WSA 161 Water Industry Standard for Alkali Activated Binder Including Geopolymer Cement Mortar used for the renovation of wastewater structures and large diameter pipes

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About WSAA

The Water Services Association of Australia (WSAA) is the peak industry body representing the urban water industry. Our members provide water and sewerage services to over 24 million customers in Australia and New Zealand and many of Australia's largest industrial and commercial enterprises.

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Public Comment Draft

PREFACE

This Standard was prepared by the Water Services Association of Australia (WSAA).

The objective of this Standard is to provide performance requirements for the application of alkali activated binder including one-part geopolymer cement mortar, used for the renovation of non-pressure wastewater structures such as maintenance holes, wet-wells, tanks, pits, chambers, culverts, treatment plants and large diameter pipes (sized for personnel entry).

NOTE: Products complying with this Standard may also be suitable for the renovation of drainage pipes used for other applications such as stormwater. Design and installation requirements are covered by *WSA 201 Manual for Selection and Application of Protective Coatings and the Amendment covering CACs and Geopolymers.*

An online tool has been developed in order to assist the water industry in establishing in what sewer conditions a liner can be applied effectively and how long it can be expected to last. This tool, the Sewer Rehabilitation & Prioritisation Decision Platform, is available [location is TBC, fact sheet with details available here].

Public Comment Draft

CONTENTS

FOREWORD 6

SECTION 1 SCOPE AND GENERAL 7

1.1 **SCOPE** 7

1.2 **CONFORMITY REQUIREMENTS** 7

1.3 LIMITATIONS 7

1.4 NORMATIVE REFERENCES 8

1.5 **TERMS AND DEFINITIONS** 11

1.6 **SYMBOLS AND ABBREVIATED TERMS** 12

SECTION 2 MATERIAL REQUIREMENTS "M" STAGE 14

2.1. COLOUR 14

2.2. PARTICLE SIZE 14

2.3. MATERIALS SPECIFICATION 14

2.4. STORAGE AND TRANSPORT 14

2.5. MARKING 15

SECTION 3 MATERIAL REQUIREMENTS "I" STAGE 19

3.1. **INSTRUCTIONS** 19

3.2. PERFORMANCE REQUIREMENTS 19

4. SAMPLING 22

APPENDIX A - MEANS FOR DEMONSTRATING CONFORMITY WITH THIS STANDARD 23

APPENDIX B - TEST METHODS ASSOCIATED WITH THIS STANDARD 28

BIBLIOGRAPHY 29

Public Comment Draft

FOREWORD

This Standard addresses the material and performance requirements of materials and finished products used in the renovation of wastewater pipelines, or structures, by the application of alkali activated binder including one-part geopolymer cement mortar. It is intended to provide manufacturers and specifiers with a means of demonstrating fitness for purpose.

This Standard differs from those applicable to conventionally installed piping systems in that it is required to verify certain characteristics of the components as manufactured as well as in the installed condition. In accordance with ISO terminology these have been identified as the “M” stage for the collective materials used to fabricate the liner and the “I” stage for the liner as installed.

The service life of products conforming to this Standard will be dependent upon the condition of the host pipe, or structure, the quality of the liner material and its application and the service conditions. The material and process selection shall therefore be in accordance with the requirements of the asset owner with respect to extending the service life of the host pipeline, or structure. Liners shall meet the compositional and material property requirements including elemental and mineralogical analysis of both the binder and aggregates. Use of supplementary and admixture materials needs to be declared. All materials are required to meet the performance requirements of this Standard.

As part of its product appraisal process, WSAA may request details of previous successful installations or require contractors to undertake trial installations. Such trial details may include:

- the type and size of structure renovated;
- service conditions, e.g. temperature, relative humidity, CO_2 and H_2S concentrations;
- the lining material and applied thickness;
- application method(s) and equipment used, e.g. trowel applied, sprayed;
- the cure time between the application of the liner and the restoration of the service;
- methods and equipment used to verify the quality of application;
- contractor details and date of installation; and
- where relevant, details of any subsequent rectification work applied to the renovation.

Public Comment Draft

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies the performance requirements and test methods for in-situ application of alkali activated binder including one-part geopolymer cement mortar spray linings for use in the renovation of non-pressure wastewater structures such as maintenance holes, wet-wells, tanks, pits, chambers, culverts, treatment plants and large diameter pipes (sized for personnel entry).

The standard is applicable to alkali activated binder including one-part geopolymer cement mortar applied as a spray lining or hand-trowelled to concrete and masonry structures in accordance with the WSAA code of practice *WSA 201 Manual for the selection and application of protective coatings*. The principal intent of applying such a liner is to extend the service life of the structure by providing corrosion protection in sewer conditions.

Geopolymer cement mortar can be supplied as one-part geopolymers or two-part geopolymers. One-part geopolymers are supplied as a dry powder in bags and only require the addition of water, i.e. the activating agent is pre-mixed into the powder. Two-part geopolymers consist of a dry powder and a liquid activating agent that require mixing, as well as the addition of water. The water industry has focused on one-part geopolymers due to the advantages in transportation and mixing offered.

An online tool has been developed in order to assist the water industry in establishing in what sewer conditions a liner can be applied effectively and how long it can be expected to last. A combination of the results from tests required in this product standard and sewer conditions are used in the model. This tool is available [location is TBC, fact sheet with details available here].

1.2 CONFORMITY REQUIREMENTS

Methods for demonstrating conformity with this Standard shall be in accordance with Appendix A.

Product certification, when required, shall be undertaken in accordance with WSA TN-08.

Note: The word ‘shall’ is used in this Standard to designate a mandatory requirement. ‘Should’ indicates a recommendation.

1.3 LIMITATIONS

This standard considers the application of alkali activated binder including one-part geopolymer cement mortar products in relation to their corrosion

Public Comment Draft

resistance properties. Structural repair of wastewater assets using geopolymer cement mortar is beyond the scope of this standard.

1.4 NORMATIVE REFERENCES

The following are the normative documents referenced in this Standard.

AS

1012.3.1 Methods of testing concrete Determination of properties related to the consistency of concrete - Slump test

1012.3.5 Methods of testing concrete Determination of properties related to the consistency of concrete - Slump flow, T and J-ring test

1012.9 Determination of the compressive strength of concrete specimens

1012.10 Determination of indirect tensile strength of concrete cylinder

1012.13 Method for determination of drying shrinkage of concrete

1012.21 Methods of testing concrete Determination of water absorption and apparent volume of permeable voids in hardened concrete

1141.35 Methods for sampling and testing aggregates detection of sugar contamination in concrete aggregates

1478.1 Chemical admixtures for concrete, mortar and grout – Part 1: Admixtures for concrete

1478.2 Chemical admixtures for concrete, mortar and grout – Part 2: Methods for sampling and testing admixtures for concrete, mortar and grout

1580.408.5 Paints and related materials - Methods of test - Adhesion - Pull-off test

1580.505.1 Paints and related materials - Methods of test pH of water-based paints

2350.4 Methods of testing Portland, blended and masonry cements, Method 4: Setting time

2563-1996 Wavelength dispersive X-ray fluorescence spectrometers - Determination of precision

2758.1 Aggregates and rock for engineering purposes Concrete aggregates

3582.1 Supplementary cementitious materials – Part 1: Fly ash

Public Comment Draft

3582.2 Supplementary cementitious materials – Part 2: Slag - Ground granulated iron blast-furnace

3582.3 Supplementary cementitious materials – Part 3: Amorphous silica

3972 General purpose and blended cements

APHA
5520 Standard Methods for the Examination of Water and Wastewater, Oil & Grease

ASTM

C67 Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile

C114 Standard Test Methods for Chemical Analysis of Hydraulic Cement

C143 Standard Test Method for Slump of Hydraulic-Cement Concrete

C150 Standard Specification for Portland Cement

C227-10 Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)

C581 Standard Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fiber-Reinforced Structures Intended for Liquid Service

C618 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

C642 Method for Determination of the DIH Purity of Nuclear

C989 Standard Specification for Slag Cement for Use in Concrete and Mortars

C1240 Standard Specification for Silica Fume Used in Cementitious Mixtures

C1400–11 Standard Guide for Reduction of Efflorescence Potential in New Masonry Walls

C1603 Standard Test Method for Measurement of Solids in Water

D512 Standard Test Methods for Chloride Ion in Water

D516 Standard Test Method for Sulfate Ion in Water

Public Comment Draft

D1691 Standard Test Methods for Zinc in Water

D3559 Standard Test Methods for Lead in Water

D7705/D7705M Standard Test Method for Alkali Resistance of Fiber Reinforced Polymer (FRP) Matrix Composite Bars used in Concrete Construction

E168 Standard Practices for General Techniques of Infrared Quantitative Analysis

E1131 Standard Test Method for Compositional Analysis by Thermogravimetry

E1252 Standard Practice for General Techniques for Obtaining Infrared Spectra for Qualitative Analysis

CEN/TS

14429 Characterization of waste - leaching behaviour tests - influence of pH on leaching with initial acid/base addition

14997 Characterization of waste - leaching behaviour tests - influence of pH on leaching with continuous pH-control

DIN

1048-5 Testing concrete - testing of hardened concrete (specimens prepared in mould)

ISO

7890-1 Water quality — Determination of nitrate — Part 1: 2,6-Dimethylphenol spectrometric method

20720 Microbeam analysis — Methods of specimen preparation for analysis of general powders using WDS and EDS

24418 Microbeam analysis - A Guideline for Long Period Analysis Using SEM-EDS

JSCE

F 563-2005 Part4 “JSCE Standards for Sprayed Concrete” Test Method for Rebound Percentage of Sprayed Concrete (Mortar)

EN

196-1 Methods of Testing Cement - Part 1: Determination of Strength

Public Comment Draft

196-21 Methods of Testing Cement – Part 21: Determination of the Chloride, Carbon Dioxide and Alkali Content of Cement

WSAA

WSA 201 Manual for Selection and Application of Protective Coatings and the Amendment covering CACs and Geopolymers.

1.5 TERMS AND DEFINITIONS

For the purpose of this Standard, the following terms and definitions apply.

1.5.1 Admixtures
Those ingredients in mortar other than cement, water, and aggregates that are added to the mixture immediately before or during mixing. Admixtures are chemical formulations added to the mortar mix that affect the way the plastic or hardened mortar forms.

1.5.2 Cement
Hydraulic powder that reacts with water to form a solid mass.

1.5.3 Coating
A layer of any substance spread over any surface.

1.5.4 Corrosion classification
A classification system that provides a grade to an asset from 1 to 5 based on the conditions in the sewer and its impact on the expected life of the asset. See fact sheet.

1.5.5 Cured geopolymer
Geopolymer product that has completed a polycondensation reaction process. Curing can be carried out at ambient conditions (20-23°C) for on-site application for periods of 28 to 56 days. Curing can be accelerated with heat or steam at 40-140°C for periods from 8 to 24 hours followed by rest periods of 7 to 28 days.

1.5.6 Declared value
Limiting value of a characteristic declared in advance by the lining system supplier, which becomes a requirement for the purposes of assessment of conformity.

1.5.7 Liner
A protective layer of material formed over the substrate after installation and curing is completed.

1.5.8 Geopolymer
A geopolymer is an inorganic cement binder. Geopolymers are prepared by reacting aluminate and silicate bearing minerals, and/or

Public Comment Draft

waste, with an alkaline activator resulting in a polycondensate structure.

1.5.9 Geopolymer cement mortar
A mortar that uses geopolymer as the binder, it contains aggregates that maybe natural or wastes, e.g. glass. Aggregates shall be fine (≤ 5 mm).

1.5.10 Pipeline system
Interconnecting pipe network for the conveyance of fluids.

1.5.11 Product stages
The liner material as installed and the component materials from which it is made can be considered at two distinct stages as follows:

1.5.11.1 "M" Stage
the stage as manufactured before any site processing or mixing of the components.

1.5.11.2 "I" stage
the stage as installed. That is, the final configuration of the material after site processing and installation.

1.5.12 Renovated pipeline system, or structure
Existing pipeline system, or structure, plus the installed lining system used to renovate it, as well as any grout or other annular filling material used.

1.5.13 Renovation
Work incorporating all or part of the original fabric of the pipeline, or structure, by means of which its current performance is improved.

1.5.14 Maximum service temperature
The maximum sustained temperature at which the geopolymer liner system is intended to operate.

1.5.15 Simulated installation
Installation of a lining system into a simulated host structure using representative equipment and processes to provide samples for testing which are representative of the actual installation.

1.5.16 Type Testing
Testing performed to prove that a material is capable of conforming to the requirements given in the applicable standard.

1.6 SYMBOLS AND ABBREVIATED TERMS

The following abbreviations apply to this Standard:

OPC Ordinary Portland Cement

Public Comment Draft

GEO Geopolymer Mortar

Public Comment Draft

SECTION 2 MATERIAL REQUIREMENTS “M” STAGE

This section specifies the requirements for the components that together make an alkali activated binder and geopolymer cement mortar.

The actual values of the properties for the materials at the “M” stage are to be stated by the supplier and used for ongoing monitoring of quality.

2.1. COLOUR

Colouration may be used to monitor the quality of the mixing of individual ingredients in the geopolymer cement mortar.

2.2. PARTICLE SIZE

The supplier shall specify the maximum particle size of the product in order to ensure compatibility with the intended spray nozzle diameter.

The maximum size of aggregate shall be 5 mm.
If geopolymer cement mortar contains fibres, the fibre size shall never be greater than 70% of the nozzle diameter.

2.3. MATERIALS SPECIFICATION

The manufacturer shall:

2.3.1. Provide a qualitative description of the alkali activated binder and geopolymer.

2.3.2. Provide a specification listing relevant properties including specified values and tolerances. The properties shall include those listed in Table 1. Any other properties relevant to the particular lining system shall also be specified.

2.3.3. Nominate the minimum and maximum lining thickness appropriate for the product, corrosion classification or service conditions, service life required and any relationship between pipe/structure diameter and liner thickness.

2.3.4. Specify that potable quality water is used, or where recycled water is specified that it meets the requirements listed in Table 5.

2.3.5. Provide details of any admixtures to be used. For example, glass fibres for strength or shrinkage control and accelerators to reduce the curing time.

2.3.6. Required quality assurance to ensure successful installation.

2.4. STORAGE AND TRANSPORT

The manufacturer of the alkali activated binder and geopolymer shall

Public Comment Draft

provide instructions regarding the storage and transport of the material and/ or components including shelf life and any storage temperature limitations or other factors, e.g. humidity.

2.5. MARKING

Marking shall be applied to the outside of the alkali activated binder and geopolymer containers as delivered to the installation site.
Marking shall include:
- manufacturer's name and/or trademark;
- lining system, e.g. geopolymer spray lining;
- application, e.g. Wastewater;
- Date of manufacture; and
- Batch number.

2.6. PERFORMANCE REQUIREMENTS

2.6.2. REBOUND

Rebound represents material wastage during application and is important in order to determine the correct amount of material to supply for the works.

Rebound is generally given as a percentage or as a mass per area measurement:

$$Rebound\ (\%) = \frac{Mass\ rebounded\ (kg)}{Total\ mass\ applied\ (kg)}\ \%$$

or

$$Rebound\ \left(\frac{kg}{m^2}\right) = \frac{Mass\ rebounded\ (kg)}{Area\ (m^2)}$$

The procedure outlined in JGC No.8 Recommendations for Shotcreting JSCE-F 563-2005 Test Method for Rebound Percentage of Sprayed Concrete (Mortar) shall be followed.

2.6.3. TYPE OF ACTIVATOR

The type of the activator(s) used shall be declared. Both the state and composition of the activator shall be declared as per the following examples:

- Solid activator: sodium meta-silicate- anhydrous.
- Solid activator: sodium meta-silicate pentahydrate.
- Solid activator: potassium carbonate.
- Solid activator: calcium hydroxide.

Public Comment Draft

TABLE 1 PROPERTIES OF THE INDIVIDUAL COMPONENTS OF THE GEOPOLYMER CEMENT MOTAR (UNCURED)

Property	Test Method [a]	Conditions
Precursors	Varies by precursor type, refer Table 2.	Refer Table 2
Composition of reacted or hardened cement phases	TGA: ASTM E1131 Refer Test Method 2B.4	Refer Table 3
Composition of aggregate	Elemental/compositional analysis by XRF: • AS 2563-1996 (R2016); or • ASTM C114-18 Refer Test Method 2B.2	Refer Table 4
Composition of fibres	Declared value	Conform to alkali resistance as specified in ASTM D7705/D7705M Conform to chemical resistance as specified in ASTM C581 Steel fibres shall not be used.
Use of admixtures [c]	AS 1478.1 AS 1478.2	Record value
Composition of activator	Declared value	Refer 2.6.3
Binder aggregate ratio (w/w)	Declared value	Aggregates shall be a maximum of 60% of the dry solid concrete
Acceptable moisture content in storage [b]	Declared value	<5%, or as specified by the supplier
Notes a. Alternate test methods, for example ISO or ASTM, may be nominated by the supplier if their appropriateness can be demonstrated. b. May be used to determine if storage requirements met, or if shelf life expired.		

Public Comment Draft

TABLE 2. ACCEPTABLE ALUMINA SILICATE PRECURSORS, CEMENT AND SUPPLEMENTARY CEMENTING MATERIALS (SCM)

Materials	Type	**Conditions**
Metakaolin (natural pozzolan, clay)	Precursor	• Conform to ASTM C618 • For composition the precursor shall conform to high-reactivity metakaolin with threshold composition of (SiO_2+ Al_2O_3+ Fe_2O_3) >90% • Maximum metakaolin in the binder is 40%
Fly ash	Precursor	• Class F • Conform to ASTM C618 • AS 3582.1 • (SiO_2+ Al_2O_3+ Fe_2O_3) >70%; SO_3≤4.0%, moisture content ≤3.0%, and LOI content ≤10% • Maximum fly ash in the binder is 40%
Ground granulated blast furnace slag (GGBFS)	Precursor	• ASTM C989 • AS3582.2 • Maximum GGBFS in the binder is 60%
General Purpose Concrete	Cement	• ASTM C150 Type 1 • AS 3972 • Maximum general purpose cement (e.g. OPC) in the binder mixture shall be 80%
Silica fume	SCM	• ASTM1240 • AS3582.3
Glass cullets	SCM	• Conform to ASTM C 618, Classification N • (SiO_2+Al_2O_3+Fe_2O_3)≥70.0%, SO_3≤4.0%, moisture content ≤3.0%, and LOI content ≤10%

TABLE 3 CHEMICAL COMPOSITION OF CEMENT PHASES

Substance[a]	**Weight (%)**[b]
CEMENT PHASE I	>0.9
CEMENT PHASE II	>0.6
CEMENT PHASE III	>0.6
CEMENT PHASE IV	>0.5
Total hydrates	>3.3

Notes:

a. For specification of hydrates see Test Method 2B.4 Analysis of Alkali Activated Binders including Geopolymer Cement Phases by Thermal Gravimetric Analysis.

Public Comment Draft

b. The composition of the cement phases shall be estimated by thermal gravimetric analysis.

TABLE 4 CHEMICAL COMPOSITION OF AGGREGATE

Substance	Weight (%)
Al_2O_3	<3.0
CaO	<10.0
SiO_2	70-99
Fe_2O_3	<0.4
MgO	<4
Na_2O, K_2O	<15
Sulfate content (as SO_3)	≤ 0.5 %
LOI	≤0.5 %
Other elemental oxides (e.g., MnO, TiO_2)	trace

Notes:

a. Aggregate used shall be pre-mixed by the manufacturer.
b. Maximum aggregates shall be 60% of the dry solid concrete.
c. LOI is Loss on Ignition.

TABLE 5 CHEMICAL LIMITS FOR NON-POTABLE MIXING WATER

Chemical	Limit (pp)m	Test Method
Chloride (Cl)	1,000	ASTM D512
Sulfate ($SO_{4)}$	3,000	ASTM D516
Alkalies as (Na_2O + 0.658 K_2O)[1]	1,500	ASTM C114 EN 196-21
Total solids	50,000	ASTM C1603
Harmful substances[2] Sugars Phosphate (P_2O_3) Nitrates (NO_3^-) Lead (Pb^{2+}) Zinc (Zn^{2+})	 100 100 500 100 100	 AS 1141.35 ISO 7890-1 ASTM D3559 ASTM D1691
pH	>5.0	AS 1580.505.1
Oil and grease	<50	APHA 5520

Notes:

1. Total sodium and potassium ions, computed as Na_2Oeq, from all ingredients is limited to 2.8 kg/m^3 of concrete to safeguard potential alkali-aggregate reaction if used with reactive aggregate.
2. In the first instance, qualitative tests may be carried out. If the qualitative tests show positive results, either the quantity of the substance shall be determined or tests for setting time and compressive strength shall be performed

Public Comment Draft

SECTION 3 MATERIAL REQUIREMENTS "I" STAGE

3.1. INSTRUCTIONS

Technical information relating to the alkali activated binder, including one-part geopolymer cement mortar, and correct installation methods shall be readily available to aid the user and installer. The information may be in the form of a technical manual or equivalent document and be written in plain English and supplemented by figures and diagrams as applicable. The information provided shall satisfy the requirements of a warranty as referenced in the Plumbing Code of Australia (PCA) and those requirements of the AS/NZS 3500 series of Standards.

The information shall consider the requirements in WSA 201, Manual for the Selection and Application of Protective Coatings. Where deviation from the requirements of this manual is necessary this shall be highlighted for the review and approval of the asset owner.

The information shall include details of:

3.1.1. the mixing ratio of the components by mass or volume as appropriate, including the acceptable ratio tolerance;
3.1.2. the temperature band within which the components and blend shall be maintained;
3.1.3. curing times and whether these are thickness dependent;
3.1.4. any restrictions on the ambient conditions on site that might adversely affect the application of the lining;
3.1.5. surface preparation including whether the prepared surface need be wet or dry, including acceptable range of moisture vapour emission rate; and
3.1.6. finishing requirements, e.g., trowelling;
3.1.7. suitable substrate material;
3.1.8. repair of pipelines renovated using GEO mortar product;
3.1.9. safety data sheets;
3.1.10. work health and safety requirements.

3.2. PERFORMANCE REQUIREMENTS

The geopolymer cured in accordance with the manufacturer's written instructions, shall be tested as per Table 6.

3.2.1. Self-compaction
Geopolymer mortar shall be self-compacting such that any voids are less than 4 mm.

Public Comment Draft

Verification of self-compaction: 2 core samples of a field application, i.e. not a laboratory prepared sample, shall be taken following initial curing. Each sample shall be cut with a diamond saw to provide two cross sections (4 total tests surfaces). Cross sections shall be examined visually, and any voids measured.

Measurement equipment: micrometer, calliper, or other suitable gauge, capable of measuring to within 0.1 mm.

3.2.2. Segregation

The geopolymer mortar shall be tested for segregation of aggregate. Segregation is not acceptable.

Verification of segregation: 2 core samples of a field application, i.e. not a laboratory prepared sample, shall be taken following initial curing. Each sample shall be cut with a diamond saw to provide two cross sections (4 total tests surfaces). Cross sections shall be microscopically examined visually for segregation of aggregate.

TABLE 6 PROPERTIES OF THE GEOPOLYMER CEMENT MORTAR (I STAGE)

Property	**Test Method** [a]	**Conditions**
Maximum water to dry solids ratio (litres/20kg)	Declared value	None (information required for application)
Bulk Densities of Mortar (conforming to optimal and maximum water to concrete ratio) (kg/m^3)	Declared values	None (information required for application)
Placement Tests		
Setting times (initial and final) [c, d]	ASTM C403/C 403M	The final setting shall not be less than 80 minutes and shall not be greater than 240 minutes for application in tidal region.
Slump test [e]	AS1012.3.5 AS/NZS 2350.4 ASTM C143	0-10 mm
Rebound test	JSCE-F 563-2005	Refer 2.6.1

Public Comment Draft

	Test Method for Rebound Percentage of Sprayed Concrete (Mortar)	Report as per requirements of JSCE-F 563-2005
Properties of cured material		
Compressive strength	AS 1012.9	@ 24 hours ≥ 17 MPa @ 28 days ≥ 40 MPa
Flexural strength	EN 196-1	@ 7 days ≥ 5 MPa @ 28 days ≥ 9 MPa
Tensile strength	AS 1012.10	@ 28 days ≥ 5 MPa
Drying shrinkage	AS 1012.13	@ 56 days ≤ 600 microstrain
Maximum service temperature	Declared value	See note b
Water Absorption and Volume of Permeable Voids	AS 1021.21	Recorded value
Acid Neutralisation Capacity	European Committee's CEN/TS 14429 and CEN/TS 14997	Recorded value
Self-compaction	Refer 3.2.1	Voids < 4.0 mm
Segregation	Refer 3.2.2	Pass
Alkali Aggregate Reaction (AAR) Test	ASTM-C227	Pass
Efflorescence	ASTM C1400 ASTM C67	Recorded value
Permeability	DIN 1048-5	Recorded value

Notes

a. Alternate test methods, for example ISO or ASTM, may be nominated by the supplier if their appropriateness can be demonstrated.
b. The expected range of sewage temperatures is 10-30°C, though higher temperatures are possible.
c. Longer final setting times could be used if the asset is off-line and in maintenance holes above the flow line.
d. If setting times cannot be met, manufacturers shall recommend an appropriate curing accelerating curing reagent. The utility shall be consulted on the acceptability of the use of curing reagents. Test of compatibility of curing reagent to mortar and dosage shall be submitted to the utility.
e. Note for wet-spray application a positive displacement pump should be considered (e.g., continuous mixing rotor stator pump).

General: curing temperature shall be at typical ambient conditions: 15-30°C.

Public Comment Draft

4. SAMPLING

The supplier shall document the method used for acquiring samples for testing for installation quality control purposes. Unless otherwise noted, the samples may be obtained by means of one of the following methods:

(a) a simulated installation;
(b) an installation; or
(c) any other method that can be demonstrated to replicate the characteristics of an installation.

Number of tests required and acceptable results shall be as per the relevant standard. Where a standard does not specify these requirements 3 tests shall be conducted and the closeness of agreement between results shall be within ±5% of the mean value.

Public Comment Draft

APPENDIX A - MEANS FOR DEMONSTRATING CONFORMITY WITH THIS STANDARD

(Normative)

A1 SCOPE

This Appendix sets out a means for consistent demonstration of conformity with this Standard through the use of a minimum sampling and testing frequency plan. Where variations to this plan are made, demonstration of conformance with the minimum requirements may be necessary.

A2 RELEVANCE

The long-term performance of pipeline systems is critical to the operating efficiency of water agencies in terms of operating licences and customer contracts. The long-term performance of plumbing systems is similarly critical to the durability of building infrastructure, protection of public health and safety and protection of the environment.

A3 DEFINITIONS

A3.1 Acceptable quality level (AQL)

When a continuous series of lots or batches is considered, the quality level which, for the purpose of sampling inspection, is the limit of a satisfactory process average (see AS 1199.1).

NOTE: The designation of an AQL does not imply that a manufacturer has the right knowingly to supply any non-conforming unit of product.

A3.2 Material or compound batch

A clearly identifiable quantity of a particular material or compound.

A3.3 Production batch

A clearly identifiable collection of units, manufactured consecutively or continuously under the same conditions, using material or compound to the same specification.

A3.4 Lot

A clearly identifiable subdivision of a batch for inspection purposes.

A3.5 Sample

One or more units of product drawn from a batch or lot, selected at random without regard to quality.

Public Comment Draft

NOTE: The number of units of product in the sample is the sample size.

A3.6 Sampling plan

A specific plan, indicating the number of units of components or assemblies to be inspected or tested.

A3.7 Process verification test (PVT)

A test performed by the manufacturer on materials, components, joints or assemblies at specific intervals to confirm that the process continues to be capable of producing components conforming to the requirements of the relevant Standard.

NOTE: Such tests are not required to release batches of components and are carried out as a measure of process control.

A3.8 Batch release test (BRT)

A test performed by the manufacturer on a batch of components, which has to be satisfactorily completed before the batch can be released.

A3.9 Type testing (TT)

Testing performed to prove that the material, component, joint or assembly is capable of conforming to the requirements of the relevant Standard.

A4 MINIMUM SAMPLING AND TESTING FREQUENCY PLAN

A4.1 General

Table A1 sets out the minimum sampling and testing frequency plan for a manufacturer to demonstrate compliance to this Standard. Where variations to this plan are made, demonstration of conformance with the minimum requirements may be necessary.

A4.2 Testing

Testing shall be conducted by a testing laboratory or facility that fulfils the requirements of AS ISO/IEC 17025, General requirements for the competence of testing and calibration laboratories.

NOTE: AS ISO/IEC 17025 can apply to first-party, i.e. manufacturer or supplier, second-party or third-party testing laboratories and facilities.

A4.3 Retesting

In the event of a test failure, the products manufactured since the previous test(s) conforming to the requirements outlined in Table A1 shall be

Public Comment Draft

quarantined as a batch. A further set of samples shall be selected randomly from the quarantined batch using a sampling plan to AS 1199.1. If the retest requirements are met, the batch may be released and compliance with this Standard for the quarantined batch may be claimed.

Should a failure on retesting occur, then the quarantined batch shall be rejected and claims and/or marking indicating conformity to this Standard shall be suspended until the cause of the failure has been identified and corrected.

A4.4 Rejection after retest

In the event of a quarantined batch being rejected after retesting, it may be subjected to 100% testing for the failed requirement(s), and only those items found to comply may be claimed and/or marked as conforming with this standard.

TABLE A1
MINIMUM SAMPLING AND TESTING FREQUENCY PLAN

Characteristics	Clause	Requirement	Test method	Frequency
GENERAL PROPERTIES OF GEOPOLYMER CEMENT MORTAR				
Colour	2.1	Details needed if used for quality control.	Declared value	At any change in material formulation, design or process
Particle size - aggregates	2.2	≤ 5mm (spray)	AS 2758.1	
Particle size - fibres	2.2	≤ 70% of nozzle diameter	Declared value	
Nozzle size	2.2	Specify nozzle diameter in mm compatible with product	Declared value	
Min./max. lining thickness	2.3.3	Declared values	Declared value	
Storage conditions	2.4	Declared value	Declared value	
MATERIAL PROPERTIES OF GEOPOLYMER CEMENT MORTAR COMPONENT MATERIALS AT "M" STAGE (UNCOMBINED, UNCURED)				
Precursors	Table 1 Table 2	Refer Table 2	Varies by precursor type, refer Table 2.	At any change in material formulation, design or process
Composition of reacted or hardened cement phases	Table 1	Refer Table 3	TGA: ASTM E1131 Refer Test Method 2B.4	
Composition of aggregate	Table 1	Refer Table 4	Elemental/compositional analysis by XRF: AS 2563; or ASTM C114 Refer Test Method 2B.2	
Composition of fibres	Table 1	Declared value	Conform to alkali resistance as specified in ASTM D7705/D7705M Conform to chemical resistance as specified in ASTM C581 Steel fibres shall not be used.	
Use of admixtures	Table 1	Declared value	AS 1478.1	

Public Comment Draft

Characteristics	Clause	Requirement	Test method	Frequency
			AS 1478.2	
Composition of activator	Table 1	Refer 2.6.3	Declared value	
Binder aggregate ratio (w/w)	Table 1	Declared value	Aggregates shall be a maximum of 60% of the dry solid concrete	
Acceptable moisture content in storage.	Table 1	Declared value	<5%, or as specified by the supplier	
MATERIAL PROPERTIES OF GEOPOLYMER CEMENT MORTAR (COMBINED, UNCURED)				
Maximum water to dry solids ratio (litres/20kg)	3.1.1 Table 6	Declared value	None (information required for application)	At any change in material formulation, design or process
Temperature range of mixed components	3.1.2	Declared value	Declared value	
Curing time	3.1.3	Declared value. May be thickness dependent.	Declared value	
Ambient conditions restrictions	3.1.4	WSA 201 (application between 10-35°C only)	Declared value	
Surface preparation requirements	3.1.5	Supplier specified	WSA 201	
Acceptable range of moisture vapour emission rate	3.1.5	Supplier specified	WSA 201	
Finishing requirements	3.1.6	Declared value	WSA 201	
Bulk Densities of Mortar (conforming to optimal and maximum water to concrete ratio) (kg/m^3)	Table 6	Declared values	None (information required for application)	
Setting times (initial and final)	Table 6	80-240 minutes for application in tidal region	ASTM C403/C403M	
Slump test	Table 6	0-10 mm	AS 1012.3.1 ASTM C143	
Rebound test	2.6.1 Table 6	Record value	JSCE-F 563 Test Method for Rebound Percentage of Sprayed Concrete (Mortar)	
MATERIAL PROPERTIES OF GEOPOLYMER CEMENT MORTAR AT "I" STAGE (COMBINED, INSTALLED, CURED)				
Compressive strength	Table 6	@ 24 hours ≥ 17 MPa @ 28 days ≥ 40 MPa	AS 1012.9	At any change in material formulation, design or process
Flexural strength	Table 6	@ 7 days ≥ 5 MPa @ 28 days ≥ 9 MPa	EN 196-1	
Tensile strength	Table 6	@ 28 days ≥ 5 MPa	AS 1012.10	
Drying shrinkage	Table 6	@ 56 days ≤ 600 microstrain	AS 1012.13	
Max. service temperature	Table 6	Declared value	Declared value	
Water Absorption and Volume of Permeable Voids	Table 6	Report measured values	AS 1021.21	
Acid Neutralisation Capacity	Table 6	Recorded value	CEN/TS 14429 and CEN/TS 14997	
Self-compaction	Table 6	Voids < 4.0 mm	Refer 3.2.1	
Segregation	Table 6	Pass	Refer 3.2.2	

Public Comment Draft

Characteristics	Clause	Requirement	Test method	Frequency
Alkali Aggregate Reaction (AAR) Test	Table 6	Pass	ASTM-C227	
Efflorescence	Table 6	Record value	ASTM C1400 ASTM C67	
Permeability	Table 6	Record value	DIN 1048-5	
Notes: Number of tests required and acceptable results shall be as per the relevant standard. Where a standard does not specify these requirements 3 tests shall be conducted and the closeness of agreement between results shall be within ±5% of the mean value				

Public Comment Draft

APPENDIX B - TEST METHODS ASSOCIATED WITH THIS STANDARD

Test Method 2B.2 Analysis of the Elemental Composition of Concrete by X-ray Fluorescence

Test Method 2B.4 Analysis of General Purpose and Alkali Activated Binders including Geopolymer Cement Hydrates by Thermal Gravimetric Analysis

Public Comment Draft

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ii. ISO 11296.1- 2018. Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks – Part 1: General. ISO Geneva, Switzerland.

iii. Sydney Water Standard Specification SS 212, Rehabilitation and Corrosion Protection of Sewers using Geopolymer Concrete

Public Comment Draft