



STUDENT MANUAL MODULE 2a SHORING BASICS

MODULE PURPOSE

The purpose of this unit is to explain **WHY** we build shoring in the **FEMA Response System** in the way that we do. In **SHORING CONSTRUCTION, Module 2b**, the student will be informed as to **HOW** each type of shore is constructed. Then all will be given a chance to become proficient at building them.

TERMINAL OBJECTIVES & BASIC DEFINITION:

The student will understand the function and capacity of the shoring used in US&R to support damaged structures.

The student should also understand why the shores are constructed in the configurations that are shown.


Shoring for US&R is the temporary support of only that part of the structure that is required for conducting operations at reduced risk

KEY LEARNING POINTS

At the conclusion of this module the student should be able to answer the following:

- What is Size and Type of Load that needs to be supported?
 - The weight of the supporting structure plus its overload, or just its overload
 - Broken Structure or Rigid Structure
- How much Shoring do you need?
 - Should Shoring be similar to a Life Jacket? – Providing just enough lift to keep one afloat
 - Some portion of the load can be (is being) carried by the un-shored structure
- What is the Capacity for the various types of US&R Shoring Systems?
- How to configure US&R Shoring to ensure a predictable & slow Failure Mode
- How to sequence the construction of US&R shoring in order to Minimize Risk
 - What are initial, short-term systems
 - What are more long-term systems
 - What are Class 1, 2, & 3 Systems
 - What is sequence in Multi-Story Shoring?
- How and When to Inspect US&R Shoring

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Terminal Objectives


- The Student shall understand the function & capacity of the Shoring used in US&R to support damaged structures
- The Student should also understand why and how these Shores are constructed

Basic Definition

Shoring for US&R is the **TEMPORARY Support of Only That Part of a Damaged Structure that is REQUIRED for Conducting Operations at REDUCED RISK**

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Key Learning Points

- What is Size and Type of Load that needs to be supported?
 - The weight of the supporting structure plus its overload, or just its overload
 - Broken Structure or Rigid Structure
- How much Shoring do you need?
 - Should Shoring be similar to a Life Jacket? – Providing just enough lift to keep one afloat
 - Some portion of the load can be (is being) carried by the un-shored structure

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Key Learning Points (continued)

- What is the Capacity for the various types of US&R Shoring Systems?
- How to configure US&R Shoring to ensure a predictable & slow Failure Mode
- How to sequence the construction of US&R shoring in order to Minimize Risk
 - What are initial, short-term systems
 - What are more long-term systems
 - What are Class 1, 2, & 3 Systems
 - What is sequence in Multi-Story Shoring?
- How and When to Inspect US&R Shoring

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INTRODUCTION

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

As stated above, the **Basic Definition**, shoring for US&R is the temporary support of only that part of the structure that is required for conducting operations at reduced risk

A Shoring system is like double funnel. It needs to collect the load with headers/sheathing, deliver it into the post/struts, and then to distribute it safely into the supporting structure below.

Shoring should be built as a system with the following:

- Header beam, wall plate, 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 system from racking (becoming parallelogram), and prevent system from buckling.
- Built-in forgiveness (will give warning before failure)

Minimum level of lateral strength in any vertical support system should be at least 2% of vertical load, but more is desirable where aftershocks are expected. The Structure Specialist should be consulted regarding extra lateral support

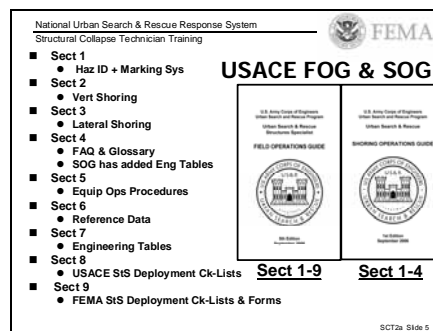
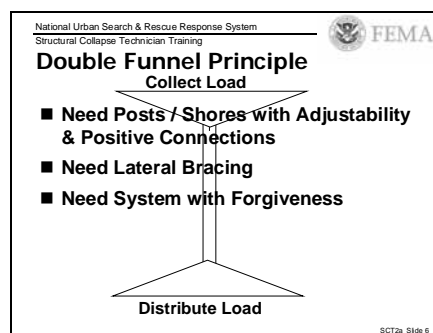
Trench Shores provide opposing lateral support - to keep trench/hole etc. from filling in. Design is normally based on Type C Soils. Manufacturers provide design aids that specify size and spacing of struts plus sheathing members

US Army Corps of Engineers StS FOG & US&R SOG

Sections 2 and 3 of the USACE StS FOG and US&R SOG contain graphics, information and procedures for constructing the FEMA Shores that are discussed in this Module & Module 2b.

Section 2 contains vertical shoring and Section 3 contains lateral shoring. They have both graphics and step by step procedures for assembly

The student should become familiar with these documents, since they provide a very useful "Pocket Guide" for constructing shores.





CONSIDERATIONS for DESIGN

WEIGHTS OF COMMON BUILDING MATERIALS.

- Concrete = 150 PCF PCF = lbs per cubic ft
- Masonry = 125 PCF PSF = lbs per square ft
- Wood = 35 PCF psi = lbs per square inch
- Steel = 490 PCF
- Conc/Masonry Rubble=10PSF Per Inch (of thickness)
- **NOTE that heavily reinforced concrete Beams & Columns can weigh more than 150 PCF (up to 200 PCF and more)**
- Another way to quickly calculate the weights of concrete and steel members is to use a known weight per square foot of a unit thickness. (12" for concrete and 1" for steel)
 - A 12" concrete slab or wall weighs 150psf
 - Therefore as adjacent slide shows: 10" = 125psf, 8" = 100psf, 6" = 75psf, 4" = 50psf and so on
 - A 1" thick steel plate weighs 40 psf (exactly 40.8)
 - Therefore a 7/8" pl = 35psf. 3/4" pl = 30psf. 5/8"pl = 25psf, 1/2" pl = 20psf, 3/8" pl = 15psf, and 1/4" pl = 10psf

WEIGHTS OF COMMON BUILDING CONSTRUCTION

- Concrete floors weigh from 90 to 150 PSF
- Steel beam w/ concrete-filled metal deck = 50-70PSF
- Wood floors weigh from 10 to 25 PSF (floors w/ thin concrete fill are 25 PSF or more)
- Add 10 to 15 PSF for wood or metal stud interior walls, each floor level
- Add 10 PSF or more for furniture/contents each floor (more for storage, etc.)
- Add 10 to 20 PSF for Rescuers
 - 10 PSF on large slab that spreads out load
 - 20PSF on wood floors to allow for concentrations

EXAMPLE: shown in slide at right

- 20ft x 30ft Slab
- Total for 8" concrete slab, 6" of debris, allowance for lights & ceiling, and 10psf for rescuers = 105,000 lbs
- In this case the 10psf allows for 24-250lb rescuers – looks OK

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Weights of Building Materials

- Reinforced concrete = 150 pcf = .09 pci
 - Concrete columns & beams weigh more (16"sq w/ 5% rebar = 170pcf)
- Masonry = 125 pcf
- Wood = 35 pcf (dry)
- Steel = 490 pcf = .28 lbs per cubic inch = pci
- Concrete or masonry rubble = 10 psf per inch

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Quick way to estimate weights

Base estimate on approximate weight per square foot for unit thickness of concrete (12") and steel (1")

- 12" conc slab = 150 psf =
 - 10' conc slab = 125psf
 - 8" conc slab = 100psf
 - 6" conc slab = 75psf (and so on)
- 1" steel plate = 40psf
 - 3/4" steel pl = 30psf
 - 1/2" steel pl = 20psf
 - 1/4" steel pl = 10psf (and so on)

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Weights of Building Construction

- Concrete floors = 90 to 150 psf
 - Light weight concrete is about 80%
- Steel systems w/ conc fill slabs = 50 to 70 psf
- Wood floor = 10 to 25 psf
 - (post 1960 wood floors may have concrete fill)
- Add 10 to 15 psf for wood/metal interior walls
 - each floor
- Add 10 psf or more each floor or furniture etc.
 - More for storage
- Add 10 psf or more for Rescuers

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Example

- Assume that this 20ft x 30ft classroom has an 8" thick concrete roof with 6" of debris on it
WHAT IS THE TOTAL LOAD TO SHORE ?

8" concrete	= 100 psf x 20 x 30 =	60,000 lb
6" debris	= 60 psf x 20 x 30 =	36,000 lb
Lights, ducts, ceiling, etc.	= 5 psf =	3,000 lb
Rescuers	= 10 psf x 20 x 30 =	6,000 lb*
TOTAL	(105 Kips)	= 105,000 lb

* 6,000 lb Rescuers allows for 24 - 250 lb FF
Is this reasonable ?

- If not use more, this is a MINIMUM

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CONSIDERATIONS for DESIGN (continued)

Shoring In Multi-Story Structures

- For existing, sound, wood structures, the excess live load capacity in an undamaged floor will usually be enough to support the weight of a damaged floor. This assumes that the damaged floor is not highly loaded with debris. Also the undamaged floor is assumed to not be heavily loaded with storage or other material, and no “occupants” (other than Rescue Forces) would be present.
- For existing, steel frame structures), it would take, **at least** two undamaged floors to support one damaged floor (with same loading assumptions as for wood floors)
- For existing, cast in place concrete (C.I.P.), it would take, **at least** three undamaged floors to support one damaged floor (again, with loading assumptions as for wood floors)
- For Precast Concrete (PC) and all Concrete parking structures, all shoring should be extended to the ground, or a “Base Slab” that has been designed to support the impact forces of a progressive collapse. Unfortunately, due to the competitive nature of many structures of this type, one must approach them with extra caution
- Special caution needs to be practiced when **Structures under Construction** have become a partially collapsed, US&R incident. This would also apply to **Existing Structures that Collapse Unexpectedly** (due to no apparent cause)
 - Since the cause of the collapse may involve an inadequacy in the original design or construction, US&R operations should proceed with great caution, and only after review by a Structures Specialist.
 - For C.I.P. concrete structures, the age or underlying floors and “Re-shoring” scheme would need to be considered in deciding if undamaged floors could safely share any additional load.
 - PC concrete and concrete parking structures, have proven to be vulnerable to secondary collapse, and must be approached only after careful evaluation. Risk of further collapse must be weighed against to possible Reward of live recoveries. De-construction may be the only viable option.
 - Since these structures may contain unconnected elements that may also bear on narrow corbels, any shoring system must be complete enough to reduce the possibility of both vertical & lateral progressive collapse

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Shoring in Multi-story Structures

- For Existing, “Sound” Bldgs - Only
 - Wood Bldg, one undamaged floor can support one damaged floor
 - Steel Bldg, 2 undamaged for 1 damaged
 - Reinforced Concrete, 3 for 1
 - Precast Conc, Start at ground
- Assumptions
 - “Normal” loading - no heavy debris, etc
 - Not for buildings under construction
 - ◆ See Manual & Input from StS
 - Not for any bldgs that collapse unexpectedly – w/o Quake, Blast, etc

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CONSIDERATIONS for DESIGN & SELECTION (continued)

Sequence Considerations

- When shoring is placed in a multi-story incident, one should begin the shoring directly below the damaged floor.
 - This should be done in as safe a manner as possible, but the intent is to “Share the Load” of the damaged floor, as soon as reasonable

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

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

SELECTION CONSIDERATIONS

Condition of structure to be supported

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

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

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Shoring in Multi-story Structures – cont.

- **Sequence for multi-story Shoring – Where do you start?**
 - Start directly under lowest “Damaged” or “Overloaded” Floor in order to share the load
 - Keep shoring in all stories vertically aligned
- **Other Strategies**
 - Shore from Outside - In
 - Shore for Team Access & Egress
 - Phased approach – see next slide
 - ◆ Spot shore - Class 1
 - ◆ 2 Dimensional - Class 2
 - ◆ 3 Dimensional - Class 3

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Shoring Selection Considerations

- **Condition of damaged floor / wall**
 - Solid with cracks
 - Badly cracked concrete or masonry
 - Wood joist - Wood truss
 - Steel beam - Steel bar joist
 - PC Concrete - T, Dbl T, I-Beam, Slab (hollow sections)

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Shoring Selection Considerations

- **Condition of supporting surface**
 - Solid ground - slab on ground
 - Rubble covered ground or slab
 - Undamaged floors in multi-story bldg
 - Basement - but now many floors below
- **Availability of shoring materials & local contractors**

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SELECTION CONSIDERATIONS (continued)

The Condition of foundation/support of shoring – solid or soft ground, slab on ground, floor over basement below, rubble, number of un-damaged stories below, determines extent of system.

Availability of shoring materials - pre-plan, local contractors. For collapsed structures want light, portable, adjustable, reliable, and forgiving shoring system.

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

- Buildings that are out of plumb due to cracked (damaged) walls and/or columns require lateral support in proportion to the slope of the offset story
 - This is easily calculated as illustrated here.
 - Wood buildings have been found that were racked at a slope of as much as 2 feet in one 10 foot story
 - It is rare to find damaged, uncollapsed masonry walls that are racked at more than 5% (6" in 10 feet)
- If structure is partly supported by tension structure-like system, horizontal forces are induced in remaining structure.
- Collapses that have large remaining pieces can be extra dangerous. Interconnected pieces may depend on each other for support.
- Collapsed structures containing sloped surfaces are especially difficult, since loads are vertical due to gravity, but contact surfaces are sloped, and therefore, vertical and lateral forces induced in shoring are both very large.
- Total load of structure above can be relatively easily calculated, but where individual load concentrations are being applied is often difficult to determine. A shoring system that will give warning of overload is therefore most desirable.
- It is difficult to decide on the design load when a damaged structure is at rest, but of questionable stability.
 - Should vertical shoring support the weight of the damaged but currently stable floor, or only the weight of rubble resting on it?
 - A four story wood building that is offset one foot in ten in the lower story will require a ten percent stabilizing force, but what additional force should be allowed for wind or aftershock?

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Shoring Selection Considerations

- Damaged buildings often contain vertical as well as lateral instabilities
- Uncollapsed buildings have been 10% out of plumb in one story (requires lateral shoring to support 10% of total weight of building + aftershock)
 - StS needs to design

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Building Out of Plumb Forces

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Shoring Selection Considerations

- Collapses with large pieces may have unseen interdependencies
- Sloped floors & walls are difficult.
 - Loads are vertical due to gravity
 - Contact surfaces are sloped & lateral forces need to be considered and resisted.

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Needs for Shoring Systems

- Easy to calculate Total Load of structure
- Don't know where load is concentrated
- Similar to mine collapse - unknown load distribution
- Shoring system must give warning of overload
 - Need recognizable "Structural Fuses"
- Brittle failure mode is highly undesirable
 - Avoid systems that have Buckling Failure

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SELECTION CONSIDERATIONS (continued)

Using the Desirable Properties of Wood to Advantage

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

Example: 4x4 length for L/D of 25 = $25 \times 3.5 = 88"$ = 8ft

6x6 length for L/D of 25 = $25 \times 5.5 = 138"$ = 12ft

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

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Use Unique Property of Timber To Provide Warning of Overload

- Growth pattern of Tree
- Rapid growth in spring deposits relatively soft fiber
- Slower growth rate in summer deposits more dense fiber
- If load end grain, crushing strength is determined by summerwood
- If load is on side (crossgrain), soft springwood determines strength
- Crossgrain bearing failure is slow & noisy - (gives warning)

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Capacity Of Wood Posts

- Slenderness (L/D) determines the buckling strength of a wood post (L/D = length/width)
 - Buckling failure is sudden and undesirable
 - The maximum allowable L/D is 50
- For better failure mode posts should be constructed so their L/D is less than 25
 - This will insure that crossgrain crushing can occur and be observed at a load that is lower than the Buckling Load.

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Capacity of Wood Posts

- For L/D to be 25 or Less
 - 4 x 4 should be kept shorter than 8 feet
 - 6 x 6 should be kept shorter than 12 feet
- This is not always possible
- If a post is properly braced at its mid-height, it's Effective length is half it's Total length.
 - Bracing must be placed in N-S as well as E-W direction and properly nailed
- FEMA, US&R shoring has lots of bracing

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FEMA SHORING SYSTEMS

We will now discuss the following FEMA shores:

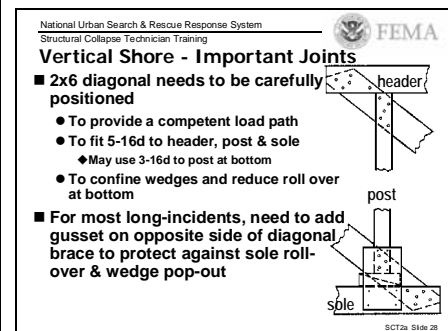
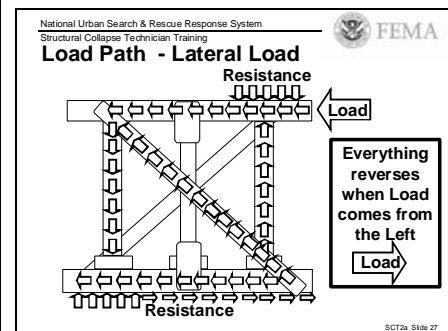
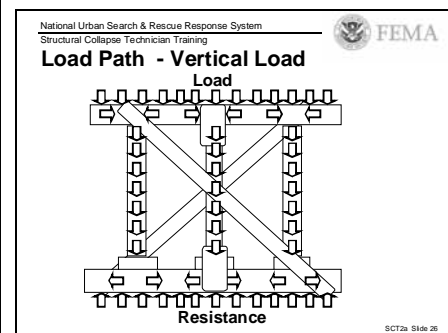
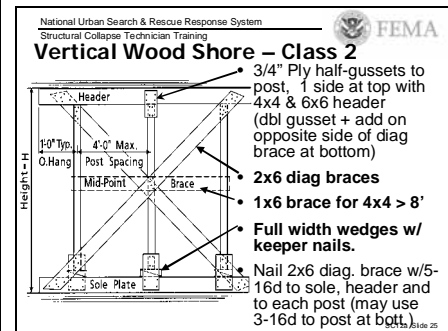
- Vertical Shores
- Sloped Floor Shores
- Lateral Shores
- Raker Shores and **Tieback Systems** – built when walls are too high for Raker Shores

VERTICAL SHORES

- Most all these systems use wood wedges to provide for adjustability. Wedges also provide an ideal “Structural Fuse” since they will deform and “Cup” when the posts are loaded to about 1.5 to 2x allowable bearing load (about 1000 to 1200psi)
 - Wedges should be checked at least twice a day and after & significant change in loading, inc aftershocks
- All wood post systems should have diagonal wood bracing, in north-south and east-west direction if possible.
 - Bracing should be designed for at least 2%, of the vertical capacity of the shoring system.

POST WOOD SYSTEMS (3 or more and 2 Post Systems)

- The graphic **SHOR-1** illustrates the construction and capacity of a **3 Post Wood Post, Vertical Shore**.
 - Connections at top & bottoms of posts are nailed gussets. For 4x4 and 6x6 headers a single sided half-gusset may be used at the top, however, half-gussets should be placed each side at the bottom to prevent Wedge Pop-Out in Aftershocks
 - Diagonal braces are nailed to each post and also provide top & bottom connections for exterior posts.
 - It is difficult to provide lateral stability in the “out of plane” direction for these, **two dimension shores**
 - Shores of this type may be built with more than three posts. **For 2 Post Vertical Shores, see page 11**
- The connection at the top & bottom of exterior posts is of special interest, since the diagonal must be carefully positioned to transfer the Lateral Load
 - The diagonal must also be nailed to the header, post, sill, and also confine the wedges.
 - A half-gusset needs to be placed on the opposite side of posts at bottom to reduce risk of sole rollover & wedge pop-out. Also a half-gusset should be added on opposite side at top when header is deeper than its width.





VERTICAL SHORES – 3 POST WOOD SYSTEM (continued)

- The table on the lower part next page, below the Vertical Shore diagram (SHOR-1), gives design values for two systems (4x4 and 6x6 posts) based on Post Design Strength for various lengths (Height)
 - Header size is specified as 4x4 and 6x6 minimum based on the following:
 - The maximum post spacing for 4x4 is 4 feet (6x6, 5ft), and posts are aligned under floor beams and/or joists
 - When concrete slabs and/or beams are being supported, the concrete is not badly cracked and is, therefore, capable of spanning between posts.
 - When the conditions for the 4x4 and 6x6 headers cannot be met, a Structure Specialist will need to design a larger header, based on required bending and shear resistance
 - Deeper headers will require that double half-gusset plates are used at the header to post connection, in order to prevent roll-over
- The headers of vertical shores may slope as much as 6" in 10 feet or 5 percent (about 3 degrees)
 - For slopes that are greater, one should use a Sloped Floor Shore, discussed later in this section.
- The 3-Post wood systems have been built for many years, but they have several shortcomings.
 - Because of its length, it is often difficult to prefabricate
 - It is only a two dimensional system, therefore the posts can only be braced in the plane of the X bracing.
 - Therefore the effective length of the posts cannot actually be reduced.
 - To assure stability, the header would need to be connected to the load at the top. If it is not connected, it could shift sideways during an aftershock.
 - The sole plate should also be restrained from moving sideways.
 - In order to overcome these problems, one can construct 2-Post Vert Shore in pairs, and lace them together to form Laced Post Shores.

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Assumptions - Vertical Shore

- Configurations show Post Design Load for given heights
- The 4x4 and 6x6 Header Size assumes:
 - Posts are 4 ft max o.c.
 - Post are aligned with Floor Beams
 - Or that Supported Concrete is rigid enough to span between posts
 - If Not the Case - StS must Design Header
- Max. slope of floor/header is 5% (6" in 10')

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Properties Of Good Wood

- Minimum of 8 Rings per Inch
- Slope of Grain = 8 to 1 or Less
- Maximum Tight Knot = 1 1/2 in.
- Maximum Loose Knot = 3/4 in.
- If Doug Fir or Southern Pine have this type of grain, Factor of Safety = 2 ?

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2-Post Vertical Wood Shores

3/4" Ply half-gussets ea. side ea. post, except at Diag. (gussets only one side for 4x4, 6x6 Header)

2x4 diag (7'-6" max long to resist tension & compression)

2x4 mid brace

Nail 2x diag. brace w/3-16d ea end

2x wedges w/ nails.

Posts 4' o.c. - 4x4 (5' max at 6x6)

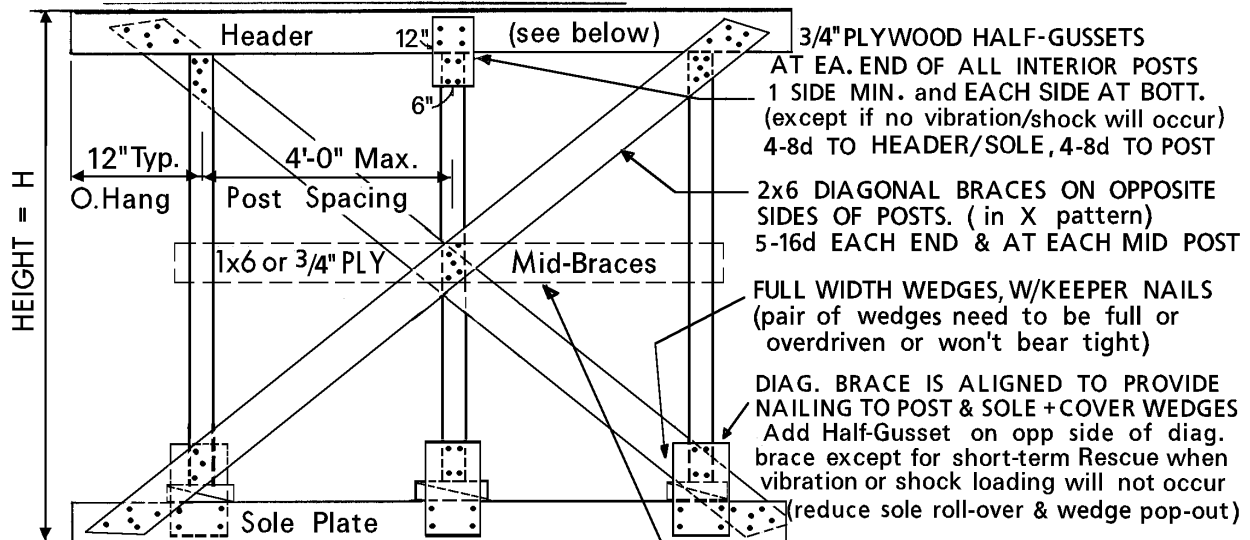
Same as One Face of Laced Post Shore

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Load from Wood, Steel or Concrete Structure

SHOR-1 R9 03/09



Support from firm/sound slab, floor or ground
Align posts w/structure or shoring below

MID-POINT BRACE is placed one side when 4x4 post is > 8'-0" long and 6x6 post is > 12'-0" long

4x4 POST SYSTEM - USE 4X4 SOLE PLATE

HEIGHT = H	DESIGN LOAD, EA. POST	HEADER SIZE
8'-0"	8,000 LB *	Use 4x4 min. if place posts directly under floor beams or when supporting intact/rigid concrete slab or beam.
10'-0"	5,000 LB	
12'-0"	3,500 LB	See Structure Specialist for other conditions

6x6 POST SYSTEM - USE 6X6 SOLE PLATE

HEIGHT = H	DESIGN LOAD, EA. POST	HEADER SIZE
12'-0"	20,000 LB *	Use 6x6 min. if place posts directly under floor beams or when supporting intact/rigid concrete slab or beam.
14'-0"	14,500 LB	
16'-0"	12,000 LB	
18'-0"	9,000 LB	See Structure Specialist for other conditions
20'-0"	7,500 LB	

SPECIAL NOTES:

- * = Limited by 660 psi Cross Grain Bearing on Wood.
- Spacing of Posts may be closer than 4ft in order to increase system capacity and/or align Posts under floor beams or joist.
- Header Size is HIGHLY dependent on ability of The Shored Structure to bridge between the Shoring Posts. If in doubt check w/Structure Spec.

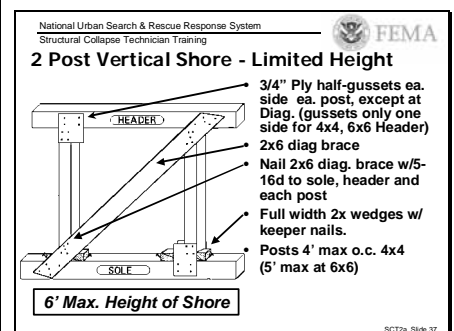
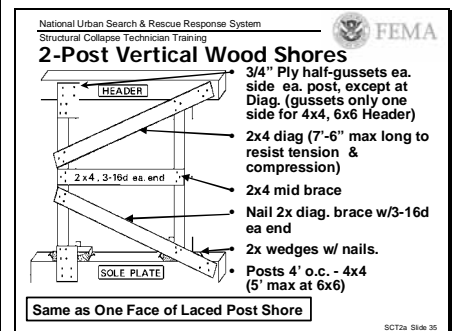
VALUES GIVEN FOR ALL WOOD SHORES IN THIS TEXT HAVE AN APPROXIMATE FACTOR OF SAFETY OF 2 TO 1 IF NO. 1 DOUGLAS FIR OR SOUTHERN PINE ARE USED. PIECES SHOULD BE SELECTED FOR GOOD GRAIN (MIN. OF 8 RINGS PER INCH, SLOPE OF GRAIN NOT GREATER THAN 8 TO 1, AND HAVING 1 1/2 INCH OR SMALLER TIGHT KNOTS / 3/4" MAX LOOSE KNOTS)



VERTICAL SHORING SYSTEMS (continued)

2 POST SYSTEM

- This Shore is preferred by engineers for constructing a vertical shore using wood posts
 - One would prefabricate the 2 posts, header, and upper diagonal and horizontal braces. This is a 2 dimensional, Class 2 shore, same as a 3 or more post vertical shore.
 - After positioning the prefabricated part, the sole, wedges, lower diagonal and half-gussets would be installed.
 - An additional 2 post systems could later be placed in an adjacent location in order to form the stable, 3 dimensional Laced Post System – a Class 3 Shore
- The 2 Post Wood Systems is shown in the adjacent slide
 - A full height 2 Post Shores, the diagonal bracing is best configured as shown in the adjacent slide.
 - Posts should be spaced 4ft max o.c. for 4x4 and 5ft max for 6x6
 - Maximum height using 4x4 posts is 12 feet. (6x6 is 20ft) If the 2-post shore becomes a part of a laced post the height may be greater (see Laced Post info)
 - The 2x diagonals are configured the same as a Laced Post, so their L/D is small enough to allow them to resist both compression and tension.
 - Diagonals should not be greater than 7'-6" long from end to end (6.5 ft clear between posts on diagonal)
 - The safest way to build this shore is to prefabricate as discussed above, then the sole, wedges, half-gussets and lower Diagonal can be added in Collapse Zone.
 - For heights from between 11 and 17 feet, 2 horizontal braces and 3 diagonals should be used
 - For conditions in Collapse Zones where shoring heights are 6 feet and less, the short, 2 Post Vertical Shore, as shown in adjacent slide may be used.
 - In this case, again, the 2x diagonal brace is short enough so that it can resist Compression and Tension, and, therefore, "X" bracing is not required
 - Cribbing may be the best choice at heights 3ft and less. (to be discussed later)





VERTICAL SHORING SYSTEMS (continued)

ELLIS CLAMP - WOOD POST SYSTEMS

ELLIS SHORES - ADJUSTABLE 4x4

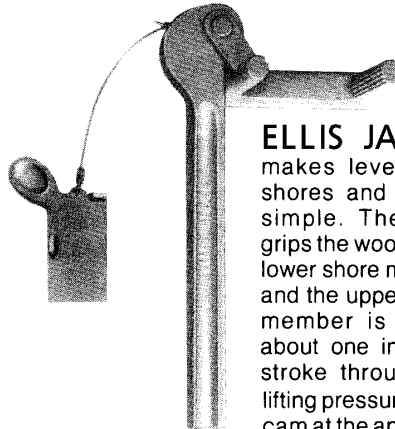
SHOR-2

6/99



ELLIS
CLAMP

need 2 per
shore

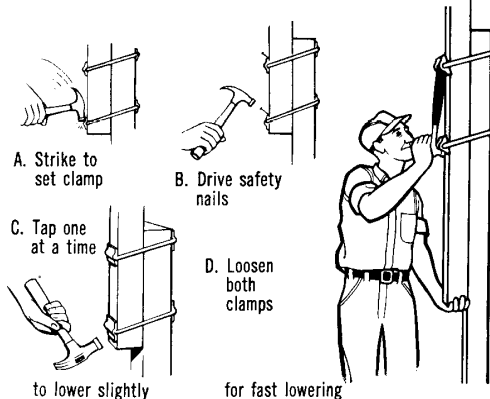


ELLIS JACK

makes leveling of shores and purlins simple. The Jack grips the wood of the lower shore member and the upper shore member is raised about one inch per stroke through the lifting pressure of the cam at the anchored end of the Jack handle.

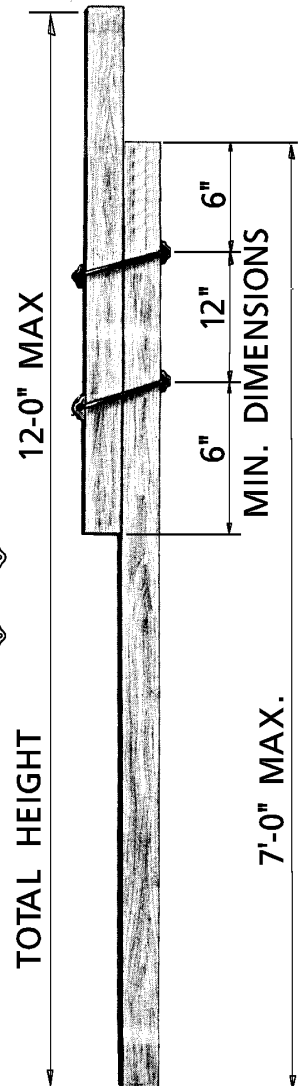
How to Use Ellis Shores:

First, get the proper length lumber to make an Ellis Shore of the desired height — that being a 7' lower shore member and an Ellis Stick of the proper length. The sketches at the right give some suggestions for best results in the operation of Ellis Shores. The picture at the left shows a man raising the upper shore member to the approximate shore height, final adjustment is made with the Ellis Jack. When the desired height is obtained, the clamps should be tapped down (a hammer lug is provided on the clamp plate) to seat them and a safety nail is driven in the shore above each plate. This nail does not support any load, but simply keeps the clamps from vibrating loose.



to lower slightly

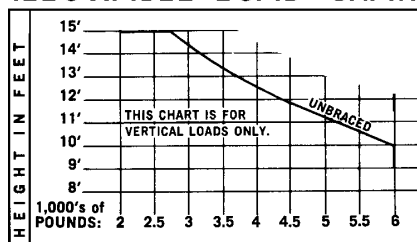
for fast lowering



ELLIS CLAMPS MAKE A PAIR OF 4x4 POSTS INTO AN ADJUSTABLE 4x4 SHORE

Max allowable load is 6000 lbs for shore that is 10ft or shorter with a factor of safety of more than 2 (based on No.1 Doug. Fir/So. Pine)

ALLOWABLE LOAD CHART





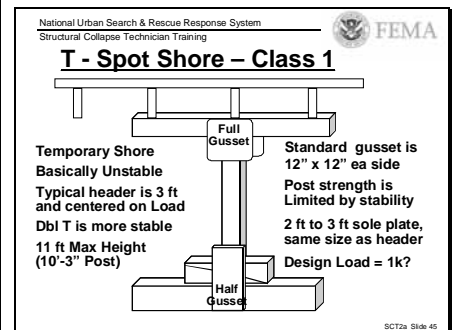
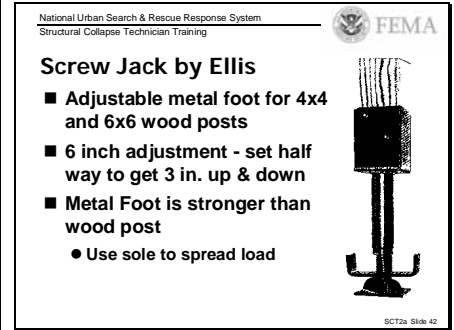
VERTICAL SHORING SYSTEMS (continued)

ELLIS CLAMP - WOOD POST SYSTEMS

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

T - SPOT SHORE

- This type shore is used for initial stabilization of dangerous areas where fully braced systems (such as 2 or more post Vertical Shores) are to be constructed.
 - They provide temporary support of damaged floors, but they are basically unstable.
 - They can only support loads that are balanced about the vertical post, and therefore the header needs to be kept to a maximum of 3 feet long. **Previous versions of the FEMA US&R Student manuals allowed the use of a 4 ft header if the gusset plates were increased to 18" square. The 4 ft header makes the T even more unstable, and is not recommended. It also makes the shore less portable.**
 - They can be prefabricated into the "T" shape, carried into the area that needs support, and then the sole, wedges and half-gusset (or cleat) can be quickly installed
- The capacity of the 4x4 post depends on length as in Vertical Shores (8ft long 4x4 safely supports 8000lb)
 - However, one would expect that stability would govern the failure mode
 - The suggested capacity of these shores should be somewhere in the range of 1000 to 3000 lbs
 - **Maximum Height of T Shore should be 11 ft**
- They are normally installed with Wedges, Sole Plate & half-gussets to spread the load & tighten the shore against the load.



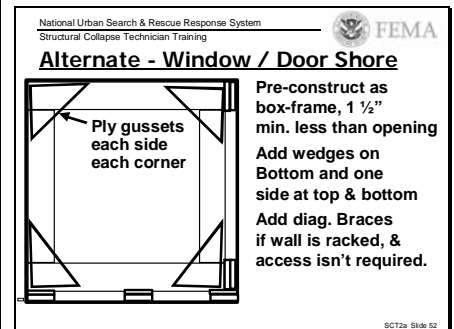
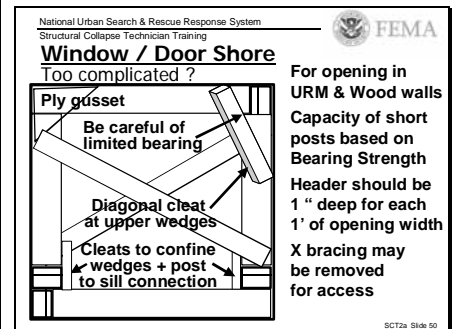
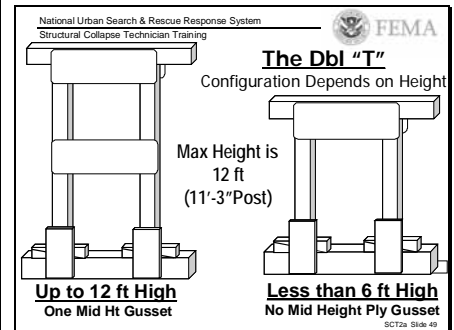
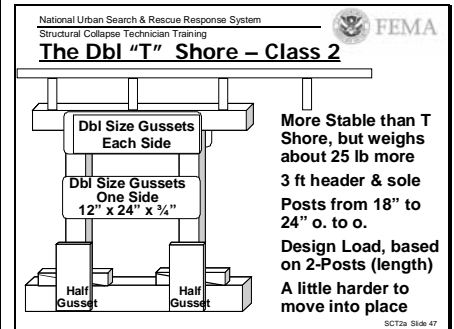


DOUBLE T SHORE

- This type shore may also be used for initial stabilization of dangerous areas.
 - They would provide temporary support of damaged floors, and are much more stable than the "T" Shore.
 - With a 3 foot header and the posts placed 24 inches out to out, most of the load would be centered between the posts
 - Due to its limited width of 3 feet, this shore is not as desirable as the 2 or multi post vertical shores, but its portability allows it to be installed with minimum exposure of rescue workers
 - For shore height less than 6ft, omit mid-height gusset.
 - For heights over 11ft, mid-height gussets should be placed at 1/3 height and 2/3 height. **Max Height of shore is 12ft.**
- The capacity of the 4x4 posts depend on length as in Vertical Shores (1-8ft long 4x4 safely supports 8k, 10ft long = 5k)
- They need to be installed with wedges, sole plate, and half-gusset to spread the load & tighten shore against the load.

WINDOW & DOOR SHORES

- They are used mostly in URM buildings to confine and support loose masonry over openings in the URM walls.
 - They are quite complicated if all corners are properly connected and wedges are confined
 - They may also be used in Wood or other buildings where door or window headers have been damaged.
 - They also have been used in badly racked wood buildings, as diagonal bracing (use 4x or larger Compression Diagonals that are on same plane as Header, Sole and Posts)
- The capacity of the wood posts (which are usually short) usually depends on the cross grain bearing strength (between 300 and 700psi depending on wood species)
 - A rule of thumb for headers size is to make the depth the same in inches as the opening width in feet.
 - The header width should be 6 inches for thick, URM walls, but may be 4 inches for thinner walls, such as wood and hollow concrete block (cinder block)
- A simpler, pre-constructed configuration is shown in adjacent slide, which uses 2x wedges under sole over and at one side
 - It can be built in safe area and possibly reused
 - It can Support as much vertical load as the standard Window Shore, but may not be practical for badly racked openings





VERTICAL SHORING SYSTEMS (continued)

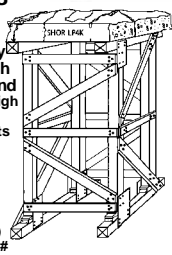
LACED POSTS

- Four posts may be placed in a square pattern and laced together with 2x4 or 2x6 horizontal and diagonal bracing.
 - The spacing of posts is 4 ft max for 4x4 (5ft for 6x6) so that the length of 2x diagonal braces is 7'-6" max to allow them to resist compression as well as tension forces.
 - The max height with 4x4 posts is 17ft (20ft for 6x6)
 - 2x4 Diagonals, 3-16d each end, are used with 4x4 posts
 - 2x6 Diagonals, 5-16d each end, are used with 6x6 posts
 - This is a three dimensional, Class 3 Shore – most stable
- The connections between diagonals and header/sole need to be made with care as for the vertical post shore, since the 2x diagonals must be nailed properly to header, post, sole, and confine the wedges as shown in the adjacent slide.
 - A half-gusset is, again, useful opposite the diagonal to sole connection to guard against roll-over and wedge pop-out
- The strength of each post may then be calculated on the basis of the length/height between the Horizontal Braces. (8K for 4x4 and 20K for 6x6)
- Header beams and Sole plates usually are required to collect and distribute the load, as criteria as for Vertical Shores.
 - The surface that is being supported may have a slope of 6" in 10 ft in any direction.
 - Use Sloped Floor Shores for larger slopes.
- The space inside the laced posts may be useful as a safe haven, since it is relatively strong and one may climb in relatively quickly
- The safest and most effective way to construct laced posts is to build two, 2 post vertical shores, then lace them together.
 - 2 Post vertical shores should be prefabricated, without their sole plates, then assembled in the collapse zone.
- The most common configuration of laced post has one mid-point horiz. brace & two sets of diagonal braces, these should be used for shoring heights between 6 ft and 11 ft.
 - For heights from 11 ft to 17 ft, use horizontal brace at one-third points and 3 sets of diagonal braces.
 - For heights below 6 ft, in limited height areas, one can build a short, braced shoring system, that is essentially a half height, Laced Post
 - The configuration of the diagonals is discussed above-right. The K configuration is easy to teach and remember.

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Laced Posts - Class 3

- 4x4 Posts=4ft max o.c.
 - 6x6 Posts = 5 ft max. o.c.
- Increase long post capacity due to short effective length
- Add 2x4 lacing, 3-16d @ end
 - 3 bays bracing if over 11ft high
 - Use K layout or any other
 - 2x6 lacing, 5-16d at 6x6 Posts
- Need Header & Sole
 - Connections like Vert Shore
- Height NOT to exceed 4 times overall width
- Can use as Safe Haven
- Design Load (660psi bearing)
 - 4 - 4x4x17'-0" max. = 32,000#
 - 4 - 6x6x20'-0" max. = 80,000#



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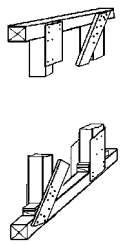
The Diagonal Bracing is shown in the preferred, 4-K configuration. In previous editions of this manual, 3-K plus one reverse K was shown. This may have been a better layout for Torsion, but it placed a large group of nails at one post – leading to possible splitting

Since the capacity of diagonals is likely governed by the shear loading on the nails, any other configuration of diagonals is acceptable

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Laced Posts - Connections

- Need to carefully place diagonal at post to beam & post to sole
 - Nail 3-16d to beam & post at top
 - Nail 3-16d to sole & post at bottom + confine wedges
- Use gusset, one side at other post to beam & each side to sole (+ opposite side diagonal)
 - 5-8d to post
 - 8-8d to beam & sole

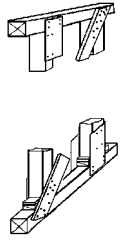


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Laced Posts - Connections

- Need to carefully place diagonal at post to beam & post to sole
 - Nail 3-16d to beam & post at top
 - Nail 3-16d to sole & post at bottom + confine wedges
- Use gusset, one side at other post to beam & each side to sole (+ opposite side diagonal)
 - 5-8d to post
 - 8-8d to beam & sole



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VERTICAL SHORING SYSTEMS (continued)

CRIBBING


- Cribs have a multi member lay-up of 4x4 to 8x8 lumber in two, three or more members per layer configuration.
- The Design Load is determined by the perpendicular to grain loading on the sum of all bearing surfaces. 500 psi is used for Douglas Fir and Southern Pine lumber
- Failure is slow, noisy crushing of the softer wood fibers, which make system desirable for the unknown loading of US&R work.
- Heavily loaded cribs will crush so that they may lose from 10% to 20% of their height.
 - This is a good thing as far as providing warning of overload, but may present problems regarding stability and the need to adequately support the damaged structure.
 - It means that one must figure that cribbing cannot “share” load with the damaged structure. The structure must completely fail, and “give-up” the load to this system.
- Stability of cribs is an important issue
 - Height to width of crib and should not exceed 3 to 1.
 - Need to overlap corners a minimum of 4” to guard against splitting off corners of individual pieces.
 - Testing has shown that stability of taller cribs is an issue. It is recommended to limit the total height of cribs with 4x lumber to about 4 feet and 6x lumber to about 6 feet.
 - Stability is also dependent on, more or less, uniform crushing under each line of crib bearing. The presence of knots and different density/angle of grain at the bearings can provide non-uniform conditions, leading to stability failures.
- Lateral movement between individual crib pieces during aftershocks is normally resisted by friction.
 - Individual pieces may be notched like Lincoln logs, to improve lateral resistance, but this is very time consuming and all notches must be same height.
 - Metal clips may also be used to improve lateral strength, as well as diagonal braces between pairs of cribs.
 - Sheathing the crib with plywood would help lateral resistance, but is incompatible with crib vertical deflection
- Solid levels can be used spread the load at the ground level.
- Shrinkage of green lumber will cause crib to shorten and they should be checked daily for tightness.
- Cribs used on sloped surfaces as will be discussed later

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Wood Cribbing – Class 1?

- Capacity based on crossgrain bearing area of system
- Allow stress varies from 200 to 1000psi for wood species
- For 2 member x 2 member crib
 - 4x4 Design Load = 24,000# (500psi)
 - 6x6 Design Load = 60,000#
- Limit Height to Width to 3 to 1*
 - See recommended height limit below
- Stability and Deflection Issues
 - Crib can crush as much as 20%
 - *Recommended to Limit Ht to 4 ft for 4x lumber & 6 ft for 6x
 - Overlap corners 4” minimum



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VERTICAL SHORING SYSTEMS (continued)

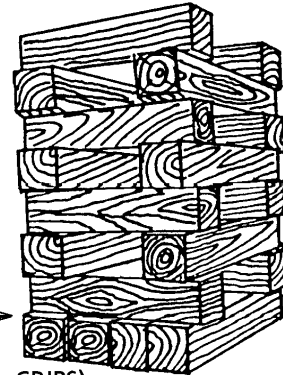
DESIGN STRENGTH is BASED on CROSSGRAIN BEARING
(VARIES FROM 200 PSI TO 1000 PSI DEPENDING ON WOOD SPECIES
500 PSI IS USED HERE - EXAMPLE $500 \times 3.5 \times 3.5 \times 4 = 24,000$)

FOR 2 MEMBER x 2 MEMBER LAYOUT

4 x 4 CRIB DESIGN LOAD = 24,000 LBS (12 TONS)

6 x 6 CRIB DESIGN LOAD = 60,000 LBS (30 TONS)

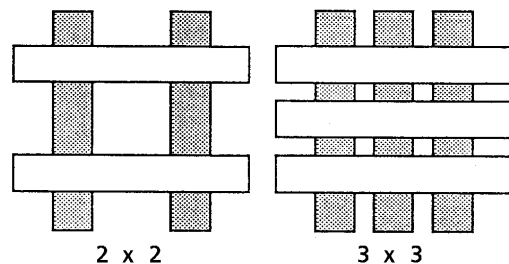
FOR 3-MEMBER x 3-MEMBER CRIB, DESIGN LOAD IS 9/4 AS MUCH
 $500 \times 3.5" \times 3.5" \times 9 = 55,000$, $500 \times 5.5" \times 5.5" \times 9 = 136,000$



- BOTTOM LAYER SHOULD BE SOLID TO SPREAD THE LOAD ESPECIALLY ON SOIL OR ASPHALT PAVING
- LIMIT HEIGHT TO 3 TIMES WIDTH (SHORTEST WIDTH FOR NON-SQUARE CRIBS)
- OVERLAP CORNERS BY 4 INCHES TO ASSURE SLOW CRUSH TYPE FAILURE

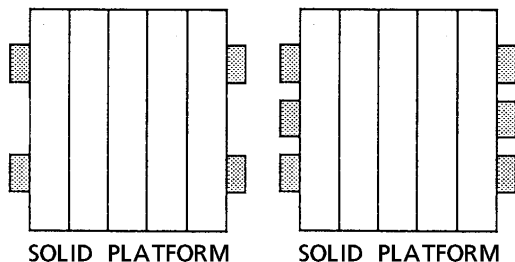
SHOR-4

06/06



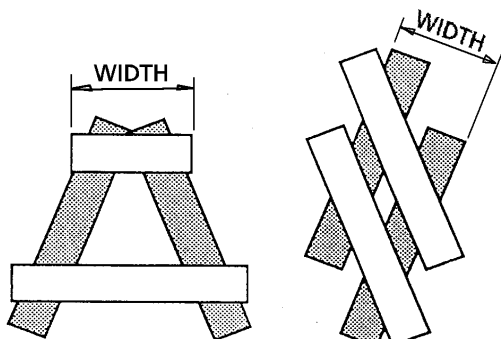
2 x 2

3 x 3



SOLID PLATFORM

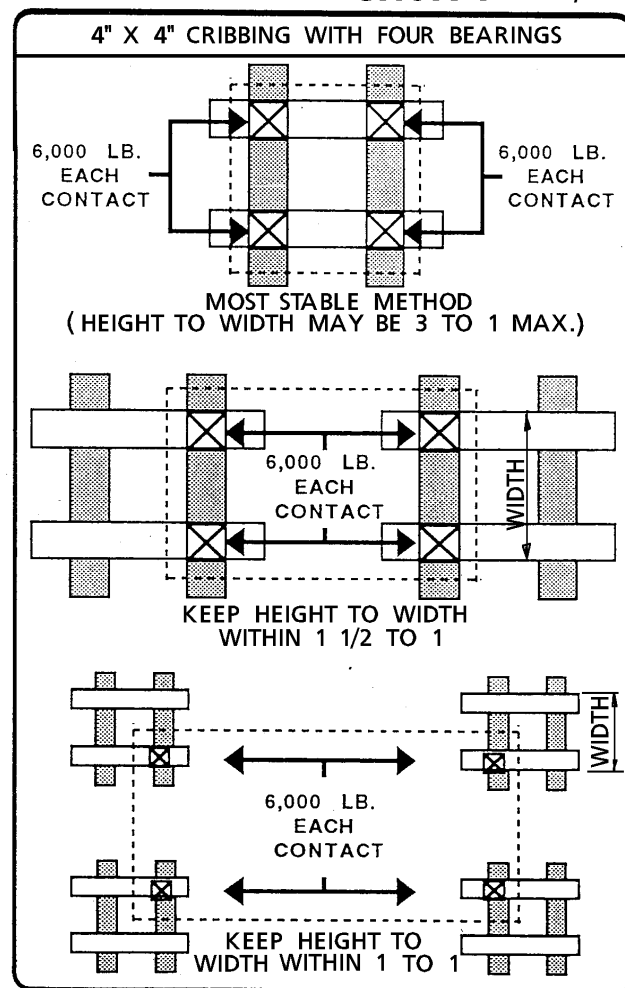
SOLID PLATFORM



TRIANGLE

PARALLELOGRAM

BOTH ARE NOT VERY STABLE, KEEP
HEIGHT TO WIDTH WITHIN 1 TO 1





VERTICAL SHORING SYSTEMS (continued)

STEEL PIPE SYSTEMS

- Pipe capacity depends on buckling strength.
- Design Load = $F_c \times \text{Area}$
 - F_c (Allow. Compression Stress) given in Sect 7 StS FOG
 - F_c is dependant on L/r (L = length in inches; r = radius of gyration = average radius of pipe)

Example: Design Capacity of 2" diameter Standard Pipe x 8 ft long

(2.375" O.D., Area = 1.07 sq in, from Sect 7 StS FOG

$L/r = 96"/.787 = 122$; from StS FOG, $F_c = 10\text{ksi}$

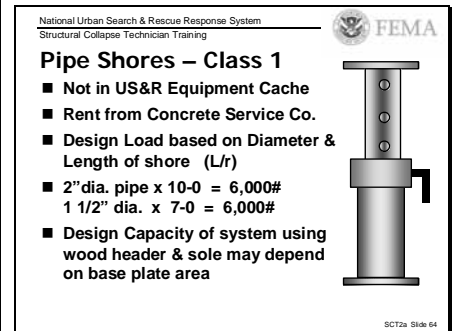
Design Capacity = $10\text{ksi} \times 1.07 \text{ sq. in.} = 10.7 \text{ kips} = 10,700 \text{ lbs}$

(The author uses about 90% of this value, based on the manufacturing tolerances of pipe)

- Retractable pipe shores are normally adjustable by screw end and/or sleeve and pin. They may have square steel feet that may even have slope adjustment and nail holes for attachment.
- Pipe shores used for bracing tilt-up concrete walls come in lengths up to 30 feet and have rated capacities listed in tables supplied by rental companies.
- Pipe systems are often used with wood spreader beams and sills, which could limit their capacity. Engineers should be used to design these systems.
- Pipe systems normally fail by buckling, and are, therefore, less desirable than well braced wood systems that can be proportioned to initially fail by crushing of wood

TRENCH JACKS

- Vary from about two to more than eight feet long and normally have a rated capacity. They are intended to support the opposing sides of a trench, with the addition of spreaders & sheathing. They should be Schedule 40 Pipe
- May be used as initial, unbraced shoring to permit building of more stable system. Not first choice
- They could be used as a two or 3-post system, nailed to header and sole. Diagonal X bracing would need to be only nailed to the header and sole





VERTICAL SHORING SYSTEMS (continued)

DIAGONALLY BRACED METAL FRAMES

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

ALUMA BEAMS

- These are light gage, shaped aluminum joist or beams that are normally used as shoring for wet concrete.
- They have been used to construct shelters from falling debris, as plywood sheathing can be placed between the Aluma Beams and nailed too them to provide a surface that is quite flexible but strong.
- The flexibility of the aluminum (3 times that of a similar steel structure) is ideal for catching falling objects, since the flexibility reduces the strength required for the CATCH structure.

PNEUMATIC SHORES (STRUTS)

- Lightweight aluminum pneumatic piston ram shore, which is highly adjustable with ranges up to 16 ft. They can be configured with various end connections (see slide).
 - Airshore manufacturers 3½" diameter Struts in seven ranges of length. (From 2 to 16 feet)
 - Paratech manufactures 3" diameter Struts in four ranges of length (from 2 to 8 feet). **Dark Grey anodized color**
 - Paratech also makes a 3½" diameter, Long Strut, in three ranges of length (from 6 to 16 feet). **Gold anodized**
- When used in trenches, these shores are initially set with pressurized air.
 - After securing the shore in place with a large locking nut or steel pins with collar, the safe working load can range from 20,000 lbs. for a 6-foot shore to 3000 lbs. for a 16-foot shore.
 - Load charts for the two manufactures are listed in the adjacent and subsequent slides and the US&R Structural Specialist FOG, Sect 7.
 - Loading is based on using swivel end connections

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Aluminum Frames – Class 3

- Available in 20k per 2 leg frame up to 50k
- Design Capacity of frame may depend on foot bearing plate
- AlumaBeams have wood nailer & can span up to 20'
 - Have been used as shelter

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Aluma Beams

- Available from Concrete Supply (Burke)
- Up to 20 ft spans - use Plywd Sheathing
- Good Dynamic Properties to stop falling objects more slowly - absorb energy

3s

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Pneumatic Shores – Class 1

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

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What About using Extensions for Pneumatic Shores?

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

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Recommended Design Strength for AIRSHORE Struts used in US&R

Length	Load	Comment
16 ft	3000 lbs	May use one 6ft extension
15	3400	"
14	3800	May use one 6ft or 4ft extension
13	5000	May use one extension
12	7000	"
11	10000	"
10	12000	Do not use extensions
9	14000	"
8	15000	"
7	18000	"
6 & less	20000	"

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VERTICAL SHORING SYSTEMS (continued)

PNEUMATIC SHORES (continued)

- When used in US&R, these shores should be hand tightened, so as not to apply any sudden pressure to a damaged structure.
 - Air may be used to raise vertical struts, but the pressure must be limited to 50 psi max – due to accident potential
 - The sleeve nut or steel pins are used to adjust length.
 - They may be included in a system with headers, sole plate, and bracing, but are considered best as temporary shores that allow braced systems to be installed at reduced risk.
- The manufactures also make simple aluminum tubing extensions in lengths from one to six feet.
 - Extensions should only be used when other alternatives are not available.
 - Only one extension should be used with each strut
 - See slide at right regarding use of extensions.

SPECIALTY SHORES (Airbags are lifting device - not shores)

- **AIRBAGS** – tough neoprene bags that come in sizes from six inches to thirty-six inches square.
 - They are pressurized to lift very heavy objects a short distance, and are helpful in releasing an entrapped victim.
 - Note that they can be punctured by rebar, and that objects that are lifted must be laterally restrained by other means, since the bags have little lateral strength.
- **STEEL OR REINFORCED CONCRETE CULVERT** sections could be used as a protection device for entry thru an area where protection from smaller falling hazards was required.
- **SHORING AT COLUMN/SLAB CONNECTIONS** - The danger of a punching shear failure occurring at a flat slab/column joint is often present due to heavy debris loading on slabs that do not collapse initially.
 - Since most of the cracking that warns of this type of collapse hazard is on the top of the slab and may be covered by the debris, it is best to increase the column's periphery by adding vertical shoring on all four sides.
 - Shoring consisting of vertical posts that are tied around the column could be used. All the normal problems i.e. what's the load, support system, need to be considered.

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Recommended Design Strength
For Paratech Long Shore Struts in US&R

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

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Recommended Design Strength
For Paratech Long Shore Struts in US&R

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

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PARATECH Rescue Struts – Load Table
Based on Tests by Paratech,
Reviewed by Wiss, Janney, Elstner, Engineers
Available from 1.5 to 7ft
Extensions avail. In 12", 24" and 36" lengths
(use max. of one extension per strut)

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

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VERTICAL SHORES ON SLOPED SURFACES

- In normal sloped roof construction, sloped rafters are fabricated with horizontal bearings cut-in, so that the vertical, gravity load can be directly transferred into the supporting structure.
- When attempting to shore a damaged, sloped floor, however, the vertical, gravity load is transferred from structure to shoring thru a sloped surface where two forces are generated.
 - A force that is Perpendicular to the sloped surface, and
 - A force that will act down the Slope – Slope Force
- In many cases, especially for reinforced concrete slabs, the Slope Force may be assumed to be resisted by:
 - The connection of the Sloped Floor to the remaining structure at the top, or
 - The Sloped Floor is firmly embedded in rubble at the bottom.
 - When this is the case, the **Perpendicular to Slope Method** shores may be used to successfully support the sloped floor.
- Two variations of the Perpendicular Method of Sloped Floor Shore are shown on SHOR-9.
 - **Type 1** was to be placed on an earth surface, with bearings cut into ground, perpendicular to the shores, but its use is **not recommended**.
 - The “Digging-in” of the post bases is too dangerous
 - **Type 2** may be built on concrete, paving or soil, and uses cleats nailed to the Sole, and needs a Sole Anchor
- When the sloped floor is not reliably connected to the remaining structure or embedded in rubble, the **Sloped Friction Method - Type 3** Shore should be used. This may be used on Concrete, Paving or Soil SHOR-8
 - In this case the Perpendicular and Slope force are combined within the system to allow the shore posts to be placed in a vertical alignment.
 - Since the reliance on friction, especially during Aftershocks may be problematical, the header should be positively attached to the sloped floor, especially if floor is sloped greater than 5%.
 - Small bars ($\frac{1}{2}$ " to $\frac{3}{4}$ " diameter) could be drilled into bottom of slab (through pre-drilled holes in header) and held in place with epoxy (or by interference fit)
 - Shore could bear on sides of beams, etc.

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Shores for Sloped Floors – Class 3
In Normal Construction, one cuts Level Bearings in Wood Rafters (Birds Mouth)

WE CAN'T DO THIS
UNSAFE AND NOT PRACTICAL

Since bearings are level, loads are transferred vertically without generating any sloped forces
Not the case for Sloped Floor Shores

SCT2a Slide 79

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Shores for Sloped Floors

- Sloped Floor is defined as over 5%
 - 6" in 10 feet
- Build them in Pairs w/bracing between
 - Similar to Laced Posts = Class 3
- There are basically Three Designs
 - Perpendicular to Slope Method
 - ◆ Type 2 (Type 1 is no longer recommended)
 - Friction Method – Type 3
 - Cribbing – Type 4
 - ◆ 3 ft in 10ft Max

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Shores For Sloped Floors
Perpendicular to Slope Method

To shore sloped surfaces we must provide a system that will resist both vertical & lateral forces

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Type 2 – Sloped Floor Shores

Type 2 - On Concrete, Paving or Soil (Perpendicular to Slope Method)

SCT2a Slide 82

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Type 3 – Sloped Floor Shores
What to do if Sloped floor is NOT connected to Remaining Structure or Embedded in Rubble

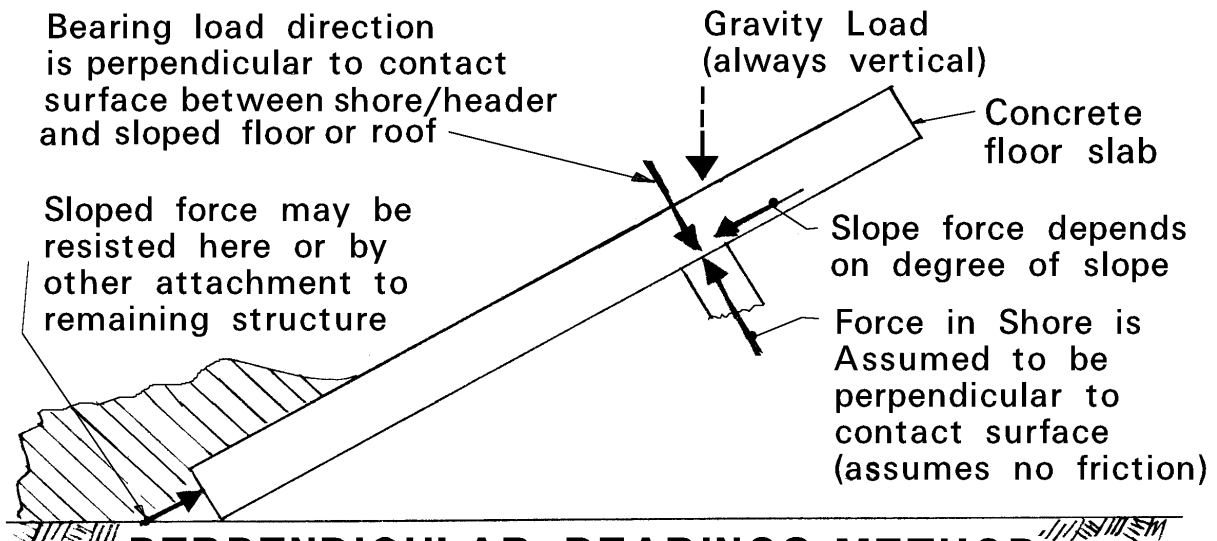
Type 3 - Friction Method (On Concrete, Paving or Soil)
(For slopes over 5% need Connection between Header & Slab)

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SHORES FOR SLOPED FLOORS

SHOR-8 08

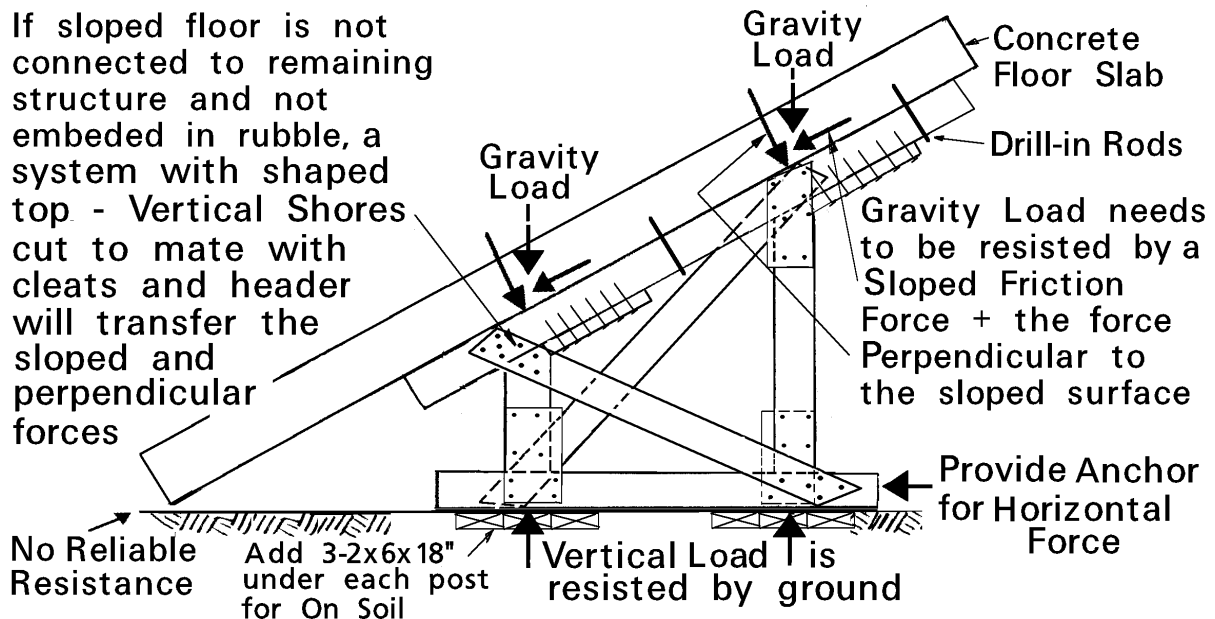


PERPENDICULAR BEARINGS METHOD

(based on assumption that slope force is resisted by attachment to remaining structure or sloped floor is firmly embedded in rubble)

Use TYPE 2, Type1 is Not Recommended

If sloped floor is not connected to remaining structure and not embedded in rubble, a system with shaped top - Vertical Shores cut to mate with cleats and header will transfer the sloped and perpendicular forces



SLOPED FRICTION METHOD • TYPE 3

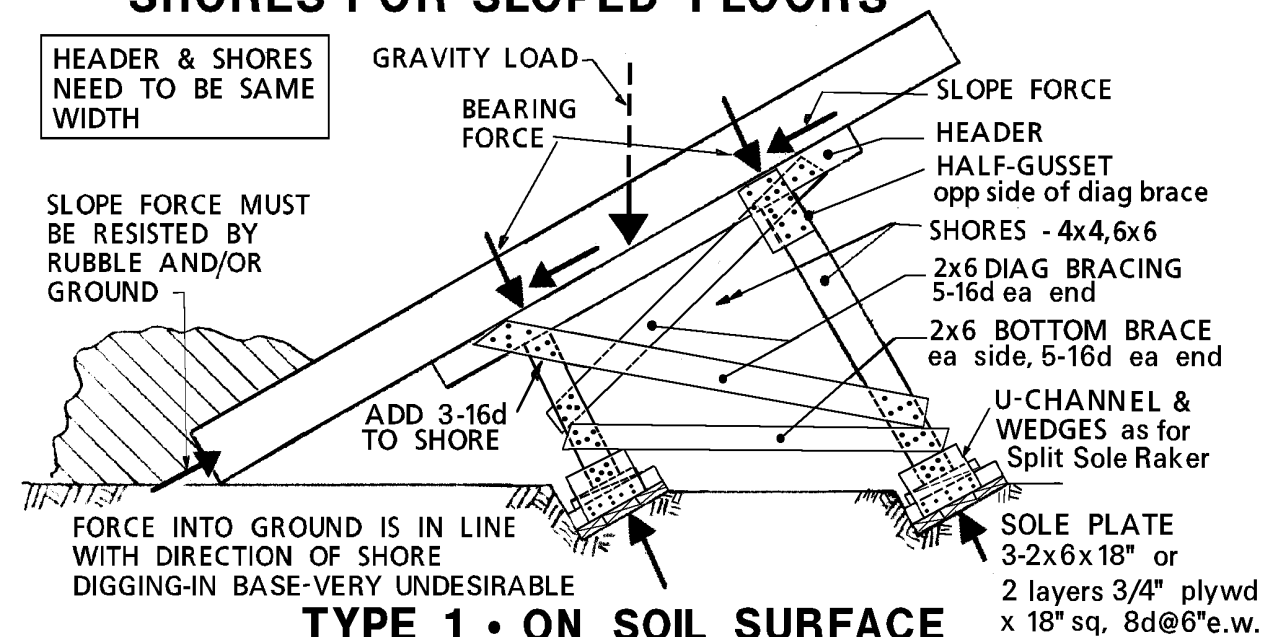
May be built on Concrete, Paving or Soil Surface

At slopes over 5% need to enhance Friction by making some type of Connection between Header and Sloped Floor

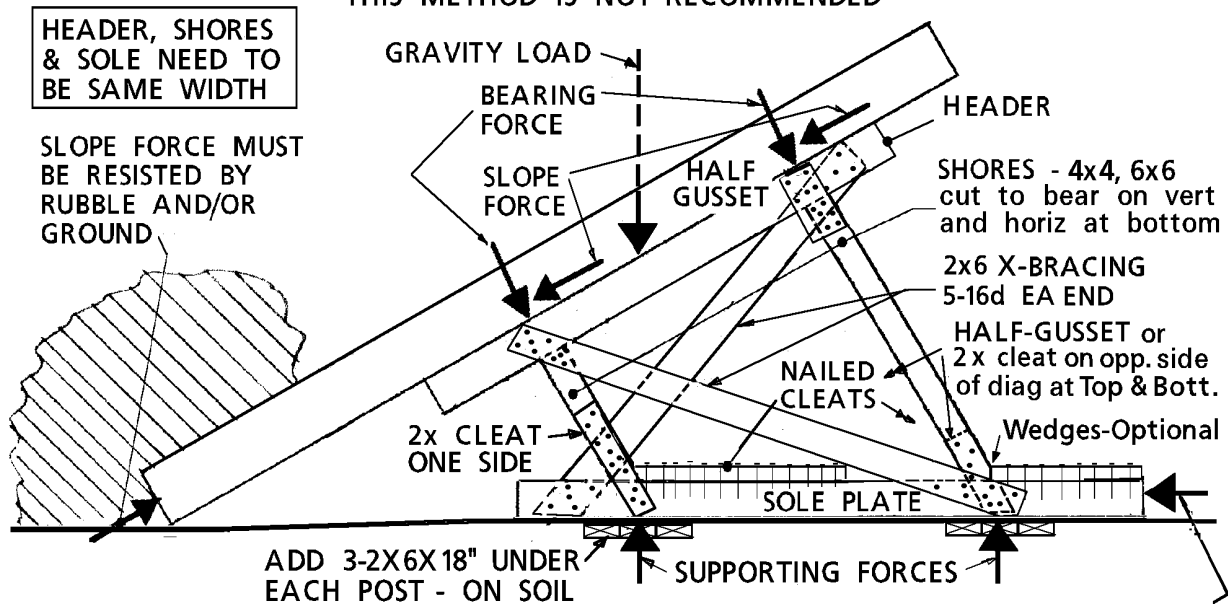


SHORES FOR SLOPED FLOORS

SHOR-9 08



THIS METHOD IS NOT RECOMMENDED



SOLE MUST BE KEPT FROM SLIDING AWAY FROM LOAD

TYPE 2 • ON CONC, PAVING or SOIL

PERPENDICULAR TO SLOPED FLOOR METHOD



VERTICAL SHORES ON SLOPED SURFACES (continued)

- Sloped floor shores should be built as three dimension, Class 3 Systems, similar to Laced posts
 - Construct systems as a minimum of two, two post shores.
 - 4x4 Posts spaced 4ft max and 6x6 posts spaced 5ft max
 - Diagonal bracing (X bracing) should be placed in the plane of the shore (as shown in SHOR-9)
 - Bracing should be designed for 10% min, weight of supported structure.
 - Bracing between shores should be configured as lacing (Laced Post Shores) if shores are kept within 5 ft o.c.
 - However if shores are spaced more than 5 ft but less than 8 ft o.c., they should be laterally braced using horizontal and X bracing as for Raker Shores
 - When the height of to shorter end of the shore gets as small as three feet, a 12" to 24" wide strip of $\frac{3}{4}$ " plywood should be used between shores instead of X bracing.
 - Nail plywood with 8d @ 3" o.c. staggered each end
 - 6x6 shore posts should be used where heavier, concrete floor systems are encountered
- For conditions where the shore height is less than 4 feet, Cribbing can be used to support sloped floors.
 - Slope for crib-supported floor should not exceed 30%. (3 feet in 10 feet, approx. 15 degrees)
 - Cribs can be built into the slope, but care must be taken to properly shim the layers in order to maintain firm, complete bearings. These will be called **Type 4 Sloped Floor Shores**
 - Notches, nails, or metal clips could be used to interconnect crib members so they would better transfer lateral loads.
- Well braced systems using normal Vertical Shores (SHOR-1) may be used when floors are sloped less than 5% (6" in 10ft)
 - Use the shores in pairs with either lacing or horizontal plus X or V bracing in between

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Lateral Bracing
For Paired Sloped Floor Shores

- For pairs of shores, spaced up to 5 ft o.c. use bracing between shores as in Laced Posts
- or
- For pairs of shores, spaced up to 5 ft o.c. use solid plywood strip when height is 3 ft and less
- or
- For 2 or more shores, spaced up to 8 ft o.c., use longitudinal and X and/or V bracing as in Raker Shores.

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Slope Floor Lacing

SCT2a Slide 89

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Slope Floor Brace
When too short for lacing

SCT2a Slide 90

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Slope Floor X Bracing

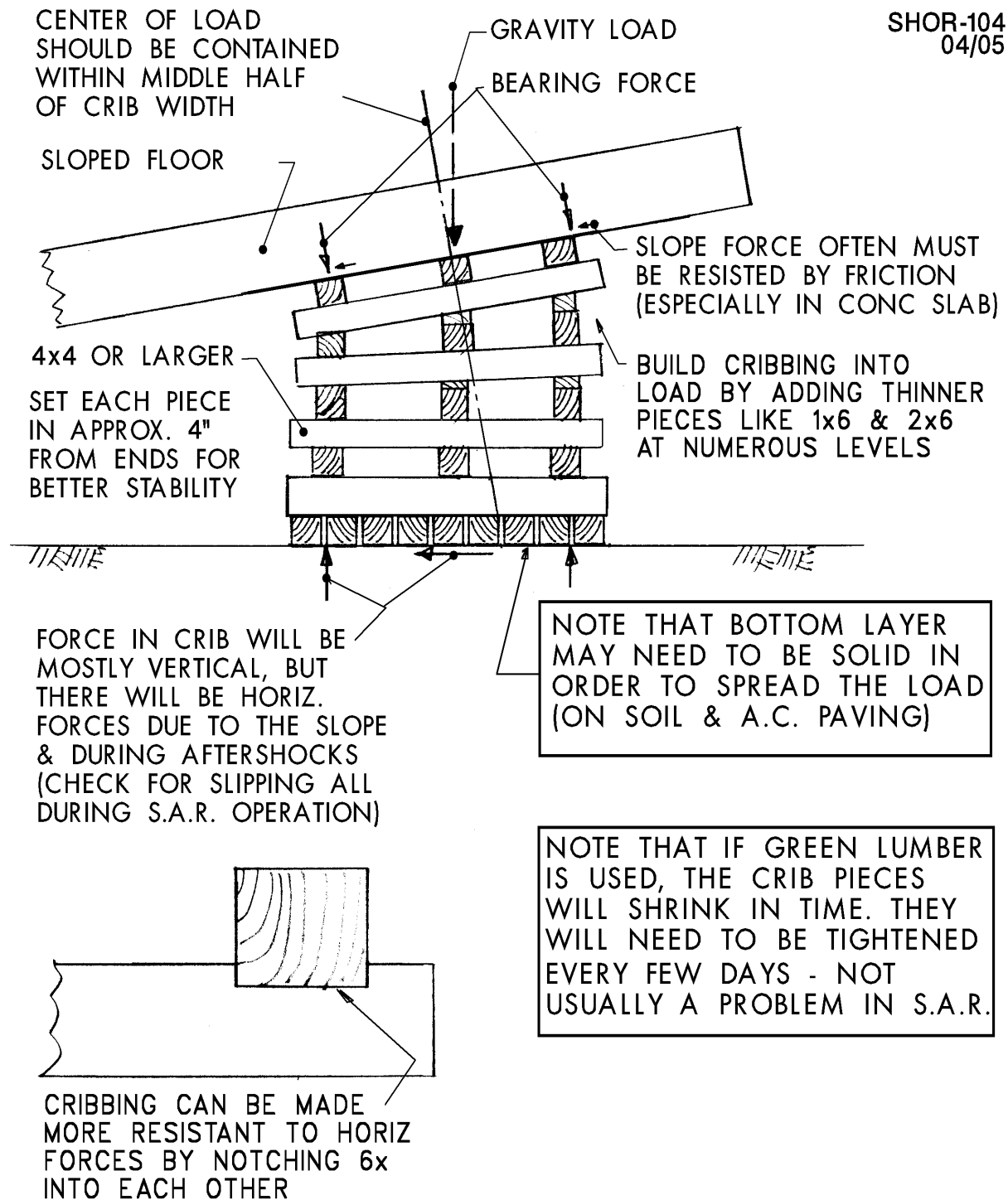
SCT2a Slide 91



VERTICAL SHORES ON SLOPED SURFACE – CRIBBING

SHORES FOR SLOPED FLOORS • CRIBBING • TYPE 4

SHOR-104
04/05





■ Summary for Sloped Floor Shores

- Sloped Floor Shores are complicated. No one solution will work for all conditions. Need to resist load in direction that it is tending to move.
 - To shore sloped wood floors the header needs to be placed perpendicular to the joist
 - Very adequate bracing is required
- Cribbing should be limited in height and slope
- Above 45 degrees, one should consider other alternatives.
 - Work with StS and develop solution that best fits the actual conditions.
- Perpendicular Bearing method works best in cases with concrete floors that are still somewhat connected.
- Friction Method requires a connection between header and the floor. That may not be possible in some wood floors.
- Capacity of a pair of well braced Sloped floor Shores:
 - Would always be less than a Laced Post system, and may be similar for angles less than 15 degrees.
 - The angular forces, adequacy of the bracing, and sole anchor strength can significantly reduce the capacity – especially over 15 degrees
 - The StS should always be asked to determine the size and number of shores that are needed.


LATERAL SHORING SYSTEMS

We will now discuss the Lateral Shoring Systems shown in the adjacent slide:

- **Principles of trench shoring** may sometimes need to be applied to US&R, where pulverized masonry rubble tends to cave into an otherwise accessible space.
 - As previously discussed, Pneumatic Shores may be used in vertical applications since they have positive locking devices
- There are several systems used as Lateral Shores, such as
 - Wood Horizontal Shores
 - Hydraulic Shores,
 - Pneumatic Shores,
 - Tieback Systems
 - Drilled-in Solid or Pole Systems.

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

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Summary (continued)

For sloped floor shores

- Perpendicular Bearing Method may work most of the time for concrete floors, since they usually remain connected to structure.
- Sloped Friction Method needs connection between header & floor to be reliable
- Capacity of a pair of well braced, sloped floor shores:
 - May be similar to but less than that of Laced Posts for angles less than 15 degrees (3 ft in 10 ft)
 - The angles and adequacy of the bracing can significantly reduce the strength, especially for steeper angles
 - Just as in Rakers, the capacity of the sole anchor is critical
 - The StS should always determine the design capacity

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Lateral Shoring Systems

- Horizontal Shores
- Trench Shores
- Raker Shores
- Tiebacks

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WOOD HORIZONTAL SHORES

- Are used in damaged buildings to support bulging walls.
- Horizontal wood posts are usually short their capacity is based on cross grain bearing strength (300 to 700psi)
- Wall plates are used to spread load from 2 or more posts.
 - Wedged are used to tighten the horizontal struts.
 - Bracing and cleats are added to complete each shore.
 - The normal **X** braces may need to be eliminated to allow for access, corner, plywood gussets are added to help connect corners and brace the shore

The shores are normally spaced at 8 feet on center, depending on the situation.

HYDRAULIC TRENCH SHORE

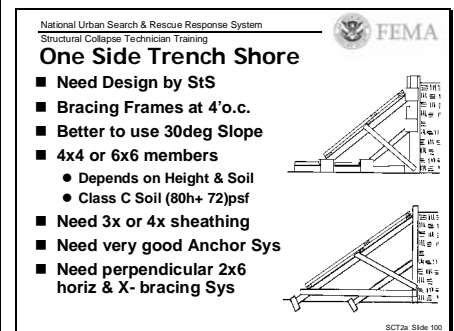
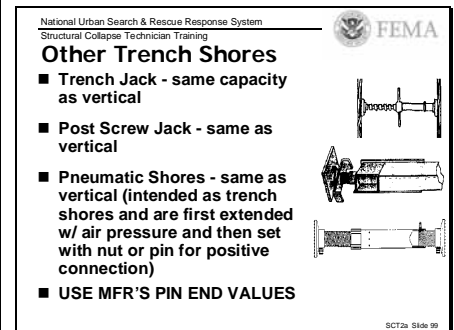
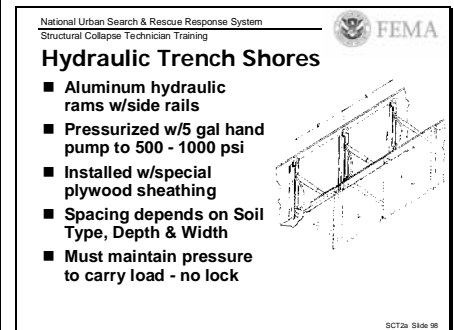
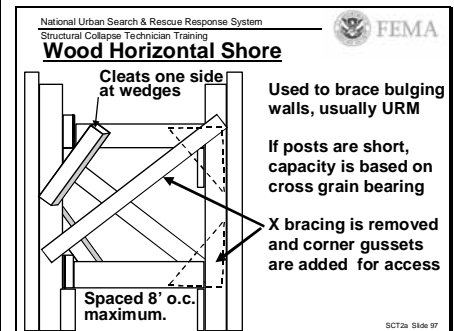
- These are frames made from aluminum hydraulic ram(s) with continuous side rails
- They are intended to be dropped into open trenches from the top and pressurized with a 5-gallon hand pump to between 500 - 1000 PSI.
 - Plywood panels are added against the soil to spread the load and confine soils.
 - There is no locking device as for pneumatic shores, therefore **hydraulic shores are not recommended** for supporting vertical loads.
- Hydraulic Shores can have a single ram with 2 feet long rails or double rams with rails up to 12ft long. Standard double ram frames have rails in 3.5ft, 5ft and 7ft lengths

OTHER TRENCH SHORES

- Trench Jack (Screw Jack)
- Post Screw Jack
- Pneumatic Shore
- All have same capabilities as in vertical application.

ONE-SIDED TRENCH SHORE

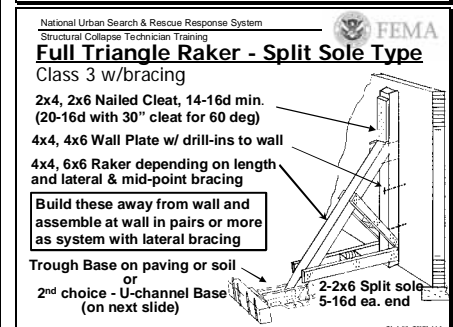
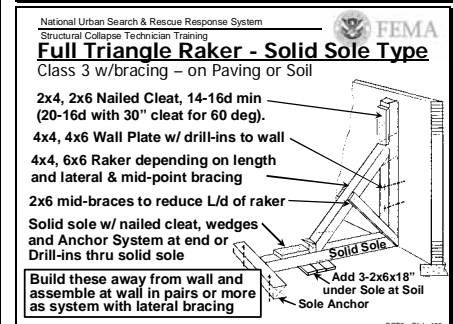
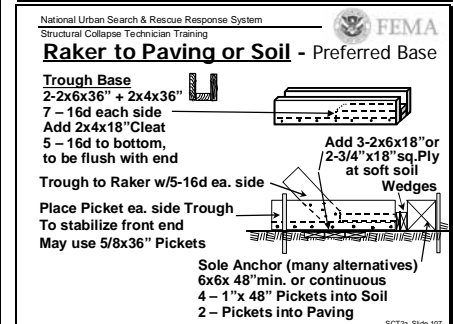
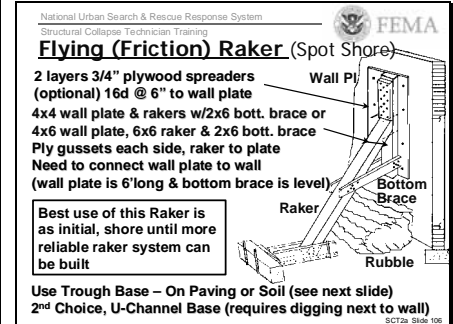
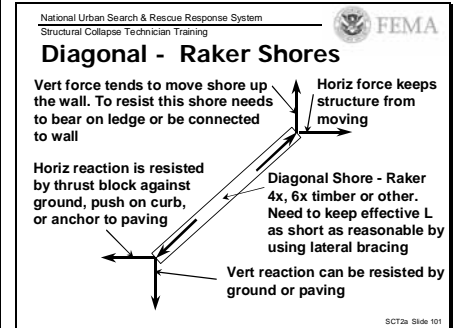
- This type of shoring is needed when one side of a trench has caved-in, or for basement excavation cave-ins.
 - This type of shore needs to be designed by a qualified Structures Spec
 - If no Soil Evaluation is available, one must assume Class C Soil (Uniform Pressure = $80h + 72\text{psf}$)
- Bracing Frames (like Double Rakers) may be placed 4ft o.c.
 - Use 30 or 45deg slope with 4x4 or 6x6 members, depending on height
 - Sheathing between Frames may need to be 3x or 4x
 - Anchor System is very important
 - Perpendicular Bracing needs to be installed





RAKER SHORES

- Useful in bracing URM and other heavy walls that have cracked, (especially at corners) and/or are leaning away from building.
- Need to be configured in system that will account for both vertical and horizontal components of force in diagonal member
- The vertical component may be resisted by:
 - Friction, which may be increased in a full triangular configuration, by applying more horizontal load at the base, against the wall. However, friction should not be considered as reliable, especially during aftershocks.
 - By placing drilled-in anchors thru the wall plate into the masonry. (This may be too dangerous in some areas of badly cracked walls)
 - By bearing the wall plate against a projection in the wall surface, or by placing the raker at an opening and nailing a cleat onto the plate so that it will bear on the opening head.
- The required horizontal force may be less than two percent of the wall weight, since URM walls are seldom left standing very far out of plumb. However, since aftershocks are likely to occur, raker systems should be designed for about 10 percent of the weight of the wall and roof that is within the tributary area that they support.
- Rakers should be built away from dangerous area next to wall and then carried/walked into place
 - Rakers should be spaced at 8ft maximum on center
 - When the Insertion Point is greater than 8ft, the Raker needs to be configured with a mid-height brace
- Rakers may be configured using the Full Triangle method (called Fixed raker) or as a Flying Raker (Friction Raker)
 - Full Triangle Rakers may be configured as Solid Sole or Split Sole Rakers
 - The preferred **Solid Sole Raker** may be built on Concrete, Paving or Soil.
 - The **Split Sole Raker** may also be built on Concrete, Paving or Soil. Since the Sole/Bottom Brace may be sloped, this Raker may be constructed in locations where some rubble is present next to the base of the wall.
 - Full Triangle Rakers should always be built in groups of 2 or more, with Lateral Bracing Systems connecting them together (see following pages)





RAKER SHORE SYSTEMS

DIAGONAL (RAKER) SHORES

SHOR-12 8 06/08

VERTICAL FORCE TENDS TO CAUSE SHORE TO MOVE UP THE WALL. TO RESIST THIS, THE SHORE NEEDS TO BEAR ON A LEDGE OR BE CONNECTED TO WALL

*Don't rely on friction
Think aftershocks
and wind*

HORIZ. FORCE TENDS TO KEEP WALL AND/OR BUILDING FROM MOVING

DIAGONAL SHORE - MAY BE 4x OR 6x DEPENDING ON ITS LENGTH BETWEEN POINTS WHERE LATERAL BRACING IS PROVIDED *IN EACH DIRECTION*

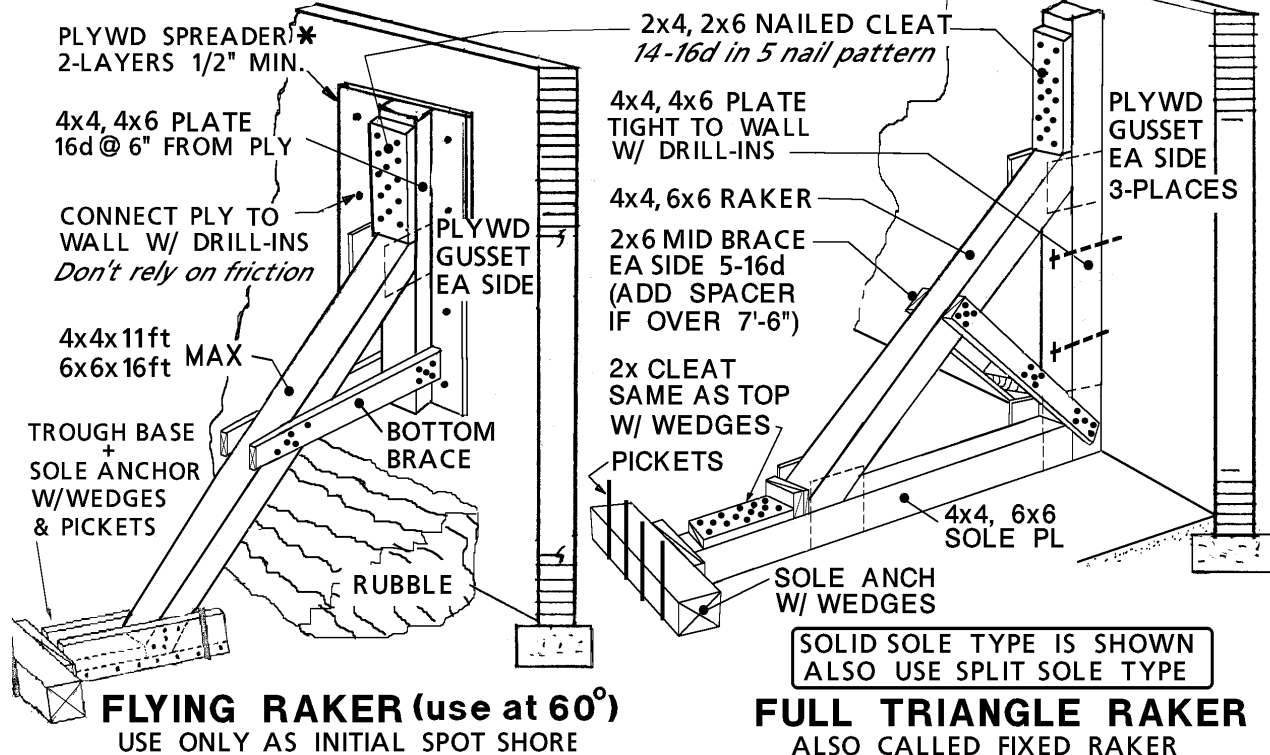
4x should have mid point bracing if over 11ft long
6x " " " " " " " " 16ft "

HORIZONTAL REACTION MAY BE RESISTED BY CUTTING THRUST BLOCK INTO GROUND, BY PUSHING AGAINST CONCRETE CURB, OR BY SOLE PLATE WITH CLEATS, WEDGES, & ANCHORS

VERTICAL REACTION NORMALLY CAN BE RESISTED BY GROUND, PAVING

FORCES IN RAKER SHORES

* = may need to use spreader at either type if wall is badly cracked

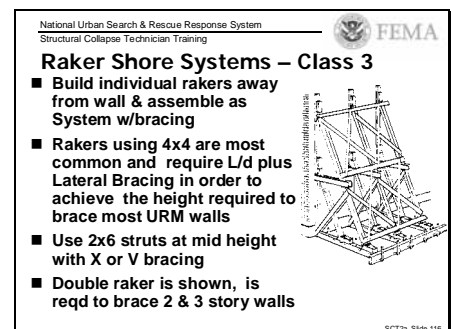
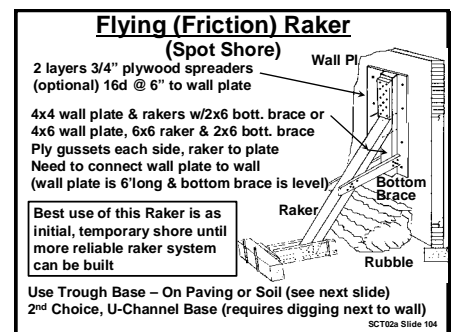
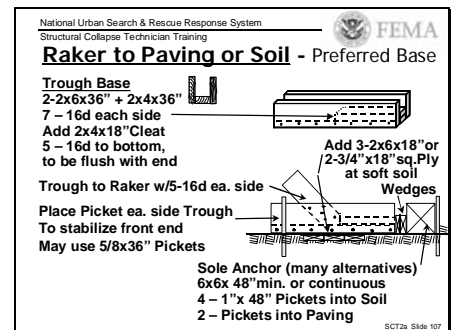
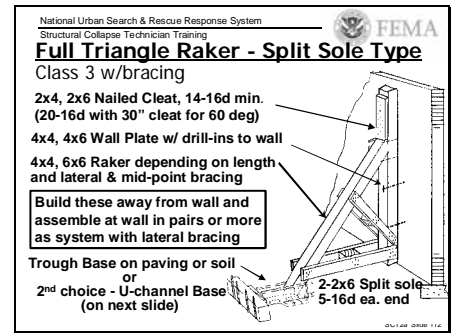


EXCEPT FOR INITIAL, TEMPORARY STABILIZATION, RAKER SHORES SHOULD BE BUILT IN SYSTEMS OF TWO OR MORE, WITH LATERAL BRACING BETWEEN THEM



RAKER SHORES (continued)

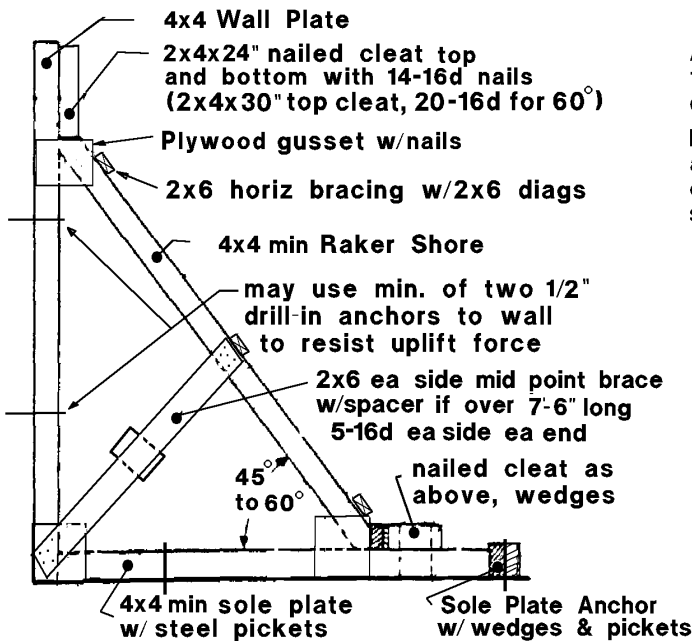
- The capacity of Rakers is usually limited by the nailed cleat connections, and/or the connection to the ground.
 - A Trough Base may be used along with a Sole Anchor for Flying and Split Sole Rakers that bear on Paving or soil. This base is preferred, since it keeps the rescuers farther from the collapse zone during its installation.
 - As a second choice, U-channels may be used to connect the shore to soil for Flying and Split Sole Rakers. A 18" sq foot is added for the Split Sole. This base does require rescuers to dig-in the base, within the wall's collapse zone.
- It is difficult to obtain lumber over 20 ft. long, but splices may be made in rakers as long as they are located near where the diagonal and lateral braces connect. (SHOR-14) Use $\frac{3}{4}$ inch plywood x (width of Raker) x 3ft each side of splice, nailed with 8-8d each side each end.
 - Also 1x4x3ft may be used to splice the Raker, with same nailing as for plywood (more splitting may occur)
- Flying Rakers can be used as Spot Shores to temporarily restrain a wall that has rubble piled up near its base (without removing it). Flying Rakers are intended for only limited use.
 - Unless there are some special conditions, Flying Rakers should be quickly constructed using:
 - Six foot wall plate with a 24" cleat (14-16d nails)
 - A pair of 2x6 as bottom brace, placed at 90 degrees to the wall plate
 - Configure at 60 degrees & and use a Trough Base
 - In most conditions, it is recommended to initiate wall stabilization by using either a Solid Sole or Split Sole, full triangle raker system
- Lateral bracing, consists of continuous horizontal struts (capable of resisting compression and tension) and diagonal bracing (in either V or X configuration)
 - When the height of Raker required a mid-brace, horizontal struts are placed at the bottom, mid and top of the Raker
- Solid Sole Rakers can be built into tall, multi-raker configurations using 4x4 members with lateral bracing to bring the L/D ratio to between 35 and 40. (SHOR-14R)
 - Multi-raker is fairly complicated, but shows how the smaller timbers can be used in a system to stabilize a two-story wall. Note that the bracing needs to be placed in two mutually perpendicular directions.



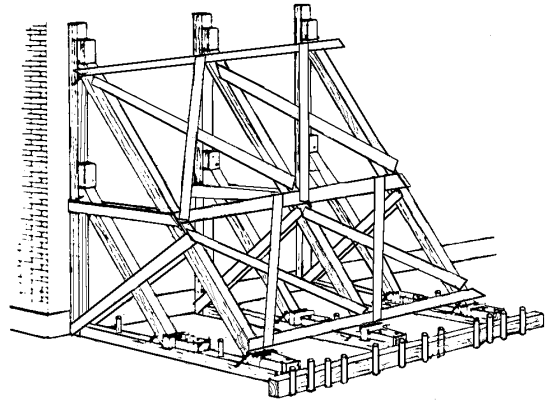


RAKER SHORE SYSTEMS

SHOR-14 R 09/06



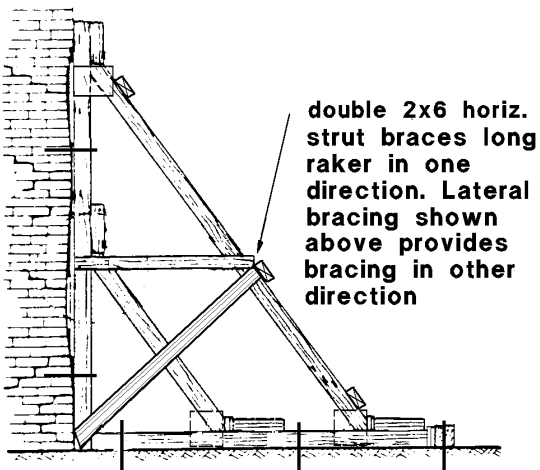
All systems using 4x4 members over 11ft long should be braced in two directions in order to limit L/D to 25±. Its better to have a 2x6 continuous at top, mid, & bottom w/ X-braces every forty ft or so than what is shown here.



PREFERRED FULL TRIANGLE RAKER SHORE CONFIGURATION (SOLID SOLE FULL TRIANGLE RAKER)

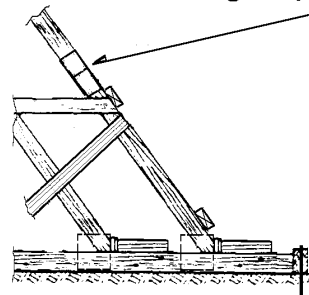
RAKER SHORE FRAMES MUST BE BRACED

Double configurations allow 4x4 members to be used in taller walls by providing bracing to reduce L/D to 35 or so



4x & 6x Rakers may be spliced using 36" long plywood strips x full width of Raker, placed each side. Splice needs to be located near intersection of lateral braces with raker. 8-8d in 5 nail pattern to each Raker, each side.

Use 1x material, same size as plywood if ply not available (with same nailing as ply)

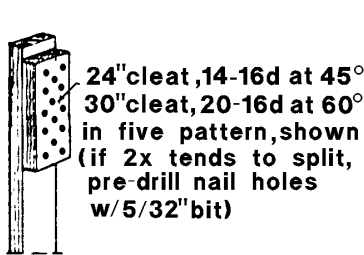


DOUBLE DIAGONAL

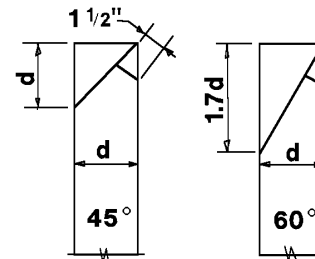
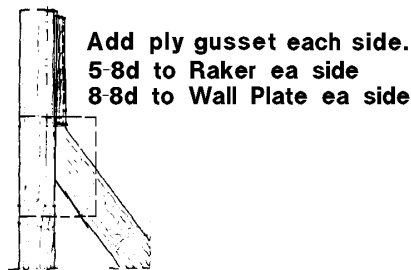


RAKER SHORE CONNECTIONS

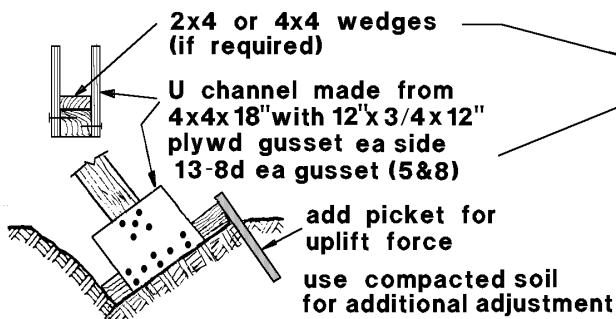
SHOR - 15 8 06/08



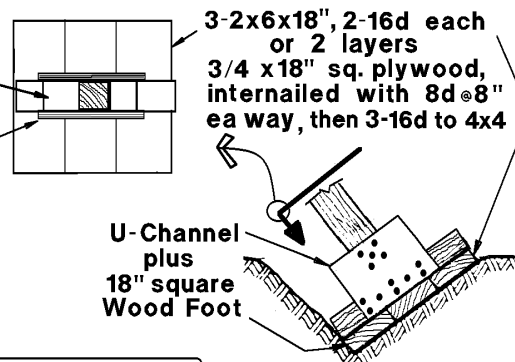
NAILED TOP



RAKER END CUT

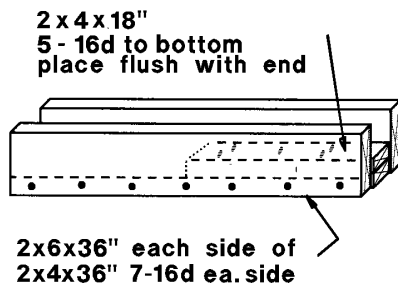


AT FLYING RAKER

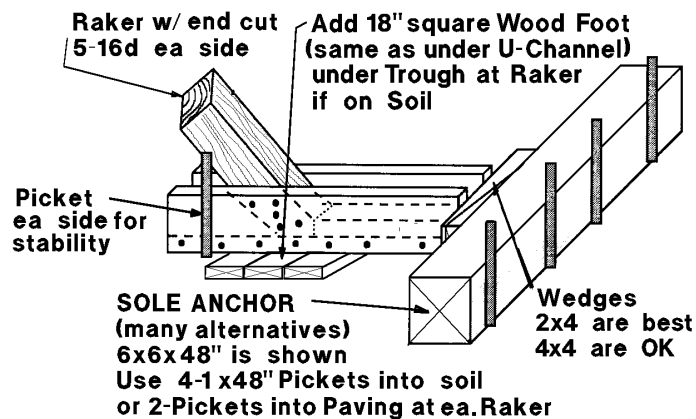


AT SPLIT SOLE RAKER

DETAILS at U-CHANNEL BASE



TROUGH DETAIL



DETAILS at TROUGH BASE

Preferred Base at Split Sole & Flying Rakers. No need for digging

FABRICATION AND ERECTION

- ALL RAKERS SHOULD BE FABRICATED IN AN AREA AWAY FROM A DAMAGED MASONRY WALL, SINCE AFTERSHOCK COULD CAUSE COLLAPSE
- AFTER FABRICATION, THE RAKERS NEED TO BE CARRIED OR WALKED TO THE WALL, AND ADJUSTED FOR TIGHT FIT.



LATERAL SHORING SYSTEMS (continued)

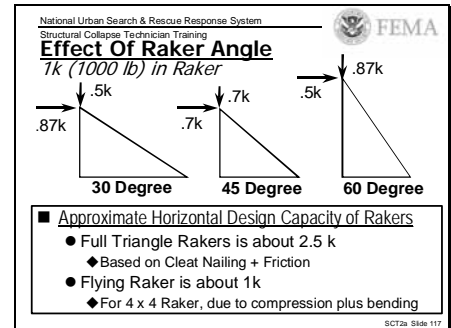
RAKER ANGLE

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

- If the angle is 30 degrees, the horizontal force applied to the wall is 87% of the force in the diagonal, and the upward force that needs to be resisted at the wall face is only 50% of the diagonal force. Limited access may be a problem
- When the angle increases to 60 degrees the horizontal is 50%, and the vertical is 87%.
- At 45 degrees the two are equal at 71% of diagonal force.
- The disaster "field" conditions such as need for access, available timber length, and/or clearance, normally limit the choice to either 45 or 60 degrees.
 - The simplest to build are 45 degrees (1 to 1) and 60 degrees (1.7 to 1). Both are extensively used in US&R
 - The 60-degree angle is preferred for the Flying Raker, and the Split Sole Raker when a U-channel Base is used (better bearing capacity of soil)

RAKER SHORE CONSTRUCTION

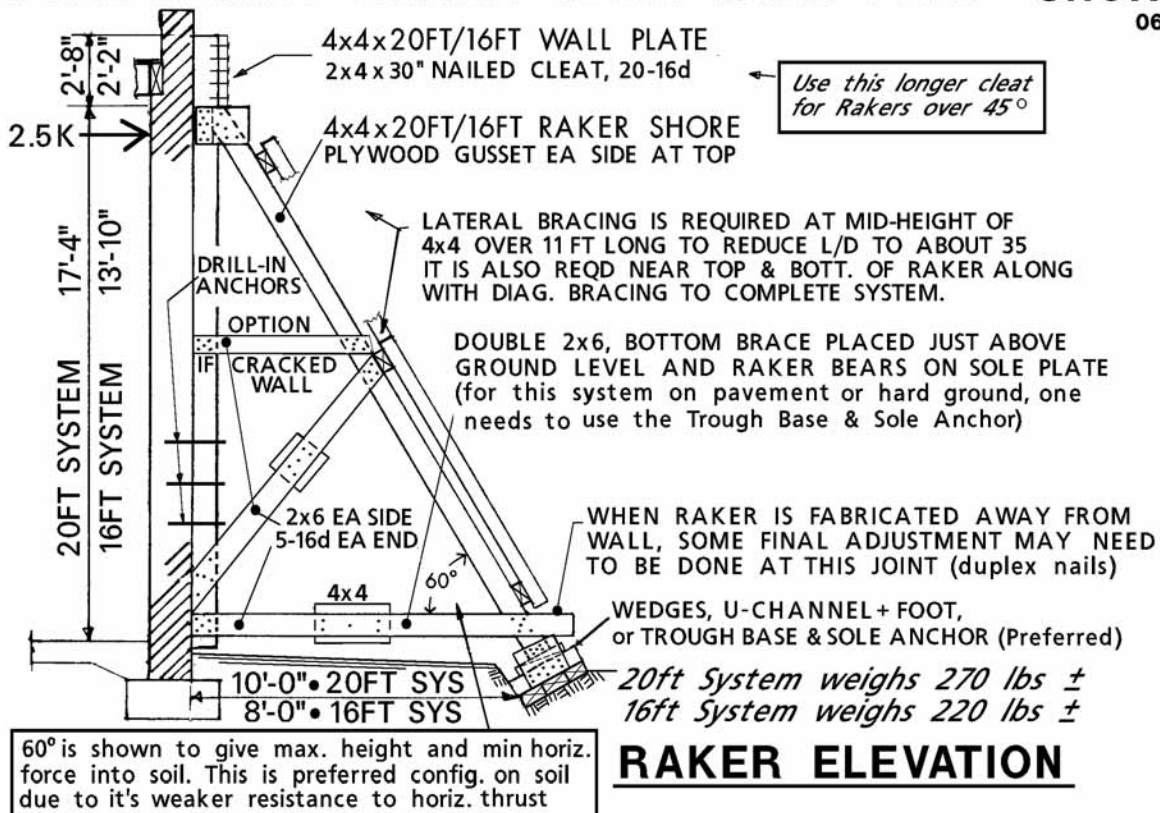
- The Design Strength of individual, single, full triangle Rakers is in the range of 2500 lbs. (2.5k). This is normally sufficient to brace most masonry or concrete walls up to about 20 ft high.
 - This is the capacity based on the horizontal load of the wall. (The force in the sloped Raker member may be as much as twice the horizontal load)
 - The 2500 lbs is based on the cleat nailing of 14-16d nails plus some friction between the Raker and its bearings.
 - The Design Strength of Flying Rakers is about 1000 lbs (1.0k) based on a 4x4 Raker that may need to resist bending plus compression (if the wall bulges).
- The full Triangle Rakers can be configured with a split sole plate (SHOR-17, next page), which is most useful for bearing on ground. This example shows how a 4 x 4 lumber x 20 ft. long can be used to brace a 20 ft. wall.
 - Lateral bracing is required at mid-height of the 4 x 4 in each direction.
 - Overall lateral bracing is required to stabilize the system of Rakers, especially during aftershocks.
- A second configuration of full Triangle Raker is shown with solid sole plate (SHOR-18). This is most useful where paving is found next to the wall. It has the same L/D and overall bracing requirements as the split sole type.



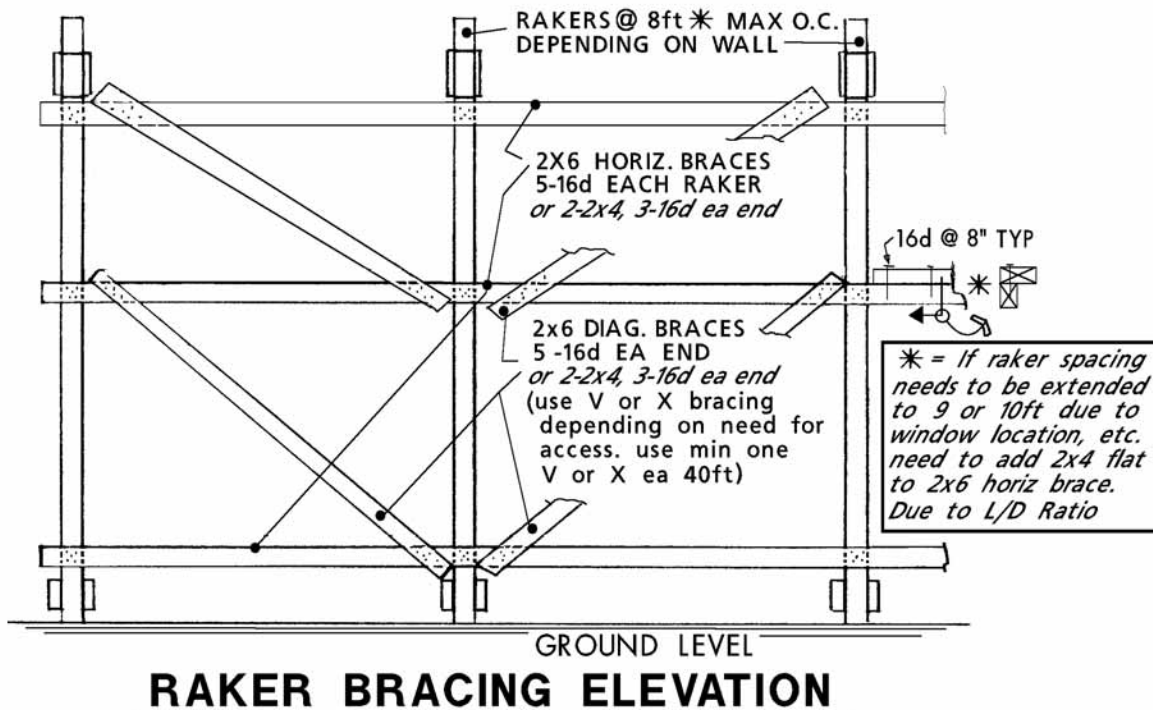


FULL HEIGHT RAKER • SPLIT SOLE TYPE SHOR-17₈

06/08



RAKER ELEVATION

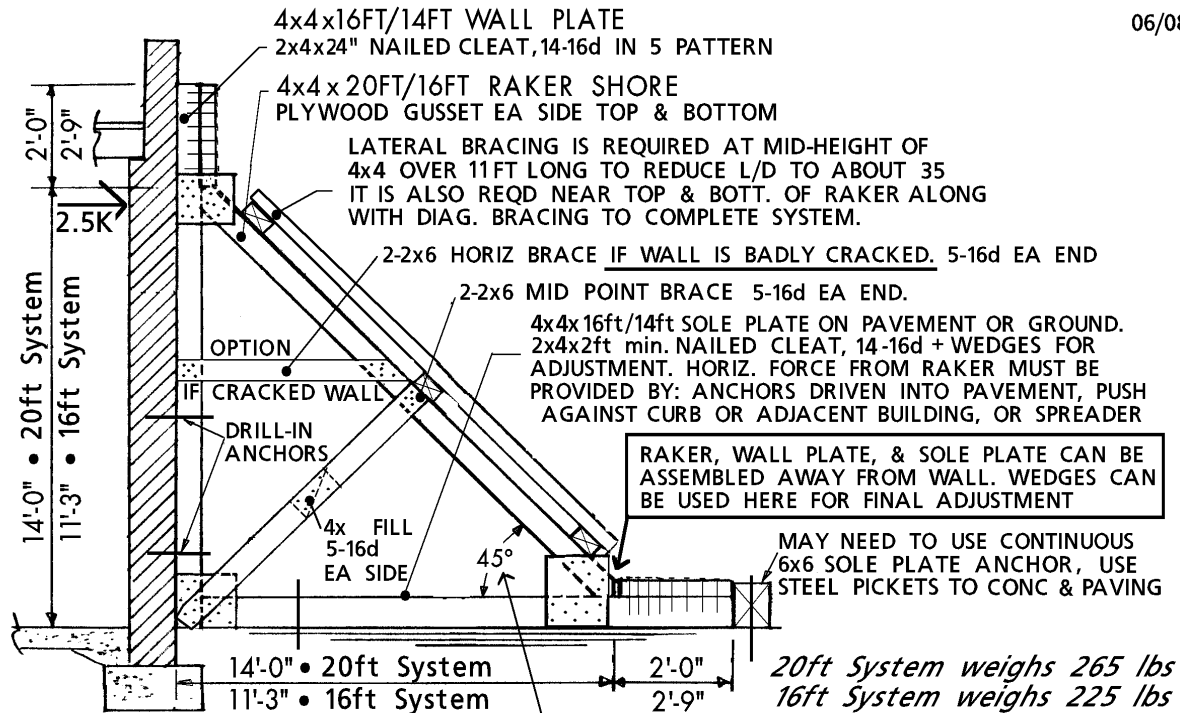


RAKER BRACING ELEVATION



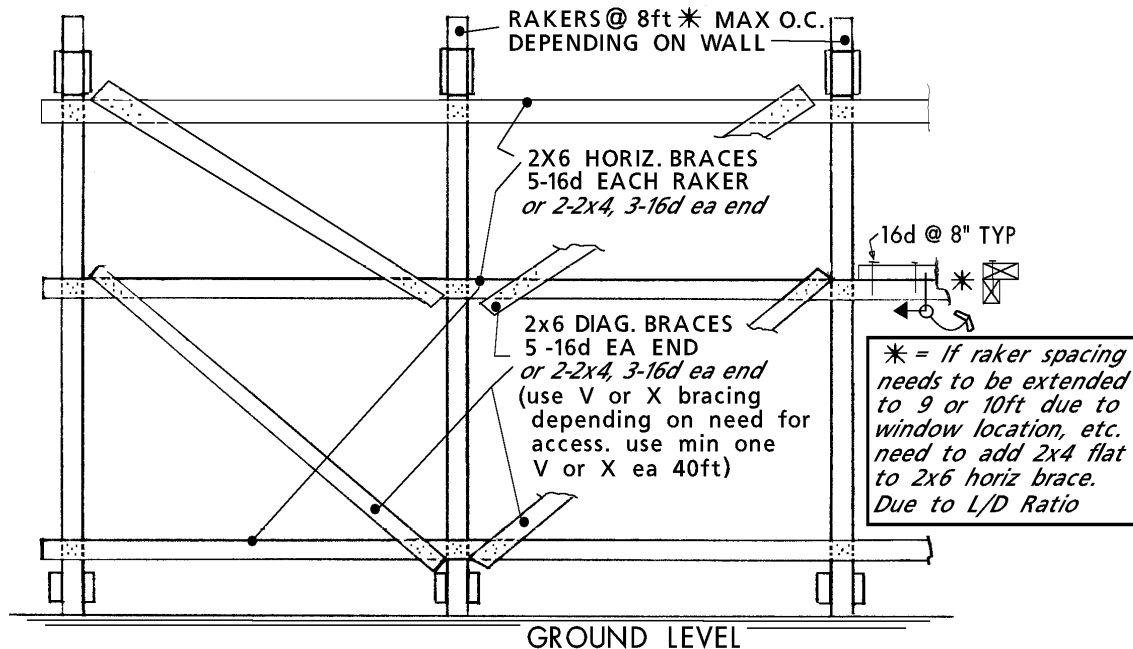
FULL HEIGHT RAKER • SOLID SOLE TYPE SHOR-18₈

06/08



45° is shown as simplest sys for on paving. 60° config would be preferred on soil, since horiz thrust at ground is less and height reached on wall is greater.

RAKER ELEVATION



RAKER BRACING ELEVATION

LATERAL SHORING SYSTEMS (continued)

PNEUMATIC SHORES USED AS RAKERS

A quick, temporary raker can be constructed using pneumatic shores. (See Shor-16a on next page)

- They can be used as individual units, but should be configured in a system of two Rakers that are interconnected with 2x6 wood bracing.
- Special rails and connections are available from Airshore and Paratech, as well as base plate and bracing connections.
- Load values for both are shown in adjacent slide and StS FOG Sect 7


TILT- UP WALL BRACES

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

TIEBACKS

- When URM walls are over thirty feet tall it is probably impractical to attempt to brace them with raker shores.
- Vertical and/or horizontal strongbacks could be placed on the face of a hazardous wall and tied across the structure to a floor beam or the opposite sidewall. (See Shor-16a on next page)
- The strongbacks could be made from double 2x6 wood members with the tie being placed between them. Solid 4x or 6x members could also be used.
- The ties that have been placed by contractors were steel rods with turnbuckles, bearing washers etc. Cables with come-along could also be used as well as utility rope, chain, etc. One may need to be creative to obtain an adequate tie, but climbing rope, used by firefighters should be considered only as a last resort. (Climbing rope is considered unreliable with the rough treatment of this type of application and would be discarded)

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Recommended Design Strength

for *AIRSHORE* Struts Raker System


- System is made from 2 rakers spaced 8ft max. apart with X-bracing.
- Rakers need to be attached to wall surface and restrained at ground.
- For use 45 degree angle.

Raker Length	Height to Insertion	Horiz. Design Load on 2 Rakers w/ X-bracing
16 ft	11.0 ft	4200 lbs
15	10.5 ft	4800
14	10.0 ft	5400
13	9.0 ft	7100
12 & less	8.5 ft	10,000 lbs

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 **FEMA**

Recommended Design Strength

for **AIRSHORE** Struts Raker System

- 2 rakers spaced 8ft max. apart with X-bracing
- Rakers need to be attached to wall surface, and restrained at ground.
- For use 60 degree angle.

Raker Length	Height to Insertion	Horiz. Design Load on 2 Rakers w/ X-bracing
16 ft	13.8 ft	3000 lbs
15	13.0 ft	3400
14	12.0 ft	3800
13	11.3 ft	5000
12	10.4 ft	7100
11 & less	9.5 ft	10,000 lbs

©/Tza Slide 134

Recommended Design Strength for *PARATECH* Struts Raker System

- System is made from 2 rakers spaced 8ft max. apart with X-bracing.
- Rakers need to be attached to wall surface and restrained at ground.
- For use **45 degree angle.**


Raker Length	Height to Insertion	Horiz. Design Load on 2 Rakers w/ X-bracing
16 ft	11.0 ft	5000 lbs
15	10.5 ft	6400
14	10.0 ft	7800
13	9.0 ft	9200
12 & less	8.5 ft	10,600 lbs


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Tilt-up Wall Bracing


Spot Shores w/conn ea end






FEMA

- Can be used to brace reinforced concrete or masonry wall
- Use Drill-in Anchors for connections to wall & floor slab.
- Can act in Tension or Compression



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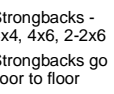


FEMA

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Tieback Systems

- Use to keep wall from falling when too high for Rakers
- Strongbacks - 4x4, 4x6, 2-2x6
- Strongbacks go floor to floor
- Tiebacks - rope, cable, chain
- Extend tiebacks across bldg or tie to floor bms or columns



SCC-10, Slide 21

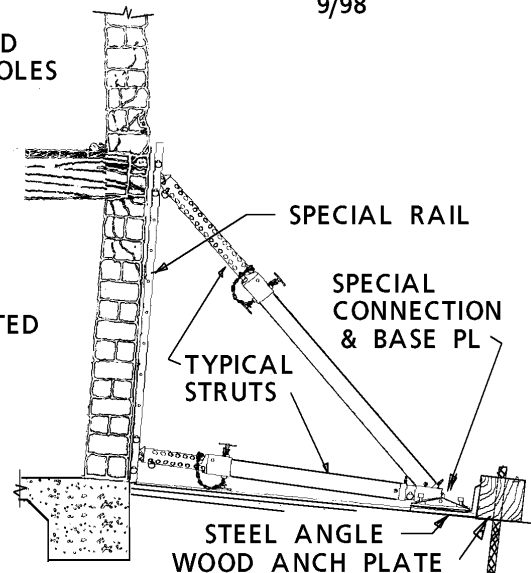


PNEUMATIC STRUTS USED AS RAKERS

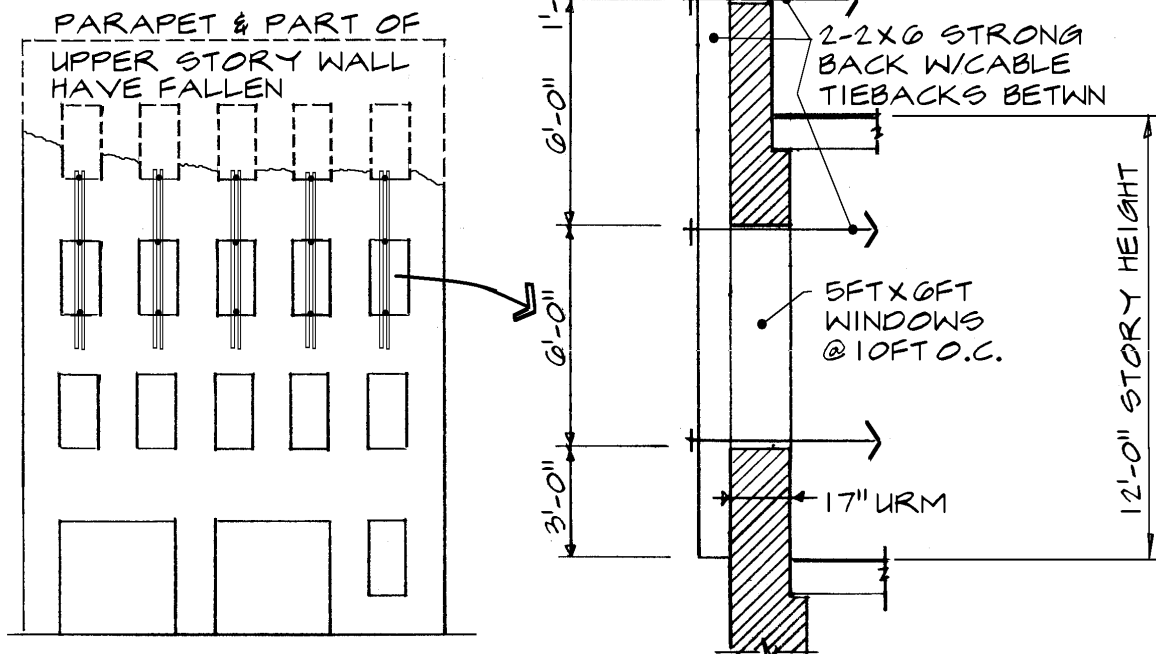
- INDIVIDUAL RAKERS CAN BE CONFIGURED FROM TWO STRUTS (UP TO 16FT LONG) AND A SPECIAL RAIL THAT HAS CONNECTION HOLES
- MANUFACTURED BASE PLATE CAN BE CONNECTED TO PAVING THRU EXISTING HOLES USING STEEL BARS/DRILL-INS. STEEL ANGLE CAN BE ADDED UNDER BASE PLATE TO PROVIDE SURFACE TO BEAR ON TYPICAL WOOD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

SHOR-16a

9/98



WALL TIEBACKS



4 STORY U.R.M. OFFICE BUILDING TYPICAL WINDOW SECTION

- THE STRONG-BACKS COULD BE MADE FROM 4x4, 4x6, OR 2-2x6.
- THE STRONG-BACKS SHOULD EXTEND FROM FLOOR TO FLOOR IN ORDER TO HAVE THE FLOOR PLANES TO PULL AGAINST.



LATERAL SHORING SYSTEMS (continued)

SHORING SYSTEMS USED IN US&R

The Special Medical Response Team, a group of medical first responders organized to aid mine collapse victims, has a plan to use a combination of pneumatic shores and cribbing to assure vertical support in order to provide medical care within the collapse. They first set the pneumatic shores and then follow with the cribbing.

STABILIZE WOOD APARTMENT

The House Moving Contractor, R. Trost, provided emergency shoring after the 1989 Loma Prieta Quake for twenty-five buildings in the San Francisco Marina District. The 3 & 4 story wood buildings were out of plumb in the first story as much as 2 feet. As shown in SHOR-21 & 22, they provided lateral stability by placing 6x8 diagonal shores from the inside of the street curb to the second floor, and added 6x6 diagonals in doorways. They later placed story high cribbing and large steel beams to provide better vertical support, and allow for later straightening of the buildings.

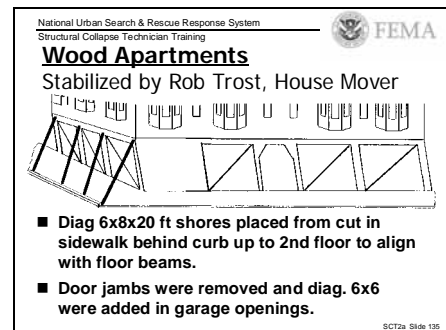
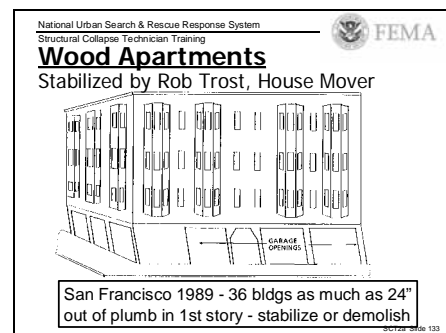
- One must carefully consider where this type of bracing is connected to the structure in order for it to effectively obtain a vertical reaction while it is providing the horizontal resistance

STABILIZE TALL HIGHWAY STRUCTURES

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

USE OF NON-TRADITIONAL SHORING DEVICES

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





SHORING FOR SPECIFIC BUILDING TYPES


SHORING for LIGHT FRAME, MULTI-STORY BLDGS

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

SHORING FOR URM BUILDINGS (HEAVY WALL)

- URM walls may be cracked (especially at corners) or peeled and need diagonal/raker shores.
- Cracked URM walls may also require shoring of openings.
- When URM exterior walls have collapsed, the remaining wood floors may require vertical shoring.
- Floors often collapse into the following patterns:
 - **LEAN-TO** - shoring is usually required under the suspended floor and possibly on the outside wall, opposite where the floor is still connected. Victims might be found under the suspended floor and on top of this floor at the lowest end
 - **V-SHAPE** - shoring is usually required under the two suspended floor pieces and possibly on the outside walls, opposite where the floors are still connected. Victims might be found under the two suspended floor pieces and on top of the floor in the middle of the V.
 - **PANCAKE** - shoring is usually required under the floors. Victims might be found under the floors. Voids are formed by building contents and debris wedged between floors
 - **CANTILEVER** - this type is similar to the pancake pattern with the added problem of some of the floor planes extending, unsupported from the debris pile. Shoring is usually required under and above the floors starting at the lowest level. Victims might be found under the floors as in the pancake condition.

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Most Probable Shoring

For Common Bldg Types

- Student Manual contains suggestions for the following types of buildings:
- Light Frame
- URM - Heavy Wall
- TU - Heavy Wall
- C1 - Concrete Frame Heavy Floor
- PC2 - Precast Concrete

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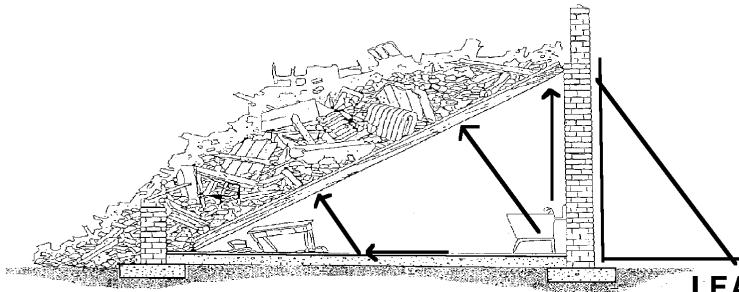


SHORING FOR SPECIFIC BUILDING TYPES (continued)

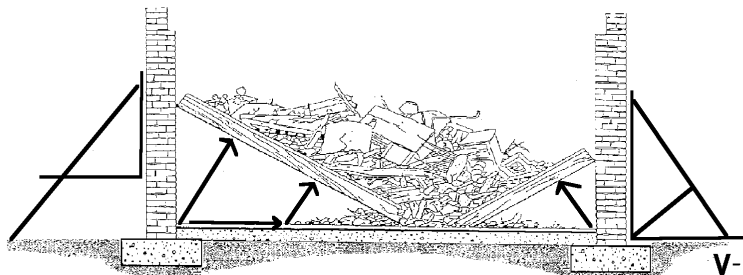
URM WALL / WOOD FLOOR COLLAPSE PATTERNS

SHOWING POSSIBLE SHORING LOCATIONS

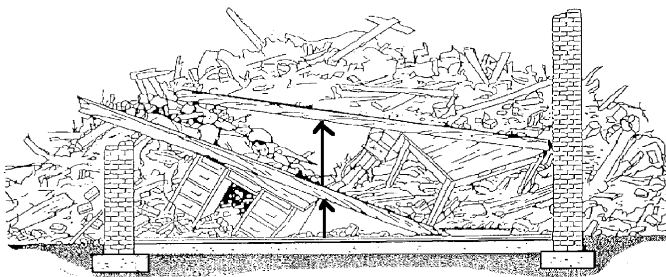
SHOR-23s 9/98



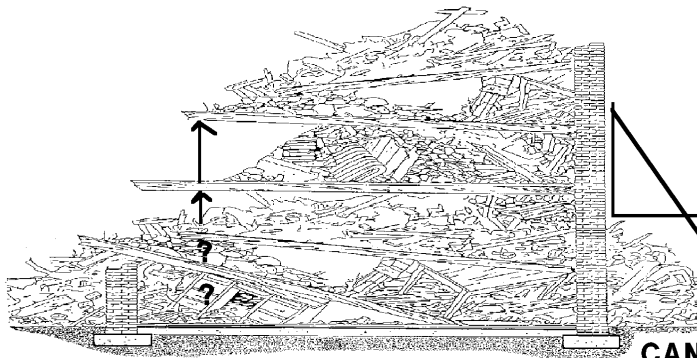
LEAN-TO FLOOR COLLAPSE



V-SHAPE FLOOR COLLAPSE



PANCAKE FLOOR COLLAPSE



CANTILEVER FLOOR COLLAPSE
(pancake with extended floor)



SHORING FOR SPECIFIC BUILDING TYPES (continued)

SHORING FOR REINFORCED CONCRETE BUILDINGS

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

SHORING FOR PRECAST CONCRETE STRUCTURES

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




INSPECTION OF US&R SHORING

- Following its installation, US&R Shoring should be periodically inspected. The Structure Specialist should perform inspections at the following times:
 - Just prior to and/or following the 12-hour shift change.
 - Following any significant change in loading, such as following Earthquake Aftershocks, when expecting and following the occurrence of High Winds, and following any secondary disturbance like a secondary explosion
 - Prior to and following the removal of significant amounts of debris
- Properly proportioned shoring with adequately braced posts, should be considered as a crude "Load Cell".
 - When the posts are braced so that buckling is limited, a slow failure can be achieved. In order to achieve this the effective L/D should be limited to between 20 and 25 for each post (in each direction).
 - Signs of overload should be able to be seen at approx 150% to 200% of Design Load
 - One should then be able to observe:
 - The cupping of wedges
 - Crushing of the Header under its contact with the post
 - Splitting of the Ends of the Header

Note that Header-end splitting is caused by the Catenary Action of the longitudinal wood fibers that are trying to resist the vertical forces applied by the Post. As these fibers are crushed, they indent and form the catenary that, then, induces Longitudinal Tension Forces in the bottom one inch or so of the Header. The Tension Forces then cause the Header to split along a soft, Spring-Wood plane


- The Struct. Spec. will need to take Appropriate Action, when any sign of Overload is observed
 - Appropriate Action could include:
 - Adding shores inline with the existing ones, or at a location that will reduce or share the load.
 - Re-evaluate the entire situation, since the structure may be responding differently than expected
 - Re-assessing the original design to check for errors in assumptions, and/or calculations

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Inspection of US&R Shoring

- Should be done at each Shift Change + following any known loading change
 - Aftershocks, Winds, Secondary Explosion
- Properly proportioned Wood Shoring should be considered as a crude Load Cell
- What are the signs of Overload?
 - Cupping of Wedges
 - Crushing of Header at Post
 - Splitting of Header at end of O Hang
 - Indicates about 1.5 to 2 times Design Load

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Inspection of US&R Shoring

- Overloading requires "Appropriate Action" by StS
- Overloading could indicate:
 - More Shores are needed
 - That structure is responding differently than expected, and need to Re-evaluate entire situation.
 - That something was wrong with the original design


SCT2a Slide 14E



SUMMARY FOR EMERGENCY SHORING OF STRUCTURES

- Shores need to be strong, light, portable, adjustable, and reliably support the structure as gently as possible.
- Systems should be used that are positively interconnected, laterally braced, and have slow, predictable failure mode.
 - A typical shoring scenario would begin with the placement of Spot Shores (Class 1) to initially stabilize, followed by
 - Individual multi post shore systems with in-plane bracing, (Class 2) followed by
 - Pairs (or greater numbers) of multi post shores that are X braced together as two-dimensional systems. These would be called Class 3 Shores (3-dimensional)
 - As just discussed, periodic inspection of US&R Shoring is essential. It should be made part of the every day checklist.
- Braced Wood Post Systems and Cribbing are desirable since they can be constructed to have the following properties:
 - Made from light pieces that are adjustable & can be built into most any conceivable situation including sloped surfaces
 - Relatively wide and stable. Will spread the load.
 - Can be proportioned to have slow failure mode that will give warning
- Testing of Rakers, Laced Posts, Paired Double Tees and Cribbing has been done as a port of Advanced Struct Spec Training (StS2) starting in Sep04. These test have indicated:
 - As long as the Sole Anchors are adequate, properly braced Rakers can resist up to 6 times Design Load before failure.
 - More than 20 Raker Pairs have been tested as of May08
 - The high Safety Factor is justified, since it is very difficult to calculate what Lateral Force to Rakers will be subjected to during the term of an incident.
 - Since rakers are designed and constructed to resist lateral forces, earthquake aftershocks may apply very high loads to rakers, so what may appear to be excess capacity, turns out to be needed protection for Rescuers.

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US&R Shoring Summary

- Shores - strong, light, portable
- Support as gently as possible
- Need slow, predictable failure mode.
 - Use wood posts with L/D = 25 or less
- Systems - positive connections & bracing
 - Start with Class 1 (1-dimensional) Spot Shores, then progress to
 - Class 2 (2-dimensional) Shores, and eventually upgrade to
 - Class 3 (3-dimensional) Systems
- Periodic Shoring Inspection is Essential

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US&R Shoring Summary (continued)

- Testing has been helpful – Part of StS2 Training
 - Raker Shores – What is Failure Mode?
 - Laced Posts - What configurations are better?
 - ◆ Load at which initial "Wedge Cupping" occurs
 - ◆ Does spaced Ply Bracing Work as well as 2x Diagonals
 - Double Tees – Paired like Laced Posts
 - ◆ Can they perform as well as Laced Posts to 17 ft high
 - Cribbing – Explore ways other than friction to transfer of lateral forces.
 - ◆ Observe just how much system deflects
 - What amount of friction is developed between Concrete Slabs and Wood Shoring?
 - ◆ On level or sloped surfaces

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Review Key Learning Points

- What is Size and Type of Load that needs to be supported?
 - The weight of the supporting structure plus its overload, or just its overload
 - Broken Structure or Rigid Structure
- How much Shoring do you need?
 - Should Shoring be similar to a Life Jacket? – Providing just enough lift to keep one afloat
 - Some portion of the load can be (is being) carried by the un-shored structure

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SUMMARY FOR EMERGENCY SHORING OF STRUCTURES

- Testing of Rakers, Laced Posts, Paired Double Tees and Cribbing (continued)
 - Laced Posts normally fail at just above 3 times allowable load. Cupping of wedges can normally be observed as soon as the load exceeds 1.5 times allowable load. Horizontal Splits often form in the ends of the Header Overhang when load exceeds 2 times allowable.
 - Failure occurred when individual posts were broken and diagonal braces come free from their connections.
 - Over 18 Laced Posts have been tested – as of May08
 - Therefore, the wedges can be observed as a good indication of Shore Overload – a Structural Fuse
 - Paired Dbl-T failed at from 85% to 100% of the load at which Laced Posts failed. However, only 7 have been tested as of May 2008. – more tests are planned using more extensive plywood bracing, ½” plywood instead of ¾”, and using OSB.
 - Two Tests of Cribbing have been done by end of 2005
 - Tests indicated that 6ft high cribs (4x4x 48” pieces in 2 x 2 lay-up) crushed 6” when loaded to about 1.5 times allowable load.
 - This performance indicates that cribbing installations will have significant deflection.
 - This “Softness” would indicate that Cribbing needs to be proportioned so that it is capable of carrying all the Vertical Load in a specific location, instead of being able to assume the remaining structure could “Share” in resisting some of the Load
- Copies of the USACE StS FOG & US&R SOG have been sent to all FEMA US&R Task Forces
 - Electronic copies can be obtained from the DisasterEngineer.org website
 - The SOG should be most useful to Rescue Specialists

FINAL SUMMARY

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

Review the Key Learning Points

The student should have a basic understanding of these Objectives in order to provide Effective Advice to US&R Forces

