Concrete Pipe Association of Australasia

Developments in design of bedding materials

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$$T_c = W_g / F + W_q / F_q$$

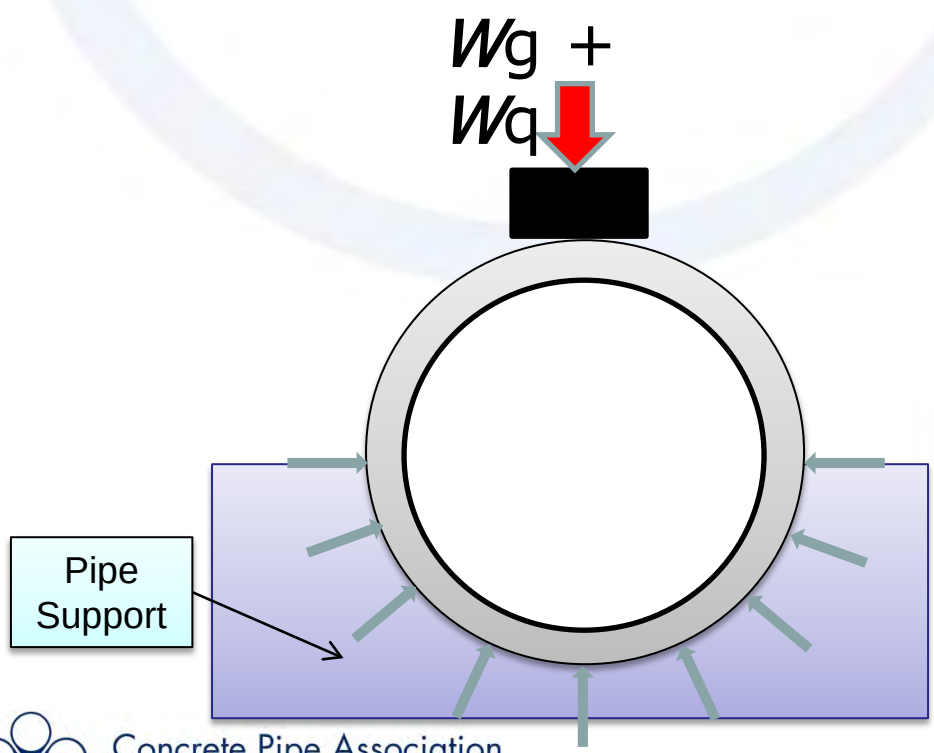
Where

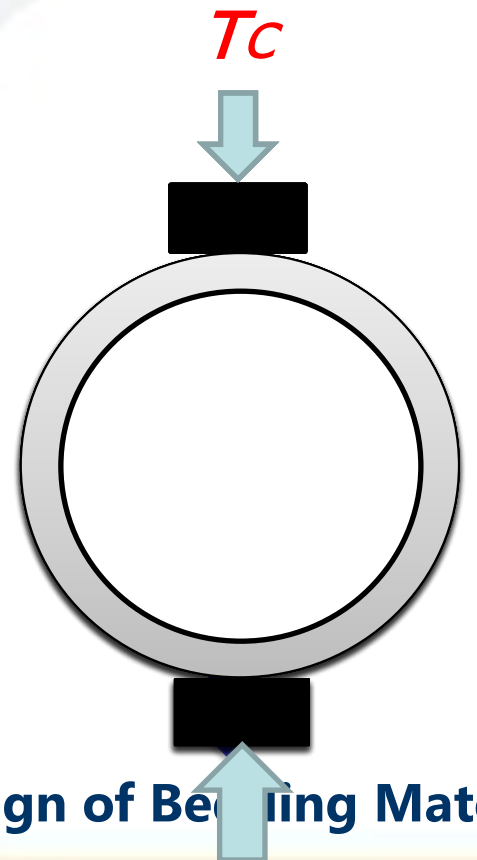
W_g = Working load due to fill and superimposed loads

W_q = Working load due to superimposed live loads

F = Bedding Factor (1 – 4 depending on type of pipe support)

F_q = The lesser of 1.5 and F





AS/NZS 3725

- The requirements for the material selection, or select fill, for bedding construction have been in place in AS/NZS 3725 since 1989.
- Select fill is defined in the Standard as:

"The material obtained from excavation of the pipe trench or elsewhere with a particle size not greater than 75 mm, and which conforms with the soil classes given in Table 1."

TABLE 1 FROM AS/NZS 3725: SOIL CLASSES AS DEFINED IN AS 1726

Abbreviation	Description
SC	Clayey sands with fines of low plasticity
SP	Poorly graded sands
SW	Well-graded sands
GC	Clayey gravels with fines of low plasticity
GW	Well-graded sand and gravel mixtures with little or no plastic fines
GP	Poorly graded sand and gravel mixtures with little or no plastic fines

AS/NZS 3725

- AS/NZS 3725 – 2007 includes details of the material required to achieve minimum compaction levels that are aligned with the various support types recommended for steel reinforced concrete pipe.
- It outlines strict grading requirements and specific compaction levels for the material required for the construction of –
  - Bed and haunch zones (Table 6, AS/NZS 3725)
  - Side zones (Table 7, AS/NZS 3725).

TABLE 6 – GRADING LIMITS FOR SELECT FILL IN BED AND HAUNCH ZONES

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 – GRADING LIMITS FOR SELECT FILL IN SIDE ZONES

Sieve size (mm)	Weight passing (%)
75.0	100
9.5	100 – 50
2.36	100 – 30
0.60	50 – 15
0.075	25 – 0

BEDDING FACTORES FOR WORKING DEAD LOADS

Support Type		Minimum depth, mm		Minimum zone compaction, %			Bedding factor (*F*)
		Bed zone x	Haunch zone y	Bed and haunch zones *ID*	Side zones		
					ID	*RD*	
U		75					1.0
H	H1	100 if D < 1500; or 150 if D > 1500	0.1D	50			1.5
	H2		0.3D	60			2.0
HS	HS1	100 if D < 1500; or 150 if D > 1500	0.1D	50	50	85	2.0
	HS2		0.3D	60	60	90	2.5
	HS3		0.3D	70	70	95	4.0

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AS/NZS 3725

- It is expected that this be replicated on site so as to achieve the design requirements.
- However, what if these specific fill materials are **not** available?
- What alternatives are there when the selected fill materials and corresponding grading limits outlined in AS/NZS 3725 cannot be sourced or achieved, **without** compromising the bedding factor associated with the designed support type?

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Other Standards

- **ASTM C1479-13 -** 2013 US Standard – installation of SRCP
- **ACPA** – "Standard Installations and Bedding Factors for Indirect Design"

Table 1 Equivalent USCS and AASHTO Soil Classifications for SIDD Soil Designations				
	Representative Soil Types		Percent Compaction	
SIDD Soil	USCS	AASHTO	Standard Proctor	Modified Proctor
Gravelly Sand (Category I)	SW, SP GW, GP	A1, A3	100 95 90 85 80 61	95 90 85 80 75 59
Sandy Silt (Category II)	GM, SM, ML Also GC, SC with less than 20% passing #200 sieve	A2, A4	100 95 90 85 80 49	95 90 85 80 75 46
Silty Clay (Category III)	CL, MH GC, SC	A5, A6	100 95 90 85 80 45	90 85 80 75 70 40

- Category 1 - SW and GW typical of AS/NZS 3725 but SP and GP not well graded (but can be easily compacted).
- Category 2 – GC and SC common with AS/NZS 3725 requirements.
- Category 3 – these soil types are not permitted as select fill by AS/NZS 3725

Other Standards

- **ASTM C1479-13 -** 2013 US Standard – installation of SRCP
- **ACPA** – "Standard Installations and Bedding Factors for Indirect Design"

Table 2 Standard Installations Soils and Minimum Compaction Requirements

Installation Type	Bedding Thickness	Haunch and Outer Bedding	Lower Side
Type 1	D_o/24 minimum, not less than 3 in. If rock foundation, use D_o/12 minimum, not less than 6 in.	95% Category I	90% Category I, 95% Category II, or 100% Category III
Type 2	D_o/24 minimum, not less than 3 in. If rock foundation, use D_o/12 minimum, not less than 6 in.	90% Category I or Category II	85% Category I, 90% Category II, or 95% Category III
Type 3	D_o/24 minimum, not less than 3 in. If rock foundation, use D_o/12 minimum, not less than 6 in.	85% Category I, 90% Category II, or 95% Category III	85% Category I, 90% Category II, or 95% Category III
Type 4	D_o/24 minimum, not less than 3 in. If rock foundation, use D_o/12 minimum, not less than 6 in.	No compaction required, except if Category III, use 85% Category III	No compaction require, except if Category III, use 85% Category III

- Installations compared:
  - Type 1 = HS3
  - Type 2/3 = HS2
  - Type 3/4 = HS1
  - Type 4 = H1

- Compaction standards vary with material category.
- Compaction levels required the same for equivalent in AS/NZS 3725.
- Material category chosen depends on installation type.

Other Standards

- **AS/NZS 2566.1** – Flexible Plastic Pipe (Design)
- This standard covers the design of buried flexible pipelines and as such the bedding design and installation is critical to the overall success of the completed pipeline.
  - Embedment materials must provide a minimum support stiffness as measured by compaction ratios.
  - Includes materials nominated in AS/NZS 3725 Table 1.
  - Typical compaction ratios range from Rd 85 to 95.
  - Note 2 of the table recognises the **need to protect against the migration of fines** where appropriate.

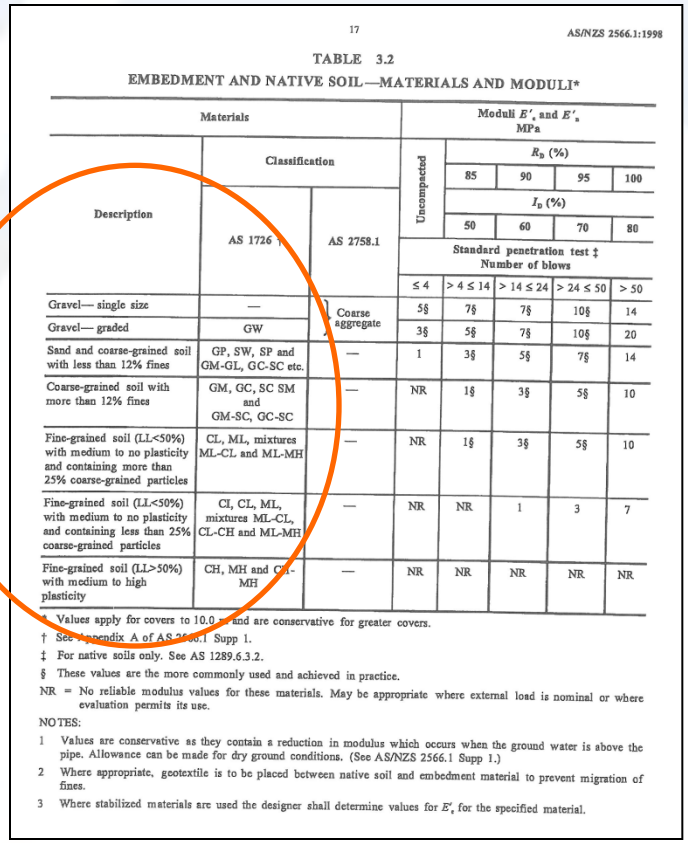

TABLE 3.2

EMBEDMENT AND NATIVE SOIL—MATERIALS AND MODULI*

Materials			Moduli E'_s and E'_n MPa				
Description	Classification AS 1726 †	Classification AS 2758.1	Uncompacted	R_D (%) 85	90	95	100
				I_D (%) 50	60	70	80
				Standard penetration test ‡ Number of blows ≤ 4	> 4 ≤ 14	> 14 ≤ 24	> 24 ≤ 50	> 50
Gravel— single size	—	Coarse aggregate	5§	7§	7§	10§	14
Gravel— graded	GW		3§	5§	7§	10§	20
Sand and coarse-grained soil with less than 12% fines	GP, SW, SP and GM-GL, GC-SC etc.	—	1	3§	5§	7§	14
Coarse-grained soil with more than 12% fines	GM, GC, SC SM and GM-SC, GC-SC	—	NR	1§	3§	5§	10
Fine-grained soil (LL<50%) with medium to no plasticity and containing more than 25% coarse-grained particles	CL, ML, mixtures ML-CL and ML-MH	—	NR	1§	3§	5§	10
Fine-grained soil (LL<50%) with medium to no plasticity and containing less than 25% coarse-grained particles	CI, CL, ML, mixtures ML-CL, CL-CH and ML-MH	—	NR	NR	1	3	7
Fine-grained soil (LL>50%) with medium to high plasticity	CH, MH and CH-MH	—	NR	NR	NR	NR	NR

* Values apply for covers to 10.0 m and are conservative for greater covers.

† See Appendix A of AS 2566.1 Supp 1.

‡ For native soils only. See AS 1289.6.3.2.

§ These values are the more commonly used and achieved in practice.

NR = No reliable modulus values for these materials. May be appropriate where external load is nominal or where evaluation permits its use.

NOTES:

1 Values are conservative as they contain a reduction in modulus which occurs when the ground water is above the pipe. Allowance can be made for dry ground conditions. (See AS/NZS 2566.1 Supp 1.)

2 Where appropriate, geotextile is to be placed between native soil and embedment material to prevent migration of fines.

3 Where stabilized materials are used the designer shall determine values for E'_s for the specified material.

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Selecting Materials for Bedding SRCP

- It can be seen that AS/NZS 3725 can be restrictive with regard to the selection of suitable materials bedding support systems.
- Other pipe standards use a wide range of soil materials in bedding support systems, requiring different –
  - compaction standards and design,
  - testing
  - quality control initiatives.
- Anecdotal evidence would suggest that the use of "non-complying" materials, when installing concrete pipe, has always occurred.
- However, in areas where formal sign off to AS/NZS 3725 is needed, how restrictive is the Standard being and to what cost?

Selecting Materials for Bedding SRCP

- The CPAA Engineering Guideline "Selecting Materials for Bedding SRCP" suggests that alternative materials can be used.
- These alternatives should be confirmed as suitable by:
  - Implementing sound construction and quality control plans.
  - Conducting field trials to demonstrate required compaction standards can be achieved
  - Reviewing and preparing design to mitigate the potential migration of fines (i.e. including geotextiles)
- With sound construction and geotechnical input, an innovative and cost effective bedding support solution, consistent with the bedding factors outlined in AS/NZS 3725 to achieve design requirements, can be achieved.

Recommendations (summary)

- In addition to the requirements of AS/NZS 3725, the CPAA recommends the following guidelines be considered:
- Select fill complying with the generic soil classes as defined in AS 1726 and shown in Table 1 of AS/NZS 3725,

TABLE 1 FROM AS/NZS 3725: SOIL CLASSES AS DEFINED IN AS 1726

Abbreviation	Description
SC	Clayey sands with fines of low plasticity
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but not complying with the particle size distribution of Tables 6 and 7 of AS/NZS 3725 may be used in the bed, haunch, and side zone, provided that:

Selecting Materials for Bedding SRCP

a) It shall be demonstrated through construction plans, quality control plans, and field trials that the degree of compaction shown in Table B of this guideline, corresponding to the selected bedding type and material, can be achieved, and,

Table B

MINIMUM COMPACTION REQUIREMENTS FOR VARIOUS BEDDING TYPES AND SELECT FILL SOIL CLASSES

Bedding Type	HS3		HS2		HS1		H2		H1	
Bedding Material	I_D	R_D	I_D	R_D	I_D	R_D	I_D	R_D	I_D	R_D
SW, SP, GW, GP	70	95	60	90	50	85	60	90	50	85
SC, GC	n/a	n/a	70	95	60	90	70	95	60	90

NOTES: 1. I_D refers to Density Index (%) and is for cohesionless materials (refer to Clause 8, AS/NZS 3725 for more information).
2. R_D refers to Dry Density Ratio (%) and is for cohesive materials (refer to Clause 8, AS/NZS 3725 for more information).

b) Methods to prevent migration of soil fines from, and into the bedding material, shall be provided when ground water movement or existing soil and bedding conditions are conducive to particle migration, and

Selecting Materials for Bedding SRCP

c) Long thin particles are not used (despite complying with the grading standards), due to their angular shape which increases the risk of stress on the pipe due to inadequate or non-uniform bedding, and,

d) Maximum particle size of select fill materials in bed, hunch, and side zones shall not be greater than the recommended limits given in Table C, or so selected to ensure uniform support around the pipes, and prevent concentrated point loading.

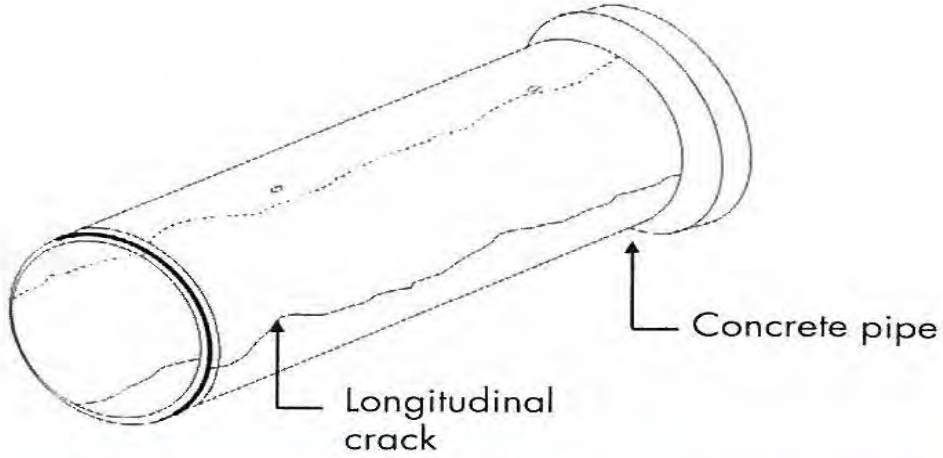
Alternatively, if a) to d) inclusive cannot be achieved, the bedding material must be cement stabilised.

Table C

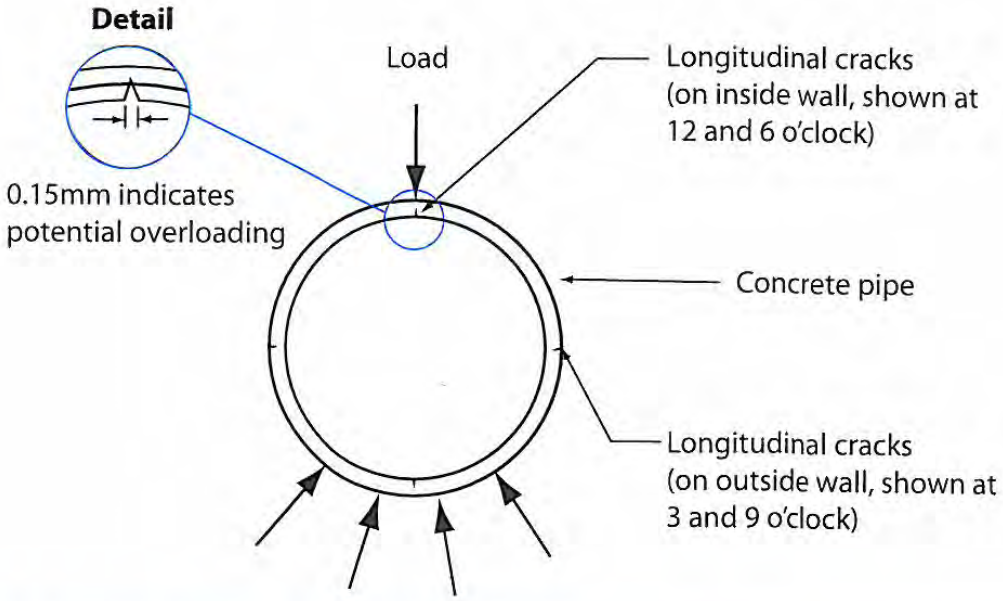
RECOMMENDED MAXIMUM PARTICLE SIZE (mm)

Pipe diameter	Bedding Zone	
DN	Bed and Haunch	Side
225- 1350	20	40
1500 - 2250	40	75
> 2250	65	75

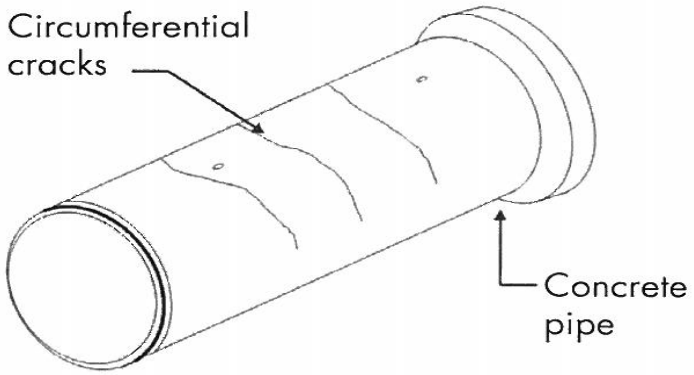
NOTES: If the requirements for the above recommendations are met, the bedding factor reduction outlined in AS/NZS 3725 Clause 9.3.2will not apply. However, as in accordance with AS/NZS 3725 Clause 9.3.3, bedding factors will be reduced in line with the Standards recommendations if the conditions prescribed for the use of these materials cannot be demonstrated or achieved.

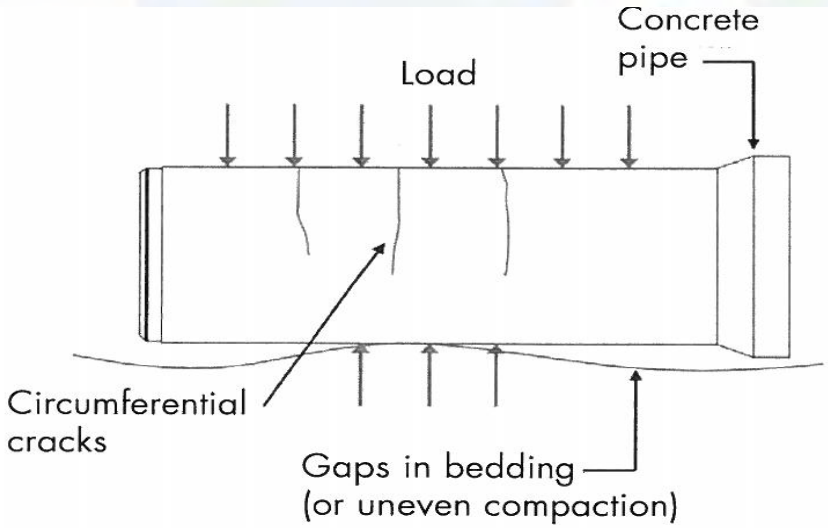


3D view of where longitudinal cracks can occur and what they look like.

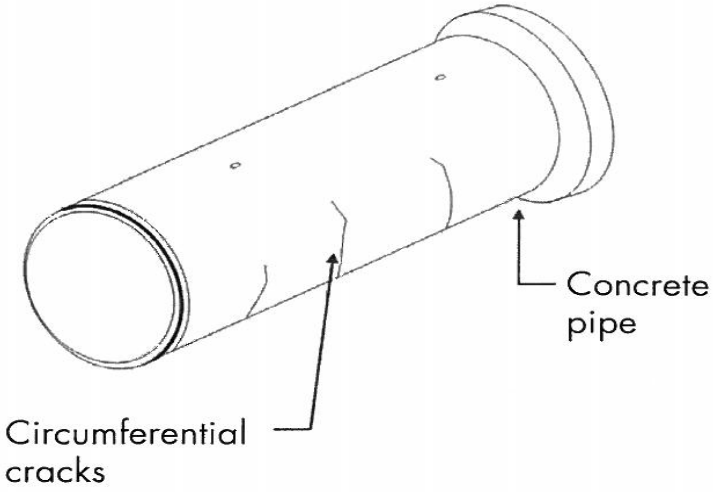


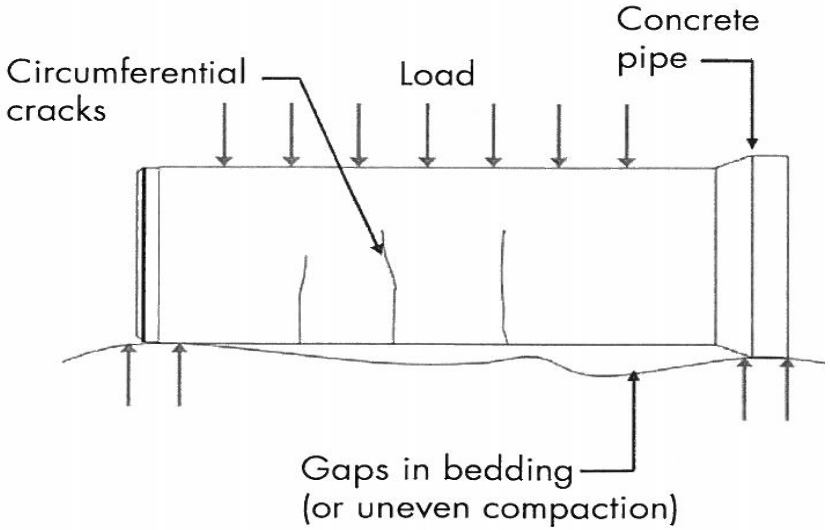
Looking at a pipe in section and the effect that overloading can have on a pipe.





Pipes can crack circumferentially at the top where support is not uniform and it is forced to act like a cantilever beam.





Pipes can crack circumferentially at the bottom where uniform support is not achieved. Pipes are not designed to act as beams.

Defect	Description	Magnitude	Solution
Type 1	Circumferential crack	Width <0.15 mm	Accept
	Longitudinal crack	Width <0.15 mm	Accept
Type 2	Circumferential crack	0.15 mm< Width <0.50 mm	Accept
	Longitudinal crack	Width >0.15 mm	Assess Design
Type 3	Circumferential crack	Width >0.50 mm	Assess implication of ingress
	Longitudinal crack	Width >0.50 mm	As per Type 2
Type 4	Chip or spall	Depth <0.25\cover	Accept
Type 5 or 6	Chip or Spall	Depth >0.25\cover	Assess implication Repair

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