RIB LOC AUSTRALIA PTY LTD

SERIES 2000 STORMWATER PIPE

TECHNICAL MANUAL

BY

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1.0 Introduction

Rib Loc is an Australian company well known in the plastic piping industry. As well as Series 2000 it has also pioneered a leading pipe relining system. Currently its products are manufactured or sold in over 40 countries around the world.

Rib Loc Series 2000 is a high-density polyethylene stormwater pipe, enhanced in the higher stiffness classes with externally wound galvanised steel profiled strip.

Series 2000 is manufactured by winding a high-density polyethylene (HDPE) strip which incorporates T-shaped stiffening ribs. The strips are joined to form a pipe by both a ribbed lock and a bead of polyethylene weld. The steel enhancement is also in a profile shape for optimum reinforcement. It is this combination which gives Series 2000 its high strength to weight ratio.

The pipe is manufactured in internal diameters from 225mm to 1800mm and in four Stiffness Classes, according to the amount of steel enhancement. An advantage of polyethylene is that it can be easily fabricated, and thus a range of fittings can be easily manufactured to the specifier's requirements.

2.0 Benefits of Series 2000 Stormwater Pipe

Series 2000 High Density Polyethylene (HDPE) stormwater piping is a major component of the Rib Loc product range. Released just over 6 years ago, Series 2000 has experienced a steady increase in sales, especially in the public sector. A number of key product features are listed below:

- Series 2000 stormwater pipe's lightweight yet robust design. This feature is especially important when considering occupational health and safety issues.

- Unlike concrete piping, fittings and elbows for Series 2000 pipes can be tailor made to any angle, diameter and class of pipe.

- 50% of the plastic used in the manufacture of Series 2000 is recycled HDPE which would otherwise have been used as landfill.

When considering the above factors, it can be seen that using Series 2000 stormwater pipe not only improves speed and safety of installation but also helps the environment.

These characteristics have led to significant demand for the product, the first to effectively use HDPE and steel in a composite stormwater pipe.

3.0 Series 2000 Material and Pipe Properties

3.1 Abrasion Resistance

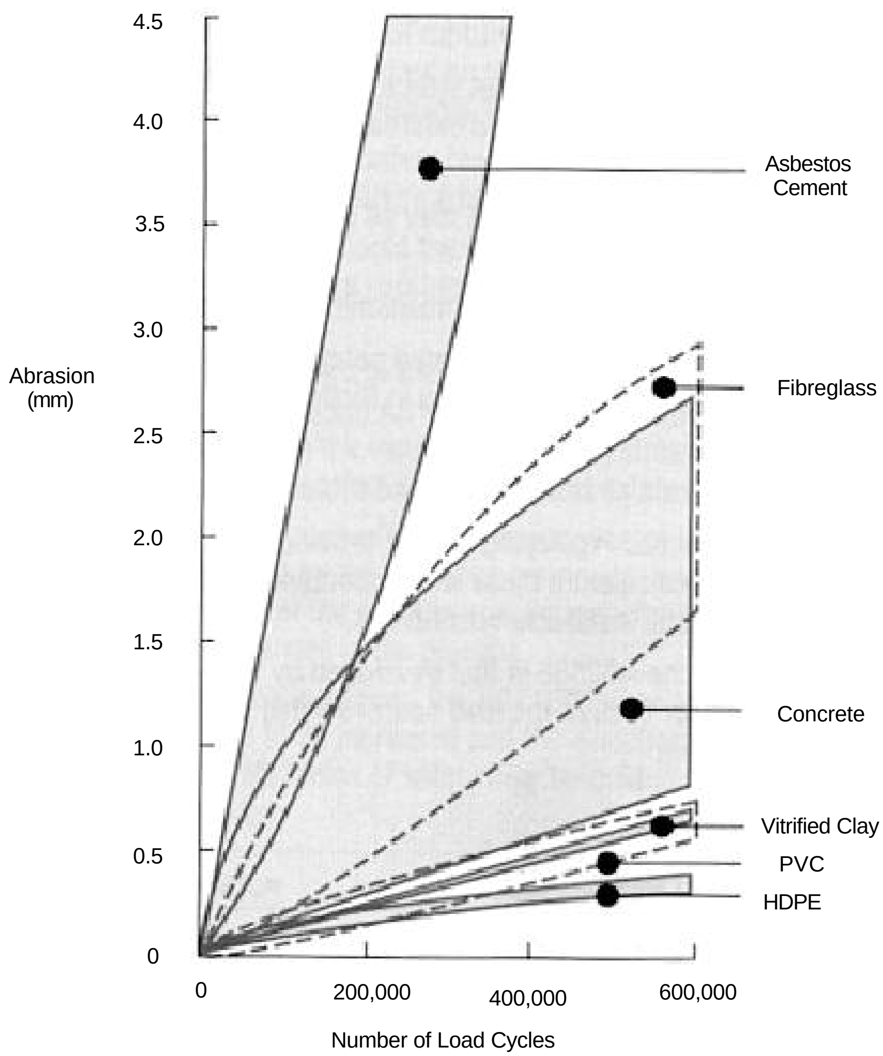
HDPE is an extremely abrasion resistant material. Pipes made from it can be expected to have a life at least as long as other types of stormwater pipe.

The main use of HDPE pipe in Australia is in mining applications, where durability and abrasion resistance are important properties. It is frequently used for slurry lines and other highly abrasive applications.

Testing of abrasion resistance generally aims to compare the relative performance of pipe materials under test conditions. These test conditions are more severe than would be encountered in a normal stormwater application.

The tests consisted of charging a half metre section of pipe with a quartz sand/gravel mixture and rocking it backwards and forwards. As can be seen overleaf, after 600,000 cycles the abrasion of the HDPE pipe was around 0.3mm, and the rate of wear appeared to be decreasing. This is to be expected as the more brittle inner surface of the pipe (which cools most quickly after extrusion) was worn away.

By comparison, the abrasion of the concrete pipes tested was up to 8 times greater, with the difference becoming greater as the experiment proceeded. Full results can be obtained upon request from Rib Loc.



3.2 Chemical Resistance

HDPE is one of the most chemically inert plastics available and stands alone against other stormwater pipe materials. Indeed, HDPE has often been used to line pipes manufactured from other materials to provide protection from chemical attack. Detailed HDPE chemical resistance data is included in Appendix A.

3.3 Steel Corrosion

Corrosion of the galvanised steel band has a major influence on the life of the pipeline. Soil conditions are by far the largest factor in affecting the choice and life of steel and coating material. The moisture content and pH of relative soil types as well as the rise and fall of the water table in some areas dictates the type of steel and galvanising required for each application.

Galvanised steel pipes have been used for many years in Australia and overseas with the majority of cases having quite long service lives. Rib Loc Series 2000 pipes use the same Z600 galvanised steel in their steel enhancement to provide additional support during installation and initial consolidation of the backfill. Once installed, the soil support provides strength to the pipe system and the HDPE pipe remains uniform and intact indefinitely.

Option: In areas with aggressive soils or varying water table the steel band around Series 2000 can be fully encapsulated. Rib Loc have developed an extruded HDPE coating which over-wraps the steel enhancement and bonds to the HDPE base profile. This totally encases the steel section and prevents contact with oxidising agents, effectively giving the steel (and therefore the pipe) an indefinite service life.

3.4 Ultra Violet Radiation

Rib Loc Series 2000 pipe is black in colour with 2% carbon black content. Carbon black is an additive that protects the pipe by absorbing ultra violet light and preventing material breakdown internally from ultra violet light. Tests on Rib Loc Series 2000 pipes containing carbon black have shown excellent resistance to environmental stress cracking.

3.5 Impact Strength

The polyethylene profile used in the manufacture of Series 2000 pipes has been tested for impact strength in both the short and long term by an independent testing laboratory. The results of these tests showed that the impact strength of the material did not vary significantly with time.

3.6 Flow Capacity

The flow capacity of Series 2000 pipes should at least equal, and in most cases exceed, that of other stormwater pipe typically available in Australia.

Series 2000, reinforced concrete and fibre reinforced concrete pipes are manufactured with the same nominal internal diameters. However, Australian Standard AS 2200 *“Design Charts for Water and Sewerage Pipes”* rates polyethylene as having the greatest flow capacity.

Tests conducted at the University of South Australia confirmed that, for spirally wound pipe carrying clean water, Manning's "n" values of between 0.008 and 0.0094 are obtained. This value equates to the other friction factors as given AS 2200.

The smoother bore of the Series 2000 pipe could be expected to be maintained because of the abrasion and corrosion resistance of polyethylene.

Series 2000 has fewer joints to cause interruptions to the flow. The standard lengths of 6 metres and 4 metres are longer than other types of stormwater pipe.

3.7 Pipe Stiffness

Series 2000 pipes derive their stiffness from the steel enhancement, spirally wound around the outside of the pipe and locked under the T-shaped plastic profile. With the advent of the HDPE coating over the bands, the steel is totally protected against oxidising agents and therefore the pipe will retain its specified stiffness over its entire service life.

In accordance with the Australian Standard for buried flexible pipelines, AS2566, Rib Loc has determined the Pipe Stiffness at key diameters within its pipe range, through an independent testing program with Engtest at the University of Adelaide. These test results in shown in bold text in the table below and are also summarised in Section 12.1 Parallel Plate Testing. The stiffness values for other diameters within Rib Loc's pipe range were then interpolated from these test results and are also listed below:

Pipe Diameter (mm)	Pipe Class	Pipe Stiffness (N/m/m)
225	6	2230
300	6	**1473**
	10	**13002**
375	10	6800
450	10	5680
	15	11360
525	10	4560
	15	9120
600	10	**3255**
	15	**6333**
675	10	2790
	15	5210
750	10	2200
	15	4310
825	15	3500
900	15	**2857**
1050	15	1955
	40	4100
1200	40	**3379**
1350	40	2640
1500	40	**2169**
1650	40	1770
1800	40	**1566**

4.0 Series 2000 Pipe Dimensions

4.1 Pipe Classes and Diameter Range

Four classes of Rib Loc Series 2000 pipe are available depending on loading requirements and pipe diameter. The classes correspond to different levels of steel enhancement.

Pipe Class	Description	Diameter Range
Class 6	HDPE only - no steel	225 - 300mm
Class 10	Light Steel Enhancement - 1 band	300 - 750mm
Class 15	Light Steel Enhancement - 2 bands	450 - 1050mm
Class 40	Heavy Steel Enhancement	1050 - 1800mm

4.2 Weight

Pipe weight of Rib Loc Series 2000 is dependent on both the pipe class and diameter.

Pipe Diameter (mm)	Pipe Class	Pipe Length (m)	Approx. weight per metre (kg)	Approx. weight per pipe (kg)
225	6	6	3.6	22
300	6	6	3.6	22
	10	6	6.3	38
375	10	6	7.9	47
450	10	6	9.4	56
	15	6	13.4	80
525	10	6	11.0	66
	15	6	15.7	94
600	10	4	12.6	50
	15	4	17.9	72
675	10	4	14.2	57
	15	4	20.1	80
750	10	4	15.7	63
	15	4	22.4	90
825	15	4	24.6	98
900	15	4	26.9	108
1050	15	4	31.3	125
	40	4	33.7	135
1200	40	4	38.5	154
1350	40	4	43.3	173
1500	40	4	48.1	192
1650	40	4	52.9	212
1800	40	4	57.8	231

4.3 Length

Rib Loc Series 2000 stormwater pipes come in standard lengths as shown below:

∅ $<$ 600mm - 6.0m length
∅ $\geq$ 600mm - 4.0m length

The Rib Loc manufacturing process also allows the economical production of non-standard lengths.

5.0 Fittings

5.1 Fitting Dimensions

The nature of Rib Loc pipe enables it to be easily manufactured into numerous types of fittings for many applications. The most commonly required fittings include 90° and 45° bends, reducers and expansions (transitions to change the size of pipe), and 'T' and 'Y' sections. Any variation on these themes can also be catered for, ie. different angle bends are easily constructed and all fittings are available over the entire range of both pipe class and diameter.

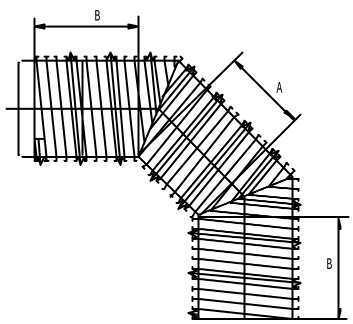
The diagrams of fittings shown below are only an indication of the concepts behind the geometry of each fitting. Depending on the diameter of the pipe or specific in-ground characteristics, the pieces may be manufactured differently in terms of the number of sections in each fitting, (especially in the case of 90° and 45° bends).

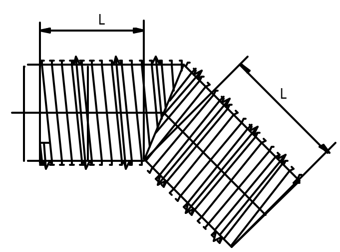
5.1.1 Mitre & Lobster Back Bends

All mitre and lobster back bends are manufactured in segments although the number of segments may vary.

Segments are cut from standard Series 2000 pipe of the required class and welded together using HDPE welding rod.

Lobster back bends can be manufactured to any radius greater than the pipe diameter.

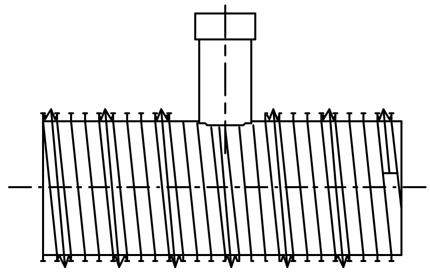




Diameter (mm)	Throat Radius (mm)	A (mm)	B (mm)	L (mm)
225	300	249	200	200
300	300	249	200	200
375	375	311	200	200
450	450	373	300	300
525	525	435	300	300
600	600	497	300	300
675	675	559	400	400
750	750	621	400	400
825	825	683	400	400
900	900	746	400	400
1050	1050	891	400	400

5.1.2 Intersections

'T' and 'Y' sections are also available in any configuration of class and diameter and are manufactured in the same manner as mitre and lobster bends.



5.1.3 Transitions

Rib Loc can make transition pieces to change the diameter of the pipe. This is done by fitting a blanking plate to end of the larger pipe and then fitting the smaller diameter pipe. The transition is thus instantaneous. It is generally recommended that if the transition is for water flowing from a larger diameter to a smaller diameter pipe that a concrete thrust block be formed behind the blanking plate.

6.0 Design Guide

6.1 Design Methodology

6.1.1 Design for External Loading

Series 2000 stormwater pipes are flexible and derive their soil-load carrying capacity from this flexibility. Under soil load the pipe tends to deflect, thereby developing passive soil support at the sides of the pipe. At the same time the ring deflection relieves the pipe of the majority of the vertical soil load, which is picked up by the surrounding soil in an arching action over the pipe.

The effective strength developed by this pipe-soil system can be remarkably high. Therefore, designing a pipeline to resist external loading requires consideration of the properties of the surrounding soil as well as the stiffness of the pipe. Soil properties generally govern, with the load carrying capacity of the pipe-soil system being more dependent on the strength and compacted density of the soil than the properties of the flexible pipe.

6.1.2 Earth Loads (Clause 4.3 in AS2566)

The first solution to the problem of earth loads on buried pipe was published by Professor Marston of Iowa State University in 1913. His solutions were subsequently refined through research carried out over the years, initially on corrugated steel drainage pipe and culverts.

The basic concept of the theory is that the load due to the weight of the column of soil above the pipe is modified by the response of the pipe.

For a flexible pipe, the prism of soil directly over the pipe attempts to settle more than the prisms of soil adjacent to the pipe. This differential settlement produces friction forces at the planes where these prisms join, and thus the central prism over the pipe is supported by the two adjacent prisms. Consequently, the earth load on a flexible pipe will always be less than the weight of the prism of soil above it.

Various formulae are available for predicting the actual load on a flexible pipe using coefficients dependent on installation conditions (see AS2566 *"Buried flexible pipelines Part 1: Structural Design"*). For simplicity, Rib Loc recommends using the full prism load, recognising that, for a pipe with the flexibility of a stormwater pipe, this will always produce conservative results. This will be true whether the pipe is installed in a narrow trench, wide trench or embankment condition.

Using this assumption, the earth load on a Series 2000 pipe can be estimated from the formula:

$$w_g = \gamma H$$

where:

w_g	=	Earth load (kN/m^2)
γ	=	Assessed unit weight of trench fill or embankment fill (kN/m^3)
H	=	Cover to top of pipe (m)

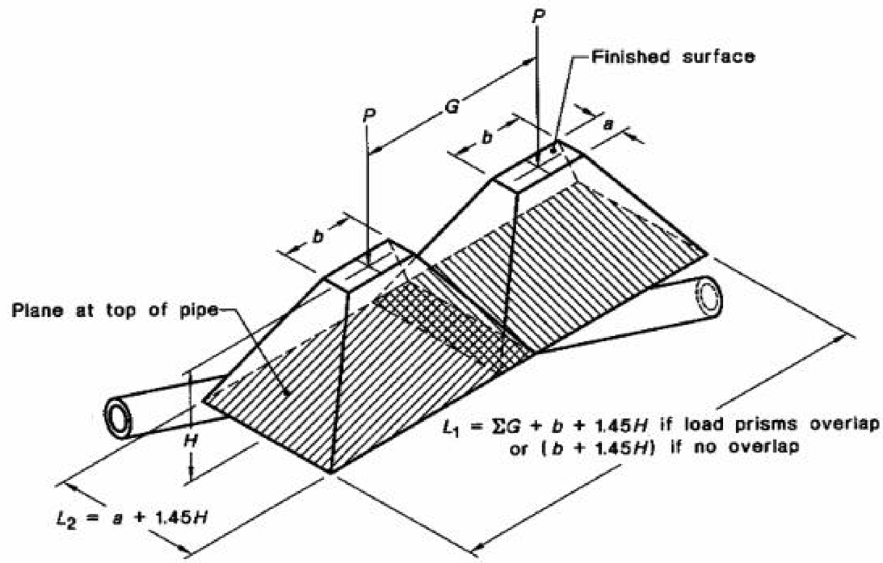
Where the unit weight of the soil above the pipe is not known, use 20 kN/m^3. Except in extreme conditions, this will be conservative. The commentary for AS2566 also gives unit weights for several soil types.

6.1.3 Live Loads (Clause 4.7 in AS2566)

In shallow embedment conditions, live load from traffic becomes significant. For pipelines passing under a road which may be subject to heavy traffic, Austroads Standard W7 wheel loading should be used for design purposes. This principally comprises a 70kN wheel load applied over a surface area of 500mm x 200mm. The load may be reduced where it is known that there will only be light loading.

Where the cover (H) is less than 0.4 m, the wheel load shall be considered to act at the top of the pipe on an area equal to the contact area of such a load.

Where the depth of fill over a pipe or pipes is 0.4 m or more, a wheel or track load shall be uniformly distributed, at the top of the pipe, over an area similar to the contact area of such load, and with sides equal to 1.45 H greater than the sides of the contact area, as demonstrated in the diagram below:



As shown above when the surcharges from loads overlap, the total load shall be considered as uniformly distributed over the areas defined by the outside limits of the combined areas.

Thus the total live load applied to the top of the Rib Loc pipe is:

$$w_q = \frac{\sum P}{L_1 L_2} \alpha$$

where:

The "impact factor, α", is calculated from the formula: $\alpha = 1.4 - \frac{H}{7}$

but should not be less than 1.1

Construction loads are dependent on the equipment used and appropriate loads should be obtained from the manufacturer and can then be applied in the same fashion as the W7 loads described above.

Therefore the total load on the pipe becomes:

$$w = w_g + w_{gs} + w_q \qquad (kN/m^2)$$

where:

w_g = vertical design load pressure at top of pipe due to soil dead load (kPa)
w_{gs} = vertical design load pressure at top of pipe due to surface applied dead load (kPa)
w_q = vertical design load pressure at top of pipe due surface applied live load (kPa)

6.1.4 Pipe Design

Rib Loc Series 2000 pipes derive most of their short term strength from the steel enhancement. So for installation design purposes, the sectional properties used are those for the steel only. The polyethylene is assumed to support the steel enhancement and provide a corrosion and abrasion resistant inner wall.

Designing a pipeline to resist external loading generally means the consideration of three design criteria:

- ✓ Vertical Deflection
- ✓ Strength
- ✓ Pipe Buckling

6.1.4.1 Vertical Deflection (Clause 5.2 in AS2566)

Following Clause 5.2 in AS2566, the predicted long-term shall satisfy the following equation:

$$\frac{\Delta y}{D} \leq \frac{\Delta y_{all}}{D}$$

where:

$$\frac{\Delta y}{D} = \frac{K \times 10^{-3} \times (w_g + w_{gs} + w_q)}{8 \times 10^{-6} \times S_{DL} + 0.061 E'}$$

where:

K is assumed to be 0.1 unless detailed engineering assessment shows otherwise.
S_{DL} = long-term ring-bending stiffness of pipe (N/m/m)
E' = effective combined soil modulus (MPa)
w_g = vertical design load pressure at top of pipe due to soil dead load (kPa)
w_{gs} = vertical design load pressure at top of pipe due to surface applied dead load (kPa)
w_q = vertical design load pressure at top of pipe due surface applied live load (kPa)

For Rib Loc pipes, classed as steel with a flexible lining, the allowable long-term vertical pipe deflection is taken as 5.0%, as stipulated by Table 2.1 in AS2566. For Rib Loc Series 2000 Class 6 pipes, without steel, AS2566 stipulates a long term deflection limit of 7.5%. Rib Loc has decided to adopt a conservative figure of 5% as for its other pipes to keep design as uniform as possible.

6.1.4.2 Strength (Clause 5.3 in AS2566)

Trench fill or embankment fill and superimposed dead and live loads, in the long term, cause strain in the pipe wall. The predicted long-term ring-bending strain shall satisfy the following equation:

$$e_b \le e_{ball}$$

where:

$$e_b = D_f \left(\frac{\Delta_y}{D} \right) \frac{t_{es}}{D}$$

and

$$D_f = \frac{3.33 \times 10^{-6} \frac{S_{DL}}{E'} + 0.00136}{1.11 \times 10^{-6} \frac{S_{DL}}{E'} + 0.000151}$$

t_{es} = the effective wall thickness of the pipe

This is only applicable for Rib Loc Series 2000 pipes of Class 6 designation, ie. that with no steel bands reinforcing the high density polyethylene liner. For the purpose of this calculation, AS2566 Table 2.1 specifies that an allowable long term ring bending strain (ε_{ball}) is 4%.

6.1.4.3 Buckling (Clause 5.4 in AS2566)

Buckling capacity may be the limiting criteria particularly if there is considerable loading from groundwater. AS2566 stipulates the use of the following calculations, dependant on the design conditions.

For the general case where the ground surface is not below water:

$$g_L \left(\frac{D_e}{2} + H_W \right) + g_{sub} \left(\frac{D_e}{2} + H \right) + w_{gs} + w_q + q_v \le q_{all}$$

where:

H = cover height (m)
H_w = height of water surface above the top of the pipe (m)
γ_L = the assessed unit weight of liquid external to the pipe, eg 10.0 for water (kN/m^3)
D_e = the external diameter of the pipe barrel (m)
γ_{sub} = the submerged unit weight of trench fill or embankment fill (kN/m^3)

$$= \left(\frac{r_s - 1}{r_s} \right) g$$

w_{gs} = vertical design load pressure at top of pipe due to surface applied dead load (kPa)
w_q = vertical design load pressure at top of pipe due surface applied live load (kPa)
q_v = internal vacuum, not allowed in Rib Loc piping (kPa)
q_{all} = the allowable buckling pressure for the pipe (kPa), which is the greater of the following:

$$q_{all\ 1} = \frac{1}{F_s}\frac{24}{1-\boldsymbol{u}^2} S_{DL}\, 10^{-3} \qquad \text{.......(1)}$$

$$q_{all\ 2} = \frac{\left(S_{DL} \times 10^{-6}\right)^{1/3} \left(E'\right)^{2/3} \times 10^{3}}{F_S} \qquad \text{.......(2)}$$

The equations are applicable for cover heights greater than or equal to 0.5 metres. For cover heights less than 0.5 metres only the first equation applies.

Rib Loc Series 2000 are generally not suitable for use with cover heights less than 0.5 metres, according to the new AS2566, due to the lack of guaranteed soil support for pipes in this region. This is further discussed in the Supplement to AS/NZS 2566.1, under Clause C5.4 Buckling. The only exception to this rule is for 300mm diameter Class 10 pipes, where the minimum cover height requirement is 0.4 metres.

When the ground surface is below water, please consult Rib Loc for further advice.

6.2 Standards

The new Australian Standard, AS2566, covering the design of flexible pipeline systems was released on the 5th of January 1998. This Standard is suitable for use in the design of Series 2000 pipe systems as detailed in 6.1 Design Methodology.

Rib Loc Series 2000 has, until this point, been designed around the requirements of relevant Australian and International Standards, specifically:

AS 1254	uPVC pipes and fittings for storm and surface water applications
AS 2033	Installation of polyethylene pipe systems
AS 2200	Design charts for water supply and sewerage
AS 2439, Part 1	Perforated plastics drainage and effluent pipe and fittings
AS 2566	Plastics pipelaying design
ASTM D 2321	Standard installation of flexible thermoplastic sewer pipe
ASTM F 405	Specification for corrugated polyethylene tubing and fittings
ASTM F 667	Specification for large diameter corrugated polyethylene tubing and fittings
AASHTO M 252	Corrugated polyethylene pipe
AASHTO M 294	Corrugated polyethylene pipe 12in. - 36in. diameter
DIN 16 961	Pipes and fittings of thermoplastics with profiled walls and smooth bores

6.3 Cover Height Table

The table below shows the maximum cover heights for Rib Loc Series 2000 piping of all diameters, according to the calculation procedure outlined above taken from AS2566. The minimum cover height for all pipes other than for 300 diameter Class 10 is 0.5 metres, as described in Section 6.1.4.3.

Pipe Diameter (mm)	Pipe Class	Recommended Minimum Cover Height (m)	Maximum Cover Height (m)
225	6	0.5	9.3
300	6	0.5	8.2
300	10	0.4	12.9
375	10	0.5	11.5
450	10	0.5	11.4
450	15	0.5	12.7
525	10	0.5	10.9
525	15	0.5	11.9
600	10	0.6	10.8
600	15	0.5	11.4
675	10	0.6	10.3
675	15	0.5	11.3
750	10	0.65	9.6
750	15	0.6	11.2
825	10	0.65	8.8
825	15	0.6	11.1
900	10	0.7	8.4
900	15	0.65	10.6
1075	15	0.8	9.3
1075	40	0.6	11.4
1200	15	0.9	8.4
1200	40	0.65	11.3
1350	40	0.7	10.5
1500	40	0.75	9.8
1650	40	0.8	9.2
1800	40	0.85	8.8

These above cover heights are based on the following information:

- soil modulus values of 5 MPa for the embedment modulus (corresponding to 90% dry density ratio or 60% density index sand and coarse grained soil with less than 12% fines) and 7 MPa for the natural soil modulus
- W7 wheel loading
- no superimposed dead load other than the fill material, whose unit weight has been taken at $18kN/m^3$
- no water table influence

7.0 Installation Guide

Rib Loc Series 2000 pipe is easy to install, requiring no special skills or equipment. It is basically installed in the same manner used for other lightweight flexible pipes. The following are general guidelines only.

7.1 Handling, Transportation and Storage

Pipes may be delivered to site either singly or in crates. If different diameters have been ordered they may be "nested" with smaller size pipes inside larger ones.

Reasonable care should be taken with unloading. Pipes of 600mm diameter or less are light enough to be unloaded by hand; for larger sizes a forklift, backhoe or other lifting device will be needed. Pliable straps, slings or ropes may be used to lift the pipe. Steel cables or chains are not recommended, and pipes should not be lifted by passing a rope through the middle.

Under no circumstance should pipes be dropped off the truck or dropped into a trench. Like all other types of pipe, they should be lowered into position.

Pipe should be stored in stockpiles on flat even ground free of sharp stones and objects that may cause damage. Stockpiles should be no more than 2 metres in height and pipes should be chocked to prevent rolling in high winds. Pyramid stacking, or stacking with timber bearers with a minimum width of 80mm placed 1 metre apart can be used.

7.1.1 Delivery within Metropolitan Area (less than 50km)

7.1.1.1 Equipment

(a) Load binders or ropes in safe order and of load rating of at least one tonne.

(b) Where gates are required they must be in safe order and condition, such that there is no structural damage or breaks in welds on gates and that all locating lugs and pins and other securing devices are in working order.

(c) Where HI-AB trucks are required for delivery they shall have lifting straps in safe working order and be of sufficient load rating to lift up to one tonne.

7.1.1.2 Inspection of equipment

(a) The Rib Loc storeman shall inspect equipment on the truck to ensure that all required equipment is in safe working order and may request that the driver change his equipment.

(b) In the event the storeman assesses that the truck or equipment is in defective condition, he will report it to the Production Supervisor for confirmation, who will then report it to the transport company and request that the truck be changed. The Production Supervisor shall then issue a non-conformance to the transport company.

7.1.1.3 Securing of Pipes

(a) Pipes shall be secured by load binders or ropes that are in safe order and condition in such a way as to prevent any dislodging of pipe during transit.

(b) Where pipes are to be unloaded by driver only and require lifting by HI-AB crane, pipe shall be loaded with timber bearers placed between layers or packs of pipes, to allow for placements of slings for lifting.

(c) Gates must be used for loads exceeding two full layers of pipe.

(d) Where gates are required they must be in safe order condition (refer to equipment list).

7.1.1.4 Unloading of Pipes

(a) When unloading, pipes must not be dropped in any way either from the tray of the truck to ground or from any lifting equipment to the ground. Pipes shall be lifted from the truck and lowered into place.

(b) Where pipes are to be unloaded by driver only, the driver may unload pipes manually when:

- a load consists of 6 metre pipes up to one layer of maximum 450mm diameter, or
- 4 metre pipes up to one layer of maximum 600mm diameter pipes.

This shall be done by sliding a pipe off the end of the truck and placing one end on the ground, then lifting the other end of pipe down to the ground. Where loads are above these limits they will be transported by approved HI-AB trucks and drivers. They may be loose or in packs dependent on the number of pipes of a given size being delivered.

(c) When being lifted from the truck by a HI-AB crane, pipes shall be lifted using two approved lifting straps, positioned to spread the load evenly.

7.1.2 Delivery outside Metropolitan Area (further than 50km)

7.1.2.1 Packaging Pipe

Pipes shall be crated whenever practicable prior to being transported beyond the metropolitan area.

7.1.2.2 Loading Pipe

There are no special requirements for loading crated pipes.

Un-crated pipes should be loaded as follows:

- Nesting (ie placing smaller pipes inside larger ones to save space) should be carried out on the ground before loading.
- Measures should be taken to ensure that pipes loaded from the side of the truck do not roll off the other side, eg fitting a gate on the opposite side of the truck or tying the pipe to the forklift to prevent it from rolling.
- Where painted pipes are being loaded care must be taken to ensure that the paint is not damaged by sliding or rolling the pipes on hard surfaces.
- A suitable means of loading painted pipes is for one forklift to lift the pipe off the ground with a boom, and then a second forklift with long tines to come in from the side and load onto the truck.

7.1.2.3 Transport over Long Distances

There are no special requirements for transport of crated pipes. For un-crated pipes only transport companies which have agreed to Specification SP-006 should be used for transport exceeding 50km. If a company which has not agreed to this specification is hired, the Production Supervisor shall ensure that the requirements set out below are nevertheless adhered to. The requirements of SP-006 are as follows:

- Where pipes and other products are to be transported together and there is a risk of cross-contamination, pipes must be physically separated from the other products.
- Gates which are in contact with pipe walls or pipe ends shall be covered with rigid sheeting such as plywood to prevent damage to pipes.
- Where pipes are nested or liable to slide, rigid sheeting shall be placed between the stacks of pipes and between gates and ends of pipes to prevent damage to joiners and pipe ends.

- Where load binders (strapping) is used to hold pipes in place, the load binders should be positioned over the steel so that it does not tear the plastic away from the steel.
- Load binders and ropes should not be tied so tightly that the pipes are damaged.

7.1.2.4 Transport over Short Distances

Load binders and ropes should not be tied so tightly that the pipes are damaged.

7.2 Excavation

Excavate all trenches to lines, levels and grades as shown on the design drawings.

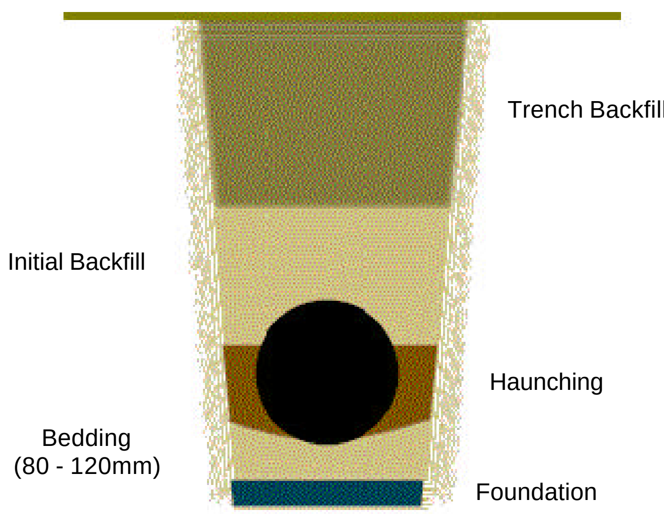
Trenches should generally be straight between manholes, inspection points, junctions and the like, but curves with a radius of not less than 130 times the diameter of the pipe should be permitted. Sides should be vertical and grades uniform.

The minimum trench width measured at the level of the top of the pipe should be:

For pipe sizes 300mm to 450mm:	Diameter + 400mm
For pipe sizes 525mm to 900mm:	Diameter + 600mm
For pipe sizes 1050mm to 1500mm:	Diameter + 700mm
For pipes larger than 1500mm:	Diameter + 0.5 x Diameter

The trench should be excavated to allow for a depth of bedding of 100mm below the pipe. Trench shields, if necessary, should not extend down below the level of the top of the pipe.

7.3 Fill Materials



7.3.1 Materials - Bedding and Haunching

The same material should be used for both bedding and pipe surround up to a level of 70% of the pipe diameter.

Suitable materials are those which comply with Class I or Class II of AS 1726 “Site Investigation Code.” These are:

- Class I - Crushed Rock - Angular, 6 - 13 mm graded stone.
- Class II - Coarse Sand/Gravels GW, GP, SW, SP - with little or no fines.

This material should be free from clay, large stones or lumps, organic material and other deleterious matter. It should be capable of compaction in layers to form a dense stable fill.

7.3.2 Materials - Initial Backfill

The initial backfill extends from a level at 70% of the pipe diameter to 300mm above the pipe. Material in this region provides the pipe with only minor support, and its function is chiefly to protect the pipe from point loads from the final backfill and surface loading. Its other important function is to ensure stability of the ground surface. Therefore the specification for initial backfill may differ depending on the nature of the pipeline route eg. under roads, open fields etc.

If Class I materials have been used for bedding and haunching, they should also be used for initial backfilling. Other materials used in this region may be subject to the migration of fines into the gaps into the Class I material, causing a loss of support.

Otherwise Class II and Class III materials are suitable for use as initial backfill, provided they are adequately compacted. Class III material is defined as:

- Coarse Grained Soils with less than 12% fines. GM, GC, SM, SC.

7.3.3 Materials - Trench Backfill

Any available material from the excavation or elsewhere. It should be free of large rocks which may migrate and cause point loads on the pipe.

7.4 Laying of Pipelines

The key to successful installation of any type of pipe is achieving stable and permanent support of the pipe.

7.4.1 Installation of Bedding and Haunching

The materials described above should be compacted to;

- 95% Standard Proctor Density if cover to the pipe is over 1.5 metres or the trench is to be subjected to traffic loading
- 85% otherwise

Bedding should be compacted by light tamping. Over-compaction is not desirable as the ribs of the pipe must penetrate into the bedding. The degree of compaction should be accepted either by observation or by field tests.

Class I material can be compacted adequately by spearing with forks, crowbars or vibratory compactors. Thickness of compaction layers should be not more than 300mm.

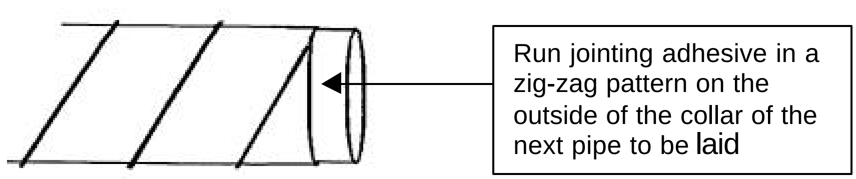
Class II material requires vibratory compaction or watering in to achieve 95% Standard Proctor Density. Thickness of compaction layers should not be more than 200mm. Care should be taken to ensure no voids exist within the haunch zone.

Care should also be taken to ensure that the pipe is not forced out of shape due to uneven compaction on opposite sides of the pipe, and that line and grade of the pipe are not disturbed.

7.4.2 Jointing

Series 2000 pipes are supplied with a jointing collar welded on to one end. Tubes of jointing adhesive are also supplied.

The pipeline should be constructed so that the end of the pipe with the jointing collar is the downstream end. So if construction starts from the downstream end of the pipeline, the jointing collar is always inserted into the previously laid pipe.



The connection is effected with the aid of a sealant. The exposed face must be clean, dry and free from grease and dust before application. This is then fitted into the adjacent pipe, and rotated to ensure a full seal. The jointing sealant (supplied by Rib Loc) is Plaskem Multi-Fix, or other as approved by the manufacturer.

At larger diameters, a steel enhanced joiner strip is used to connect adjacent pipes. The same basic idea of an internal double spigot is used, however this spigot incorporates a concentric ring of steel to add stiffness to the joint region.

Due to the fact that this type of joiner is only applied to man-entry pipes, the on site connection is usually achieved with an HDPE weld effected from inside the pipe. This is a secure, easy and cost effective method of connection. Rib Loc can provide training and equipment should this option be desired.

Special “shoe horns” are available for loan from Rib Loc to assist with locating the collar into the next pipe in larger sizes.

Placing of embedment at the sides of a pipe should not proceed until the next pipe joint has been made.

7.4.3 Installation of Initial Backfill

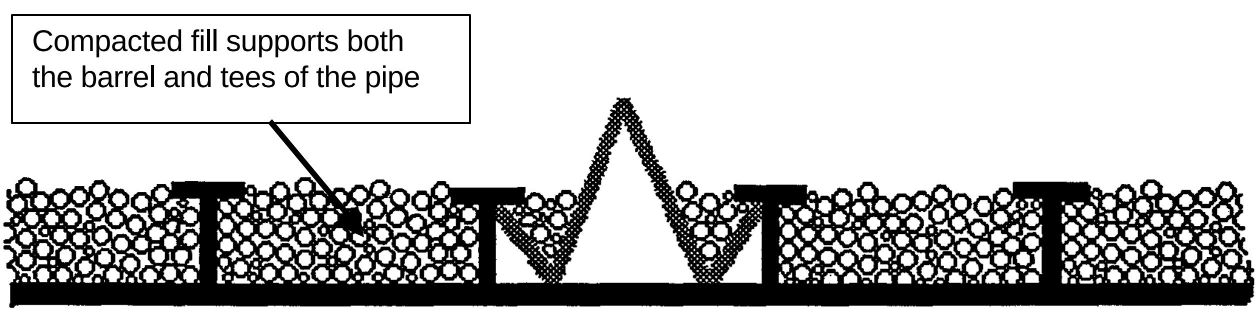
Material should not be placed in this zone until compaction in the bedding and haunching zones has been completed.

Class I, II or III material may be used in this zone. Compaction should be to a Standard Proctor Density of:

- 95% Standard Proctor Density if cover to the pipe is over 1.5 metres or the trench is to be subjected to traffic loading
- 85% otherwise

Class III materials should be compacted in layers of not more than 150mm using impact tampers. Wetting facilitates compaction of this material.

Care should be taken not to impact the pipe with any form of compaction equipment. Backfilling should be carried out simultaneously on both sides of the pipe to ensure it is not displaced or deformed. It should be compacted in layers of 200mm - 300mm. It is essential that the granular backfill material properly supports the haunch of the pipe and it must also be compacted against the undisturbed trench walls.



7.4.4 Installation of Trench Backfill

The requirements of Australian Standard AS 3500.3 *“National Plumbing and Drainage Code (Stormwater Drainage)”* should be followed. This Standard states that the material used as backfill should be either the same as the pipe surround material or material excavated from the trench or imported, provided it is free from rocks, pieces of concrete, bricks or builders waste.

Compaction of the backfill should be sufficient to ensure there is no differential settlement between the surface of the trench and the surrounding surface.

The use of heavy compaction equipment (vibratory rollers etc.) should not be permitted within 600mm of the top of the pipe.

Minimum cover to the top of the pipes should be in accordance Australian Standard AS 2566 *"Buried flexible pipelines",* that is, by Clause 5.4 Buckling, which stipulates 0.5 metres. This clause applies to all pipes other than 300mm Class 10 pipes, in which case 0.4 metres is sufficient.

7.5 Other Installation Issues

7.5.1 Trench Shields

Any temporary trench shoring or movable shields should be raised or removed progressively to ensure that:

- Placing and compaction of backfill occurs below such trench protection and against the undisturbed native soil
- Removal of the trench protection does not disturb already compacted backfill

7.5.2 Installation on Steep Slopes

Where the slope of the pipeline exceeds 10%, anchor blocks should be constructed at intervals of at least one per pipe length to adequately restrain the pipe. These blocks should key into the solid walls and base of the trench.

7.5.3 Connection to Rigid Structures

When connecting Series 2000 to a rigid structure such as a concrete manhole, the pipe should be either cast in-situ into the concrete wall, or securely mortared. The T-shaped ribs of the pipe act as "weep flanges" to give a sufficiently watertight seal, provide restraint and prevent longitudinal movement.

Experience has shown that short lengths of "rocker pipe" are not required with HDPE pipe (refer Sydney Water Board: Recommended Installation of Large Diameter Flexible Plastic Pipes for Non-Pressure Applications: March 1989).

Forces due to any differential settlement are accommodated by the flexibility and strain characteristics of polyethylene, which are superior to those for uPVC. Any stresses induced in the pipe by differential settlement diminish over time because of the stress relaxation properties of polyethylene.

7.5.4 Installation in Common Trenches

When two or more pipes are installed in a common trench a minimum amount of backfill is required to provide adequate side support and a minimum spacing is needed to allow the fill to be compacted. Australian Standard AS2042 *"Design and Installation of Corrugated Steel Pipes"* states that the minimum spaces between pipes laid in a common trench should be:

- 300mm for pipes up to 600mm diameter
- 0.5 times the pipe diameter for pipes 600mm to 1800mm diameter

7.5.5 Installing Pipe on a Curve

Generally pipes should be laid straight between manholes, inspection points etc. Laying of Series 2000 in a smooth curve is permitted so long as the radius of curvature is not less than 130 times the pipe diameter.

7.5.6 Field Maintenance and Repair

For minor cuts in the polyethylene pipe wall, the pipe should be reinstated by welding with polyethylene weld material. If damage has caused a hole to appear, a small patch of polyethylene should be used to close the hole and should be welded to the pipe.

For larger areas of damage the reinstated piece should be covered with a concrete blanket.

7.5.7 Stormwater Ties

Slope junctions are available from Rib Loc for installation where necessary during pipeline construction.

7.5.8 Inspection

The installation should be inspected and approved by the Superintendent at the following stages:

1. After completion of the haunching to ensure that adequate compaction has been obtained.

2. After completion of the backfill. This should be to ensure that deflection is not excessive. At this stage the pipe should have deflected vertically by not more than 3% (allowing for a maximum final deflection of 5%). Inspection should be visual, as deflections of this magnitude are obvious.

8.0 Engineering Background - Flexible Pipes

Rib Loc has carried out a testing program at Utah State University, under the leadership of Dr Moser, whereby large diameter Series 2000 pipes were loaded in an out-door soil box to determine their load capacity. The report was favourable with 2000mm diameter pipes withstanding over 10 metres of fill. When this is compared to the relatively low flat-plate support strength of Series 2000 and other flexible pipes, it is often difficult to understand how the pipe can withstand such large soil pressures when actually installed.

It must be clear that there is no direct comparison between the strength of rigid and flexible pipes since they carry loads in two completely different ways. The following extract was drawn from "Buried Pipe Design", by Dr A. P. Moser of Utah State University and effectively summarises the difference between pipe types.

"A flexible pipe derives its soil-load carrying capacity form its flexibility. Under soil load, the pipe tends to deflect, thereby developing passive soil support at the sides of the pipe. At the same time, ring deflection relieves the pipe of a major portion of the vertical soil load, which is picked up by the surrounding soil in an arching action over the pipe. The effective strength of the flexible pipe-soil system is remarkably high. For example, tests at Utah State University indicate that a rigid pipe with a three-edge bearing strength of 3300lb/ft buried in class C bedding will fail by wall fracture with a soil load of about 5000lb./ft. However, under identical soil conditions and loading, a PVC sewer pipe deflects only 5 percent. This is far below the deflection that would cause damage to the PVC pipe wall. Thus the rigid pipe has failed, but the flexible pipe performed successfully and still had a factor of safety with respect to failure of 4 or greater. Of course, in flat-plate or three-edge loading, the rigid pipe will support much more than the flexible pipe. This anomaly tends to mislead some engineers because they relate low flat-plate supporting strength with in soil load capacity - something one can do for rigid pipes but cannot do for flexible pipes."

As described briefly above, flexible pipes carry soil load by effectively shedding this load to the surrounding soil. It is the strength of the soil that actually provides most of the strength of the system. Having said this, and appreciating that good compaction is essential to the strength of the pipe-soil system, it is interesting to note that in the soil box tests undertaken at Utah State on Series 2000, a low quality backfill material compacted to only around 85% Standard Proctor Density still provided enough strength for the pipes to withstand 10 m of soil pressure with only 3% vertical deflection.

Obviously, at extremely low cover heights, rigid pipes often withstand greater loads since any vehicle loads applied would approximate a flat-plate bearing load. However, as the depth of cover increases and soil load becomes the predominant factor, flexible pipes begin to come into their own in the way that they can "shed" load to the surrounding soil.

9.0 Product Evaluation

9.1 Scope

9.1.1 Testing of HDPE Material Properties

- **Environmental Stress Cracking Resistance**
  In this test the time to failure by crack growth is greatly accelerated by subjecting a highly strained specimen to the combination of an initial flaw, elevated temperature and powerful stress-cracking reagent in accordance with ASTM D1693.

  Stress cracking of various plastics has been well documented since the early stages of plastic pipe development. The importance of making pipe from high stress crack resistant polyethylene has therefore been recognised and heeded with the development of Series 2000. One of the earliest means for evaluating the stress crack sensitivity of HDPE is by the use of an environmental stress crack resistance (ESCR) test. (Mruk, 1990, pg 26).

- **Tensile Testing**
  Tensile tests are performed to determine the pipe wall tensile strength at yield. The relationship between tensile strength and strain can also be investigated with this test.

9.1.2 Testing of Series 2000 Pipe Properties

- **Parallel Plate Test**
  Parallel plate tests are performed to determine pipe stiffness factors at specified deflections. These factors are used to determine load versus deflection behaviour of the pipe in addition to pipe buckling behaviour.

- **Soil Box Testing**
  Soil box testing enables behaviour to be analysed under controlled conditions which simulate those in the field. Variations in loading, cover height and soil density can be achieved much more easily than with on-site testing.

9.2 Testing

9.2.1 Testing of HDPE Material Properties

9.2.1.1 Environmental Stress Crack Resistance Testing

When polyethylene is highly stressed by either external deformation or frozen-in strain, and is in contact with certain materials, cracking may occur. This happens even though these materials are poor solvents for polyethylene or are only slightly absorbed.

The aim of this testing was to determine the environmental stress cracking resistance of the current blended HDPE resin. Tests were performed on a number of different blends of varying percentages of virgin and regrind resin.

Testing was performed in accordance with ASTM D1693. Bent specimens, each having a controlled imperfection on one surface, were exposed to a surface active agent. The proportion of the total number of specimens that cracked in a given time was observed.

The suggested test duration was 48 hours. Previous experience with the test showed no failure at 48 hours for Rib Loc HDPE blends. Advice from Kemcor, the material supplier, indicated that a test duration in excess of 300 hours was unnecessary due to stress relaxation of the plastic. For this reason 14 day tests were proposed. Testing was performed at the Royal Melbourne Institute of Technology (RMIT) - Polymer Technology Centre.

Information from this test method is not intended to be used for direct application to engineering problems. Only an indication of the relative environmental stress cracking resistance is obtained. The size of the extruded sample together with the conditions and method of fabrication may well completely dominate the resulting performance for a particular application.

Results

Initial results obtained by RMIT in May 1994 (Wang, May 1994):

NO.	SAMPLE ID		TEST DURATION (HOURS / NO. OF CRACKING IN 10 SPECIMENS)							
	REGRIND	VIRGIN	8	24	27	32	48	72	144	168
1	0	100	0	0	0	0	0	-	-	-
2	50	50	0	0	0	0	0	-	-	-
3	0	100	0	0	0	0	0	-	-	-
4	50	50	0	0	0	0	0	-	-	

Samples 1 and 2 were made from profile manufactured by Rib Loc whilst samples 3 and 4 were extruded from granules supplied to RMIT by Rib Loc.

After 48 hours the test was stopped and no failures were observed. The 48 hour duration was chosen as it is the minimum specified in ASTM D1693.

Results obtained by RMIT in September 1994 (Wang, Sept. 1994):

NO.	SAMPLE ID		TEST DURATION (HOURS / NO. OF CRACKING IN 10 SPECIMENS)							
	REGRIND	VIRGIN	8	24	27	32	48	72	144	168
1	0	100	0	0	0	0	0	0	7	10
2	70	30	0	3	5	8	10	-	-	-
3	60	40	0	0	10	-	-	-	-	-
4	50	50	0	0	2	4	8	10	-	-
5	100	0	0	10	-	-	-	-	-	-
6	50	50	0	0	0	0	10	-	-	-
7	60	40	0	0	10	-	-		-	-

Samples 2-5 were prepared by RMIT using a Brabender twin screw extruder to compound, then a single screw extruder was used to produce test pieces 1-5. Samples 6 and 7 were cut from material extruded by Rib Loc.

Inconsistencies between the September 1994 and the May 1994 tests performed by RMIT are believed to be due to the method of sample preparation. Rib Loc uses a single extruder pass to produce the Series 2000 profile compared with the two stage preparation process used by RMIT for samples 2-5 in the September 1994 tests.

Due to the inconsistency in results, a second series of tests were undertaken which had only one preparatory process rather than the two stage process used for the September 1994 tests.

Results obtained by RMIT in October 1994 (Wang, Oct. 1994):

NO.	SAMPLE ID		TEST DURATION (HOURS / NO. OF CRACKING IN 10 SPECIMENS)							
	REGRIND	VIRGIN	8	24	27	32	48	54	72	144
1	0	100	0	0	0	0	0	0	0	-
2	70	30	0	10	-	-	-	-	-	-
3	60	40	0	4	6	10	-	-	-	-
4	50	50	0	0	0	0	0	8	10	-
5	100	0	0	10	-	-	-	-	-	-

All samples were compounded and extruded in the one process via a Brabender twin screw extruder.

Further testing was done by RMIT on profile manufactured by Rib Loc in each of the five blends. The intention of this was to obtain two sets of consistent results to conclude the ESCR testing program. These results are shown below:

NO.	SAMPLE ID		TEST DURATION (HOURS / NO. OF CRACKING IN 10 SPECIMENS)							
	REGRIND	VIRGIN	8	24	32	48	72	80	120	144
1	0	100	0	0	0	0	0	0	0	0
2	70	30	0	0	0	0	0	0	2	5
3	60	40	0	0	0	0	0	0	0	0
4	50	50	0	0	0	0	0	0	0	0
5	100	0	0	2	8	10	-	-	-	-

Comments

It can be seen in the September and October sets of results that the ranking of blends has changed only marginally. However, the time to failure has generally increased. This increase in resistance to environmental stress cracking is due to the reduction in processing of the samples before testing. Processing of the polymer causes scission of the long molecular chains reducing the performance of the polymer.

The process used by Rib Loc in the production of Series 2000 profile only involves one extruder pass as in the October series of tests. These tests can therefore be assumed to most accurately represent the ESCR of Series 2000 profile.

The Rib Loc prepared samples tested in September 1994 exhibited shorter ESCR compared to the RMIT prepared samples of the same composition. This is due to the greater thickness of the Rib Loc prepared samples and the corresponding greater stress in the samples when bent for the test.

It must be remembered that crack growth in this test is greatly accelerated by subjecting the test specimens to high strains in combination with an initial flaw, elevated temperature and powerful stress-cracking reagent. This acceleration is necessary to cause failure in a relatively short time so that indications of ESCR can be obtained quickly.

The final set of results from tests performed on Rib Loc prepared profile are much improved when compared with results obtained from RMIT prepared profile.

This is despite the fact that the Rib Loc material is thicker, a property which will induce greater stresses in the material when bent. In addition, the die used to produce the Rib Loc profile is much more complicated than the die used by RMIT. Both these points lead to a reduction in ESCR rather than the observed increase.

As all samples have been manufactured from the same material the only variables can be in the method of sample preparation. If the samples behave as expected and relax with time, a point will be reached where a blend that has begun to fail will cease failing.

9.2.1.2 Tensile Testing

The aim of this testing was to determine the pipe wall tensile strength at yield.

Testing was performed in accordance with ASTM D638. This method covers the determination of the tensile properties of unreinforced and reinforced plastics in the form of standard dumbbell-shaped test specimens.

As extruded materials have different properties along and across the direction of extrusion, five samples were taken in the direction of flow and five across it. Testing was performed by Amdel Limited.

Results

The following results were obtained by Amdel (Lynch & Pickering, 1994):

Material		Direction	Tensile Stress at Yield (MPa)	Tensile Stress at Break (MPa)	Elongation at Yield (%)	Elongation at Break (%)	Tensile Modulus (GPa)
Regrind	Virgin						
50	50	with flow	22.3	28.3	12%	838%	0.95
50	50	across flow	23.3	13.3	10%	68%	0.98
60	40	with flow	21.7	30.0	20%	950%	1.00
60	40	across flow	24.3	15.1	10%	204%	0.99

The following is product data published by Kemcor for virgin HPDE resin (specifically HD2467):

Tensile Stress at Yield (MPa)	Tensile Stress at Break (MPa)	Elongation at Break (%)	Flexural Modulus (GPa)
24	30	800	0.97

Comments

Current design methods do not consider the contribution of the plastic to the strength of the pipe with the exception of Class 6 pipe. At present a value of tensile yield stress of 25MPa is being used for design purposes for Class 6 pipe. This represents a difference of under 10% from the experimentally obtained value.

The effect of the orientation is extremely evident in the testing. The samples taken across the flow of the material are much more brittle than those taken along the flow. Due to the nature of Rib Loc pipe this poses no problem as the stresses in the circumferential direction are much larger than those in the axial direction.

In the largest of the Class 6 sizes, 300mm diameter, the strain in the plastic due to winding is 5.6% in the circumferential direction and considerably less in the axial direction.

Even though a value of 25MPa is used for design purposes no alterations are necessary to existing design calculations as hoop stress is rarely the limiting case and Class 6 pipes only constitute a marginal percentage of the market.

It must be remembered when considering strain across joints that HDPE does creep with time and relieves stresses.

9.2.2 Testing of Series 2000 Pipe Properties

9.2.2.1 Parallel Plate Testing

The parallel plate test is used to measure "pipe stiffness" for flexible pipes. Pipe stiffness is employed as a measure of pipe resistance to bending deformation due to applied load.

The aim of this testing was to determine the pipe wall stiffness and deflection at failure and to confirm the composite behaviour of steel/HDPE ribs without local buckling or separation.

Testing was in carried out by the University of Adelaide in accordance with ASTM D2412. A short length of pipe is loaded between two rigid parallel plates at a controlled rate of compression. Load versus deflection (of the inside pipe diameter) data are obtained. It must be noted that ASTM D2412 applies to plastic pipe and not a steel/HDPE composite. For this reason the results must be considered carefully and used appropriately.

Results

Results were provided in the form of a table of stiffnesses at 5% deflection as well as graphs of load versus deflection for each pipe. Values of pipe stiffness at 3% deflection were interpolated from the graphs. Stiffnesses at both 5% and 3% appear in Appendix C.

The results of the testing performed by the University of Adelaide are shown below:

Diameter (mm)	Class	Stiffness to ASTM D2412 (kPa)	ISO 9969 Equivalent Stiffness (N/m/m)
300	6	79	1473
300	10	698	13002
600	10	175	3255
600	15	340	6333
600	25[1]	511	9523
900	15	153	2857
900	25[1]	222	4127
1200	25[1]	112	2090
1200	40	181	3379
1500	40	117	2169
1800	40	84	1566

[1] Production of Class 25 Series 2000 pipe has since been discontinued

Comments

The graphs of the steel reinforced pipes show that there is some yielding of the steel reinforcement starting in the range of 3% to 4% deflection. The values obtained are similar to those previously being used for design purposes. However, the values obtained from testing will be used for all future designs. Those diameters not covered by the testing will be obtained from in-house tests.

9.2.2.2 Utah State University Soil Box Testing

In order to verify theoretical modelling of Series 2000 pipe behaviour a number of soil box tests were undertaken at Utah State University. The University has two soil boxes, the larger capable of testing pipes up to 2.0 metres in diameter and the smaller up to 0.75 metres in diameter.

Soil box testing enables pipe behaviour to be analysed under controlled conditions which simulate those in the field. Variations in loading, cover height and soil density can be achieved much more easily than with on site testing.

The following table shows the size and configuration of pipes sent to Utah for testing:

Diameter (mm)	Number	Reinforcing Class	Nominal Diameter	Joiner
2000	2	40	1950	1
1900	1	40	1950	
750	3	15	750	1

The 1900mm and 2000mm pipes were buried in the large cell, onto which a vertical soil load was applied by means of 50 hydraulic cylinders. The 750mm pipes were tested in the small cell where a vertical load was applied by means of 16 hydraulic cylinders. One pipe at each of 750mm and 2000mm diameter had a join in the middle so that the join could also be tested.

Results

Pipes were tested at three different nominal soil densities, 75%, 85% and 95%. The height of cover was increased until various performance limits were obtained. The deflection was measured at various intervals during the backfilling process to produce a continuous curve. The test cells had been calibrated so as to give soil pressure at various depths and longitudinal and horizontal locations in the test cell as a function of pressure applied by the hydraulic rams. Increments of pressure, equivalent to soil cover height, at which measurements were taken are as follows:

0.5m increments to 4.0m
1.0m increments to 10.0m
5.0m increments until performance limits were achieved.

Graphs were provided showing vertical and horizontal pipe deflection as a function of height of cover for each soil density tested and for each pipe diameter. Notations were also provided on the curves showing heights of cover when various performance limits took place, such as the initiation of wall dimpling, the initiation of wall buckling, or the initiation of wall crushing.

Test results are summarised in the following table:

Diameter (mm)	Compaction (%)	Local Buckling		General Buckling		Collapse	
		Cover Height (ft)	% Defl'n	Cover Height (ft)	% Defl'n	Cover Height (ft)	% Defl'n
750	87%	25	3.5%	62	10.5%	68	11%
750 (joint)	85%	26	6%	66	16.6%	69	18.4%
750	75%	31	22%	38	26%	41	27%
1900	87%	51	4.1%	59	6.8%	59	6.8%
2000 (joint)	86%	46	4.2%	52	5%	58	7.8%
2000	91%	40	0.9%	52	1.4%	57	5.2%

Comments

The results obtained for the 750mm diameter Class 15 pipe at 87% compaction indicate that the mode of failure was a classical textbook failure mode for a flexible pipe. At failure the pipe split along the joint, and through the split it was evident that the reinforcing steel and plastic profile were still firmly locked together.

No excessive corrugation of the pipe was observed and according to staff carrying out the test, the pipe behaved more like a steel pipe than a plastic pipe. A plastic pipe tends to compress at the springline reducing horizontal deflection whereas the horizontal deflection of a steel pipe is more pronounced.

When comparing the 750mm pipe with the unstiffened joiner element in the centre of the pipe length, it can be seen from the graph in Appendix D that the experimental values of joint displacement are higher than for an unjointed pipe. This is to be expected due to the lack of continuity of the steel enhancement through the joint area.

9.2.2.3 University of South Australia Soil Box Testing

A soil box test was carried out on a 450mm Class 10 pipe at the University of South Australia. Loading was by means of a 100kN hydraulic ram applying force through a 200mm x 500mm plate, consistent with the NAASRA A14 vehicle load.

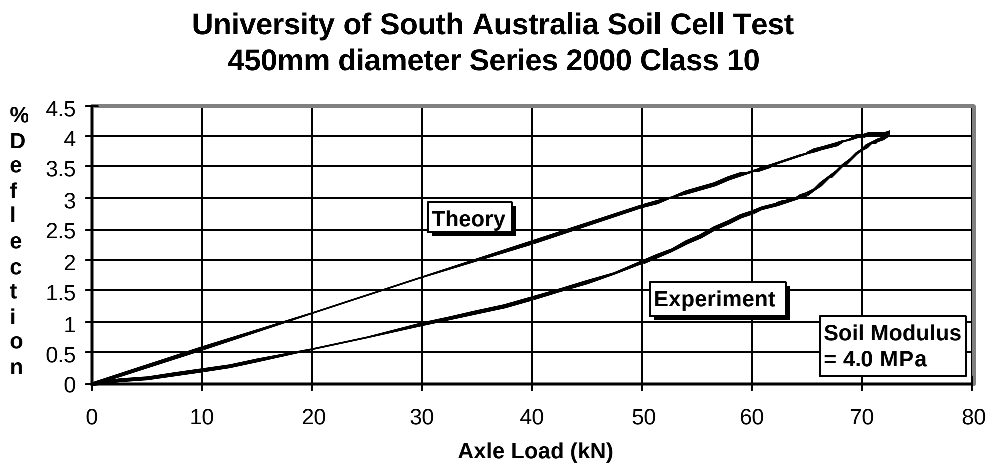
Results

Results obtained by the University for the 450mm diameter pipe with 600mm cover and theoretical equivalents are shown below:

Load (kN)	Experimental Diametric Strain (%)	Theoretical Diametric Strain (%)
0	0	0
10	0.22	0.5
20	0.56	1.2
30	0.96	1.7
40	1.38	2.3
50	1.96	2.9
60	2.78	3.5
65	3.07	3.7
70	3.80	4.0
72.5	4.02	4.1

Note: Soil Modulus = 4.0 MPa for both experimental and theoretical calculations.

A graph of the above results is shown below:



Comments

On inspection of the pipe after removal of the load no damage was evident. The steel and plastic remained clipped together for the duration of the test. Examination of the bore of the pipe during the test showed the bore to be relatively smooth giving rise to the opinion the steel and plastic acted as a composite.

At 600mm cover the 450mm diameter Class 10 pipe withstood 70kN as required by the NAASRA A14 vehicle loading. Diametral deflection was under the 7.5% specified in Australian Standard –AS2566. This particular pipe therefore passes all relevant performance criteria. A graph of Diametric Strain (%) versus Load (kN) for this test is given in Appendix E.

Up until loading reached 50kN a close relationship existed between the experimental and theoretical results. Beyond this point punching shear failure of the soil reduces the effective cover height of soil above the pipe. The theoretical calculations do not take this reduction in cover height into account and therefore underestimates the load being resisted by the pipe.

Punching shear failure occurs when there is compression of the soil under the applied load, accompanied by shearing in the vertical direction around the edges of the load. The ultimate bearing capacity of the soil in punching shear failure is not well defined (Craig, pg 289) and therefore makes design considerations difficult.

Rib Loc design tables limit diametral deflection to 3.0% rather than the commonly accepted 5%. This reduction in deflection limit adequately accounts for reductions in cover height due to the punching shear failure of the soil.

10.0 Rib Loc Quality System

Rib Loc Australia Pty Ltd is a Quality Endorsed Company with ISO 9001 accreditation. The Quality Plan defines how the Rib Loc Quality System is to be applied to the manufacture and supply of polyethylene profile and pipe for stormwater and related applications. Its particular function is to specify which Work Instructions, Specifications and other specific requirements are applicable to these products.

As part of the Quality Plan for Polyethylene Stormwater Pipe, Rib Loc Australia Pty Ltd carry out the following inspections and testing:

- Checks on virgin polyethylene material as supplied to Rib Loc Australia Pty Ltd
- Dimensional checks of extruded PE Profile at the beginning and end of each spool, and during production

A copy of the Quality Plan for Polyethylene Stormwater Pipe is included in Appendix F. A copy of the ISO 9001 Certificate of Registration is also included in Appendix F.

11.0 Case Studies

Two case studies which involve the use of Rib Loc Series 2000 Stormwater pipe are included in Appendix G, namely:

1. Construction of a Large Multi-Celled Flexible Pipeline under a Freeway, which was presented by John Monro from Rib Loc Australia Pty Ltd at the Pipes Wagga Wagga Conference in October 1997. This project involved the use of 900mm nominal diameter Series 2000 Stormwater Pipes.

2. HEP Drainage Case Study, which has been reprinted for Rib Loc Australia Pty Ltd from "Municipal Engineering in Australia" June 1995 Edition - Volume 22 No. 3. This project involved the use of both 1650mm and 1950mm diameter Series 2000 Stormwater Pipes.

Appendix A - PE Chemical Resistance Data

POLYETHYLENE CHEMICAL RESISTANCE TABLE

Polyethylene is highly resistant to the following chemicals at temperatures up to 125°C.

- acetic acid 60%
- aromatic acids
- acrylonitrile
- adipic acid
- allyl alcohol
- alums
- aluminium chloride
- aluminium fluoride
- aluminium sulfate
- ammonia
- ammonium acetate
- ammonium carbonate
- ammonium chloride
- ammonium hydroxide
- ammonium nitrate
- ammonium phosphate
- ammonium sulfate
- ammonium sulfide
- aniline
- antifreeze
- antimony chloride
- arsenic acid
- barium carbonate
- barium chloride
- barium hydroxide
- barium sulfate
- barium sulfide
- battery acid
- beer
- benzoic acid
- boric acid
- brine
- butane gas
- butanediol
- butanol
- butyl glycol
- calcium carbonate
- calcium chlorate
- calcium chloride
- calcium hydroxide
- calcium hypochlorite
- calcium nitrate
- calcium sulfate
- carbon dioxide
- carbon monoxide
- carbonic acid
- caustic potash
- caustic soda
- chloroacetic acid
- chrome alum
- citric acid
- coal gas
- coconut oil
- copper chloride
- copper cyanide
- copper fluoride
- copper nitrate
- corn oil
- cottonseed oil
- cresol
- cyclohexane
- cyclohexanol
- cyclohexanone
- decalin
- detergents, synthetic
- dextrin
- dextrose
- dichloroacetic acid
- diethylene glycol
- dioxane
- esters
- ethanol
- ethylene glycol
- ferric chloride
- ferric nitrate
- ferric sulfate
- ferrous chloride
- ferrous sulfate
- film solution
- fluoboric acid
- fluorsilicic acid
- formaldehyde
- formic acid
- fruit juice
- gelatine
- glucose
- glycerine
- glycol
- hexanol
- hydrobromic acid
- hydrocyanic acid
- hydrochloric acid
- hydrofluoric acid
- hydrogen
- hydrogen peroxide
- hydrogen sulfide
- hypochlorous acid
- magnesium carbonate
- magnesium chloride
- magnesium hydroxide
- magnesium nitrate
- magnesium sulfate
- maleic acid
- methanol
- mercuric chloride
- mercuric cyanide
- mercurous nitrate
- mercury
- methanol
- milk
- molasses
- nickel chloride
- nickel nitrate
- nickel sulfate
- nitric acid 30%
- orthophosphoric acid
- oxalic acid
- oxygen
- paraffin oil
- petroleum
- phenol
- phosphates
- phosphoric acid
- phosphorous oxychloride
- phosphorus pentoxide
- phosphorus trichloride
- phthalic acid
- picric acid
- potash
- potassium borate
- potassium bromate
- potassium bromide
- potassium carbonate
- potassium chlorate
- potassium chloride
- potassium chromate
- potassium cyanide
- potassium dichromate
- potassium ferricyanide
- potassium fluoride
- potassium hydroxide
- potassium hypochlorite
- potassium nitrate
- potassium perborate
- potassium perchlorate
- potassium permanganate
- potassium persulphate
- potassium sulfate
- potassium sulfide
- propyl alcohol
- propylene glycol
- prussic acid
- salicylic acid
- sea water
- selenic acid
- silicic acid
- silicone oil
- silver acetate
- silver cyanide
- silver nitrate
- soap solutions
- sodium acetate
- sodium benzoate
- sodium bicarbonate
- sodium bisulphate
- sodium bisulphite
- sodium borate
- sodium bromide
- sodium carbonate
- sodium chlorate
- sodium chlorite
- sodium cyanide
- sodium ferricyanide
- sodium fluoride
- sodium hydroxide
- sodium hypochlorite
- sodium nitrate
- sodium nitrite
- sodium sulfate
- sodium sulfide
- sodium thiosulfate
- stannic chloride
- stannous chloride
- starch
- stearic acid
- sulfur dioxide
- sulfuric acid 70%
- sulfurous acid
- tannic acid
- tartaric acid
- transformer oil
- trichloroacetic acid
- urine
- vinegar
- wine
- yeast
- zinc carbonate
- zinc chloride
- zinc oxide
- zinc sulfate

POLYETHYLENE CHEMICAL RESISTANCE TABLE (cont'd)

Polyethylene is generally suitable for use with the following chemicals up to 75°C and conditionally suitable up to 125°C.

acetic acid glacial	diethylether	naphtha
acetone	ether	naphthalene
amyl acetate	ethyl acetate	nitric acid 50%
amyl alcohol	fuel oil	nitrobenzene
butyl acetate	gasoline	nitroluene
butyric acid	heptane	oils and fats
camphor	hexane	oleic acid
chromic acid	iodine	perchloric acid 70%
dibutyl ether	isopropanol	petroleum ether
dibutyl phthalate	isopropyl ether	sulphuric acid 80%
diesel oil	mineral oil	turpentine

Polyethylene is conditionally suitable for use with the following chemicals up to 75°C and generally unsuitable over this temperature.

nitric acid 70%	ozone	sulphuric acid 98%

Appendix B - Series 2000 Flow Chart

Appendix C - Parallel Plate Pipe Stiffness

at 5% and 3% Deflection

Appendix D - Utah Soil Box Test

Unjointed vs Jointed Pipe

Appendix E - University of South Australia

Soil Box Test

Appendix F - Rib Loc Quality System

Appendix G - Case Studies

Appendix H - References

ASTM, D1693 - 70, Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics, American Society for Testing and Materials, 1988.

ASTM, D638 - 93, Standard Test Method for Tensile Properties of Plastics (Metric), American Society for Testing and Materials, 1993.

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