RESCUE TECHNIQUES FOR EMERGENCY RESPONSE

Field Guide

Collapsed Structure Rescue

V.I.A.T.I.C.U.M.

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edited by Trevor Calafato

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Contents

Contributors

The Collapsed Structure Rescue field guide has been prepared by volunteer members of three teams, who have worked in close collaboration together:

Edelweiss (Italy)
Pompiers de l'Urgence Internationale (PUI, France)
SERVE ON (UK)

More information on these teams may be found on the VIATICUM project website:

https://www.viaticumrescue.eu/who-are-we/

The **Emergency Fire & Rescue Unit** (EFRU, Malta) has also supported the creation of this field guide, while overall coordination was performed by **Edelweiss** (Italy).

Editing of this field guide has been entrusted to Trevor Calafato, who has also edited *Rescue Techniques for Emergency Response: An Introductory Manual for European Volunteer Rescuers* Vol. 1 and Vol. 2.

Preface

The purpose of these field guides is to act as a quick reference tool while being operational. Written and compiled by rescuers with vast expertise in different kinds of rescue techniques and who authored both Vol. 1 and Vol. 2 of *Rescue Techniques for Emergency Response: An Introductory Manual for European Volunteer Rescuers*; these field guides contain a pool of techniques that are in use and have been tested in various circumstances.

The aim is to provide a platform that briefs the various rescue methods that could be utilized in diverse scenarios. As editor I could only commend and laud such initiative, where the intention is that even in times of pressure the deployed rescuers can assess the effectiveness and functionality of these different approaches while facing dire circumstances.

Thus, I hope that the ambition expressed by these authors to provide advice and guidance, that adhere to best practices within the field in a succinct and comprehensive, yet easy manner, is well received and fulfils its principal utilities – the saving of lives while keeping the rescuer relatively safe.

Trevor Calafato
Editor

Introduction

The idea of the Collapsed Structure Rescue field guide was born from a real need for volunteer rescuers, both trainers and trainees, to have with them a guide in the pocket or in the backpack.

Collapsed structures, potentially trapping victims underneath rubble, require a degree of expertise by the rescuers, both for the sake of safety of the rescuers and victims, but also for the sake of efficiency of the rescue efforts. This field guide makes it possible for rescuers to quickly refer to information during operations and training.

Oftentimes, the term Urban Search and Rescue (USAR) is used to describe rescue response to such incidents involving collapsed structures. This term may therefore also be encountered throughout this field guide.

Essentials

Team Roles

- Team Leader
- Deputy Team Leader
- Health & Safety Officer
- Civil Engineer
- Logistics
- Search – K9
- HAZMAT
- Medical Team
- Load movement
- Rescue

Safety Considerations

- Establish overall cordon
- Check area with CBRN detection, identification and monitoring equipment
- Assess for risks of fire, flooding, secondary collapses, presence of voids and sewers
- Assess for secondary devices & personal security threats
- Assess the need to work at heights/confined spaces
- Appoint Safety/Sector/Specialist Officers as required
- Ensure any discovered hazards are clearly identified
- Eliminate risks from utilities and building services
- Consider wind direction (gas-dust-smoke plumes, etc.)
- Establish PPE requirements and arrange provision
- Ensure safe systems of work are in place
- Ensure rescue-evacuation-medical support is available if necessary
- Confirm evacuation signal & roll call area to all personnel.

Personal Equipment

Personal protective equipment (PPE) used when working in collapsed structure rescue.

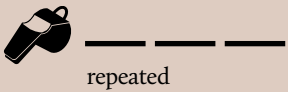
General equipment	Phone charger GPS Sunglasses Mosquito repellent Money Camera Multi-tool	Whistle Sunscreen Lighter / matches ID / passport Extra batteries Electrical socket adapters
Clothing	Underwear Socks Sleeping bag Sleeping mat	T-shirts Waterproof jacket and trousers Reflective jacket
PPE	Safety helmet Head torch Ear defenders Safety goggles Dust mask Whistle Uniform (boiler suit)	Harness Elbow pads Safety (working) gloves Latex gloves Handheld torch Knee pads Safety shoes
Personal hygiene	Towel Tooth paste Tooth brush Soap Toilet paper	Toiletries Wet wipes Shaving kit Personal first aid kit Personal medication
Food	Vacuum flask Plastic plate Cutlery Cup	Small stove Dried / tinned food Fresh water and canister

Suggested list of items to be packed for deployment.

Emergency Signals

Emergency whistle / air horn signals.

(These are used in USAR, as defined by INSARAG)

Evacuate (3 short blasts, 1 second each – repeated until site is cleared)	
Cease Operations – Quiet (1 long blast, 3 seconds long)	
Resume Operations (1 long blast + 1 short blast)	

Cordon Marking

Operational Zone Cordon

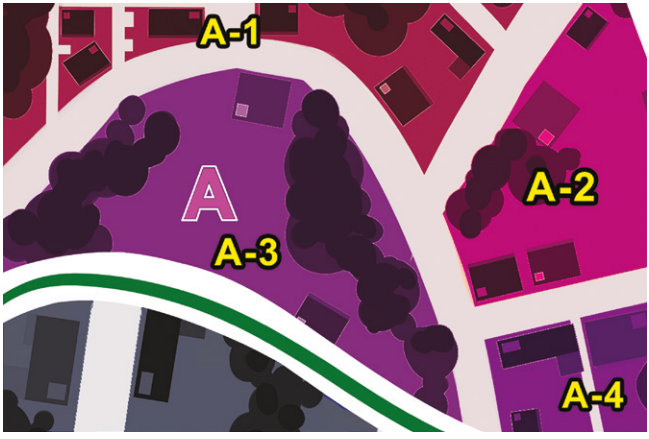
Exclusion Zone Cordon

Sectorisation

Disasters normally affect a large territory, making it necessary for the local emergency authorities to break the area down into sectors. This is done in order to facilitate planning, coordination and assignment of work to responding teams.

The size and shape of sectors depend on a combination of factors such as geographical features, the resources available as well as the degree of intervention required. The sectorisation plan is usually performed by Local Emergency Management Authorities (LEMA) or by OSOCC.

Area Sectors

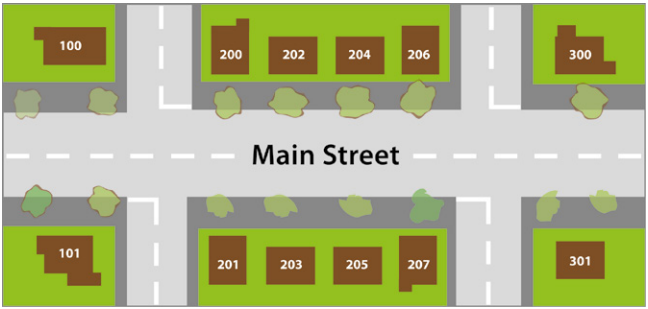


Sector Worksites

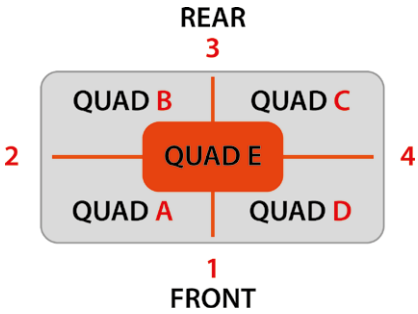
Sub-Worksites

General Area Marking

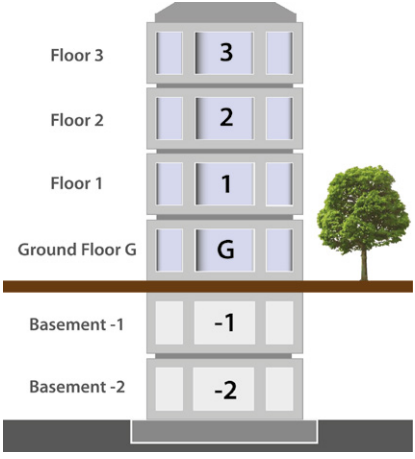
General area marking is based on street address and the singular building numbers, in addition to exterior and interior identification characteristics shown on a plan of the structure.



Structure Orientation



The external and internal parts of a building shall be identified on a plan view of the structure.

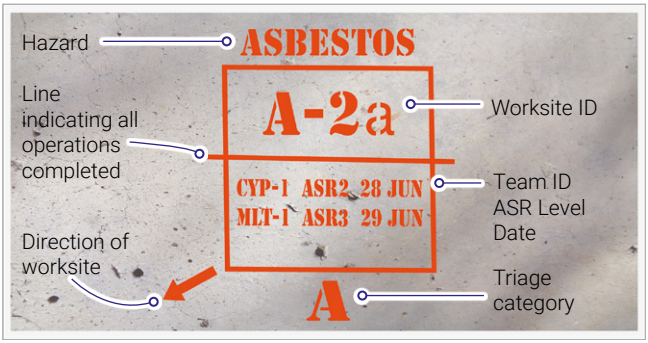


The identification of each floor follows the sequence shown in the previous figure.

Markings

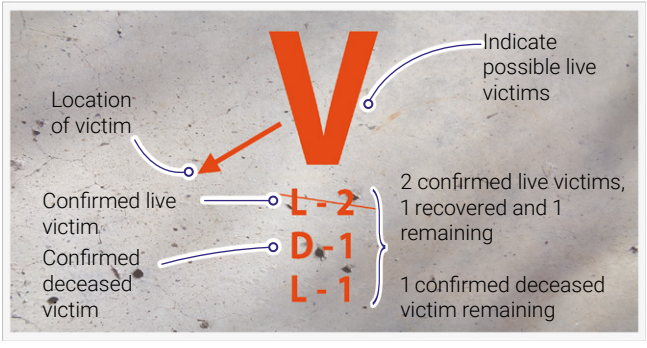
Worksite Markings

These markings must be applied to the front of a building structure (or as close as possible to it) or main entrance to the construction site. These markings shall be in the form of a rectangle of 1.2 meter x 1.0 meter (approximately).



Victim Location Markings

These markings are made as close as possible to the surface point identified as the place of the accident. The size should be around 50cm.



Rapid Clearance Markings

These markings indicate that an area has been searched and marks the status of remnants inside the structure.

Dimensions: approx. 20 cm x 20 cm

Structure is free from any living or deceased victim

Full level of search has been completed but only deceased victims remain in place

Assessments

Assessment Search Rescue (ASR) Levels

LEVEL 1: Wide Area Assessment

This is a fast visual check of the area to establish the extent of the incident, identify hazards, potential BoO locations, infrastructure issues, urgent resource requirements and the development of a sectorisation plan. No actual rescue takes place during this level of assessment.

LEVEL 2: Worksite Triage Assessment

This assessment is to identify possible rescue sites within each sector, carried out by part of a USAR team. The assessment needs to be fast but methodical and may involve search dogs or technical search equipment. Information from the locals and other response teams can be helpful.

LEVEL 3: Rapid Search and Rescue

This task is usually carried out by MUSAR or HUSAR teams, who rapidly perform rescues beyond the capabilities of local response teams. These rescues should take no more than a few hours and should be carried out by employing canine and technical searches, removal of debris, limited shoring, breaking and breaching and limited penetration into building material.

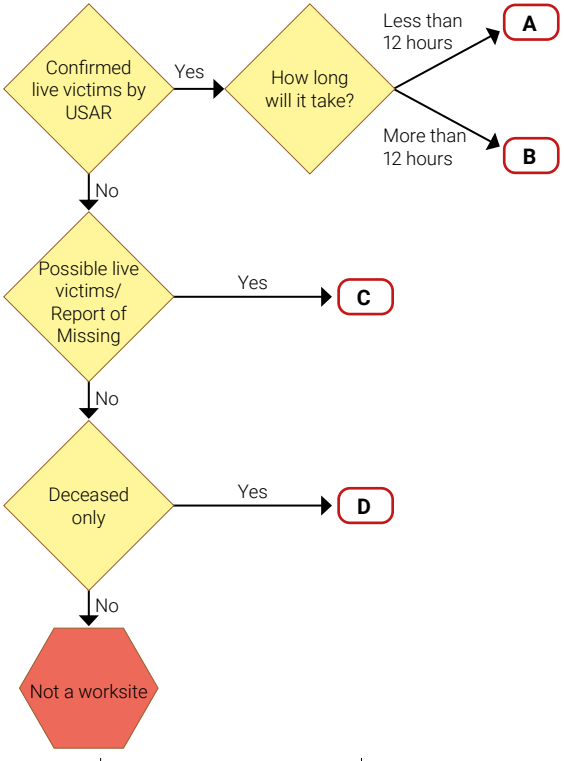
LEVEL 4: Full Search and Rescue

This level involves the search and rescue of heavily trapped survivors by MUSAR or HUSAR teams and involves penetration into survivable voids using a wide range of techniques. This may include heavy breaking and breaching work, extensive shoring and confined-space rescue deep inside these structures. There may be more than one team working at the same site.

LEVEL 5: Total Coverage Search and Recovery

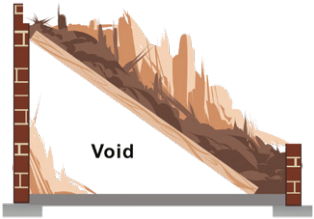
The final level usually involves the recovery of deceased victims once the rescue phase is complete. It is normally carried out by local resources and the LEMA.

Starting from the worksite triage assessment (ASR Level 2), the Triage Category flowchart shown below is used to determine the priority of each worksite, basing on knowledge of confirmed casualties or otherwise, the survivability rate expected as well as the resources expected to be required to effect the rescue.

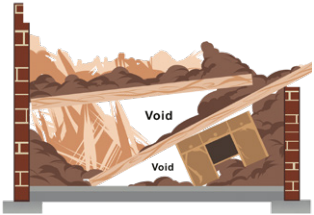


Triage categories	Life saving potential	Expected duration of operation
A	Confirmed live victims	Less than 12 hours
B	Confirmed live victims	More than 12 hours
C	Possible live victims	Not assessed
D	Deceased only	Not assessed

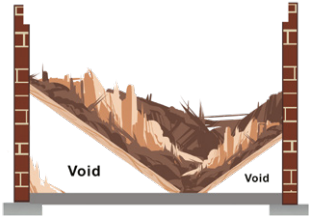
Types of Partial Building Collapse



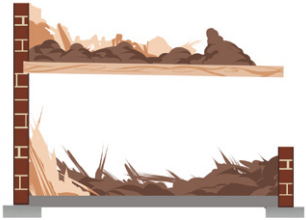
Lean-to-floor collapse



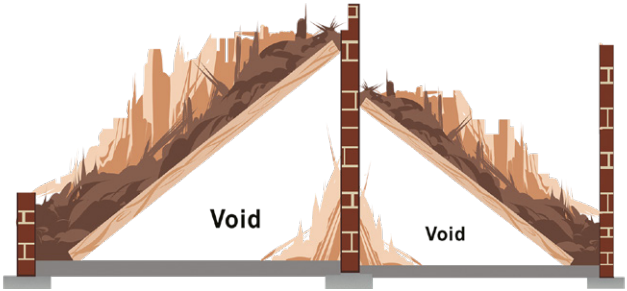
Pancake collapse



V-shape collapse



Cantilever collapse



A-frame collapse

Structure Assessment Checklist

External

- Presence of leaking gas, water, oil etc.
- Corner and structure face alignment
- Vertical load path alignment
- Floor alignment
- Horizontal load path
- Door and window opening alignment
- Projecting elements from faces
- Falling or spalling masonry

Internal

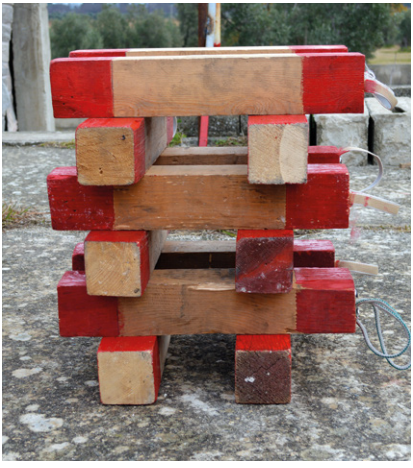
- Presence of leaking gas, water, oil etc.
- Integrity of columns, walls and floor
- Integrity of stair well and lift shafts
- Identify safe areas and escape routes
- Basement structure and foundation
- Alignment of doors and window frames
- Listen for any noise from structure
- Building contents, processes, hazchem etc.

Cribbing

Cribbing is used to transfer the weight of a load and provide a simple temporary support during rescue operation.

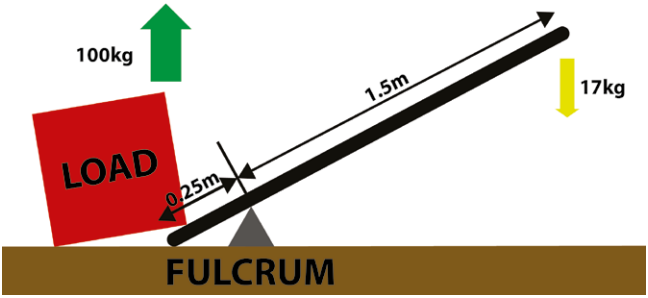
Measurements: length 50 cm - width 10 cm - thickness 10 cm.

Max capacity 1250 kg per crossing point.



Example of wedges on top of box cribbing

Load Shifting



Principle of levers (illlustration not to scale)

Using levers

N.B. for information on mechanical advantages that may be used during load shifting, please refer to the rope rescue manual.

Using levers

Hi-Lift Jack : used to lift weights up to 2000 kg

Using Hi-Lift Jacks

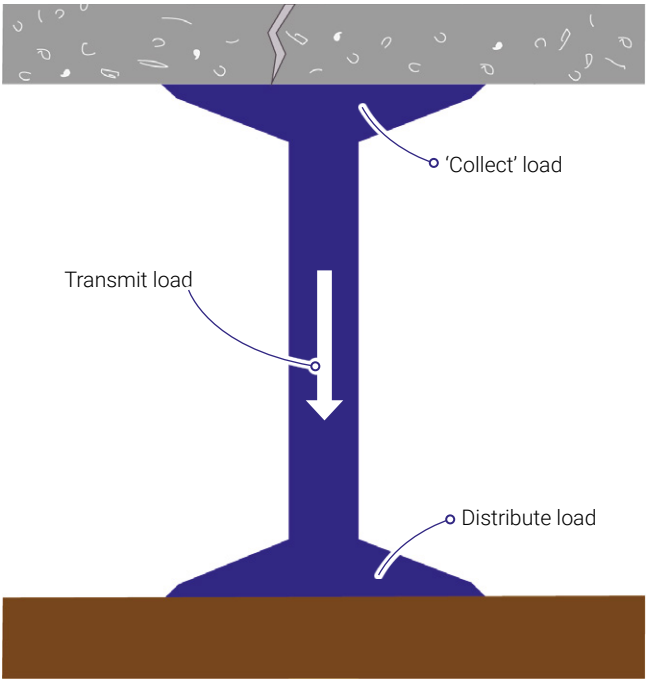
Using A-frames for load shifting

A-frames provide high anchor points for mechanical advantage systems

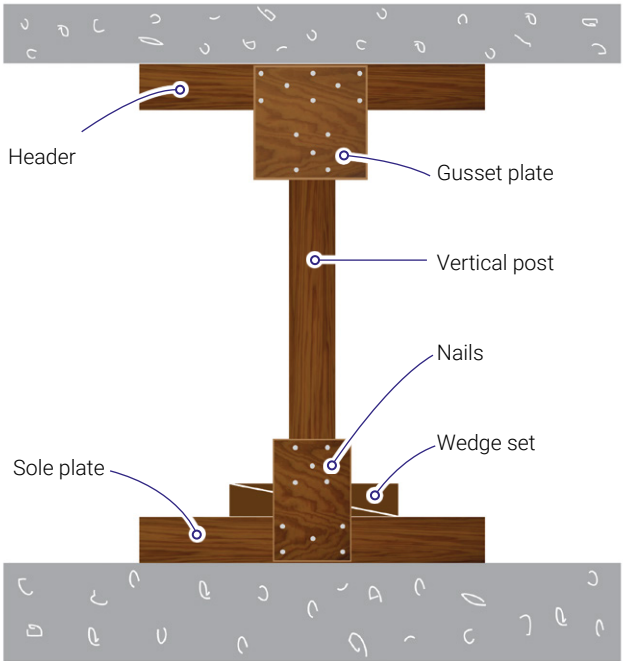
Using lifting bags

Timber Shoring

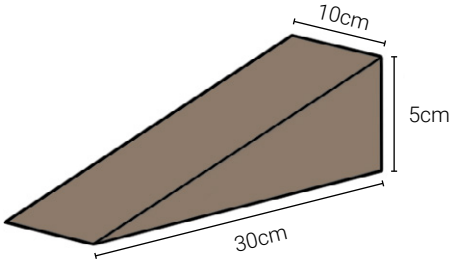
Terms and Basic Concepts



The concept of shoring: collecting, transmitting and distributing the load

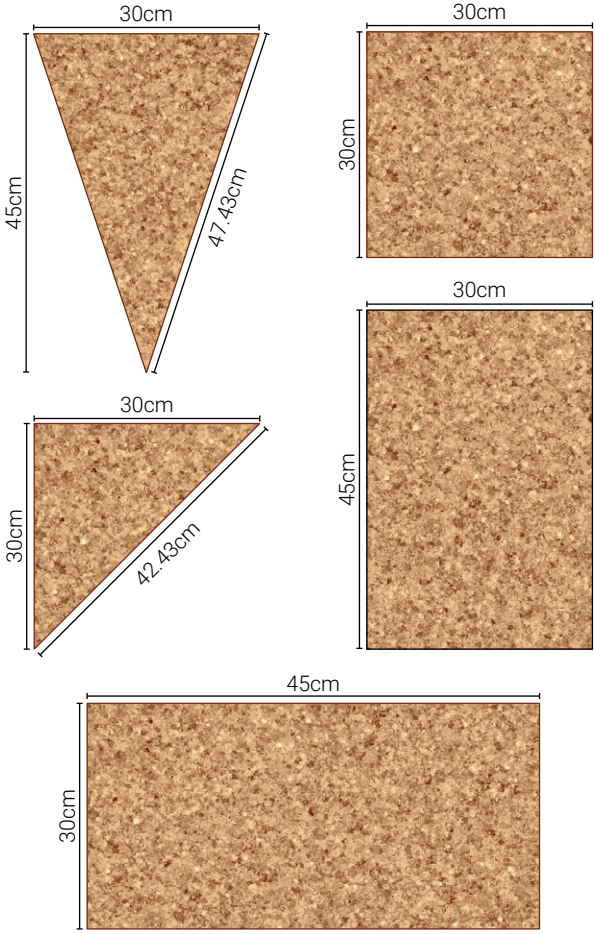


Basic shoring terms



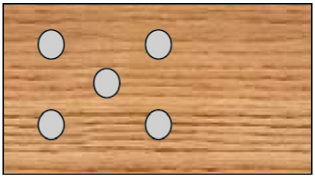
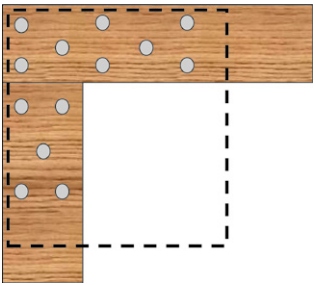
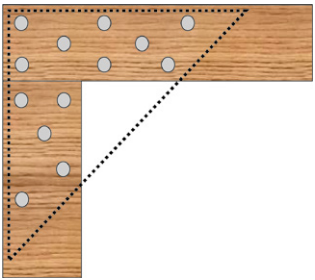
Standard Wedges: cut diagonally from 10cm X 5cm timber

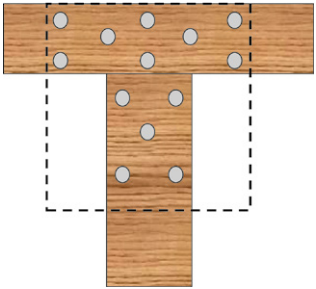
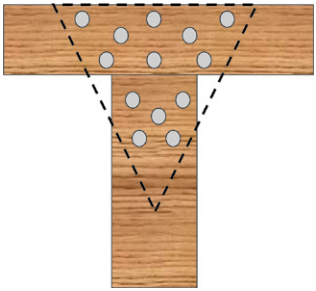
Always use wedges with diagonal faces married together

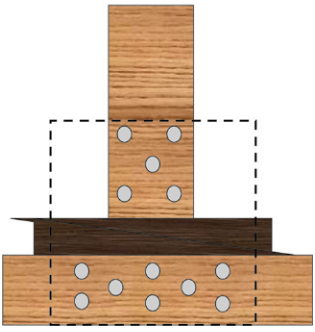
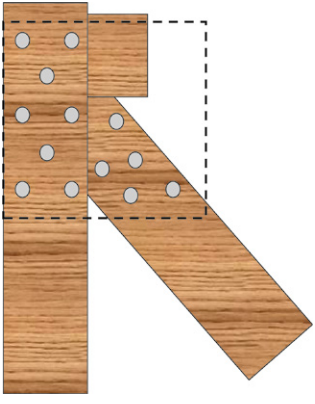


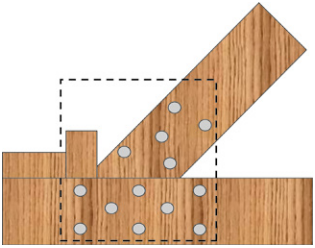
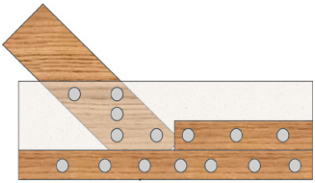
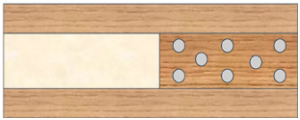
Gusset plate sizes (Gussets must have an inset of 10mm on all sides)

Standard Nail Patterns

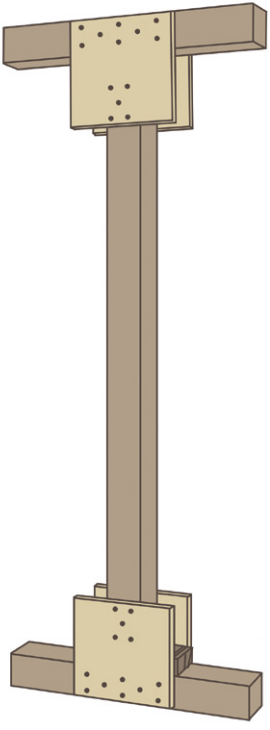
Nail Pattern	Usage
	Bracing
	Window/door shores corners
	Wall timber to sole plate joint on raker shores Header to post on sloped floor shores

Nail Pattern	Usage
	Posts to header
	Posts to header: alternate for confined spaces

Nail Pattern	Usage
	Post to sole plate
	Top of raker

Nail Pattern	Usage
	Bottom of raker
	Base of flying and split-sole raker shores when placed on flat hard ground (on soft ground this may still be used if plywood is used underneath)
	

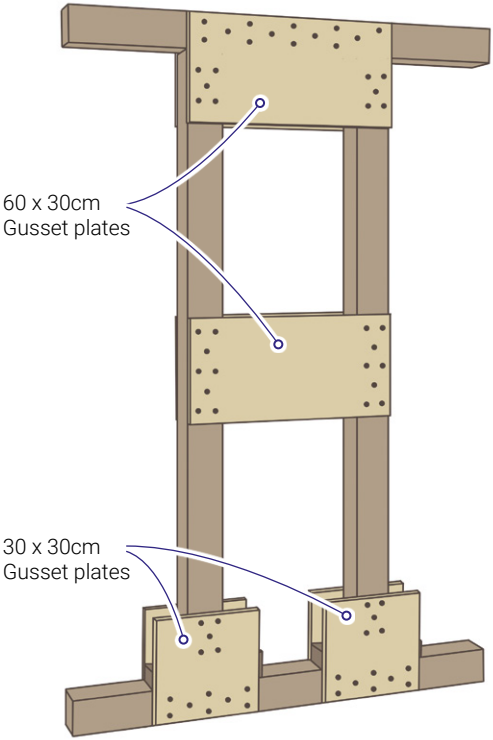
Vertical T-Spot Shore



30 X 30cm Gussets Used

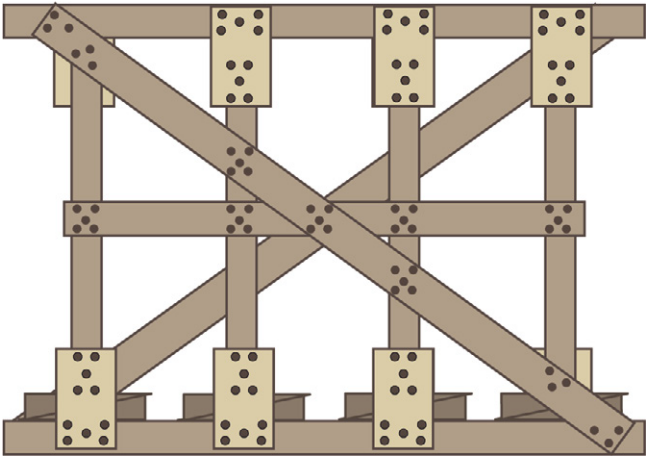
- Temporary shore
- Maximum Load Capacity: 2500kg
- Maximum Height: 3.6m

Double T Shore



- Temporary shore
- Maximum Load Capacity: 5000kg
- Maximum Height: 3.6m

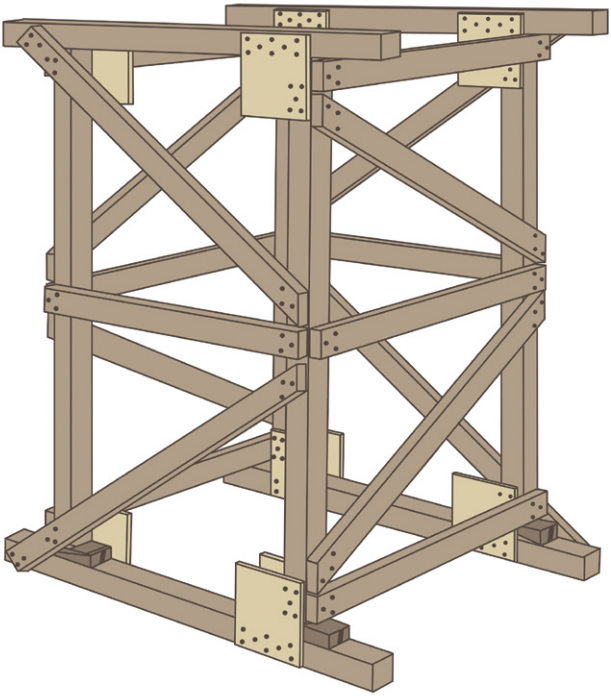
Vertical Multi-Post Shore



30 X 45cm Gussets used

- Maximum Load Capacity: 2500kg per post
- Maximum Height: 3.5m
- Post to be placed 1m-1.2m apart

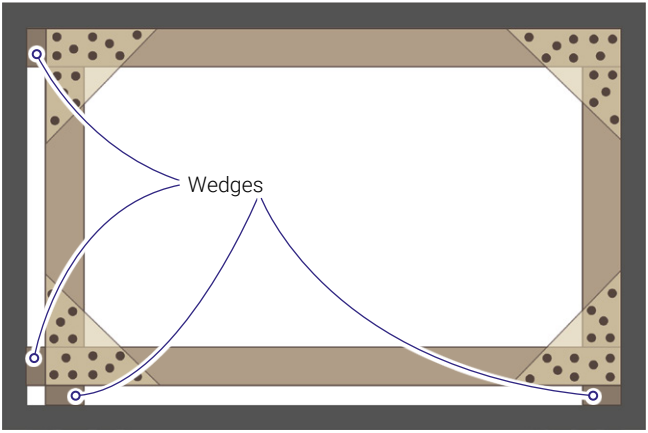
Column Shore



30X30cm Gusset plates used

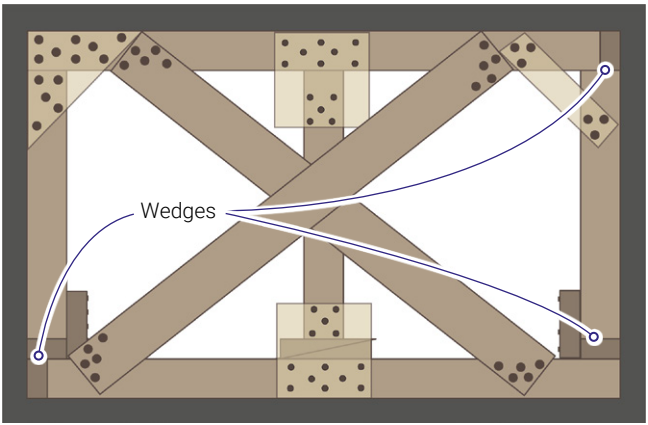
- Maximum Load Capacity: 2500kg per post/10000kg per column
- Maximum Height: 4 x width
- Post to be placed 1m-1.2m apart

Door or Window Shore Preconstructed



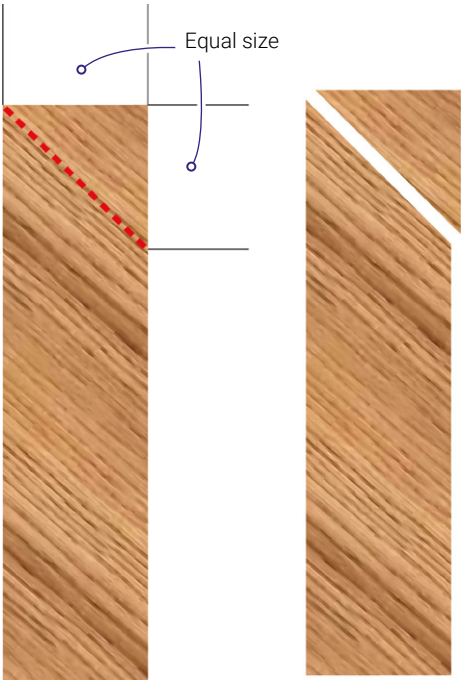
- Preconstructed box frame (4cm less than the opening)
- Maximum load capacity: 5000k
- Maximum height: 2.5m

Door or Window Shore

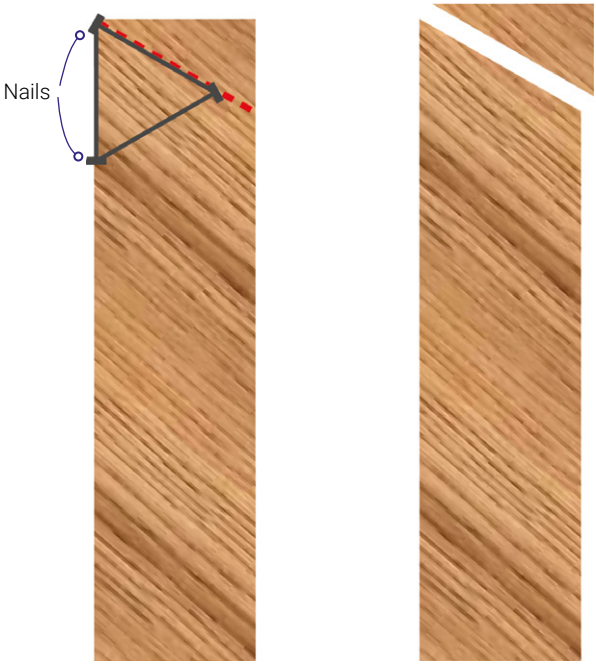


- Maximum load capacity: 2500kg per post
- Additional posts can be inserted as shown above
- X-braces may be removed if access is required
- Maximum height: 2.5m

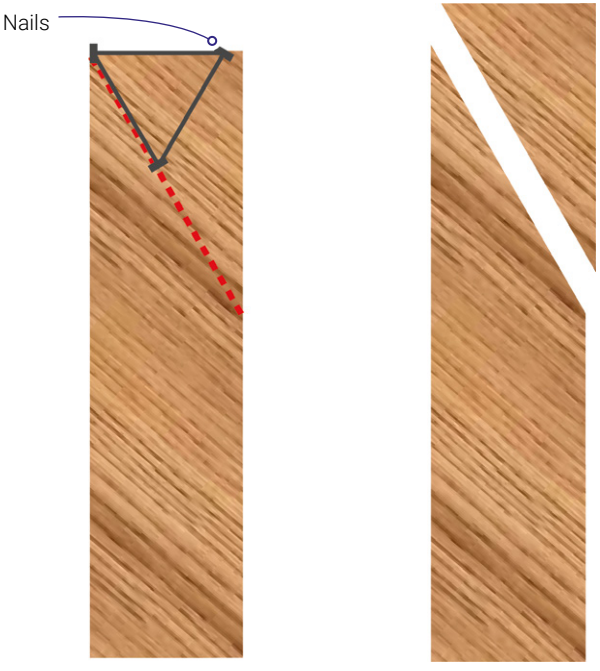
Raker Cutting



No measure 45° raker cutting
(post will be shortened by 36mm at each end)



No measure 30° raker cutting
(post will be shortened 15mm at each end)

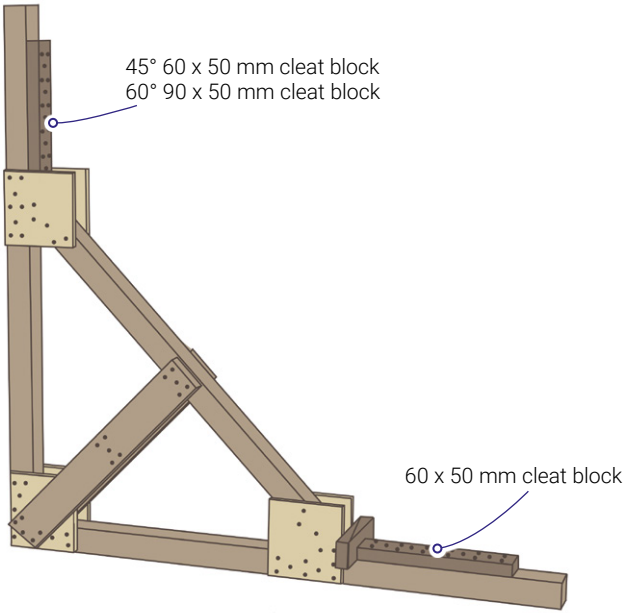


No measure 60° raker cutting
(post will be shortened 75mm at each end)

Raker return cut
(This must be done to all raker cuts outlined in this section)

Solid-Sole Raker Shore Assembly

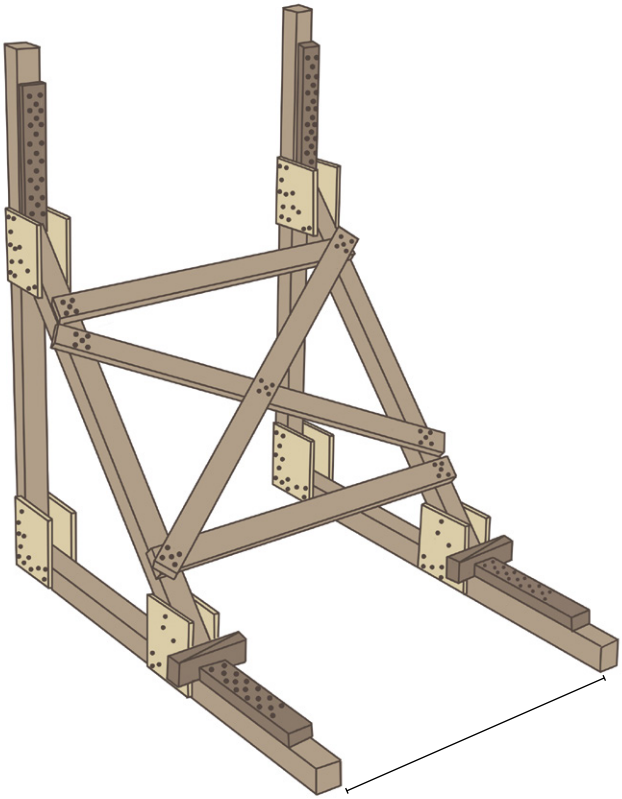
Used to support single floor slab. on flat, hard ground with no obstructions.



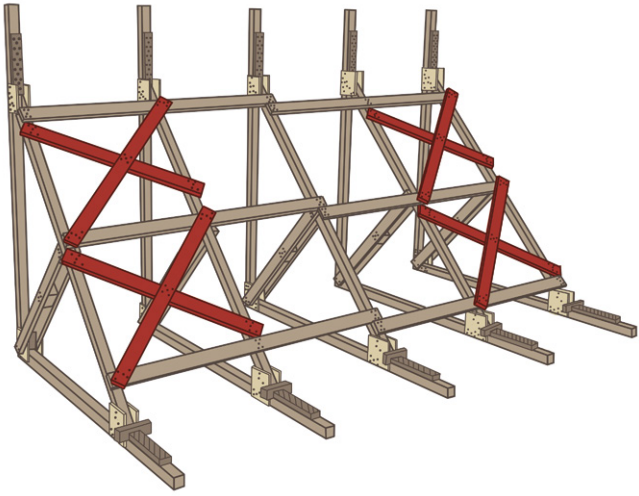
30X30cm Gusset plates used

- Maximum Horizontal Load Capacity: 1,000kg per raker
- Minimum of 2 rakers per shore
- To be wedged against a kerb beam
- Avoid using 60° raker shores except where space is limited
- Remember: 30° shores take a lot of space to construct

Bracing Bays of Raker Shores



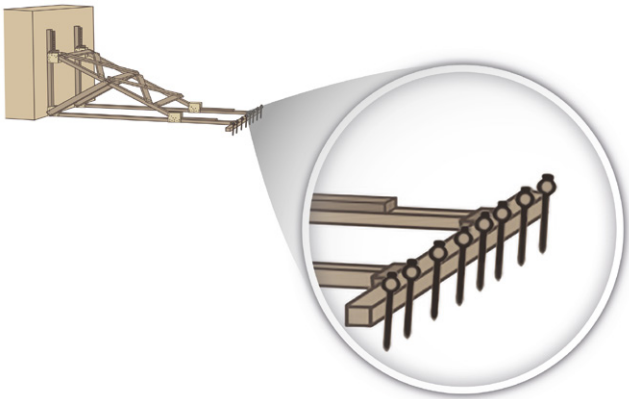
Maximimum distance of 2.4m



Each 4th bay must be X-braced

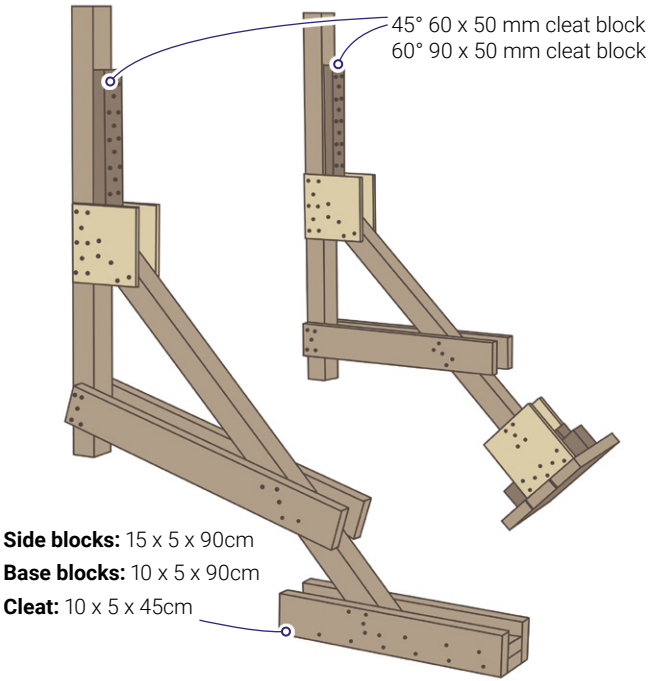
KERB Beams

To tie in raker sole beams, use a kerb of at least 10x10cm timber and insert wedges between the kerb and the sole beam.



Important: do not insert the pickets at an angle. They must always be in line with the kerb.

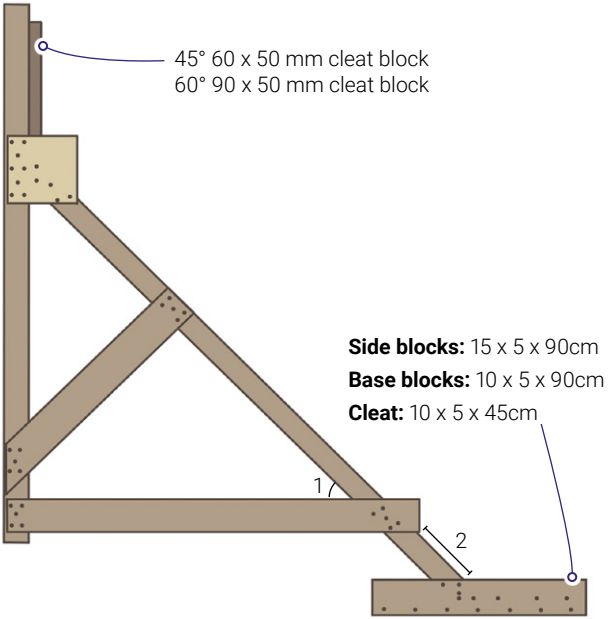
Flying Raker Shore



30X30cm Gusset plates used

- Used as a temporary shore
- Maximum Horizontal Load Capacity: 500kg per raker
- Minimum of 2 rakers per shore
- Avoid using 60° raker shores except where space is limited
- Base type to be used depending on ground condition

Split-Sole Raker Shore

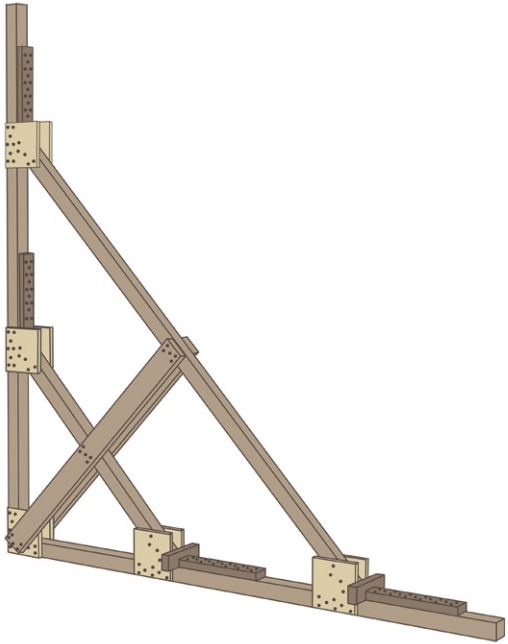


30X30cm Gusset plates used

- Used to support a single floor slab on flat, hard ground where there may be obstructions close to the wall
- Maximum Horizontal Load Capacity: 1000kg per raker
- Keep angle 1 above 30°
- Keep sole as low as possible to the ground (distance 2 as low as possible)
- To be wedged against a kerb beam

Multi Insertion Point Raker

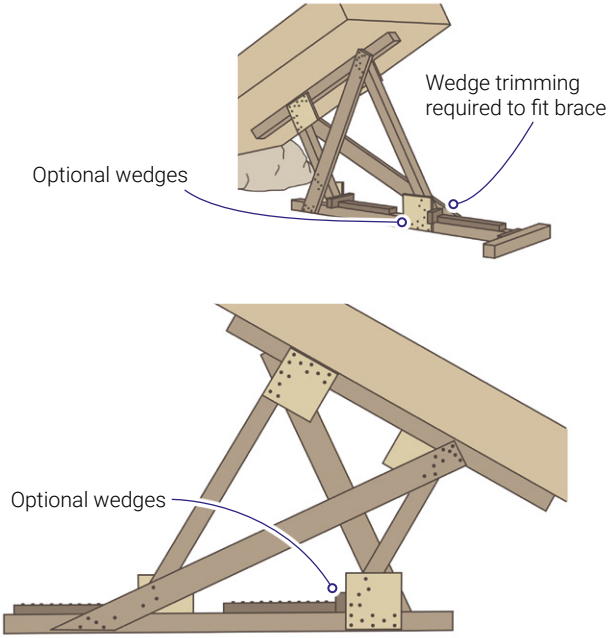
The same build as the Solid-Sole with an added raker to support slabs on different floor levels, or where there is a high buckle risk.



30X30cm Gusset plates used

- Maximum Horizontal Load Capacity: 1000kg per raker
- Minimum of 2 rakers per shore
- Keep both rakers at the same angle
- To be wedged against a kerb beam

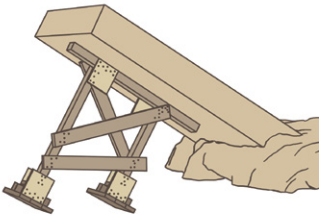
Sloped Floor Shore Perpendicular Type 1

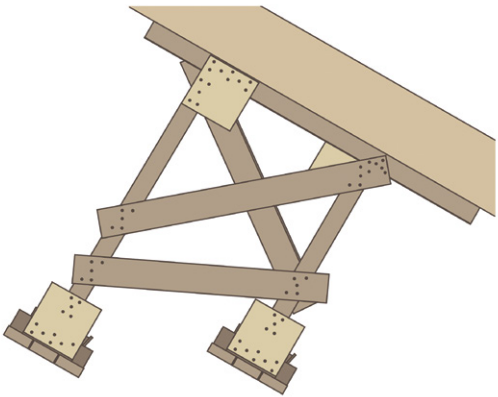


30X30cm Gusset plates used

- To be used where there is no possibility of the slab to slide
- Minimum of 2 posts per shore
- Maximum Vertical Load Capacity: 2500kg per post
- Maximum Length 3.5m
- Post to be placed maximum 1.2m apart
- To be wedged against a kerb beam

Sloped Floor Shore Perpendicular Type 2

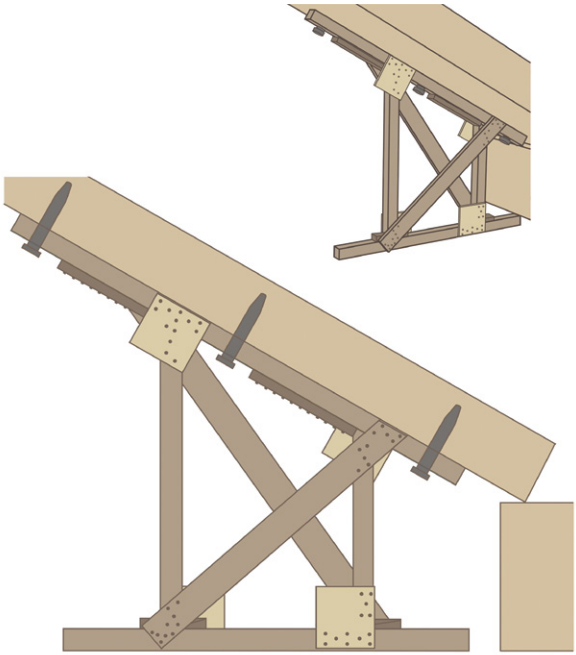




30X30cm Gusset plates used

- To be used on soft ground
- To be used where there is no possibility of the slab to slide
- Minimum of 2 posts per shore
- Maximum Vertical Load Capacity: 2500kg per post
- Maximum Length 3.5m
- Post to be placed maximum 1.2m apart

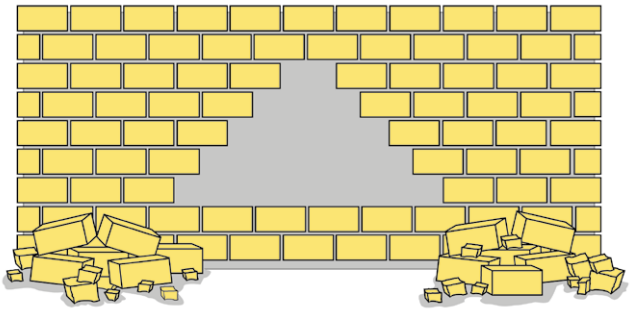
Sloped Floor Shore - Friction Type



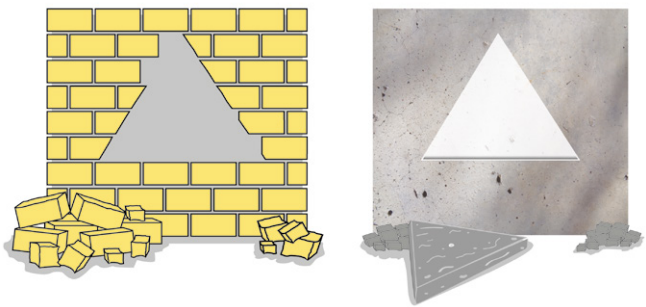
30X30cm Gusset plates used

- To be used where the slab may slide (Header must be strongly fixed to the slab to prevent movement)
- Minimum of 2 posts per shore
- Maximum Vertical Load Capacity: 2500kg per post
- Maximum Length 3.5m
- Post to be placed maximum 1.2m apart

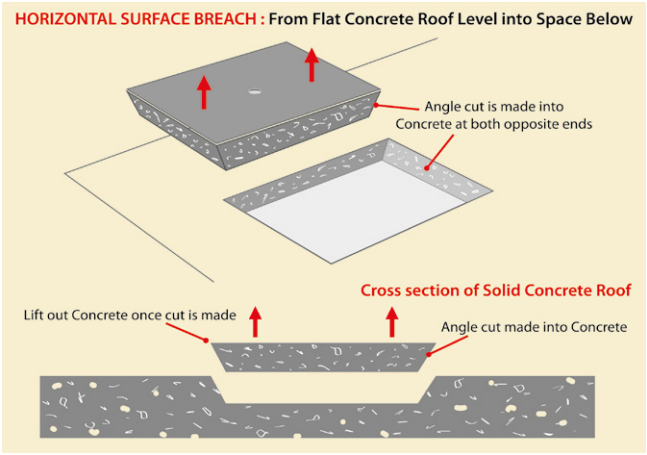
Breaching



Triangular breaching in masonary and in pre-cast concrete



Mortar cut and block removal



Horizontal surface breach with bevel cut

When breaching through walls, it is important that the shape of the breach chosen retains the structural integrity of the wall. For this reason, triangles are often used in walls. In ceilings it is possible to use a square breach.

Prior to cutting through walls, it is critical to drill a pilot hole and use a camera to check if any casualties are behind the wall!

Equipment

Electric (Corded) Tools

Electric tools require a source of electrical power to function.

Tools

- Cutters (disc, blade and chain).
- Breakers.
- Drilling tools.

Safety

- Operation in wet environment creates risk of electrocution.
- A safety device should be present to avoid electrocution.
- The proper diameter for extension cables should be used.
- Earthing is necessary, especially when a generator is used.

Advantages

- Compact and lightweight.
- Minimum maintenance required.
- Do not emit fumes (useful in confined space).
- Do not require fuel.

Disadvantages

- Require an electrical source nearby.
- Require a cable to be connected continuously to the source.
- Cable may be damaged by debris.
- Generators (when used as a source) generate noise.
- Cannot be used in wet environments.
- Form dust during operation.

Disc cutter

Chain saw.

Rock driller

Electric (Battery-Operated) Tools

These are powered by a battery and are standalone tools.

Tools

- Disc cutters.
- Drills.
- Breakers.
- Saws.

Safety

- Operation in wet environment creates risk of electrocution.
- Charging should take place using the charger supplied by the manufacturer.
- Should not be left near a heat source.

Advantages

- Portable, as no power cord is necessary.
- Generally lightweight.
- Do not emit fumes (useful in confined space).
- Battery may be interchangeable with that of other tools (by the same manufacturer).
- Advancements in battery technology offer longer times between charging.
- Not dependable on distance from an electricity source.

Disadvantages

- Less powerful than corded electric tools.
- Requires charged spare batteries to avoid interruption in use.
- Charging requires availability of electricity source and takes time.
- Higher cost than corded tools.
- Batteries discharge even when not in use.
- As the quality of the battery deteriorates, so does the power or torque generated.

Breaker hammer drill.

Mechanical Tools

These tools are hand-operated with a mechanical advantage provided by the tool to facilitate operation.

Tools

- Jacks / Hi-Lift.
- Steel cable winch.
- Manual chain hoist.

Safety and Maintenance

- Keep the tools properly lubricated.
- Ensure that jacks are properly stabilised before taking any load.
- Place a blanket or similar item on the tensioned steel cable when operating cable winches to minimise recoil in case it snaps.

Advantages

- Easy to operate.
- No electricity or fuel required.
- Low cost.
- Multi-purpose and highly versatile.

Disadvantages

- Relatively light loads can be lifted or moved.
- Cable winches need a good anchor point in line with the direction that the load needs to be moved.
- Operation of mechanical tools is usually slow and requires frequent stopping and resetting of the system.

Hydraulic Tools

Hydraulic tools operate by highly pressurised oil.

Tools

- Cutters.
- Spreaders.
- Lifting jacks.
- Shoring rams.

Safety and Maintenance

- Gloves and eye protection should always be worn during operation.
- Pressure should be released at the end of operations.
- An operator should control the hydraulic pump at all times.
- Damage to the hydraulic hoses should be avoided.
- Fittings and hoses should be inspected prior to any operation.
- Oil leakages are not acceptable.

Advantages

- Relatively compact and light.
- Minimum maintenance is required.
- Do not emit fumes (useful in confined spaces).

Disadvantages

- A power source is required for the hydraulic pump.
- The reach of the hoses is normally limited.
- If the hydraulic pump is driven by an internal combustion engine, it cannot be used in confined spaces.
- An additional person is required constantly by the hydraulic pump.

Hydraulic pump with hoses and cutters.

Hydraulic hand pump and rams.

Pneumatic Tools

Pneumatic tools use compressed air to function. Compressed air may be obtained from a compressor on site or from compressed air cylinders.

Tools

- Breakers.
- Drills.
- Disc cutters.
- Water pumps.
- Airbags.

Safety and Maintenance

- Avoid releasing compressed air from loose hose ends.
- A rescuer should always be at the compressor to control the air flow.
- When uncoiling the hoses avoid any sharp edges and hose kinking.
- Smaller air bags should always be placed on top.
- For stacked air bags, the maximum load is that of the smallest airbag.
- During lifting all personnel should be at a safe distance.
- Cribbing should be placed after every lifting step.
- The compressed air should not contain humidity.

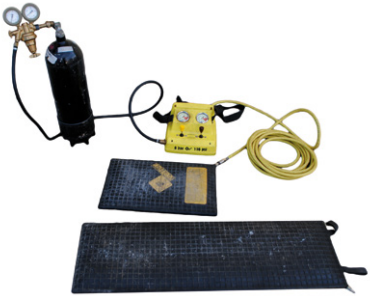
Advantages

- Easy to use.
- More powerful than electric and self-powered tools.
- May be used in all weather conditions.
- Low maintenance.
- Portable (when used with a compressed air cylinder).
- The compressed air cylinder used is the same as that used in self-contained breathing apparatus.
- Do not emit fumes (useful in confined space).

Disadvantages

- Require a dedicated source of compressed air.
- The compressor generates a lot of noise.
- Limited range of distance for operations due to hoses.
- A dedicated person is required at the compressed air source.
- Spare compressed air cylinders required.
- Longer set up time required compared to electrical and self-powered tools.

Air compressor and disc cutter.



Compressed air cylinder with controller and air bags.

Internal Combustion Engine

These are self-powered tools that are equipped with an internal combustion engine that powers the tool.

Tools

- Chain saw.
- Disc cutters.
- Breakers.
- Water pumps.

Safety and Maintenance

- Powerful chain saws and disc cutters may 'kick back' so the operator needs to be aware and ready all the time.
- Proper protection from high speed flying particles needs to be worn.
- Fuel may create a fire hazard in the working environment.
- Exhaust fumes are produced, therefore adequate ventilation is necessary.

Advantages

- Portable.
- Not limited by hoses or cables.
- Considerable power to weight ratio.
- Fast set up time.

Disadvantages

- High noise levels.
- Produce fumes that preclude the tools from being used in confined spaces.
- Flammables present at the operations area.
- Require substantial maintenance.
- Require availability of fuel.

Disc cutter.

Confined Space Considerations

Prior to entering any confined space, the air quality in the area must be checked by a qualified Hazardous Substances Technician with an appropriate air monitoring device to determine if the space is safe to enter.

If the air quality is determined to be unsafe, it must be ventilated and made safe prior to any entry. If the area cannot be ventilated, and entry must be made to retrieve a living victim, rescue personnel shall follow Confined Space Rescue Procedures to ensure the safety of rescue personnel entering the area. The Incident Command must be informed of any confined space rescue operation and kept updated.

Some gases that may be found in confined spaces, their associated characteristics and effects are shown below.

	Characteristics	Effects
Carbon Dioxide	• Colourless • Odourless • Heavier than air	• Shortness of breath • Reduced vision • Fatigue • Drowsiness • Confusion

	Characteristics	Effects
Carbon Monoxide	• Colourless • Odourless • Poisonous • Slightly lighter than air • Caused by internal combustion equipment in enclosed space	• Light-headedness • Nausea • Headache • Confusion • Shortness of breath • Tiredness • Dizziness • Unconsciousness • Death
Natural Gas	• Colourless • Lighter than air • Highly flammable • An artificial smell is normally added to make it recognisable. • May be caused by a leak from broken gas pipes.	• Reduced oxygen • Dizziness • Fatigue • Nausea • Headache • Irregular breathing • Explosion and fire

	Characteristics	Effects
Butane Liquid Petroleum Gas (LPG)	• Colourless • Heavier than air • Toxic • Highly flammable • An artificial smell is normally added to make it recognisable. • May be caused by a leak from broken gas pipes.	• Shallow breathing • Confusion • Loss of consciousness • Cardiac arrest • Death • Explosion and fire
Hydrogen sulphide	• Colourless • Foul 'rotten egg' smell • Heavier than air • Highly toxic • Highly flammable and explosive	• Nausea • Eye irritation • Headaches • Airway problems • Fatigue • Dizziness • Altered breathing • Unconsciousness • Death • Explosion and fire

Conclusion

Rescuers responding to incidents involving collapsed structures with trapped casualties make use of specialist knowledge and skills to deal with the situation safely and efficiently.

Situations may greatly vary, from relatively small incidents involving a single house to a protracted emergency involving a whole area, such as an earthquake. However, the approach to be taken always makes use of the same basics, as presented in this field guide.

References

This field guide has been prepared with reference to:

- Calafato, T. (Ed.), *Rescue Techniques for Emergency Response*, Volume 1, (Malta: EVOLSAR, 2017).
- Calafato, T. (Ed.), *Rescue Techniques for Emergency Response*, Volume 2, (Malta: EVOLSAR, 2020).

List of Abbreviations

ASR	Assessment, Search and Rescue
BoO	Base of Operation
CBRN	Chemical, Biological, Radiological, Nuclear
HAZMAT	Hazardous Material
HUSAR	Heavy USAR
INSARAG	International Search and Rescue Advisory Group
K9	Canine (homophone)
LEMA	Local Emergency Management Agency
LUSAR	Light USAR
MUSAR	Medium USAR
OSOCC	On-site Operations Coordination Centre
PPE	Personal Protective Equipment
USAR	Urban Search and Rescue

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