WATER SERVICES
ASSOCIATION OF AUSTRALIA

LITERATURE REVIEW AND GAP ANALYSIS

Renovation techniques applicable to water reticulation and sewer pipes

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RENOVATION TECHNIQUES APPLICABLE TO WATER RETICULATION AND SEWER PIPES - LITERATURE REVIEW INCLUDING GLOBAL INDUSTRY STANDARDS AND GAP ANALYSIS

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EXECUTIVE SUMMARY

According to the Scope of the Standards Drafting project (V3), the objective is to initially identify gaps in the current literature relating to CIPP, spray lining, CAC and geopolymers. This exercise is to form the basis of laboratory testing required for preparation of standards and product specifications. The standards to contain industry agreed performance requirements and testing regimes and are intended to enable the water utilities to use the lining products with confidence and ultimately allow WSAA to undertake product appraisals. Ultimately it is expected performance classification standards for the Renovation of both Water reticulation and Sewer pipes will be developed, each covering the whole process of pipeline rehabilitation.
The process includes, in order of sequence:

- condition assessment of the original pipeline;
- setting requirements for the new pipeline and design aspects;
- classification and selection of the type of renovation;
- application of renovation technique; and
- testing requirements.

In parallel to drafting the performance standards, the Standards Drafting project, requires four Product specifications to be drafted for:

- Water: Cured In Place Pipe (CIPP) structural lining;
- Water: Spray lining;
- Sewer: Calcium Aluminate Cements (CAC) lining; and
- Sewer: Geopolymer lining.

This literature review has been undertaken to find standards and specifications that would provide input for the sequential process steps for the two envisaged performance standards, focusing in particular on the four lining techniques, as appropriate.

The most comprehensive international standards addressing water and sewer pipeline renovation have been published by the International Standards Organisation (ISO) complemented by European Standards (EN) published by the European Committee for Standardisation (CEN).

The series of ISO Standards cover generic definitions, classifications of pipeline rehabilitation techniques and their application. In addition, within ISO, product standards for a wide range of pipeline renovation techniques have been published, amongst others addressing a number of renovation techniques using polymeric materials, but of those pertinent to this review, only CIPP has been completed and only for sewer and drainage applications, not drinking water. Ultimately this series is expected to address all techniques utilising plastics materials. For example, work has commenced on a CIPP document for water applications but this is in the very early stages of development and a final document is not expected to be available for at least twelve months. Documents covering polymeric spray linings have not yet been commenced at ISO. Additionally, ISO has commenced to address conformity and this could form part of a suite of documents for the Australian water industry.

Relevant CEN standards have been published on, for example, the condition assessment of existing pipelines (in particular on sewer pipes) and the design, selection and application of renovation techniques.

It is recommended that the definitions and terminology expressed in the suite of ISO Standards be adopted by the Australian water industry. This has already been done by the plumbing industry in

AS/NZS 3500.2. The use of common terminology will ultimately minimise the risk of confusion at tendering and application stages. This is particularly important given pipeline renovation products tend to be developed and promoted internationally.

Furthermore there would be an advantage in the documents being structured in such a manner that allows easy integration of other renovation methods in the future. Finally, it might be considered an advantage to use language and document structure that is consistent with that of Standards Australia in order to facilitate future conversion of ISO standards to national Standards/Specifications.

Several national organisations have published documents on pipeline renovation. ASTM has published four Standards addressing CIPP, each using a slightly different approach and they appear to be largely product specific. ASTM has also published a Standard for spray lining water pipes.

It is also recommended that a hierarchy of documents be established in a similar manner to ISO, rather than a set of completely individual documents as per ASTM. An example of such a hierarchy has been included with this report.

The UK water industry has published a number of Specifications (WIS) and Information and Guidance Notes (IGN) on, amongst others, spray lining of non-man entry sewers and water pipes and CIPP of sewers. At present CIPP is not approved for potable water applications in the UK but a related product, melt-in-place pipe[1] (MIPP) by Aqualiner has DWI approval and NFS61 approvals. The structure of the UK water industry documents is such that an IGN is informative and supports a WIS document that is written in mandatory terms specifying the outcomes that must be achieved.

Several South Korean & German Standards and Specifications have been published dealing with CIPP for both sewer and potable water pipes but appear not to be available in English.

NOTE 1: A significant number of Standards relating to CIPP and spray lining have been identified along with technical papers and presentations. Whilst many apply explicitly to sewer pipes, the principles are also applicable to renovation of water pipes. The main differences being that for water, besides the drinking water approval, the long-term hoop strength is of primary interest whilst ring stiffness is the major mechanical property for sewer drains. Compliance with AS/NZS 4020 is clearly required for materials used for renovation of water pipes in Australia.

NOTE 2: In the case of calcium aluminate cements and geopolymers renovation of pipes, no national or international standards have been discovered. Most of the literature available appears to be proprietary or are of a general technical nature, rather than specific to sewer pipe or sewer structure rehabilitation. Additionally, some utility documents have been published, for example Sydney Water Product Specifications 208 (Rehabilitation and Corrosion Protection of Sewers using Calcium Aluminate Cement Mortar) and 212 (Rehabilitation and Corrosion Protection of Sewers using Geopolymer Concrete). Such documents are not necessarily in the public domain.

In addition to this Report, three literature lists have been prepared and presented in the form of spread sheets. The first list covers Standards, Specifications and Codes of Practice (including the ones listed in the References section of this report) categorised according to their application. The list includes a category of Standards, specifications and codes that address the techniques of interest but not in combination with the specific applications being addressed in this project. The second listing categorises the references according to the issuing authority. The third list documents relevant

[1] A feature of a cured-in-place pipe, as defined in ISO and ASTM Standards, is the product comprises a flexible tube impregnated with a thermosetting resin (which undergoes a chemical reaction in situ). Melt-in-place-pipe (MIPP) also uses an impregnated flexible tube but the thermoplastic polymer is melted by hot air after insertion, forming a solid liner on re-cooling. The MIPP relining process does not involve any chemical reaction. Despite the differences in material characteristics (thermoset mixture compared to thermoplastic) CIPP and MIPP share a number of features, especially with respect to host pipe condition assessment and preparation.

technical papers, conference presentations and proprietary information.

Mr W. Elzink of The Netherlands and Mr M. Shepherd of the UK collaborated in the literature review.

1. INTRODUCTION

The undersigned has been engaged by Water Services Association of Australia and CRC-P Program Manager to initially undertake a literature review of existing standards and specifications that would provide input for the planned performance classification standards for the renovation of both water pipes and sewer structures.

The performance classification standards should cover the whole process of pipeline rehabilitation, in order of sequence:

- condition assessment of the original pipeline or structure;
- setting requirements for the new pipeline/structure and design aspects;
- classification and selection of the type of renovation;
- application of renovation technique; and
- testing requirements.

The CRC-P Program also covers the drafting of four Product Specifications for specific lining techniques and this should be taken into account in the literature review, where applicable.

- Water: Cured-In-Place Pipe (CIPP) structural lining;
- Water: Spray-lining;
- Sewer: Calcium-Aluminate-Cement lining; and
- Sewer: Geopolymer lining.

It is noted that CIPP products can be fully structural or semi structural depending upon the design., Other lining techniques available to the market, such as lining with continuous pipes (slip lining), close-fit pipes (using site-reduced or factory-reduced pipes) and spirally-wound pipes, are excluded from this review.

This document sets out the relevance of the international standards for the different process steps to be covered in the Performance classification standards.

Mr W Elzink of the Netherlands has participated to this review. Mr Elzink, formerly of Wavin and now a consultant, has been an active participant in subcommittee ISO TC138 SC8, responsible for developing Standards on the rehabilitation of pipeline systems. In particular, Mr Elzink is the convenor of WG 6 Assessment of conformity of plastics piping systems used for rehabilitation and WG 1 Classification and Design.

Mr M. Shepherd, formerly of Thames Water and now a consultant to the UK water industry has also contributed. He too is active in the ISO subcommittee and convenor of WG 3 Renovation of water supply networks.

The author has had a long involvement in the Australian plastics pipes industry. This includes membership of several Australian Standards committees and chairmanship of PL021 together with participation in number of ISO TC138 subcommittees and working groups.

The literature references are presented in Clause 5 of this Report.

2. STANDARDS ON LINING OF PIPELINES

Nationally and internationally quite some work has already been done on the process of pipeline renovation. The background of the organisations and the relevance of the work in this respect is presented in general in the following sub clauses. Detailed considerations of some documents are given in Clause 3.

2.1. Standards Australia / Australian Building Codes Board

Standards Australia is the country's leading independent, non-governmental, not-for-profit standards organisation, producing voluntary standards setting out specifications, procedures and guidelines, for amongst others water utilities.

Regarding the current focus on pipeline rehabilitation, no Australian standards exist yet, but AS/NZS 4020, "Testing of products for use in contact with drinking water" is relevant. It specifies requirements for the suitability of products, with regard to their effect on the quality of water, including amongst others materials used in coating and lining.
Furthermore AS/NZS 3500.2, "Plumbing and drainage - Part 2: Sanitary plumbing and drainage" contains rehabilitation information, although it covers a different field of application from that addressed in this report. That is, AS/NZS 3500 addresses applications within the property boundary rather than infrastructure.

The Australian Building Codes Board (ABCB) is responsible for the National Construction Code, (NCC) on behalf of the States and Territories. Volume Three of the NCC comprises the "Plumbing Code of Australia" (PCA), providing national consistency on technical solutions for plumbing and drainage designs and installations.

At a state level, different initiatives are ongoing regarding specifications on pipeline and infrastructure rehabilitation options. As an example, Sydney Water made available their document SS 210 "Corrosion Protection and Rehabilitation of Maintenance Holes" and SS 208 "Rehabilitation and Corrosion Protection of Sewers using Calcium Aluminate Cement Mortar".

2.2. ISO

ISO, the International Organization for Standardization, is a worldwide federation of national standards bodies (ISO member bodies), developing voluntary standards and promoting their use in 162 countries. ISO has its headquarters in Geneva, Switzerland.
The work of preparing International Standards is normally carried out through ISO technical committees, which have to respect strict directives set to ensure full independency. Developing a new ISO standard is only possible when supported by a 2/3 majority of participating countries, sufficient international contribution and compliance with a formal set of rules. Also, it is not possible to create an ISO standard for an individual product or company. ISO Standards specify a set of requirements that apply to a range of products from different suppliers.

Standardising products used for the rehabilitation of existing pipelines has been addressed since 1989. The ISO task committee ISO/TC 138, "Plastics pipes, fittings and valves for the transport of fluids", has established a dedicated sub-committee ISO/TC 138/SC 8, "Rehabilitation of pipeline systems". To date, a general guidance standard, ISO 11295, as well as a set of 18 additional standards on the subject of pipeline rehabilitation have been completed.

Under the banner of ISO/TC138, work is restricted to plastics pipe solutions for rehabilitation, and therefore cement mortar spraying for example, is not within its scope of activities. Nevertheless, the terminology/definitions and classification of the different techniques can be utilised across all rehabilitation processes. This necessitates the establishment of requirements and test methods essential for the product characteristics of the different techniques. The three most important categorizations addressed by ISO/TC 138/SC 8, explained in further detail below are:

- Grouping in Technique Families;
- Recognition of an “M”-stage (manufactured) and an “I”-stage (installation) of products used for rehabilitation; and
- Making distinction between independent and interactive pressure pipe liners.

2.3. ASTM / AWWA / ANSI

ASTM, originating from ‘American Society for Testing and Materials’, develops voluntary technical standards for a wide range of materials and products. The standards are primarily meant for application in the United States, and may be adopted by individual states and authorities in other countries in their regulations. Headquartered in Philadelphia, PA, USA.

Contrary to the work in ISO, membership in the organization is open to anyone with an interest in its activities. Upon request of one of the members new standards drafting work may be initiated via a task committee. Hence, for example this may be done for a particular type of pipeline rehabilitation product/technique, as long as there is also interest from end users.

ASTM Standard Practices addressing material properties and installation recommendations for pipeline rehabilitation have been produced since the early 1990s, generally via its Subcommittee F17.67 on Trenchless Plastics Pipeline Technology. As such, multiple specifications exist for lining water mains with CIPP e.g. ASTM F1216, F1743, F2019, and spray lining e.g. ASTM D3182. ASTM F1216 includes non-mandatory design considerations that are referenced in ASTM F1743 and F2019, but no design considerations are provided in ASTM D3182.

AWWA, American Water Works Association, deals with water quality and supply. AWWA members largely come from water utilities, manufacturers and environmental and health associations. It has over 40 sections in the USA and some abroad. The organisation develops industry standards for products, processes and best water supply practices, for different types of pipeline for water distribution.

For pipeline rehabilitation, AWWA developed its Manual AWWA M28 ‘Rehabilitation of Water Mains’, which provides guidance on selecting rehabilitation techniques for water distribution systems, covering amongst others, cured-in-place lining techniques. In addition AWWA has produced specifications for, spray lining and cement-mortar lining.

ANSI, American National Standards Institute, provides accreditation to over 200 standards developers in the United States, when complying with their essential requirements for a proper development process. Relevant to rehabilitation of water pipelines is a standard developed by NSF: NSF/ANSI 61 ‘Drinking water system components – Health effects’.

2.4. CEN

CEN, the European Committee for Standardization, officially recognised as a European standards body by the European Union, is an association that joins the National Standardization Bodies of 34 European countries. The National Standardization Bodies (e.g. BSI, DIN) are the Members of CEN.

In task committees they develop and define voluntary European Standards (ENs) in response to specific needs that have been identified by businesses and other users of standards.

Even although published ENs are voluntary, each National Standardization Body that is part of the CEN system is obliged to adopt each European standard as a national standard and make it available to customers in their country. They also have to withdraw any existing national standard that conflicts with the new European Standard. So, once an EN is adopted, it automatically becomes the national standard in all 34 countries covered by CEN Members. As such, an EN prevents any cross-border conflicts regarding technical barriers of products complying with the same requirements.

The CEN task committee CEN/TC 155, “Plastics piping systems and ducting systems”, established in 1992 a dedicated working group CEN/TC 155/WG 17, “Rehabilitation of pipeline systems”, taking over the respective work from ISO/TC 138, until 2004 when the ISO working group was reinstated again. By this time CEN/TC 155/WG 17 had seen 9 of their standards for pipeline rehabilitation published as ENs. Since then, work has been carried out in close cooperation with ISO/TC 138/SC 8, who has the lead. In parallel with voting in ISO, voting in CEN took place on all the standards now developed and published, leading to the same set of 19 pipeline rehabilitation standards as prepared by ISO, but published as EN ISO.

Next, the CEN task committee CEN/TC 165, “Wastewater engineering”, generally dealing with functional requirements, has two working groups with (in part) work in pipeline rehabilitation: CEN/TC 165/WG 13 “Renovation and repair of drains and sewers”, and CEN/TC 165/WG “Drain and sewer systems outside buildings”. From these, standards have been published on the performance assessment and design associated with the rehabilitation of sewers.

2.5. Water UK / DWI

In the UK, the original British Standards addressing pipeline rehabilitation have all been replaced by BS ENs.

Water UK provides in addition Water Industry Specifications (WISs) for products for which there is no suitable standard. Water UK also provides Information & Guidance Notes (IGNs). Both have proven to give good guidance, in particular on application and testing aspects. Finally, Water UK also published their “Principles of Water Supply Hygiene”, focussing on maintaining water supply quality based around the proactive management of risk and a holistic approach to drinking water safety. This document and the associated Technical Guidance Notes (TGNs) are generally incorporated into internal operational procedures of the UK Water companies.

The Drinking Water Inspectorate (DWI) exercises governmental powers and duties in relation to regulation of drinking water quality. On the DWI website a ‘List of approved products for use in public water supply in the United Kingdom’ is presented and regularly updated.

2.6. DIN / UBA / DVGW

In Germany, like in the UK, European standards are applicable and are published as DIN ENs. Where possible these have replaced the former DIN standards. Some DIN standards are still operative, but only where no relevant ENs exist. Regarding pipeline rehabilitation this concerns DIN 18319, Part C covering the general technical specifications in trenchless pipelaying contracts.

The German Federal Ministry for the Environment (UBA) has published a guideline for hygienic assessment of organic coatings in contact with drinking water.

Furthermore, the German water industry is heavily regulated with DVGW (German Association of Gas Water products) specifications. Like the ISO standards, the DVGW documents describe in detail the essential product characteristics and their test methods, but additionally provides the rules for the assessment of conformity (sampling, frequency of testing, etc.). Most DVGW documents are only available in German language although some also may be in English.

3. CONTENT OF STANDARDS

3.1. General

3.1.1. Terminology

In **ISO 11295**, "Classification and information on design and applications of plastics piping systems used for renovation and replacement", the generic terms rehabilitation, renovation, etc. have been defined. See the next sub clause for the specific definitions. These terms and their definitions have been adopted throughout all the respective ISO and CEN standards and the use of common terminology helps avoid confusion in tender specifications for example.

By way of illustration, according to ISO TC138 methods such as lining with cured-in-place pipes, lining with adhesive-backed hoses, lining with close-fit pipes etc. are classified as renovation techniques. Replacement 'on the line' techniques include pipe bursting, pipe eating and pipe extraction. Horizontal directional drilling would be considered to be replacement 'off the line'. Both renovation and replacement are subsets of the term 'rehabilitation'.

It is noted that the International (ISO) terminology is already used in Australia in AS/NZS 3500.2. It is considered there are long-term benefits in adopting ISO classification and terminology.

3.1.2. Definitions

3.1.2.1. rehabilitation
measures for restoring or upgrading the performance of existing pipeline systems, including *renovation* (3.1.2.2), *repair* (3.1.2.3) and *replacement* (3.1.2.4)

3.1.2.2. renovation
work incorporating all or part of the original fabric of the pipeline, by means of which its current performance is improved

3.1.2.3. repair
rectification of local damage

3.1.2.4. replacement
construction of a new pipeline, on or off the line of an existing pipeline, where the function of the new pipeline system incorporates that of the old

3.1.2.5. maintenance
routine work undertaken to ensure the continuing performance of an asset

3.2. Condition assessment of the existing pipeline

In general the performance condition of an existing pipeline is important for both the users and the responsible pipeline owner. The condition should be in accordance with the functional requirements set at the original design and construction of the pipeline.

With a properly managed pipeline network, the system owner handles an operations and maintenance system, where maintenance includes continuous performance condition assessment through adequate records and regular analyses.

Properly assessing the performance deficiencies is a crucial part of the development of a plan for pipeline rehabilitation.

ISO 11295, clause 8.2, provides significant general information and indicates methods for determining the condition. These differ in some respects for pressure applications and non-pressure applications and as a function of material, section size and shape.

3.2.1. Condition of water supply pipelines

Assessment of structural condition should be undertaken by non-destructive methods, which typically vary according to pipe material, and/or by extraction and evaluation of pipe samples. Assessment of geometric characteristics, where applicable, may be made by profiling or gauge pigging. For water supply pipelines, the quantity of any leakage detected should be assessed where this is a factor in rehabilitation design.

ISO 24512, "Guidelines for the management of drinking water utilities and for the assessment of drinking water services", provides numerous guidelines for the management of drinking water utilities and for objectives, service assessment criteria and related performance indicators, appropriate for the assessment of drinking water services.

Further recommendations for operations and maintenance of water supply pipelines are given in **EN 805**, "Water supply – Requirements for systems and components outside buildings". Clause 14 contains information on inspection and monitoring, which shall be executed to minimize disruptions of water supply and to identify malfunctions or leakages in pipes. It shall include flow and pressure measurements, levels of service and public health effects

EN 15975-2 "Security of drinking water supply - Risk management " supports water suppliers to actively address safety issues in the context of routine water supply management and operations:

- Risk analyses: to estimate the likelihood of a hazard occurring and consequences of the hazard;
- Risk evaluation: compare and prioritise risks regarding their estimated effect on the system's integrity.

Complimentary to (BS) EN 15975-2, Water UK has published WIS 4-01-04, "Risk assessment and management", providing details of UK practice in relation to its Water Safety Plan (WSP) and a robust approach to ensure that all water company risk assessments can be used as a basis to justify a risk based approach. The risk analysis scores each risk individually to allow categorisation and prioritization for action: Risk = Likelihood x Consequence

Useful information on the condition evaluation of water mains is also provided in AWWA M28, "Rehabilitation of Water mains", following methods for guidance on pipe rehabilitation:

- Leak/break performance. For example, the occurrence of only a few problems may indicate a non-structural lining is sufficient.
- Sample extraction/evaluation (estimating remaining life on samples).
- In-situ testing (non-destructive detection of weak spots, e.g. with acoustic detection methods).

3.2.2. Condition of wastewater discharge pipelines

Best practice for operations and maintenance of wastewater pipelines is presented in detail in **EN 752**, "Drain and sewer systems…", particularly in Clause 11. It provides recommendations on data collection and storage of records of inspections and any incidents such as blockages, collapses,

flooding incidents and rising main failures.

Visual inspection in the form of a high-definition colour close-circuit television (CCTV) survey is generally the first method to assess the condition of a wastewater pipe. In addition, profiling equipment may be used in small sewers or manual access in large mains.

The European Standard **EN 13508**, "Condition of drain and sewer systems...", provides information on establishing the condition of drain and sewer systems by inspection, status codification, consideration of external factors, etc. It is applicable to drain and sewer systems, which operate essentially under gravity, from the point where the sewage leaves a building or roof drainage system, or enters a road gully, to the point where it is discharged into a treatment works or receiving water.
Part 1 of EN 13508 specifies general requirements.

Part 2 contains a detailed coding system (160 pages) for the internal condition of drains, sewers, manholes and inspection chambers identified through visual inspection. It can also be used for pressure systems. By using the system the results from visual inspections can be objectively recorded. The system comprises a series of codes that shall be used to describe the defects and features found in wastewater networks. Colour photographs showing examples of some observations are included to illustrate the used of the coding systems.

For the pipes, as well as for the manholes/chambers/shafts, a distinction is made related to the condition of the structure (e.g. deformation, cracks, collapses, surface damage, hanging sealing material and displace joints) and codes related to the operation (e.g. root intrusion, encrustation, deposits and water ingress).

WSAA also publishes Conduit Inspection Reporting Code of Australia. The Code was primarily based on two documents, EN 13508-2 and the superseded Australian Conduit Condition Evaluation Manual (ACCEM). It is used a reference document for inspection and condition assessment of wastewater pipes and structures by WSAA members.

3.3. Requirements and design of the new pipeline

ISO 11295, "Classification and information on design...", provides information on the principles of, the design of systems used for pipeline rehabilitation, covering:

- existing pipeline and site conditions;
- functions of the new pipeline;
- structural and hydraulic performance; and
- installation aspects and other factors affecting technique selection.

It does not give the detailed methodologies for design.

Regarding structural performance, ISO 11295 states, amongst other things, that loads acting on a liner and the associated response of the lining system are not generally comparable with those of a pipe buried directly in soil by open excavation, because:

- the lining pipe is installed without disturbing the existing pipe-soil structure; and
- the lining systems response to internal pressure as well as external loads can be either positively or negatively influenced by the presence of the existing pipeline, which cannot be ignored, even if it is severely deteriorated.

Regarding hydraulic performance, ISO 11295 mentions that determining the capacity needed is a key factor in the selection of the most economic rehabilitation technique. The required capacity fixes the minimum internal dimensions of the installed pipeline system.

3.3.1. Requirements and Design of water supply pipelines

EN 805, "Water supply systems – Requirements…", specifies amongst others requirements for the design and construction of water supply systems, including the rehabilitation of existing systems. It provides a detailed consideration of hydraulic design aspects (using Colebrook/White's theory), as well as structural design aspects. Furthermore, it includes general requirements for product standards.

DVGW W 400-1, "Technical rules for water supply systems – Part 1: Design"', is valid for newly installed systems as well as systems to be rehabilitated. It incorporates all relevant requirements in EN 805 and on water quality the national legal requirement TrinkwV is applicable. Stagnation of flow (velocity < 0.005 m/s) shall be prevented to avoid sliming and colorization of the water. With a minimum velocity of 0.3 m/s sliming is negligible.

- Low velocities shall generally be ≤ 2.0 m/s to limit dynamic pressure changes. In distribution lines and service pipes ≤ 2.5 m/s. Pressure variations shall be limited to 2 bar.
- Design pressure (MDP) shall be ≥ 10 bar. Operational pressure (without surge; DP) ~MDP – 2 bar.
- Pressures at the tap should be at least 1 bar, but, 0.5 bar is permitted.
- At the main-service pipe connection the pressure (SP): ≥ 2.0 bar + 0.35 per floor of the dwelling.

AWWA M28, "Rehabilitation of Water Mains", addresses in Ch.1 hydraulic and structural improvement. In Ch. 2, detailed practical recommendations and requirements are given related to preconstruction activities and advance planning considerations.

3.3.2. Requirements and Design of wastewater discharge pipelines

EN 752, "Drain and sewer systems outside buildings", sets out the objectives for drain and sewer systems (like public health and environmental protection) and specifies the functional requirements for achieving these objectives. It also provides principles for strategic and policy activities relating to planning, design, installation, operation, maintenance and rehabilitation. The standard gives detailed guidance on the rehabilitation process, starting with producing a plan to fulfil the performance requirements.

Detailed design considerations include hydraulic design and environmental aspects.

EN 13380, "General requirements for components used for sewer rehabilitation", specifies general requirements and general test methods for:

- components such as pipes and fittings with their respective joints, manholes/chambers; and
- materials such as mortar and chemicals intended to be used for sewer rehabilitation.

Amongst others things the Standard states that components after installation shall withstand without leakage an internal hydrostatic pressure test from 0 kPa rising to 50 kPa.

Regarding the structural design of liners, a uniformly applicable and adopted calculation method does not exist.
Generally, when a sewer requires rehabilitation it is assumed that the existing pipe has no residual strength. In that case, a liner is required that can perform independently from the existing pipe, in other words, does not need the support of the existing pipe. Liners consisting of flexible material, shall then

have sufficient stiffness and liners consisting of rigid material, shall have sufficient crushing strength to withstand external loading. However, where the existing pipe is still structurally sound, the liner does not have to take the full external loads.

The condition of the existing pipe is crucial for structural design considerations. Unfortunately, a generally adopted structural design approach does not appear to have been established in any international standard.

In the UK, the **WRc Sewerage Rehabilitation Manual** provides guidance on the whole pipeline rehabilitation process, including the structural assessment of the existing pipeline. Regarding the liner design, the old pipe condition is considered the dominating factor. Amongst others aspects, distinctions are made between partially deteriorated condition (less than 10% diameter distortion) and fully deteriorated (badly deformed) condition of the existing sewer.

In the USA, **ASTM F1216**, "… Rehabilitation by the Inversion and Curing of a Resin-Impregnated Tube", also distinction is made between partially and fully deteriorated pipe, described as follows:

> "Partially deteriorated pipe: the original pipe can support the soil and surcharge loads throughout the design life of the rehabilitated pipe. The soil adjacent to the existing pipe must provide adequate side support. The pipe may have longitudinal cracks and up to 10.0% distortion of the diameter".

"Fully Deteriorated Pipe: the original pipe is not structurally sound and cannot support soil and live loads or is expected to reach this condition over the design life of the rehabilitated pipe. This condition is evident when sections of the original pipe are missing, the pipe has lost its original shape, or the pipe has corroded due to the effects of the fluid, atmosphere, soil, or applied load."

In Germany, regulation **DWA-A 143-2**, "Renovation of sewers- structural design", recognises three different structural modes of the old pipe:

- Condition I – old pipe that is structurally sound with leaks, but with no cracks.
- Condition II – is applied to a stable pipe-soil structure with longitudinal cracks and minor deformation.
- Condition III – is described as having an unstable pipe-soil structure, clear deformation and cracks along with active soil and traffic loads.

For a liner inside, the two most critical liner load cases are:

- Ground water pressure, possibly causing buckling of the liner.
- Earth and traffic loads, possibly causing material failure of the liner.

DWA-A 143-2 includes a detailed calculation method, taking into account all possible influencing factors, such as condition of the existing pipe, the liner dimensions, the amount of annular gap between old and new, etc.

Within CEN, activities have just started to try and come to an internationally accepted technical standard for structural design of liners, perhaps to include FEM (finite element method) calculations to be considered for e.g. large diameter CIPP pipelines, but the outcome is still well into the future.

3.4. Classification and selection of lining techniques

3.4.1. Technique Families

In order to be able to set requirements for certain types of techniques, ISO and CEN adopted the term 'Technique Family', defined in **ISO 11295**, "Classification and information on design...", with groupings of renovation or trenchless replacement techniques considered to have common characteristics for standardization purposes.

Even although ISO 11295 deals primarily with techniques making use of plastics pipes, the split in technique families can have wider application. Figure 1 of ISO 11295 illustrates the split in renovation and trenchless replacement technique families. According to ISO 11295, the term 'rehabilitation' covers repair, renovation and replacement. Renovation in turn includes a range of techniques such as lining with continuous pipes, close-fit pipes, cured-in-place pipes, discrete pipes, adhesive backed hoses, spirally wound pipes, pipe segments, rigidly anchored plastics inner lining, sprayed polymeric materials and inserted hoses. For information, it is noted ISO 11295 breaks replacement methods into either trenchless or open-trench techniques.

Other pipeline rehabilitation Technique Families, in particular for wastewater pipelines, have been classified by **EN 15885**, "Classification and characteristics of techniques for rehabilitation of drains and sewers". An additional renovation technique family 'Lining with sprayed, trowelled or cast-in place material' is recognised and dealt with.

Both ISO 11295 and EN 15885 describe the various technique families and provide schematic diagrams to illustrate the principles and specific features of the respective family. Examples of lining with cured-in-place pipes (CIPP) are schematically represented in ISO 11295 Figure 5 (installation by inversion) and Figure 6 (installation by winching and subsequent inflation). Figure 16 of ISO 11295 is a schematic representation of the application of a polymeric spray lining.

3.4.2. Lining/Liner stage

The approach taken by CEN and ISO is to provide the tools (standards) to demonstrate and assure the long-term quality of the liners.
Drafting system standards for products for renovation of existing pipelines brought along one complexity: many products in their manufactured state undergo a change in shape and/or composition during installation.
It could be stated that the products as supplied by the manufacturer are half-products only, whilst the user is only interested in proof of functionality of the product after installation.

3.4.2.1. "M" & "I"

This complication was tackled in the (EN) ISO renovation product standards, **ISO 11296, -97, -98**, by considering the lining system at two distinct stages as follows:

- "M" stage – stage as manufactured, before any subsequent site processing of components associated with the particular renovation technique;
- "I" stage – stage as installed, i.e. in final configuration after any site processing of components associated with the particular renovation technique.

3.4.2.2. lining pipe

pipe inserted for renovation purposes

3.4.2.3. liner

lining pipe after installation

3.4.2.4. actual and simulated testing

Following this, the ISO System Standards for renovation of existing pipelines are distinguished from those for conventionally installed piping systems by setting requirements for certain characteristics in the as-installed condition, after site processing. This is in addition to specifying requirements for system components as manufactured.

To verify conformity of a liner to "I" stage requirements, testing can be done on a representative sample taken either from the actual installation or from a simulated installation. In a simulated installation "as installed" samples are produced under conditions incorporating all relevant circumstances which may affect the end-product characteristics. ISO 11298.1 Figure 3 illustrates the relationship between simulated and actual installation processes.

The feature 'approval of installed products before they even have been installed' is unique in pipeline construction, even with newly installed pipes.

Pipes, fittings and assemblies should preferably be produced by the manufacturer under a quality system (preferably conforming to ISO 9001) which includes a quality plan. Installation should likewise be executed under a quality system that includes site procedures documented in an installation manual.

By using the above procedures, suppliers should be capable demonstrating the viability of the liners installed with their technique and assure the quality of installed product.

3.4.3. Classification of non-pressure liners

For non-pressure applications, **ISO 11295**, "Classification and information on design", declares stiffness as the main structural design criterion for flexible liners. The stiffness required for a particular installation obviously depends upon external loads (including ground water pressure), but also on installation loads and internal loads (including surcharge pressures). Non-structural liners for non-pressure applications may rely on adhesion between the liner and host pipe in order to resist collapse.

EN 13380, "General requirements for components used for renovation and repair of drain and sewer systems" states that components, depending on material characteristic, shall be classified according to their characteristic structural behaviour ("flexible", "rigid" or "semi-rigid").

Where appropriate, product standards then shall state: minimum crushing strengths (kN/m) and/or minimum stiffness values (kN/m²).

3.4.4. Classification of pressure pipe liners

For pressure pipe liners, strength is the main structural design criterion.
Internationally, two classification systems are known.

- In ISO 11295, four pressure pipe liner classes are defined: Class A – D, with Class A being the strongest type of liner.
- In AWWA M28, also four pressure liner classes are defined: Class I – IV, with class IV being the strongest.

Explanations of these classes are given below.

For the purpose of this Report, ISO Class A and AWWA Class IV are considered equivalent. Similarly Class B and Class III, Class C and Class II and Class D and Class 1 are essentially equivalent.

ISO 11295 Class A structural pipe liners for pressure applications are defined as being able to survive internally or externally induced (burst, bending or shear) failure of the host pipe, have a long-term pressure rating greater than or equal to the maximum allowable operating pressure (PFA), adequate inherent ring stiffness, long-term hole and gap spanning at PFA and provide an internal barrier layer. Class B liners are required to have sufficient ring stiffness to be self-supporting in the event of depressurisation, have long-term hole and gap spanning capability and provide an internal barrier layer. Class C liners rely on adhesion to the host pipe in order to be self-supporting in the event of depressurisation, have long-term hole and gap spanning capability and provide an internal barrier layer. The ISO classification system for pressure pipes is presented comprehensively in Table 16 of ISO 11295.

Classes B and C are considered to be semi-structural in accordance with ISO 11295.

The ISO 11295 structural classifications for pressure pipes commensurate with the various plastics / polymeric products are presented in Table 17 of ISO 11295. For example, CIPP products may be either Class A, B or C. Sprayed polymeric linings are generally Class B.

According to **AWWA M28**, Class IV (i.e. ISO Class A) structural criteria, the liner material must have the ability to essentially replace the host pipe in the event of structural failure of the host pipe. If the host pipe fractures, a Class IV spray lining must separate from the host pipe whilst having sufficient structural strength to function independently under load and working pressures. Class IV liners are required to have a 50 year burst strength equal to or greater than the working pressure when tested independently of the host pipe.

AWWA Class II and II linings “are both interactive and semi-structural systems. When installed, the liners closely fit the host pipes, and any remaining annulus is rapidly eliminated when internal operating pressure expands the lining”. Stresses due to the internal pressure are transferred to the host pipe. Such linings are required to sustain the internal pressure loads at discontinuities in the host pipes or if the host pipe suffers structural failure. A Class II or III liner does not exhibit a 50-year burst stress at working pressure independent of the host. Class II liners have minimal inherent ring stiffness and depend upon adhesion to the pipe wall to prevent collapse if the pipe is depressurised. Class III liners are at least self-supporting if depressurised.

AWWA Class 1 linings “are essentially non-structural systems used to protect the inner surface of the host pipe from corrosion. They have no effect on the structural performance of the host pipe and have minimal ability to bridge any existing continuities. According to AWWA M28 examples of Class 1 linings include cement mortar lining and epoxy linings”.

3.4.5. Selection criteria

After having set the requirements for the new pipe, the pre-selection of the techniques that are suitable can made, by taking account of the following issues, the importance of each depending on the particular pipeline being dealt with:

1. Does the technique provide required operational performance?
2. What are the technical capabilities?
3. How does the installation impact the environment: social life, traffic, local commerce?

To enable independent quality assurance, the international standardisation organisation, ISO, in conjunction with the European standards organisation, CEN, has developed standards for pipe line renovation techniques, for pressure and non-pressure applications (ISO 11296, 11297, 11298).

The approach taken in these international standards is to provide the tools (requirements and test methods) to demonstrate and assure the long-term quality of the liners.

Finally, from the pre-selected techniques and the offers on response to the tender documents, the most cost-effective solutions can be taken.

3.5. Application of lining techniques

3.5.1. Australian specifications

For approval for drinking water applications, the following standard shall be complied with: **AS/NZS 4020**, "Testing of products for use in contact with drinking water".

Relevant for spray lining is:
AS/NZS 1516, "The cement mortar lining of pipelines in situ".

Regarding the use of geopolymers, some **Austroads** specifications provide useful information:
AP-R531-16, AP-T318-16, AP-T329-17, ABC-SAS203-14

3.5.2. ISO product standards

For the Technique Families, as set out in clause 3.4.1,
ISO TC138 SC8 has developed a suite of pipeline rehabilitation Standards, amongst others:

- **ISO 11296-1**, -2, -3, -4, -7 for renovation of non-pressure wastewater pipelines;
- **ISO 11297-1**, -2, -3, -4 for renovation of pressurised wastewater pipelines;
- **ISO 11298-1**, -2, -3, -4 for renovation of pressurised water supply pipelines.

These are listed in Clause 5, along with other referenced Standards and specifications.

> NOTE 1: Of the range of lining techniques addressed by SC8 to date, only CIPP and sprayed polymeric linings are included in the current CRC project. For information, the other renovation techniques currently addressed by SC8 or expected to be addressed in the future are lining with continuous pipes, close-fit pipes, discrete pipes, pipe segments, adhesive-backed hoses, spirally-wound pipes, rigidly-anchored plastics inner lining and inserted hoses.

In the ISO renovation standards, part 1 is providing general information applicable to all technique families. Parts 2, 3, etc. prescribe for a specific technique family the requirements and test methods of essential characteristics to be validated.
As an example, ISO 11297.1 is a general part that builds on ISO 11295 in regards to pressurised wastewater pipes. The requirements are essentially qualitative. For example, in Clause 8.2 General characteristics it is stated "The installed lining system shall meet a water pressure test to ensure the integrity of pipes, joints and fittings and other components, such as anchor blocks and the fitness for purpose requirements in the technique-related parts of ISO 11297, as applicable". The Standard does not describe how this is to be achieved.

ISO 11297.4 then addresses CIPP renovation for pressurised wastewater pipes and nominates relevant short and long-term mechanical characteristics and appropriate test methods and specifies the minimum value for the characteristic such as initial ring stiffness, short-term and long-term flexural modulus, long-term failure pressure etc. The value for the characteristic ultimately selected by the end use can be substantially higher as this is dependent upon a number of factors relating to the specific technique/product, host pipe and service conditions. ISO 11297-4 also provides installation requirements and recommendations, e.g. on reconnections to the existing pipeline system.

The suite of standards is not yet complete. In some cases a Standard has been published for a technique applied in one application class but has yet to be finalised for another application class. For example,

ISO 11297.4 has been published for CIPP renovation of sewer pipes under pressure but ISO 11298.4 has not been published for CIPP renovation of drinking water pipes. When published ISO 11298.4 is expected to be similar.

The suite of ISO Standards makes reference to spray lining with polymeric materials but only at a very high level in ISO 11295. Part 10 of each of the various network system Standards has been allocated to spray lining. However, Part 10 has not yet been published for any application, including water supply. The suite of ISO Standards does not address the non-polymeric techniques of calcium aluminate cements or geopolymers that have been nominated for sewer renovations.

In ISO/TC 138/SC 8 work has started on the development of a limited series of technical specifications on the assessment of conformity for the whole suite of rehabilitation standards.

For Australia, technical specifications per technique family that would probably also have to include more detailed technique related information regarding condition assessment of the host pipe, materials handling and conformity assessment.

3.5.3. USA specifications and guidance

As mentioned in clause 2.3, ASTM specifications have been developed for pipeline rehabilitation. Relevant in this context are the following:

For CIPP lining:

- **ASTM D5813**, “Standard Specification for Cured-In-Place Thermosetting Resin Sewer Piping Systems”;
- **ASTM F1216**, “Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube”;
- **ASTM F1743**, “Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Cured-in-Place Thermosetting Resin Pipe (CIPP)”;
- **ASTM F2019**, “Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Glass Reinforced Plastic (GRP) Cured-in-Place Thermosetting Resin Pipe (CIPP); and
- **ASTM F2994**, “Standard Practice for Utilization of Mobile, Automated Cured-in-Place Pipe (CIPP) Impregnation Systems”.

Other ASTM Standards and publications include:

- **ASTM F3182, “**Standard Practice for the Application of Spray-Applied Polymeric Liners Inside Pipelines for Potable Water”;
- **ASTM F2414**, “Standard Practice for Sealing Sewer Manholes Using Chemical Grouting
- **ASTM C 1138M**, “Standard Test Method for Abrasion Resistance of Concrete (Underwater Method)”; and
- **ASTM STP1566**, “Standard Test Method for Abrasion Resistance of Concrete (Underwater Method)”.

In addition, AWWA has published with respect to the context of this study, the following:

- **AWWA M28**, “Rehabilitation of Water mains”, in which different technique families are described;
- **AWWA C20/07**, “Spray-applied in-place Epoxy lining of water pipelines, 3in. (75 mm) and larger”;
- **AWWA C104/A.21.4**, “Cement-Mortar Lining for Ductile-Iron Pipe and Fittings”;

- **AWWA C620-07**, “Spray-applied in-place Epoxy lining of water pipelines, 3 In. (75 mm) and larger”; and
- **AWWA C651**, “Disinfecting Water Mains”.

For US approval for drinking water applications, the following specification shall be complied with:

- **NSF/ANSI 61** ‘Drinking water system components – Health effects’.

3.5.4. EN specifications and guidance

All ISO standards, as mentioned under 3.5.2, were developed in cooperation with CEN, and are published as EN ISO standards with the same content:

- **EN ISO 11295, EN ISO 11296-1, -2, -3, -4, -7;**
- **EN ISO 11297-1, -2, -3, -4;**
- **EN ISO 11298-1, -2, -3.**

However, even although these EN ISOs still have a voluntary character, it is not permitted for the CEN member countries (like UK, GE, FR) to maintain in parallel national standards dealing with the same subject. In addition, the following European standards provide relevant information on product and technique requirements:

- **EN 752, “**Drain and sewer systems outside buildings”;
- **EN 805**, “Water supply - Requirements for systems and components outside buildings”,
- **EN 1717**, Protection against pollution of potable water installations and general requirements of devices to prevent pollution by backflow”;
- **EN 12889**, “Trenchless construction and testing of drains and sewers”;
- **EN 13380**, “General requirements for components used for renovation and repair of drain and sewer systems outside buildings”;
- **EN 14647**, “Calcium aluminate cement - Composition, specifications and conformity criteria”;
- **EN 14654-**2, “Management and control of operational activities in sewer systems. Rehabilitation”; and
- **EN 16421**, “Influence of materials on water for human consumption - Enhancement of microbial growth (EMG)”.

3.5.5. UK specifications and guidance

The UK Water industry has published documents, complementing the EN/ISO standards:

General documents:

- **TGN 1-16**, “Principles of Water Supply Hygiene and Technical Guidance notes 1-16”;
- **WIS 4-00-02**, “Evaluation of new products and development of specifications”;
- **WIS 4-01-04**, “Specification for the audit of water industry risk assessments and risk management processes”; and
- **WIS 4-01-03**, “Pressure testing of pressure pipes and fittings for use by public water suppliers”.

For spray lining:

- **WIS 4-02-01**, “Operational requirements: In situ resin lining of water mains”. The Specification addresses spray lining of water main. Appendix A of the WIS provides information about the qualification process for certification and re-certification of contractors as required by Water UK;

- **IGN 4-02-02**, “Code of practice: In situ resin lining of water mains”. This is a companion document to WIS 4-02-01 and provides background information and guidance for spray lining schemes;
- **WIS 4-02-03**, “Operational requirements: In situ polymeric lining of service pipes”. This document addresses the lining of small diameter service pipes;
- **WIS 4-02-04**,”Operational requirements: In situ polymeric lining of sewer pipeline”;
- **WIS 4-52-01**, “Specification for polymeric anti-corrosion (barrier) coatings”; and
  IGN 4-02-05, “Code of practice: In situ polymeric lining of sewer pipelines”. Whilst the application of this lining method to sewer pipes is outside the scope of the project the guidance note provides insight into the technique.

Other UK Water Industry Specifications related to the renovation of sewers include:

- W**IS 4-34-05**, “Specification for polyester resin concrete (PRC) sewer linings”;
- **WIS 4-34-04**, “Specification for renovation of gravity sewers by lining with cured-in-place pipes”; and
- **WIS 4-34-06**, “Specification for localised sewer repairs using cured-in-place systems with or without re-rounding”.

In addition, **DWI**, the Drinking Water Inspectorate, has published on-line: “List of approved products for use in public water supply in the United Kingdom”.

Finally, useful information is provided by the **WRc CESWI** (Civil Eng. Spec. for Water Industry)”.

3.5.6. German specifications and guidance

DIN 18319, “German construction contract procedures (VOB) - Part C: General technical specifications in construction contracts (ATV) - Trenchless pipelaying”.

The German Federal Ministry for the Environment (UBA) has published several regulations to which compliance is required. Relevant in the context of this investigation are:

- **UBA CG**, “Guideline for hygienic assessment of organic coatings in contact with drinking water”; and
- **UBA KTW**, “Guideline on the hygienic assessment of organic materials in contact with drinking water”.

As mentioned in clause 2.6, the German water industry is strongly regulated with DVGW (German Association of Gas Water products) providing in addition to EN standards, detailed specifications including rules for the assessment of conformity (sampling, frequency of testing, etc.). Most DVGW documents unfortunately are only are available in German language, this includes amongst others:

- **DVGW GW 325**, “Trenchless installation techniques for gas- and water services - Requirements, quality assurance and testing”; and
- **DVGW W 343**, “Renovation of buried cast iron and steel pipelines by cement mortar lining - application, requirements, quality assurance and test”.

However, some are also in English, for example:

- **DVGW W 101**, “Guidelines on drinking water protection areas - Part 1: Groundwater protection areas”;
- **DVGW W 270**, “Microbial enhancement on materials to come into contact with drinking water - Testing and assessment”; and

- **DVGW W 347**, “Hygiene requirements for cement-bound materials intended for use in drinking water supply systems - Testing and evaluation”.

3.6. Testing requirements

The testing requirements are generally included in the product standards and complimentary national specifications. For example, Table 5 of ISO 11297.4 specifies the performance requirements, test parameters and test methods for liner terminations under positive and negative pressures.

4. GAP ANALYSIS

The previous clauses have demonstrated that there is already a wealth of information available to enable drafting of performance standards for the renovation of water reticulation by both spray lining and CIPP. However, rehabilitation of sewer structures with geopolymers or CAC is not well covered in either national or international Standards, specifications or guidance notes. An exception being the Sydney Water Product Specifications 208 and 212 noted previously.

There appears to be little conflict in the content of the standards/specifications relating to renovation of pipelines, even where these are of different origin.

It is recommended that the uniform terminology in the documents produced by ISO, CEN and the European standards and approval bodies be adopted in Australia.

What is lacking in the available standards/specifications is a uniformly applicable and accepted structural design calculation method for water pipes[2].

The techniques addressed by ISO TC138 SC8 including CIPP, spray lining and various insertion and close-fit solutions are either well documented, or in the process of being documented, albeit not necessarily in the application forming part of this project. On the other hand, formal documentation of pipeline renovation techniques using calcium aluminate cements or geopolymers is non-existent. Nevertheless, the document structure established by TC138 SC8 can equally be applied to these latter techniques.

[2] Renovation of sewer structures by CAC and Geopolymers is mainly directed at deterioration that has occurred above the water line. Structural considerations such as described in ISO 11295 Table 16 for pressure pipe liners do not apply.

5. REFERENCES

AW-2020-70 Standards and Specifications Sorted by Issuing Body

Authority	Document Name	Year	Title
ISO	ISO 11295	2010	Classification and information on design of plastics piping systems used for renovation
ISO	ISO 24512	2007	Activities relating to drinking water and wastewater services -- Guidelines for the management of utilities and water services
ISO	ISO 11296-1	2018	Plastic piping systems for renovation of underground non-pressure drainage and sewerage networks - Part 1 General
ISO	ISO 11296-4	2018	Plastic piping systems for renovation of underground non-pressure drainage and sewerage networks - Part 4 Lining with CIPP
ISO	ISO 11298-1	2018	Plastic piping systems for renovation of underground water supply networks - Part 1 General
ISO	ISO 11297-1	2018	Plastic piping systems for renovation of underground drainage and sewerage networks under pressure - Part 1 General
ISO	ISO 11297-4	2018	Plastic piping systems for renovation of underground drainage and sewerage networks under pressure - Part 4 Lining with CIPP
ASTM	F 1216	2016	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube
ASTM	F 1743	2017	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Thermosetting resin CIPP
ASTM	F2019	2011	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Glass Reinforced CIPP
ASTM	F2994	2018	Standard Practice for Utilization of Mobile, Automated Cured-in-Place Pipe (CIPP) Impregnation Systems
ASTM	F 3182	2016	Standard Practice for the Application of Spray-Applied Polymeric Liners Inside Pipelines for Potable Water
ASTM	C 1138M	2012	Standard Test Method for Abrasion Resistance of Concrete (Underwater Method)
ASTM	STP 1566	2013	Geopolymer Binding Systems
ASTM	F 2414	2016	Standard Practice for Sealing Sewer Manholes Using Chemical Grouting
ASTM	D5813	2012	Standard Specification for Cured-In-Place Thermosetting Resin Sewer Piping Systems
AWWA	M28	2014	Rehabilitation of water mains
AWWA	C620-07	2017	Spray-applied in-place Epoxy lining of water pipelines, 3 In. (75 mm) and larger
AWWA	C651	2014	Disinfecting Water Mains
AWWA	C104/A.21.4	2016	Cement-Mortar Lining for Ductile-Iron Pipe and Fittings
CEN	EN 1717	2011	Protection against pollution of potable water installations and general requirements of devices to prevent pollution by backflow
CEN	EN 15975-2	2013	Security of drinking water supply - Guidelines for risk and crisis management - Part 2: Risk management
CEN	EN 16421	2015	Influence of materials on water for human consumption - Enhancement of microbial growth (EMG)
CEN	EN 805	2010	Water supply - Requirements for systems and components outside buildings
CEN	EN 752	2017	Drain and sewer systems outside buildings - Sewer system management
CEN	EN 12889	2000	Trenchless construction and testing of drains and sewers
CEN	EN 13380	2001	General requirements for components used for renovation and repair of drain and sewer systems outside buildings.
CEN	EN 13508-1	2013	Conditions of drain and sewer systems outside buildings - Part 1: General requirements
CEN	EN 13508-2	2011	Conditions of drain and sewer systems outside buildings - Part 2: Visual inspection coding system
CEN	EN 15885	2016	Classification and characteristics of techniques for renovation, repair and replacement of drains and sewers
CEN	EN 14654-2	2013	Management and control of operational activities in drain and sewer systems outside buildings. Rehabilitation
CEN	EN 14647	2006	Calcium aliminate cement - Composition, specifications and conformity criteria
Water UK	TGN1-16	2017	Principles of Water Suppy Hygiene and Technical Guidance notes 1-16.
Water UK	WIS 4-02-01	2014	Operational requirements: in situ resin lining of water mains
Water UK	IGN 4-02-02	2014	Code of practice: in situ resin lining of water mains
Water UK	WIS 4-34-05	1986	Specification for renovation of gravity sewers by lining with polyester concrete pipes
Water UK	IGN 4-02-05	2018	Code of practice: In situ polymeric lining of sewer pipelines
Water UK	WIS 4-02-04	2018	Operational requirements: In situ polymeric lining of sewer pipeline
Water UK	WIS 4-34-04	2018	Spec. for renovation of gravity sewers by lining with cured-in-place pipes
Water UK	WIS 4-34-06	2010	Specification for localised sewer repairs using cured-in-place systems with or without re-rounding
WRc	CESWI	2011	Civil Engineering specification for the Water Industry 7th Edition
WRc	SRM	2013	Sewerage Rehabilitation Manual
DIN	DIN 18319	2016	German construction contract procedures (VOB) - Part C: General techn. Specif. in construction contracts - Trenchless pipelaying
DIN	DIN 18319 *)	2016	German construction contract procedures - Part C: General technical specifications in construction contracts - Trenchless pipelaying
DVGW	W 101	2006	Guidelines on drinking water protection areas - Part 1: Groundwater protection areas
DVGW	W 270	2007	Microbial enhancement on materials to come into contact with drinking water - Testing and assessment
DVGW	W 400-1	2015	Technical rules for water supply systems - Part 1: Design *(only in german)*
DVGW	W 343	2005	Renovation by cement mortar lining - application, requirements, quality assurance and test *(only in german)*
DVGW	W 347	2006	Hygiene requirements for cement-bound materials intended for use in drinking water supply systems - Testing and evaluation
DVGW	GW 325	2007	Trenchless installation techniques for gas- and water services - Requirements, quality assurance and testing *(only in german)*
DWA	DWA-A 143-2	2015	Renovation of sewers - Structural design *(only in german)*
UBA	KTW	2016	Guideline on the hygienic assessment of organic materials in contact with drinking water (KTW Guideline)
UBA	CG	2016	Guideline for hygienic assessment of organic coatings in contact with drinking water (Coating Guideline)
SA/SNZ	AS/NZS 1516	1994	The cement mortar lining of pipelines in situ
SW	208	2011	Rehabilitation and Corrosion Protection of Sewers using Calcium Aluminate Cement Mortar
SW	SS210	2012	Corrosion Protection and Rehabilitation of Maintenance Holes https://www.sydneywater.com.au/web/groups/publicwebcontent/documents/
SW	2012	2018	Rehabilitation and Corrosion Protection of Sewers using Geopolymer Concrete
Austroads	AP-T318-16	2016	Specification and use of Geoplymer concrete in the manufacture of structural and non-structural components: Review of literature
Austroads	New Item	2016	New Geopolymer concrete guidance
Austroads	AP-T329-17	2017	Specification and use of Geoplymer concrete in the manufacture of structural and non-structural components: Experimental work
Austroads	AP-R531-16	2016	Specification for Geopolymer concrete: General Guide
Austroads	ABC-SAS203-14.	2014	Specification and use of Geopolymer concrete

AW-2020-70 Standards and Specifications Sorted by Application

Application	Liner Material	Characteristic	Authority	Document Name	Year	Title
Water	General	Hygiene	AWWA	C651	2014	Disinfecting Water Mains
			CEN	EN 1717	2011	Protection against pollution of potable water installations and general requirements of devices to prevent pollution by backflow
			CEN	EN 15975-2	2013	Security of drinking water supply - Guidelines for risk and crisis management - Part 2: Risk management
			CEN	EN 16421	2015	Influence of materials on water for human consumption - Enhancement of microbial growth (EMG)
			DVGW	W 101	2006	Guidelines on drinking water protection areas - Part 1: Groundwater protection areas
			DVGW	W 270	2007	Microbial enhancement on materials to come into contact with drinking water - Testing and assessment
			UBA	KTW	2016	Guideline on the hygienic assessment of organic materials in contact with drinking water (KTW Guideline)
			UBA	CG	2016	Guideline for hygienic assessment of organic coatings in contact with drinking water (Coating Guideline)
			Water UK	TGN1-16	2017	Principles of Water Suppy Hygiene and Technical Guidance notes 1-16.
				TGN1	2017	Medical surveillance of personnel
				TGN3	2017	Repair and connection of existing mains
				TGN4	2017	Renovated mains
				TGN5	2017	Temporary overland mains and services
				TGN11	2017	Storage and use of bottled water
				TGN12	2017	Tankers, static tanks and bowsers
				TGN13	2017	Preparation of Chlorine solutions
				TGN14	2017	Disposal of chlorine solutions and chlorinated water
		Classification & Design	AWWA	M28	2014	Rehabilitation of water mains
			CEN	EN 805	2010	Water supply - Requirements for systems and components outside buildings
			DIN	DIN 18319	2016	German construction contract procedures (VOB) - Part C: General technical specifications in construction contracts (ATV) - Trenchless pipelaying
			DVGW	GW 325	2007	Trenchless installation techniques for gas- and water services - Requirements, quality assurance and testing *(only in german)*
			DVGW	W 400-1	2015	Technical rules for water supply systems - Part 1: Design *(only in german)*
			ISO	ISO 11295	2010	Classification and information on design of plastics piping systems used for renovation
			ISO	ISO 24512	2007	Activities relating to drinking water and wastewater services -- Guidelines for the management of drinking water utilities and for the assessment of drinking water services
			WRc	CESWI	2011	Civil Engineering specification for the Water Industry 7th Edition
		Quality criteria	ABCB	NCC Vol.3	2012	National Construction Code - Plumbing Code of Australia (PCA)
			BS	BS 6920-1	2014	Suitability of non-metallic materials and products for use in contact with water intended for human consumption with regard to their effect on the quality of the water. Specification
			DVGW	GW 120	2010	Network documentation in supply companies *(only in german)*
			DVGW	GW301	2011	Companies for the construction, repair and integration of pipelines - Requirements and Tests *(only in german)*
			DVGW	GW302	2001	Qualification criteria for companies for trenchless new installation and rehabilitation of not-operational pipelines *(only in german)*
			DVGW	W290	2017	Disinfection of Drinking Water - Requirements and Conditions of Application
			DWI		2018	List of approved products for use in public water supply in the United Kingdom
			NSF/ANSI	NSF/ANSI 61	2017	Drinking water system components – Health effects
			SA/SNZ	AS/NZS 4020	2018	Testing of products for use in contact with drinking water
			SA/SNZ	AS/NZS 3500.2	2018	Plumbing and drainage - Part 2: Sanitary plumbing and drainage
			Water UK	WIS 4-00-02	2007	Evaluation of new products and development of specifications
			Water UK	WIS 4-01-04	2018	Specification for the audit of water industry risk assessments and risk management processes
			Water UK	IGN 4-01-03	2015	Pressure testing of pressure pipes and fittings for use by public water suppliers
			Water UK	WIS 4-02-03v2	2016	In situ lining of service pipes - operational requirements

AW-2020-70 Standards and Specifications Sorted by Application (continued)

Application	Liner Material	Characteristic	Authority	Document Name	Year	Title
Water	CIPP	Product requirements & Testing	ASTM	F 1216	2016	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube
			ASTM	F 1743	2017	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Cured-in-Place Thermosetting Resin Pipe (CIPP)
			ASTM	F2019	2011	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Glass Reinforced Plastic (GRP) Cured-in-Place Thermosetting Resin Pipe (CIPP)
			ASTM	F2994	2018	Standard Practice for Utilization of Mobile, Automated Cured-in-Place Pipe (CIPP) Impregnation Systems
			AWWA	M28 *)	2014	Rehabilitation of water mains
			ISO	ISO 11296-1	2018	Plastic piping systems for renovation of underground non-pressure drainage and sewerage networks - Part 1 General
			ISO	ISO 11296-4	2018	Plastic piping systems for renovation of underground non-pressure drainage and sewerage networks - Part 4 Lining with Cured-in-place pipes
			ISO	ISO 11298-1	2018	Plastic piping systems for renovation of underground water supply networks - Part 1 General
			ISO	ISO 11297-1	2018	Plastic piping systems for renovation of underground drainage and sewerage networks under pressure - Part 1 General
			ISO	ISO 11297-4	2018	Plastic piping systems for renovation of underground drainage and sewerage networks under pressure - Part 4 Lining with Cured-in-place pipes
	Spray Lining	Product requirements & Testing	ASTM	F 3182	2016	Standard Practice for the Application of Spray-Applied Polymeric Liners Inside Pipelines for Potable Water
			AWWA	C620-07	2017	Spray-applied in-place Epoxy lining of water pipelines, 3 In. (75 mm) and larger
			DVGW	W 343	2005	Renovation of buried cast iron and steel pipelines by cement mortar lining - application, requirements, quality assurance and test *(only in german)*
			DVGW	W 347	2006	Hygiene requirements for cement-bound materials intended for use in drinking water supply systems - Testing and evaluation
			ISO	ISO 11298-1 *)	2018	Plastic piping systems for renovation of underground water supply networks - Part 1 General
			ISO	ISO 11297-1 *)	2018	Plastic piping systems for renovation of underground drainage and sewerage networks under pressure - Part 1 General
			Water UK	WIS 4-02-01	2014	Operational requirements: in situ resin lining of water mains
			Water UK	IGN 4-02-02	2014	Code of practice: in situ resin lining of water mains
Sewers	General	Classification & Design	CEN	EN 752	2017	Drain and sewer systems outside buildings - Sewer system management
			CEN	EN 12889	2000	Trenchless construction and testing of drains and sewers
			CEN	EN 13380	2001	General requirements for components used for renovation and repair of drain and sewer systems outside buildings.
			CEN	EN 13508-1	2013	Conditions of drain and sewer systems outside buildings - Part 1: General requirements
			CEN	EN 13508-2	2011	Conditions of drain and sewer systems outside buildings - Part 2: Visual inspection coding system
			CEN	EN 15885	2016	Classification and characteristics of techniques for renovation, repair and replacement of drains and sewers
			DWA	DWA-A 143-2	2015	Renovation of sewers - Structural design *(only in german)*
			DIN	DIN 18319 *)	2016	German construction contract procedures (VOB) - Part C: General technical specifications in construction contracts (ATV) - Trenchless pipelaying
			ISO	ISO 11295 *)	2010	Classification and information on design of plastics piping systems used for renovation
			WRc	SRM	2013	Sewerage Rehabilitation Manual
		Quality criteria	CEN	EN 14654-2	2013	Management and control of operational activities in drain and sewer systems outside buildings. Rehabilitation
			DVGW	GW301 *)	2011	Companies for the construction, repair and integration of pipelines - Requirements and Tests *(only in german)*
			DVGW	GW302 *)	2001	Qualification criteria for companies for trenchless new installation and rehabilitation of not-operational pipelines *(only in german)*
			Sydney Water	SS210	2012	Corrosion Protection and Rehabilitation of Maintenance Holes https://www.sydneywater.com.au/web/groups/publicwebcontent/documents/
			Water UK	WIS 4-00-02 *)	2007	Evaluation of new products and development of specifications
			Water UK	WIS 4-01-04 *)	2018	Specification for the audit of water industry risk assessments and risk management processes
	CAC Mortar	Product requirements & Testing	ASTM	C 1138M	2012	Standard Test Method for Abrasion Resistance of Concrete (Underwater Method)
			ASTM	STP 1566	2013	Geopolymer Binding Systems
			AWWA	C104/A.21.4	2016	Cement-Mortar Lining for Ductile-Iron Pipe and Fittings
			CEN	EN 14647	2006	Calcium aliminate cement - Composition, specifications and conformity criteria
			SA/SNZ	AS/NZS 1516	1994	The cement mortar lining of pipelines in situ
			SW	208	2011	Rehabilitation and Corrosion Protection of Sewers using Calcium Aluminate Cement Mortar
	Geopolymers		ASTM	F 2414	2016	Standard Practice for Sealing Sewer Manholes Using Chemical Grouting
			SW	212	2018	Rehabilitation and Corrosion Protection of Sewers using Geopolymer Concrete
			Water UK	WIS 4-34-05	1986	Specification for renovation of gravity sewers by lining with polyester concrete pipes

Standards, Specifications and Codes Relating to Combinations of Applications and Methods Outside the Scope of the Current Project.

Application	Liner Material	Authority	Document Name	Year	Title
Sewer	Spray Lining	Water UK	IGN 4-02-05	2018	Code of practice: In situ polymeric lining of sewer pipelines
		Water UK	WIS 4-02-04	2018	Operational requirements: In situ polymeric lining of sewer pipeline
	CIPP	ASTM	D5813	2012	Standard Specification for Cured-In-Place Thermosetting Resin Sewer Piping Systems
		ASTM	F2561	2017	Standard Practice for rehabilitation of a sewer service lateral and its connection to the main using a one piece main and lateral cured-in-place liner
		ASTM	F2599	2016	Standard Practice for the sectional repair of damaged pipe by means of an inverted cured-in-place liner.
		Water UK	WIS 4-34-04	2018	Spec. for renovation of gravity sewers by lining with cured-in-place pipes
		Water UK	WIS 4-34-06	2010	Specification for localised sewer repairs using cured-in-place systems with or without re-rounding
Gas	CIPP	ASTM	F2207	2013	Standard Specification for Cured-in-Place Pipe Lining System for Rehabilitation of Metallic Gas Pipe
Roads	Geo polymers	Austroads	AP-T318-16	2016	Specification and use of Geoploymer concrete in the manufacture of structural and non-structural components: Review of literature
		Austroads	New Item	2016	New Geopolymer concrete guidance
		Austroads	AP-T329-17	2017	Specification and use of Geoploymer concrete in the manufacture of structural and non-structural components: Experimental work
		Austroads	AP-R531-16	2016	Specification for Geopolymer concrete: General Guide
		Austroads	ABC-SAS203-14	2014	Specification and use of Geopolymer concrete

Authority Abbreviations

ASTM	American Society for Testing and Materials
Austroads	Australasian road transport and traffic organisation
AWWA	American Water Works Association
BS	British Standards
CEN	European Committee for Standardization (french: Comité Européen de Normalisation)
DIN	German Institute for Standardization (Deutsches Institut für Normung e.V.)
DVGW	German Association for the Gas and Water Industry (Deutsche Vereinigung des Gas- und Wasserfaches)
DWI	UK Drinking Water Inspectorate
ISO	International Organization for Standardization
SA/SNZ	Standards Australia / Standards New Zealand
SW	Sydney Water
UBA	Federal Ministry for the Environment in Germany (UmweltBundesAmt)
Water UK	organisation representing water and waste water service providers in the UK
WRc plc	UK Water Research company
ABCB	Australian Building Codes Board
DWA	German Association for Water, Waste water and Waste
NSF	US Health and Safety organization

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Application	Liner Material	Author / Company	Publication	Year	Title
General		Chan, D., Shannon, B., Kodikara, J.	Oz Water Conference, Melbourne	2016	Relative importance of external factors on pipe performance
		Downey, D.	Int. No-Dig Conf., Sydney	2013	Water Mains Rehabilitation – Challenges and Opportunities
		Downey, D., Koo, D.	Int. No-Dig Conf., Beijing	2016	Challenges in the rehabilitation of pressure pipe
		Elzink, W.	Trenchless Asia Pacific Conf., Hong Kong	2009	Renovation of Pressure Pipelines – Quality Assurance with ISO standards
		Elzink, W.	No-Dig Down Under Conf., Brisbane	2011	Close-fit lining of pressure pipe lines and the quality assurance after installation
		Elzink, W.	Trenchless Asia Conference, Shanghai	2012	Design considerations when renovating existing pipelines
		Elzink, W.	Trechless International magazine	2014	Rehabilitation standards
		Gumbel, J., Schrock, J., a.o.	American Society of Civil Engineers	2007	Emerging concepts for the design of pipeline renewal systems
		Petersen, R., Melchers, R.	Conf. of the Australasian Corrosion Assoc.	2012	Long-Term corrosion of cast iron cement lined pipes
		Shepherd, M., Headford, A., a.o.	Plastics Pipes XIII, Washington	2006	Development of a whole life costing model for large diameter water mains
		Vitanage, D., Allen, G., Kodikara, J.	mag. Water Asset Managment International	2014	Collaborative research on condition assessment and pipe failure prediction of creitical water mains
		Wells, T., Melchers, R.	Oz Water Conference, Melbourne	2016	Concrete sewer pipe corrosion - Findings from an Australian field study
Water		John, L.	Conf. Water New Zealand	2016	Improving resilience through innovative water main & drainage rehabilitation techniques
		König, H-J.	Trenchless Asia Conference, Hong Kong	2016	Innovative use of UV-cured CIPP: A way forward to conserve the economic sustainability of potable water pipelines
		Salvo, P., di Fruscia, T.	Int. No-Dig Conf., Singapore	2010	Case study - Small diameter CIPP water main in the City of Montreal
		Stetter, N., Sinclair, D., Stokes, M.	Oz Water Conference, Melbourne	2017	Cured-in-place pipe (CIPP) - Rehabilitation of AC water mains
	CIPP	Aarsleff Pipe Technolgies	diverse documents		http://www.aarsleff.com/about-aarsleff/pipe-technologies
		Aqua Pipe	diverse documents		http://www.aqua-pipe.com/
		Insituform Technologies	diverse documents		http://www.aegion.com/about/our-brands/insituform https://www.trenchless-australasia.com/listings/insituform-pacific-pty-limited/
		NordiTube Technologies	diverse documents		https://www.norditube.com/
		Saertex Multicom	diverse documents		http://www.saertex-multicom.de/index.php?lang=en
		AECOM	WSAA UE32 Subscription Project	2019	PRODUCT AND INSTALLATION GUIDANCE DOCUMENT: Fully Structural CIPP Lining Products for Asbestos Cement & Cast Iron Drinking Water Mains (DN100-300mm)
		AECOM	WSAA UE32 Subscription Project	2019	Class A CIPP Lining Products for AC and CI Water Pipes
	Spray Lining	Griffen J.	Underground Construction 61.7 (trade publication)	2006	Polyurea lining offers quick-install, spray-on lining
		Howell, N., de Rosa, J.	Int. No-Dig Conf., Singapore	2010	Resin spray lining - Developments and challenges
		Rajasärkkä, J., Pernica,M., a.o.	mag. Water Research 103	2016	Drinking water contaminants from epoxy resin-coated pipes: A field study
		Robinson I., Brown D., a.o.	Int. No-Dig Conference, Moscow	2008	Semi-structural spray lining: A novel rehabilitation technique for drinking water mains
		Zech, H.	RSV special edition on Cement mortar	2006	Cement mortar coating - General *(in german)*
		Subterra Radius Plus	diverse documents		http://www.radius-plus.co.uk/uploadedfiles/17-1390918118-subcote_flyer1.pdf
		VersaFlex	diverse documents		http://versaflex.com/products/potable-water-systems/aquavers-415-potable-water-spray-polyurea/
		Sagewater	diverse documents		https://sagewater.com/lining-problems/ https://sagewater.com/lining-problems/epoxy-lining/installation-concerns/

AW-2020-70 Technical Papers, Conference Presentations and Proprietory Information (continued)

Application	Liner Material	Author / Company	Publication	Year	Title
Sewer	CAC Mortar	AWMC, Univ.of Queensland	SCORe proj. (Sewer corrosion & odour)	2013	Fact sheet Calcium Aluminate Cement
		Britton, J., Bateman, I.	Trenchless International journal - Fall Issue	2018	Wessex Water Calls in Overseas Utility for Rehabilitation
		Goyns, A.	Inst of Mat. Conf. Calcium Aluminate Cements. Edinburgh	2001	Calcium Aluminate Cement Linings for Cost-Effective Sewers
		Hackett A., Brown J.	Conf. No-dig Downunder, Sydney	2013	A Hard Look at Calcium Aluminate Cement Mortars for Sewer Rehabilitation
		Herrison J., Guegeun-Minerbe M. et al	Materials and Structures (DOI 10.1617/s11527-016-0919-0)	2017	Influence of the binder on the behaviour of mortars exposed to H2S in sewer networks: a long-term durability study
		Saucier F., Herisson J.	Institute of Concrete Technology Yearbook	2015-16	Use of Calcium Aluminate Cements in H_2S Biogenic Environment
		Saucier, F., Lamberet, S.	Conf. Concrete in agressive aqueous environments, Toulouse	2009	Calcium aluminate concrete for sewers: Going from qualitative to quantitative evidence on performance
		Smith, O., Rogers, R.	Conf. Water New Zealand	2016	
		Stein, D., Stein, R.	Unitracc.de (E journal)	2016	Cement mortars https://www.unitracc.de/know-how/fachbuecher/rehabilitation-and-maintenance-of-drains-and-sewers/en/
		Imerys Sewpercoat	diverse documents		http://www.sewpercoat.com/
	Geopolymers	Royer J., Allouche, E.	NASTT No-dig Conference. Paper WM-T6-03	2016	Laboratory testing and analysis of geopolymer pipe-lining technology for rehabilitation of sewer and stormwater conduits
		Royer J., Iseley T.	NASTT No-dig Conference. Paper TM2-T3-04	2017	Laboratory testing and analysis of geopolymer pipe-lining technology for rehabilitation of sewer and stormwater conduits, Part II - CMP Culvert analysis
		Royer J., Koo D.		2015	Comparative analysis of geopolymer technology for sewer system rehabilitation
		Royer, J., Mauro, M., Hepfinger, J.	Conf. Water New Zealand	2014	Advanced Geopolymer Pipe & Structure lining system
		Concrete Institute of Australia	CIA Biennial Conference	2011	Some Limitations of Geopolymer Concrete www.concreteinstitute.com.au/
		Concrete Institute of Australia	CIA Handbook Z16	2011	Geopolymer-Concrete https://www.concreteinstitute.com.au/OnlineStore/Recommended-Practices/Geopolymer-Concrete
		BluCem Geospray	Technical Data Sheet	2017	High performance spray applied Geopolymer
		Hermes Technologie	diverse documents		http://www.hermes-technologie.com/en/rehabilitation-processes/drain-sewer-renovation/manhole-relining.html
		Milliken Infrastructure	diverse documents		http://infrastructure.milliken.com/
		Waterland Detection Eng.	diverse documents		http://www.waterland.t3webspace.com/wp-content/uploads/2016/05/Waterline_Cast_Geo.pdf

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1) AS/NZS 2566.1 Buried flexible pipelines – Structural design
2) AS/NZS 2566.1 Supp 1. Buried flexible pipelines – Structural design – Commentary
3) AS/NZS 2566.2 Buried flexible pipelines - Installation

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