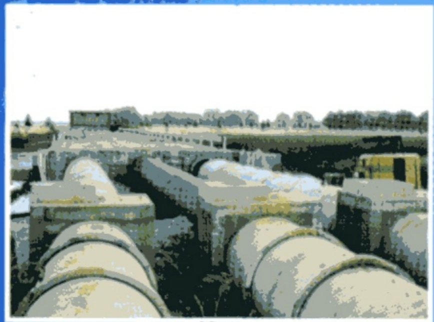
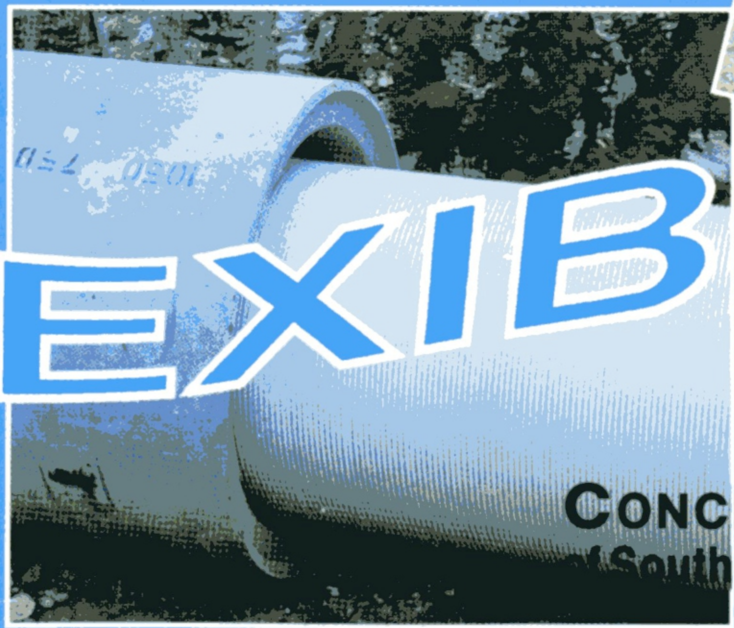
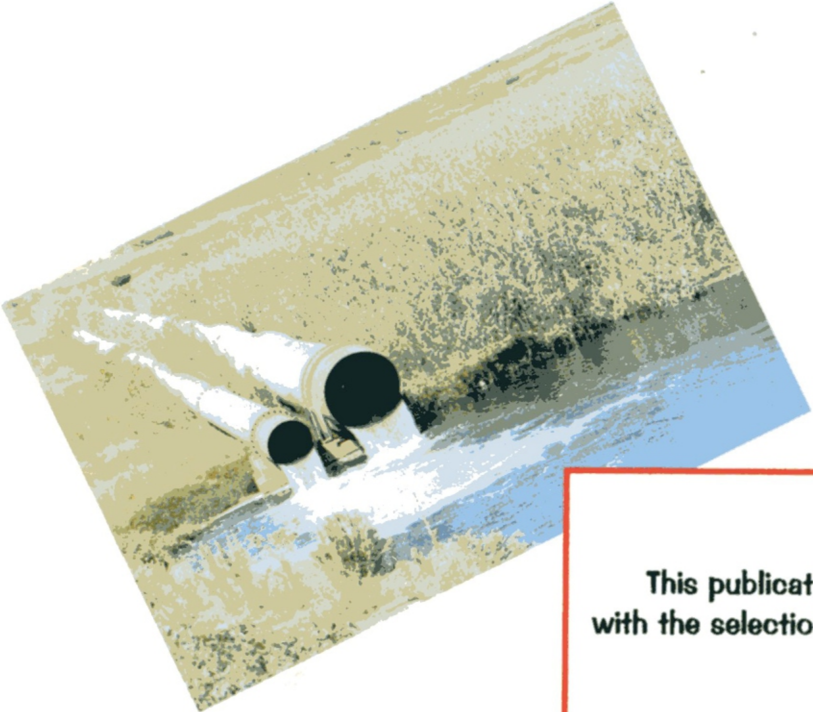
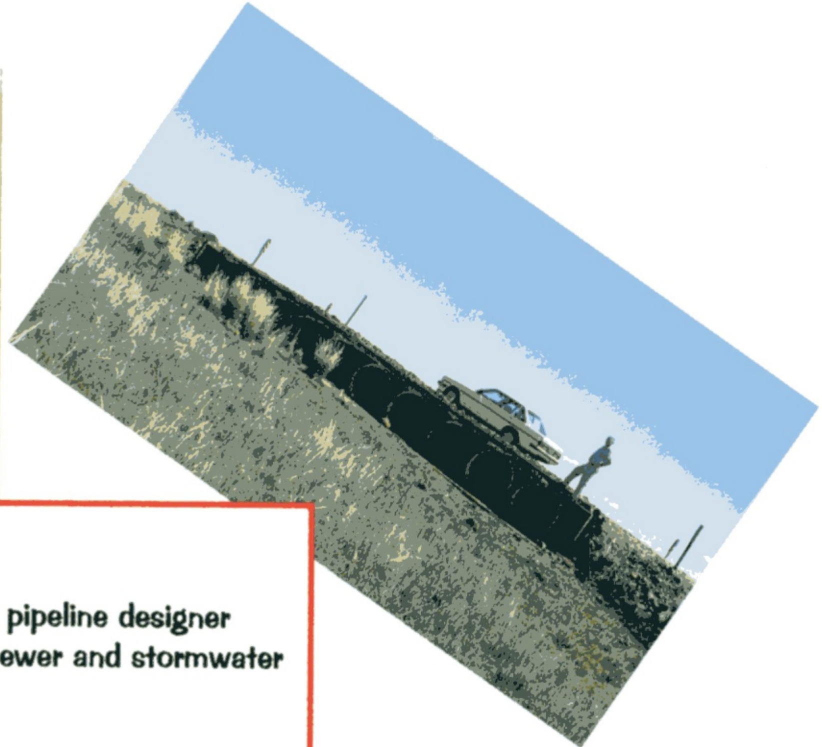
RIGID VERSUS FLEXIBLE





CONCRETE PIPE ASSOCIATION
of Southern Africa
Reprint August 1997



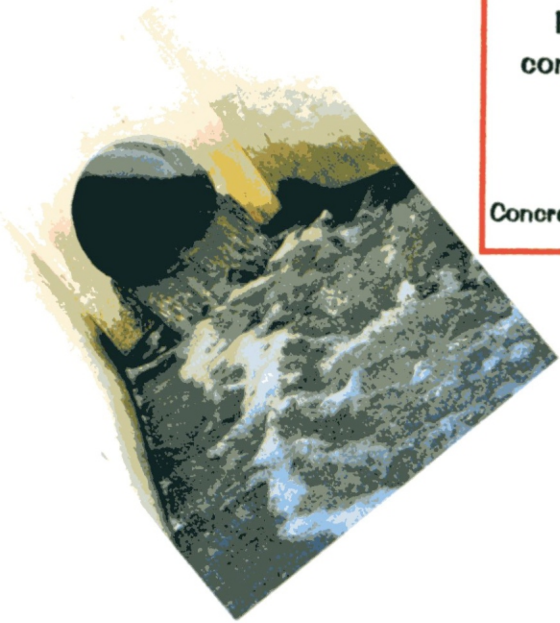


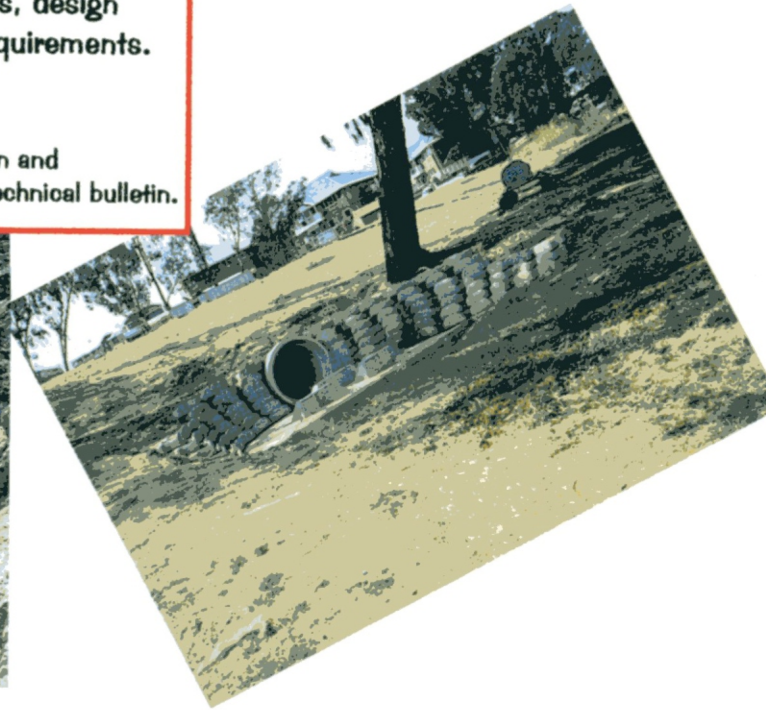
INTRODUCTION

This publication has been prepared to assist the pipeline designer with the selection of pipe materials to be used for sewer and stormwater drainage projects.

It covers various aspects of pipe types and characteristics, design considerations, specification, installation and operational requirements.

Acknowledgment is given to American Concrete Pipe Association and Concrete Pipe Association of Australasia for the information used in this technical bulletin.





Technical Bulletin
Concrete Pipe Association of Southern Africa
No 01/95 May 1995

IMPORTANT DIFFERENCES IN THE DESIGN, CONSTRUCTION AND OPERATIONAL REQUIREMENTS FOR PIPELINES

COMPILED BY RODNEY C CORIN , Pr Eng. DIRECTOR CPA

1. DEFINITIONS:

	RIGID PIPE	FLEXIBLE PIPE
According to SABS 1200 LB-1983 Bedding (Pipes) Clause 2.3	A pipe of which the diameter is reduced by not more than 1% under an external radial force before the appearance of cracks.	A pipe of which the diameter is reduced by more than 1% under an external radial force before the appearance of cracks.

According to SABS 0102 Part I-1987 Code of Practice for The Selection of pipes for buried pipelines Part I: General Provisions.

Classification is in terms of a Flexural Stiffness Ratio Y which is the ratio of the plain-strain elastic modulus of the soil and the pipe.

Figure 2 reproduced on the next page gives an approximate classification for various pipe-soil systems.

For a more detailed approach, please consult the Code.

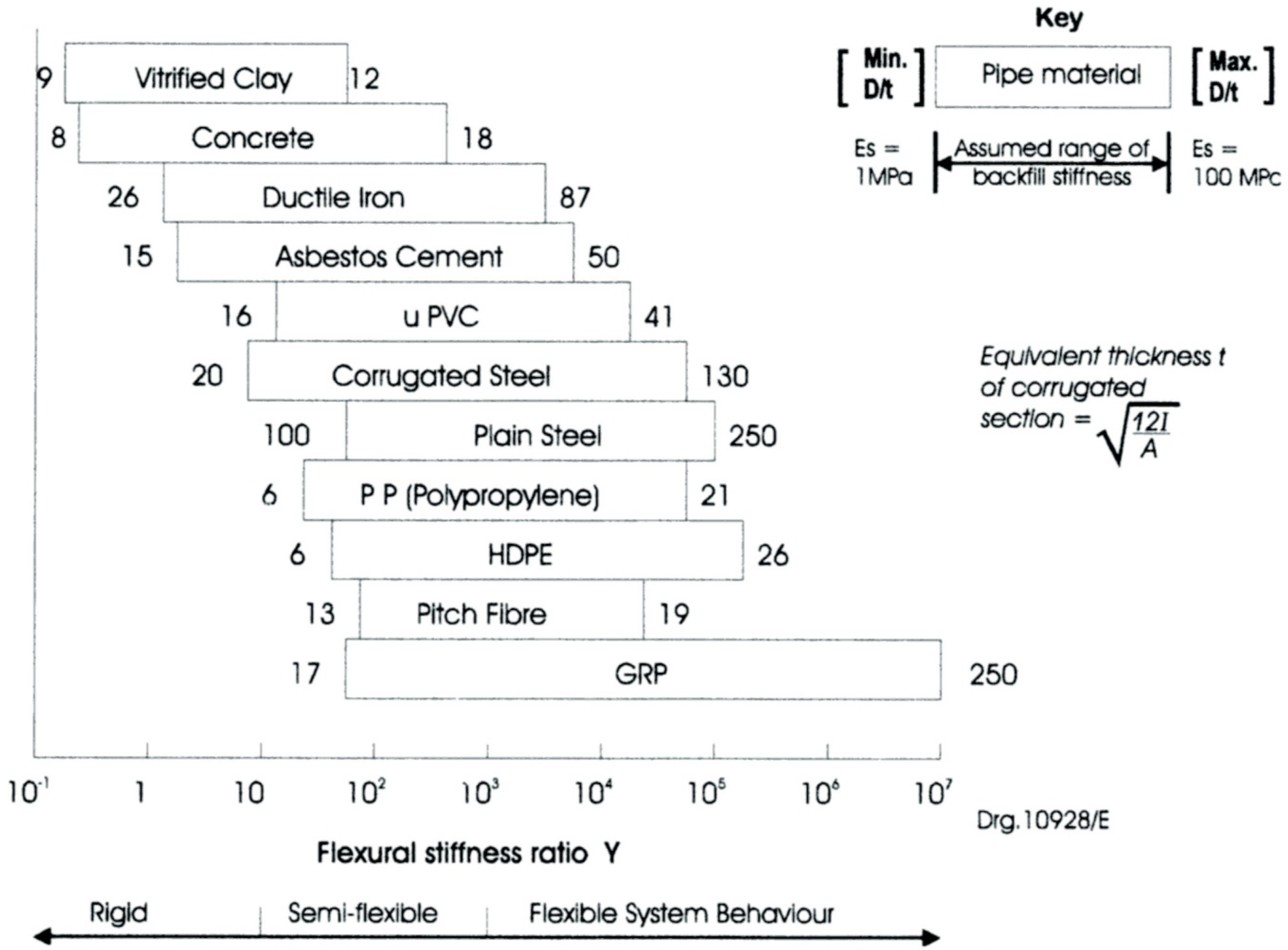


Fig. 2 - Typical Ranges of system Behaviour for Different Pipe Materials

2. TYPICAL PIPE TYPES:

Definitions from SABS 0120: Part 3 Section LB-1983 Bedding (Pipes) Clauses 2.1.5 and 2.2.3

RIGID PIPE

Reinforced and unreinforced Concrete Pipe, Vitrified Clay and small diameter Ductile Iron and Asbestos Cement Pipes.

FLEXIBLE PIPE

Steel pipes that are not coated or lined with concrete, all PVC and GRP (glass reinforced plastic) pipes, thin-walled pitch-impregnated fibre pipes, and Asbestos Cement Pipes of diameter exceeding 1000mm.

3. DESIGN CONSIDERATIONS

NOTE: It is essential that the design of the pipe bedding and the design of the pipeline be carried out in conjunction with each other.

	RIGID PIPE	FLEXIBLE PIPE
3.1 General:	Concrete pipes, manufactured, designed and installed in accordance with SABS Standards, covering every aspect of the production, selection and bedding of pipes for buried pipelines, have a proven field performance in South Africa exceeding 80 years. Similar standards and years of successful application also exist in Australia and the USA.	There are presently no generally recognised standards or procedures for the design of flexible pipe for buried pipelines in South Africa - neither in Australia nor the USA. To quote from an American source (K K Kienow) "The lack of adequate design technique for low stiffness pipe is one of the best kept secrets of the plastic pipe industry today".
3.2 Recommended Design Procedures: **According to SABS 0102 Part I - 1987 General Provisions**	Based on the Marston-Spangler theory where only vertical loads are considered. This procedure is well researched and documented in easy to follow formats - both written and computer software.	Requires the use of more sophisticated design theories or techniques. For semi-flexible pipe-soil systems the "concentration factor" approach is prescribed. For flexible pipe the phenomenological approach to soil-structure interaction is prescribed.
3.3 SABS Code of Practice for the Selection of Pipes for Buries Pipelines.	SABS 0102 Part II - 1987 Rigid Pipes is fully documented, available and in use.	SABS 0102 Part III: Semi-flexible pipes and Part IV: Flexible Pipes According to sources at the SABS no progress has been made in commencing with the drawing up of these sections.

3.4 Design Approach

RIGID PIPE

Rigid pipes are able to support, by their own strength, a major portion of the imposed load.

The load on the pipe is limited to its proof load as tested in accordance with SABS Standards at the factory, multiplied by a factor corresponding to the type of bedding specified.

These bedding factors have been well researched and documented since 1930.

The strength of a rigid pipe, as concrete pipe, is defined in terms of its D-Load designation where the D-Load is the proof load expressed in kN/m of pipe diameter per metre length.

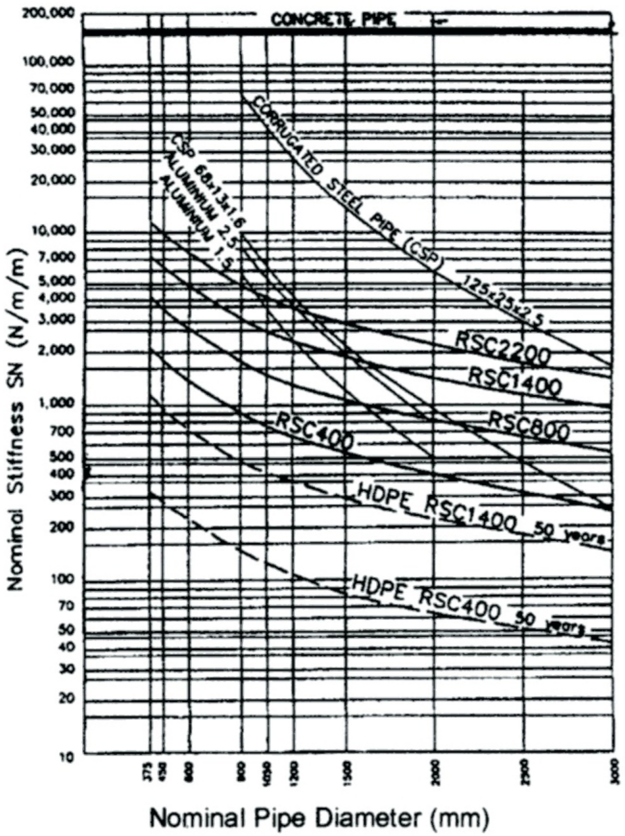


FIGURE 4. PIPE TYPE STIFFNESS

FLEXIBLE PIPE

Flexible pipes are unable to support, by their own strength, more than a small fraction of the imposed load.

The shape which a flexible pipe takes up when it is installed and under load, is determined by the bedding and backfill and also by a structural property of the pipe itself, referred to as its "stiffness".

Pipes are being manufactured and offered for use, with a wide range of stiffnesses, and, as would be expected, stiffer pipes tend to be more expensive.

The load on a flexible pipe is limited to ensure that the "long term" deflection under installed conditions does not exceed between 5% to 7½%.

See **Figure 4** for a comparison of stiffnesses including time related decreases.

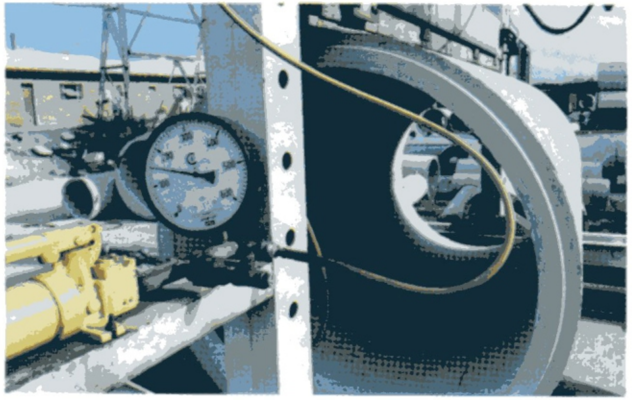
The Texas Department of Transport restricts the use of flexible pipe for road culverts to those roads with an Average Daily Traffic count (ADT) of less than 2000 vehicles per lane, and subject to specific fill height tables. They also require special flowable concrete mixes for backfill.

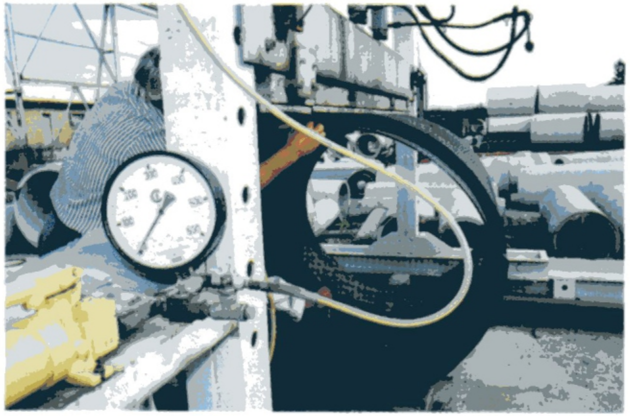
3.5 Strength Characteristics of Pipe

RIGID PIPE

The strength characteristics of Precast Reinforced Concrete Pipe increase with time.

CONCRETE PIPE AT 50 kN/m





FLEXIBLE PIPE AT 5kN/m

(i.e. 1/10th of load on Concrete Pipe above)

FLEXIBLE PIPE

It is commonly recognised that the strength properties of plastics diminish with time and provision must be made in the design and testing of plastic pipes for these changes with time.

Stiffness of plastic pipe in the long term is much less than indicated in the short term tests used for classifying the pipes.

See **Figure 5** for details.

FLEXIBLE PIPE DN1050
with TOP LOAD 1 tonne/metre (10kN/m)

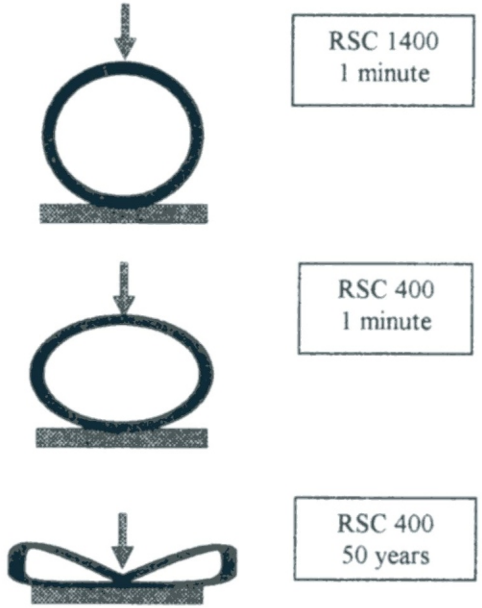


FIGURE 5. ILLUSTATION OF EFFECTS FROM DIFFERENT RSC (RING STIFFNESS CONSTANT) AND DURATION OF LOAD AND HDPE PIPE

3.6 Specification of Bedding Material to ensure design assumptions and requirements are met.

RIGID PIPE

The load capacity of a buried precast concrete pipeline is predominantly dependent upon the structural strength of the pipe itself, and although the type of foundation, type and density of bedding and type and density of embedment soil is important in determining its ultimate load carrying capacity, variations in the soil conditions relative to the above elements can be accommodated with minor changes in the level of compaction or bedding support.

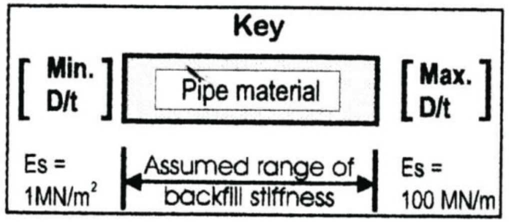
FLEXIBLE PIPE

The load capacity of a buried flexible pipeline is predominantly dependent upon the strength of the soil embedment of the pipe and the pipe-soil interaction. The flexible pipe merely transfers the vertical loads to the side "soil abutments" by deforming and causing a sideways thrust: this is termed "pipe arching".

The lower the stiffness of the pipe, the higher is the required strength of the soil embedment around the pipe. According to SABS 0120 Part 3, Section LB-1983 and SABS 1200 LB-1983 Bedding (Pipes), a special class of bedding is required for flexible pipes to assist in ensuring that loads are evenly distributed. Only selected granular material can be used for the full embedment of the flexible pipe to 100mm above the soffit of the pipe over the full width of the trench. The embedded pipe must then also be covered with a further 200mm of selected fill blanket compacted in 100mm layers with special care to be taken when compacting over the pipeline.

The above procedures normally require imported material to be used. This also means that the unusable excavated material must be removed from site.

Ideally a soil investigation should be carried out along the length of the pipeline during the pre-tender period to establish whether bedding materials, that will comply with the requirements, can become available from the excavations and/or are available within an economic distance of the areas in which pipelaying is to be carried out. It must also be borne in mind that selection of



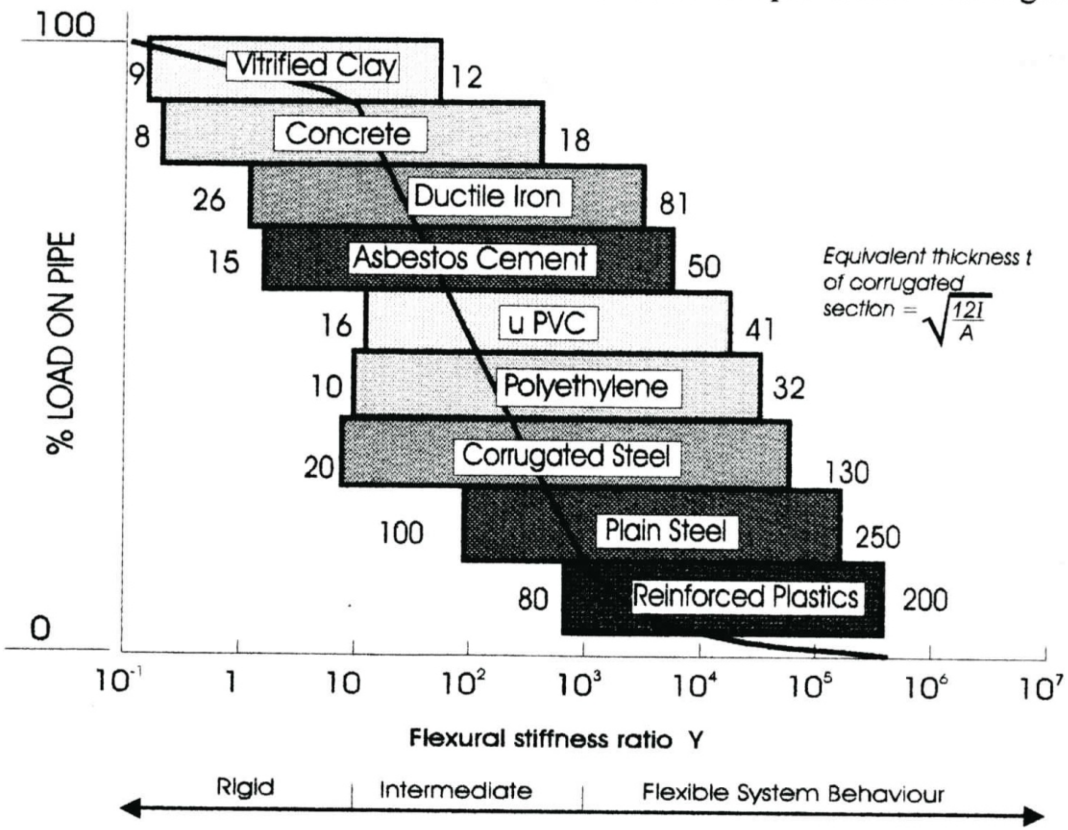


Fig. 1.4. Typical ranges of system behaviour for different pipe materials, (reproduced by permission of the Transport and Road Research Laboratory)

RIGID PIPE

Ideally during the design of general types of pipelines, a Class C bedding should be assumed so that any variations in soil conditions encountered during construction can be catered for by minor adjustments to the placing and compacting of the foundation and bedding material.

The most severe requirement for the highest class of bedding for rigid pipe is to compact selected granular material in 100mm layers to the springline.

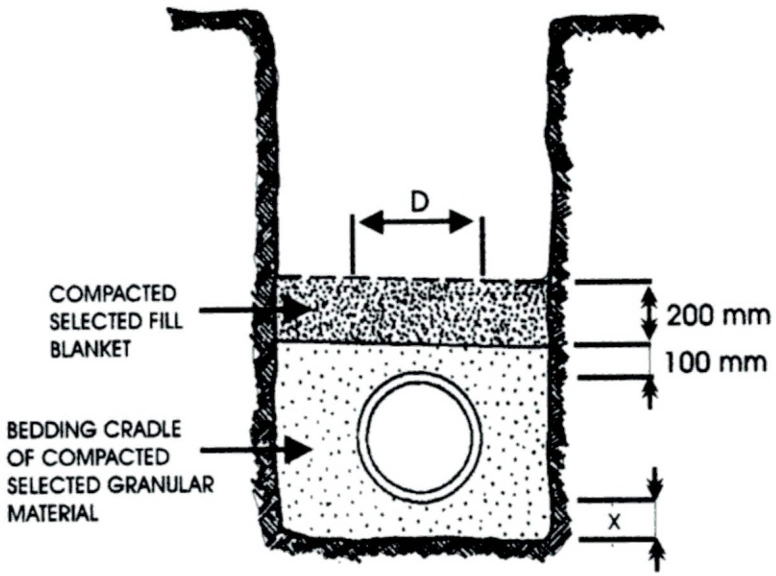
Only in special cases of high fills and obviously poor in-situ soil conditions will special attention to design procedures be required.

These could include pre-tender soil investigations and the importing of bedding material.

It is important to note that with bedding requirements identical to the minimum requirements for flexible pipe, a cheap low strength reinforced precast concrete pipe could be specified which would give better service conditions than that of the required flexible pipe under the same load conditions. Therefore when considering alternative pipe materials, it is important to compare the full cost for the total installed condition and not only pipe costs

FLEXIBLE PIPE

materials during pipe trench excavation is difficult and even more so if the soil characteristics change with depth.



$x = {}^{D}/_{4}$ subject to x being not less than 100mm and not more than 200mm

(a) Flexible Pipes

SABS 1200 LB-1983
Bedding (Pipes)

3.7 Prevention of flotation of the pipeline.

RIGID PIPE

The specific gravity of concrete is approximately 2,4 times that of water, but there are several installation conditions where the possibility of pipe flotation exists. Some of these conditions are:

- the use of flooding to consolidate backfill;
- flooding of the trench during construction by rainwater;
- pipelines in areas which can become inundated, such as, a flood plain or under a future man-made lake;
- subaqueous pipelines; and
- pipelines in areas with a high ground water table.

When such conditions exist, flotation probability of the concrete pipeline should be checked.

FLEXIBLE PIPE

The specific gravity of flexible pipe materials is generally less than that of water. In all cases, where the water table might be located above the bottom of the pipe, it is imperative that the designer calculate the weight (and therefore depth) of backfill required to counteract the buoyant forces.

In the case of shallow buried flexible pipe, when buoyancy conditions can occur, anchor straps and blocks will be required to restrain it from "floating" out of the embedment.

Buoyancy also reduced the Buckling resistance of flexible pipelines.

4. CONSTRUCTION CONSIDERATIONS

4.1 General

According to SABS 0102, Part 1-1987, Code of Practice for the Selection of Pipes for Buried Pipelines, Part I. General Provisions

"The two extremes of loading on a buried pipe are uniform hydrostatic loading and concentrated loading (two-edge bearing).

The former results in uniform thrust (compression or tension) in the pipe wall while the latter results in thrust, bending moments and shear in the pipe wall.

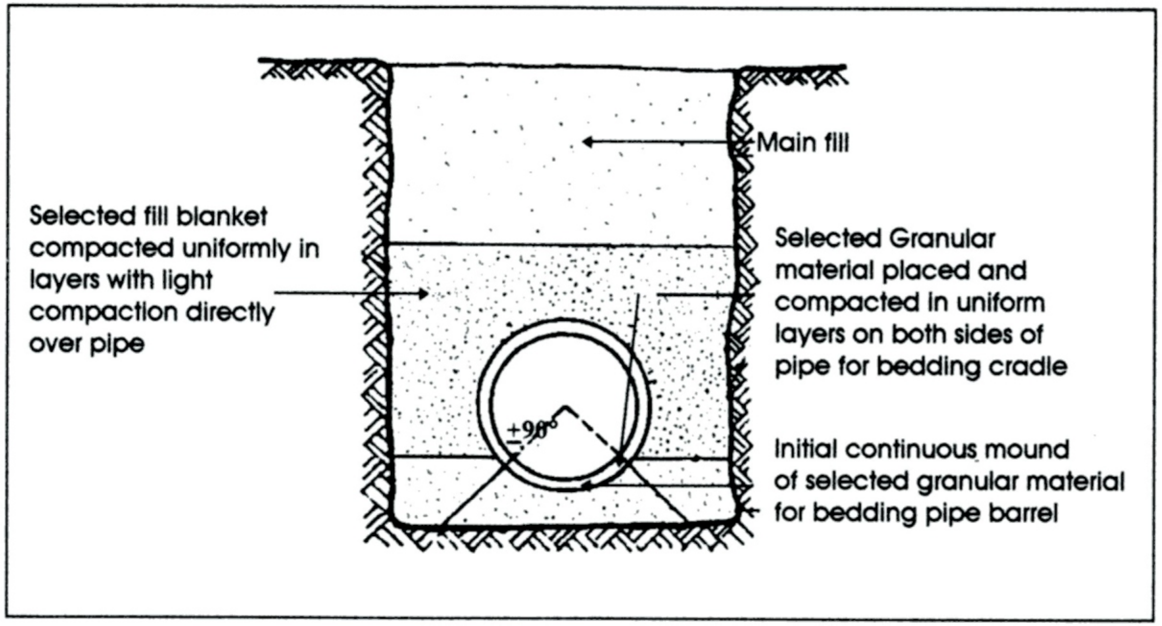
The objective of the installation procedure is to reduce the load concentrations on the pipe and to achieve a load distribution as close to hydrostatic loading as possible.

It is imperative that the designer ensures that the installation procedures used during construction do not compromise the design assumptions. This is especially applicable when the design allows for the development of lateral pressures and arching in the soil around the pipe", which is always the case for flexible pipelines.

(Note: ***The latter condition is an absolute requirement for all pipelines using flexible pipe while only being applicable to the highest class of bedding for rigid pipes used for pipes under high fills.)***

		RIGID PIPE	FLEXIBLE PIPE
4.2	**Storage of pipe on site**	Only the normal requirements relating to safety, protection of pipe integrity and ease of handling are important.	Additional requirements are contained in SABS 0112-1971 (Reaffirmed 1992) - Code of Practice for the Installation of Polyethylene and unplasticised Polyvinyl Chloride Pipes. • Pipes in storage should be adequately supported at all times. • Pipes should not be stacked in large piles, especially under warm conditions; the lower pipes in the stack may become distorted with consequent difficulty in jointing. • Pipes in storage should be protected from sunlight. • Pipes of different diameters should not be nested, one inside the other, when stacked.
4.3	**Minimum Trench Width**	Trenches to be excavated and prepared in accordance with SABS 1200 DB which allows for sufficient width, but no greater than necessary, to ensure working room to properly and safely place and compact haunching and other embedment materials and subject to the stability of the trench walls.	An additional requirement of extra width and/or depth is dependent on the size and stiffness of the pipe, stiffness of the embedment material and in-situ soil, and depth of cover to ensure that the load transferred by the pipe-soil interaction from the embedment material to the in-situ material can be adequately supported by the in-situ material in the trench side wall and foundation.
4.4	**Laying and Joining of Pipe**	Lay and join pipe in accordance with the Manufacturers' recommendations.	Additional aspects requiring consideration: Experience has shown that some difficulty could be experienced when joining larger diameter flexible pipe due to the differences in stiffness between the joint and the pipe barrel as well as variations in deformations due to thermal effects at manufacturing and/or during storage on site.

	RIGID PIPE	FLEXIBLE PIPE
4.5 Placing and compacting of embedment material	Embedment material shall be placed in layers and compacted in accordance with the particular requirements of the specified class of bedding.	According to SABS 1200 LB-1983, Bedding (Pipes) Clause 5.3:



(b) Class C Bedding

SABS 0102 Bedding Factor = 1,5

"In addition to complying with the applicable requirements of 5.1, the Contractor shall construct bedding for flexible pipes in accordance with the following requirements:

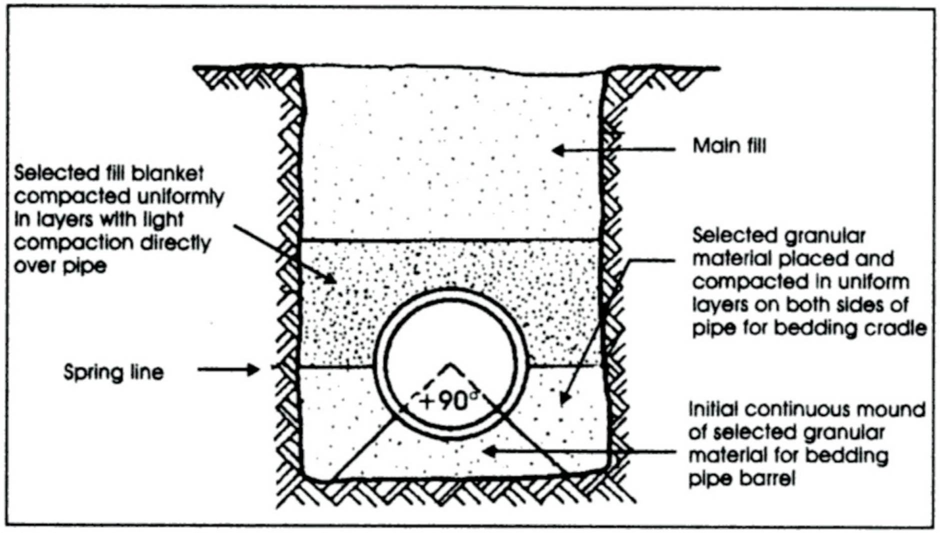
a) Bedding Cradle

Flexible pipes shall be supported on a continuous bed of selected granular material of compacted depth at least 100mm and covering the full width of the trench. The granular material shall be compacted to the density specified in 5.1.4." (That is 90% Mod AASHTO).

"Additional selected granular material shall then be placed carefully and evenly between the sides of the trench and the pipeline, in layers of uncompacted thickness, approximately 100mm as shown on Drawing LB-2 and in accordance with the construction details shown for flexible pies on Drawing LB-3(d).

Each layer shall be compacted individually to the density specified in 5.1.4" (i.e., 90% Med. AASHTO) "Particular care shall be exercised to prevent damage, deflection or displacement of the pipeline".

RIGID PIPE



(c) Class B Bedding
SABS 0102 Bedding Factor = 2,0

In both America and Australia, new installation technology with respect to concrete pipe has been developed over the last 20 years with investigation and research into the behaviour of concrete pipe in the buried condition.

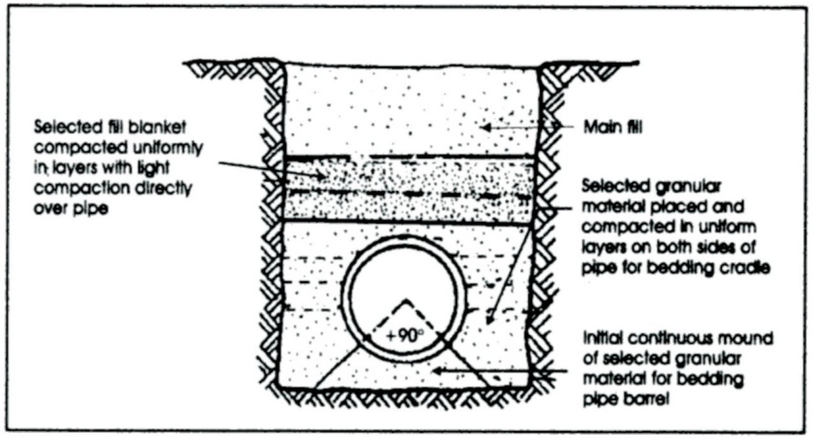
A number of Standard Installation conditions have been defined with measurable and verifiable soil types and compaction levels for the materials used in the installation.

These Standard Installations represent the first major change in recommended installation and bedding factors for

FLEXIBLE PIPE

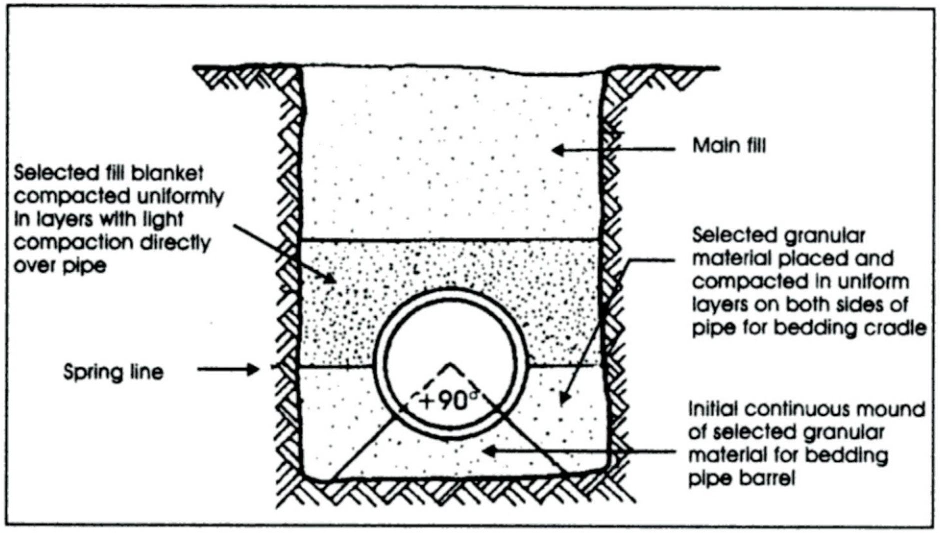
"b **200mm Selected fill blanket**

After completion of the bedding cradle, selected fill blanket shall be placed carefully in layers of 100mm uncompacted thickness over the full width of the trench and shall be compacted to the density specified in 5.1.4" (i.e., 90% Mod AASHTO) up to a height of at least 300mm above the top of the pipeline. Special care shall be taken when compacting over the pipeline."



(d) Flexible Pipe Supported on Selected Granular Material

RIGID PIPE



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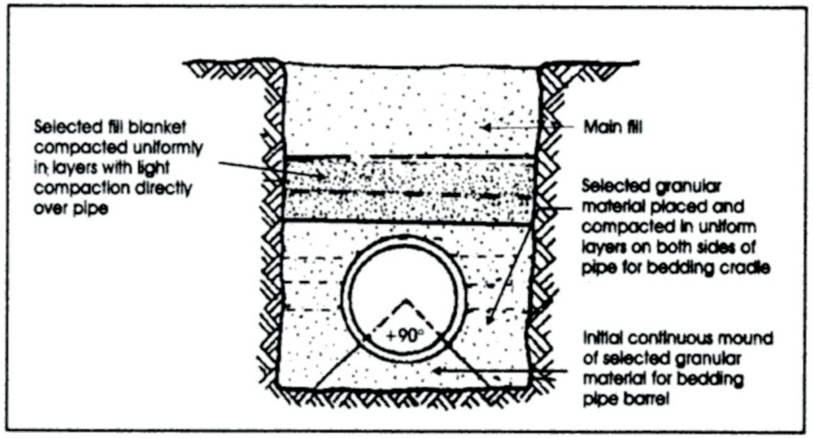


(d) Flexible Pipe Supported on Selected Granular Material

RIGID PIPE

concrete pipe for over 70 years.

The new installations recognise the difficulty in obtaining good compaction in the haunch area below the pipe and assume poorly compacted material in this zone. However, the new installations recognise improved backfilling procedures, compaction methods and the introduction of modern testing equipment which provide engineers the opportunity of using these new state-of-the-art installations which are more cost effective.

The four broad categories of installation go from the lowest sophistication of minimal requirements for soil type and compaction level, to the highest quality requiring selected granular material to be well compacted.

The design associated with the standard installations, is founded on conservatism and yet much improved bedding factors of up to 4 have been achieved.

This new installation technology will need to be implemented in South Africa to ensure cost effective design and construction of concrete pipelines in the future.

FLEXIBLE PIPE

c) Other Considerations

- According to SABS 0112-1971 (Reaffirmed 1992) Code of Practice for the Installation of Polyethylene and Unplasticised Polyvinyl Chloride Pipes, Clause 6 "Careless backfilling, on the other hand, can easily result in collapse of the pipe. Thin-walled pipes of large diameter are likely to buckle and collapse even though the backfilling is carefully carried out. Such pipes should not be used for underground lines".

- American Standards recommend a maximum diameter of 900mm for Polyethylene Pipe and 750mm for Polyvinyl Chloride Pipe. They also recommend that no heavy earth moving or compaction equipment be permitted over the pipeline structure, which include the full pipe-soil embedment up to 300mm above the pipe, until a minimum of 1200mm of carefully placed and compacted fill has been placed over the top of the pipe-soil embedment structure. (i.e., a minimum of 1500mm above top of pipe).

A further additional requirement which depends on the in-situ soil conditions, is lining the trench and enclosing the entire pipe-soil embedment structure with geotextile to prevent the migration of fines from the in-situ soil into the granular embedment material which could cause loss of soil support for the pipe-soil envelope and thus lead to subsequent further deflection and possible collapse of the pipe.

	RIGID PIPE	FLEXIBLE PIPE
4.6 Contractor and Supervising Engineer Quality Control Requirements	• After initial laying and jointing an inspection must be carried out to ensure adequate jointing and sealing. • Occasional visual inspections of the pipeline for cracking is recommended. • Regular penetrometer tests are required to monitor the degree of strength and compaction of embedment material up to the springline of the pipe.	• After initial laying, jointing and inspection, regular monitoring is required to ensure that differential distortion during embedment and backfilling does not compromise the integrity of the joints. • Regular monitoring of the vertical and horizontal pipe deflections is required to ensure that excessive distortion does not occur as a result of the placing and compacting of the various embedment and backfill layers. • Regular penetrometer tests are required to monitor the degree of strength and compaction of the embedment material to 300mm above the top of the pipe.
4.7 Inspection Requirements after completion of construction	The pipeline is to be visually inspected to check the crack widths of any cracks that might have developed in the concrete pipes relative to the SABS requirements.	According to the newly released (August 18, 1994) requirements of the Texas Department of Transport, USA "Pipe deflections shall be measured after the final backfill has been in place at least thirty (30) days. Any pipe that fails to meet the 5% deflection limitation shall be removed and replaced by the Contractor at no additional cost to the Client".

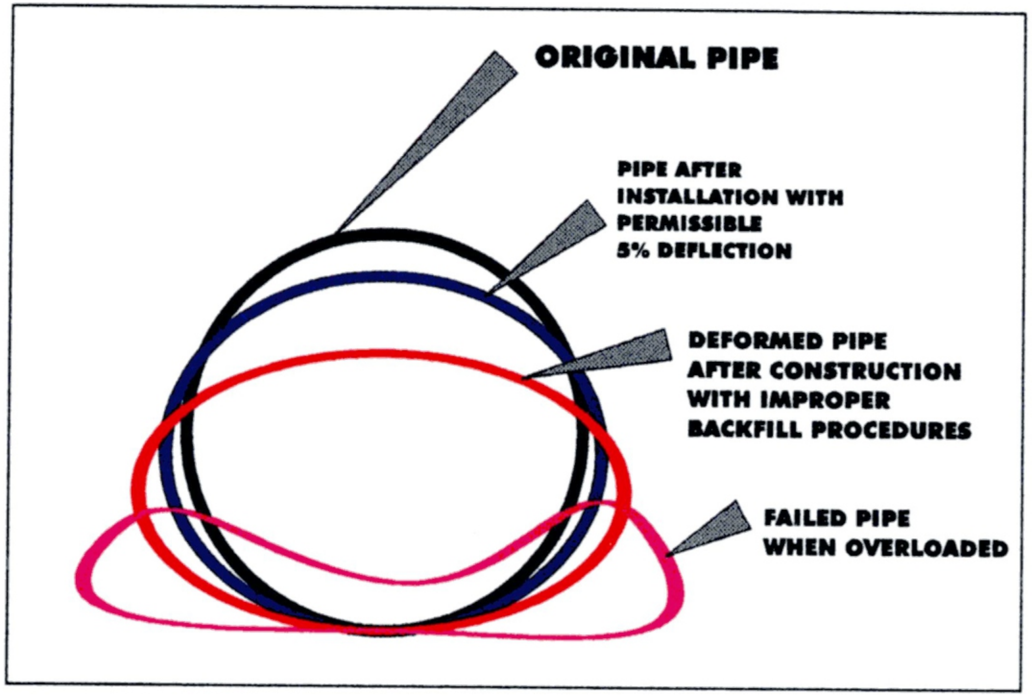


FIGURE 2
Failure/Deflection of a Flexible Pipe from Vertical Loads

FLEXIBLE PIPE

The prescribed minimum monitoring requirement during and after completion of construction are as follows:

Measurements shall be observed and recorded at 3m intervals along the length of the pipeline when the pipe is initially installed and at various stages; when the pipe is backfilled to the springline of the pipe, top of the pipe and at 300mm intervals from the top of the pipe until the backfill is complete, including at 30 days after completing of backfilling.

These measurements shall include:

a) The inside diameter of the pipe, about it's horizontal axis.

b) The inside diameter of the pipe, about it's vertical axis.

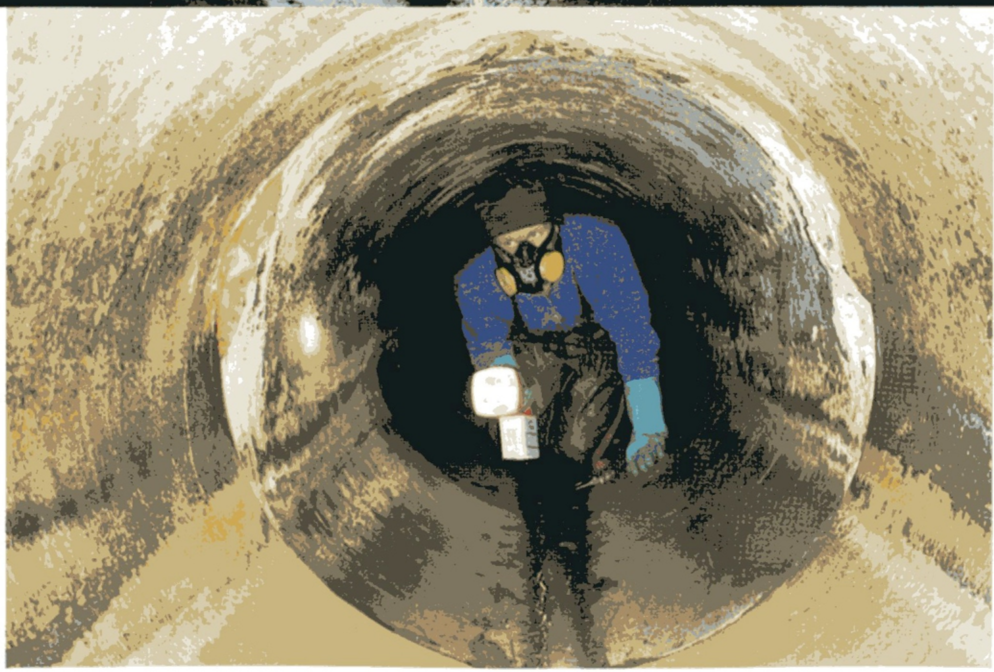
c) Horizontal alignment of the pipe and vertical alignment of the pipe by using a stringline or by any other suitable method.

After the pipe has been installed, the installation shall be inspected again at 6 months and 12 months after completion of construction, and further at the Engineer's discretion.

During all these inspections a), b) and c) shall be measured and recorded.

The dimensions of the pipe prior to installation shall be compared with measurements made during inspections.

In addition, during all the above-mentioned inspections, all joints shall be checked for leaks and structural defects, if any are present in the pipe, they shall be noted.


	RIGID PIPE	FLEXIBLE PIPE
5. OPERATIONAL CONSIDERATIONS		
5.1 Excavation for future works near to pipeline	Pipelines constructed of Rigid Precast Reinforced Concrete Pipe to SABS specifications rely essentially on the strength of the pipe for its lateral stability so that it is unlikely to suffer damage if soil is disturbed around it due to future works requiring excavations in close proximity to it.	Pipelines constructed of Flexible Pipe of various stiffnesses depend on constant soil stability and strength all around the pipe - soil embedment zone to retain its shape and integrity which could be lost should future works requiring excavations be carried out in close proximity to it.
5.2 Cleaning and Maintenance of flow passage of pipeline	Pipelines constructed of Rigid Precast Reinforced Concrete Pipe to SABS Specifications have a constant internal shape and size as well as a rugged abrasion resistant surface and are therefore unlikely to present problems when using the equipment normally used for cleaning, unblocking and desilting pipelines.	Pipelines constructed of Flexible Pipe will have a varying shape profile which will complicate the use of the equipment normally used for cleaning, unblocking and desilting pipelines. A further complication is that the surfaces are vulnerable to tearing and scraping by the equipment.

5.3 Fire Hazards

The incidence of fire in stormwater and sewer pipelines, and pipe storage areas, is not as uncommon as one may assume.

Pipelines and pipe in storage areas are vulnerable to fires caused by oil, petrol and other inflammable spills, bushfires and, regrettably, fires lit by vandals.

To evaluate the performance of various pipe materials under fire, the American Concrete Pipe and Sewer Pipelines Association contracted with the Hardwood Plywood Manufacturers Association (HPMA) to test pipe samples in accordance with accepted standards in their laboratories. This laboratory regularly performs a wide range of fire tests designed to rate different building materials for susceptibility to flamespread, smoke generation and toxicity. The flamespread and smoke density factor are obtained by comparison to those for asbestos-cement board, rated at 0, and red oak flooring, rated at 100.

Standard stock pipe for culvert and sewer use was selected in accordance with ASTM and AASHTO standards. 24 feet long (7,3m) samples of eight different pipe materials were tested. The results are as follows:

RIGID PIPE

Reinforced Concrete Pipe:

There was no ignition or smoke generation of the concrete during the test. Upon completion of the test and removal from the tunnel, it was observed that the first four foot (1,2m) section of pipe was slightly darkened and had a network of surface checking on the inside surface as a result of rapid heating. The remaining 20 feet (6,1m) of pipe appeared sound and no checking or spalling was apparent.

Concrete pipes subjected to severe heat and fire, photographed several weeks after the fire.

5.3 Fire Hazards (continue)

Collapsed sections of road formation following fire in HDPE pipeline

Surface collapse as a result of fire

FLEXIBLE PIPE

Corrugated Steel Pipe with Asphalt Lining and Coating:

The asphalt on this material proved to be highly flammable, producing a flamespread value of 80 and a smoke density of 860. The asphalt lining and coating melted and dripped to the tunnel floor and burned long after the gas burners were shut down. All of the asphalt was consumed and the pipe sagged about six inches (150mm) in the first section.

Corrugated Steel Pipe with Polymeric Lining and Coating

The lining on this sample, a PVC formulation, ignited just 17 seconds into the test and produced a flamespread value of 35 and a smoke density factor of 580. The lining was consumed for 14 feet and scorched the remaining ten feet.

Corrugated Aluminium Pipe

There was no ignition of the aluminium during the test, but smoke was observed, resulting in a smoke density factor of 35. The first section of pipe sagged, and several areas melted within three feet of the flame source.

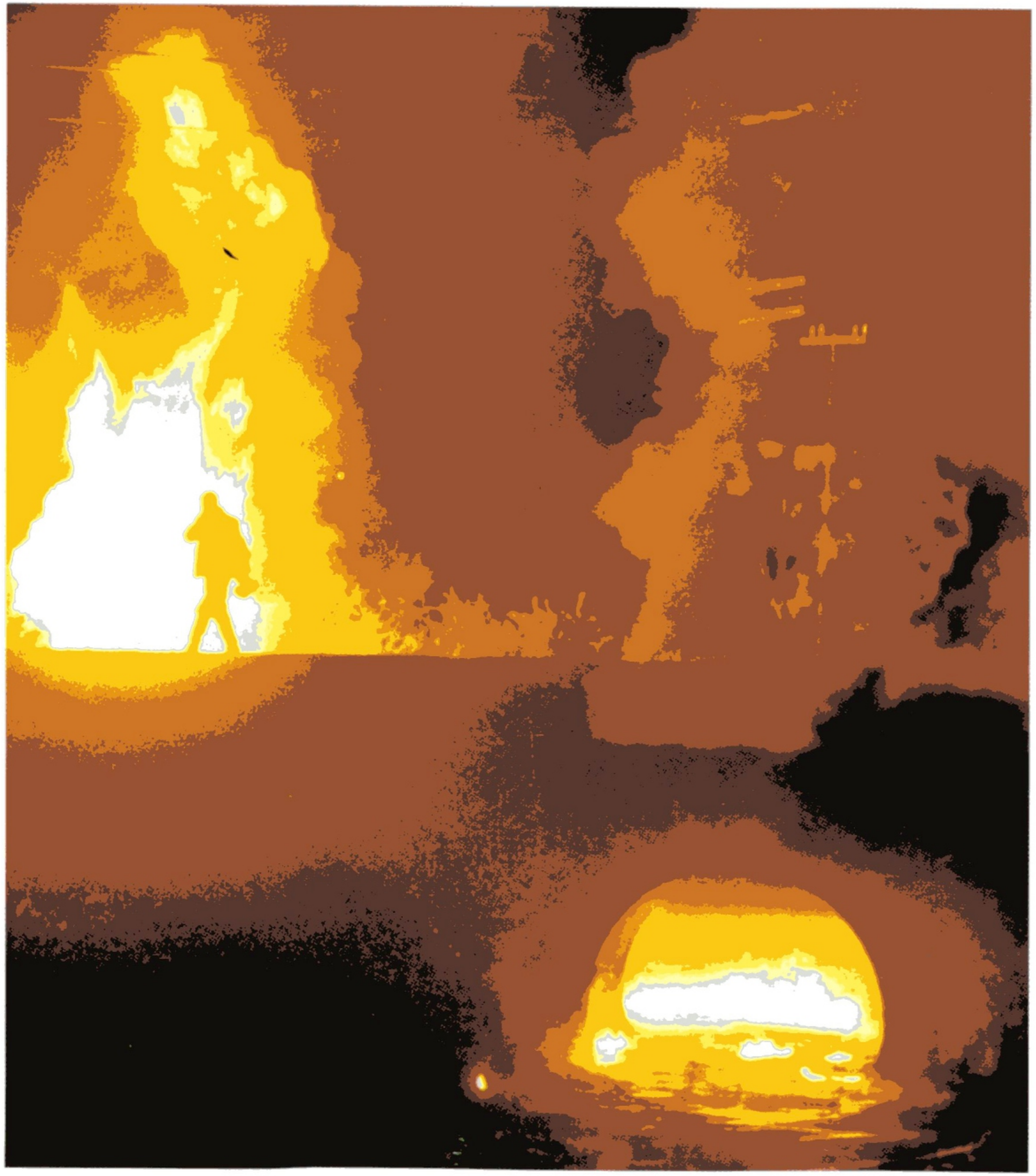
Ribbed PVC Sewer Pipe

The PVC ignited in 52 seconds and produced a flamespread value of ten and a smoke density factor of ten. After two minutes under flame, the sample was sagging to the tunnel floor in one area, and, at five minutes, the entire section had collapsed.

PVC Sewer Pipe

The solid wall PVC burned differently from the ribbed PVC in that it ignited more quickly and produced much more smoke. Flamespread and smoke density values were 20 and 330, respectively. This sample also collapsed to the floor after two minutes and ten seconds.

5.3 Fire Hazards (continue)



FLEXIBLE PIPE

ABS Composite Pipe

This pipe material burned rapidly and totally, leaving little more than the lightweight concrete filler after the test was completed. The high flamespread value of 260 is attributable to the tremendous duel capacity of the ABS in this sample. Smoke density was also substantial at 435.

Ribbed Polyethylene Pipe

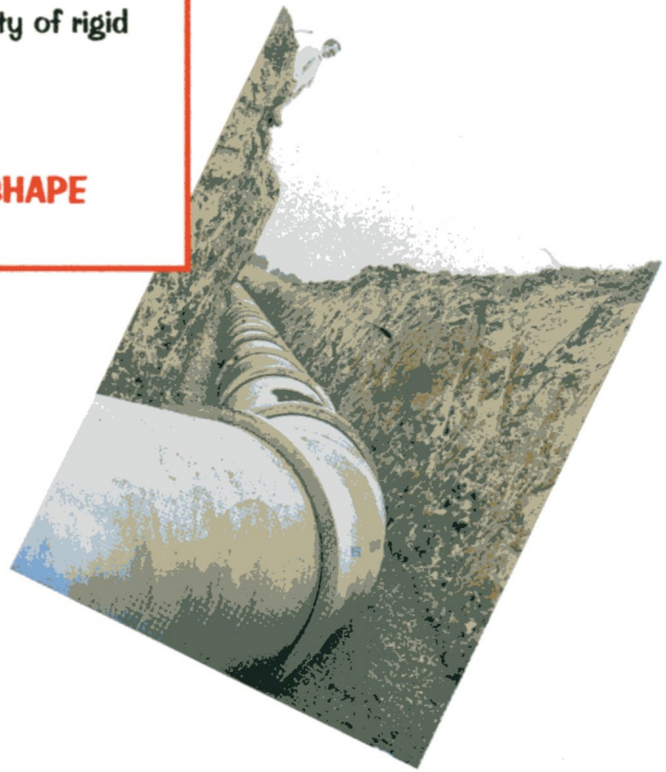
The polyethylene pipe sample was consumed totally during the tunnel test, generating a flamespread of 60 and a smoke density factor of 820. The sample lost strength and sagged to the tunnel floor where it burned long after the gas jets were closed down.

CLOSURE

Concrete pipe has an inherent structural rigidity and a proven record of performance that goes back more than 100 years. When you are specifying pipe, why take chances with flexibility ?

Significantly reduce your risk factors with the proven reliability of rigid concrete pipe.

TRUST CONCRETE PIPE
IT IS FAR MORE FORGIVING AND IT STAYS IN SHAPE



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