls or components.
- Wireless sensors for monitoring dangerous areas.

Monitoring can be used to track:

- Global building movement.
- Element or component movement.
- Debris field movement.
- Localized area deformations.

Monitoring can be used independent of, or in conjunction with, other forms of hazard reduction methods. Monitoring is usually quick to set up and does not require significant resources.

Effective monitoring equipment and procedures for rescue operations can be found in:

- StS-1-5: Introduction to Mitigation & Monitoring Methods
- US&R Structures Specialist FOG

Both of which can be found on [www.DisasterEngineer.org](http://www.DisasterEngineer.org).



### 1.1.4.5 Stabilization

The most costly in terms of personnel, material and time resources is mitigating the hazard by stabilizing the structure. When there is considerable risk to rescue personnel and the rescuers will need to work in the high risk area for a significant amount of time, stabilization of the structure is warranted.

There is a large array of stabilization techniques in a rescue team's toolbox that can be divided into two basic categories:

- Shoring.
- Repair and Strengthening.

## 1.2 Definition of Shoring

Emergency shoring used in urban search and rescue incidents is defined as the temporary stabilization or re-support of damaged structural members or systems subject to continued movement or collapse. The shoring support is applied as necessary to only a section of, or structural element of, or a part of the compromised structure. Shoring is used in order to provide a safer and more efficient working environment while conducting victim search and rescue operations. If hazards exist that cannot be mitigated by other means (i.e., avoidance, minimizing exposure, or removal), then shoring can be used to reduce the risk environment for the collapse incident's victims, as well as the rescue personnel.

Rescue shoring is to properly re-support the structurally damaged or unstable element by "receiving and collecting" loads from damaged elements and "transmits and or distributes" these loads to structural elements in the remaining part of the building that are sound and capable of handling the additional collapse caused loads.

Effective Shoring Includes

- Adjustability.
- Positive Connections.
- Lateral Bracing.
- Ductility.
- Warning of Overload.



### 1.3 Definition of Repair and Strengthening

Repair and strengthening is the stabilization of the residual strength of damaged structural elements and/or the improvement of the residual strength.

### 1.4 Definition of Size-up

Size-up is the process of gathering on-scene information that will assist rescuers in making efficient, effective, and safe decisions during ongoing operations. It is the foundation for subsequent decision making.

### 1.5 Building Size-up

There are many events that may initiate structural damage and collapse requiring search and rescue efforts. These include earthquakes, wind events, landslides/debris flows, floods/tsunamis, fire, high energy impacts, industrial accidents, structural defects and overloads, and explosions. Regardless of the initiating incident, the responding rescuers are tasked with evaluating the damaged structure and identifying hazards to rescue personnel as they operate in the building.

The Building Size-Up provides a survey of structural damage and potential victim locations to conduct rescue operations. The process includes:

- Identifying structural hazards, damage and potential victim locations.
- Determining best method to mitigate the structural hazards.
- If required, determining the type and placement of shoring systems in relation to structural hazards, damage, and potential victim locations.

## 1.5.1 Size-Up Considerations

### 1.5.1.1 Victims

The objective of search and rescue operations in damaged structures is to locate and extricate live victims. Therefore a top priority is how many victims are trapped, and where are they located. Another consideration is whether this information is coming from reliable sources and whether it can be confirmed.

### 1.5.1.2 Six-Sided Approach to Building Survey

Survey all four sides plus the top and the bottom of the entire structure paying particular attention to the collapse area.

Of special note are the top and bottom survey.

- The top survey identifies loose or hanging debris and structural elements, and other overhead hazards.
- The bottom survey includes identification of:
  - Structures or utilities below the damaged area.
  - The condition of these structures or utilities.
  - Supporting foundation and/or soil failures.

### 1.5.1.3 Structure Survey

When approaching a damaged building, the following observations should be noted:

- Building construction type and materials.
- Racked openings.
- Walls out of plumb.
- Damaged bearing walls.
- Damaged beams, columns, arches, joists and other structural supporting elements.
- Damaged connections between structural elements (walls and roofs, beams and columns, etc).
- General age and condition of the structure.

### 1.5.1.4 Collapse Warning Signs

Continual surveillance of the structure from several vantage points must be maintained from the time of arrival to the time the last rescue personnel have exited the building.

While total stations and theodolites are excellent tools for detecting building movement, there are a number of warning signs that everyone on the rescue site should be aware of:

- Shifting debris.
- Airborne dust.
- Changes in crack patterns.
- Sounds from the structure such as creaking and cracking.

### 1.5.2 Hazard Identification

The following sections discuss the typical falling and collapse hazards for five types of buildings. The discussion includes the expected hazards and behavior when the buildings are subject to extreme events, including

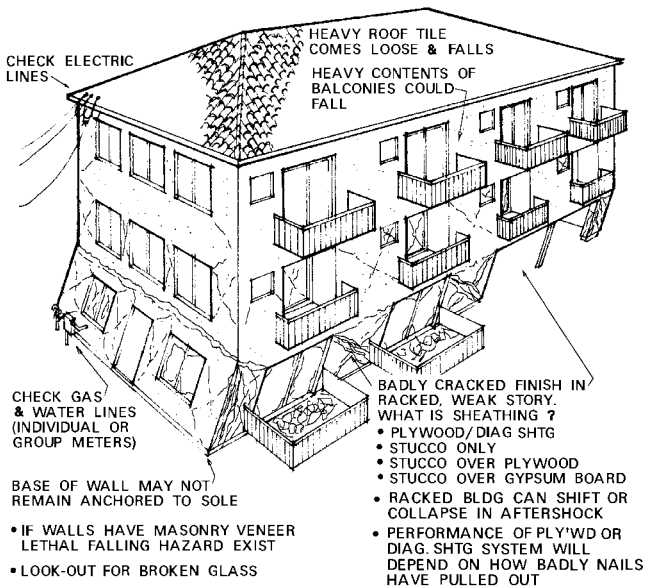
- Earthquakes.
- Explosions.
- Fire.
- High Energy Impacts.
- Wind.
- Structural Overload or Defect.

The types of buildings discussed here are:

- Multi-Story Light Frame Buildings: wood frame construction.
- Heavy Steel Frame Buildings: either moment frame or diagonally braced frame buildings.
- Light Metal Buildings: Pre-engineered light steel buildings.
- Heavy Wall Buildings: unreinforced masonry (URM), unreinforced concrete masonry units (CMU).
- Heavy Wall Tilt-up: Low-rise buildings with prefabricated concrete walls.
- Heavy Floor Buildings: concrete framed buildings.
- Precast Concrete Buildings: buildings constructed with prefabricated concrete structural elements.

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## 1.5.2.1 Multi-Story Light Frame Buildings - Hazards

**CHARACTERISTICS**

- Mostly wood frame, box type – up to 4 stories.
- Residential or Light Commercial.

**KEY PERFORMANCE ASPECTS**

- Many walls create redundant structures w/ductile failure modes, dependant on sheathing type.
- Presence of concrete floor fill can enhance possibility of offset collapse.

**TYPICAL FAILURE MODES**

- Failure in Wall Sheathing – Racking of Walls.
- Failure should be slow and noisy.
- Soft/Weak stories can rack and collapse.

**COMMON COMBINATIONS**

- Many are built over reinforced concrete (R/C) parking garages.

**EXPECTED PERFORMANCE – for the following:**

- **Progressive Collapse** – Extensive connection failures. Members & components are likely to remain intact.
- **E. Quake** – Generally good performance - common failure is ductile racking of first story. Raked stories are subject to ratcheting and offset collapse in Aftershocks.
- **Explosion** – Walls become disconnected from floors (horizontal diaphragms), leading to part or total collapse.
- **Fire** – Rapid combustion and collapse unless fire resistant. Light wood truss systems are especially hazardous.
- **High Energy Impact** – Little resistance to collapse in immediate area. Remainder of structure remains stable.
- **Wind** – Damage is highly dependent on wind speed vs. shape and proper detailing. Tornadoes can destroy even well constructed wood buildings.
- **Struct Overload/Defect** – Roof failures due to snow, especially on longer span roofs.

**CHECK POINTS**

- Badly cracked and/or leaning walls.
- Leaning first story in multi-story buildings.
- Cracked, leaning/loose veneer or chimney.
- Offset of building from foundation.
- Separated porches, split level floors/roof.
- Connection failures - nail pullout/bolt pull-through.

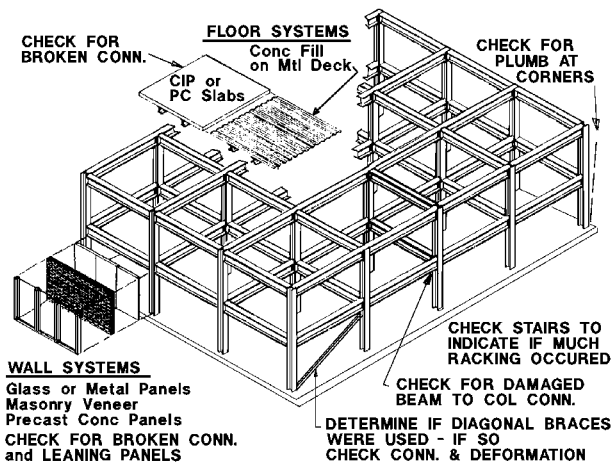
**HAZARD REDUCTION**

- Shut off gas and reduce other fire hazards.
- Avoid or pull-down damaged veneer and chimneys.
- Place vertical and/or lateral shores.
- Monitor changes in racked/leaning structures.

**VICTIM ACCESS**

- Vertical access through floor/roof from above collapsed area.
- Horizontal entry through existing cavities or walls.
- Remove or shore hazards near victims, if required.

### 1.5.3 Heavy Steel Frame Building - Hazards



**SINCE MOST MEMBERS AND CONNECTIONS ARE HIDDEN, BEST INDICATION OF FAILURE IS EXCESS MOVEMENT CAUSING DAMAGE TO NON-STRUCTURAL ELEMENTS AND OUT OF PLUMB CONDITIONS**

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#### CHARACTERISTICS

- Heavy "W" steel beam & column framing – 2 to many stories.
- Office and Commercial Occupancies, some industrial.

#### KEY PERFORMANCE ASPECTS

- Normally well engineered, but performance is dependent on ductility of connections. Precast (PC) floor systems are suspect.
- Welded connections may be subject to brittle failure.
- Diagonally braced frames may have buckled columns or braces.

#### TYPICAL FAILURE MODES

- Connection failure leading to partial collapse. Total collapse is rare.

#### COMMON COMBINATIONS

- May have masonry, precast or metal panel exterior walls.
- Cast-in-place (CIP) floors over metal deck, or PC/CIP directly on steel.



**EXPECTED PERFORMANCE – for the following:**

- **Progressive Collapse** – Rare, since members maintain integrity even with damaged/failed joints.
- **E. Quake** - Good performance of frame - Failure of diagonal bracing and fracture of welded joints have occurred. Facing, especially PC panels could fall and are danger in Aftershocks.
- **Explosion** – Good performance of frame, but wall & floor panels could be dislodged. Frame collapse is unlikely.
- **Fire** – Plastic deformation of floors and some joint failure. Strength is usually regained upon cooling. Collapse rare.
- **High Energy Impact** – Impacted members are severed/destroyed. Connection failures near impact only.
- **Wind** – Frame at low risk – Skin, especially glass, may be destroyed leading to interior partition failure.
- **Struct Overload/Defect** – Failures during erection and long-span failures are most common. Members usually maintain integrity with failures at joints.

**CHECK POINTS**

- Indications of movement – plumb corners, stair and non-structural damage – as clues to potential structure damage.
- Main beam to column connections – remove finishes as required.
- Broken PC floor and miscellaneous beam bolt connections.

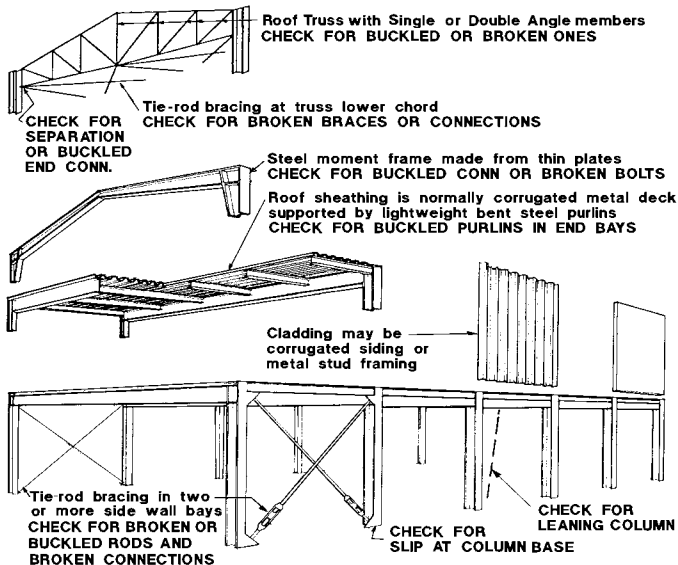
**HAZARD REDUCTION**

- Shore beams near damaged or broken connections.
- Remove/avoid/tieback damaged exterior facing.
- Monitor changes in racked/leaning structures.

**VICTIM ACCESS**

- Vertical access by cutting through slabs from above victims.
- Horizontal entry through existing cavities & openings.
- Remove or shore hazards near victims, if required.

## 1.5.4 Light Metal Building - Hazards



### CHARACTERISTICS

- Light-gage steel, pre-fabricated metal buildings – up to 3 stories.
- Industrial and Commercial Occupancies – most 1 story.

### KEY PERFORMANCE ASPECTS

- Highly engineered with little redundancy or reserve capacity.
- Very flexible, especially in lateral direction.

### TYPICAL FAILURE MODES

- Weakest Link Behavior – loss of sheathing allows buckling, leading to collapse of supporting structure.
- Diagonal rod bracing elongation & joint failure.
- Roof systems may be subject to rapid collapse due to overload.

### COMMON COMBINATIONS

- May have masonry, precast or tilt-up exterior walls.
- May have wood or metal interior partitions and mezzanine.

**EXPECTED PERFORMANCE – for the following:**

- **Progressive Collapse** – Joint failure and member buckling could lead to part or complete collapse.
- **E. Quake** – Good performance – Failure of rod bracing is common, but collapse is rare. Minor aftershock response.
- **Explosion** – Skin blown away, possibly leading to frame/roof collapse. Entire building blown away in some cases.
- **Fire** – Rapid loss of strength and collapse due to heating. Long span structure could suddenly collapse.
- **High Energy Impact** – Little resistance to impact. Damage may involve several bays of structure.
- **Wind** – At high risk – as skin is blown away, frames/trusses can buckle and collapse. Frames can rack and collapse.
- **Struct Overload/Defect** – Lateral torsion buckling of built-up members. Joint failure and member buckling, leading to part or complete collapse.

**CHECK POINTS**

- Broken, elongated and/or buckled rod bracing & connections.
- Buckled purlins, truss members, and steel frames.
- Broken and/or elongated bolt connections and anchor bolts.

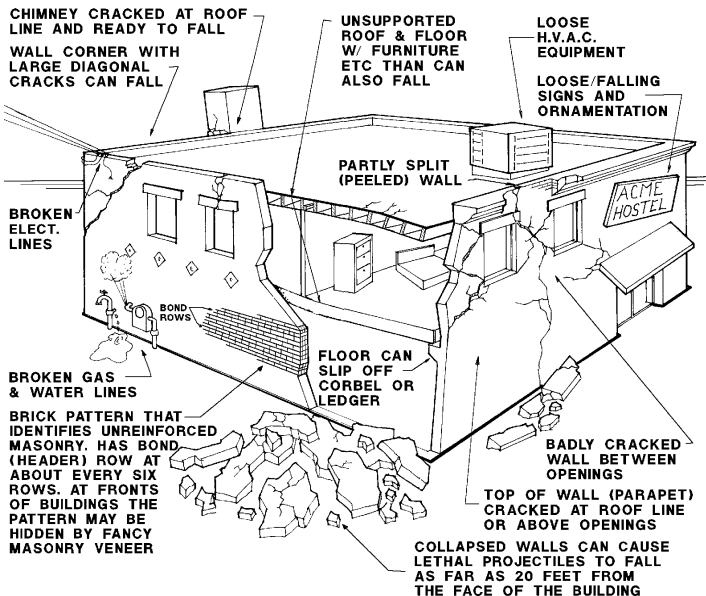
**HAZARD REDUCTION**

- Shore and/or diagonally brace racked building frames.
- Remove loose or lightly connected members and sheathing.
- Monitor changes in racked/leaning structures.

**VICTIM ACCESS**

- Vertical/Horizontal access by removal or cutting sheathing.
- Horizontal entry through existing cavities and openings.
- Remove or shore hazards near victims, if required.

## 1.5.4.1 Heavy Wall - URM - Buildings - Hazards

**CHARACTERISTICS**

- URM Ext walls, wood floors/roof - box type – to 8 stories.
- Lack of wall strap anchors – Red Brick & CMU low-rise.
- Residential, Commercial and Industrial occupancies.

**KEY PERFORMANCE ASPECTS**

- Walls Brittle with little resistance to unanticipated lateral loads.
- Redundant interior walls may prevent floor collapse.

**TYPICAL FAILURE MODES**

- Walls separate from roof/floors, leading to falling walls and collapsed roof/floors.
- Cracked/peeled walls create brittle falling hazards.

**COMMON COMBINATIONS**

- Heavy timber, light frame walls and floors.
- Steel joist floors w/concrete fill in multi-story buildings.

**EXPECTED PERFORMANCE – for the following:**

- **Progressive Collapse** – URM walls likely to disintegrate, and interior structure may stand independently.
- **E. Quake** - Poor performance - out of plane ext wall failures, loss of connection to floors leading to partial or total collapse. Many aftershock falling and collapse hazards.
- **Explosion** – Walls become disconnected from floors (horizontal diaphragms), leading to part or total collapse.
- **Fire** – Loss of roof/floors will leave walls unbraced. Collapsing roof/floors can thrust walls in or out.
- **High Energy Impact** – Exterior URM walls disintegrate upon impact leaving lethal falling hazards & possible floor collapse. Massive masonry is more resistant.
- **Wind** – Roof vulnerable to uplift, leading to partial or total collapse or roof & walls. Massive masonry is more resistant.
- **Struct Overload/Defect** – Roof failures due to ponding and snow. Wood decay, brick disintegration or remodeling in older buildings.

**CHECK POINTS**

- Loose, broken parapets and ornamentation.
- Connections between exterior walls and roof/floors.
- Cracked wall corners and openings, plus peeled walls.
- Unsupported and partly collapsed roof/floors.

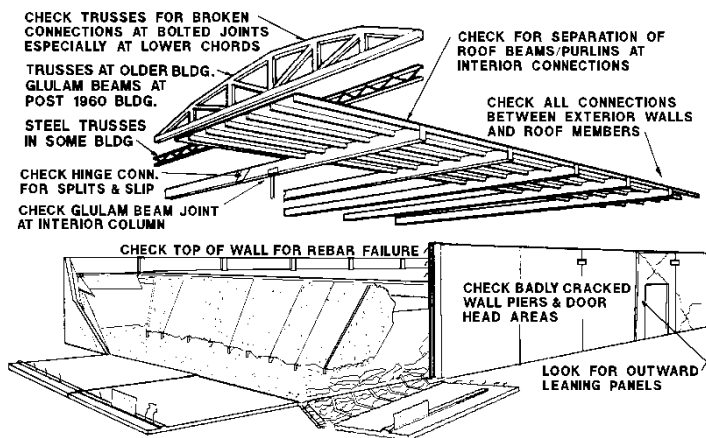
**HAZARD REDUCTION**

- Shut off gas and reduce other fire hazards.
- Diagonally shore. tie-back, avoid, remove hazardous walls.
- Shore hazardous roof/floor beams, etc.
- Monitor changes in racked/leaning structures.

**VICTIM ACCESS**

- Vertical access through floor/roof from above collapsed area.
- Horizontal entry through existing cavities and openings.
- Remove bricks by hand, excavator, or crane with clamshell.
- Remove or shore hazards near victims, if required.

### 1.5.4.2 Heavy Wall Tilt-Up - Hazards



#### CHARACTERISTICS

- Concrete exterior walls, wood floors/roof, some steel floors with concrete fill.
- Older wood roofs: wood trusses, joists, diagonal shtg.
- Newer wood roofs: glulam beams, purlins & plyw'd shtg.
- Some may have steel roof trusses/bar joist & metal deck.
- Long span roof (50ft+) and floors (25ft+).
- Similar performance with CIP concrete or reinforced masonry walls.
- Office, Commercial and Light Industrial occupancies – to 4 stories.

#### KEY PERFORMANCE ASPECTS

- Robust exterior walls, but many buildings may have weak wall connections to roof.

#### TYPICAL FAILURE MODES

- Walls separate from roof/floors, leading to falling walls and collapsed roof/floors.
- Roof systems may be subject to rapid collapse due to overload.

#### COMMON COMBINATIONS

- Light frame walls & floors – 1.5" concrete fill on floors.
- Steel joist, long span floors w/concrete fill.

**EXPECTED PERFORMANCE – for the following:**

- **Progressive Collapse** – Out-leaning walls could progress to roof/floor collapse in bay adjacent to exterior. Remainder could stand independently – but poorly braced.
- **E. Quake** – Pre 1995 - poor performance – out of plane ext wall failures, loss of connection to roofs leading to partial or total collapse. Lethal aftershock falling and collapse hazards.
- **Explosion** – Walls become disconnected from floors (horizontal diaphragms), leading to part or total collapse
- **Fire** – Loss of roof/floors will leave walls unbraced. Collapsing roof/floors can thrust walls in or out.
- **High Energy Impact** – Impact on exterior walls likely to be localized. Could lead to localized roof/floor collapse.
- **Wind** – Roof vulnerable to uplift, leading to partial or total collapse or roof and walls. Penetration through large doors can lead to critical uplift and blow-out pressures.
- **Struct Overload/Defect** – Roof failures due to ponding and snow. Wood decay in older buildings.

**CHECK POINTS**

- Connections between exterior walls and roof/floors.
- Beam to beam and other interior roof connections.

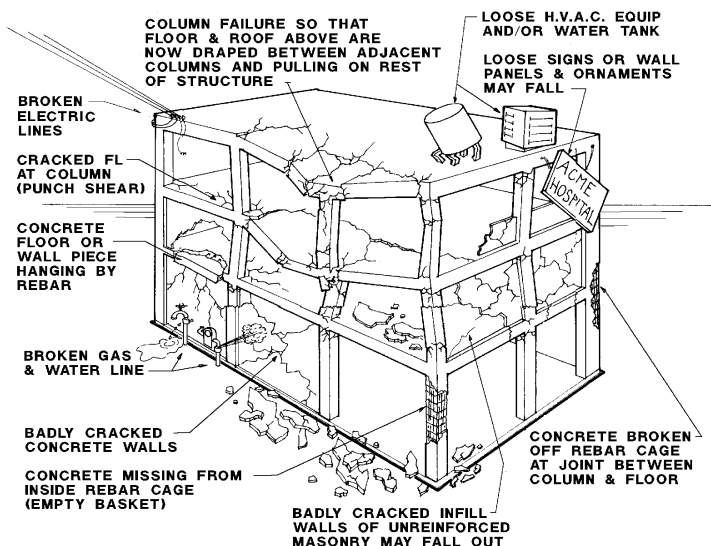
**HAZARD REDUCTION**

- Diagonal or Raker shore concrete walls.
- Shore hazardous roof/floor beams, etc.
- May pull-down leaning walls after dealing w/roof support.
- Monitor changes in racked/leaning structures.

**VICTIM ACCESS**

- Vertical access through floor/roof from above collapsed area.
- Horizontal entry through existing cavities and openings.
- Cut holes in wall panels, 2 feet minimum from joints.
- Remove large wall panels and roof sections by crane.

## 1.5.4.3 Heavy Floor Buildings - Hazards

**CHARACTERISTICS**

- CIP concrete frames.
- Few have concrete walls, but URM infill in older buildings.
- Office and Commercial.

**KEY PERFORMANCE ASPECTS**

- Non-ductile design may experience brittle failure modes when loaded beyond capacity.
- Heavy infill walls may fail.

**TYPICAL FAILURE MODES**

- Beam-column joint failure or column shear leading to partial or total collapse.
- Collapse can be partial or complete pancake.

**COMMON COMBINATIONS**

- May have URM and/or metal stud wall interior partitions.



**EXPECTED PERFORMANCE – for the following:**

- **Progressive Collapse** – Members likely to break into smaller pieces. Rubble piles may shift.
- **E. Quake** – Non-ductile frames – Brittle failures of columns and beam/column connections, leading to partial or pancake collapse. Aftershocks cause added collapse, falling hazards and shifting.
- **Explosion** – Poor slab performance due to reverse gravity loading can lead to loss of column stability and collapse.
- **Fire** – Good resistance to fire, but fire may cause spalling of concrete surfaces.
- **High Energy Impact** – Damage limited to area of impact. Could leave damaged members of questionable strength.
- **Wind** – Unlikely to be damaged by wind. Exterior skin and curtain walls could be damaged/destroyed.
- **Struct Overload/Defect** –Construction falsework failures most common. Members break into pieces w/poor integrity.

**CHECK POINTS**

- Beam/column connections above and below floors.
- Badly confined concrete in columns (empty basket).
- Cracks in beams and slabs near columns.
- Attachment of URM walls and other heavy objects.
- Cracks in concrete shear walls and stairs.

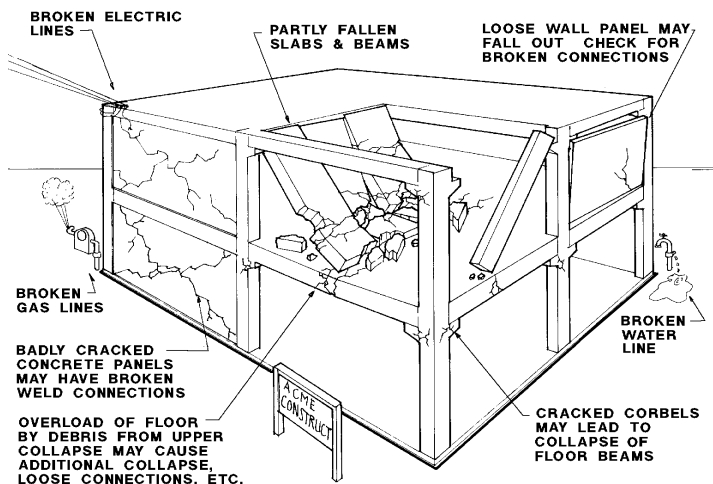
**HAZARD REDUCTION**

- Shore/avoid badly cracked slabs, beams and/or columns.
- Shore/avoid overloaded slabs due to punching shear.
- Remove/shore unstable wall and floor elements.
- Monitor changes in racked/leaning structures.

**VICTIM ACCESS**

- Vertical access through existing access shafts.
- Vertical access by cutting through slabs from above victims.
- Horizontal entry through existing cavities and openings.
- Cut non-bearing/infill walls after careful assessment.
- Remove large pieces by crane, after cut rebar.

## 1.5.4.4 Precast Concrete Buildings - Hazards



AFTERSHOCKS ARE LIKELY TO CAUSE LARGE, LOOSELY CONNECTED CONCRETE PARTS TO SHIFT AND FALL. DEBRIS PILES OF LARGE CONCRETE PARTS CAN ALSO SHIFT AND TRAP RESCUE WORKERS. BE ESPECIALLY CAREFUL OF STANDING STRUCTURES WITH OUT OF PLUMB COLUMNS SINCE ADDITIONAL COLLAPSE IS MORE PROBABLE THAN OTHER TYPES OF STRUCTURES.

## CHARACTERISTICS

- Factory built lightweight concrete parts— up to 14 stories.
- Systems w/o interior concrete panels are greatest problem.

## KEY PERFORMANCE ASPECTS

- Highly engineered systems, but often brittle connections.
- Little capacity for unanticipated loads.
- Residence type may be highly redundant due to many walls.

## TYPICAL FAILURE MODES

- Failure of interconnections between parts leading to partial or total collapse, depending on redundancy.

## COMMON COMBINATIONS

- May have CIP floor slabs or reinforced concrete topping.
- Use of Reinforced Masonry shear walls and metal stud walls.

**EXPECTED PERFORMANCE – for the following:**

- **Progressive Collapse** – Failed single story columns have lead to progressive collapse. Heavy elements vs. brittle connections are critical issues. Members collapse in large pieces.
- **E. Quake** – Very poor performance – except for multi-wall residence buildings. Failed connections lead to partial or total collapse. Aftershock falling, shifting and collapse hazards.
- **Explosion** – Poor performance due to weak-link connections leading to part or total collapse.
- **Fire** – Could cause annealing of tendons and prestress loss.
- **High Energy Impact** – Impact on ext elements likely to be localized. Brittle connections could be damaged.
- **Wind** – Unlikely to be damaged by wind. Exterior skin and curtain walls could be damaged/destroyed.
- **Struct Overload/Defect** – Failures in connections, leading to cascading structure failure. Members should retain integrity.

**CHECK POINTS**

- Beam/column connections, broken welds and cracked corbels.
- Column cracking at top, bottom and wall joints.
- Wall connections at floors, columns and foundation.
- Badly cracked walls and columns plus falling hazards.

**HAZARD REDUCTION**

- Remove/avoid leaning/hanging, concrete elements.
- Shore damaged roof/floor beams, especially next to bad columns.
- Remove/shore unstable wall and floor elements.
- Monitor changes in racked/leaning structures.

**VICTIM ACCESS**

- Vertical access through thin horizontal sections from above.
- Horizontal entry through existing cavities and openings.
- Cut holes in wall panels, 2 feet min. from joints.
- Carefully remove large wall/floor sections by crane.

### 1.5.5 Hazard Identification Summary

In summary, the problem of identifying hazards after a structural collapse is extremely difficult. Buildings are often complicated, and there are many different types and configurations. What remains after the triggering event may have come to rest, but the danger of further collapse and/or falling objects is often present. A damaged structure may be “At-Rest,” but that does not mean that it is “Stable.”

Measures to mitigate the danger must be factored into the overall rescue effort.

### 1.5.6 Hazard Assessment

Based on the previous section on Hazard Identification, the next step is to assess the risk to personnel during rescue operations. Assessment applies to the building structural system, the rubble pile and individual void spaces. The first question should be “Do we need to be in this area at all?” If the answer is “No” because the likelihood of locating survivors is extremely low, then simply avoid that area. Hazard avoidance is the preferred option. Additional questions to be considered, are:

- What caused the collapse?
- Has the structure collapsed to a stable condition?
- Does the structure have remaining stored potential energy?
- How have the load paths changed due to the collapse?
- Will the structure exhibit brittle or ductile behavior?
- Are there potential instabilities in the building or in the rubble?
- What redundancy is present?
- What may happen if there is an aftershock?
- What are the operating objectives.
- If personnel are to enter a hazard area, where are the escape routes and/or safe havens?
- Are there overhead or leaning wall falling hazards?
- How can the hazards be mitigated to an acceptable level of risk for the rescuers?
- Can additional mitigation measures be provided to reduce the potential for secondary collapse while limiting the significant risk associated with providing the mitigation?

The results of this hazard assessment should be prioritized and documented in order to develop a mitigation plan that addresses operational requirements and risk vs. reward considerations.

### **1.5.7 Hazard Mitigation Planning**

A prioritized Hazard Mitigation Plan needs to be rapidly developed to aid rescue operations. This plan may start as nothing more than rough sketches but will typically be revised and improved as the incident progresses.

Eventually, a final written plan should be developed that will become part of the incident record.

At least some risk is involved in most rescue operations. In addition, many of the most viable mitigation options involve risk during their installation. The Hazard Mitigation Plan must consider the risk of implementing the mitigation measure. The least mitigation measures with the least risk should be considered first. These usually include the mitigation options that require the least time to install or implement such as avoiding the hazardous area.

If live victims are located, their survival may depend on the speed with which they are removed from the collapsed structure. There may not be time to construct well braced shoring systems or other elaborate mitigation methods. Accordingly, the acceptable risk level for emergency personnel is higher and rapidly deployable mitigation methods are essential. The Hazard Mitigation Plan must be as innovative as possible in order to find a balance between the desired risk reduction and the time it takes to implement the mitigation.

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## **2 Vertical Shoring Construction**

## 2.1 Standard Built-in-Place Shoring

Wood Shoring is built as a system that has the following:

- Header beam, wall plate or other element collects load.
- Post or other load carrying element that has adjust ability and positive end connections.
- Sole plate, bearing plate or other element to spread the load into the ground or other structure below.
- Lateral bracing to prevent shoring system from racking (becoming parallelogram) or buckling.
- Will give warning before failure.

The minimum level of lateral strength in any vertical support system should be at least 2% of vertical load, but 10% is desirable where aftershocks are expected.

### 2.1.1 Wood Shoring Design Concepts

To most efficiently use the physical properties of timber, the following are desirable:

- Load should be transferred by bearing, so that initial distress can be observed as crushing of wood at contact surfaces.
- Connection fasteners should be as small as practicable.
- Systems should be used that are braced in both directions.

The strength of a wood post system is governed by:

- Perpendicular to grain bearing on the header or sole plate (allowable bearing stress varies from 300 psi to 700 psi depending on wood species).
- Vertical capacity of the posts.
- Strength of header beam and/or sole plate.
- Strength of ground or structure below sole plate.

Most rescue shoring is proportioned to give warning of failure by crushing the softer crossgrain at the bearing of the post on the header and cupping of wedges at the sole plate. These systems are normally made adjustable by cutting and shimming with full bearing, opposing, wood wedges.



## 2.2 Vertical Shores: General Information

Vertical shores are used in rescue operations to stabilize damaged, and/or partly collapsed floors/roofs. There are 3 classes: Class 1 (1-dimensional), Class 2 (2-dimensional), and Class 3 (3-dimensional).

### SHORING SIZEUP

Seek assistance from a FEMA trained disaster engineer.

Identify damage, hazards, and potential victim locations.

- What caused collapse?
- Potential for aftershocks?
- Is structure leaning and/or are openings racked?
- Are floors sloped? Is there a ladder affect pushing out on the supporting wall? Is the floor hinged?
- Determine best method to mitigate the hazards and damage. Avoid and remove may be best.

If shoring is to be built, determine type and placement of shoring systems in relation to hazards & victim location.

- What type of structure: Concrete; Wood; URM; Precast Concrete; or several types combined?
- What will support the shoring: Slab on ground; Soil; Basement slab; or Upper story slab?
- What is type & condition of structure: Solid but cracked slabs; beams supporting slabs or joist; beamless slabs; wood or steel trusses; or badly cracked concrete?
- Supporting the beams that support slabs or joists is most desirable. Check sagging beams/girders, or beams with damaged connections.
- For wood structures, to support joists, place shores perpendicular to joist and align posts under joist.
- Consider Sloped Floor Shores or Cribbing for limited height conditions.

Prepare the area to be shored:

- May need to remove debris and floor coverings.
- If soil supported, use an 18"x18" foot under post location.
- Consider temporary shores to reduce risk (T or DbI-T).
- Prefabricate shoring as much as possible to reduce risk.
- Add bracing after wedges are tightened.

## SHORING SEQUENCE

1. Basic shoring sequence should go as follows:
  - Shore from outside in, from safe into unsafe regions.
  - In very dangerous areas, reduce risk by quickly installing Spot Shores.
  - If operations require, follow w/ Class 2 (two or more post) Vertical Shores.
  - To further reduce risk, assure that all shoring has all posts braced in two directions as Class 3 Shores.
  - An efficient way that this can be achieved is as follows:
    - Place T or Dbl-T shores.
    - Place pairs of 2-post Verticals or Dbl-T, 4 ft apart.
    - Finally tie the 2-post Verticals or Dbl-T together as Laced Posts or Plywood Laced Posts.
2. Sequence when shoring a single damaged floor in a multi-story, otherwise sound, existing building is as follows:
  - For Wood-frame structure: 1-undamaged floor to support 1-damaged floor.
  - For Steel-frame structure: 2-undamaged floors to support 1-damaged floor.
  - For Reinforced Concrete structure: 3-undamaged floors to support 1-damaged floor.
  - For Precast Concrete, the shoring should extend to the ground.
  - This does not apply to structures that are under construction, subject to cascading/progressive collapse, or to structures that have collapsed suddenly without any apparent cause.
  - Usually the best strategy for multi-story shoring is to start directly under the damaged floor and work down in placing the shores, in order to share the load as soon as possible.
    - Another strategy would be to place all levels of shores (with loose wedges) and then tighten the wedges simultaneously.

## SHORING INSPECTION

1. Inspect shores every 12 hours (Shift Change), and/or following any known loading change.

Following aftershocks, high winds, secondary explosion, or load shift.

- Check to see if posts are straight, plumb, and have full bearing on header and wedges.
- Are connections tight and wedges snug?
- Is header in full contact with supported structure?
- Has sole deflected due to soft soil or support?

Check for signs of overload.

- Cupping of wedges and crushing of sole.
- Crushing of header at post.
- Splitting of header at end of overhang.

Actions to be taken if signs of overload are observed.

- Add additional shoring.
- Have structure re-evaluated by a disaster engineer to see if it is responding differently than expected.
- Check for errors in original shoring design.

## FACTORS AFFECTING SHORE STRENGTH

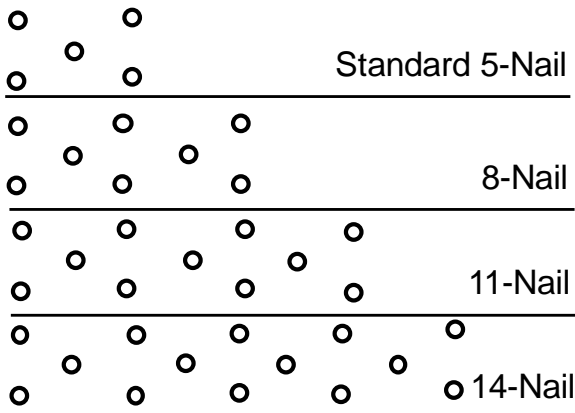
1. The strength of wood shoring systems depends on the following:
  - Perpendicular-to-grain bearing of post on header.
  - Vertical capacity of posts (based on height/length).
  - Strength of header and sole.
  - Strength of ground or floor slab under sole.
2. The size of a header depends on the stiffness of the header compared to the structure being supported:
  - When supporting intact concrete slabs, and posts are no more than 4 ft o.c., the concrete structure is much stiffer than a wood header. 4x4 or 6x6 headers are OK.
  - When supporting a wood floor, the header should be a depth of 1" for each foot of span – 4x4 minimum.
  - For all other conditions, the header should be designed for the actual load.
  - The total length of 2x4 & 2x6 lacing (diagonal bracing members that are capable of resisting both tension and compression) should be limited to 7'-6".
  - The length of 2x4 & 2x6 X-bracing may be 10 or more feet, since each member is only required to resist tension.

**NOTES for VERTICAL SHORING DIAGRAMS**

1. Wood should be selected for good grain: minimum of 8 rings per inch; maximum slope of grain of 8 to 1; tight knots up to 1-1/2"; and maximum loose knots of 3/4".
2. Design Load (Safe Working Load) for Class 1 & 2 Shores is based on shore height (not post length).
3. The use of 4x4 & 6x6 Headers is desirable, since this maintains a relatively stable 1 to 1 height to width ratio. This allows the use of 1-sided connections for posts to headers.
4. It is desirable to use 2-sided connections at posts to sole plates at wedges in order to confine the wedges. The connectors should be 6"x12" Half Gussets. Gussets may be cut from 5/8" or 3/4" plywood or Oriented Strand Board (OSB). OSB only to be used where wet conditions will not occur.
5. For wood or light metal floor/roof systems, 1-sided connections, at wedges, may be used in situations where lateral displacement of the shore is unlikely. Displacement may be caused by lateral loads, vibrations, and/or structural shifting.
6. The use of 4x4 headers for 4ft o.c. posts and 6x6 for 5ft o.c. posts is based on supporting normal wood floors and Intact concrete floors. For supporting badly cracked concrete floors, and for shores with larger post spacing, a disaster engineer should be consulted.
7. Headers are intended to have 12 inch overhangs, except at T, Double-T, and outer ends of Sloped Floor Shores.

**VERTICAL SHORES: NAILED CONNECTIONS**

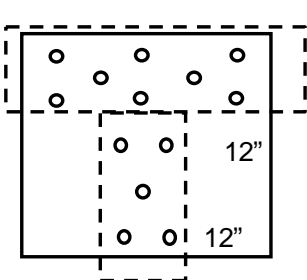
Nails are used to connect members together in Vertical Shores, but not to transfer direct loads.

**Standard 5 - Nail Patterns****Nail Standards**

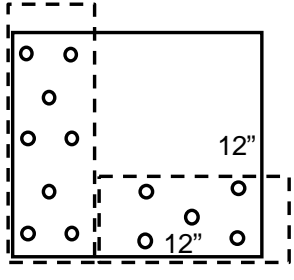
- Hand or gun driven nails may be used, however gun driven nails normally produce less impact vibration. Palm nailers produce the least amount of vibration.
- Full head nails are preferred, but the head is set off-center for most gun nailers.
- Clip head nails may be used, but care must be taken to not over-drive the nails.
- Wedge cut-out, headed nails should not be used.
- The preferred 16d nail is a 0.148" x 3.25" coated nail. (Standard 16d nails are 0.162" x 3.5" and have greater tendency to split the wood).
- 8d nails should be 0.131" x 2.5" with a plastic coating.
- Duplex nails are used in some cases at wedges, in order to pull the nails when adjusting the wedges.

**Plywood Gussets (used at Headers & Soles)**

Plywood may be 5/8" or 3/4" thick, (or may use OSB where wet conditions will not occur) Use 8d nails.

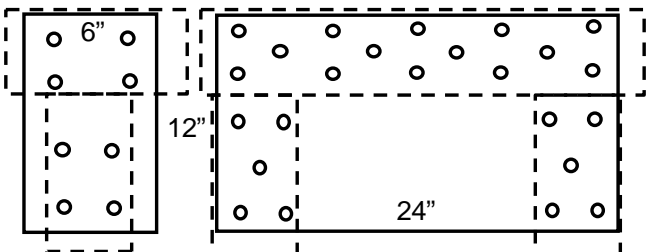


**T-Shore – Header/Post**



**Raker – 3 locations**

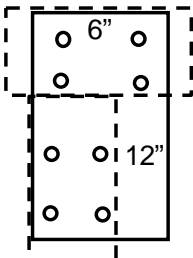
**FULL GUSSET – 12' X 12"**



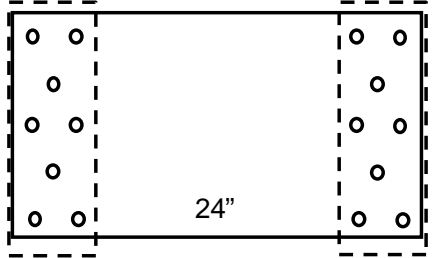
**Half Gusset at Vertical Shore**

**Dbl Gusset to Header - Dbl T & 2x4 PLP**

**HALF AND DOUBLE GUSSETS**



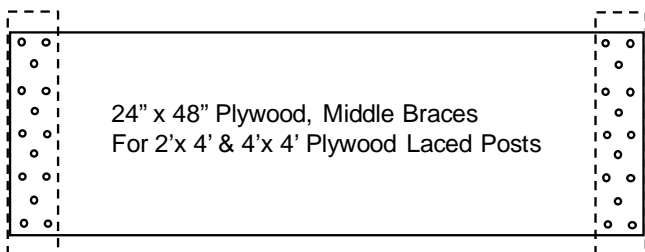
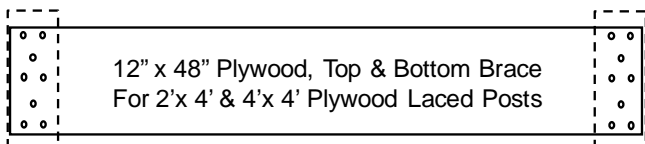
**Half Gusset at 2-Post & Laced Post**



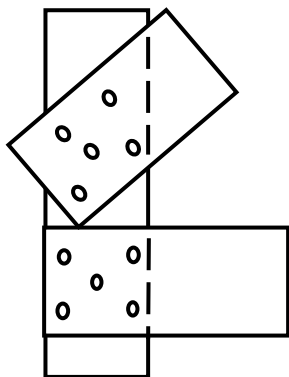
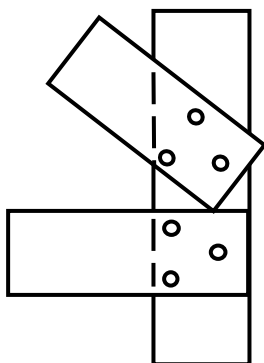
**Dbl Gusset for Dbl T & 2'x4' PLP Mid-braces**

**Plywood Gussets (used for Plywood Laced Posts)**

Plywood may be 5/8" or 3/4" thick, (may use OSB where wet conditions will not occur) Use 8d nails.

**PLYWOOD BRACES FOR PLP****Nailed Connections of 2x6 and 2x4 Braces**

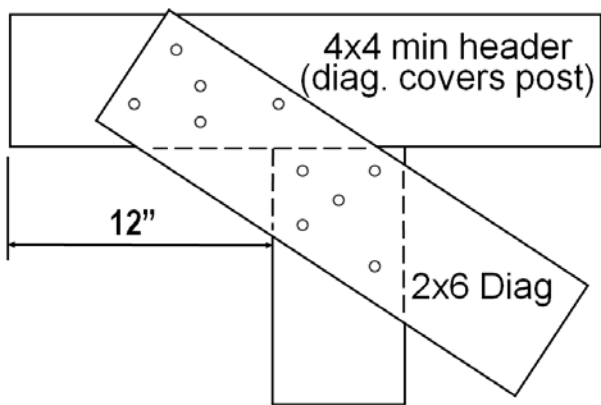
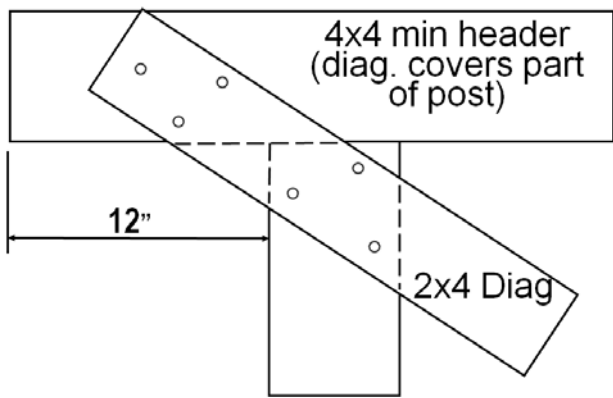
Use 16d coated nails (0.148" x 3.25") are preferred to reduce splitting. Also note placement of nails away from the ends of the 2x.

**2x6 to Posts, Laced Posts****2x4 to Posts, 2-Post Shore**



**Nailed Connections of 2x6 and 2x4 to Header**

2x6 diagonal braces are used, in this case to provide bracing, as well as connect the post to the header. One needs to carefully place diagonal so that the required nails can be placed without splitting the post.

**End Post to Header Connection at Vertical Shore****Post to Header Connection at 2-Post Shore**

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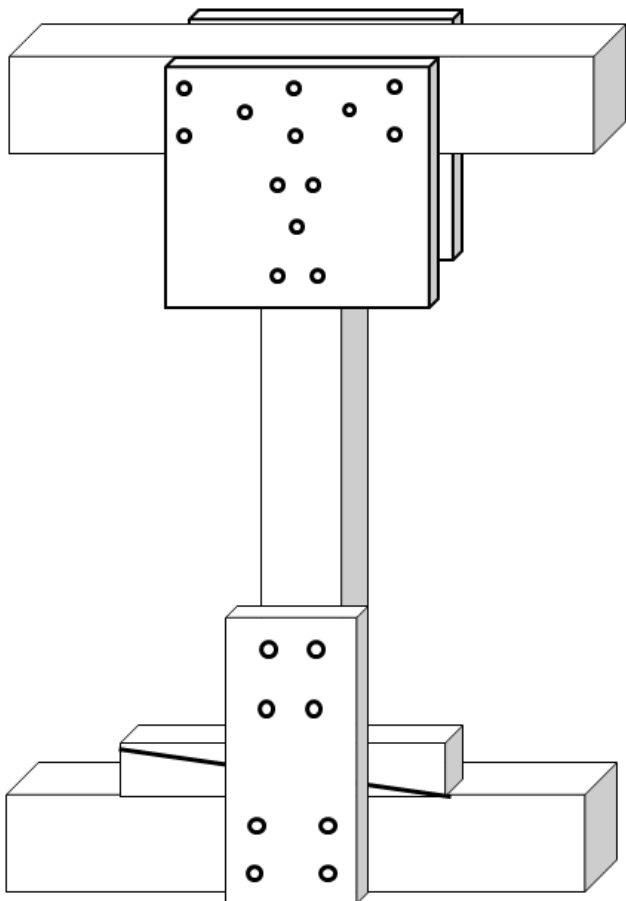
## **2.3 Class 1 Shores**

### 2.3.1 T Spot Shore (Vertical/Class 1)

This is a rapidly assembled and installed temporary shore that is intended to be used only until a complete shoring system can be installed. It can become unstable if it is not centered under the load.

#### Material List

Header and Sole	One Wedge Set
One Post	2 Full Gussets
	One Half Gusset



## HOW TO CONSTRUCT THE T SPOT SHORE

1. Determine where T Spot Shores should be built in order to quickly reduce risk. (Prior to building more stable shores).
2. Determine height of area to be shored and remove least amount of debris required to place shore.
3. The 4x4 post should be 10'-3" max long, so the Total Height of the shore is not more than 11 feet
4. Cut header and Sole to 3 feet long.
5. Cut post to proper height (remember to deduct header, sole and wedge height when cutting post).
6. Prefabricate header to post.
  - Toe-nail post to header and make square.
  - Place and nail Full Gusset plate on one side.
  - Nail Full Gusset to post with and to header with 8-8d.
  - Flip shore over and place another Full Gusset on other side.
7. Place T Shore in position, centered under the load.
8. Position header across (perpendicular to) the roof/floor joists and position the post directly under a joist.
9. Slide sole plate under T and tap wedges into position.
10. Check for straightness & position directly under the load, and then tighten the wedges.
11. Install bottom Half Gusset; nail 4-8d to post and to sole.
12. Note that a 2 x 4 x 18" cleat may be used, but the 3-16d nails to post and to sole may tend to split the cleat. Also the nailing of 16d causes more impact within the danger zone than for 8d nails.
13. Anchor the shore to floor above and sole to floor below, if practical.

**ADDITIONAL INFORMATION**

1. Load must be centered on post, or shore may become unstable.

Header, sole and post must be same width.

Use 4 x 4 post x 10'-3" max long.

Header and sole are 4 x 4 x 36", maximum.

Full Gussets each side at top.

Half Gusset one side at bottom,

May use 5/8" or 3/4" plywood (or OSB unless wet conditions are present or expected),

**PERFORMANCE CRITERIA**Structural Performance

Design Load:	1,000 to 4,000 lbs (Based on Stability)
Safety Factors:	2 to 1
Failure Mechanism:	Buckling of posts, or offset of shore
Material Compatibility:	Intact, solid Surfaces
Tested and Documented:	Yes
Safe Haven:	No

Installation

Ease of Installation:	Carpenter skills
Time to Install:	6 – 9 minutes
Portability on disaster site:	Easy
Portability within structure:	Easy until assembled
Environmental limitations:	None
Tools required for installation:	Cutting and nailing tools
Power source required:	Generator for saw
Appropriate for small spaces:	Yes
Trainings or certifications required:	Shoring training recommended

Evaluation of Installed Systems

## Over/Under load indicators:

- Audible: Creaking/cracking of wood
- Visual: Movement of header, and  
Cupping of Wedges
- Equipment: Hammer
- Power source: Not Required

Inspection Recs:	Every 12 hrs and after every aftershock or load shift
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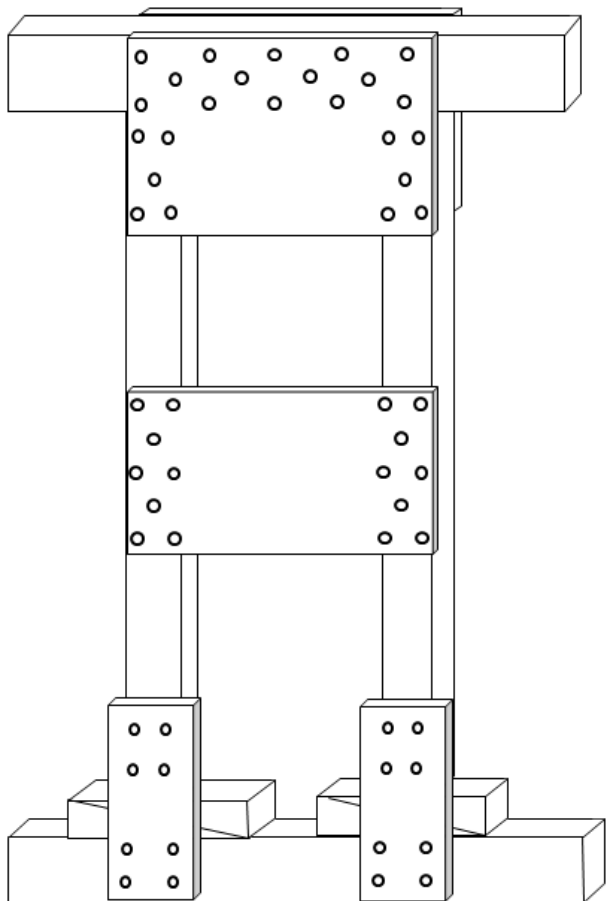
## **2.4 Class 2 Shores**

## 2.4.1 Double T Shore (Vertical Class 2)

This is the most stable spot shore, and much preferred to the marginally stable, T-Shore.

Material List:

Header and Sole	2 - Half Gussets
2 - Posts	2 - Wedge Sets
2 - Double Gussets	One 12"x 24" ply mid- brace

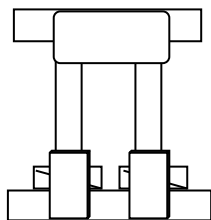


## HOW TO CONSTRUCT THE DOUBLE T SHORE

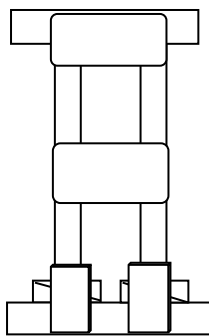
1. Determine overall height of area to be shored and remove least amount of debris required to place shore.
  - The 4x4 post should be 11'-3" maximum long, so the total height of the shore is not more than 12 feet.
2. Measure and cut header, sole and post (remember to deduct header, sole and wedge height when cutting post). Header and sole are 3 feet long.
3. Prefabricate header to posts.
  - Toe-nail posts to header and make square.
  - Place and nail Double Gusset plate on one side of both posts.
  - Nail 5-8d to each post and 14-8d to header.
  - Flip shore over and place another Double Gusset on other side.
4. Nail mid-height plywood, Double Gusset to one side of posts (8-8d to each post).
5. Place Double T in position, centered under the load.
6. Slide sole plate under Double T and tap wedges into position.
7. Check for straightness plus stability, and then tighten wedges.
8. Install bottom Half Gussets and nail 4-8d to each post and sole.
9. Anchor the shore to floor above and sole to floor below, if practical.

**ADDITIONAL INFORMATION**

1. Header, posts and soles must be the same width.
2. Posts:
  - 4 x 4 minimum
  - Spacing: Maximum 24 inches out to out.
  - Spacing: Minimum 18 inches out to out.
  - Height: Maximum 11'-3" (overall shore maximum height: 12 feet).
3. Header and Sole: 4 x 4 x 36"
4. Half Gussets on one side at bottom.
5. Double Gussets each side at top.
6. Mid-Point Braces: 12" x 24" plywood, one side.
  - May omit mid-point brace if height is 6 feet or less.
  - Nail plywood mid-braces with 8-8d each post.
7. May use 5/8" or 3/4" plywood (or OSB unless wet conditions are present or expected).



3ft to 6 ft high



6 ft to 12 ft high

**PERFORMANCE CRITERIA**Structural Performance

## Design Load:

Height = 8 feet	16,000 lb
Height = 10 feet	10,000 lb
Height = 12 feet	7,000 lb

## Safety Factors:

2 to 1

## Failure Mechanism:

Buckling of posts

## Material Compatibility:

Intact, solid Surfaces

## Tested and Documented:

Yes

## Safe Haven:

No

Installation

## Ease of Installation:

Carpenter skills

## Time to Install:

8 - 10 minutes

## Portability on disaster site:

Easy

## Portability within structure:

Easy

## Environmental limitations:

None

## Tools required for installation:

Cutting and nailing tools

## Power source required:

Generator for saw

## Appropriate for small spaces:

No

## Trainings or certifications required

Shoring training  
recommendedEvaluation of Installed Systems

## Over/Under load indicators:

- Audible: Creaking/cracking of wood
- Visual: Cupping of Wedges/Sap seepage
- Equipment: Hammer
- Power source: Not Required

## Inspection Recs:

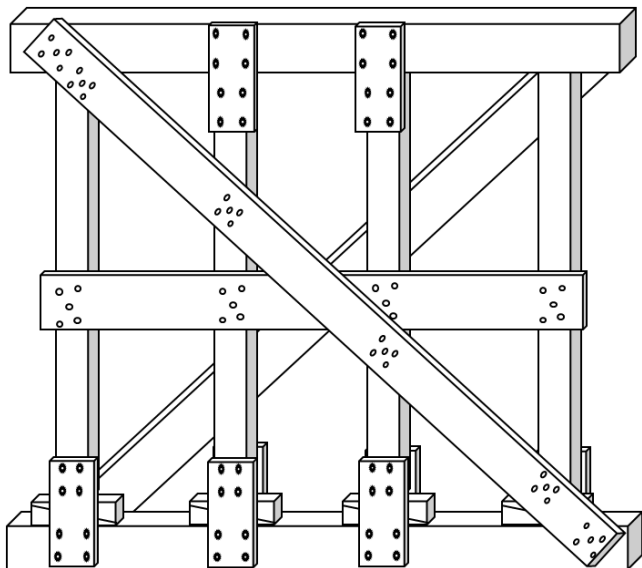
Every 12 hrs and after every  
aftershock or load shift.

## 2.4.2 Vertical Shore (Vertical/Class 2)

This multi-post shore normally needs to be built in-place in the danger zone. To reduce risk, spot shores should precede the erection of this vertical shore. As an alternate to Vertical Shore, one may use several Double T, 2-Post, or Laced Post shores, since they can be partly prefabricated, and more quickly erected in danger zone.

### Material List

1 Header & 1 Sole	1 -Wedge Set each post
2 or more Posts	2 - 2x6 Diagonals ("X")
Half Gussets – 5 for 3-post, 8 for 4-post, & 11 for 5-post	
Mid-brace (1 x 6 or 6" ply) see Additional Information	



4 – Post Vertical Shore (may have 3 or 5 posts)

## HOW TO CONSTRUCT THE VERTICAL SHORE

1. Install temporary, spot shores to reduce risk.
2. Lay the sole plate on the floor or ground directly under and in line where the header will be installed. The sole plate should be as level as possible.
3. Measure and cut the posts to the proper height:
  - Place the header on top of the sole plate.
  - With the end of the tape measure on top of header where the posts are to be installed, slide the tape up to the bottom of the structural element to be shored and measure in at least three places deducting the width of the wedges.
4. If possible, anchor the header to the area that is to be shored, square and in line with the sole plate. Secure it at the lowest point and shim the structural elements down to the header trying to keep it as level as possible.
5. Install the posts between the header and sole plate under each structural element to be supported. 4x4 Posts should be spaced 4 feet on center, maximum.
  - Install first two posts 12" from ends of header.
  - Toe-nail each post to header and sole, and keep the posts in line & plumb with header and sole plate.
6. Install a set of 2x4 wedges under each post, on top of Sole, and tap them together simultaneously until the posts are tight. Nail behind the wedges to secure them.
7. Attach the diagonal braces to each side of the vertical shore.
  - Mid-point brace, when needed, should be installed prior to the diagonal braces.
  - The diagonal braces should be long enough to span its entire length and be attached to the sole plate and header and each post.
  - If possible, diagonal braces should be installed in a "X" pattern on opposite sides of the system.
  - Vertical shoring systems which are very long may require several sets of diagonal braces.
8. Attach half-gussets to one side of header to post, except where diagonal braces attach. Add Half Gussets to each side of each post to sole plate, except where diagonal braces attach (then only one side). Nail with 8-8d.

**ADDITIONAL INFORMATION**

1. Maximum shore height for 4 x 4 posts: 12 feet.
2. Maximum shore height for 6 x 6 posts: 20 feet.
3. Posts:
  - 4 x 4 minimum.
  - Spacing for 4 x 4 posts: Maximum 4 feet on center.
  - Spacing for 6 x 6 posts: Maximum 5 feet on center.
4. Header and Sole:
  - Same size as posts in most cases.
  - If supported slab is badly fractured concrete or masonry, larger header should be designed.
5. Half Gussets at bottom:
  - Each side to confine wedges, except where diagonal connects, then only one side.
6. Half Gussets at Top:
  - One side if header is the same size as post, except where diagonal connects.
  - Each side if header is taller than width.
7. Mid-Point Braces:
  - Use 1x6 or 5/8" min plywood x 6", 5-8d to each post.
  - Use if 4 x 4 posts are greater than 8 feet long.
  - Use if 6 x 6 posts are greater than 12 feet long.
8. Diagonal X Braces:
  - 2 x 6 each side of shore (place in X configuration and over mid-brace, one side)
  - 5-16d each end, to header, sole, and posts. May reduce nailing to 3-16d at end posts if space is limited in order to reduce tendency to split post.



**PERFORMANCE CRITERIA**Structural Performance

## Design Load 4 x 4 posts:

Height = 8 feet	8,000 lb each post
Height = 10 feet	5,000 lb each post
Height = 12 feet	3,500 lb each post

## Design Load 6 x 6 posts:

Height = 12 feet	20,000 lb each post
Height = 14 feet	14,500 lb each post
Height = 16 feet	12,000 lb each post
Height = 18 feet	9,000 lb each post
Height = 20 feet	7,500 lb each post

Safety Factors:

2 to 1

Failure Mechanism:

Buckling of posts

Material Compatibility:

Intact, solid Surfaces

Tested and Documented:

Yes

Safe Haven:

No

Installation

Ease of Installation:

Carpenter skills

Time to Install:

12 – 15 minutes

Portability on disaster site:

Easy

Portability within structure:

Easy

Environmental limitations:

None

Tools required for installation:

Cutting and nailing tools

Power source required:

Generator for saw

Appropriate for small spaces:

No

Trainings or certifications required:

Shoring training recommended

Evaluation of Installed Systems

## Over/Under load indicators:

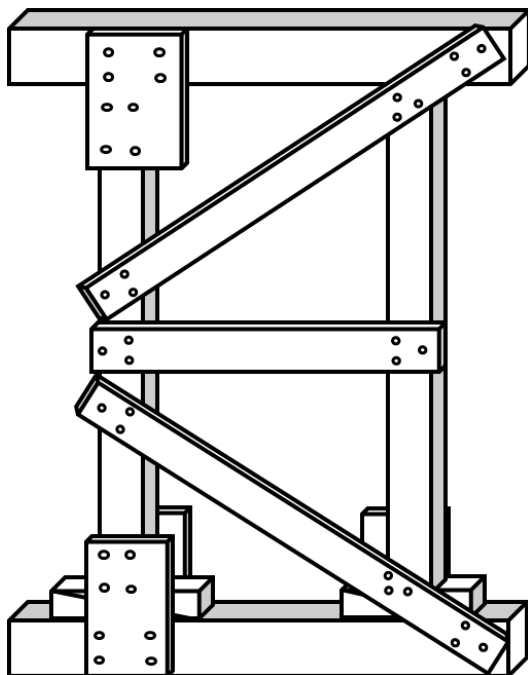
- Audible: Creaking/cracking of wood
- Visual: Cupping of Wedges/Sap seepage
- Equipment: Hammer
- Power source: Not Required

Inspection Recs:

Every 12 hrs and after every aftershock or load shift.

### 2.4.3 2-Post Vertical Shore (Vertical/Class 2)

This shore is the same as one side of a laced post. It can be partly pre-fabricated, then assembled in danger area	
Material List:	
1 - Header & 1 Sole	2 - Wedge Sets
2 - Posts	4 - Half Gussets
2 x Diagonal Bracing (Max height for shore w/ 4x4 posts is 12ft)	1 for shore up to 6 feet high 2 for shore from 6ft to 11 ft 3 for shore from 11ft to 17 ft 4 for shore from 17ft to 20 ft
1x Horizontal Bracing	1 for shore from 6ft to 11 ft 2 for shore from 11ft to 17 ft 3 for shore from 17ft to 20 ft

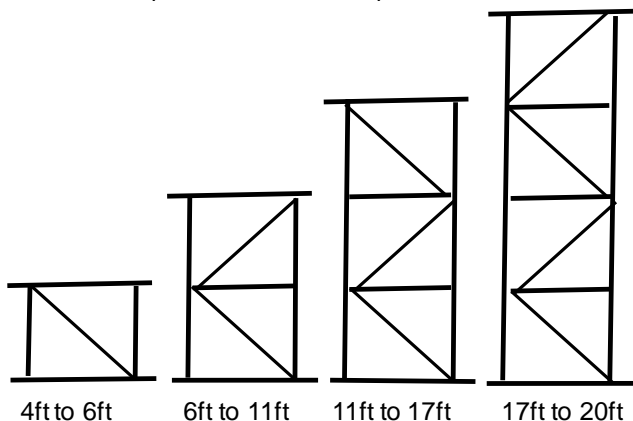


**HOW TO CONSTRUCT THE 2-POST VERTICAL SHORE**

1. Determine where to erect the 2-Post vertical shore and the condition of the supporting structure and/or ground.
  - If practical, this shore should be partially prefabricated, same as for the Laced Post
  - If using 4x4 posts, space them 4 feet, max on center. 6x6 posts may be 5 feet max on center. If access is limited, Post Spacing may be reduced to 3 feet o.c.
  - The intent would be to support the damaged structure as quickly and safely as possible, but be able to later convert two adjacent, single 2-post vertical shores into a Laced Post for better stability.
2. Measure and cut the posts to the proper height. (remember to deduct for header, sole & wedges when cutting posts). Also, cut the mid-brace and diagonals to proper lengths.
  - Header shall have a 12 inch overhang each end.
  - Toe-nail posts to header and make square.
  - Nail Half Gusset plate at top of one post.
  - Nail Mid Brace to both posts.
  - Nail 2x4 diagonal to posts and header.
3. Cut the sole and wedges. Sole is same length as header.
4. Place 2-Post Shore in position, centered under the load.
5. Slide sole plate under shore and tap wedges into position.
6. Check for straightness plus stability, then tighten wedges.
7. Install lower diagonal and the three half gussets with proper nailing.
8. Anchor the shore to floor above and sole to floor below, if practical.

**ADDITIONAL INFORMATION**

1. Maximum shore height for 4 x 4 posts: 12 feet.
2. Maximum shore height for 6 x 6 posts: 20 feet.
3. Posts: 4 x 4 or 6 x 6.
  - Spacing for 4 x 4 posts: Maximum 4 feet on center
  - Spacing for 6 x 6 posts: Maximum 5 feet on center
4. Header and Sole:
  - Same size as posts in most cases.
  - If supported slab is badly fractured concrete or masonry, one needs to engineer larger sized header.
5. Half Gussets at Bottom:
  - Each side to confine wedges, except where diagonal connects, then only one side.
6. Half Gussets at Top:
  - One side if header same size as pos, except where diagonal connects.
  - Each side if header is taller than width.
7. Diagonal Braces: (Max. length is 7'-6")
  - 2 x 4 for 4 x 4 posts.
  - 2 x 6 for 6 x 6 posts.
8. Mid-Point Braces: (see below for configurations).
  - 2 x 4 for 4 x 4 posts & 2 x 6 for 6x6 posts.



**Note: Maximum height using 4 x 4 post is 12 feet**

**PERFORMANCE CRITERIA**Structural Performance

Design Load 4 x 4 posts:	
Height = 8 feet	16,000 lb
Height = 10 feet	10,000 lb
Height = 12 feet	7,000 lb
Design Load 6 x 6 posts:	
Height = 12 feet	40,000 lb
Height = 14 feet	29,000 lb
Height = 16 feet	24,000 lb
Safety Factors:	2 to 1
Failure Mechanism:	Buckling of posts
Material Compatibility:	Intact, solid Surfaces
Tested and Documented:	Yes
Safe Haven:	No

Installation

Ease of Installation:	Carpenter skills
Time to Install:	8 - 12 minutes
Portability on disaster site:	Easy
Portability within structure:	Easy
Environmental limitations:	None
Tools required for installation:	Cutting and nailing tools
Power source required:	Generator for saw
Appropriate for small spaces:	No
Trainings or certifications required:	Shoring training recommended

Evaluation of Installed SystemsOver/Under load indicators:

- Audible: Creaking/cracking of wood
- Visual: Cupping of Wedges/Sap seepage
- Equipment: Hammer
- Power source: Not Required

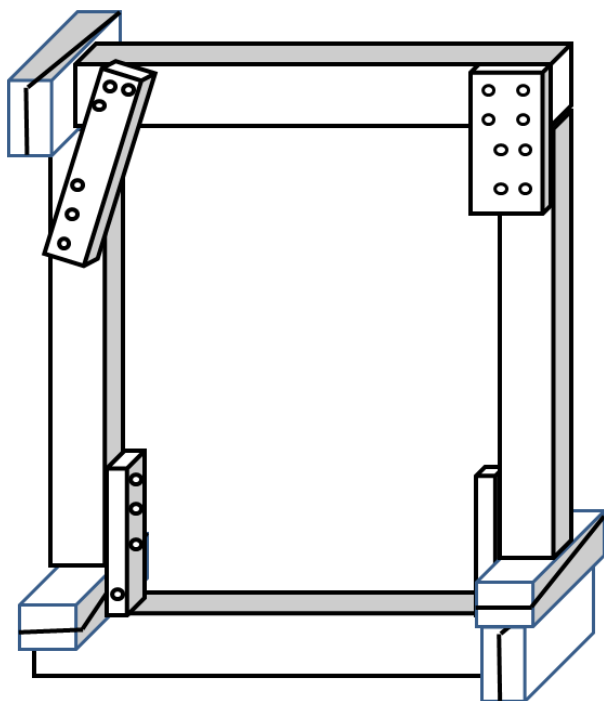
Inspection Recs:	Every 12 hrs and after every aftershock or load shift.
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## 2.4.4 Door and Window Shore (Vertical/Class 2)

This shore is used in URM buildings to support loose masonry over openings. May be used in other building types where door or window headers have been damaged.

### Material List

Header and Sole	4 Wedge Sets
2 Posts	1 Half Gusset
3 Cleats	Shims as required
Diagonal Braces	2 - 2 x 4 (if not used for access)



## HOW TO CONSTRUCT THE DOOR & WINDOW SHORE

1. Measure and cut the sole plate and header to the proper length deducting the width of the wedges to be used.
2. Measure and cut the posts to the proper height.
  - Place the header on top of the sole plate.
  - With the end of the tape measure on top of the header where the posts are to be installed, slide the tape up to the bottom of the structural element to be shored on both sides deducting the width of the wedges to be used. (Use the shorter of the two measurements).
3. Install the sole with a set of wedges at one end and tap them together simultaneously until the sole is tight.
4. The sole should be as level as possible: use shims as necessary under the sole plate.
5. Install the header with a set of wedges at the opposite end of the sole and tap them together until the header is tight.
6. The header should be as level as possible; use shims as necessary above the header.
7. Install the posts between the header and sole, and against the sides of the opening.
8. Install the first post under the wedge side of the header to prevent movement if the header wedges loosen.
9. Keep posts in line and plumb with header and sole.
10. Install a wedge set under each post, on top of the sole. Wedges are then tightened to lock shore in place.
11. Attach cleat and half-gusset to at least one side of the header and posts (as shown) and nail in place.
12. Confine the wedges by placing a cleat against the inside face of each post at the bottom and nail them in place with 3-16d nails to each post and 2-16d toe nails to the sole.
  - Nails may need to be Duplex for future adjustment of the wedges.

**ADDITIONAL INFORMATION**

1. The header requires 1 inch of thickness for every foot of opening (i.e. 3 foot opening requires 4 x 4 minimum).
  - Design headers for openings over 4 feet.
2. Posts are to be 4 x 4 minimum.
3. If opening is not going to be used as access, install one 2 x 4 diagonal brace on each side (in opposite direction).
4. Header, posts and sole plate should be the same width for diagonal braces to be properly aligned.



**PERFORMANCE CRITERIA**Structural Performance

Design Load:	2,000 lb (depends on header)
Safety Factors:	2 to 1
Failure Mechanism:	Crushing and/or splitting of header
Material Compatibility:	Intact, solid Surfaces
Tested and Documented:	Yes
Safe Haven:	No

Installation

Ease of Installation:	Carpenter skills
Time to Install:	6 – 9 minutes
Portability on disaster site:	Easy
Portability within structure:	Easy until assembled
Environmental limitations:	None
Tools required for installation:	Cutting and nailing tools
Power source required:	Generator for saw
Appropriate for small spaces:	Yes
Trainings or certifications required:	Shoring training recommended

Evaluation of Installed Systems

## Over/Under load indicators:

- Audible: Creaking/cracking of wood
- Visual: Cupping of Wedges/Sap seepage
- Equipment: Hammer
- Power source: Not Required

Inspection Recs: Every 12 hrs and after every  
aftershock or load shift.

## 2.4.5 Door and Window Shore - Prefabricated

Alternate to built in-place Door & Window Shore. Main advantage is to allow pre-construction a safe distance from the dangerous wall or collapse zone. Also the shore can be reused

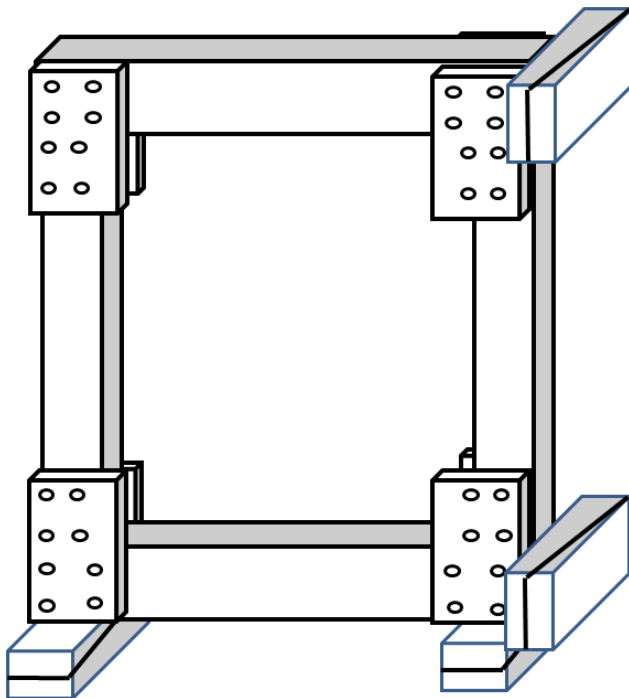
### Material List

Header and Sole

4 - Wedge Sets

2 - Posts

8- Half Gussets



## HOW TO CONSTRUCT THE PREFABRICATED DOOR AND WINDOW SHORE

1. Measure opening and check to see if it is square or racked.
2. Measure and cut header and sole 1-1/2 inches less than opening width to allow for wedges.
3. Measure and cut post. Length should allow for the thickness of sole and header and an additional 1-1/2 inches for wedges.
4. Place one Half Gusset from each post to header and to sole. Nail each half gusset with 8-8d.
5. Turn shore over and place a half gusset on opposite side of previously installed gussets.
6. Carry shore to opening and install one wedge set under the sole at each end.
7. Install one wedge set between header and door/window side edge.
8. Install one wedge set between sole and door/window side edge.
9. Place shims between top of header and top edge of opening at mid-span and as required for adequate support.

**ADDITIONAL INFORMATION**

1. The header requires 1 inch of thickness for every foot of opening (i.e. 3 foot opening requires 4 x 4 minimum).
2. Posts are to be 4 x 4 minimum.
3. Header, posts and sole must be the same width.
4. If opening is not going to be used as access, install one 2 x 4 diagonal brace on each side (in opposite direction).
5. Pre-fabricated Door & Window Shores may not be practical in badly racked or otherwise deformed openings.
6. For large openings, pre-constructed shores may be too heavy to carry up to locations above ground floor.
  - Design headers for openings over 4 feet.
7. If existing header is badly damaged, great care should be taken during installation of the shoring and shims.
8. If shims are needed at the top, one may be able to eliminate the wedges at the bottom.

**PERFORMANCE CRITERIA**Structural Performance

Design Load:	2,000 lbs
Safety Factors:	2 to 1
Failure Mechanism:	Buckling of posts
Material Compatibility:	Intact, solid Surfaces
Tested and Documented:	Yes
Safe Haven:	No

Installation

Ease of Installation:	Carpenter skills
Time to Install:	6 – 9 minutes
Portability on disaster site:	Easy
Portability within structure:	Easy until assembled
Environmental limitations:	None
Tools required for installation:	Cutting and nailing tools
Power source required:	Generator for saw
Appropriate for small spaces:	Yes
Trainings or certifications required:	Shoring training recommended

Evaluation of Installed Systems

## Over/Under load indicators:

- Audible: Creaking/cracking of wood
- Visual: Cupping of Wedges/Sap seepage
- Equipment: Hammer
- Power source: Not Required

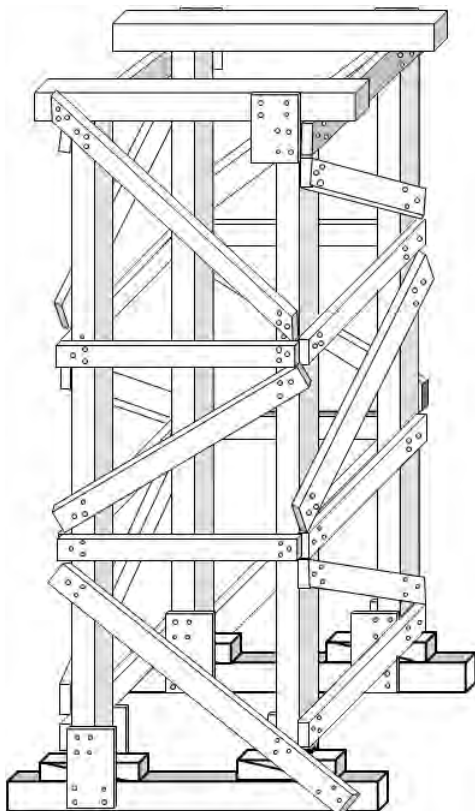
Inspection Recs: Every 12 hrs and after every aftershock or load shift.

## **2.5 Class 3 Shores**

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### 2.5.1 Laced Post Shore (Vertical/Class 3)

High Capacity four post system. It is constructed similar to a pair of 2-post vertical shores, but laced together.	
Material List:	
2 each Header & Sole	6 Half gussets
4 Posts	4 Wedge Sets
Diagonal and Horizontal Bracing (number for each)	4 for shore up to 6 feet high 8 for shore from 6ft to 11 ft 12 for shore from 11ft to 17 ft 16 for shore from 17ft to 20 ft



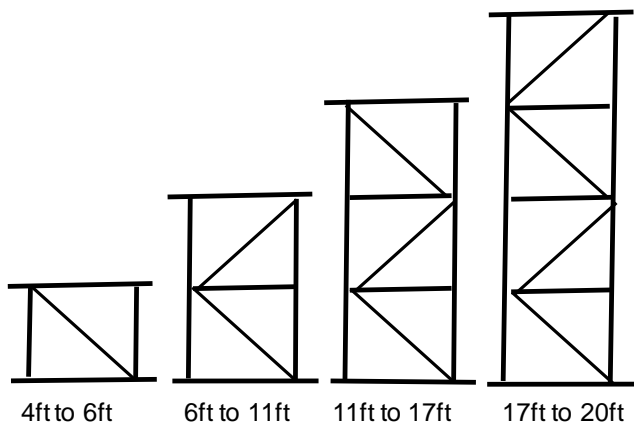


## HOW TO CONSTRUCT THE LACED POST SHORE

1. Determine the length and height of the shore.
  - Cut the header and sole plates 24 inches longer than width of the shore to allow for 12 inch overhangs.
  - Cut the posts to allow for header, sole and wedges.
2. Nail posts to header with toenails and keep them square.
  - Check by making X measurements (outside top right to outside bottom left, should be same as outside top left to outside bottom right).
  - If posts are not straight, set both with bow-out.
  - Nail a half-gusset to one post/header joint, then nail the midpoint brace (braces) in position. Re-check X measurement and pull-in any bow-out.
3. Measure and install the top diagonal, so it overlaps and ties into the header. Use proper nail pattern.
4. Measure and install mid-diagonals, if required by height.
5. Fabricate the second section, using first as template
6. Have the horizontal tie-in braces precut for ease of assembly.
7. Bring both sections and the sole plates into position and place the prefabricated units on top of the sole plates.
8. Install wedges under each post, and check post spacing.
9. Nail the horizontal braces to the two sections on both sides. Start with the lowest mid-brace and work up.
10. Measure for all the diagonals, and configure in K or parallel layout, as best works for the situation.
  - Avoid intersecting too many diagonals on a post at a single location.
11. At the sole plate, make sure the bottom diagonal extends past the post and nails into the sole plate.
  - Place a half-gusset plate onto the opposite side of this post and to each side of the other posts at the base.
12. Anchor the shore to the ceiling and floor, if practical.
13. Make sure all wedges are snug and the proper nail patterns were used.

**ADDITIONAL INFORMATION**

1. Maximum shore height for 4 x 4 posts: 17 feet.
2. Maximum shore height for 6 x 6 posts: 20 feet.
3. Posts: Same spacing each way.
  - 4 x 4 posts: Maximum 4 feet on center.
  - 6 x 6 posts: Maximum 5 feet on center.
4. Header and Sole: same size as posts.
5. Half Gussets at Top:
  - One side (exterior) where no diagonal.
6. Half Gussets at Bottom:
  - One side (interior) at diagonals.
  - Each side where no diagonals.
7. Diagonal Braces:
  - 2 x 4 for 4 x 4 posts.
  - 2 x 6 for 6 x 6 posts.
8. Mid-Point Braces and Horizontal Struts: 2 x 4, 2 x 6 in configuration shown below. (equally spaced)



**Note: Maximum height using 4 x 4 posts is 17 feet**

**PERFORMANCE CRITERIA**Structural Performance

Design Load 4 x 4 posts:	32,000 lb
Design Load 6 x 6 posts:	80,000 lb
Safety Factors:	2 to 1 Minimum
Failure Mechanism:	Buckling of posts
Material Compatibility:	Intact, solid Surfaces
Tested and Documented:	Yes
Safe Haven:	Yes

Installation

Ease of Installation:	Carpenter skills
Time to Install:	12 - 30 minutes
Portability on disaster site:	Easy
Portability within structure:	Easy
Environmental limitations:	None
Tools required for installation:	Cutting and nailing tools
Power source required:	Generator for saw
Appropriate for small spaces:	No
Trainings or certifications required:	Shoring training recommended

Evaluation of Installed Systems

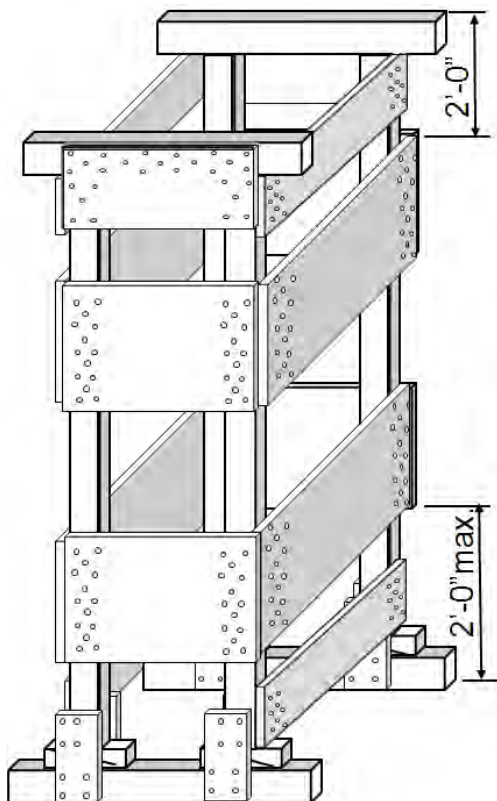
## Over/Under load indicators:

- Audible: Creaking/cracking of wood
- Visual: Cupping of Wedges/Sap seepage
- Equipment: Hammer, tape-measure, square
- Power source: Not Required

Inspection Recs: Every 12 hrs & following Aftershocks or load shifts

### 2.5.2 2 x 4 Plywood Laced Post (Vertical/Class 3)

High Capacity four post system. It is constructed similar to Std. Laced Post, but laced together with plywood. It is lighter and easier to carry into damaged area.	
Material List:	
2- each, Header & Sole	8- Half gussets, 2 Dbl gussets
4 - Posts	4 - Wedge Sets
12" x 48" top/bottom plywood braces	Use 4 for all heights
24" x 24" mid-braces & 24" x 48" mid-braces	Use 2 up tp 9ft Use 4 from 9ft to 13ft

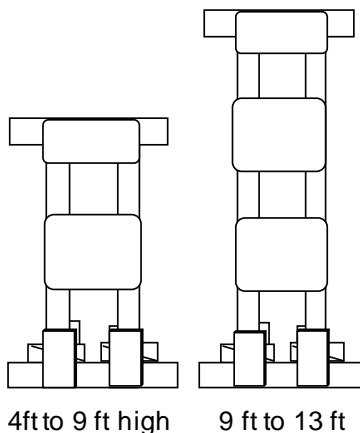


## HOW TO CONSTRUCT THE 2 X 4 PLY LACED POST

1. Determine the height of the shore.
  - Cut the header and sole plates to 4 feet in length.
2. Nail posts to header with toenails and keep them square.
  - Check by making X measurements (outside top right to outside bottom left, should be same as outside top left to outside bottom right).
  - If posts are not straight, set both with bow-out
  - Nail a double gusset header & both posts.
  - Nail the plywood mid braces in position. Re-check X measurement, & if posts bow-out, pull them in with the plywood braces. Use proper nail pattern.
3. Fabricate the second section, using first as template
4. Have the plywood braces precut for ease of assembly.
5. Bring both sections and the sole plates into position and place the prefabricated units on top of the sole plates.
  - Make sure that the prefabricated units are spaced 4 foot out to out, to allow for 4 ft plywood braces.
6. Install wedges under each post, and check post spacing.
7. Nail the plywood braces to the two sections on both sides (start with lower ones and climb up).
8. Nail the top and bottom plywood braces in place.
  - Place a half-gusset plate on each side of each post, with outside edge of gusset flush w/ post outside face.
9. Anchor the shore to the ceiling and floor, if practical.
10. Make sure all wedges are snug and the proper nail patterns were used.

**ADDITIONAL INFORMATION**

1. Maximum shore height for 4 x 4 posts: 13 feet.
2. Maximum shore height for 6 x 6 posts: 13 feet.
3. Posts: 4 x 4 and 6 x 6 are spaced the same.
  - Space 2 foot x 4 foot out to out.
4. Header and Sole: same size as posts.
5. Double gusset on outside at top, header to both posts.
6. Half Gussets, each side at each post at bottom.
7. Plywood top and bottom braces : 12" x 48" plywood.
8. Plywood middle braces: 24" x 24", 24" x 48" plywood.
  - Distance from top or bottom of shore to nearest middle brace for 9ft to 13ft heights shall be 2'-0" maximum.
9. All plywood may be 5/8" or 3/4" (or OSB for dry conditions).
10. Plywood bracing configuration for various heights is shown below:



**PERFORMANCE CRITERIA**Structural Performance

Design Load 4 x 4 posts:	32,000 lb
Design Load 6 x 6 posts:	80,000 lb
Safety Factors:	2 to 1 (Minimum)
Failure Mechanism:	Buckling of posts
Material Compatibility:	Intact, solid Surfaces
Tested and Documented:	Yes
Safe Haven:	Yes

Installation

Ease of Installation:	Carpenter skills
Time to Install:	12 - 30 minutes
Portability on disaster site:	Easy
Portability within structure:	Easy
Environmental limitations:	None
Tools required for installation:	Cutting and nailing tools
Power source required:	Generator for saw
Appropriate for small spaces:	No
Trainings or certifications required:	Shoring training recommended

Evaluation of Installed Systems

## Over/Under load indicators:

- Audible: Creaking/cracking of wood
- Visual: Cupping of Wedges/Sap seepage
- Equipment: Hammer
- Power source: Not Required

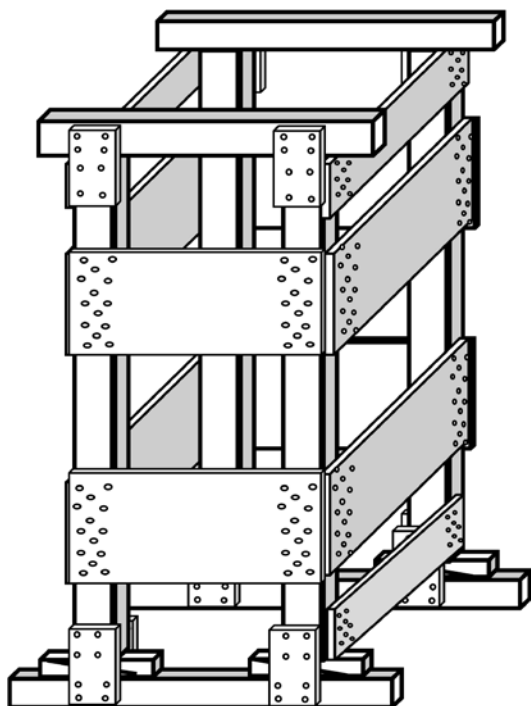
Inspection Recs: Every 12 hrs & following Aftershocks or load shifts

### 2.5.3 4 x 4 Plywood Laced Post (Vertical/Class 3)

High Capacity four post system. It is constructed similar to standard Laced Post, but braced together with plywood.

Material List:

2- each Header & Sole	12 - Half gussets
4 - Posts	4 - Wedge Sets
12" x 48" top/bottom braces	Use 4 for all heights
24" x 48" ply mid-braces	Use 4 up to 9ft
	Use 8 from 9ft to 13ft
	Use 12 from 13ft to 17ft



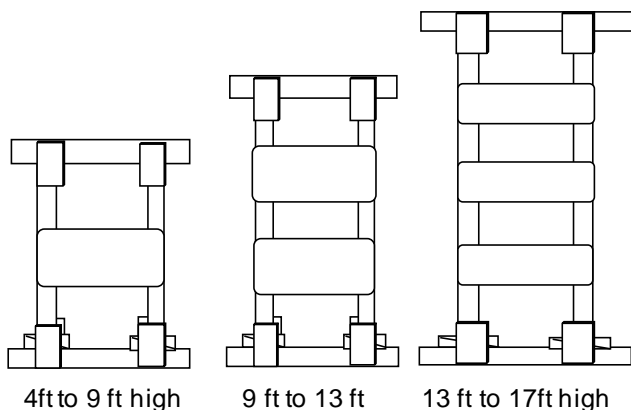


## HOW TO CONSTRUCT THE 4 X 4 PLY LACED POST

1. Determine the height of the shore.
  - Cut the header and sole plates to 6 feet in length.
2. Nail posts to header with toenails and keep them square.
  - Check by making X measurements (outside top right to outside bottom left, should be same as outside top left to outside bottom right).
  - If posts are not straight, set both with bow-out.
  - Nail a half gusset from header to both posts.
  - Nail the plywood mid braces in position. Re-check X measurement, & if posts bow-out, pull them in with the plywood braces. Use proper nail pattern.
3. Fabricate the second section, using first as template.
4. Have the plywood braces precut for ease of assembly.
5. Bring both sections and the sole plates into position and place the prefabricated units on top of the sole plates.
  - Make sure that the prefabricated units are spaced 4 foot out to out, to allow for 4 ft plywood braces.
6. Install wedges under each post, and check post spacing.
7. Nail the plywood braces to the two sections on both sides (start with lower ones and climb up).
8. Nail the top and bottom plywood braces in place.
  - Place a half-gusset plate on each side of each post, with outside edge of gusset flush w/ post outside face.
9. Anchor the shore to the ceiling and floor, if practical.
10. Make sure all wedges are snug and the proper nail patterns were used.

**ADDITIONAL INFORMATION**

1. Maximum shore height for 4 x 4 posts: 17 feet.
2. Maximum shore height for 6 x 6 posts: 17 feet.
3. Posts: 4 x 4 and 6 x 6 are spaced the same.
  - Space 4 foot x 4 foot out to out (to match plywood).
4. Header and Sole: same size as posts.
5. Half Gusset on outside at top for each post.
6. Half Gussets each side each post at bottom.
7. Plywood top and bottom braces: 12" x 48" plywood.
8. Plywood middle braces: 24" x 48" plywood.
  - Distance from top or bottom of shore to nearest middle brace for 9ft to 17ft heights shall be 2'-0" maximum.
  - There shall be a middle brace placed, centered at the half-height of the shore for 13ft to 17ft heights.
9. All plywood may be 5/8" or 3/4" (or OSB for dry conditions).
10. Plywood bracing configuration for various heights is shown below:



**PERFORMANCE CRITERIA**Structural Performance

Design Load 4 x 4 posts:	32,000 lb
Design Load 6 x 6 posts:	80,000 lb
Safety Factors:	2 to 1 (Minimum)
Failure Mechanism:	Buckling of posts
Material Compatibility:	Intact, solid Surfaces
Tested and Documented:	Yes
Safe Haven:	Yes

Installation

Ease of Installation:	Carpenter skills
Time to Install:	12 - 30 minutes
Portability on disaster site:	Easy
Portability within structure:	Easy
Environmental limitations:	None
Tools required for installation:	Cutting and nailing tools
Power source required:	Generator for saw
Appropriate for small spaces:	No
Trainings or certifications required:	Shoring training recommended

Evaluation of Installed Systems

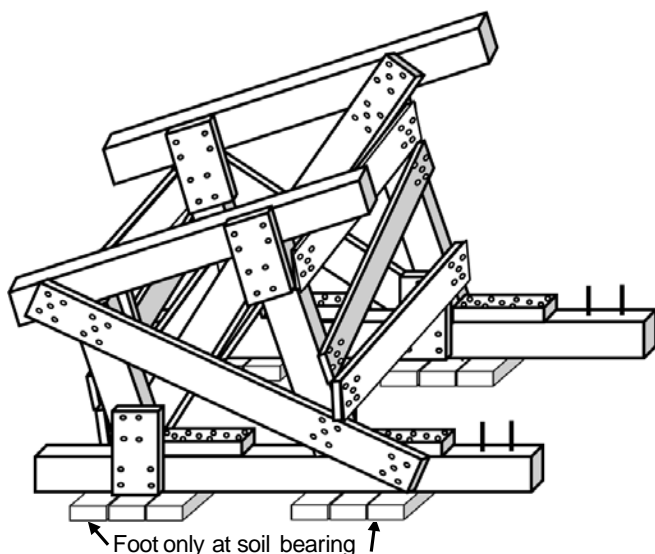
## Over/Under load indicators:

- Audible: Creaking/cracking of wood
- Visual: Cupping of Wedges/Sap seepage
- Equipment: Hammer
- Power source: Not Required

Inspection Recs: Every 12 hrs & following Aftershocks or load shifts

## 2.5.4 Sloped Floor Shore–Type 2 (Vertical/Class 3)

Built in pairs similar to a laced post shore. Used to support damaged and sloped, concrete floors that <b>are still connected</b> to remaining structure. (hinging slabs)	
Material List: (for a pair of shores)	
2 - Headers & Soles	8 - Half Gussets
4 Posts	4- 2x cleats x 18" long, 11-16d
4 - Diagonal Braces (1 each side each shore)	
Anchor Sole with 4-1/2 x 8 drilled- in anchors in sole or Sole Anchor from 4 x 4 / 6 x 6 w/ 4 - 1" dia. X 36" pickets.	
Bracing between shores: Shores 5ft apart: 2x6 top & bottom + diagonal Shores 5ft apart: 3/4" x 12" plywood strip, at end of shores that 3ft and less in height Shores 8ft apart: 2x6 top & bottom + X diagonals (see graphic under Additional Information)	

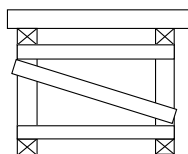


**HOW TO CONSTRUCT SLOPED FLOOR SHORE–TYPE 2**

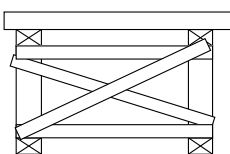
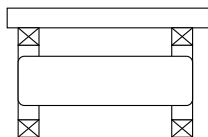
1. Determine length and width of shore and post locations.
  - Header overhang is 12 inch maximum. Sole must extend 30 inches longer from front of longer post.
2. Cut and install the header and sole.
  - If shore is installed on soil, the standard 18" x 18" foot should be placed under to sole at each post.
3. Measure, install the two posts, toe-nail to header, drive the bottom of posts tight and toe-nail.
4. Install bottom cleats.
5. Anchor the sole plate, as follows:
  - Anchor sole using drilled-in anchors or 1"dia. X 36" rebar to anchor to concrete or paving, based on Structures Spec. recommendations. (2 minimum per shore).
  - Alternate sole anchor using Sole Plate Anchor system shown with Rakers.
6. Measure for the diagonal braces inside and outside each section.
7. Install the 2x6 diagonal braces in position and nail into posts and header and sole plate.
  - Cleat/Half Gusset plate the opposite side of the posts, top and bottom, using the 4 and 4 nail pattern.
  - Need to place Half Gussets to clear the horizontal and diagonal braces (to be installed next), or use 2x cleats instead of gussets (but cleats w/ 16d are not preferred).
8. Brace the two sections together, same as in Laced Posts. (See Additional Information for alternatives).
  - Do this at both posts to tie the two sections together.
  - You may use a wide piece of 5/8" or 3/4" plywood (12" to 24" wide) if shore is too short to fit X braces.
  - The plywood or 2x6 bracing may be installed on the inside of the shorter posts, if that is easier.
9. Attach to the floor and ceiling. (If possible).

**ADDITIONAL INFORMATION**

1. Posts:
  - Spacing for 4 x 4 posts: Maximum 4 feet on center.
  - Spacing for 6 x 6 posts: Maximum 5 feet on center.
  - Spacing between shores as pairs: 4ft to 8ft on center.
2. Header and Sole: same size as posts.
3. Half Gussets: on opposite sides of diagonals, top & bottom.
4. Diagonal Braces: (2 x 6 on each side or shore)
5. Soil Support: (18" x 18" foot at soil bearings only)
  - 3 - 2 x 6 x 18" (flat) or 2 - 3/4" x 18" x 18" plywood layers, placed under each post.
6. May directly anchor sole with 2 - 1/2" x 8" drill-in anchors through sole into concrete.
7. Alternate Sole Anchor: see Section 4.1.2 for details.
  - 4 x 4 or 6 x 6 (preferred) x spacing of shores + 4ft.
  - 2 x 4 or 4 x 4 wedges at each shore.
  - 4 or more 1" diameter x 36" long pickets.
8. Bracing/lacing between shores: (all are 2x6).
  - Built in Pairs and Braced/laced together.
  - Built in groups (4ft min to 8' max on center).
  - Horizontals & Diagonals are 2 x 6 ( 2 - 2 x 4 alternate).
  - Horizontal Plywood Braces: 5.8" or 3/4" x 12" (min). where height is 3ft or less, 11-8d each end.



Up to 5ft o.c.

5ft to 8ft o.c.  
Bracing between Shores

3ft or less high

**PERFORMANCE CRITERIA**Structural Performance

Design Load 4 x 4 posts:	Depends on slope 20,000lb max. per pair
Design Load 6 x 6 posts:	Depends on slope 50,000lb max. per pair
Safety Factors:	2 to 1
Failure Mechanism:	Crushing of Header & Sole, or sudden offset
Material Compatibility:	Concrete Slab
Tested and Documented:	Yes
Safe Haven:	Yes

Installation

Ease of Installation:	Carpenter skills
Time to Install:	20 – 25 minutes
Portability on disaster site:	Easy
Portability within structure:	Easy
Environmental limitations:	None
Tools required for installation:	Cutting and nailing tools
Power source required:	Generator for saw
Appropriate for small spaces:	No
Trainings or certifications required:	Shoring training recommended

Evaluation of Installed SystemsOver/Under load indicators:

- Audible: Creaking/cracking of wood
- Visual: Cupping of Wedges/Sap seepage
- Equipment: Hammer
- Power source: Not Required

Inspection Recs: Every 12 hours and following aftershocks or load shifts.

## 2.5.5 Sloped Floor Shore–Type 3 (Vertical/Class 3)

Built in pairs similar to Type 2 Sloped Floor Shore. Support concrete floors that **are not connected** to remaining structure and may slide.

Material List: (for a pair of shores)

2 - Headers & Soles

8 - Half Gussets

4 – Posts

4- 2x cleats x 18" long, 11-16d

4 - Diagonal Braces (1 each side each shore)

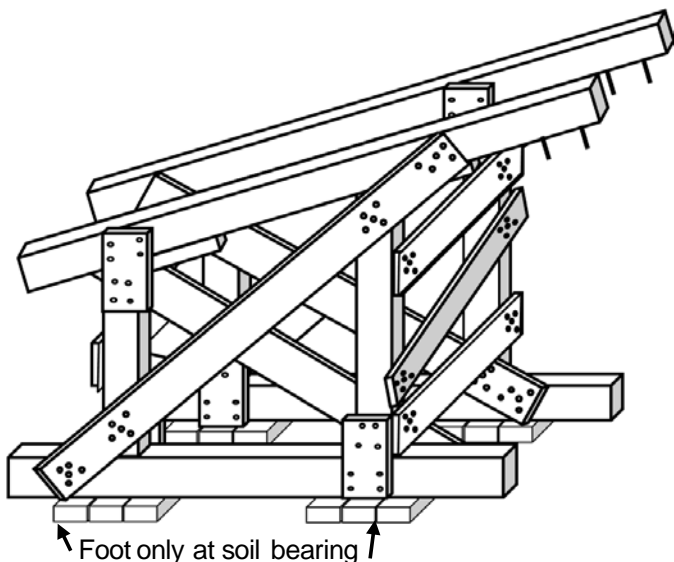
Sole Anchor from 4 x 4 / 6 x 6 w/ 4 - 1"dia. X 36"pickets.

Bracing between shores:

Shores 5ft apart: 2x6 top & bottom + diagonal

Shores 5ft apart: 3/4" x 12" plywood strip, at end of shores that 3ft and less in height

Shores 8ft apart: 2x6 top & bottom + X diagonals  
(see graphic under Additional Information)



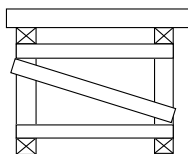


**HOW TO CONSTRUCT SLOPED FLOOR SHORE–TYPE 3**

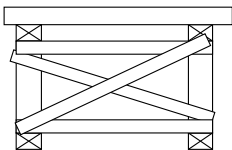
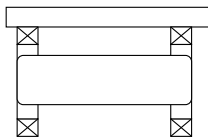
11. Determine length and width of shore and post locations.
  - Header overhang is 12 inches on lower end, but should be increased to 24 inches at high end. Sole plate should extend 12 inches beyond each post.
  - Install the header and sole.
  - If shore is installed on soil, the standard 18" x 18" foot should be placed under to sole at each post.
  - Prepare to install one 18 inch cleat for each post on underside of header with 11-16d nails (may pre-install one or more of the short post cleats on header, when practical, to reduce nailing in Collapse Zone).
12. Measure, install the two posts, anchor to header, and drive the post tops tight.
13. Install top cleats.
14. Make sure posts are vertical.
15. Attached header to ceiling/slab bottom with at least 2 – 1/2" bar or rebar x 8' long. (embedded at least 3").
16. Anchor the sole plate, if required, and re-check/re-drive the post tight.
17. Measure for the diag. braces inside/outside each section.
18. Install the 2x6 diagonal braces in position and nail into posts and header and sole plate.
  - Half Gusset plate the opposite side of the posts, top and bottom, and complete gusset nailing – 4 & 4, 8d.
  - Need to place Half Gussets to clear the horizontal and diagonal braces (to be installed next), or use 2x cleats instead of half-gussets. (cleats w/ 16d are not preferred).
19. Brace the two sections together, same as in Laced Posts. (See Additional Information for alternatives).
  - Do this at both posts to tie the two sections together.
  - You may use a wide piece of 5/8" or 3/4" plywood (12" to 24" wide) if shore is too short to fit X braces.
  - The plywood or 2x6 bracing may be installed on the inside of the shorter posts, if that is easier.
20. Attached to the floor and ceiling. (If possible).

**ADDITIONAL INFORMATION****Posts:**

- Spacing for 4 x 4 posts: Maximum 4 feet on center.
  - Spacing for 6 x 6 posts: Maximum 5 feet on center.
  - Spacing between shores as pairs: 4ft to 8ft on center.
2. Header and Sole: same size as posts.
  3. Half Gussets: on opposite sides of diagonals, top and bottom.
  4. Diagonal Braces: (2 x 6 on each side or shore).
  5. Soil Support: (18" x 18" foot at soil bearings only).
    - 3 - 2 x 6 x 18" (flat) or 2 - 3/4 x 18" x 18" plywood layers, placed under each post.
    - Must directly anchor header with 2 - 1/2" x 8" drill-in anchors, or 1/2" x 8" bar, through header into concrete.
  6. Alternate Sole Anchor: (see 4.1.2).
    - 4 x 4 or 6 x 6 (preferred) x spacing of shores + 4ft.
    - 2 x 4 or 4 x 4 wedges at each shore.
    - 4 or more 1" diameter x 36" long pickets.
2. Bracing/lacing between shores: (all are 2x6).
    - Built in Pairs and Braced/laced together.
    - Built in groups (4ft min to 8' max on center).
    - Horizontals & Diagonals are 2 x 6 ( 2 – 2 x 4 alternate).
    - Horizontal Plywood Braces: 5.8" or 3/4" x 12" (min) where height is 3ft or less, 11-8d each end.



Up to 5ft o.c.

5ft to 8ft o.c.  
Bracing between Shores

3ft or less high

**PERFORMANCE CRITERIA**Structural Performance

Design Load 4 x 4 posts:	Depends on slope 20,000lb max. per pair
Design Load 6 x 6 posts:	Depends on slope 50,000lb max. per pair
Safety Factors:	2 to 1
Failure Mechanism:	Crushing of Header & Sole, or sudden offset Concrete Slab
Material Compatibility:	Concrete Slab
Tested and Documented:	Yes
Safe Haven:	Yes

Installation

Ease of Installation:	Carpenter skills
Time to Install:	20 – 25 minutes
Portability on disaster site:	Easy
Portability within structure:	Easy
Environmental limitations:	None
Tools required for installation:	Cutting and nailing tools
Power source required:	Generator for saw
Appropriate for small spaces:	No
Trainings or certifications required:	Shoring training recommended

Evaluation of Installed Systems

## Over/Under load indicators:

- Audible: Creaking/cracking of wood
- Visual: Cupping of Wedges/Sap seepage
- Equipment: Hammer
- Power source: Not Required

Inspection Recs: Every 12 hours and following aftershocks or load shifts.

## **2.6 Cribbing**

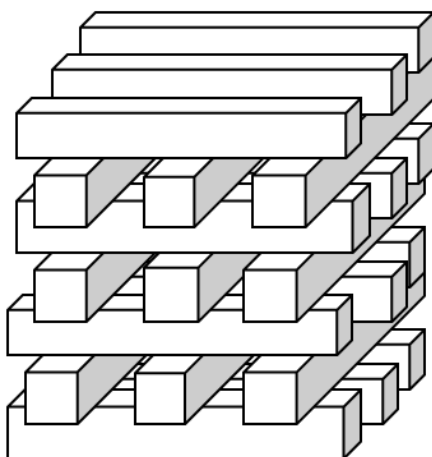
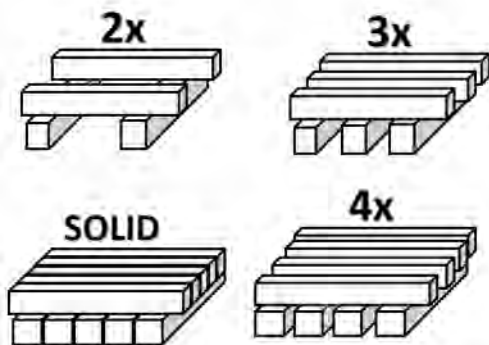
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## 2.6.1 Cribbing (Vertical/Class 3)

Cribbing is an easily adjustable shore for height and width dimensions. Height must be limited due to large amount of deflection due to crushing, and due to possibility of stability failure caused by different crushing rates at different bearings.

Material List:

Depends on height, number of pieces per layer and the height of each piece. See configurations below.



## HOW TO CONSTRUCT CRIBBING

1. Determine where Spot Shores should be built in order to quickly reduce risk.
2. Determine overall height of area to be shored and remove least amount of debris required to place shore.
3. Determine the desired width dimensions of the crib.
4. Determine the size of the members to be used, and the configuration of the crib layers.
  - Use 6x6 members if crib needs to be more than 4 ft high.
  - Note that the 3-member x 3-member configuration is more than 2 times as strong as 2-member x 2-member.
5. Decide if the first layer needs to be a solid layer, depending on the type of bearing material. (soil or other surface softer than a concrete slab.
  - If the supporting surface is concrete, make sure that it has the required stiffness and capacity, and there is not a basement story below.
6. Carefully slide the members in for each layer, and keep the crib aligned and as square as possible.
7. When the crib reaches required height, add shims to make sure that all intersections of crib members are in solid contact with the supported structure.
8. Attach the crib to the supporting surface (or confine its movement), if practical.
9. Where vibration and aftershocks may occur, interconnect the crib layers with 3/8" min x 16" long plywood strips that are 1.5 times as high as the cribbing members.
  - The plywood strips need to be placed on all 4 sides of the crib.
  - Nail plywood strips at top and bottom edges to crib members with 8d at 3 inches on center.

**ADDITIONAL INFORMATION**

1. Height: Maximum = 3 x shortest width.
  - Recommended Max. height for 4x4 systems is 4feet.
  - Recommended Max. height for 6x6 systems is 6 feet.
2. Use solid bottom layer for soil or asphalt applications.
3. Overlap corners by at least 4 inches.
4. Design Load Basis –
  - Cross-grain bearing of the wood (varies from 200 psi to 1,000 psi – Use 500 psi for Douglas Fir and Southern Pine).
  - Load per bearing point.
  - Number of Bearing Points.
  - Design Load Formula:  $L = A \times N \times P$ 
    - L = Load
    - A = Area of single bearing point (sq. in.)
    - N = Number of Bearing Points
    - P = Allowable bearing pressure (psi)
  - Design Load for 4x4 Douglas Fir & Southern Pine.
    - 2 member x 2 member system = 24,000lbs
    - 3 member x 3 member system = 54,000lbs
  - Design Load for 6x6 Douglas Fir & Southern Pine.
    - 2 member x 2 member system = 80,000lbs
    - 3 member x 3 member system = 180,000lbs



**PERFORMANCE CRITERIA**Structural Performance

Design Load for Doug Fir  
& Southern Pine:

Varies 24,000lbs to  
180,000lbs (see  
previous page)

Safety Factors:

2 to 1

Failure Mechanism:

Crushing of wood at  
bearings, or offset-  
collapse of entire crib if  
crushing is uneven.

Material Compatibility:

Intact, solid Surfaces

Tested and Documented:

Yes

Safe Haven:

No

Installation

Ease of Installation:

Carpenter skills

Time to Install:

12 - 30 minutes

Portability on disaster site:

Easy

Portability within structure:

Easy

Environmental limitations:

None

Tools required for installation:

Cutting tools

Power source required:

Generator for saw

Appropriate for small spaces:

No

Trainings or certifications required:

Shoring training  
recommended

Evaluation of Installed Systems

Over/Under load indicators:

- Audible: Creaking/crushing of wood
- Visual: Crushing at bearings and Sap/moisture seepage
- Equipment: Hammer
- Power source: Not Required

Inspection Recs:

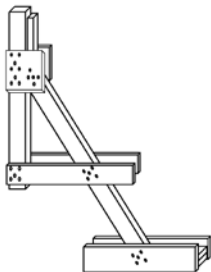
Every 12 hrs and after every  
aftershock or load shift.

### **3 Lateral Shoring**

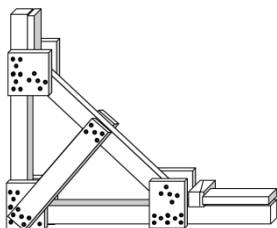
### **3.1 Raker Shores**

### 3.1.1 Raker Shores: General Information

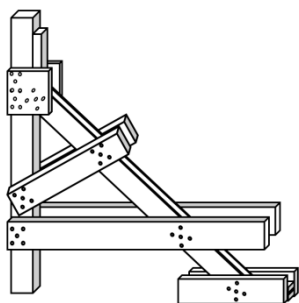
Description:
Used in search and rescue incidents to stabilize leaning and/or damaged walls. There are 3 types: Flying, Solid Sole and Split Sole. All have their unique characteristics.
Material List; see each individual system



Raker: Flying (Friction)  
temporary, spot rakers when debris are piled next to the base of the



Raker: Solid Sole (Full Triangle)  
Most desirable rakers, are normally built in groups of 2 or more as Class 3 Systems with lateral bracing.



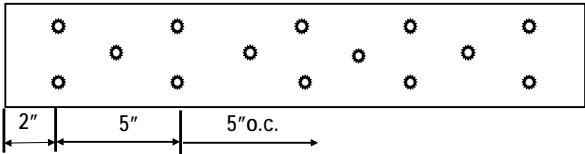
Raker: Split Sole  
Intended to be used when there is soil adjacent to the wall, and/or there is a limited amount of debris next to the wall. Should be built as Class 3 Systems.

## RAKER SHORES: GENERAL INFORMATION

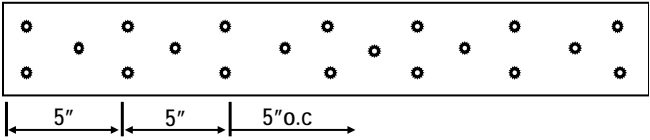
1. As with Vertical Shores, Raker Shores may be built in a logical progression, starting with Flying Raker, Spot Shores to initially stabilize the wall, followed by a group of Full Triangle Rakers (Since Full Triangle Rakers are mostly pre-fabricated, they may be installed without first installing Flying Rakers).

2. Top Cleat for 4 x 4 Raker.

- 24 inches with 14 – 16d nails for 45 degree rakers.



- 30 inches with 20 - 16d nails for 60 degree rakers.



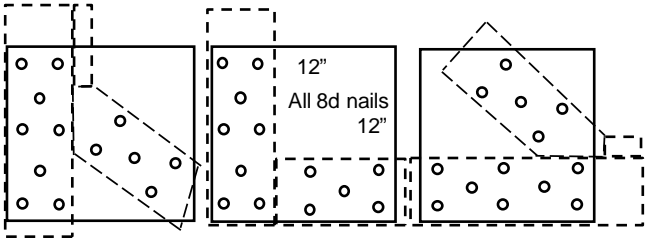
3. Top Cleat for 6 x 6 Raker.

- 24 inches with 20 – 16d nails for 45 degree rakers.
- 30 inches with 29 - 16d nails for 60 degree rakers.

4. Bottom Cleat:

- 24 inches with 14 – 16d nails for 4 x 4 rakers.
- 24 inches with 20 - 16d nails for 6 x 6 rakers.

5. Plywood gussets: 5/8" or 3/4" (OSB if not wet area).



Top of Raker

Bottom of Raker

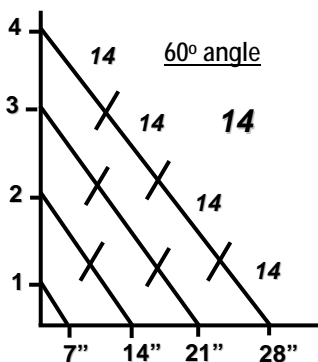
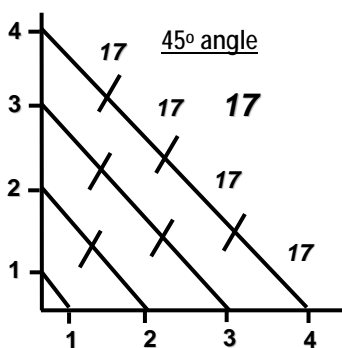
Rear of Raker

10. Sole Anchor: All rakers need some sort of Sole Anchor.

- See Section 4.1.2 for details.

**DETERMINING RAKER SHORE ANGLE & LENGTH**

- Any angle between 30 and 60 degrees will work effectively.
  - The lower the angle, the more efficient the raker will be.
- The two most common angles used are 45 and 60 degrees. A 60 degree angle is the maximum recommended angle used to safely erect a raker shore.
- Determining the height at which the raker shore needs to intersect the wall (Insertion Point) will identify the angle to work best with the available lengths of lumber. A 45 degree angle raker shore requires longer lumber than a 60 degree Raker.
  - The Insertion Point for a Wood Bldg should be between the Top of the Floor Joist and 2 feet below that point.
- The length of a 45-degree angle raker shore: Height of the raker shore support point in feet multiplied by 17 will give the length of the raker, tip to tip, in inches. ( $8' \times 17 = 136''$  or  $11' 4''$ ).
- The length of a 60-degree angle raker shore: Height of the raker shore support point in feet multiplied by 14 will give the length of the raker, tip to tip, in inches ( $8' \times 14 = 112''$  or  $9' 4''$ ).



## RAKER LENGTH BASED ON INSERTION POINT HEIGHT

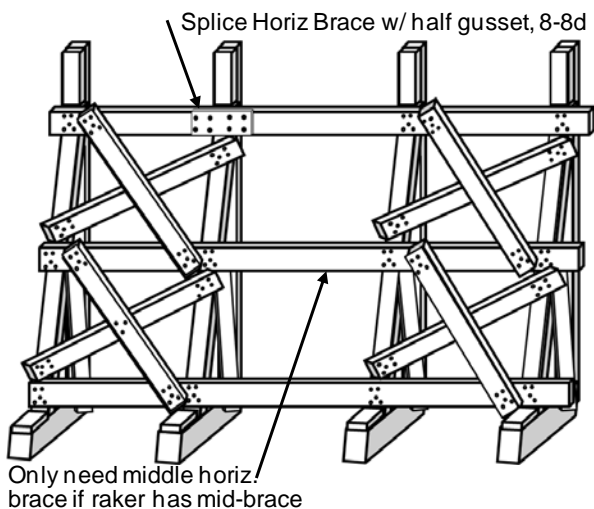
Insertion Point Ft	45° Raker L Inches / Feet	60° Raker L Inches / Feet	60° Horiz. Dist. Inches / Feet
3	51" / 4'- 3"	42" / 3'- 6"	21" / 1'-9"
4	68" / 5'- 8"	56" / 4'- 8"	28" / 2'-4"
5	85" / 7'-1"	70" / 5'- 10"	35" / 2'-11"
6	102" / 8'- 6"	84" / 7'- 0"	42" / 3'-6"
7	119" / 9'- 11"	98" / 8'- 2"	49" / 4'-1"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

### 3.1.2 Raker Shores: Multi-Shore Bracing, Backing, Raker Splice and Anchoring

Most all raker installations have multiple numbers of shores that are constructed along a damaged/leaning wall. This section will show information about:

- Bracing between rakers
- Backing against wall
- Raker Splice
- Trough Base
- Sole Anchors

Material List; see each individual system



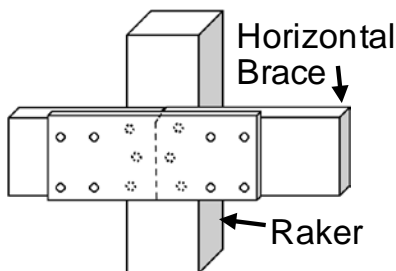
This is an example of a four raker system, when the rakers have a mid-brace. X bracing is shown, but V bracing may be used. Normally the X bracing should be installed between the end pair of rakers. There may be a 32ft space between X bracing.

Place the first diagonal of each set directly against the raker. Place the second diagonal so that it nails to the horizontal braces just adjacent to where the horizontal nails to the rakers. (No nails directly over other nails).



## BRACING

1. Rakers are normally spaced at 8 feet on center maximum. However, actual conditions may require closer spacing.
2. Lateral Bracing between rakers is normally built using 2x6 horizontals and X-bracing
3. Depending on height of insertion point, rakers may have mid-bracing to reduce to potential of buckling. In this case the lateral bracing will have a horizontal placed near the intersection of mid-brace and raker, and there will be two levels of X-bracing.
4. Horizontal Bracing: 2 x 6 or 2-2x4
  - Butt splice at center of raker. Preferred if 16ft long.
  - 3 – 16d nails at each horizontal brace to each raker.
  - Cover each splice with Half Gusset, 8-8d



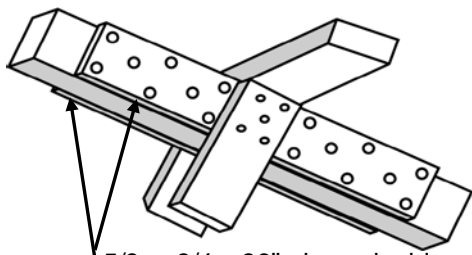
5. Middle Horizontal Bracing: (If raker has mid-point brace)
  - 4 x 4 raker: required if length of raker > 11 feet
  - 6 x 6 raker: required if length of raker > 16 feet
6. Diagonal Bracing
  - "X" bracing: Use 2 x 6 or 2-2x4 (side by side). Allow no more than 16 ft (2 bays) between bracing bays. 5-16d each end each brace, and 3-16x where they cross.
  - "V" bracing: Same as "X" bracing, but one member of the "X" is placed on the next bay. Allow no more than one un-braced bay between a "V" brace.

## BACKING

- For concrete or masonry walls, spreaders may be needed between wall plate and wall if wall is badly cracked.
  - Alternate 1: 1 piece of plywood, 4 ft x 4 ft x 3/4 or 5/8, with the top at the insertion point, and centered (left to right) on the wall plate. Nail ply to wall plate with 20-16d nails
  - Alternate 2: Use full 4 ft x 8 ft sheet of plywood with the long direction placed vertical, If the wall is badly cracked for most of its height, Same nailing
  - Alternate 3: Use 2 sheets of 1/2"plywood, for Alt1 & 2 if thicker ply is not available. Same nailing
- For wood walls, place a 2 ft high x 4 ft wide x 3/4" or 5/8" sheet of plywood centered on the wall plate, with the top near the insertion point, and/or the floor/roof line of the structure.
  - Nail backing plywood to wall plate with 20 -16d nails, equally spaced.
  - Center raker on a stud, and nail backing into studs and/or edge of floor/roof with 10 – 16d nails on each side of raker. Note: need to take care to locate studs for walls with stucco finish.

## RAKER SPLICE

- Locate center of splice within one foot each side of where mid-point brace connects to raker.
- Splice should be prefabricated on raker prior to assembling the raker shore.



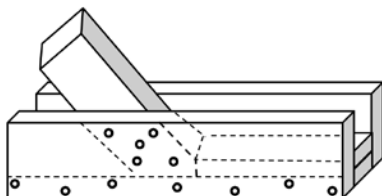
5/8 or 3/4 x 36" ply each side  
8-8d each side of center of splice

## TROUGH BASE

1. Used as base for Split Sole and Flying/Friction Raker
2. Place 18" x 18" foot under Trough for bearing on soil.

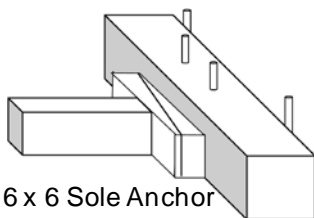
### Material List:

- 2– 2 x 6 x 36" side pieces. 7-16d to bottom each side and 5-16d to raker each side
- 1 – 2 x 4 or 2 x 6 x 36" bottom piece (match raker width)
- 1 – 2 x 4 or 2 x 6 x 18" cleat (match raker width), place flush with end. 5-16d to bottom.

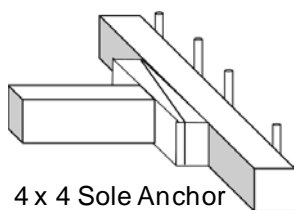


## SOLE ANCHOR

1. Used to keep rakers from moving away from wall.
  - Length of Sole Anchor is 4ft ft min.
  - Use 4 x 4 with pickets placed behind it.
  - Use 6 x 6 with pickets placed in holes through it if high winds or aftershocks are possible. Pickets may be placed behind it in other conditions.
  - Use 2 x 4 or 4 x 4 wedges. May use 2 x 6 wedges against 6 x 6.
  - Pickets into soil: Use 4 - 1" dia. x 36" min. per raker
  - Pickets into paving: Use 4 - 1" dia. x 36" min, per raker



6 x 6 Sole Anchor

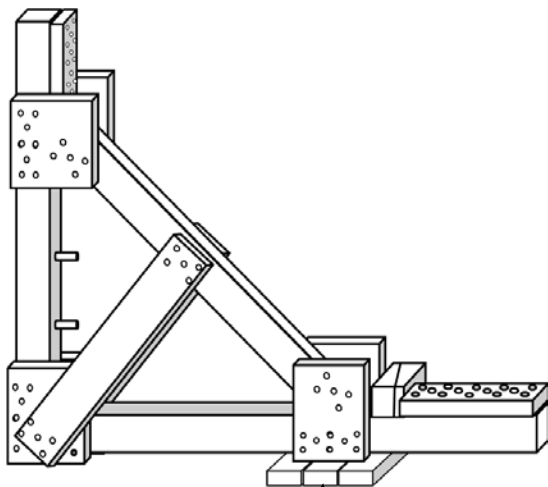


4 x 4 Sole Anchor

(May use two pickets per raker at paving)

### 3.1.3 Solid Sole Raker (Lateral/Class 3)

Used in Incidents to stabilize leaning and/or damaged walls. Solid Sole, full triangle, rakers are the most desirable rakers, and are built at 45 or 60 deg angle, in groups of 2 or more as Class 3 sys. with lateral bracing	
Material List: (per raker – need two or more)	
1 - Wall Plate	2- 1/2"x 8" wall plate anchors for 45 deg. & 3 anchors for 60 deg.
1 - Raker	6 – Full Gussets
2 - Mid-point braces	1 – 4 x 4 Wedge Set
1 – Sole Plate	2- 24" long cleats, 14-16d each for 45 degree rakers Top cleat is 30" long, 20-16d for 60 degree rakers (24" at bott.)
Sole Plate Anchors: 2 - Pickets or 4 (in soil)	
Foot at soil support: 3- 2 x 6 x 18" or 2 - 3/4 x 18" x 18" square plywood	



Foot only at soil bearing ↑

## HOW TO CONSTRUCT A SOLID SOLE RAKER

1. Determine where to erect the raker shores, the height of supported wall, and the height of Insertion Point.
2. If area is not clear of debris, consider Split Sole Raker.
3. Select angle of Raker, then measure and cut the Wall Plate, Sole Plate and Raker to the proper length.
  - Sole and Wall Plate extends at least 24" from where the raker intersects them to allow for the Cleats.
  - Angle-cut ends of raker with 1½" return cuts for full contact with the wall and sole plates, cleats and wedges.
4. Pre-fabricate Wall Plate, Raker, Sole, and Sole Anchor.
5. Toe-nail Sole to base of Wall Plate, square inside to 90deg, and secure with gusset plate on one side
  - Layout Raker at selected angle, intersection with Wall Plate and Sole. Anchor to Wall Plate with 16d nail, install top cleat and nail-on gusset one side.
  - Nail one Sole Gusset to Raker, but not to Sole at this time, since Raker may need later adjusting.
  - Mark Sole for position of Bottom Cleat, allowing for Wedges
  - Flip Raker Shore over and nail gussets on opposite side, but remember to nail the Raker to Sole Gusset, to Raker only, not to Sole to allow for later adjustment
6. Carefully move the partially prefabricated Rake Shore in place at the wall and make sure it is plumb.
  - With Raker Shore placed against the wall, the Sole should be carefully driven-in so the Wall Plate is snug against the Wall, and then the Bottom Cleat should be completely nailed, allowing space for the Wedges
  - Full contact must be maintained between the wall plate and the insertion point as well as at base of wall. (If the wall bulges out, add shims to maintain full contact)
7. After Anchoring the Sole Plate, install wedges between the bottom cleat and the base of the Raker and tighten them slightly.
  - After adjusting the shims/spacers (if any) between the wall plate and the wall being shored to ensure full contact, as in 6. above, finish tightening the wedges and complete nailing of gusset plates on each side.

**HOW TO CONSTRUCT A SOLID SOLE RAKER (contin.)**

8. With Raker shore erected, prevent the Raker shore from sliding up the wall, using a minimum of 2- 1/2" x 8" steel bars or other methods. See Additional Information.
9. Attach Mid Point Braces (required if 4x4 Raker is longer than 11 feet and/or 6x6 Raker is longer than 16 feet).
10. Attach Horizontal Braces.
  - Connect Raker shores together near the top and bottom of the Raker with at least 2x6 size material, or two 2x4s.
  - For Insertion Point greater than 8 feet, a Horizontal Brace shall be placed at mid-length of the Raker, right where the Mid-Point Braces intersect.
  - Horizontal braces may be butt-spliced at center of any raker. Use 3-16d ea end plus half-gusset with 4-8d ea side splice.
11. All Raker shore systems must be connected with either X or V bracing near the top and bottom of the Raker between at least two Raker shores with 2x4 or 2x6.
12. Attach the **first brace to the Rakers** near the top and bottom between the upper and lower horizontal braces.
11. Attach the **second brace to the upper and lower horizontal braces** near the Rakers.
13. **Methods to Anchor the Sole Plate**, in order to prevent the assembled shore from sliding away from the wall.
  - **Preferred Method:** Use **Sole Anchor** as shown on page 113, and as noted in ADDITIONAL INFORMATION on next page. This is preferred, since installation can be installed with less risk, at greater distance from wall.
  - **Alternative Method:** One may attach the sole plate directly to concrete, asphalt or soil by drilling a minimum of two 1" holes through the sole plate, concrete, or asphalt and drive 1" x 36" steel pickets or rebar directly into the ground below. Need at least 4 – 1"x 36" pickets per raker when no concrete or asphalt paving is present, and anchoring into ground only.

**ADDITIONAL INFORMATION**

## 1. Raker:

- 4 x 4 maximum length without mid-brace: 11 feet
  - 6 x 6 maximum length without mid-brace: 16 feet
3. To attach wall plate directly to a concrete/masonry wall.
- A minimum of two 1/2" drill-in anchors, lag screws or 8" long rebar should be placed through the wall plate for 45 deg rakers. Use 3 anchors for 60 deg rakers.
  - On concrete walls, if 3/4" plywood backing material is needed, then attach it to wall plate with 20-16d nails, and use at least five 3" powder charge pins with washers through the backing material into the concrete on each side of the Raker (also may use 3 - 3/8x4" Concrete Screws each side).
4. To attach the wall plate directly to a wood framed wall.
- Use 2 ft high x 4ft wide x 3/4" or 5/8" ply backing nailed with 20-16d to the wall plate. Center raker on a stud, and use at least 10-16d nails through the backing material into studs and/or edge of floor, each side of Raker.
5. Place an 18" x 18" Foot under the sole at intersection of raker, when bearing on soil.
- Use 3 – 2 x 6 x 18" or 2 – layers of 3/4" x 18" x 18" plywood.
6. A Sole Anchor can be secured to the ground or floor behind the sole plate to prevent the sole plate from backing away from the wall.
- Timber Anchors should be at least 4x4 size lumber, (6x6 is better). Place 4 – 1" diameter x 36" pickets per raker, spaced about 12" o.c., directly behind Anchor on Soil. Two pickets may be used into concrete or paving.
  - Specially made steel anchor brackets may be used with a minimum of 2- 1/2" drill-in anchors to concrete
  - Concrete curbs, walls and other nearby secure structures may also be used.

**PERFORMANCE CRITERIA**Structural Performance

Design Load 4 x 4 posts:	2,500 lb per raker
Design Load 6 x 6 posts:	3,600 lb per raker
Safety Factors:	2 to 1
Failure Mechanism:	
Material Compatibility:	Concrete Slab
Tested and Documented:	Yes
Safe Haven:	No

Installation

Ease of Installation:	Carpenter skills
Time to Install:	20 – 25 minutes
Portability on disaster site:	Easy
Portability within structure:	Easy
Environmental limitations:	None
Tools required for installation:	Cutting and nailing tools
Power source required:	Generator for saw
Appropriate for small spaces:	No
Trainings or certifications required:	Shoring training recommended

Evaluation of Installed Systems

## Over/Under load indicators:

- Audible: Creaking/cracking of wood
- Visual: Cleat slim and other movement at base, and/or moving up the wall.
- Equipment: Hammer
- Power source: Not Required

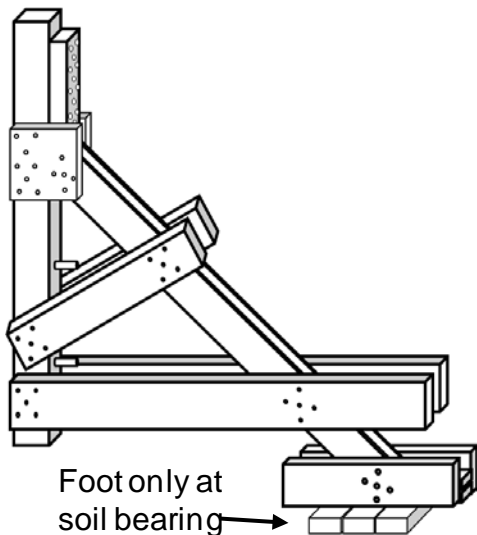
Inspection Recs: Every 12 hrs and after every Aftershock, high wind gust, or load shift.



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### 3.1.4 Split Sole Raker (Lateral/Class 3)

Split Sole Rakers, should replace Solid Sole Rakers when debris are next to the damaged wall. They should be built in groups of 2 or more with lateral bracing	
Material List: (per raker- need 2 or more for system)	
1 - Wall Plate	24" long top cleats, 14-16d each for 45 degree rakers (30" long, 20-16d for 60 deg)
1 - Raker	2 - Full Gussets
2 - Bottom Braces	1 - 4 x 4 Wedge Set
2 -Mid-point braces (When required)	2- 1/2"x 8" wall plate anchors for 45 deg. & 3 anchors for 60 deg
1 - Trough (see 4.1.2) add 18" x18" base/foot on soil.	
Trough Anchors: 2 - Pickets in paving (or 4 in soil)	
Pickets	2 or 4 (soil)



#### HOW TO CONSTRUCT SPLIT SOLE RAKER

1. Determine where to erect the Raker Shores and the height of supported wall, and height of Insertion Point.
  - Temporary shoring may be needed, but most of debris may not need to be removed for Split Sole Raker.
2. Determine where to erect the Raker Shores and the height of supported wall, and height of Insertion Point.

3. Select angle of Raker, then measure and cut the Wall Plate, Raker, and Bottom Brace to the proper length.
  - If there is rubble next to wall, wall plate will not extend to ground, and Bottom Brace will be attached at bottom of Wall Plate, and slope to within 6" of Trough Base.
  - Raker angle may be 45 or 60 deg into Trough Base
  - Angle-cut both ends of Raker with 1½ " return cuts for full contact with wall plate, top cleat, and Trough Cleat
4. Pre-fabricate, Raker, Wall Plate, Bottom Brace, and Sole Anchor to proper length, and perform raker angle cuts.
  - Layout Wall Plate, Raker and Bottom Brace at selected angle, and toe-nail Raker to Wall Plate
  - Nail-on Top Cleat, then gusset to one side of this joint
  - Nail one-Bottom Brace to Wall Plate, 6" from bottom, or in position to clear debris, but only tack-nail it to Raker
  - Turn shore over and nail-on other gusset plus other Bottom Brace to Wall Plate
  - Tack-nail Bottom Braces to Raker, so it can be moved into place at the wall.
  - Assemble the Trough, as well as the 18" x 18" foot ( if bearing on soil), and place in approximate position.
5. Move the partially prefabricated Split Sole Raker Shore in place at the wall and make sure it is plumb.
  - After securing the Sole Anchor, adjust the Trough, and drive wedges slightly against it.
  - Maintain full contact between the wall plate at the insertion point and at base of wall plate and the wall.
  - For bulging walls, add tight shims/spacers, then finish tightening wedges & finish nailing of Bottom Braces.
  - Prevent the Raker shore from sliding up concrete or masonry walls, by placing 2- 1/2"x 8" anchors for 45 deg. & 3- 1/2"x 8" anchors for 60 deg through the wall plate into the wall. For wood walls, center raker on stud and see ADDITIONAL INFORMATION, 3.
  - Place the Mid-Brace, if required by length of Raker, and erect the Horizontal and X-bracing, per Solid Sole.
  - Secure the Sole Anchor as shown on page 113, and as noted in ADDITIONAL INFORMATION on next page.

**ADDITIONAL INFORMATION**

1. Raker:
  - 4 x 4 maximum length without mid-brace: 11 feet
  - 6 x 6 maximum length without mid-brace: 16 feet
2. To attach wall plate directly to a concrete/masonry wall.
  - A minimum of two 1/2" drill-in anchors, lag screws or 8" long rebar should be placed through the wall plate for 45 deg rakers. Use 3 anchors for 60 deg rakers.
  - On concrete walls, if 3/4" plywood backing material is needed, then attached it to wall plate with 20-8d nails, and use at least five 3" powder charge pins with washers through the backing material into the concrete on each side of the Raker (also may use 3 - 3/8x4" Concrete Screws each side).
3. To attach the wall plate directly to a wood framed wall.
  - Use 2 ft high x 4ft wide x 3/4" or 5/8" ply backing nailed with 20-16d to the wall plate. Center raker on a stud, and use at least 10-16d nails through the backing material into studs and/or edge of floor, each side of Raker.
4. Use the Trough Base with a Sole Anchor.
  - Place a 18" x 18" Foot under Trough Base, when bearing on soil.
    - a. Use 3 – 2 x 6 x 18" or 2 - layers of 3/4" x 18" x 18" plywood
5. A Sole Anchor should be secured to the ground or floor behind the sole plate to prevent the sole plate from backing away from the wall.
  - Timber Sole Anchors should be as least 4x4 size lumber, (6x6 is better). Place 4 – 1" dia x 36" pickets, spaced about 12" o.c., directly behind Anchor on Soil. Two pickets per raker may be used into concrete or paving.
  - Specially made steel anchor brackets may be used with a minimum of 1- 1/2" drill-in anchors to concrete.
  - Concrete curbs, walls and other nearby secure structures may also be used.

**PERFORMANCE CRITERIA**Structural Performance

Design Load 4 x 4 posts:	2,500 lb per raker
Design Load 6 x 6 posts:	3,600 lb per raker
Safety Factors:	2 to 1
Failure Mechanism:	Raker buckling, or movement up wall, or away from wall
Material Compatibility:	Concrete Slab
Tested and Documented:	Yes
Safe Haven:	No

Installation

Ease of Installation:	Carpenter skills
Time to Install:	20 – 25 minutes
Portability on disaster site:	Easy
Portability within structure:	Easy
Environmental limitations:	None
Tools required for installation:	Cutting and nailing tools
Power source required:	Generator for saw
Appropriate for small spaces:	No
Trainings or certifications required:	Shoring training recommended

Evaluation of Installed Systems

## Over/Under load indicators:

- Audible: Creaking/cracking of wood
- Visual: Cleat slip and other movement at base, and/or moving up the wall.
- Equipment: Hammer
- Power source: Not Required

Inspection Recs: Every 12 hrs and after every Aftershock, high wind gust, or load shift.

### 3.1.5 Flying Raker Shore (Lateral Class 1)

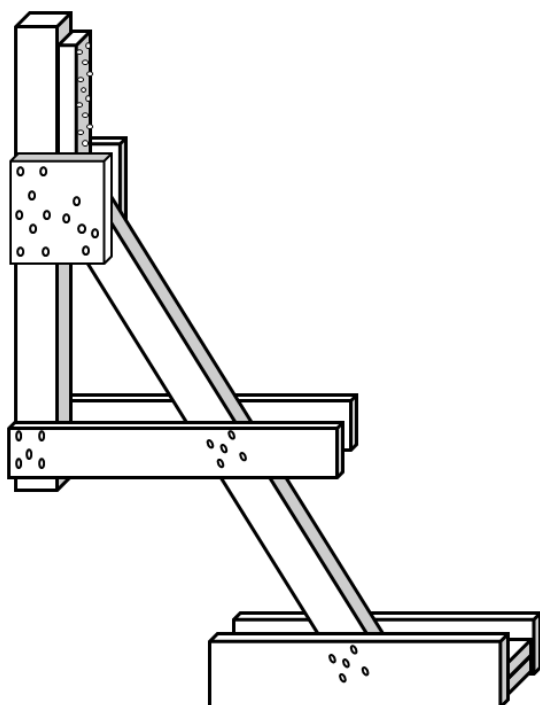
This is a rapidly assembled and installed shore that is best used as an initial, temporary shore, until a more reliable raker system can be installed. It can be erected next to a wall without removing debris.

#### Material List

4 x 4 x 6ft Wall Plate	One 2 x 4 x 24" Cleat
One 4 x 4 Raker	1 Set of 4 x 4 Wedges
2 – 2 x 6 x 48" Braces	2 Wall Plate Anchors

Trough Base (see 4.1.2)

Sole Anchor with 2 – 1" x 36" Pickets (see 4.1.2)



## HOW TO CONSTRUCT THE FLYING RAKER

1. Determine where to erect the Raker Shores and the height required to support the wall. Determine height of Insertion Point
2. Flying Raker order of construction as follows:
  - Prefabricate the shore.
  - Fit the shore into the Trough Base.
  - Install wedge and/or shims.
  - Attach to wall with drill-ins (or nails for wood walls).
  - Retighten the wedges.
3. In order to pre-fabricate, Cut Raker, Wall Plate and Bottom Brace to proper length, and perform angle cuts on Raker.
4. Layout Wall Plate, Raker and Bottom Brace at selected angle, and toe-nail Raker to Wall Plate.
5. Nail-on Top Cleat, then gusset to one side of this joint.
6. Nail one-Bottom Brace to Wall Plate in position to clear debris, but only tack-nail it to Raker.
7. Turn shore over and nail-on other gusset plus other Bottom Brace. (nailed to Wall Plate, tack to Raker)
8. Anchor Trough, then carry the partly assembled Raker into place. Snug-up the Wedges, and complete the nailing of Bottom Brace to Raker.
9. Make whatever connection to wall that is selected, see Additional Information.
10. Retighten the Wedges.

**ADDITIONAL INFORMATION**

1. The areas to be supported by Raker Shores should be considered extremely dangerous.
2. They may be used as singles spot shores, or may be built in pairs with horizontal and X bracing added between pairs.
3. To attach wall plate directly to a concrete/masonry wall.
  - A minimum of two 1/2" drill-in anchors, lag screws or 8" long rebar should be placed through the wall plate for 45 deg rakers. Use 3 anchors for 60 deg rakers.
  - On concrete walls, if 3/4" plywood backing material is needed, then attached it to wall plate with 20-8d nails, and use at least five 3" powder charge pins with washers through the backing material into the concrete on each side of the Raker (also may use 3 - 3/8x4" Concrete Screws each side).
4. To attach the wall plate directly to a wood framed wall.
  - Use 2 ft high x 4ft wide x 3/4" or 5/8" ply backing nailed with 20-16d to the wall plate. Center raker on a stud, and use at least 10-16d nails through the backing material into studs and/or edge of floor, each side of Raker.
5. In some cases the drill-ins may be omitted if the top of the Wall Plate can bear against a protrusion in brick/concrete wall. Do not rely on friction.
6. At brick/concrete wall, raker may be built at one edge of a window, with a single or double 2x4 (24" min w/14-16d) pre-nailed to the Wall Plate so it will bear on the bottom of window header (Only if header is not badly cracked)
7. Use a Trough Base that is restrained by a sole anchor.
8. A Sole Anchor can be secured to the ground or floor behind the sole plate to prevent the sole plate from backing away from the wall.
  - Timber Anchors should be as least 4x4 size lumber, (6x6 is better). Place 4 – 1" diameter x 36" pickets, spaced about 12" o.c., directly behind Anchor on Soil. Two pickets may be used into concrete or paving.
  - Concrete curbs, walls and other nearby secure structures may also be used.



**PERFORMANCE CRITERIA**Structural Performance

Design Load:	1,000 lbs
Safety Factors:	2 to 1
Failure Mechanism:	Buckling of Raker, movement at base, and/or moving up the wall.
Material Compatibility:	Intact, solid Surfaces
Tested and Documented:	Yes
Safe Haven:	No

Installation

Ease of Installation:	Carpenter skills
Time to Install:	6 – 9 minutes
Portability on disaster site:	Easy
Portability within structure:	Easy until assembled
Environmental limitations:	None
Tools required for installation:	Cutting and nailing tools
Power source required:	Generator for saw
Appropriate for small spaces:	Yes
Trainings or certifications required:	Shoring training recommended

Evaluation of Installed Systems

## Over/Under load indicators:

- Audible: Creaking/cracking of wood
- Visual: Movement at base, and/or moving up the wall.
- Equipment: Hammer
- Power source: Not Required

Inspection Recs: Every 12 hrs and after every aftershock or load shift.

## **3.2 Horizontal Shores**

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### 3.2.1 Horizontal Shore

This shore can be used to stabilize parallel, vertical walls, especially walls that are bulging.

Material List:

2 – Wall Plates

1 – 2x Wedge Set per Strut

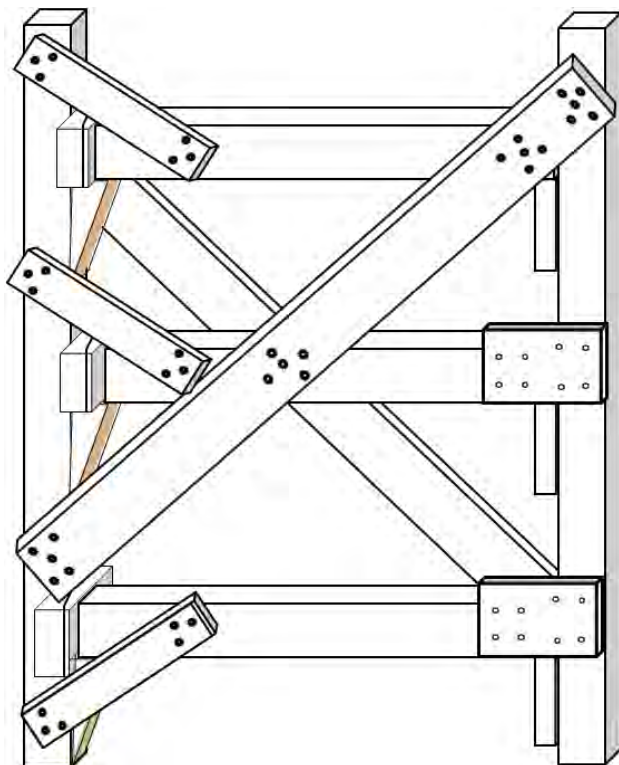
3-Struts  
(2 if used for access)

Single 4x Wedge per Strut  
2 x 4 x 14" cleat each Strut

2 x Diagonal Bracing  
(non-access use)

2 – Half Gussets  
(1 each Strut if no diagonals)

1 - 2 x 4 x 18" Angle (L) Cleat at each wedge set



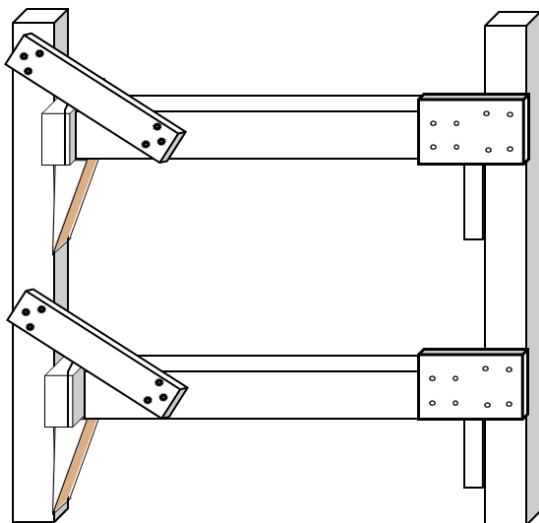
Non-access, 3 - Strut, Horizontal Shore

## HOW TO CONSTRUCT HORIZONTAL SHORE

1. Measure and cut the wall plates & struts to the proper length.
  - Measure between the wall plates where the struts are to be installed, deducting the width of the wedges.
2. Place both wall plates next to each other and attach cleats and single 4x wedges to the wall plates just below where the struts will be installed.
  - If 4x wedge is not available, use 2x wedge on top of a 2x cleat. 5-16d
3. Place the wall plates in the area that is to be shored, square and in line with each other and as plumb as possible by shimming any void spaces behind the wall plates.
4. Install the struts between the wall plates. Keep the struts in line and plumb with the wall plates.
5. Install a set of wedges horizontally between the Wall Plate and each Strut, then tap them together simultaneously until the struts are tight.
  - Toenail the wedges from top into wall plate. May need to use duplex nails for future adjustment.
  - Add 2 x 4 x 18" cleat from wall plate to strut (on top if possible) to secure wedges & strut. 3-16d each end.
6. At non-wedge end of strut, place half gusset one side.
7. If possible, attach the wall plates to the walls.
8. Attach the diagonal braces to each side of the horizontal shore when not used for access or egress.
  - The diagonal braces should be long enough to span entire length and be attached to both wall plates and each strut.
  - When used, diagonal braces should be installed in a "X" pattern on opposite sides of struts. 5-16d each end.

**ADDITIONAL INFORMATION**

1. Maximum shore width for 4 x 4 struts: 10 feet.
9. Maximum shore width for 6 x 6 struts: 16 feet.
10. Wall Plates: 4 x 4 or 6 x 6.
  - Spacing for 4 x 4 struts: Maximum 4 feet on center.
  - Spacing for 6 x 6 struts: Maximum 5 feet on center.
11. Miscellaneous:
  - X – bracing is 2 x 6 with 5-16d each end.
  - Place one half of 4 x wedge set under end of strut where wedges are installed, 5-16d nails.
  - Place 2 x 4 x 18" Angle (L) Cleat to confine wedges, 3-16d each end.
  - Place 2x, 14" long cleat under opposite end of strut from wedges. 5-16d nails. Add half cleat on side.

**Access Type, 2 - Strut, Horizontal Shore**

**PERFORMANCE CRITERIA**

Structural Performance

Design Load 4 x 4 posts:	
Width = 8 feet	16,000 lb
Width = 10 feet	10,000 lb
Design Load 6 x 6 posts:	
Width = 12 feet	40,000 lb
Width = 16 feet	24,000 lb
Safety Factors:	2 to 1
Failure Mechanism:	Crushing of wall plates, and cupping of wedges
Material Compatibility:	Intact, solid Surfaces
Tested and Documented:	Yes
Safe Haven:	No

Installation

Ease of Installation:	Carpenter skills
Time to Install:	8 - 12 minutes
Portability on disaster site:	Easy
Portability within structure:	Easy
Environmental limitations:	None
Tools required for installation:	Cutting and nailing tools
Power source required:	Generator for saw
Appropriate for small spaces:	No
Trainings or certifications required:	Shoring training recommended

Evaluation of Installed Systems

Over/Under load indicators:	
• Audible:	Creaking/cracking of wood
• Visual:	Cupping of Wedges/Sap seepage
• Equipment:	Hammer
• Power source:	Not Required
Inspection Recs:	Every 12 hrs and after every aftershock or load shift.

## **4    Manufactured Shoring**



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### 4.1.1 Pneumatic Shores

Shore Category: Vertical Class 1/2/3 and Lateral

Description:

Manufactured pneumatic shoring systems designed and manufactured specifically for rescue operations.

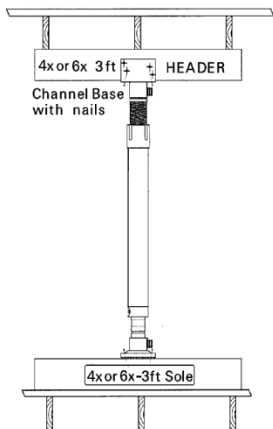
Comprised of variable length struts and accessories designed to configure struts into vertical or lateral shoring systems.

#### Applications

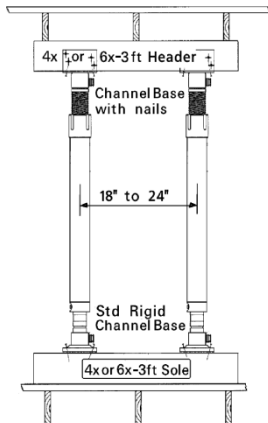
Pneumatic Shores are applicable wherever rescue shoring is needed. Stabilization and size-up philosophies are the same as those applied to built-in-place shoring (see Sections 2 and 3). Consider using pneumatic shores in lieu of built-in-place shores when shoring needs to be installed in a more rapid manner.

#### Considerations/Limitations

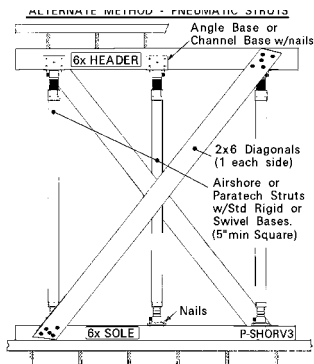
- May use 50 psi to set struts.
- Do not use air to support loads.
- Hand tighten all pneumatic shores.
- Understand signs of overload for specific system being used.
- Construct in accordance with manufacturer instructions.
- Ensure adequacy of supporting material under strut.
- Consider need for header and sole.
- Competent Professional Engineer is required for use.
- Use & load capacities for Airshore by Hurst and Paratech are included in Appendix A of this Guidebook.
- Confirm safety factors used if relying on manufacturer provided capacities.
- Capacity of 3 Strut Spot shore can be taken as 3 times the strength of single struts of same length.



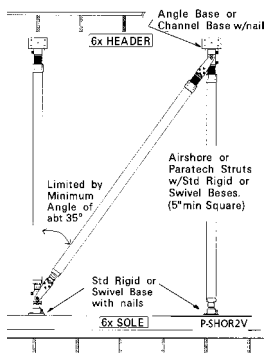
**T Spot Shore**



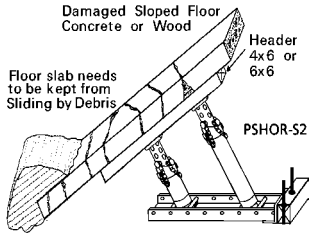
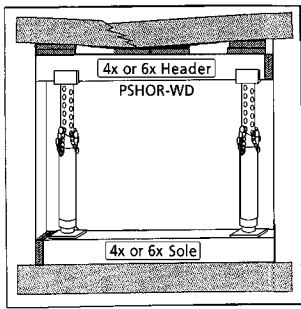
**Double T Spot Shore**



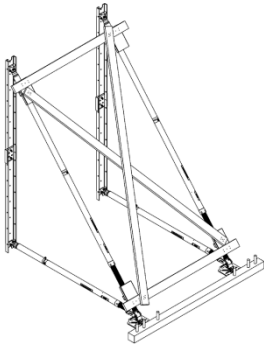
**3-Post Vertical Shore**



**2-Post Vertical Shore**

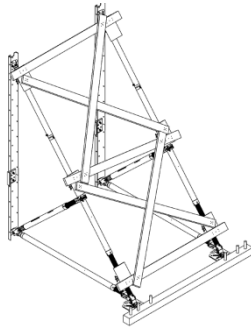


### Window Shore

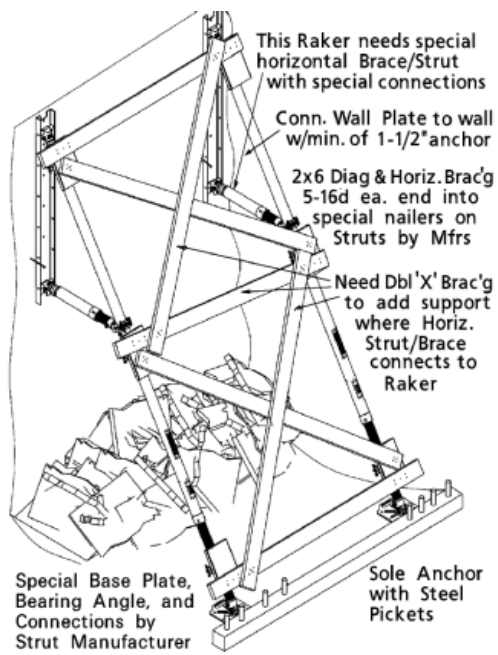


Raker with X-Brace

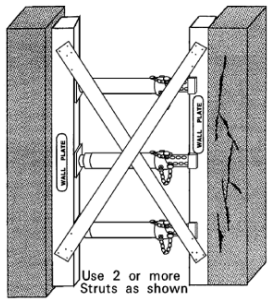
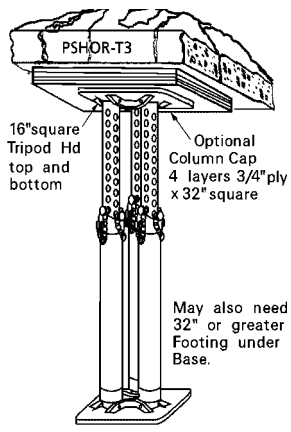
### Sloped Floor Shore



Raker with Dbl X-Brace



### Flying Raker



3-Column Spot Shore

Horizontal Shore

## 4.2 Heavy Duty Vertical Shoring

### Description:

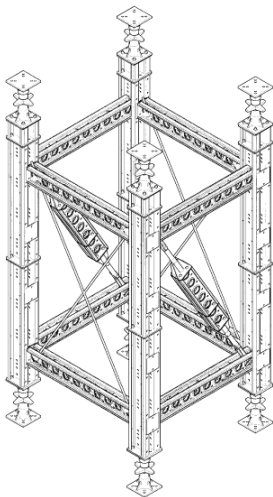
Manufactured vertical shoring systems intended to be used in construction activities may be able to be used as vertical shoring in rescue operations. The systems use modular construction.

### Applications

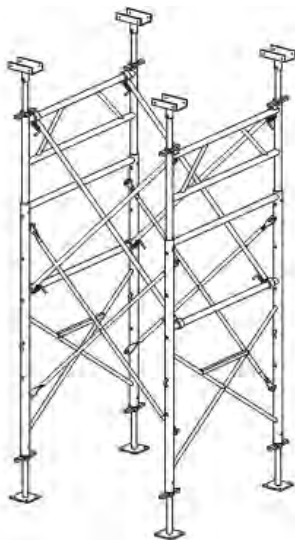
Can be used in most situations where vertical built-in-place or pneumatic shoring can be used. Shoring systems intended to support bridges may be applicable in rescue situations when shore heights greater than a single story are needed.

### Considerations/Limitations

- Work with manufacturers and Competent Professional Engineer to develop shoring solutions.
- Use & load capacities from manufacturer
- Adequacy for aftershocks should be verified
- Adequacy of supporting material under shore, and need for header and sole should be verified.



Example 1



Example 2

### 4.3 Manufactured Cribbing

**Description:**

Manufactured, modular cribbing system.

**Applications**

Can be used in most situations where vertical built-in-place or pneumatic shoring can be used. Shoring systems intended to support bridges may be applicable in rescue situations when shore heights greater than a single story are needed.

**Considerations/Limitations**

- Confirm material compatibility for HDE/PP chemical resistance.
- Do not mix different materials in crib blocks.
- Confirm adequacy of supporting material under shore, and need for header and sole should be verified.
- Use & load capacities from manufacturer.





## 4.4 Vertical Post Accessories

Description:

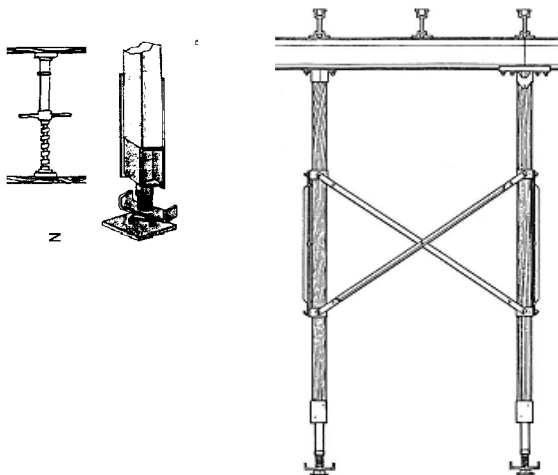
Accessories for wood and steel vertical posts.

### Applications

Can be used in most situations where vertical spot shores are required.

### Considerations/Limitations

- Accessories for post “pipe” type shoring.
- Steel pipe post properties found in Appendix A.
- Confirm adequacy of supporting material under strut, and need for header and sole should be verified.
- Competent Professional Engineer is required for use.
- Accessory use & load capacities from manufacturer.



## **5 Repair and Strengthening Techniques**

## 5.1 Introduction

The strengthening and repair of structural members, components, joints and systems during disaster operations requires innovative design solutions, coordination with contractors and consideration of time and risk.

There are no textbook solutions or systems that can be deployed that do not require forethought and engineering expertise.

Following are examples and ideas that can be, or have been, used in past disasters to stabilize, repair or strengthen structural buildings and their components during search and rescue operations.

They are presented so that the guidebook user has a toolbox of alternatives to consider when faced with similar challenges.

## 5.2 Non-Contact Fiber Wraps

Description: Repair/Retrofit Method: Grout Filled Fiber Plastic Shell

Grout Filled FRP Shell: used as a high strength, grout filled form around damaged members. Used for:-column confinement;-column reinforcing; member stabilization; component strengthening.

### Applications

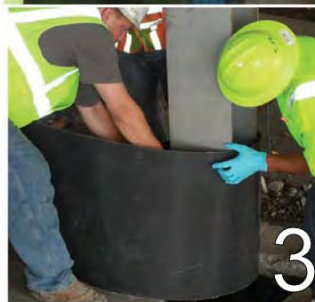
This grout filled, custom formed FRP Wrap can be applied to damaged steel, concrete or wood members, spalled concrete regions to maintain residual strength or increase strength.

### Considerations/Limitations

- Competent Professional Engineer is required for use.
- Manufacturer input is essential for application and use.
- FRP cylindrical shell can be fabricated, in-place, to any reasonable size. Wrap is available in 4ft wide rolls
- Must have access to all sides of damaged structure.

### Application Procedure

- Determine the required diameter and height of the shell.
- Cut a strip of the wrap material to be the desired height, and about 7 times the desired diameter (to allow for a double wrap plus 8"(150 mm) overlap.
- Use a trowel to apply the special 2-part, paste, epoxy to the outer 60% length of the wrap, prior to installation. (note that a similar system using water activated epoxy bands is under development)
- Form the wrap into a cylindrical shell around the damaged structure as a double wrap plus about 8".
- Temporarily hold the cylinder's shape using nylon ratchet straps in at least two locations within its height. The cylinder may touch the damaged structure at the corners, but it is better if there is at least 1/2" clearance.
- Mix and place high-strength, non-shrink cementations grout. Pressure of the grout will tighten the wrap layers
- Depending on grout, cure time could be 4hrs or more.



### Installation Sequence:

1. Trowel on 2-part epoxy.
2. Initially place FRP cylindrical shell.
3. Adjust the shell so the 2 layers are in contact.
4. Place ratchet straps to temporarily hold the shell's shape.
5. Mix and pour the non-shrink grout, and use small vibrator or rod to consolidate.

### 5.3 Epoxy Concrete Repairs

Repair/Retrofit Method: Epoxy Injected Aggregate

Description:

Pre-placed aggregate is injected with low-viscosity in order to strengthen badly damaged, oddly shaped structural joints.

#### Applications

Create a form (using various materials) around the damaged concrete regions to encompass the repair area. Clean, pea-gravel aggregate is carefully placed in the form, and then injected (starting at the bottom) with low-viscosity epoxy. This method is most applicable for repairing badly damaged joints that are difficult to surround using cylindrical shells or jackets.

#### Considerations/Limitations

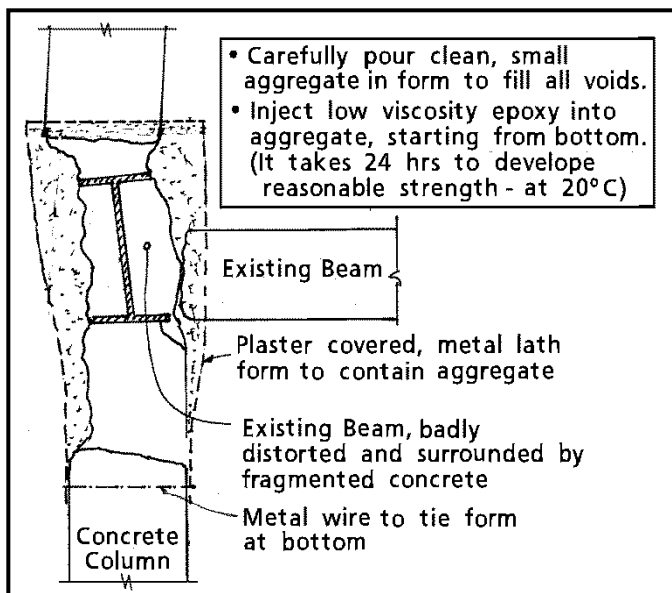
- Competent Professional Engineer is required for use.
- Manufacturer input is essential for application and use.
- Plaster covered metal lath has been used as a custom fit form. Plywood has also been used as a form.
- Aggregate must be clean and have uniform size in order to allow the epoxy to flow into the voids.
- The epoxy should be injected starting at the lowest point of the formed repair, and ports should be placed every 4" (100 mm) above so that epoxy can be seen to slowly rise within the aggregate. As the epoxy reaches each successive port the lower one should be closed, and then epoxy injected into the port at the current level of the epoxy.
- It is very important to use the proper, low-viscosity epoxy in order to avoid having the curing reaction generate too much heat (exothermic reaction). Consult epoxy manufacturer and knowledgeable, specialty contractor.
- Cure times for epoxy vary. Consult the Manufacturer.



**Before**

**After**

### Repair of Badly Damaged Column in Puerto Rico



## 5.4 Steel Jacket Column Repair

Repair/Retrofit Method: Concrete filled Steel Jacket

Description:

Jacket a damaged column with full height steel shell and fill with structural concrete for stability and/or strengthening.

Manufacturers:

Coordinated engineer, contractor & fabrication shop.

Applications

Primarily used for damaged columns. Applicable to any type of column (concrete, steel, etc).

Considerations/Limitations

- Competent Professional Engineer is required for use.
- Steel encasement is prefabricated in two half rounds and bolted and/or welded together. Bolting is preferred since less time is spent in danger area during erection.
- Steel encasement is 3/16" to 1/4" (4 to 6 mm) thick
- Encasement should clear damaged column by at least 3" (80 mm)



This photo shows a set of half-round steel encasements just prior to erection. Note that the steel encasement is stacked two high in this installation.





Damaged columns with completed encasement

## Steel Jacket Joint Repair

Repair/Retrofit Method: Grout Filled Steel Jacket

Description:

Jacket column joint with steel shell and fill with fast setting, high strength non-shrink grout for stability and/or strengthening.

Manufacturers:

Coordinated engineer, contractor & fabrication shop.

Applications

Primarily used for damaged column joints. Applicable to any type of column. Shown below for large concrete column joint retrofit. Steel encasement was prefabricated from four steel angles and four steel plates. It was prefabricated as two halves, then erected and welded at the two unconnected corners.

Considerations/Limitations

- Competent Professional Engineer is required for use.
- The space between the column and jacket should be kept small in order to minimize the thickness of the grout.
- The steel used for a square jacket needs to be in the range of 3/8" minimum thickness.
- For ease of fabrication the corners should be made using steel angles. (L3 x 3 x 5/16" minimum)
- Temporary forms will usually be needed that are placed on sound concrete below the jacket, in order to support it and keep the grout in place until it hardens.
- High strength, cementations, non-shrink grout should be used. It is available in bags, can be mixed in the field, and can attain strengths exceeding normal concrete in 12 to 24 hours (depending on outside temperature)
- The steel jacket may be heavy, with each side weighing 100 lbs (45 kg) or more. Therefore some sort of equipment may be require to lift it into place



This steel jacket was used to provide strengthening at several column joints at the bomb damaged Murrah Federal Office Building in Oklahoma City. It was placed where the concrete floor beam had been blown away from the concrete column, leaving a badly cracked, and unbraced joint.

## 5.5 Column Stability Repair

Repair/Retrofit Method: Column Length Bracing

Description:

Supporting columns and reducing the column length with bracing members.

Manufacturers:

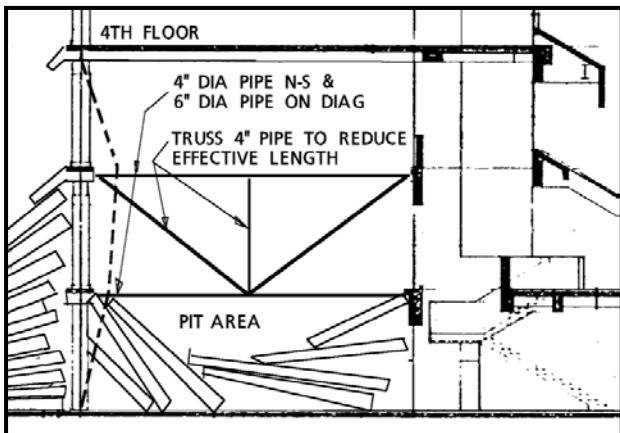
Coordinated engineer, contractor & fabrication shop.

Applications

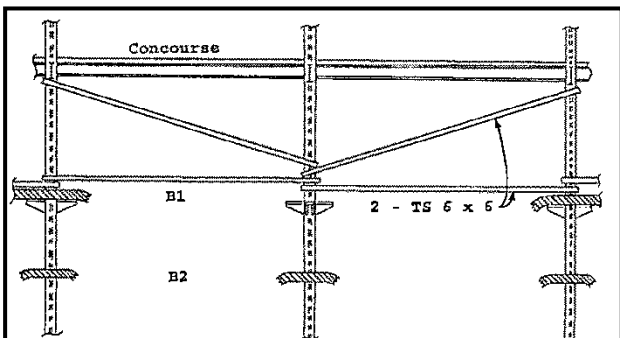
Primarily used for damaged columns that have become unsupported at floor levels. Applicable to any type of column. Additional bracing members attached to column in critical buckling directions. Steel pipes or tubes are commonly used for bracing members.

Considerations/Limitations

- Competent Professional Engineer is required for use.
- Bracing should be provided in the north-south as well as east-west direction at each level where the floors have been dislodged, if possible.
- Braces need to be of sufficient size to resist both compression and tension forces.
- Braces need to be positively connected at each end and the anchoring structure must be adequately strong and rigid.
- The minimum design force for the braces should be at least 2 percent of the total force in the damaged column. If the column is mis-aligned, the design force should be 5 percent minimum.



This cross-section at the Murrah Federal Office Building in Oklahoma City shows how a truss work of pipes was used to laterally brace Columns F22 and F20. The floors on all sides of these columns had collapsed up to the 4<sup>th</sup> FI, and they were in danger of collapsing as the debris was being removed to access the buried victims.



This schematic, partial cross-section of the World Trade Center Basement following the 1993 Truck Bombing shows the configuration of steel tube bracing that was used to brace the steel basement columns after the basement parking garage concrete floor slabs had collapsed, leaving the steel columns standing 70ft tall without lateral support.

## 5.6 Spray Applied Materials

Repair/Retrofit Method: Shotcrete/Gunite, Cementitious Spray-on Material

Description:

Spray on concrete type material that can stabilize or strengthen members, components and systems.

Manufacturers:

Local Contractors, especially those with swimming pool experience.

Applications

Damaged concrete regions are stabilized or strengthened with sprayed-on concrete type material (Gunite/Shotcrete, Air Blown Concrete). The affected area is encased with a concrete outer shell. Reinforcing steel or mesh may be placed first, in order to provide greater strength.

Considerations/Limitations

- Competent Professional Engineer is required for use.
- Application Contractor's input is essential to determine limitations and required logistics.
- The shotcrete requires at least 5 days to develop half of its strength, and 21 days to develop about 90% strength.
- The shotcrete should be cured by applying a moisture preserving seal-coat and/or keeping the surface damp.
- For greater reliability an above grade footing should be poured completely around the base of the wall, prior to applying the shotcrete.
- See facing page for use of shotcrete in New Zealand, March 2011



Wall Before  
Shotcrete



Wall After  
Shotcrete



Overall  
View of  
Repair  
Using  
Shotcrete

## 5.7 Steel Straps Used to Confine Concrete

Repair/Retrofit Method: Steel Strapping Tape

Description:

Confinement of damaged concrete members using Heavy Duty Steel Strapping

### Applications

Damaged concrete members can be confined by binding the damaged area with many layers/widths of steel strapping.

### Considerations/Limitations

- Easy to use and apply. Available locally.
- Confinement of damaged concrete members can be improved easily.
- Strapping may be applied around wood and/or plywood spreaders to better confine the concrete.
- Strapping is available in 1/2", 5/8", and 3/4" wide rolls (10 to 20 mm) in varying gauges.
- Proper installation requires tools to tighten, clamp the seal and cut the strap as shown below.







F-22 at the Murrah Federal Office Building at Oklahoma City, where the Third Floor used to be.

Steel strapping was used as a temporary measure prior to installing a grout filled steel jacket.

## 5.8 Protected Entry

Repair/Retrofit Method: Use rigid pipe/casing for access

Description:

Use rigid pipe or pile casing to provide access protected from falling hazards.

Manufacturers/Distributers:

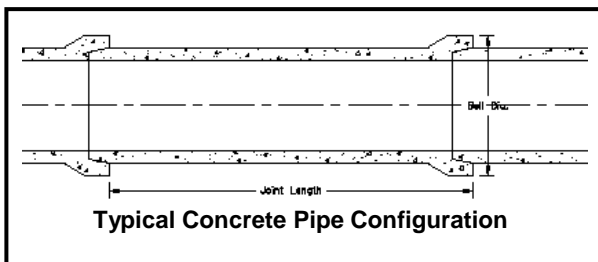
Local contractors.

Applications

Steel or concrete pipes, or steel pile casings can be pushed into a damaged building to provide protection from falling hazards originating from the exterior walls. Pipes may be pushed into the structure using heavy equipment such as; forklift, front end loader, or excavator.

Considerations/Limitations

- Easy to use, and is available locally.
- Steel pipes and casings should be available in 20ft (6m) lengths, that can be pushed together to form longer lengths.
- Steel pipe should be a minimum of 1/2" (13 mm) thick.
- Concrete pipes should be available in 10ft (3m) lengths and longer. They have tight fitting joints.
- Pipes should be 3ft (1m) or greater in diameter.
- Rescuers may need to enter the pipe to remove collected debris, in order to get it into place.



## 5.9 Protective Barriers

Repair/Retrofit Method: Use Rigid Containers & Boxes as Barriers.

Description:

Use shipping containers and/or rigid boxes as protective barriers.

### Applications

Use shipping containers, dumpsters, and/or concrete vaults as barriers adjacent to hazardous buildings and vulnerable rock faces.

### Considerations/Limitations

- Easy to use, and available locally.
- Shipping containers are available in 10ft, 20ft, 30ft and 40ft lengths.
- Steel debris boxes (dumpsters) may also be used, and are available in 20, 30, and 40 cubic foot sizes.
- These rigid containers can be ballasted with heavy objects, such as water bladders, sand bags, and steel scrap, in order to add sliding and overturning resistance.
- Containers may be stacked up to 3-high, but should be connected together using chains of high strength straps.
- Containers may be placed 2-wide to improve resistance.

## 6 Appendix A: Engineering Tables

This section contains Information and Engineering Tables that may be useful during US&R operations. The information is taken from the FEMA US&R FOG Section 7. The following contents are contained in this Appendix:

<u>Contents</u>	<u>Page</u>
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Structural Steel Tubing Dimensions and Properties	A-4
Structural Steel Pipe Dimensions and Properties	A-5
Steel Bolting Design Strengths	A-6
Wire Nail Design Strengths of US&R	A-7
Rigging – Design/Working Load	A-8
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Wire Rope Slings Capacities	A-9,10
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1-800-777-1555

[www.thecrosbygroup.com](http://www.thecrosbygroup.com)

## 6.1 Wind Pressures on Buildings, psf

Height Feet	Wind Speed in Miles per Hour									
	10	20	30	40	50	60	70	80	90	100
15	5.0	5.0	5.0	5.0	5.2	7.4	10	13	17	21
20	5.0	5.0	5.0	5.0	5.6	8.0	11	14	18	22
25	5.0	5.0	5.0	5.0	6.0	8.6	12	15	19	24
30	5.0	5.0	5.0	5.0	6.3	9.1	12	16	20	25
40	5.0	5.0	5.0	5.0	7.0	10	14	18	23	28
60	5.0	5.0	5.0	5.1	7.9	11	15	20	26	32
80	5.0	5.0	5.0	5.5	8.7	12	17	22	28	35
100	5.0	5.0	5.0	6.0	9.4	13	18	24	30	38
120	5.0	5.0	5.0	6.4	10	14	20	26	32	40
160	5.0	5.0	5.0	7.0	11	16	21	28	35	44
200	5.0	5.0	5.0	7.6	12	17	23	30	38	47
300	5.0	5.0	5.0	8.7	14	20	27	35	44	54
400	5.0	5.0	5.4	9.6	15	22	29	38	49	60

### Notes:

1. Ref. wind speed measured at height of 30 feet above grade.
12. Basic stagnation pressure,  $P = 0.00256V^2$ , where V is in mph & P is in psf. (10psf recommended for design in most situations, but may use 5psf if anticipated conditions warrant)
13. Pressure coefficient based on exposure B for urban environment.
14. Pressures include gust factor & shape coefficient of 1.3.
15. Pressure acting on net area normal to wind.
16. For open frame towers built with members angular cross-section multiply table values by 3 and apply to total normal projected area of all elements on one face .
17. For open frame towers built with members of circular cross-section multiply table values by 2 and apply to total normal projected area of all elements on one face.

Reference 1997 UBC Chapter 16, Division III and ASCE

## 6.2 Weights for Common Materials

Normal Reinforced Concrete = 150 pcf

Heavily Reinf. Conc Beams & Cols = 160 to 180 pcf

Struct. Steel = 490 pcf

Aluminum = 165 pcf

Masonry and Cement Plaster = 125 pcf

Dry Wood = 35 pcf

Wet Wood = 45 to 60 pcf

Wood Joist@16" o.c. = 3 psf

3/4" Wood Flooring = 2.5 psf

5/8" Gypsum Board = 2.5 psf

Frame wall with 1/2" Gyp ea. Side = 7 psf

Frame wall with 5/8" Gyp ea. Side = 8 psf

8" PC Hollow Plank = 60 psf

8" Hollow Conc Masonry = 40 psf

Concrete Masonry Rubble = 10 psf per inch of thkns

Interior wood & metal stud walls = 10 to 15 psf per floor

Normal home or office furniture = 10 psf (storage more)

Wood Floors weigh 10 psf to 25 psf (25 with 1.5" conc fill)

Steel Floors with metal deck & conc fill weigh 50 to 70 psf


Concrete Floors weigh from 80 to 150 psf

### Rescue Personnel

Add 10 to 15 psf for Rescuers (4-250lb in 100 sq ft = 10 psf)

Also need to account for heavy equipment

## 6.3 Structural Tubing AISC Table

STRUCTURAL TUBING						
Dimensions and properties					Square	
Dimensions			Properties			
Nominal Size	Wall Thickness		Area	<i>I</i>	<i>S</i>	<i>r</i>
In.	In.		In. <sup>2</sup>	In. <sup>4</sup>	In. <sup>3</sup>	In.
8×8	0.6250	5/16	17.4	153	38.3	2.96
	0.5625	3/8	15.9	143	35.7	3.00
	0.5000	1/2	14.4	131	32.9	3.03
	0.3750	3/8	11.1	106	26.4	3.09
	0.3125	5/16	9.36	90.9	22.7	3.12
	0.2500	1/4	7.59	75.1	18.8	3.15
	0.1875	3/16	5.77	58.2	14.6	3.18
6×6	0.5625	5/16	11.4	54.1	18.0	2.18
	0.5000	1/2	10.4	50.5	16.8	2.21
	0.3750	3/8	8.08	41.6	13.9	2.27
	0.3125	5/16	6.86	36.3	12.1	2.30
	0.2500	1/4	5.59	30.3	10.1	2.33
	0.1875	3/16	4.27	23.8	7.93	2.36
5×5	0.5000	1/2	8.36	27.0	10.8	1.80
	0.3750	3/8	6.58	22.8	9.11	1.86
	0.3125	5/16	5.61	20.1	8.02	1.89
	0.2500	1/4	4.59	16.9	6.78	1.92
	0.1875	3/16	3.52	13.4	5.36	1.95
4×4	0.5000	1/2	6.36	12.3	6.13	1.39
	0.3750	3/8	5.08	10.7	5.35	1.45
	0.3125	5/16	4.36	9.58	4.79	1.48
	0.2500	1/4	3.59	8.22	4.11	1.51
	0.1875	3/16	2.77	6.59	3.30	1.54
3.5×3.5	0.3125	5/16	3.73	6.09	3.48	1.28
	0.2500	1/4	3.09	5.29	3.02	1.31
	0.1875	3/16	2.39	4.29	2.45	1.34
3×3	0.3125	5/16	3.11	3.58	2.39	1.07
	0.2500	1/4	2.59	3.16	2.10	1.10
	0.1875	3/16	2.02	2.60	1.73	1.13
2×2	0.2500	1/4	1.59	0.766	0.766	0.694
	0.1875	3/16	1.27	0.668	0.668	0.726

## 6.4 Steel Pipe AISC Tables

PIPE Dimensions and properties							
Dimensions			Weight per Ft Lbs. Plain Ends	Properties			
Nominal Diameter In.	Outside Diameter In.	Inside Diameter In.		A In. <sup>2</sup>	I In. <sup>4</sup>	S In. <sup>3</sup>	r In.
Standard Weight				Schedule 40			
1	1.315	1.049	1.68	.494	.087	.133	.421
1¼	1.660	1.380	2.27	.669	.195	.235	.540
1½	1.900	1.610	2.72	.799	.310	.326	.623
2	2.375	2.067	3.65	1.07	.666	.561	.787
2½	2.875	2.469	5.79	1.70	1.53	1.06	.947
3	3.500	3.068	7.58	2.23	3.02	1.72	1.16
3½	4.000	3.548	9.11	2.68	4.79	2.39	1.34
4	4.500	4.026	10.79	3.17	7.23	3.21	1.51
5	5.563	5.047	14.62	4.30	15.2	5.45	1.88
6	6.625	6.065	18.97	5.58	28.1	8.50	2.25
8	8.625	7.981	28.55	8.40	72.5	16.8	2.94
10	10.750	10.020	40.48	11.9	161	29.9	3.67
12	12.750	12.000	49.56	14.6	279	43.8	4.38
Extra Strong				Schedule 80			
2	2.375	1.939	5.02	1.48	.868	.731	.766
2½	2.875	2.323	7.66	2.25	1.92	1.34	.924
3	3.500	2.900	10.25	3.02	3.89	2.23	1.14
3½	4.000	3.364	12.50	3.68	6.28	3.14	1.31
4	4.500	3.826	14.98	4.41	9.61	4.27	1.48
5	5.563	4.813	20.78	6.11	20.7	7.43	1.84
6	6.625	5.761	28.57	8.40	40.5	12.2	2.19
8	8.625	7.625	43.39	12.8	106	24.5	2.88
10	10.750	9.750	54.74	16.1	212	39.4	3.63
12	12.750	11.750	65.42	19.2	362	56.7	4.33
Double-Extra Strong							
2	2.375	1.503	9.03	2.66	1.31	1.10	.703
2½	2.875	1.771	13.69	4.03	2.87	2.00	.844
3	3.500	2.300	18.58	5.47	5.99	3.42	1.05
4	4.500	3.152	27.54	8.10	15.3	6.79	1.37
5	5.563	4.063	38.55	11.3	33.6	12.1	1.72
6	6.625	4.897	53.16	15.6	66.3	20.0	2.06
8	8.625	6.875	72.42	21.3	162	37.6	2.76



## BOLTS IN AISC STEEL

## Shear • Allowable load in kips

ASTM Designation	Connection Type	Hole Type	$F_v$ ksi	Loading	Nominal Diameter $d$ , in.						
					5/8	3/4	7/8	1	1 1/8	1 1/4	
					Area (Based on Nominal Diameter) in. <sup>2</sup>						
					.3068	.4418	.6013	.7854	.9940	1.227	
Bolts	A307	—	STD NSL	10.0	S	3.1	4.4	6.0	7.9	9.9	12.3
						D	6.1	8.8	12.0	15.7	19.9
	A325	SC Class A	STD	17.0	S	5.22	7.51	10.2	13.4	16.9	20.9
						D	10.4	15.0	20.4	26.7	33.8
			OVS, SSL	15.0	S	4.60	6.63	9.02	11.8	14.9	18.4
						D	9.20	13.3	18.0	23.6	29.8
		LSL	12.0	S	3.68	5.30	7.22	9.42	11.9	14.7	
					D	7.36	10.6	14.4	18.8	23.9	29.4
		N	STD, NSL	21.0	S	6.4	9.3	12.6	16.5	20.9	25.8
						D	12.9	18.6	25.3	33.0	41.7
		X	STD, NSL	30.0	S	9.2	13.3	18.0	23.6	29.8	36.8
						D	18.4	26.5	36.1	47.1	59.6

Allowable loads in kips  
Tension on gross (nominal) area

ASTM Designation	$F_t$ Ksi	Nominal Diameter $d$ , in.					
		5/8	3/4	7/8	1	1 1/8	1 1/4
		Area (Based on Nominal Diameter), in. <sup>2</sup>					
		0.3068	0.4418	0.6013	0.7854	0.9940	1.227
A307 bolts	20.0	6.1	8.8	12.0	15.7	19.9	24.5
A325 bolts	44.0	13.5	19.4	26.5	34.6	43.7	54.0
A490 bolts	54.0	16.6	23.9	32.5	42.4	53.7	66.3
A502-1 rivets	23.0	7.1	10.2	13.8	18.1	22.9	28.2

## 6.6 Working Load Values for Nails

Wire Nails - Doug. Fir & So. Pine (see 7-3, other species reduction)

(Values include 60% increase for emergency shoring)

Nail Size	Nail Length	Nail Diameter	Shear Value (in pounds)
8d	2 ½"	0.131	140
10d	3"	0.148	190
16d Cooler	3 ¼"	0.148	190
16d	3 ½"	0.162	225

Min. Penetration & Spacing is ½ of the Nail Length

1. The 60% increase is justified for the Raker Cleat nailing, due to the transient nature of their maximum loading.
2. Nailing should not be used to transfer direct loads in any other type of emergency shoring.

## 6.7 Rigging –Design/Working Loads

Given in terms of Diameter<sup>2</sup>

ITEM	Safe Working Load in Tons
Wire Rope (S.F.=5 )	$D^2 \times 9$ Tons
Wire Rope Slings	$D^2 \times 8.5$ Tons
Shackles (Alloy)	$D^2 \times 12.5$ Ton
Shackles (carbon)	$D^2 \times 8.5$ Tons
Chain Slings ( I. D. as Type A)	$D^2 \times 24$ Tons
Turnbuckles	$D^2 \times 5$ Tons

(Improved Plow, IWRC Wire Rope)

## 6.8 General Sling Information

### Center of Gravity

The center of gravity of an object is that point at which the entire weight may be considered as concentrated. In order to make a level lift, the crane hook must be directly above this point. While slight variations are usually permissible, if the crane hook is too far to one side of the center of gravity, dangerous tilting and/or swinging will result and should be corrected at once. For this reason, when the center of gravity is closer to one point of the sling attachment than to the other, the slings must be of unequal length. The sling stresses and sling angle will also be unequal.

### Working Load Limit or Design Load

The working load limit or design load is the useful rated capacity of a sling. This varies, depending upon the type of hitch. The working load limit table indicates, by illustration the applications for which the various useful loads apply, when the slings are new. All ratings are in tons or 2,000 pounds.

### Safety Factor

In general, a safety factor of approximately five is maintained throughout these tables. However, certain sling fittings, such as hooks, which will straighten without breaking, or links, which will deform beyond usefulness before breaking, cannot be assigned a definite numerical safety factor. In such cases, suitable safe loads are listed, based upon wide experience and sound engineering practice.

### Sling Care

Proper care and usage are essential for maximum service and safety. Wire rope and especially synthetic slings should be protected from sharp bends and cutting edges by means of corner saddles, burlap padding, or wood blocking. Heavy or continuous over-loading should be avoided as well as sudden jerks, which can build up a momentary over-load sufficient to break the sling. Wire rope slings should be stored where they are protected from moisture, and properly coiled when not in use.

## 6.9 Wire Rope Sling Capacities – Flemish Eye

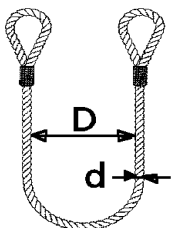
Working Capacity in Lbs (S.F. = 5) – 6 x 19 Imp. Plow

Rope Dia. Inch						
1/4	1120	800	2200	1940	1500	1120
5/16	1740	1280	3400	3000	2400	1740
3/8	2400	1840	4800	4200	3400	2400
7/16	3400	2400	6800	5800	4800	3400
1/2	4400	3200	8800	7600	6200	4400
9/16	5600	4000	11200	9600	7900	5600
5/8	6800	5000	13600	11800	9600	6800
3/4	9800	7200	19600	16900	13800	9800
7/8	13200	9600	26400	22800	18600	13200
1	17000	12600	34000	30000	24000	17000
1 1/8	20000	15800	40000	34600	28300	20000
1 1/4	26000	19400	52000	45000	36700	26000
1 3/8	30000	24000	60000	52000	42400	30000

A Basket Hitch has Twice the Capacity of a Single Leg only  
If the D/d Ratio is 25/1 and the Legs are Vertical

In order for ANY of the above Sling

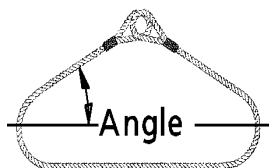
Capacities to be correct, the Size of  
any SHACKLE used Must be One Size  
GREATER or LARGER



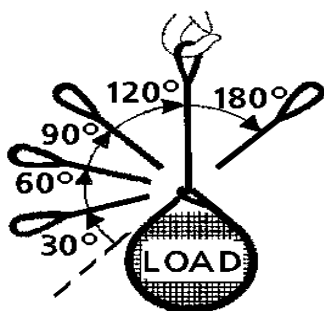
## 6.10 Wire Rope, Chain & Synthetic Sling Capacities

### Wire Rope, Chain & Synthetic Basket Slings

Sling Angle	Capacity as Percent of Single Vertical Hitch
90	200%
60	170%
45	141%
30	100%



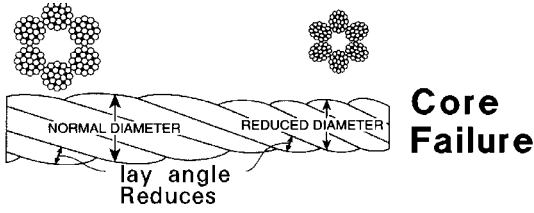
### Choker Hitches – Reduction Due to Angle



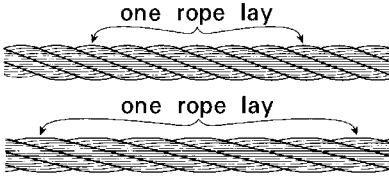
#### CHOKE ANGLE      CAPACITY

120° - 180°	75% of Vertical
90° - 109°	65% of Vertical
80° - 89°	55% of Vertical
30° - 59°	40% of Vertical

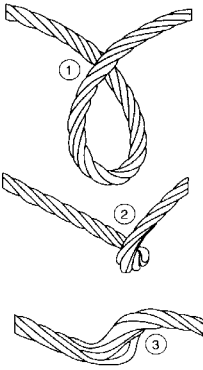
### 6.11 Wire Rope Discard Conditions



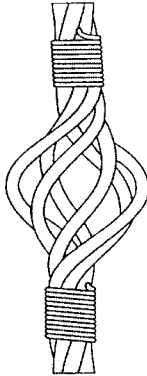
**Core Failure**



**Rope Stretch**



**Kinks**



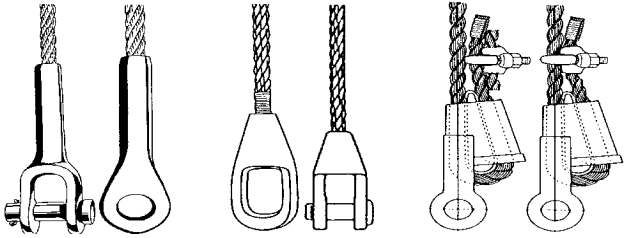
**Bird Cage**



**Core Protrude**

## 6.12 Wire Rope Socket Terminations

- Swaged & Spelter Sockets are used on standing ropes and permanent ropes like pendants
- Wedge Sockets are used to attach Crane Whip Line to the Headache Ball, etc.
- Do not attach dead end to live with wire rope clip



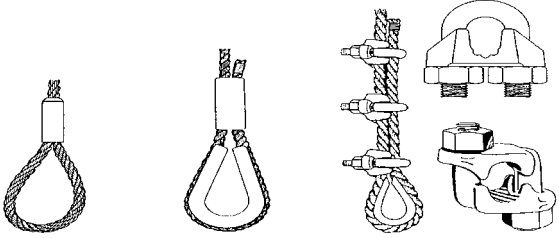
**Swaged Socket**  
(100%)

**Spelter Socket**  
(100%)

**O.K. NO**  
**Wedge Socket**  
(75 to 90%)

## Wire Rope Loop Terminations

- Without thimble, eye efficiency may be reduced as much as 10%
- Wire Rope Clips must be properly installed



**Flemish Eye**  
**Eye**  
(95-100%)

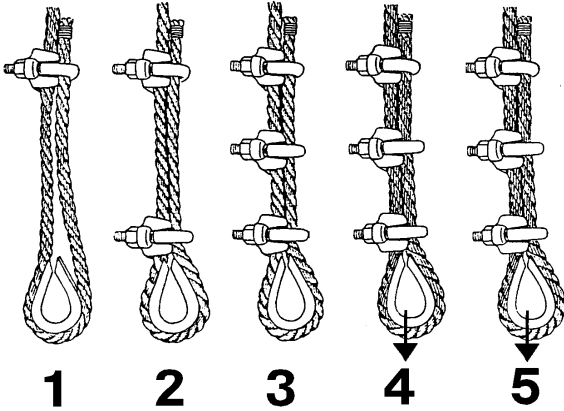
**Fold Back**  
**Eye**  
(Don't use for lifting)

**Wire Rope Clips**  
**U bolt & Fist Grip**  
(80%)



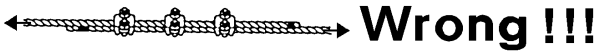
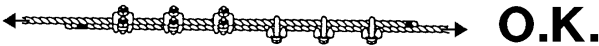
### 6.13 Wire Rope Clip Installation

1. Turnback, place 1st clip & torque/tighten
2. Place 2nd clip only snug, no torque
3. Place other clips at equal spacing
4. Apply some tension and torque/tighten
5. Recheck torque after initial operations



### WIRE ROPE CLIP SPLICES

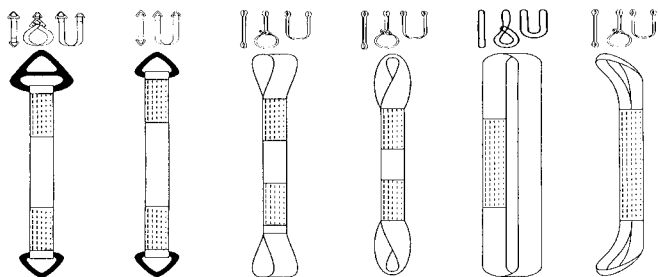
1. Use two loop ends with thimble eye
18. Overlap rope, use twice number clips required for 1 loop
19. Clips must be properly installed



## 6.14 Synthetic Sling Information

Must include manufacturer's sewn on Tag (Gives Fiber Type & Safe Working Load)

- Provided with seamless protective cover
- Use corner protection
- Need careful Inspection
- Slings stretch as much as 10%, Polyethylene 1%



Triangle Choker

Double Triangle

Dbl Eye

Rev Eye

Endless Loop

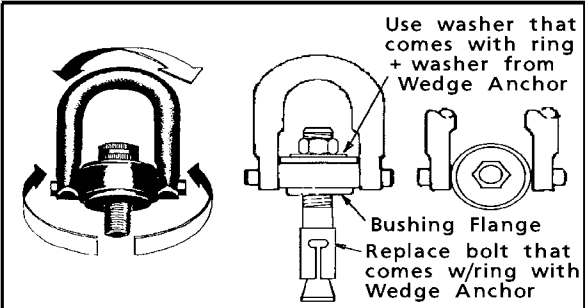
Return Eye

### Endless Round Sling Capacities

Working Capacity (Working Load Limit), in pounds

COLOR	Wt #/ft	Vertical	Choker	Basket
Purple	0.2	2,650 lb	2,120	5,300
Black	0.25	4,000	3,200	8,000
Green	0.3	5,300	4,240	10,600
Yellow	0.4	8,400	6,720	16,800
Tan	0.55	10,600	8,500	21,200
Red	0.6	13,200	10,560	26,400
White	0.9	16,800	13,400	33,600
Blue	1.0	21,200	17,000	42,400
Grey	2.15	31,000	24,800	62,000

## 6.15 Hoist Ring Capacities



### Allowable Tension & Shear Loads

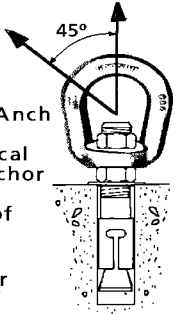
Expansion Bolt Dia.	Working Load of Ring (lbs)	Working Load of Anchor (lbs)	Required Torque (ft-lbs)
3/8	1000	1200	25
1/2	2500	2000	50
5/8	4000	2700	100
3/4	5000	3700	225

## CAST STEEL HOIST RINGS

### EYE NUTS

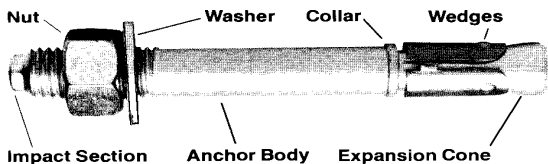
Forged, Quenched & Tempered

- Place over installed Wedge Anchor
- Safe Working Load for Vertical Tension Load is Same as Anchor
- Working load at 45° is 25% of Vertical Tension Load
- Recommended for Vertical or nearly vertical loading ONLY



## 6.16 Wedge Anchor Capacities

# WEDGE ANCHORS



*Kwik-bolt, Wedge-all or Trubolt*

### Allowable Tensile Loads (lbs)

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

### Allowable Shear Loads (lbs)

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

## 6.17 Concrete Screw Information

### Information on 1/4" SCREWS

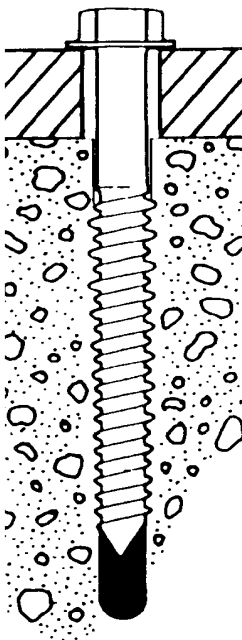
(by Hilti, Simpson or ITW Buildex)

- Use to connect devices (WBMS & Smartlevel)
- Hammer Drill hole, 5/32" bit
- Drive with Driver Drill & 1/4" Hex Socket
- Use 1/4" x 1 1/4" screw with 1" min embed
- Design Load/Allowable Load = 175 lb Ten. & 350 lb Shear

### Information on 3/8" SCREWS

(by Simpson StrongTie)

- As alternative to wedge anchor for lifting concrete
- Drill 5" deep hole w/ 3/8" bit
- Drive w/Socket or Impact Wrench & 9/16" Socket
- Use 3/8" x 6" TITAN Screw with 4 1/2" min. embed.
- Design Load/Allowable Load = 2000 lb Tension & Shear
- Use with Swivel Hoist Ring or Steel Tee (WT 3x7.5 x 0' - 4")



## 6.18 Anchors – Epoxy & Acrylic Adhesives Capacities

Allowable Loads – Threaded Rod – 2000psi Conc  
Allowable Tensile Loads – (Lbs) Dimensions in inches

Stud Dia. Inch	Drill Bit Dia	Min Embed Depth	Spacing	Edge Dist.	Ave Ult Lbs	Allow Load Lbs
3/8	1/2	3 1/2	6	5	8800	2100
1/2	5/8	4 1/4	7 1/2	6	15,700	3750
5/8	3/4	5	9 1/2	7 1/2	23,000	5720
3/4	7/8	6 3/4	12	10	35,600	8460
7/8	1	7 3/4	13 1/2	11 1/2	42,800	10,900
1"	1 1/8	9	15 3/4	13 1/2	50,500	13,800

Allowable Shear Loads (Lbs)

Stud Dia. Inch	Drill Bit Dia	Min Embed Depth	Edge Dist.	Ave Ult Lbs	Allow Load Lbs	Allow A307 Steel
3/8	1/2	3 1/2	5	5500	1380	1085
1/2	5/8	4 1/4	6	10,000	2500	1930
5/8	3/4	5	7 1/2	15,600	3900	3025
3/4	7/8	6 3/4	10	20,300	5000	4360
7/8	1	7 3/4	11 1/2	30,800	7700	5925
1"	1 1/8	9	13 1/2	33,500	8400	7740

Allowable Loads – A615 Gr 60 Rebar – 2000psi Conc  
Allowable Tensile / Shear Loads (Lbs) Dimension in inches

Bar Size No.	Drill Bit Dia	Min Embed Depth	Spa-cing	Edge Dist.	Allow Ten. Load	Allow Shear Load
#4	5/8	4 1/4	7 1/2	6	3185	2750
#5	3/4	5	10	7 1/2	5100	3940
#6	7/8	6 3/4	12	10	7960	5830
#8	1 1/8	9	15 1/2	13 1/2	12500	8360

**Note: All construction adhesives have a useful shelf - life of about one year.**

## 6.19 Hurst Airshore Rescue Strut Capacities

- Adjustable aluminum, pneumatic struts. **USE 50psi MAXIMUM AIR TO EXTEND STRUTS FOR US&R**
- **Struts are available in various ranges of length.** See Manufacturers Data for available lengths.
- Use adjustable collar and double pin system to transfer load from inner to outer tube.
- Listed loads are for use of 3 ½" O.D. struts with **SWIVEL ENDS and WITH or WITHOUT ONE 6ft, or 4ft EXTENSION placed on large (3 ½") end.**
- Adequacy of supporting material under strut, and need for header and sole should be verified by a competent Professional Engineer.

### Recommended Design Strength Hurst Airshore Strute for US&R

Length Feet	Recommended Load lbs (kg)	Comment
16 ft	3500lbs (1600 kg)	Use strut plus extension
15	4500 (2000)	or single adjustable strut
14	5500 (2500)	"
13	6500 (3000)	"
12	7500 (3400)	"
11	10,000 (4500)	"
10	12,000 (5400)	Do not use extensions
9	14,000 (6400)	"
8	15,000 (6800)	"
7	18,000 (8200)	"
6 ft & less	20,000 (9100 kg)	Max. Recommended Load for Airshore Strut

## 6.20 Hurst Airshore Raker System Capacities

- System is made from 2 rakers spaced 8ft max. apart with X bracing.
- **Use adjustable struts With or Without one 4ft or 6ft extension per strut, placed on large end**
- Raker Systems should be configured with the angle between the Raker and the Ground being between 40 and 60 degrees
- Add 12" long, 4" high, ½" thick angles to Base Plates to provide a vertical bearing surface.
- Rakers should be attached to the wall surface and restrained at the ground as in timber rakers.
- The Safe Working Strength for a pair of Hurst Airshore Rakers used in US&R should be determined by a US&R Structure Specialist from the following chart:

(Safe Horizontal load at Point of Insertion)

Note that if a mid-brace is added and Double X Lateral Bracing is used the Design Strength may be increased to 10,000lb for a pair of rakers, provided the base plate and wall plate are properly anchored – consult engineer

### Recommended Design Strength

#### Hurst Airshore Raker System at 45deg.

Raker Length	Height to Point of Insertion	Horizontal Load on 2 Rakers w/ X-bracing
16 ft	11.0 ft	5000 lbs (2300 kg)
15 ft	10.5 ft	6400 lbs (2900 kg)
14 ft	10.0 ft	7800 lbs (3500 kg)
13 ft	9.0 ft	9200 lbs (4200 kg)
12 ft	8.5 ft	10,600lbs (4800 kg)

#### HURST AIRSHORE RAKER SYSTEM at 60deg.

16 ft	13.8 ft	3500 lbs (1600 kg)
15 ft	13.0 ft	4500 lbs (2000 kg)
14 ft	12.0 ft	5500 lbs (2500 kg)
13 ft	11.3 ft	6500 lbs (3000kg)
12 ft	10.4 ft	7500 lbs (3400 kg)
11 ft	9.5 ft	10,000 lbs (4500 kg)



## 6.21 Paratech Long Shore Strut Capacities

### (GOLD ANODIZED COLOR)

- Adjustable aluminum, pneumatic struts. Use Acme Nut to transfer load from inner to outer tube.
- Struts are available in three ranges of length. (10ft to 16ft, 8 ft to 12ft and 6 ft to 10ft long)
- Listed loads are for use of 3 ½" O.D. struts with **SWIVEL ENDS and WITH or WITHOUT ONE 6ft, 4ft or 2ft EXTENSION.**
- Listed loads are **NOT** for **Paratech 3" O.D. LOCK STRUT & ACME THREAD, RESCUE STRUT.** See 2<sup>nd</sup> page following for Paratech Rescue Struts.
- Adequacy of supporting material under strut, and need for header and sole should be verified by a competent Professional Engineer.

### Recommended Design Strength

#### Paratech Long Shore Struts for US&R

Length Feet	Recommended Load lbs (kg)	Comment
16 ft	3500lbs (1600)	Use strut plus extension
15	4500 (2000)	or single adjustable strut
14	5500 (2500)	"
13	6500 (3000)	"
12	7500 (3400)	"
11	10,000 (4500)	"
10	12,000 (5400)	Do not use extensions
9	16,000 (7200)	"
8	20,000 (9100)	"
7 & 6 ft	22,000 (10,000)	"

## 6.22 Paratech Long Shore Strut Raker Capacities

- System is made from 2 rakers spaced 8ft max. apart with X bracing. See **Section 3**.
- **Use 6 to 10 ft or 8 to 12 ft struts With or Without one 2ft, 4ft, or 6ft extension per strut.**
- Raker Systems should be configured with the angle between the Raker and the Ground being between 40 and 60 degrees.
- Add 12" long, 4" high, ½" thick angles to Base Plates to provide a vertical bearing surface.
- Rakers should be attached to the wall surface and restrained at the ground as in timber systems.
- The Safe Working Strength for a pair of Paratech Rakers used in US&R should be determined by a US&R Structure Specialist from the following chart:

(Safe Horizontal load at Point of Insertion)

Note that if a mid-brace is added and Double X Lateral Bracing is used the Design Strength may be increased to 10,000lb for a pair of rakers, provided the base plate and wall plate are properly anchored – consult engineer

### Recommended Design Strength

#### Paratech Raker System at 45deg

Raker Length	Height to Point of Insertion	Horizontal Load on 2 Rakers w/ X-bracing
16 ft	11.0 ft	5000 lbs (2300 kg)
15 ft	10.5 ft	6400 lbs (2900 kg)
14 ft	10.0 ft	7800 lbs (3500 kg)
13 ft	9.0 ft	9200 lbs (4200 kg)
12 ft	8.5 ft	10,600lbs (4800 kg)

#### PARATECH RAKER SYSTEM at 60degrees

16 ft	13.8 ft	3500 lbs (1600 kg)
15 ft	13.0 ft	4500 lbs (2000 kg)
14 ft	12.0 ft	5500 lbs (2500 kg)
13 ft	11.3 ft	6500 lbs (3000 kg)
12 ft	10.4 ft	7500 lbs (3400 kg)
11 ft	9.5 ft	10,000 lbs (4500 kg)

## 6.23 Paratech Rescue Strut Capacities

### (DARK GREY ANODIZED COLOR)

- Adjustable aluminum, pneumatic struts. Use Acme Nut to transfer load from inner to outer tub
- Struts are available in 1.5 to 2ft, 2ft to 3ft, 3ft to 5ft, & 5ft to 7.2ft ranges of length. (12", 24" & 36" extensions are also available)
- Listed loads are based on **3" O.D.** struts, tested with swivel ends, with and without one extension.
- Adequacy of supporting material under strut, and need for header and sole should be verified by a competent Professional Engineer.
- **The following Load Table is based on tests performed by PARATECH and reviewed by Wiss, Janney, Elstner, Assoc., Engineers**

### Paratech Rescue Struts Load Table

(Based on compression tests using swivel bases )

Length Feet	Average Failure Strut Force (Ultimate strength)	Design Strength based on the following Safety Factors	
		3 to 1	4 to 1
2 ft	87,000 lbs	29,000 lbs	21,750 lbs
4 ft	71,750 lbs	23,920 lbs	17,940 lbs
6 ft	56,500 lbs	18,830 lbs	14,125 lbs
8 ft	48,100 lbs	16,030 lbs	12,025 lbs

End



