

Australian Standard™

Hydraulic shoring and trench lining equipment



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Hydraulic shoring and trench lining equipment

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PREFACE

This Standard was prepared by the Standards Australia Committee ME-082, Shoring and Trench Lining.

The objective of this Standard is to provide a specification for hydraulic shoring and trench lining equipment that achieves an acceptable level of safety, for reference by manufacturers, suppliers, users and regulators.

Statements expressed in mandatory terms in notes to tables are deemed to be requirements of this Standard.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

CONTENTS

	<i>Page</i>
FOREWORD.....	5
SECTION 1 SCOPE AND GENERAL	
1.1 SCOPE	6
1.2 NEW DESIGNS, INNOVATIONS AND DESIGN METHODS	6
1.3 NORMATIVE REFERENCES	6
1.4 TERMS AND DEFINITIONS	7
1.5 SYMBOLS	27
1.6 DESIGNATION	29
1.7 DECLARATION OF CONFORMITY	29
1.8 MARKING	29
SECTION 2 MATERIALS	
2.1 GENERAL	30
2.2 FASTENERS.....	30
2.3 MINIMUM ELONGATION.....	30
2.4 SPECIAL REQUIREMENTS FOR HYDRAULIC RAMS.....	30
2.5 FLEXIBLE HYDRAULIC HOSES	31
SECTION 3 STRUCTURAL COMPONENTS	
3.1 GENERAL	32
3.2 DESIGN PARAMETERS.....	32
3.3 PARTIAL SAFETY FACTORS	33
3.4 CONFIGURATION OF LOAD	33
3.5 MINIMUM VALUE OF CHARACTERISTIC RESISTANCES	37
3.6 DEFLECTION.....	37
3.7 HANDLING AND RESTRAINING POINTS (see Figure 13).....	37
3.8 WALER OR SOLDIER RAIL TO STRUT CONNECTION	38
3.9 WALER OR SOLDIER STRUTS.....	38
3.10 RESTRAINING CHAIN	39
3.11 HYDRAULIC BRACING FRAME LEG AND HYDRAULIC RAM LEG	40
3.12 WALER RAIL.....	40
3.13 SOLDIER RAIL	40
SECTION 4 HYDRAULIC COMPONENTS	
4.1 GENERAL	41
4.2 HYDRAULIC RAMS.....	41
4.3 MANUFACTURING TOLERANCES FOR RAMS	43
4.4 MOUNTING FASTENERS OR PINS.....	44
4.5 BUCKLING RESISTANCE OF PISTON ROD	44
4.6 HYDRAULIC SHORING FLUID	44
4.7 RAM ACCEPTANCE TEST (PRE-DELIVERY TESTING)	44
4.8 VALVES AND HYDRAULIC FITTINGS.....	44
4.9 HYDRAULIC PUMP	45
SECTION 5 INSTRUCTION MANUAL	
5.1 GENERAL	46
5.2 SPECIFICATION OF A PUMP AND RESERVOIR.....	46
5.3 DATA.....	46

	<i>Page</i>
5.4 SPECIFICATIONS FOR ANCILLARY ITEMS	46
5.5 INFORMATION ABOUT USE	47
5.6 MAINTENANCE	47
5.7 RAM SPECIFICATION	47
5.8 ENVIRONMENTAL, HEALTH, SAFETY AND POTENTIAL HAZARD CONSIDERATIONS	51
 SECTION 6 ASSESSMENT BY CALCULATION OR TEST	
6.1 GENERAL	52
6.2 CHOICE OF TESTING OR CALCULATION	52
6.3 ASSESSMENT BY CALCULATION	53
6.4 ASSESSMENT BY TESTING	53
6.5 EVALUATION OF LOAD-BEARING CAPACITY AND STIFFNESS FROM TESTING METALLIC ASSEMBLIES AND COMPONENTS.....	56
 APPENDICES	
A PARTIAL SAFETY FACTORS	66
B RELATING CHARACTERISTIC RESISTANCES TO PERMISSIBLE WORKING RESISTANCES GIVING VALUES FOR USE IN CALCULATIONS.....	67
C EXAMPLES OF LOAD CURVES	70
D HYDRAULIC RAM ACCEPTANCE TEST	74
E DESIGNATION CHECK LIST	76
F DOCUMENTATION OF TEST RESULTS.....	80
G EXAMPLE FOR THE DETERMINATION OF AN APPROXIMATION FUNCTION, OF THE QUOTIENT (q_e) FOR THE DISSIPATION OF ENERGY AND OF THE PARTIAL SAFETY FACT (γ_{R2})	82
H EXAMPLE FOR THE STATISTICAL EVALUATION OF TEST RESULTS AND THE DETERMINATION OF THE NOMINAL CHARACTERISTIC VALUE OF THE RESISTANCE	86
I EXAMPLE FOR THE EVALUATION OF STIFFNESS	88

FOREWORD

Hydraulically operated shoring systems comprise prefabricated equipment to provide primary support to the side of excavations. This Standard covers three types of equipment whose resistance and adjustment is hydraulic or by a combination of hydraulic and mechanical means, as follows:

- (a) Hydraulic bracing frames.
- (b) Hydraulic waler frames.
- (c) Hydraulic soldier sets.

A variety of components when assembled form a full system. The prefabricated components are used to make assemblies of different dimensions and structural capacities.

Hydraulically operated shoring equipment has a limitation in use in that it is dependent on a competent person relating soil conditions to the use of the equipment.

This Standard gives specific requirements on the main characteristics of hydraulically operated pumps, hoses and associated equipment, but does not provide requirements for their specification or assessment.

Hydraulically operated shoring equipment is frequently used in conjunction with supplementary equipment, e.g., sheet piling, trench sheeting, knee braces and intermediate bracing struts. Such supplementary equipment is not covered in the Scope of this Standard.

The characteristic resistance values specified in this Standard form a reference level.

Appendix A gives information about the values of partial safety factors for materials (γ_M) and partial safety factor for actions (γ_F). Appendix B gives information on the application of characteristic resistance values to a safe working value.

Hydraulic bracing frames have a restriction limiting the length of a single leg to 20 m. Longer lengths of hydraulic frame legs are possible, but these may require an engineering design input that is not covered in this Australian Standard.

Statements expressed in mandatory terms in notes to Tables and Figures are deemed to be requirements of this Standard.

STANDARDS AUSTRALIA

Australian Standard**Hydraulic shoring and trench lining equipment**

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies constructional and structural requirements for hydraulically operated shoring systems made from steel and aluminium for groundwork support. It also specifies methods of calculation and test to assess compliance with this Standard. It specifies minimum characteristic resistance for equipment and is limited to assemblies with components having hydraulic rams (see Note 1).

Materials other than steel and aluminium are not precluded; however, this Standard does not specify methods of assessment for equipment made of these materials.

This Standard also provides information on some of the main characteristics of hydraulically operated pumps, hoses and associated equipment, but does not cover assessment of these items.

NOTES:

- 1 Assemblies without hydraulic rams may be designed in accordance with AS 4100.
- 2 Information on the values of partial safety factors is given in Appendix A.
- 3 Information on the application of characteristic resistance values is given in Appendix B.

1.2 NEW DESIGNS, INNOVATIONS AND DESIGN METHODS

This Standard does not preclude the use of materials, designs, methods of assembly, procedures and the like which do not comply with a specific requirement of this Standard, or are not mentioned in it, but which can be shown to give equivalent or superior results to those specified.

1.3 NORMATIVE REFERENCES

The following documents are referred to in this Standard.

AS	
1180	Methods of test for hose made from elastomeric materials
1391	Methods for tensile testing of metals
1554	Structural steel welding (all parts)
1665	Welding of aluminium structures
1815	Metallic materials—Rockwell hardness test
1816	Metallic materials—Brinell hardness test
1817	Metallic materials—Vickers hardness test
2019	Fluid power—Hydraulic and pneumatic cylinders—Bore and rod dimensions
2074	Cast steels
2321	Short-link chains for lifting purposes

AS	
2845	Water supply—Backflow prevention devices
2845.1	Part 1: Materials, design and performance requirements
2848	Aluminium and aluminium alloys—Composition and designations—Wrought products
3791	Hydraulic hose
3997	Fluid power—Fire-resistant hydraulic fluids
3997.1	Part 1: Classification
4041	Pressure piping
4100	Steel structures
4744	Steel shoring and trench lining equipment
4744.1	Part 1: Design
AS/NZS	
1664	Aluminium structures
1664.1	Part 1: Limit state design
4291	Mechanical properties of fasteners (all parts)
ISO	
DIN 51524-1	Pressure fluids; hydraulic oils; HL hydraulic oils; minimum requirements
DIN 51524-2	Pressure fluids; hydraulic oils; HLP hydraulic oils; minimum requirements
DIN 51524-3	HVLP hydraulic oils; minimum requirements
SAE MS 1004	Lubricants, industrial oils, and related products Type H (hydraulic fluids)—Specification
CE TOP RP91 H	Fluids for hydraulic transmissions

1.4 TERMS AND DEFINITIONS

For the purposes of this Standard definitions below apply.

1.4.1 Characteristic axial compression resistance (R_{KC})

Resistance of a hydraulic bracing frame leg, or a ram or a waler frame/soldier set strut with the piston rod of the ram fully extended.

1.4.2 Characteristic axial resistance for the return capacity of a double acting ram (R_{TA})

Resistance of the return capacity of a double acting ram.

1.4.3 Characteristic bending resistance for a leg at a reduction in section (R_{KB2})

Resistance of a hydraulic bracing frame leg where there is a reduction in section.

1.4.4 Characteristic bending resistance of a hydraulic bracing frame leg at a specified length (R_{KB-N})

Bending resistance of a hydraulic bracing frame leg at a specified length and of a specified assembly.

NOTES:

- 1 The assembly of components can take several forms to produce a given length of a hydraulic bracing frame leg (see Appendix C).
- 2 A hydraulic bracing leg is usually formed from a number of components and may also have a significant resistance in one direction of action.

1.4.5 Characteristic bending resistance of the inner tube of an adjustable leg ($R_{KB,RI}$)

Resistance of the inner tube of an adjustable telescopic hydraulic bracing frame leg.

1.4.6 Characteristic bending resistance of the main section of a leg (R_{KB1})

Resistance of the main section of a hydraulic bracing frame leg.

1.4.7 Characteristic bending resistance of the outer tube of an adjustable leg ($R_{KB,RO}$)

Resistance of the outer tube of an adjustable telescopic hydraulic bracing frame leg.

1.4.8 Characteristic bending resistance on the compressive side of a joint to an extension leg ($R_{KB,JC}$)

Resistance of the compressive side of a hydraulic bracing leg under the arrangement of loading given in Figure 3.1.

1.4.9 Characteristic bending resistance on the tension side of a joint to an extension leg ($R_{KB,JT}$)

Resistance of the tensile side of a hydraulic bracing leg under the arrangement of loading given in Figure 3.1.

1.4.10 Characteristic compressive failure pressure (F_{KC})

Internal pressure at which compression failure occurs in a ram when extended to approximately 10% of its possible range.

1.4.11 Characteristic minimum bending resistance (R_{KB})

Bending resistance of a hydraulic bracing frame leg, soldier rail or a waler rail when assembled in the most onerous configuration.

1.4.12 Characteristic return failure pressure (F_{TA})

Internal return pressure in a double acting ram at failure of the ram.

NOTE: Clause 1.4.10 defines cylinder assembly failure pressure of a ram whereas Clause 1.4.1 defines the characteristic compression resistance of the complete ram with the ram leg fully extended, which takes into account ram leg buckling.

1.4.13 Competent person

A person who has acquired through training, qualification, experience or a combination of these, the knowledge and skill enabling that person to correctly perform the required task.

1.4.14 Cylinder end block

Component that terminates the cylinder tube and provides a connection for attaching hydraulic fittings and isolation valves and connection points to the surrounding structure (see Figures 1.1, 1.2 and 1.3).

1.4.15 Cylinder tube

Outer cylinder of the ram that resists the internal pressure and provides the outer sealing surface to the piston (see Figures 1.1, 1.2 and 1.3).

1.4.16 Double acting ram

Hydraulic ram that both extends and retracts under hydraulic pressure (see Figure 1.3).

NOTE: These rams primarily take compressive loads but also have a tensile capacity.

1.4.17 Extension leg for hydraulic bracing frame leg

Component that is either fixed or mechanically adjustable to extend a hydraulic bracing frame leg (see Figure 1.8).

NOTE: The joint between the component and its parent has a moment capacity.

1.4.18 Extension leg for waler or soldier strut

Component for in line insertion in a waler or soldier strut to increase its length.

NOTE: Three basic types are available (see Figure 1.12)—

- (a) with flanged connectors at each end;
- (b) with a pinned spigot and socket connection; and
- (c) with a pinned over-sleeve extension bar where there may be a variety of lengths.

1.4.19 Full-bore side of the piston

Side of the piston to which the active hydraulic pressure is applied.

1.4.20 Gland

Component that centralizes the piston rod and may incorporate seals, bearing rings and wiper rings (see Figures 1.1, 1.2, 1.3 and 1.4).

1.4.21 Handling/lifting point

Point for attaching lifting equipment to aid the assembly of the system and for use in transportation.

1.4.22 Hydraulic bracing frame

Minimum four-sided assembly that is designed to resist the applied loading on all sides.

NOTE: At least two opposite sides of the frame have hydraulic ram legs (see Figure 1.6).

1.4.23 Hydraulic bracing frame leg

Assembly of components, whose length is adjusted by a hydraulic ram (see Figure 1.7).

NOTES:

- 1 Each end of the leg has a pin connection. The leg includes any extension with one or more extension bars suitably connected (see Figure 1.8). The leg can also have a telescopic mechanical adjustment.
- 2 This Standard only covers hydraulic bracing frame legs up to and including 20 m.

1.4.24 Hydraulic pump

Device for operating a hydraulic ram.

1.4.25 Hydraulic ram

An assembly of hydraulically operated components, with an ability to vary length (see Figures 1.1, 1.2 and 1.3).

NOTES:

- 1 A separate hydraulic pump activates the ram.
- 2 The term 'ram' has been adopted to distinguish from the more general term 'cylinder'. Rams only receive static loading from ground pressure and do not require specific duty cycles or cycle rates.

1.4.26 Hydraulic ram leg

A member section of a 'hydraulic bracing frame leg' that houses the hydraulic ram.

1.4.27 Hydraulic seal

Flexible component that prevents fluid leakage between moving parts.

1.4.28 Hydraulic shoring fluid

Oil- or water-based fluid used to operate hydraulic rams.

NOTE: Anti-freeze is added to suit local conditions.

1.4.29 Hydraulic waler/soldier strut

Hydraulic strut that may be lengthened by the addition of extension bars and that is used in conjunction with waler or soldier rails.

NOTES:

- 1 These components resist compressive forces only (see Figure 1.10).
- 2 Hydraulic ram legs may be used as a waler/soldier strut where end loading is required.

1.4.30 Isolation valve

Mechanical valve or hydraulic valve positioned on the full bore side of a ram, which provides additional hydraulic isolation and enables a quick release coupling to be reconnected when the ram is under load.

1.4.31 Load-bearing mounting fastener

Pin or bolt that transfers the full load of the ram from the piston rod end block or from the cylinder end block to the surrounding structure (see Figures 1.1, 1.2, 1.3 and 1.5).

NOTE: The pin hole diameter normally provides a clearance tolerance and not an interference fit for the pin.

1.4.32 Mechanical locking clamp

Mechanical device, activated automatically or pre-set manually, that prevents the ram from closing down when there is a loss of hydraulic pressure (see Figure 1.11).

1.4.33 Mechanical locking telescoping over-sleeve

Telescoping component that totally encloses a hydraulic ram.

NOTE: A series of pin holes are provided so that a locking point can be positioned to prevent the strut from collapsing fully in the event of a loss of hydraulic pressure (see Figure 1.2).

1.4.34 Pilot-operated check valve

A device, usually proprietary, that ensures that the return side of a double acting ram cannot retract unless hydraulic pressure is applied to the ram.

1.4.35 Piston

Component that transmits the force created by the fluid pressure to the piston rod (see Figures 1.1, 1.2 and 1.3).

1.4.36 Piston rod

Telescoping inner load-bearing component that is terminated with a piston at one end and an end block at the other end (see Figures 1.1, 1.2 and 1.3).

1.4.37 Piston rod end block

Component that terminates the piston rod and provides a connection point for attaching to the surrounding structure (see Figures 1.1, 1.2 and 1.3).

1.4.38 Piston stroke

Difference in measurement between the fully retracted length of the ram and the fully extended length of the ram.

1.4.39 Pressure-relief valve

A device, usually proprietary, fitted to protect against unintentional over-pressurization of a ram.

1.4.40 Quick-release coupler safety valve

Automatic valve that only operates when there is mechanical damage to a quick release coupler.

NOTE: The purpose of the valve is to prevent a loss of pressure in the ram following accidental damage to a quick-release coupler.

1.4.41 Quick-release valve coupler

A pair of components, one end of which is male and the other female, that provide hydraulic connections to rams and hoses.

NOTES:

- 1 These couplings are also known as a quick-action couplings.
- 2 Both ends of the coupler are self sealing when disconnected.
- 3 Hydraulic fluid is introduced into a ram through these connections with the convention that the male end is used to introduce fluid to the extend side of the ram. On double acting rams a female end is provided to the retract side.

1.4.42 Ram acceptance test

Non-destructive test applied to all rams to confirm the specified function of the ram (see Clause 4.7 and Appendix D).

1.4.43 Rated pressure (F_{WKC})

Highest stated pressure at which the system or part of the system is intended to operate in steady state conditions.

NOTES:

- 1 This pressure is calculated as specified in Paragraph B2, Appendix B.
- 2 Auxiliary items such as quick-release couplings and all other valves have higher-rated pressures.

1.4.44 Release tool

Tool used to separate a quick-release valve coupler from a ram after installing a frame or soldier set into an excavation.

NOTE: Release tools are also used to release pressure from a ram by bleeding the male component of a quick-release valve coupler that is mounted on the ram.

1.4.45 Restraining chain assembly

Chain assembly that is adjustable in length and designed to connect to a hydraulic bracing frame leg or to a waler rail.

NOTE: The assembly supports the frame or waler rail by connecting between the top of the runner/needles or sheet and the restraining point on the frame. They are also used to support one or more frames or waler rails when they are suspended below each other (see Figure 13).

1.4.46 Restraining point

Point for connecting restraining chains.

1.4.47 Single-acting ram

Hydraulic ram that only extends and cannot hydraulically retract when under hydraulic pressure.

NOTES:

- 1 A single-acting ram can only support compressive forces.
- 2 Three types of single-acting ram are included (see Figure 1.1)—
 - (a) displacement type;
 - (b) piston type; and
 - (c) multi-stage rams, which may be piston types, displacement types or a combination of both.
- 3 A single-acting ram may be supplied with a mechanical spring return, which provides a double-acting action without the requirement for a hydraulic return. The spring activates when the hydraulic pressure is released (see Figure 1.2).

1.4.48 Soldier rail

Fixed length structural component used vertically either in isolation or with sheeting covering the excavation face.

1.4.49 Soldier set

Set comprising two soldier rails held apart by at least one hydraulic strut.

NOTE: The set is intended to be used vertically (see Figure 1.9(b)).

1.4.50 Support bracket

Component fixed to excavation sheeting so that the hydraulic bracing frame leg or waler rail is supported at the chosen level (see Figure 1.13).

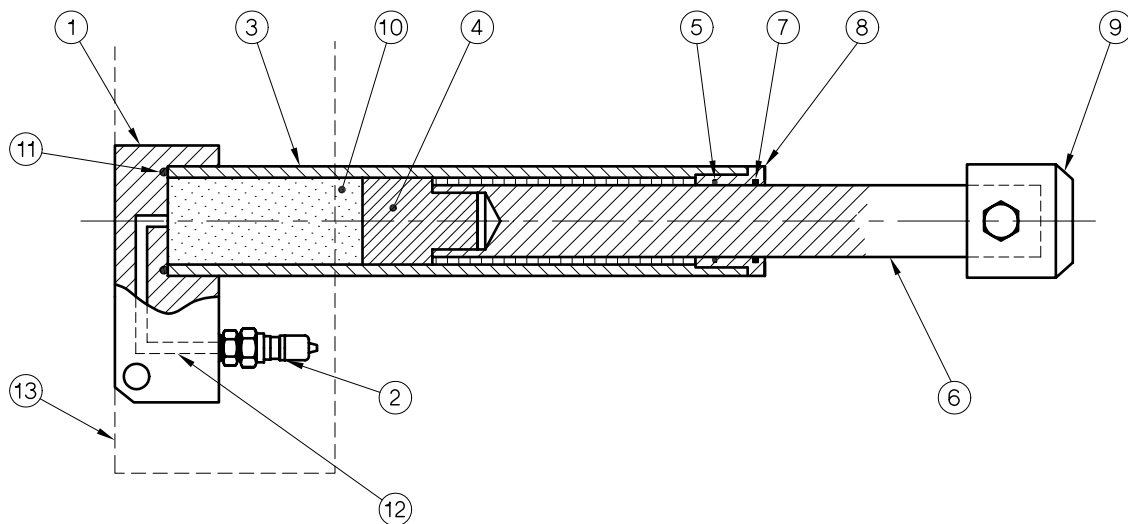
1.4.51 Waler frame

Frame comprising two waler rails held apart by at least two hydraulic struts.

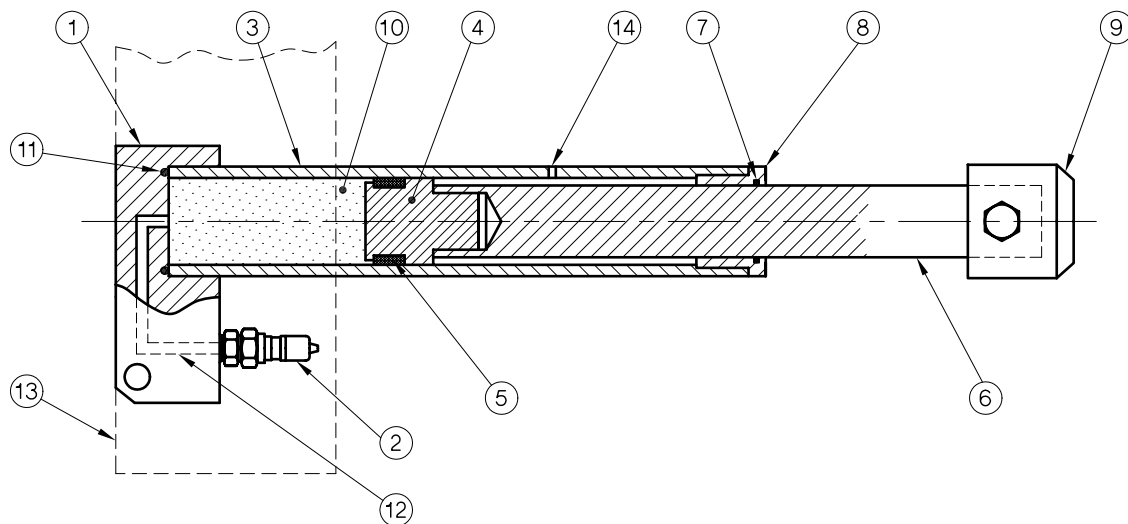
NOTE: The frame is intended to be use horizontally (see Figure 1.9(a)).

1.4.52 Waler rail

Structural component used horizontally usually to support the runners/needles or sheeting forming the bulk cover of the excavation face.



(a) Displacement type ram

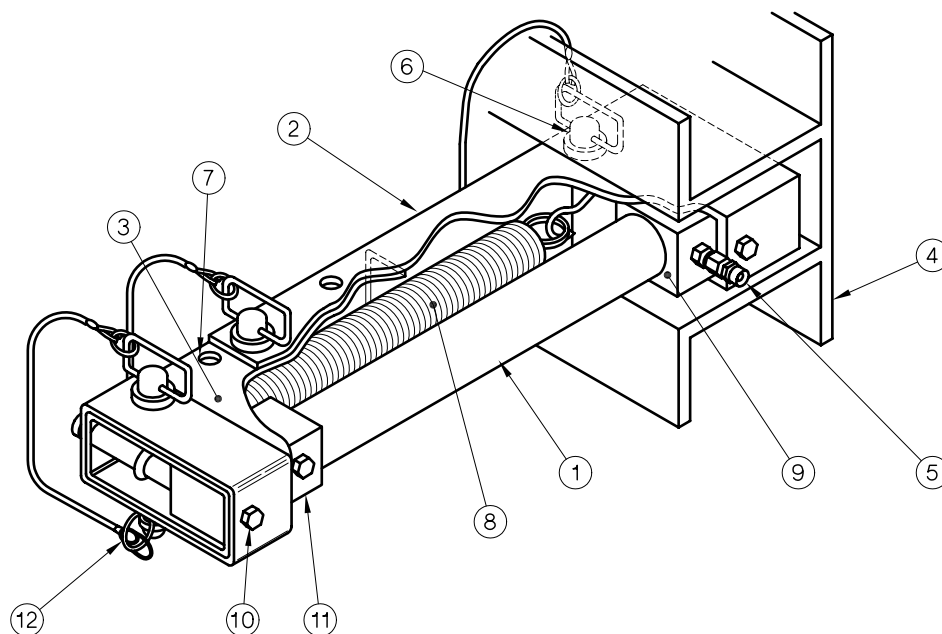


(b) Piston type ram

LEGEND:

- 1 = Cylinder feed block
- 2 = Quick-release coupler
- 3 = Cylinder tube
- 4 = Piston
- 5 = Seal
- 6 = Piston rod
- 7 = Wiper ring
- 8 = Gland
- 9 = Piston rod end block
- 10 = Full bore side of piston
- 11 = 'O' ring seal
- 12 = Location of optional isolation valve
- 13 = Waler or soldier rail
- 14 = Blow-off hole

FIGURE 1.1 EXAMPLES OF SINGLE-ACTING RAMS



LEGEND:

- 1 = Single-acting ram
- 2 = Outer section
- 3 = Inner section
- 4 = Waler rail
- 5 = Quick-release coupler
- 6 = Pin
- 7 = Alternative pin positions
- 8 = Return spring
- 9 = Cylinder feed block
- 10 = End block pins
- 11 = Piston rod end block
- 12 = Retaining clip

FIGURE 1.2 EXAMPLE OF A SINGLE-ACTING TELESCOPIC WALER STRUT WITH SPRING RETURN

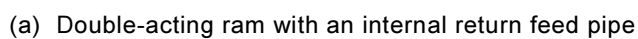
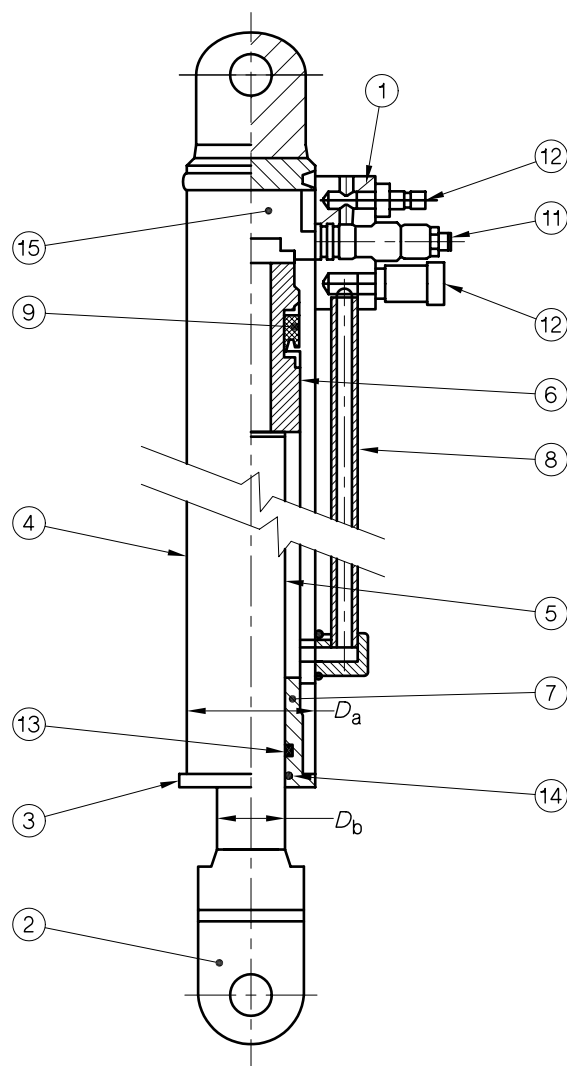


FIGURE 1.3 (in part) EXAMPLES OF DOUBLE-ACTING RAMS

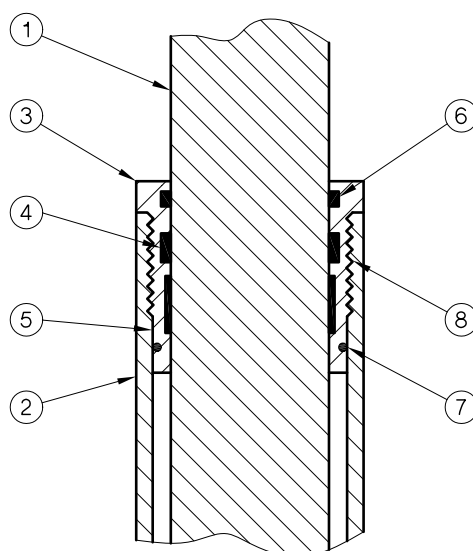


(b) Double-acting ram with an external return

LEGEND:

- 1 = Cylinder feed block
- 2 = Piston rod end block
- 3 = Restraint collar
- 4 = Cylinder tube
- 5 = Piston rod
- 6 = Piston
- 7 = Gland
- 8 = Return pipe
- 9 = Piston seal
- 10 = Return feed pipe seal
- 11 = Lock-off valve
- 12 = Quick-release hose connector
- 13 = Piston rod seal
- 14 = Wiper ring
- 15 = Full bore side of piston

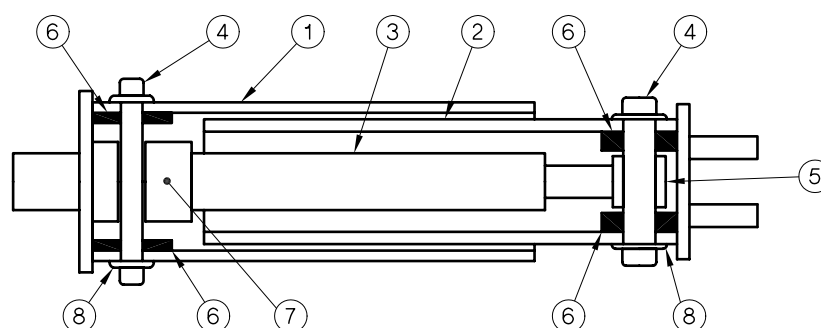
FIGURE 1.3 (in part) EXAMPLES OF DOUBLE-ACTING RAMS



LEGEND:

- 1 = Piston rod
- 2 = Cylinder tube
- 3 = Gland
- 4 = Piston rod seal
- 5 = Bearing ring
- 6 = Wiper ring
- 7 = 'O' ring
- 8 = Gland retaining thread

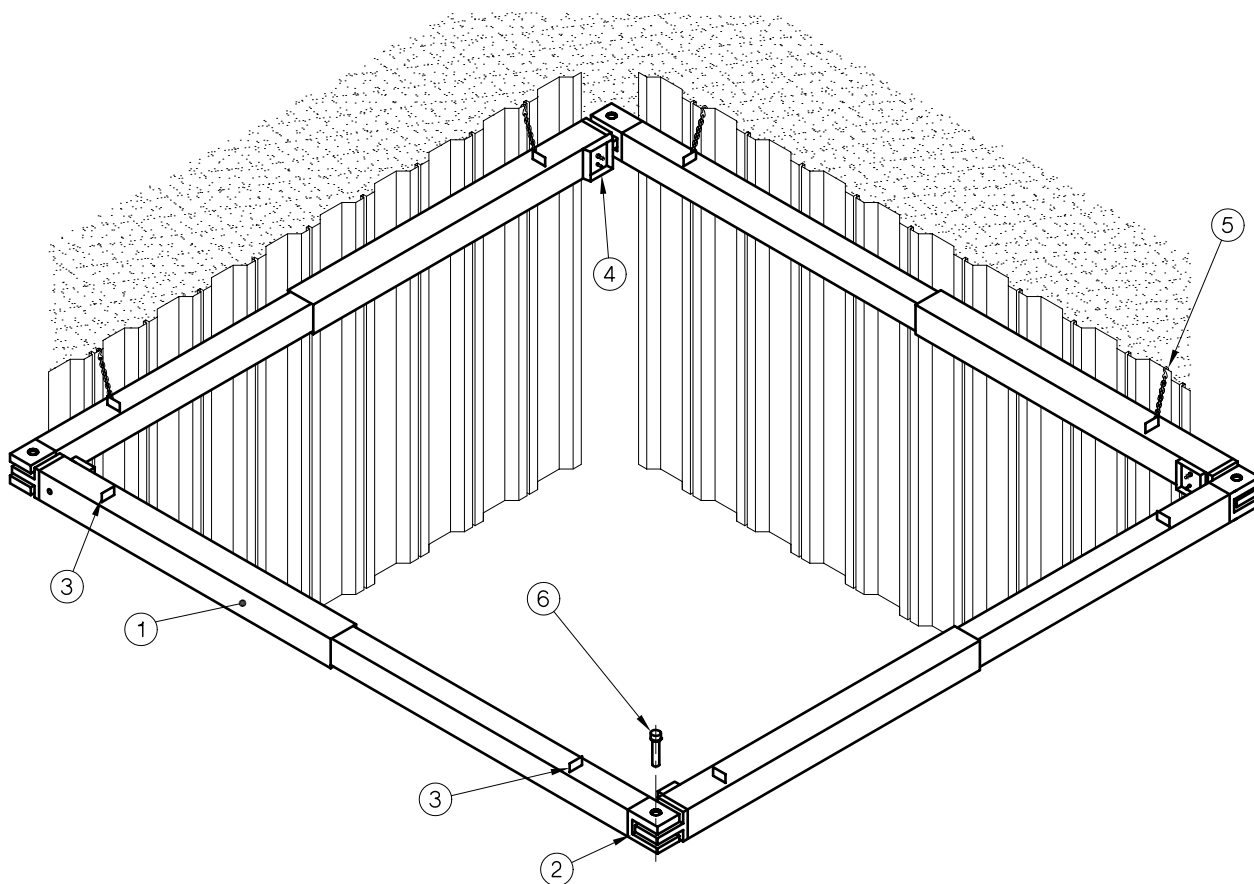
FIGURE 1.4 EXAMPLE OF A GLAND



LEGEND:

- 1 = Outer tube of the adjustable leg
- 2 = Inner tube of the adjustable leg
- 3 = Ram
- 4 = Mounting block pins
- 5 = Piston rod end block
- 6 = Mounting structure
- 7 = Cylinder feed block
- 8 = Retaining clips

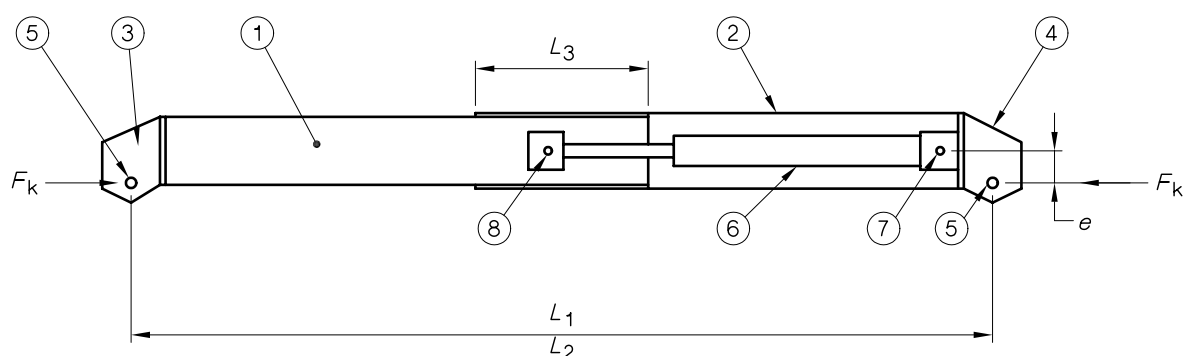
FIGURE 1.5 EXAMPLE OF MOUNTING FASTENERS AND PINS



LEGEND:

- 1 = Hydraulic bracing frame leg
- 2 = Corner detail with pin
- 3 = Handling and restraining point
- 4 = Valve housing and hose connections
- 5 = Restraining chain
- 6 = Corner pin

FIGURE 1.6 EXAMPLE OF A HYDRAULIC BRACING FRAME WITHOUT EXTENSION LEGS

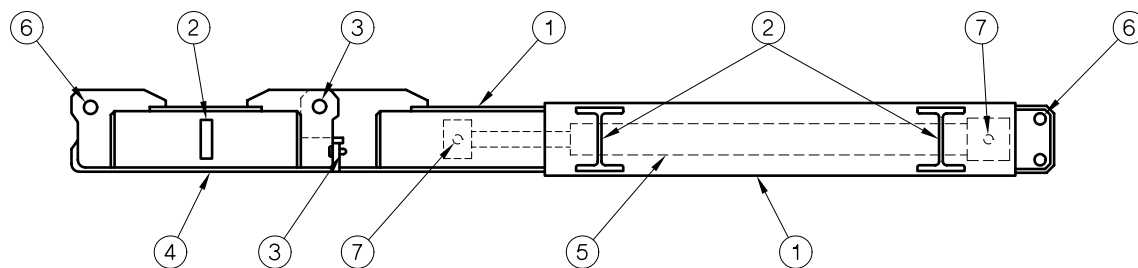


LEGEND:

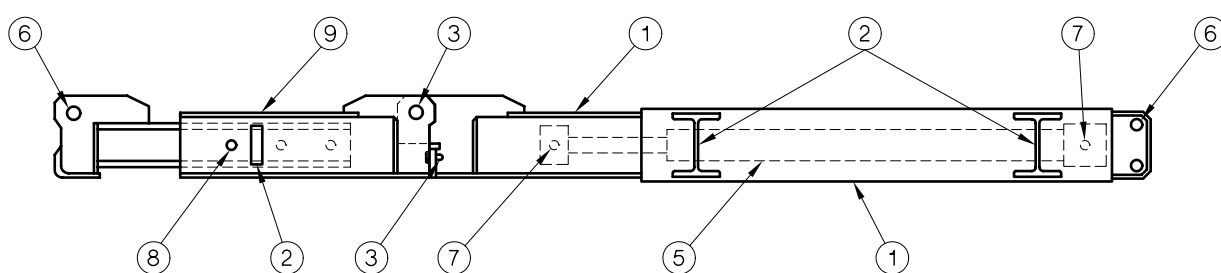
- 1 = Inner adjustable tube
- 2 = Outer adjustable tube
- 3 = Female corner connection
- 4 = Male corner connection
- 5 = Corner pin hole
- 6 = Ram
- 7 = Ram block pin
- 8 = Ram leg mounting pin

- L_1 Minimum dimension with ram closed
- L_2 Maximum dimension with the ram fully extended
- L_3 Minimum overlap of the outer tube to the inner tube

FIGURE 1.7 EXAMPLE OF A HYDRAULIC RAM LEG



(a) Hydraulic ram leg with fixed extension leg

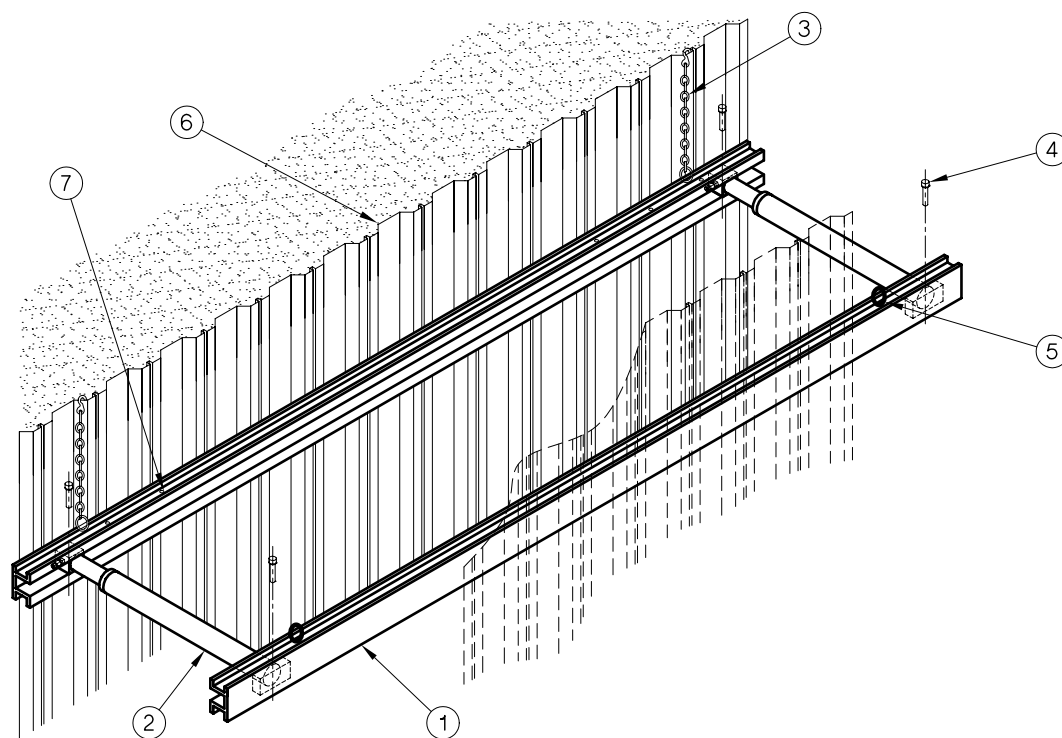


LEGEND:

- 1 = Hydraulic ram leg
- 2 = Handling and restraining points
- 3 = Bolted and pinned joint to the extension bar
- 4 = Fixed extension leg
- 5 = Ram
- 6 = Corner pin hole
- 7 = Ram leg mounting pin
- 8 = Locking pin
- 9 = Mechanical extension leg

(b) Hydraulic bracing frame leg with mechanical extension leg

FIGURE 1.8 EXAMPLE OF A HYDRAULIC BRACING FRAME LEG



LEGEND:

- 1 = Waler rail
- 2 = Hydraulic water strut
- 3 = Restraining chain
- 4 = Pin
- 5 = Handling and restraining
- 6 = Sheet piling
- 7 = Alternative strut locating holes

FIGURE 1.9(A) EXAMPLE OF A WALER FRAME

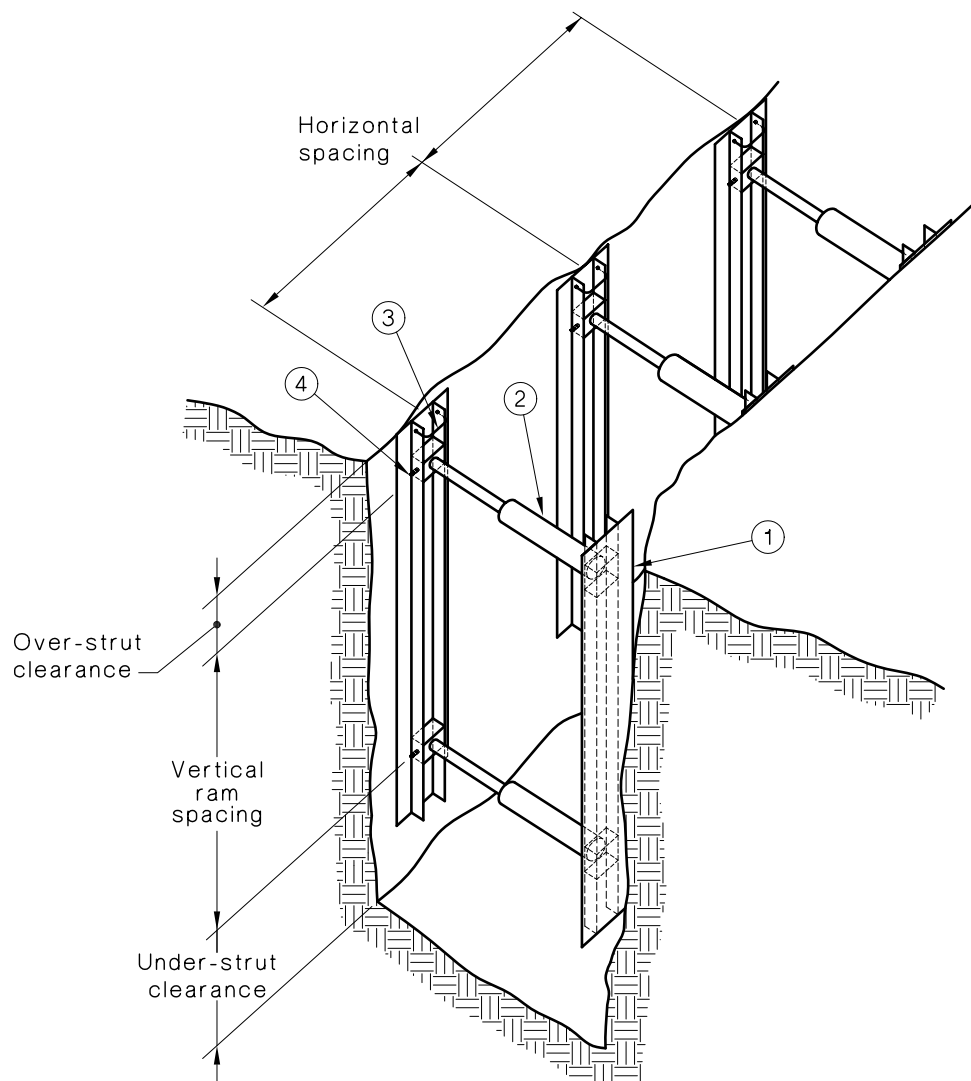
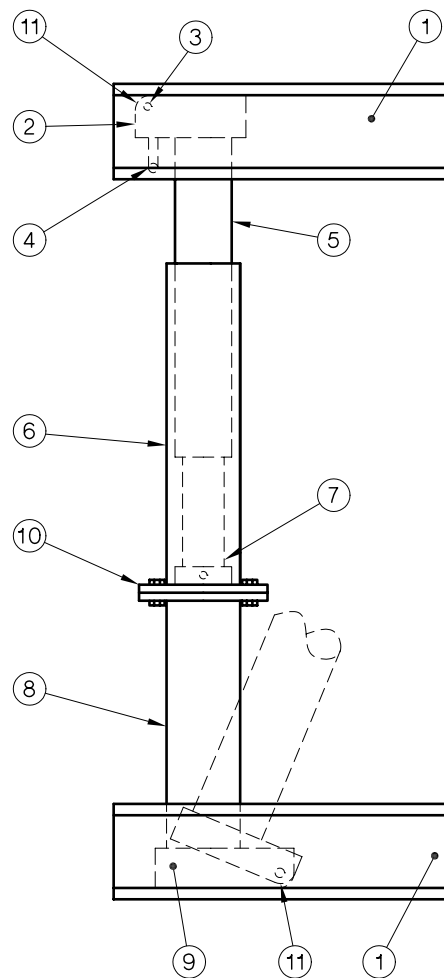


FIGURE 1.9(B) EXAMPLE OF A SOLDIER SET

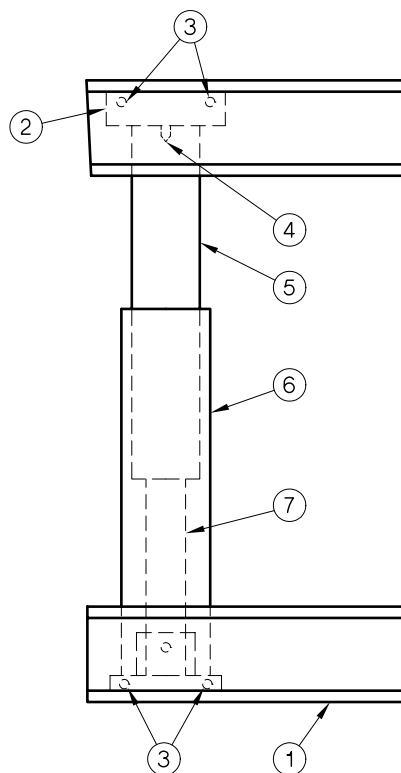


(a) Folding type

LEGEND:

- 1 = Waler/soldier rail
- 2 = Cylinder feed block
- 3 = Pin
- 4 = Quick-release valve
- 5 = Ram
- 6 = Ram with extendable over sleeve
- 7 = Piston rod with mounting block and pin
- 8 = Extension leg with end shoe
- 9 = End shoe
- 10 = Bolted connection
- 11 = Chamfer/radius to aid folding

FIGURE 1.10 (in part) EXAMPLES OF WALER/SOLDIER STRUTS

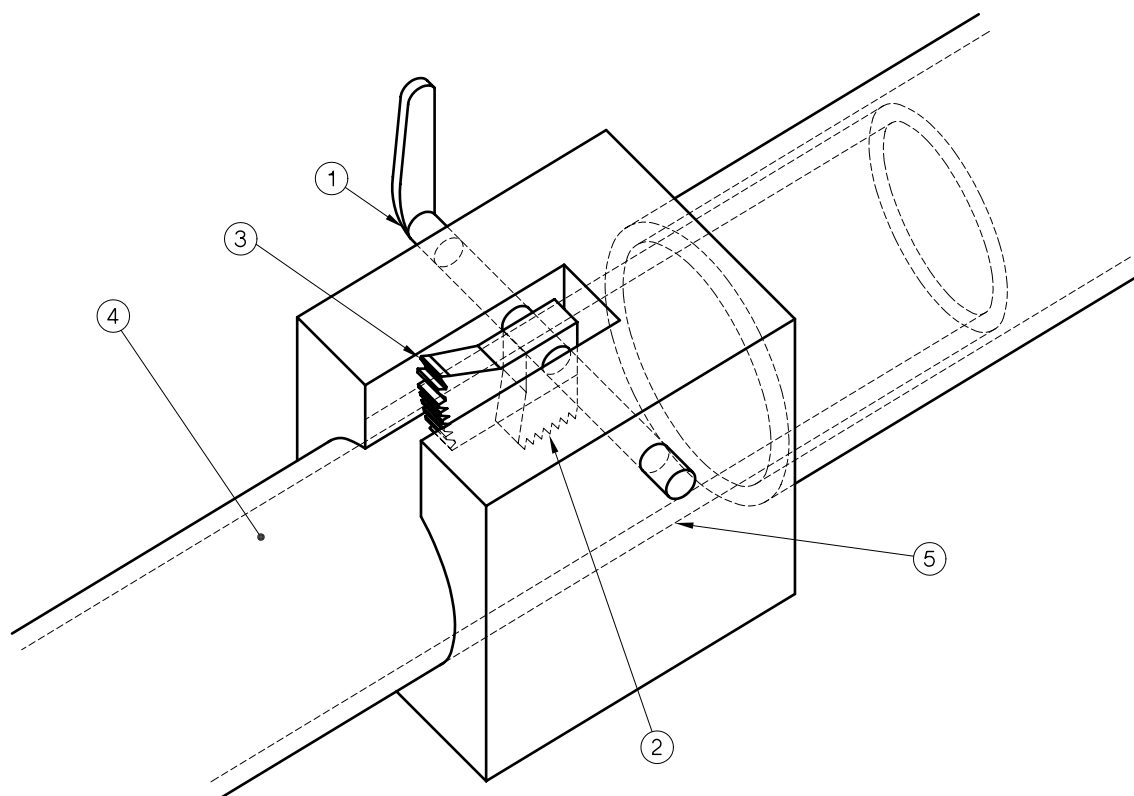


(b) Non-folding type

LEGEND:

- 1 = Waler/soldier rail
- 2 = Cylinder feed block
- 3 = Pin
- 4 = Quick-release valve
- 5 = Ram cylinder
- 6 = Over-sleeve with end shoe
- 7 = Piston rod with mounting block and pin

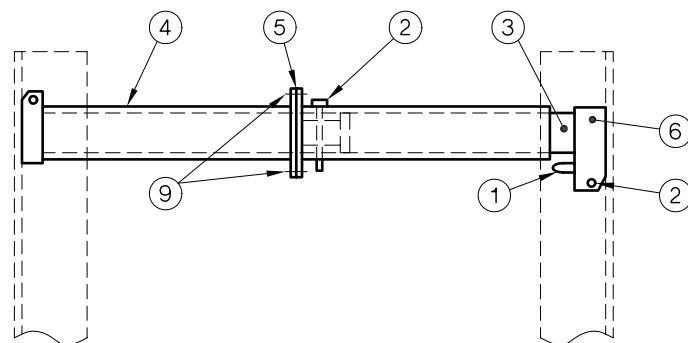
FIGURE 1.10 (in part) EXAMPLES OF WALER/SOLDIER STRUTS



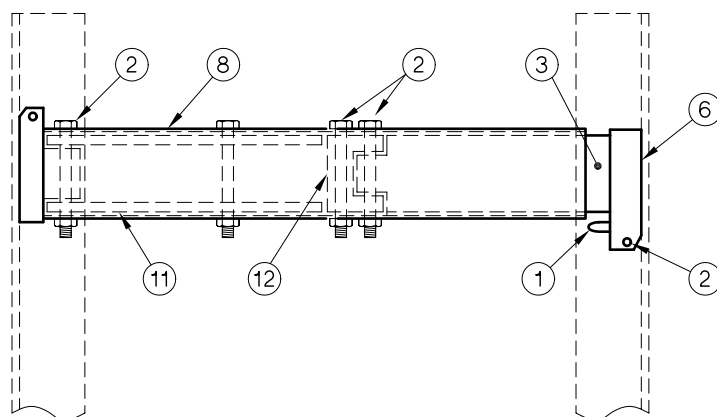
LEGEND:

- 1 = Operating pin to activate locking teeth
- 2 = Toothed locking cam in closed position
- 3 = Toothed locking cam in open position
- 4 = Ram cylinder
- 5 = Locking component mounted to extendable over-sleeve

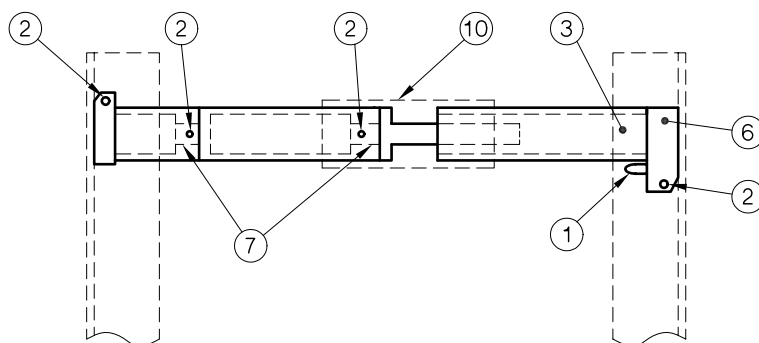
FIGURE 1.11 EXAMPLE OF A MECHANICAL LOCKING SYSTEM FOR A WALER/SOLDIER STRUT



(a) Flange type



(b) Over-sleeve type

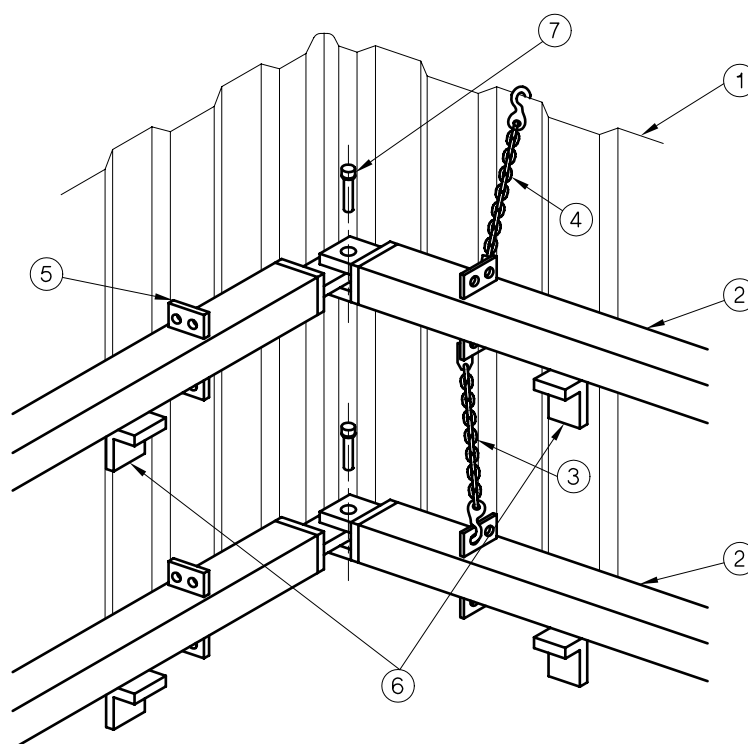


(c) Spigot type

LEGEND:

- 1 = Quick-release coupler
- 2 = Non-load-bearing pin
- 3 = Hydraulic ram
- 4 = Extension leg
- 5 = Bolted flanges
- 6 = Shoe
- 7 = Spigot
- 8 = Over-sleeve extension leg
- 9 = Bolts
- 10 = Over-sleeve
- 11 = Inner-sleeve
- 12 = Plug

FIGURE 1.12 EXAMPLES OF EXTENSION LEGS FOR WALER/SOLDIER STRUTS



LEGEND:

- 1 = Sheeting
- 2 = Hydraulic bracing frame leg
- 3 = Restraining chains-leg to leg
- 4 = Restraining chains-sheet to leg
- 5 = Restraining or handling point
- 6 = Support bracket
- 7 = Pin

FIGURE 1.13 EXAMPLE OF THE USE OF RESTRAINING CHAINS

1.5 SYMBOLS

For the purpose of this Standard the symbols given in Table 1 apply:

TABLE 1.1
MAIN SYMBOLS

Symbol	Explanation	Units
C_f	Partial safety factor for restraining chains	
D_a	External diameter of a ram	mm
D_b	External diameter of a ram leg	mm
e	Eccentricities of F_K related to the centre of the leg	mm
F_K	Axial load in a leg or waler strut	kN
F_{KC}	Characteristic compressive failure pressure of a cylinder tube	MPa
F_T	Axial load in a leg resulting from the return pressure of a double acting ram	kN
F_{TA}	Characteristic return failure pressure of a cylinder tube	MPa
F_{WKC}	Maximum rated pressure of a ram	MPa
L	The length of a waler rail	mm
L_1	Closed length of a single hydraulic leg	mm
L_2	Extended length of a single hydraulic leg	mm

TABLE 1 (continued)

Symbol	Explanation	Units
L_3	Minimum overlap	mm
L_E	The effective length of the piston rod	mm
L_P	The actual length of the ram leg	mm
N	Declared maximum number of frames	—
N_a	Maximum number of active restraining points	—
N_b	Minimum number of restraining chains supporting one frame	—
P_K	Uniformly distributed load	kN/m
R_{KB}	Characteristic bending resistance of a waler/soldier rail or of a hydraulic bracing frame leg	kNm
$R_{KB,JC}$	Characteristic bending resistance on the compression side of joint to an extension leg	kNm
$R_{KB,JT}$	Characteristic bending resistance on the tension side of joint to extension leg	kNm
R_{KB-N}	Characteristic bending resistance of a specified length of a hydraulic bracing strut leg	kNm
$R_{KB,RI}$	Characteristic bending resistance of a ram inner tube housing or mechanical inner sleeve	kNm
$R_{KB,RO}$	Characteristic bending resistance of a ram outer tube housing or mechanical outer sleeve	kNm
R_{KB1}	Characteristic bending resistance of the main section of a hydraulic bracing frame leg	kNm
R_{KB2}	Characteristic bending resistance at a reduced change of section	kNm
R_{KC}	Characteristic axial compression resistance of a hydraulic bracing frame leg or a ram	kN
R_{KRP}	Characteristic resistance of a restraining point	kN
R_{KT}	Characteristic resistance of a restraining chain	kN
R_T	Working load limit of a restraining chain	kN
R_{TA}	Characteristic axial resistance from the return capacity of a double acting ram	kN
S	Spacing between restraining chains	m
t_c	Wall thickness of a ram cylinder	mm
w	Mass per metre of a hydraulic bracing leg or waler rail or soldier set	kN/m
W	Width of a waler frame (see Figure 17)	mm
W_A	Mass of ancillary equipment e.g., bracing struts, knee braces, etc.	kN
W_F	Maximum mass of a hydraulic bracing frame or the maximum mass of a waler frame	kg
Y_1	Maximum cantilever dimension to a two strut waler frame	mm
Y_2	Maximum offset dimension for a centre strut in a three strut waler frame	mm
Y_3	Maximum cantilever dimension when two struts are repositioned in a three strut waler frame	mm
Y_4	Maximum offset of the centre strut when two struts are repositioned in a three strut waler frame	mm
γ_F	Partial safety factor for action	—
γ_M	Partial safety factor for the material	—
γ_{NA}	Partial safety factor for handling and restraining points	—

NOTE: 1 N/mm² = 1 MPa = 10 bar.