

REINFORCED CONCRETE PIPES



INSTALLATION MANUAL

MADDINGTON CONCRETE PRODUCTS Pty Ltd.

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1 Introduction

1.1 Products

Maddington Concrete Products (MCP) is a family-owned and operated Western Australian business which has been supplying high quality precast steel reinforced (SR) concrete pipes for industrial, commercial and domestic applications for more than 40 years. Built with the best dry-mix concrete techniques in the industry, MCP products have developed a reputation in the industry. Designed to specific users' requirements, they are now one of the best options in culvert and drainage applications.

This manual outlines the specifics of MCP manufactured pipes as well as a basic guideline to their installation in a range of conditions. Please refer to the general contents page for directions.

1.2 Manufacturing Sizes

MCP manufactures concrete pipes for a wide range of diameters. Table 1.1 outlines the range of diameters available. Refer to Figure 1.2 on the right hand side in order to better understand a concrete pipe's property variables.



Figure 1.1: The production facility's storage yard in Maddington, Western Australia

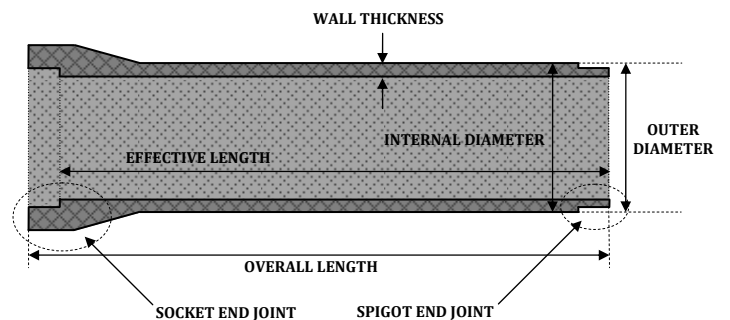


Figure 1.2: The variable properties of a concrete pipe

DIAMETER SIZE [mm]	PRODUCT CODE	OVERALL LENGTH [mm]	EFFECTIVE LENGTH [mm]	WALL THICKNESS [mm]	WEIGHT [kg]
300	P01	2440	2340	45	310
375	P02	2440	2340	45	390
450	P03	2440	2340	48	470
600	P04	2440	2340	55	690
750	P05	2440	2340	68	1130
900	P06	2440	2340	85	1700
1200	P07	2440	2340	100	2600

Table 1.1: Range of SR concrete pipes available in stock or to order

1.3 Load Classes

The Australian Standard Code for precast concrete pipes (pressure and non-pressure), also referred to as AS/NZS-4058:2007, has classified SR concrete pipes in load classes ranging from 2 to 10, 10 being the products able to withstand the greatest applied loads.

MCP manufactures all of their concrete pipes for standard strength (Loading Class 4) according to AS/NZ-4058:2007 specifics.

It is important to remind the user that the test load to determine the loading class for a particular application should be determined in

accordance with the Australian Standard Code for design for installation of buried concrete pipes, also referred to as AS/NZS-3725:2007.

1.4 Durability

All SR concrete pipes manufactured at MCP are designed to comply with AS/NZ-4058:2007, and are therefore expected to have a service life of 100 years if installed following the proper procedure.

2 Performance Testing

In order to comply with the latest version of AS/NZ-4058:2007, routine performance tests are carried out on all diameter sizes produced at MCP. Pipes are tested, using appropriate testing equipment (see Figure 2.1), to withstand both proof loading (cracking) and ultimate loading.

Proof loading is the indicated load applied on a SR concrete pipe without the formation of cracks greater than the test cracks specified in accordance with AS/NZ-4058:2007. Ultimate loading is calculated as 1.5 the proof loading for standard strength classes, and 1.25 the proof loading for super strength classes. It represents the maximum designed load which the pipe can withstand before reaching structural failure.



Figure 2.1: The load testing facility in Maddington, Western Australia

The specifics for loading classes to which all pipes manufactured at MCP have to comply with can be found in Table 2.1.

DIAMETER SIZE [mm]	STANDARD STRENGTH [kN/m]				SUPER STRENGTH ¹ [kN/m]			
	CLASS 2		CLASS 4		CLASS 6		CLASS 8	
	PROOF	ULT	PROOF	ULT	PROOF	ULT	PROOF	ULT
300	15	23	30	45	45	56	60	75
375	17	26	34	51	-	-	-	-
450	20	30	40	60	-	-	-	-
600	26	39	52	78	-	-	-	-
750	32	48	64	96	-	-	-	-
900	37	56	74	111	-	-	-	-
1200	46	69	92	138	-	-	-	-

Table 2.1: Test loads for various classes of SR concrete pipes according to AS/NZ-4058:2007

1 – Upon request MCP can design and manufacture pipes to meet the super strength class

3 Applications

3.1 Culvert

3.1.1 Overview

Culverts are short conduits used to pass water under roadways. They are constructed in circular, rectangular, and oval shapes. Concrete pipes manufactured by MCP can be used in culvert applications. The hydraulic analysis of culverts is complicated because the flow regime is variable. Section 3.1.2 outlines the basics in culvert hydraulics.

3.1.2 Hydraulics

There are 2 types of flow control for culverts: inlet control and outlet control. Generally if the culvert is operating on a steep slope, inlet control conditions can be assumed (Figure 3.1); if it is operating on a mild slope, outlet control conditions can be assumed (Figure 3.2).

The flow rate through a culvert (Q) can be determined by multiplying the intensity of a storm by the catchment area the tributary feeds off from multiplied again by the coefficient of runoff. By combining this information with other geometrical and hydraulic variables, headwater levels can be determined using appropriate nomographs. Each form of flow control requires different inputs in order to determine a solution. Using these tools, a water engineer will be able to correctly select the most suitable pipe size to fulfill all regulations regarding water discharge.

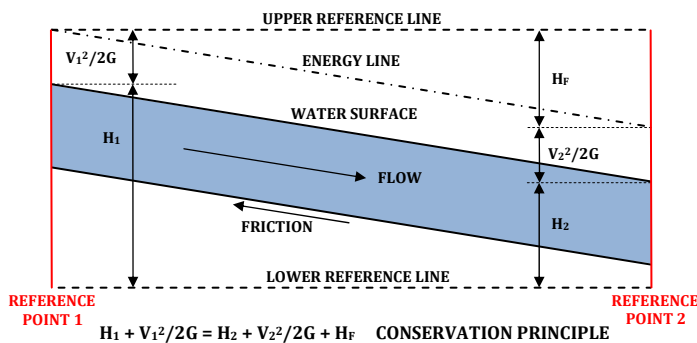


Figure 3.3: The principle of conservation of energy as outlined by Bernoulli

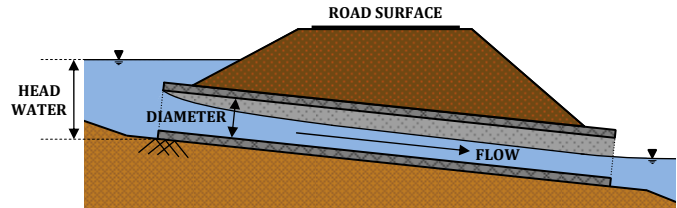


Figure 3.1: A culvert with inlet control operating conditions

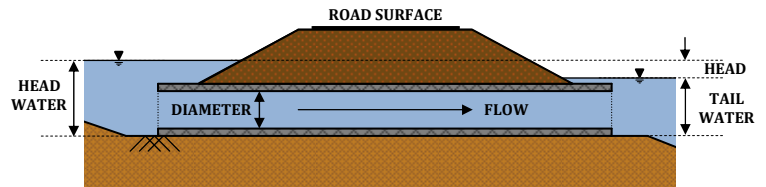


Figure 3.2: A culvert with outlet control operating conditions

3.2 Drainage

3.2.1 Overview

SR concrete pipes manufactured by MCP can be employed in the channeling and discharge of stormwater. Concrete pipes manufactured by MCP can be used in culvert applications. Rubber ring joints (RRJ) are employed in the connection of various pipe segments. For more details on the design of pipe joints consult Section 4.1.

3.2.2 Hydraulics

Drainage application systems of pipes can be dealt with using the Bernoulli Principle. Figure 3.3 outlines how the principle of conservation of energy can be used to assign a numerical value to unknown parameters. Using this tool, a water engineer will be able to correctly select the most suitable pipe size to fulfill the drainage requirements.

4 System Design

4.1 Loading & Clear-Coverage

As previously discussed in Section 2, reinforced concrete pipes are built to be able to withstand ultimate loadings in accordance to specifications which can be found in AS/NZ-4058:2007.

The soil material making up the stratum of clear-cover on the top of a pipe allows for any live loads (axle loads coming from vehicle movement on the surface) to be distributed along the trench/embankment. The degree to which these loads are distributed is very much reliant on geotechnical properties of the soil such as friction angle, unit weight of the material and level of saturation.

The deeper underground the pipe is positioned, the less concentrated the live loads are, reducing the stress on the concrete. AS/NZS-3725:2007 outlines a minimum of 150 mm of clear-cover in order to protect the concrete pipe from vibrations and other construction related issues which might arise. This value is often not sufficient in order to guarantee that the positioned pipe is not subject to direct stresses which could be greater than the ultimate loads to which the pipe has been tested to withstand.

For different diameter pipes, different desirable clear-covers apply. These values are a function of the possible live loads which could be applied on the top surface (vehicles applying pressure on the backfill). These pressures can be represented in number and intensity of axle repetitions on a surface area. The Department of Main Roads in Western Australia classifies vehicle loads in 5 axle categories:

- Single-Axle Standard Tyres (SAST)
- Single-Axle Dual Tyres (SADT)
- Tandem-Axle Single Tyres (TAST)
- Tandem-Axle Dual Tyres (TADT)
- Tri-Axle Dual Tyres (TRDT)

Each category presents limitations regarding the loading pressure which can be exerted on a road surface (and everything lying underneath). AUSRoads have produced these limitations and are enforced on Western Australian roads.

Table 4.1 outlines the desired minimum clear-covers which will not compromise the structural soundness for all the pipes manufactured at MCP.

DIAMETER SIZE [mm]	CLEAR-COVER ¹ [mm]				
	SAST	SADT	TAST	TADT	TRDT
300	150	225	250	N/A	N/A
375	150	250	260	N/A	N/A
450	150	260	280	N/A	N/A
600	150	150	150	470 ²	N/A
750	150	150	150	480	N/A
900	150	150	150	500	N/A
1200	150	150	150	150	800 ²

Table 4.1: Minimum clear-covers for various diameter pipes

1 – The clear-cover already includes the minimum 150 mm required by AS/NZS-3725:2007

2 – These values are critical and represent the minimal values for clear-cover. Maximum values should not exceed minimal +10 mm. See Reference Material in Section 8.4 for more detailed information

It is important to highlight how axle categories represent law enforced limitations, and therefore represent the worse possible scenarios for each case. These axle categories' limitations are available on the Department of Main Roads' website and should never be infringed.

Simple charts have been developed by MCP to quickly determine the ultimate load carrying capacity at varying cover depths for the different Class 4 pipe sizes - refer to Section 8.4

4.2 Multiple Pipes Conditions

Multiple pipes can be positioned parallel to each other in the same trench (see Figure 4.2). AS/NZS-3725:2007 outlines the minimum values for distances (L_c) between the pipe's outside wall and either the trench wall or the outer surface of the pipe running parallel next to it. L_c is directly related to the pipe's diameter as outlined in Table 4.2.

DIAMETER RANGE [mm]	L_c [mm]
≤ 600	150
$> 600, \leq 1200$	200

Table 4.2: Grading limits for select fill in bed and haunch zones according to AS/NZ-3725:2007

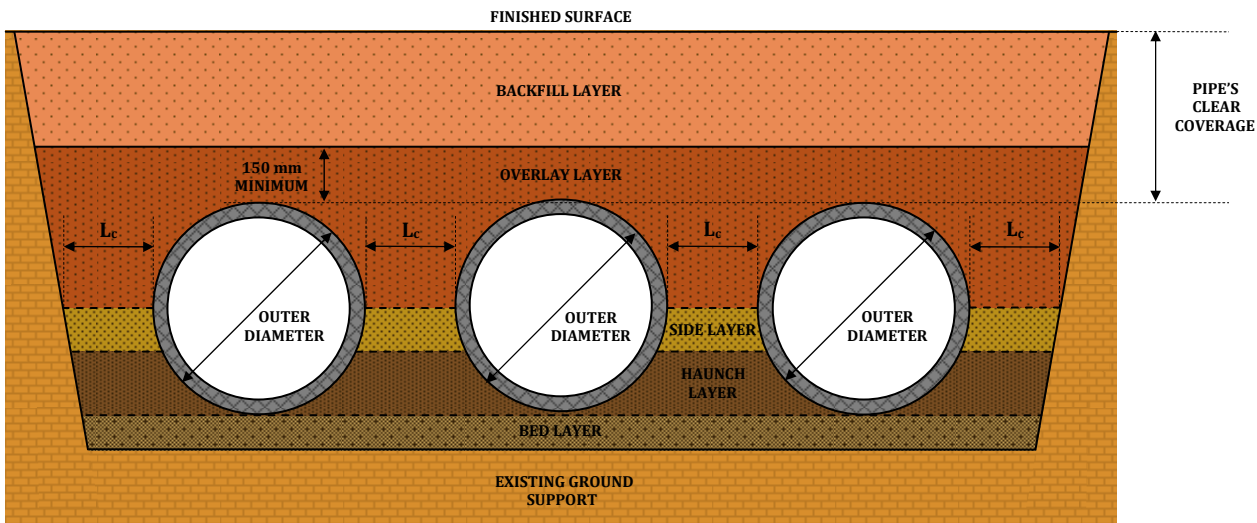


Figure 7.3: The components for pipe support materials

5 Transportation

The transportation of steel reinforced concrete pipes is a delicate task which requires correct equipment in order to ensure the safe delivery of the product purchased without compromising its structural abilities (no cracks).

A platform semitrailer is required for transportation of the product from the production site to the client's site. Platform semitrailers allow the forklifts easy access to load up the cargo from the sides without incurring in logistical problems. Semitrailers with significant lateral confinements will not be loaded with the purchased order of pipes.

The stacking process requires the pipes to be stored on "crates" which can be positioned one on top of the other in rows. Straps or chains can be utilized to secure the cargo to the semitrailer. The minimum requirement is to have two straps on each end of the stack of pipes. Two additional straps can be employed to better secure the bottom rows to the deck for additional support. Safety and conserving the structural integrity of the pipes is the main aim of such process.

6 Ground Support

The concrete pipes ready for installation have to be able to withstand the loads to which they have been designed to resist. In order to make sure the soil around the pipe is not subject to any movement which might compromise the short-term and long-term stability and functionality of the pipe system, proper ground support needs to be in place.

It is up to the design engineer's discretion to decide which technique of ground support to utilize in the final design. All specified design guidelines regarding depth of the embedment, width of the trench, haunch type and thickness and many other required variables can be found by consulting the Australia Standard AS/NZ-3725:2007. This guideline outlines 3 major techniques of ground support for pipes:

- **Unsupported (Type U):** No bed, haunch or side support for the pipe. This design provides the least support for the pipe; it is however the cheapest and least time-consuming technique to install a concrete pipe. Refer to Figure 6.1 for the cross-sectional view of the pipe support.

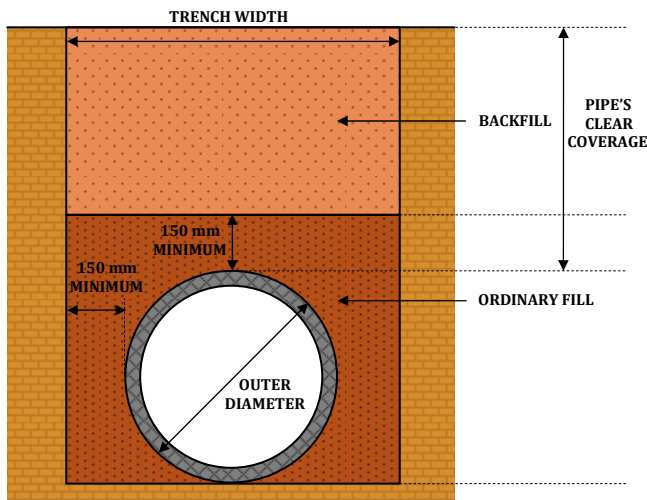


Figure 6.1: Unsupported Type U support

- **Haunch Support (Type H):** Bed layer and haunch support for the pipe are in place. This design provides medium support for the pipe. Refer to Figure 6.2 for the cross-sectional view of the pipe support.

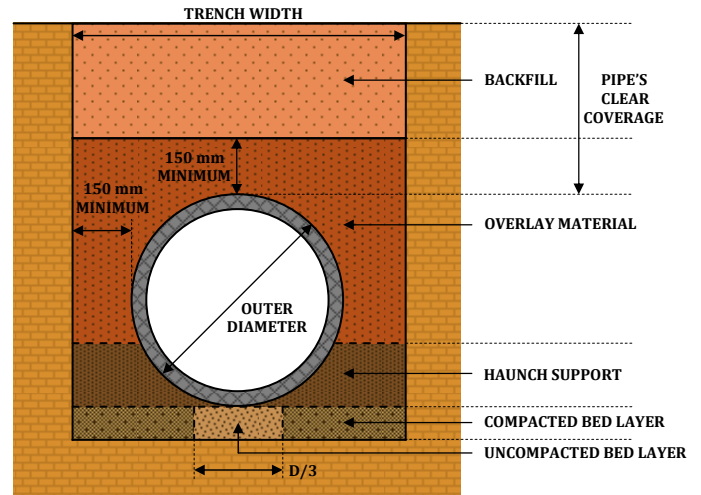


Figure 6.2: Haunch Type H support

- **Haunch & Side Support (Type HS):** Bed layer, haunch together with side support for the pipe are in place. This design provides the highest level of support for the pipe; it is however the most costly solution. Refer to Figure 6.3 for the cross-sectional view of the pipe support.

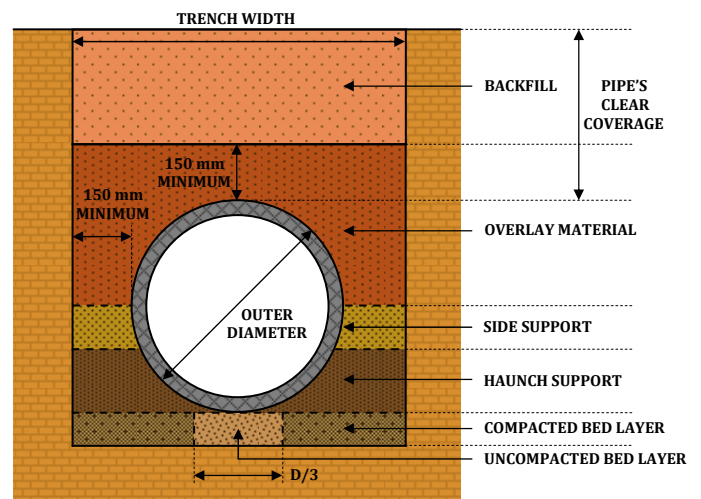


Figure 6.3: Haunch and side Type HS support

7 Installation Procedure

7.1 Trench Digging

7.1.1 Overview

Trench digging can be difficult and proper safety procedures must be followed in order to minimize chances of damage or injuries on site.

A geotechnical report of the soil in which the trench will be dug is required in order to determine the soil profile of the site. Reference to AS/NZ-3725:2007 should be taken into account together with local government regulations and procedures when considering the site's geotechnical conditions.



Figure 7.1: The excavation of a trench

7.1.2 Preparation & Specifications

Various techniques for excavation of trenches exist and depending on soil properties and depth of excavation the most suitable one should be selected at discretion of the design engineer (see Section 4).

The trench foundation layer must be firm and uniform. Large inconsistent rocks must be removed and soil voids must be filled with the proper material to ensure uniform plane on which to lay the concrete pipe. This will guarantee better stability and load distribution.

The depth to which the trench must be excavated to depends on the characteristics of the SR concrete pipe (loading class, outer

diameter...), the soil conditions and the load to which it will be subject to. Section 4.1 provides an easy to follow guideline to determine the depth of the clear-cover.

The width of the trench is also critical as the greater the width, the more vertical load the SR concrete pipe could possibly be subject to. Please refer to AS/NZ-3725:2007 for more the specifics regarding this factor as it can change due to many factors.

7.1.3 Stability

Soil material excavated from the site should be placed at appropriate distance from the trench to avoid complications during construction process.

Trenches excavated to a depth of more than 1.5 meters present a significantly higher risk of collapse increasing the risk of injuries and/or delays to the project. In order to avoid this, battering or benching, as seen in Figure 7.2, might be considered as an option to increase the stability of the walls. This is common practice among the industry.

The utilization of retaining walls or other soil strengthening techniques are also a possibility but may not be as cost-effective.

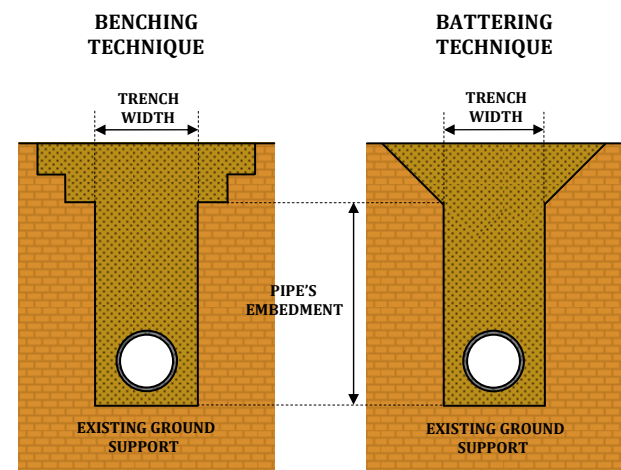


Figure 7.2: Benching and battering techniques used for deep-trench excavations

7.1.4 Groundwater

The presence of seasonal shallow groundwater might be a problem when digging a trench especially in urbanized areas. Precaution measures must be put in place in order to stabilize and control the water level. A geotechnical engineer's advice is recommended on the most suitable practice to employ for the given scenario.

7.2 Pipe Support Material

7.2.1 Overview

The pipe support material is composed of the following components:

- Bed Layer
- Haunch Layer
- Side Layer
- Overlay Layer
- Backfill Layer

Each layer must conform to specific guidelines discussed in the later sub-sections. It is important to build these layers in sections and compact the ground at every specific interval in order to achieve proper support for the concrete pipe. Figure 7.3 outlines the components of the pipe support material.

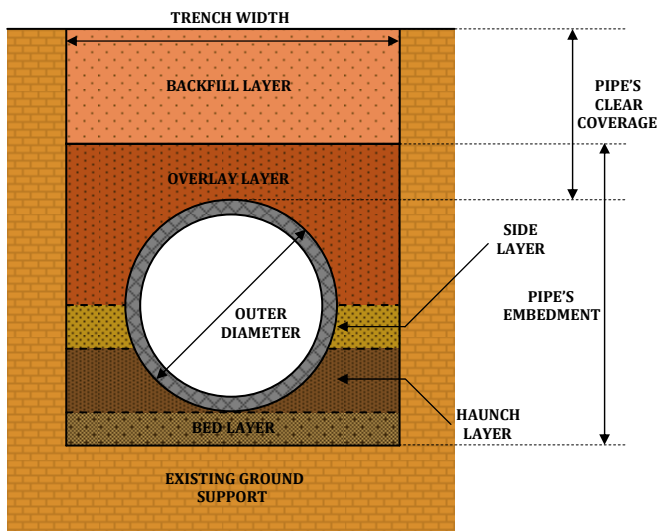


Figure 7.3: The components for pipe support materials

7.2.2 Bed & Haunch Layer

Laying the bed is a critical step of the pipe installation procedure as it provides the vertical weight support for the concrete pipe. The bed must be leveled and graded with precision so that it fulfills the designer's specifications.

The soil must be compacted, using proper equipment before laying the pipes to avoid unexpected settlements. In order to accommodate the socket of the pipe at the joints, chases must be excavated so that the load of the concrete pipes and of the soil on top is evenly distributed.

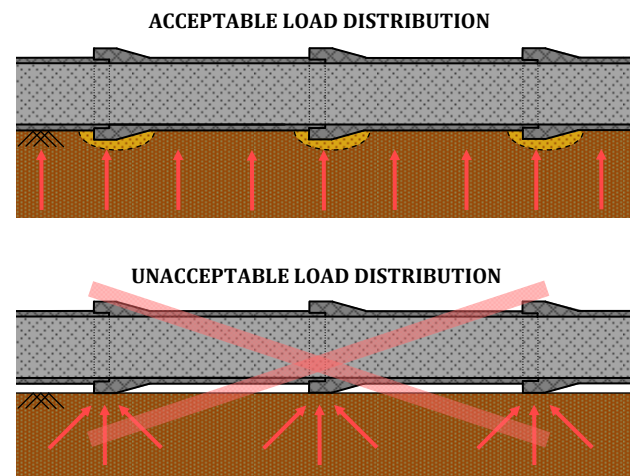


Figure 7.4: Support must be uniform in order to evenly spread the support reaction on the pipe

Both the bed and the haunch must be composed of a non-cohesive material which does not decompose over time. The granular properties to be used for these two sections must be coherent with the grain size specifications found in AS/NZ-3725:2007. Table 7.1 outlines such specifications.

SIEVE SIZE [mm]	WEIGHT PASSING [%]
19.0	100
2.36	100-50
0.60	90-20
0.30	60-10
0.15	25-0
0.075	10-0

Table 7.1: Grading limits for select fill in bed and haunch zones according to AS/NZ-3725:2007

7.2.3 Side Layer

The same soil properties used for the bed and haunch layers apply for the side layer. The granular properties are however different; for proper grain size specifications, please refer to Appendix A in the Australian Standard AS/NZ-3725:2007. Table 7.2 outlines such specifications.

SIEVE SIZE [mm]	WEIGHT PASSING [%]
19.0	100
2.36	100-50
0.60	100-30
0.30	50-15
0.15	25-0

Table 7.2: Grading limits for select fill in side zones according to AS/NZ-3725:2007

7.2.4 Overlay Layer

The overlay layer's soil does not have to conform to such strict rules as the layers underneath it. For logistical purposes, it is common to use the material used for the side layer during this procedure. This allows having an overlay free from large rock particles which could end up damaging the concrete pipe during compaction. This layer must have at least 150 millimeters thickness at the top of the concrete pipe in order to provide it enough protection.

7.2.5 Backfill Layer

The backfilling layer consists of the remaining exposed area of the trench. No clear guidelines exist to which material to use for the backfilling procedure. The choice is left to the discretion of the pipe layer which should make a decision with the relevant stakeholders.

It is important to note that the choice of the backfill material might be impacted by the function of the surface layer. If a road is to be constructed then the road base, sub-base and sub-grade design have to be incorporated. Please consult any relevant standards or guidelines before carrying out any work.

7.3 Ground Compaction

The degree of compaction of the ground around embracing and supporting the pipe is the key in ensuring the optimization of the pipe's load carrying capacity. The density index (I_D) for cohesion-less soils should be determined by a professional geotechnical engineer in accordance to the Australian Standard AS-1298:1980. Table 7.3 outlines the range limits of the grading curve the selected fill must fall inside of.

Ground compaction should take place in evenly placed layers of no more than 150 mm in thickness in order to ensure no voids are left in the support material (see Figure 7.5). Proper compacting equipment should be operated in order to achieve the desired compaction. The weight of heavy compacting equipment should be taken into account when compacting the soil above the concrete pipe. A temporary embankment should be put in place to allow sufficient clearance for the concentrated load to disperse without causing structural damage to the concrete pipe underneath.

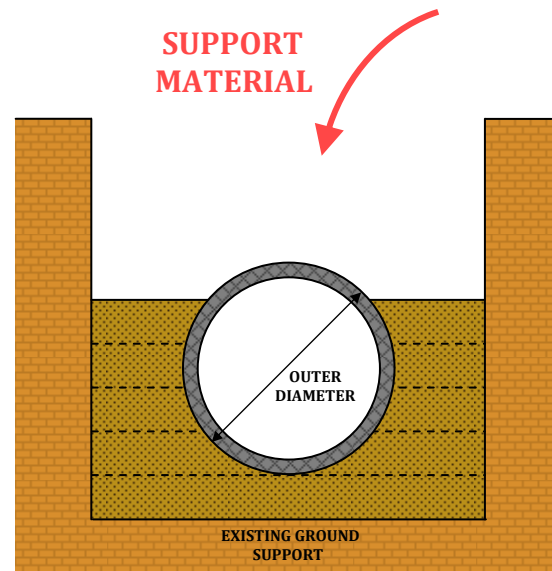


Figure 7.5: Support must be placed in uniform layers in order to increase its dry density value

SUPPORT TYPE ¹		MINIMUM DEPTH [mm]		MINIMUM ZONE COMPACTION ² [%]		
		BED ZONE	HAUNCH ZONE	BED AND HAUNCH ZONES I _D	SIDE ZONES	
					I _D	R _D ³
U		75	-	-	-	-
H	H1	100	0.1D	50	-	-
	H2	100	0.3D	60	-	-
HS	HS1	100	0.1D	50	50	85
	HS2	100	0.3D	60	60	90
	HS3	100	0.3D	70	70	95

Table 7.3: Minimum depth and zone compaction properties according to AS/NZ-3725:2007

1 – Subcategories of support types exist for trenches designed with haunch supports only (H1 & H2) and for the ones designed with side supports as well (HS1, HS2 & HS3). The higher the subcategory number, the greater compaction rate and depth layer is required. Check with a geotechnical engineer to determine which subcategory is the most suitable for the required performance.

2 – The compaction zone excludes the middle D/3 section of the bedding layer

3 – The dry density ratio (R_D) only applies if using a cohesive material as the support material, something which is not really recommended

7.4 Pipe Laying

7.4.1 Pipe Placing

Concrete pipes have to be placed in the excavated trench after the placing of the bed layer. An excavator should assist in the placing of the pipe. It is important to remember that the soil must be compacted and to the proper line and grade as previously specified in Section 7.3. If the pipe placing does not fulfill the designer's indications, then the pipe must be removed and appropriate remediation must be carried out to the bed layer. Alterations to the bedding while the pipe is still in place are dangerous and not acceptable.

7.4.2 Pipe Joining

All SR concrete pipes manufactured at MCP use rubber ring joints. The procedure for installation is simple yet effective. The elastomeric seal band is put in place and the second pipe (positioned at a relatively small distance to the one already in position) is pushed so that its spigot is pushed fully home into the socket of the pipe already in position. The use of a lever pulled by a worker at the socket end of the second pipe is useful to get the pipe into position as seen in Figure 7.6.

Under no circumstances should heavy machinery such as excavators be operated alone to push the spigot pipe home into the socket. This is highly dangerous and could result in damaging the concrete pipe ultimately compromising its efficiency and possibly its functionality.

If a deviation in the joint is required by the design, the procedure is the same as if the pipes were laid straight. The spigot must be pushed fully home into the socket. Only after this has happened, it is recommended to lever the pipe into position in order to achieve the desired angle of deviation. For more information regarding specific joints properties such as maximum angle of deviation, maximum laying gaps and others consult with a specialist at MCP.

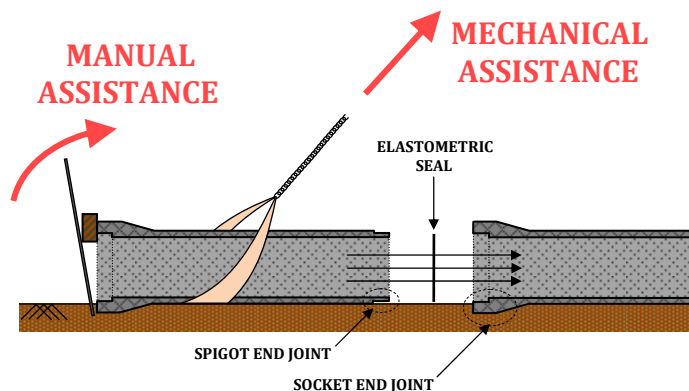


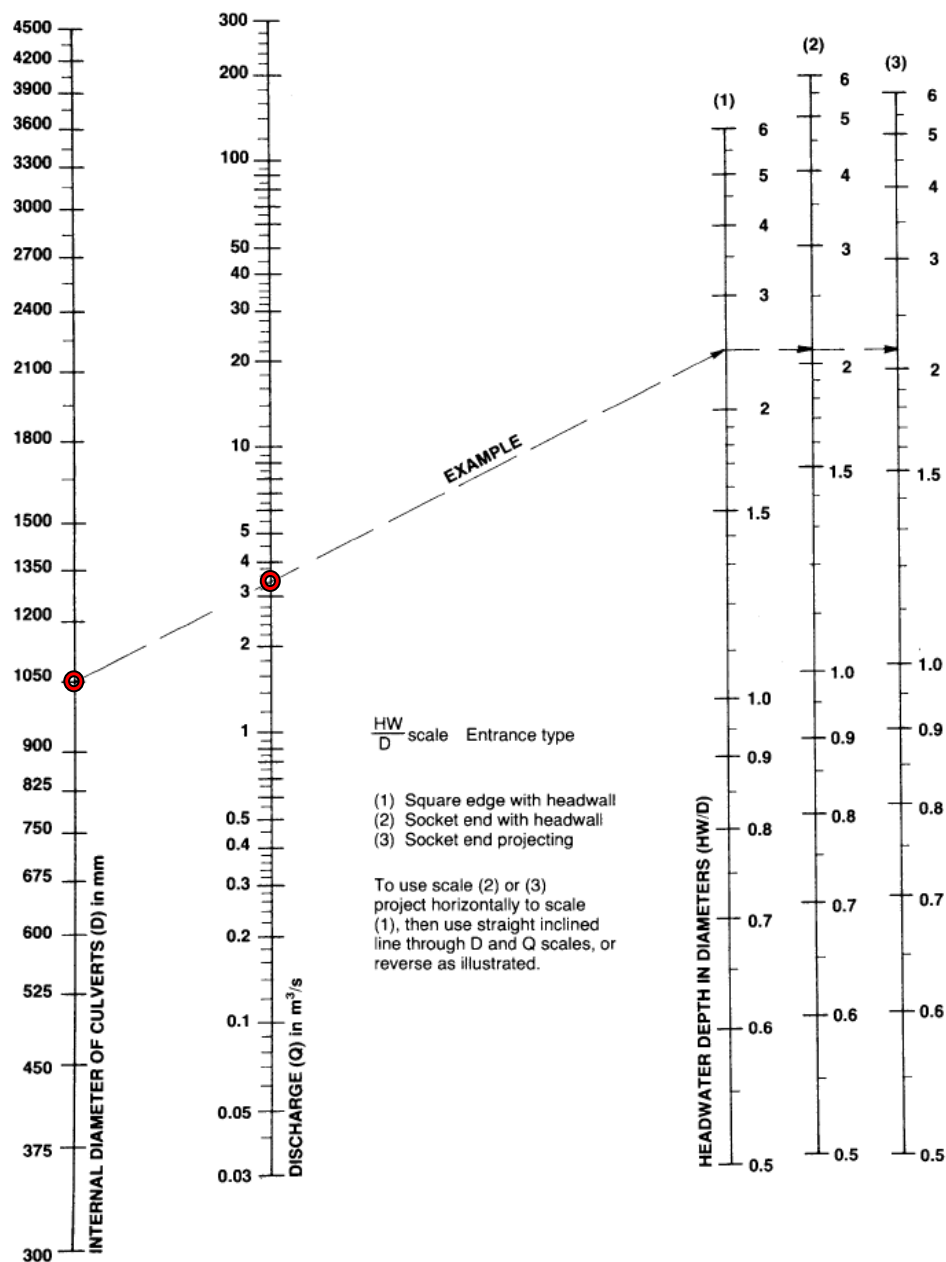
Figure 7.6: Pushing the pipe into place using both manual and mechanical assistance

8 Reference Material

8.1 Conversion Table

LENGTH	1 mm = 0.0394 in 1 cm = 0.3937 in 1 m = 3.2808 ft 1 km = 0.6214 miles	1 in = 25.4000 mm 1 in = 2.5400 cm 1 ft = 0.3848 m 1 mile = 1.6093 km
AREA	1 mm ² = 0.0016 in ² 1 cm ² = 0.1550 in ² 1 m ² = 10.7639 ft ² 1 ha = 2.4711 acres	1 in ² = 645.1600 mm ² 1 in ² = 6.4516 cm ² 1 ft ² = 0.0929 m ² 1 acre = 0.4047 ha
VOLUME	1 mm ³ = 0.0164 in ³ 1 cm ³ = 16.3934 in ³ 1 m ³ = 35.3147 ft ³	1 in ³ = 61.0240 mm ³ 1 in ³ = 0.0610 cm ³ 1 ft ³ = 0.0283 m ³
LIQUID STORAGE	1 L = 0.0353 ft ³ 1 L = 0.2200 imp gal 1 L = 0.2642 US gal 1 ML = 0.0810 acre ft	1 ft ³ = 28.3168 L 1 imp gal = 4.5461 L 1 US gal = 3.7850 L 1 acre ft = 1.234 ML
VELOCITY	1 m/sec = 3.2808 ft/sec 1 km/hr = 0.6214 miles/hr	1 ft/sec = 0.3848 m/sec 1 mile/hr = 1.6093 km/hr
VOLUMETRIC FLOW	1 L/sec = 13.1981 imp gal/min	1 imp gal/ min = 0.0758 L/sec
MASS	1 g = 0.0353 oz 1 kg = 2.2046 lb 1 tonne [1000 kg] = 0.9842 tons 1 tonne [1000 kg] = 1.1023 US tons	1 oz = 28.3495 g 1 lb = 0.4536 kg 1 ton = 1.0161 tonnes 1 US ton = 0.9072 tonnes
FORCE	1 kN = 224.8090 lb force 1 kN = 0.1004 ton force	1 lb force = 0.0044 kN 1 ton force = 9.9640 kN
PRESSURE	1 kPa = 0.1450 psi 1 MPa = 145.0377 psi	1 psi = 6.8900 kPa 1 psi = 0.0069 MPa
POWER	1 kW = 1.3400 hp	1 hp = 0.746 kW

8.2 Nomographs – Inlet Control

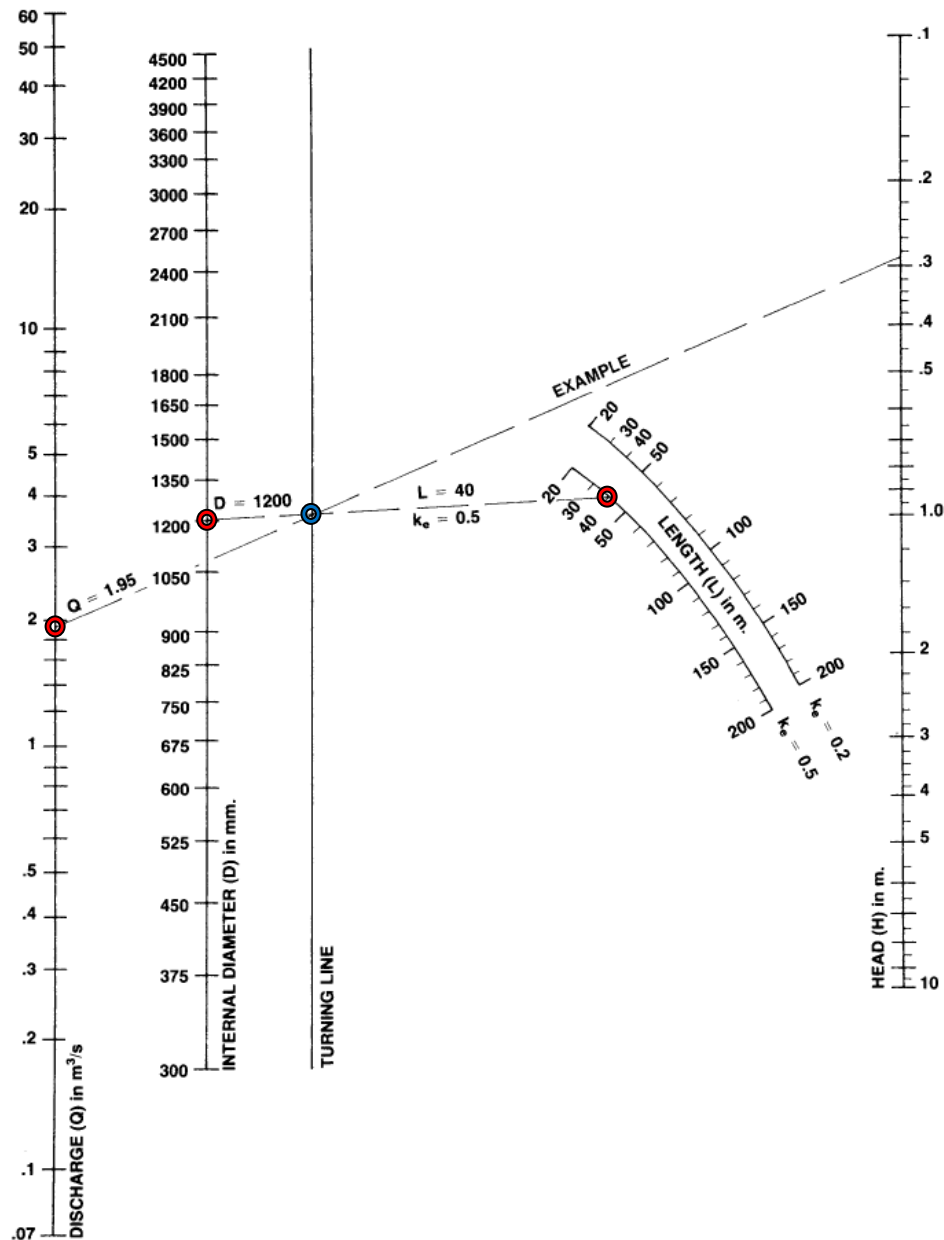


EXAMPLE

GIVEN: Internal diameter of the pipe is 1050 mm; the given discharge is 3.4 m³/sec

RESULT: Depending on the entrance type of the culvert, the headwater depth divided by the diameter of the pipe can be obtained tracing a line through the two given variables and extending that line until scale (1) is reached.

8.3 Nomographs – Outlet Control



EXAMPLE

GIVEN: Internal diameter of the pipe is 1200 mm; the given discharge is 1.95 m³/sec; the length of the pipe is 40 m; and the coefficient of entrance loss is 0.5.

RESULT: Trace a line connecting the internal diameter point and the length value of the culvert. The next step is to connect the flow-rate value with the line previously drawn at the “turning line”. Extend that line until the “Head” scale is reached revealing the head level of the water.

8.4 Load Carrying Capacity Graphs

Relevant to Section 4.1, these graphs outline the results from the Excel formulated load carrying capacities for a typical Perth sandy soil assuming:

- 45 degrees load dispersion;
- Bulk unit weight of 20 kN/m³;
- Factor of safety of 1.5

The red dashed line outlines the factored load carrying capacity for a pipe class 4 of the specified diameter complying with AS/NZ-4058:2007. Any depth cover value whose axle line is situated underneath the capacity line is suitable to be employed as a clear-cover value. All reinforced pipes have been analyzed under vehicle loads classified under these 5 axle categories:

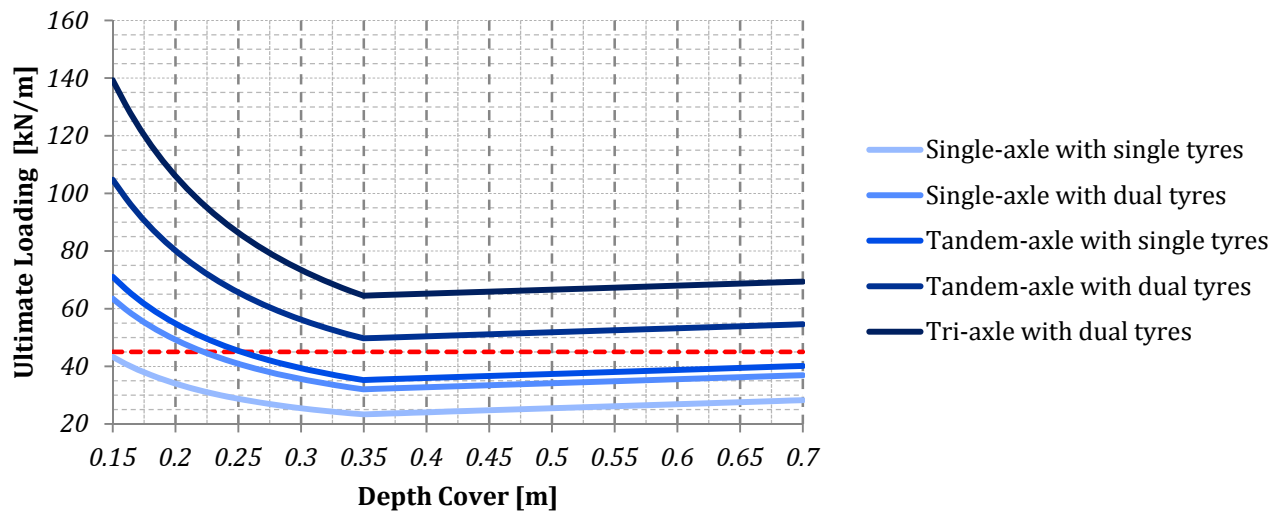
- 53.0 kN per axle; Single-Axle Standard Tyres (SAST)
- 80.0 kN per axle; Single-Axle Dual Tyres (SADT)
- 90.0 kN per axle; Tandem-Axle Single Tyres (TAST)
- 135.0 kN per axle; Tandem-Axle Dual Tyres (TADT)
- 181.0 kN per axle; Tri-Axle Dual Tyres (TRDT)

The above axle loads are working loads which are un-factored. To obtain the permissible wheel loading from these charts for the particular depth cover and axle category read the ultimate loading and divide this value by the 1.5 factor of safety (FOS).

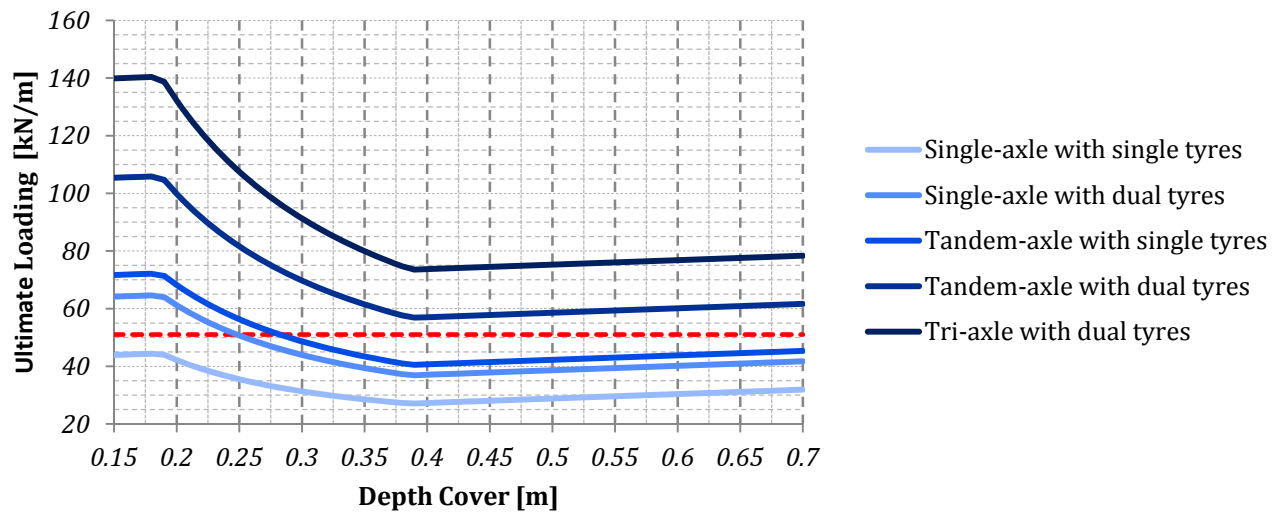
$$\text{Permissible wheel loading} = \frac{\text{Ultimate loading}}{\text{FOS}}$$

Example: 300 pipe load class 4
 Depth cover = 250mm
 Tandem-axle with single tyres
 Ultimate loading = 45 kN
 Permissible wheel loading = $45/1.5 = 30$ kN

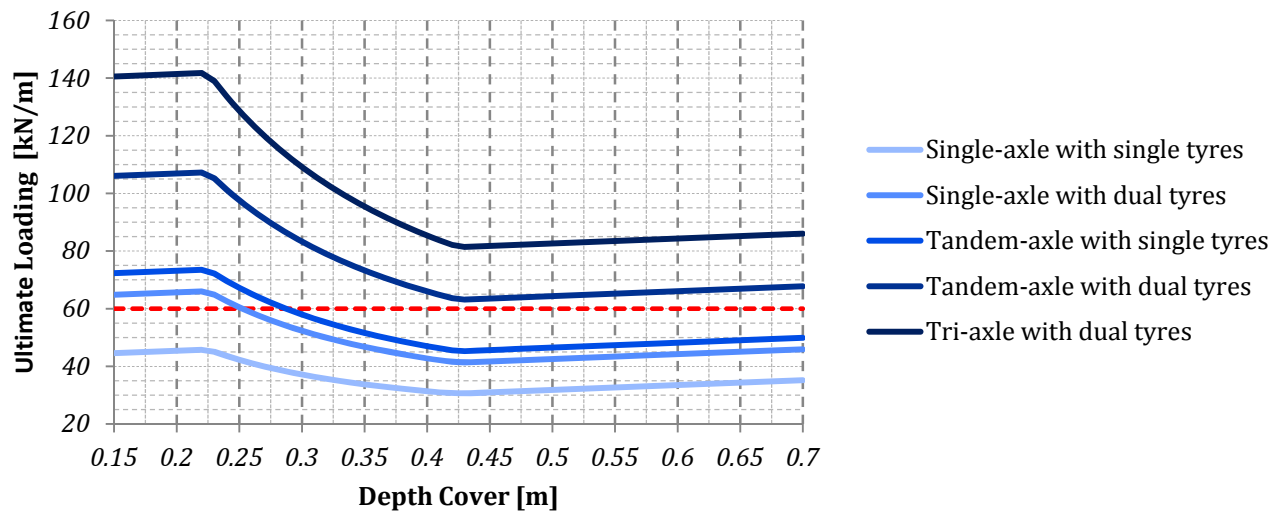
300 LOAD CLASS 4



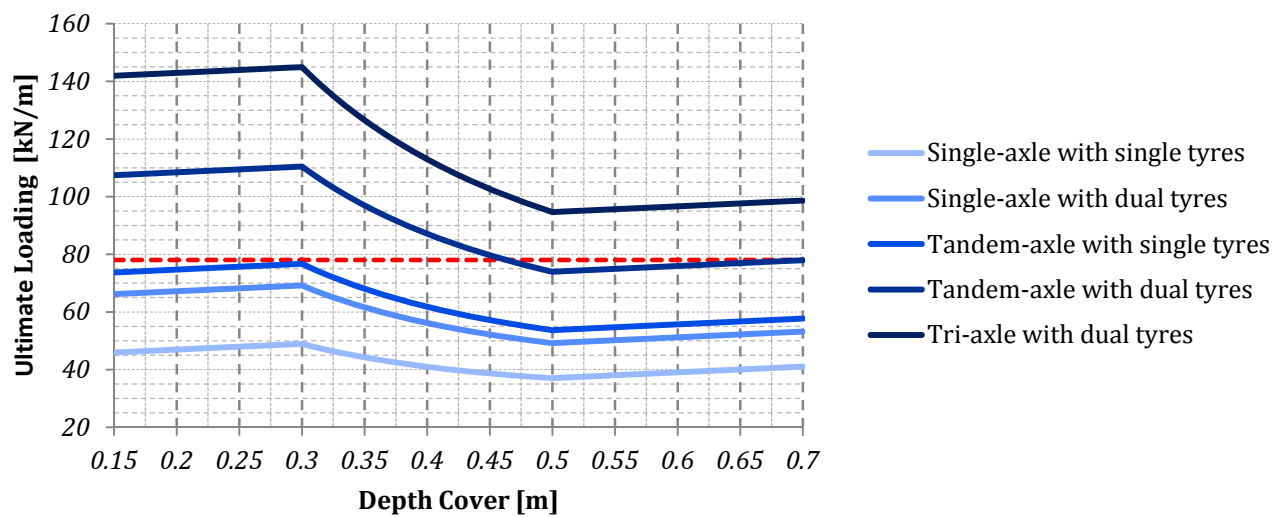
375 LOAD CLASS 4



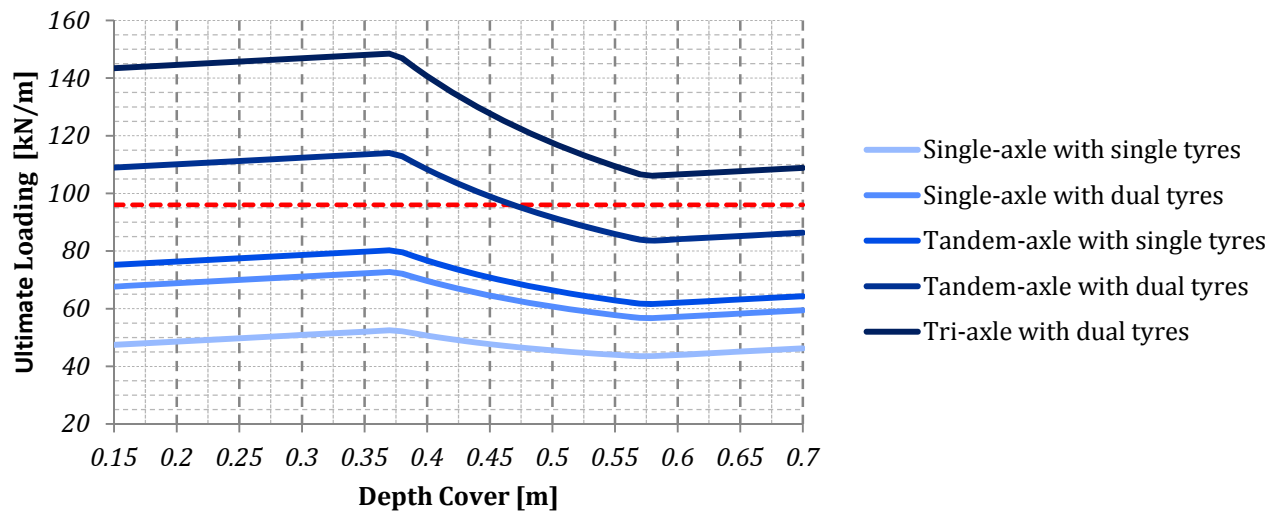
450 LOAD CLASS 4



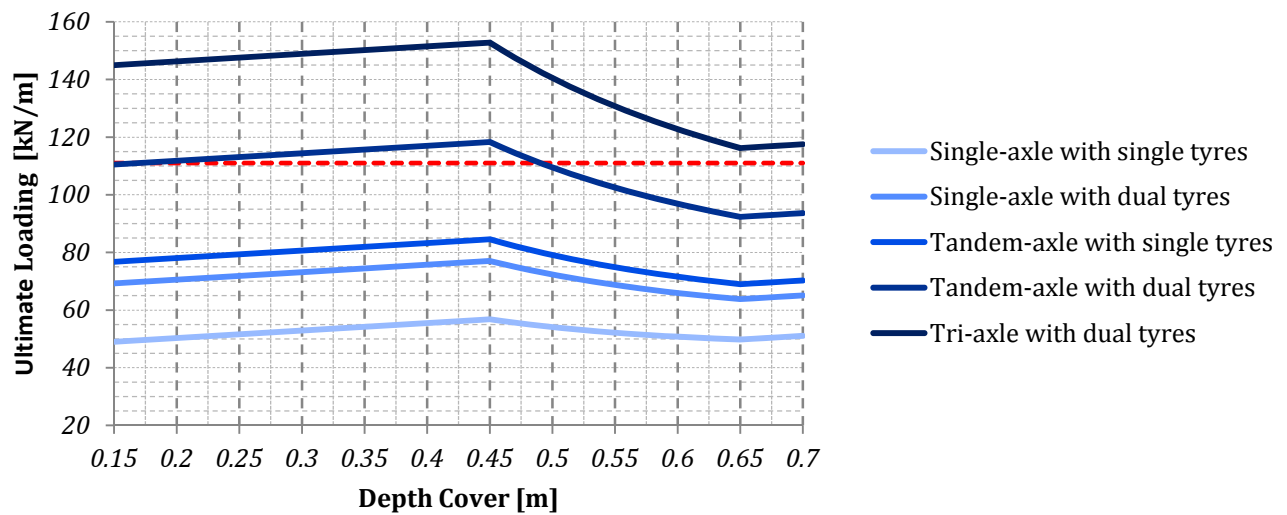
600 LOAD CLASS 4



750 LOAD CLASS 4



900 LOAD CLASS 4



1200 LOAD CLASS 4

