Engineering

Technical Standard

TS 0110 – Durability Design

Version: 1.0
Date: 24 January 2024
Status: Final

Document ID: SAWS-ENG-0110

Government of South Australia

Copyright

Application & Interpretation of this Document

It is the responsibility of the users of this Standard to ensure that the application of information is appropriate and that any designs based on this Standard are fit for SA Water's purposes and comply with all relevant Australian Standards, Acts and Regulations.

Users of this Standard accept sole responsibility for interpretation and use of the information contained in this Standard. Users should independently verify the accuracy, fitness for purpose and application of information contained in this Standard.

Only the current revision of this Standard should be used which is available for download from the SA Water website.

Documents Superseded by This Standard

Nil.

Significant/Major Changes Incorporated in This Edition

This is the first issue of this Technical Standard.

Document Controls

Revision History

Revision	Date	Author	Comments
1.0	24/01/2024	Rodney Paull / Christopher Edwards Matthew Davis / Hany Habib / Ramon Salazar-Romero	First issue.

Approvers

Role	Signature and Date
Principal Engineer, Materials Science Ramon Salazar-Romero	29/01/2024 X Signer's Name Signed by: SA003587
Principal Engineer, Civil/Structural Hany Habib	29/01/2024 X Signer's Name Signed by: HA003047
Manager Engineering Quality and Innovation Matthew Davis	7/02/2024 X Signer's Name Signed by: DA003681
Senior Manager Engineering Services Sofia Chouli	9/02/2024 X Signer's Name Signed by: CH005288

Reviewers

Role	Name	Revision	Review Date
Principal Engineer, Reticulation Networks (Acting)	John Skirrow	0.1	06/11/2023

Contents

List of tables

1 Introduction

SA Water is responsible for operation and maintenance of an extensive amount of engineering infrastructure and recognises that durability is a key consideration to ensure the longevity, reliability and functionality of its assets in achieving both customer and sustainability outcomes.

Durability decisions made in the early phases of the asset lifecycle can have substantial long-term implications on the safety of operators, disruption to the community, whole of life costs and sustainability (both in terms of carbon emissions and waste).

This standard has been developed to ensure that durability requirements are adequately addressed during the design, construction and operation and maintenance of SA Water's infrastructure.

This Standard does not directly address sustainability for structures. Most considerations of sustainability, such as the choice of material as it affects waste and energy consumption, are outside the scope of this Standard. Nonetheless sustainability considerations are required in the early stage of the planning and design of structures with emphasis on choice of:

- Materials
- Technologies
- Access
- Maintenance
- Repair and replacement.

It should be emphasised that this Standard is not comprehensive and sets only minimum requirements. Designers shall use their judgement and experience to ensure that durability aspects are catered for adequately in new structures.

1.1 Purpose

The purpose of this Technical Standard is to:

- Establish a systematic process to clearly identify and document how the minimum design life requirements for SA Water infrastructure will be achieved, through consideration of exposure environment, material selections and associated deterioration mechanisms, design detailing and maintenance activities.
- Integrate durability performance parameters into the design process so that materials performance, specifications, construction practices and maintenance requirements are considered from the outset.
- Provide a mechanism for the transfer of key maintenance and servicing information across the asset lifecycle, recognising that the design philosophy for durability can have a significant impact on the operation and maintenance of infrastructure.

This Standard is intended to be used in parallel with TS 0109 – Infrastructure Design, which outlines SA Water's minimum Design and Service Life requirements for SA Water infrastructure.

1.2 Glossary

The following glossary items are used in this document:

Term	Description
AAR	Alkali Aggregate Reaction *(Alkali Silicate Reaction [ASR] is a sub-set of AAR)*
ABS	Acrylonitrile Butadiene Styrene
ACR	Asset Criticality Rating (refer TS 0109)
ASS/PASS	Acid sulfate soil/Potential acid sulfate soil
BMT	Base Metal Thickness
BOM	Bureau of Meteorology
CIA	Concrete Institute of Australia
CP	Cathodic Protection
CPVC	Chlorinated polyvinyl chloride (CPVC)
D&C	Design and Construct
DAR	Durability Assessment Report
DCR	Design Change Request
DDST	Durability Design Summary Table
DICL	Ductile Iron, Cement Lined
DTMR	Department of Transport and Main Road (Queensland)
EBS	Earth Bank Storage
EPDM	Ethylene propylene diene monomer rubber
FCR	Field Change Request
FRP	Fibre Reinforced Plastic
GRP	Glass Reinforced Plastic
HDG	Hot Dip Galvanising
HDPE	High-Density Polyethylene
ITP	Inspection and Test Plan
NCR	Non Conformance Report
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance/Quality Control
RCP	Reinforced Concrete Pipe
SA Water	South Australian Water Corporation
TDRF	Technical Dispensation Request Form
TG	SA Water Technical Guideline
TS	SA Water Technical Standard

1.3 References

1.3.1 Use of Standards and Codes

Unless otherwise specified in the Contract, and where applicable, materials and workmanship are to be in accordance with the relevant Standard or Code.

Unless otherwise specified, use the most current published edition (prior to the closing date for tenders) of Standards and Codes applicable to the Works.

Standards and Codes shall be used consistently throughout the design, supply and installation process without interchanging between different Standards.

Overseas standards and other standard documents named in the Technical Standard are applicable in the same manner as Australian Standards to relevant materials and workmanship. In cases where an applicable Australian Standard is not published, the applicable British Standard, European, New Zealand or American Standard shall be used.

1.3.2 Precedence of Standards

When developing the design and specification the Contractor shall, unless noted otherwise, observe the hierarchy of standards should any discrepancy exist among the referred standards and references as follows:

- Contract
- SA Water Technical Standards and Procedures
- SA Water Technical Specification
- Tender and Tender Addenda
- Australian Standards and Other Standards
- Regulations and Design Codes.

1.3.3 Australian and International

The following table identifies Australian and International standards and other similar documents referenced in this document.

Number	Title
AS 2312.1	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings Paint coatings
AS 3566.2	Self-drilling screws for the building and construction industries - Part 2: Corrosion resistance requirements
AS 3600	Concrete Structures
AS 3735	Concrete structures for retaining liquids
AS 4036	Corrosion of metals – Dissimilar metals in contact in seawater
AS 2832	Cathodic Protection of Metals
AS 2832.2	Part 2: Compact buried structures
AS 2832.3	Part 3: Fixed immersed structures
AS 2832.4	Part 4: Internal Surfaces
AS 2832.5	Part 5: Steel in concrete structures
AS 4312	Atmospheric corrosivity zones in Australia
AS 5100.5	Bridge Design - Concrete

Number	Title
AS/NZS 2312.2	Guide to the protection of iron and steel against atmospheric corrosion by the use of protective coatings – Part 2: Hot dip galvanizing
AS/NZS 4020	Testing of products for use in contact with drinking water
AS/NZS 4680	Hot-dip galvanized (zinc) coatings on fabricated ferrous articles
BRE SD1	British Research Establishment Special Digest 1 Concrete in Aggressive Ground
CIA Z7/01	Planning, Recommended Practice Concrete Durability Series
CIA Z7/02	Exposure Classification, Recommended Practice Concrete Durability Series
CIA Z7/04	Good Practice through Design, Concrete Supply and Construction, Recommended Practice Concrete Durability Series
CIA Z7/05	Durability Modelling Reinforcement Corrosion in Concrete Structures, Recommended Practice Concrete Durability Series (to be published in 2022)
CIA Z7/06	Concrete Cracking and Crack Control, Recommended Practice Concrete Durability Series
CIA Z7/07	Performance Tests to Assess Concrete Durability, Recommended Practice Concrete Durability Series
Fib 34	Model Code for Serviceability Design
SA HB 84	Guide to concrete repair and protection

1.3.4 SA Water Documents

The following table identifies the SA Water standards and other similar documents referenced in this document:

Number	Title
TG 0102	Condition Assessment (when published)
TS 0109	Asset Design Life
TS 0132	Operations and Maintenance Manuals
TS 0210	Pressure Testing of Pipelines
TS 0220	Requirements for Pump Specification, Procurement & Testing and the Preparation of Pump Datasheets
TS 0230	Gate and Butterfly Valve Requirements
TS 0400	SA Water Supplement to WSA201 (when published)
TS 0440	Cathodic Protection Part 1 - Pipelines
TS 0464	PVC Waterstop
TS 0600	Water Tightness Testing of Liquid Retaining Structures
TS 0622	Pipelines (when published)
TS 0710	Concrete
TS 0711	Concrete Remedial Works
TS 0712	Temporary Works (when published)
TS 0720	Access Infrastructure for Water Tanks
TS 0721	Design Requirements for Water Storage Tanks & Associated Works (when published)
TS 0800	Materials in Contact with Drinking Water

1.4 Definitions

The following definitions are applicable to this document:

Term	Description
Accepted	Determined to be satisfactory by SA Water's Representative.
Agent	Chemical or biological substance or physical process (e.g., UV) or biological (e.g., insect attack) process that, alone or together with other agents, including contaminants in the material itself, acts on a structure or component to cause material degradation
Component	Any part of the structure and any non-structural part that may affect the durability of the structure
Constructor	The organisation responsible for constructing and installing infrastructure for SA Water whether it be a third party under contract to SA Water or an in-house entity.
Contract Documents	A set of documents supplied to the Constructor as the basis for construction; these documents contain contract forms, contract conditions, specifications, drawings, addenda, and contract changes
Corrosion	Deterioration of a metal by a chemical, electrochemical or electrolytic reaction within its service environment(s).
Design Life	Refer definition provided in TS 0109
Degradation	Material deterioration or deformation that leads to adverse changes in a critical property of a component
Deterioration	Worsening of condition with time, or a progressive reduction in the ability of a structure or its components to perform according to their intended specifications
Deterioration Model	Mathematical model that describes structural performance as a function of time, taking deterioration into account
Deterioration Mechanism	Scientifically describable process of the cause and development of deterioration
Designer	The organisation responsible for designing infrastructure for SA Water whether it be a third party under contract to SA Water, a Constructor, or an in-house entity. A Designer is a person who effects design, produces designs or undertakes design activities as defined in the *Work Health and Safety Act 2012 (SA)*.
Durability	The capability of structures, products or materials of continuing to be useful after an extended period of time and usage. In the context of performance-based design of structures, durability refers to the fulfilment of the performance requirements within the framework of the planned use and the foreseeable actions, without unforeseen expenditure on maintenance and repair. Refer CIA Z7/01 for further information.
Durability Consultant	Person or group with expert knowledge on materials deterioration and durability as applied to construction materials, additional to more common structural, civil, geotechnical and other engineering knowledge, who completes the durability assessment and is author of the durability assessment report and associated outputs. Refer to the definition in CIA Z7/01 for further detail.
Durability Design	The process of durability assessment, analysis, planning, life-cycle management inspection, monitoring and maintenance such that structures, products or materials continue to perform their function for the required design life. Refer CIA Z7/01 for further information.

Term	Description
Durability Design Summary Table	Tabular/matrix form summarising durability issues relating to infrastructure, including elements and sub-elements of a project. Durability Summary Tables are authored by the Durability Consultant. Refer to Durability Checklists in CIA Z7/01 for further information.
Durability Limit State	A limit state used to define the end of the service life of a structure. The limit state may be a condition, performance or operational limit state.
Durability Plan	Is a formal stand-alone document, authored by the durability consultant, that summarises the approach taken in an asset's design to achieve the specified Design Life (may also be referred to as the Durability Assessment Report). *Refer CIA Z7/01 for further information.*
Element	Item that forms part of, or is associated with, a structure.
Exposure conditions	Includes environmental exposure atmospheric, ground or water conditions and service conditions created by operations or products.
Environmental Action	Chemical, electrochemical, biological, physical and/or mechanical action causing material degradation of a component
Environment/Exposure influences	Physical, chemical and biological actions resulting from the atmospheric conditions or characteristics of the surroundings to the structure including macro and micro influences.
Facility	An entire plant (for example, a Water Treatment Plant, Wastewater Pump Station, desalination plant, etc.).
Failure	Loss of the ability of a structure or component to perform a specified function
Inspection	A primarily visual examination, often at close range, of a structure or its components with the objective of gathering information about their form, current condition, service environment and general circumstances
Intervention	A general term relating to an action or series of activities taken to modify or preserve the future performance of a structure or its components.
Investigation	The process of inquiry into the cause or mechanism associated with some form of deterioration or degradation of the structure and the evaluation of its significance in terms of its current and future performance
Maintenance	A set of planned (usually periodic) activities performed during the service life of the structure intended to either prevent or correct the effects of minor deterioration, degradation or mechanical wear of the structure or its components to keep their future serviceability at the level anticipated by the Designer. *Refer CIA Z7/01 for further information*.
Maintenance Plan	Instructions for maintenance specific to the structure considered, including all elements of which the structure comprises
Monitoring	To observe and record progress/changes in materials properties, condition and/or structural properties or responses with time. May also be used to control the function of an associated entity or process (e.g., warning alarms based upon parameters such as applied load, deflection etc.).
Product	A substance generated by, or used or treated, in the operation of the facility such as wastewater, treatment chemicals, seawater or brine
Reliability	Ability of a structure or component to satisfy the specified design performance requirements within the design service life under specified environmental and operating conditions
Repair	Intervention to reinstate to an acceptable level the current and future performance of a structure or its components which are either defective, deteriorated, degraded or damaged in some way so their performance level is below that anticipated by the Designer; generally, without restriction upon the materials or methods employed

<table>
<tr><th>Term</th><th>Description</th></tr>
<tr><td>Replacement</td><td>Action to substitute new components for ones which have experienced deterioration, degradation or damage that justifies replacement</td></tr>
<tr><td>Responsible Discipline Lead</td><td>The engineering discipline expert responsible for TS 0110 (via SA Water's Representative).</td></tr>
<tr><td>SA Water's Representative</td><td>The SA Water representative with delegated authority under a Contract or engagement, including (as applicable):
Superintendent's Representative (e.g., AS 4300 and AS 2124, etc.)
SA Water Project Manager
SA Water nominated contact person</td></tr>
<tr><td>Structure</td><td>Building or construction that may consist of a combination of elements.</td></tr>
<tr><td>Structure Environment</td><td>External or internal influences (e.g., rain, de-icing salts, UV, humidity) on a structure that can lead to an environmental action</td></tr>
<tr><td>Technical Dispensation Request Form (TDRF)</td><td>This form is part of SA Water's Technical Dispensation Request Procedure, which details the process by which those required to comply, or ensure compliance, with SA Water's technical requirements may seek dispensation from those requirements, prior to construction.</td></tr>
<tr><td>Testing</td><td>Procedure aiming at obtaining information about the current condition or performance of a structure or its components</td></tr>
<tr><td>Transfer Mechanism</td><td>Mechanism by which influences in the structure environment are, over time, transferred into agents on and within components or prevent such transfer</td></tr>
<tr><td>Terminology</td><td>Where an obligation is given and it is not stated who is to undertake these obligations, they are to be undertaken by the Constructor.
Directions, instructions and the like, whether or not they include the expression "the Constructor shall" or equivalent, shall be directions to the Constructor, unless otherwise specifically stated.
Where a submission, request, proposal is required and it is not stated who the recipient should be, it is to be provided to SA Water's Representative for review.
Each word imparting the plural shall be construed as if the said word were preceded by the word "all".
Each word implying persons shall, where appropriate, also be construed as including corporations.
"Authorised", "approval", "approved", "selected", "directed" and similar words shall be construed as referring to the authorisation, approval, selection or direction of SA Water's Representative in writing.
"Allow" shall mean that the cost of the item referred to is the responsibility of the Constructor.
"Provide" shall mean "supply and install".
"Submit" shall mean "submit to the SA Water Representative or their nominated delegate".
Submissions, requests, proposals are to be provided at least 10 business days prior to work commencing or material ordering (unless noted otherwise).
"Informative" shall mean "provided for information and guidance"</td></tr>
</table>

2 Scope

2.1 General

This Technical Standard covers Durability Principles to be applied to projects generally, as well as the development of a Durability Plan where preparation of such documentation is nominated by SA Water.

Durability Plans may be specified as a requirement for:

- Construction of new infrastructure to cover elements that are critical to the supply of water and wastewater services.
- Infrastructure that is subject to an aggressive environment that will affect design life (whether new infrastructure or infrastructure whose operating conditions have been modified).
- Maintenance, repair and/or replacement works (including failure investigations) of existing infrastructure.

This Technical Standard:

- Establishes a systematic process to design for durability.
- Establishes basic requirements of designing for durability, which are to be addressed in the Design Report, where a Durability Plan deliverable is not required.
- Stipulates the requirements of a Durability Plan, to document assessment of how the design life of infrastructure (refer TS 0109) will be achieved.

This Technical Standard considers major construction materials and manufactured items including, but not limited to:

- Precast and in-situ structural concrete
- Metals such as carbon steel, aluminium and stainless steel used in structures and associated elements
- Polymers such as rubber, GRP, HDPE and various types of PVC used in associated elements and pipework
- Proprietary systems and equipment.

Note: Non-structural components that can affect durability outcomes shall also be considered.

2.2 Exclusions

This Standard does not apply to temporary/enabling works used to facilitate construction, though such works are expected to comply with the requirements of TS 0712.

2.3 Application to SA Water Infrastructure

This Technical Standard shall be applied to all SA Water infrastructure projects.

Where a Durability Plan is required by SA Water, a Durability Plan, prepared in accordance with this Technical Standard by a recognised Durability Consultant, shall be submitted by the Constructor or Designer to the SA Water Representative.

Where a Durability Plan is not required, the Designer and Constructor shall still consider durability design activities (per Section 3.4.2) to achieve the required performance and satisfy the longevity requirements specified in TS 0109.

The requirement to develop a Durability Plan in accordance with this Technical Standard is shown in Table 1, based on the Asset Criticality Rating (ACR - refer TS 0109). Where deviation from these requirements is proposed, a TDRF shall be submitted for approval. In addition to the requirements contained in the TDRF itself, endorsement of the TDRF from the project sponsor shall also be provided.

Table 1 – Requirement for a Formal Durability Plan

ACR	Durability Plan
5	Required
4	Required
3	Required
2	Not required#
1	Not required#

Note: *#Durability Design is still to be considered, refer Section 3.4.2*

2.4 Durability and Sustainability

Across its 160+ years of operations, and with infrastructure dating back to the early 20th century, SA Water has substantial experience with durability issues, particularly corrosion, negatively impacting the assumed design life of its infrastructure.

Recognising the improved outcomes that can be achieved through durability design across the asset lifecycle, and the corresponding benefit to sustainability, this Technical Standard has been created in support of achieving SA Water's sustainability targets by:

- Reducing waste generated by replacement or rehabilitation of prematurely degraded infrastructure.
- Creating feasible maintenance regimes required to preserve durability measures and reduce replacement or rehabilitation magnitude and/or frequency.
- Reducing carbon emissions associated with replacement or rehabilitation of prematurely degraded infrastructure.

2.5 Technical Dispensation

Departure from any requirement of this Technical Standard shall require the submission of a Technical Dispensation Request Form (TDRF) for the review and approval (or otherwise) of the SA Water Responsible Discipline Lead, on a case-by-case basis.

The Designer shall not proceed to document/incorporate the non-conforming work before the Responsible Discipline Lead has approved of the proposed action in writing via the TDRF.

SA Water requires sufficient information to assess dispensation requests and their potential impact. The onus is therefore on the proponent to justify dispensation request submissions and provide suitable evidence to support them.

Design works that are carried out without being appropriately sanctioned by SA Water may be liable to rejection by SA Water and retrospective rectification by the Designer/Constructor.

3 Introduction to Durability Design

3.1 General

Durability Design is the process of assessment, analysis and planning for development of designs, materials and methods to satisfactorily achieve the specified performance requirements for the designated design life.

The objective of durability design is to ensure the constructed asset's required design life is met such that premature and/or unexpected maintenance or replacement is not required. This is achieved through a combination of:

- Cost-effective selection and usage of materials across the entire lifecycle.
- Design and detailing of durability elements, including provision for their ongoing maintenance.
- Construction methods which are demonstrated (and recorded) to have achieved the required durability design elements.
- Documentation of durability design elements, and their required maintenance.

Designs shall also consider and address criticality, risk, safe access, and operation of the given infrastructure relative to maintenance and inspection considerations/requirements.

Durability Design is done as part of the overall design process, with steps taken at all stages from project inception to commissioning. Its outcomes enhance construction and provide improved sustainability outcomes through efficient use of materials and effort by maximising the life of infrastructure.

The Durability Design process, depending on the asset and the concerns of the asset owner, can vary from a limited consideration of elements that will not achieve the design life without maintenance or replacement, through to full design of all the assets, elements and equipment in a facility.

3.2 Limitations of Existing Design Standards

Limitations of existing design standards with respect to design life considerations include:

- Design and construction to National/International Standards may not achieve the required design life in aggressive exposure conditions.
- Standards/Codes do not cover all environmental exposure conditions, and micro exposure conditions can be more severe than general conditions.
- The required design life of the asset owner could range from 20 to 100 years (or longer).
- Standards/codes design life can range from 40 to 100 years, or not be stated at all.
- Standards/codes do not consider ease of access and location for inspection and maintenance.
- The design code deemed-to-comply durability design requirements are minimum requirements to achieve durability, not maximum requirements, and may include un-conservative assumptions.
- Structural performance is accepted by all and is formally designed, while durability performance is expected by all, but is often not formally designed or documented.

Further information is available in CIA Z7/01.

3.3 Durability Design Considerations

The durability design process must accurately assess the environmental actions in which an asset is designed to operate, identify the relevant deterioration mechanisms, and establish suitable mitigation measures.

Durability Design shall include, but is not limited to, consideration of the following:

- Exposure conditions
- System/Component design and service life (refer TS 0109)
- Criticality of assets
- Difficulty and cost of maintenance or replacement
- Extending operation at the end of design life
- Impact of technical and/or functional obsolescence (including future availability of products/components)
- Material selection
- Impact of design detailing
- Impact of operating regime (including on future maintenance activities)
- Redundancy of the asset/constituent component
- Impact and/or limitations of construction methods to achieve required durability
- Validation and verification of durability during and after construction
- Maintenance required during design life
- Access for inspection and maintenance
- Life-cycle management inspection, monitoring and maintenance.

As well as consideration of the foregoing, Durability Design must be an integral part of the design process, to ensure that opportunities to achieve or extend the design life and/or provide a low maintenance solution are realised as early as possible.

The list above, while establishing a high-level basis for durability, is intended to provide a starting point for the Designer, Constructor and Durability Consultant to engage with key stakeholders across the asset lifecycle, co-create appropriate solutions and record the information generated through this process for future use.

3.4 Durability Design Activities

Durability Design consists of a technical analysis which determines the nature and rate of material deterioration for given macro and micro environmental conditions, which subsequently influences the design, construction, and operational inspection and maintenance. The Durability Plan must be prepared from first principles (as exposure and operation conditions can be unique to a site) and comply with National and International Standards, as well as industry guidelines.

- Care must also be taken to ensure the specified inspection, replacement and maintenance will enable the Service Life requirements of TS 0109 to be satisfied for all durability elements incorporated into the design.

3.4.1 Durability Plan Required

Where formal durability planning is required, durability design tasks to be undertaken during the asset life are defined in Section 4 for the:

- Asset owner brief
- Concept design
- Detailed design
- Construction
- Maintenance during operation.

Flow charts for the durability design process during design, construction and the operational design life are included in Appendix C (extracts from CIA Z7/01).

Durability Design to create the Durability Plan shall involve the following steps to:

- Characterise macro and micro-environments for the assets and asset components of the structures.
- Determine aggressivity of environment (severity and type); based on test data when reasonably available.
- Identify deterioration mechanisms for construction materials in the environments.
- Assessment of durability requirements according to national codes, identification of where these requirements are deemed inadequate to assess project specific requirements without additional durability assessment.
- Model deterioration mechanisms to determine future service life of materials.
- Select materials to achieve the required optimum whole-of-life cost for design life.
- Review accessibility for maintenance, need for redundancy and reliability requirements.
- Identify potential materials related construction difficulties.
- Assist with project specifications, including material property verification test types and frequencies during trials and in construction.
- Review inspection and testing plans for construction for durability critical elements of materials and workmanship.
- List and record root cause and rectification actions/verification for non-conformances and state the impact on future durability.
- Review (and amend as necessary) to achieve the project's Durability Plan key requirements the operational inspection and maintenance requirements including:
- Inspection and testing plans.
- Criteria/Triggers for expected maintenance interventions or changes to increase/decrease frequency of inspection schedules.

CIA Z7/01 provides guidance including reviews of design life in Australian Standards and the durability assessment approach to achieve a project specific design life.

3.4.2 Durability Plan not Required

SA Water considers durability to be an essential component of the design of fit for purpose infrastructure, to support expected levels of long-term performance and efficient used of finite resources.

Where a Durability Plan in accordance with Section 2.3 is not required for a given project, the Designer is still required to evaluate durability considerations (refer Section 3.3) and include a DDST (refer Appendix H) as part of the Design Report. The DDST at a minimum, shall provide information for infrastructure (including relevant components) that:

- May not achieve the required design life (e.g., coatings, sealants etc.)
- Have a service life that is less than the required design life (refer TS 0109)
- Are necessary to achieve continued performance requirements
- Are exposed or vulnerable to harsh exposure conditions
- Are difficult/costly to replace.

4 Durability Plan

4.1 Durability Plan Process

The Durability Plan sets out a multi-phase process that provides an appropriate level of durability across the design and construction processes. It comprises several different components, summarized in Table 2, which indicate future durability matters that require assessment. The "By" tasks shall be completed by staff with appropriate durability experience (to the approval of the SA Water Representative) at the nominated time.

The "Reviewed By" is listed in process order, noting that respective documents shall be reviewed and updated **before** the SA Water review is undertaken. SA Water also reserves the right to delegate their "Reviewed By" tasks to a designated consultant.

The process in Table 2 and deliverables in Table 3 refer to a Design and Construct (D&C) Contract process, however the requirements are applicable to any SA Water contracting model used to deliver works.

Projects that are major or complex may include a Durability Consultant and a third-party independent Durability Reviewer for the D&C Constructor in a similar manner to a Structural Designer and Structural Verifier. The SA Water Representative may direct that a Durability Reviewer be appointed by the Constructor at the Constructor's cost, to provide review of the Durability Plan independent of the Durability Consultant.

In projects where no Durability Reviewer is used, SA Water may engage a Durability Consultant as their representative.

Table 2 – Durability Plan Process

Item	Process	Design Tasks	By	Reviewed By
1	Durability Standard & Asset Owner Brief *(by SA Water)*	• Issue of Technical Standard TS 0110, issued by SA Water. • Project specific brief issued by SA Water covering items such as: o Level of service (frequency of disruption, response times and restoration times) o Redundancy/bypass and alternative supply of services o Operational issues o Maintenance regime o In-house capability for repair of some materials o Lessons learned o End of life expectation.	**Who** SA Water **When** N/A	1) Constructor 2) Designer 3) Durability Consultant *(for Constructor)*
2	Durability Assessment: Concept Design *(for Constructor)*	• Durability issues at concept design, using available concept design stage environment test data. • Determine investigations and studies required to close knowledge gaps for input to the Detailed design such as but not limited to: o Environmental assessment (e.g., soil, groundwater, surface water testing etc.) o Geotechnical investigations o Measurements on adjacent structures o Visual inspections o Material testing o In-situ trials o Factory acceptance testing	**Who** Durability Consultant *(for Constructor)* **When** Issued with concept design	1) Constructor 2) Designer 3) SA Water

Item	Process	Design Tasks	By	Reviewed By
		○ Predictive modelling of rates of deterioration • The Constructor, Designer and SA Water will initiate any required Durability Consultant reviews based on the Durability Assessment Report: Concept Design (DAR:CD). • Assessment based on SA Water design life requirements (refer TS 0109) for known project exposure and operation conditions. Additional investigations for durability assessment may be required.		
3	Durability Assessment: Detailed Design *(for Constructor)*	• Complete and review investigations to evaluate the findings and take into consideration in the Detailed durability design. • Complete and review theoretical studies such as modelling of deterioration to evaluate the findings and take into consideration in the Detailed durability design. • Review durability issues in detailed design, using all available design stage environment test data, investigation and study outcomes. • Durability Consultant completes material evaluation and selections collaboratively with the Designer and Constructor. • All project Drawings and Specifications that have durability impact are reviewed and durability outcomes incorporated. • The Constructor, Designer and SA Water will initiate any required Durability Consultant reviews based on Durability Assessment Report: Detailed Design (DAR:DD). • Durability influencing project changes are not expected after this report is issued.	**Who** Durability Consultant *(for Constructor)* **When** Prior to construction	1) Constructor 2) Designer 3) SA Water
4	Documenting Construction Procedures and Material Supply	• Method statements, process controls and inspection and test plans ITP's. • The Constructor, Designer and SA Water will initiate any required Durability Consultant reviews based on DAR:DD.	**Who** Constructor **When** Prior to construction	1) Durability Consultant *(for Constructor)* 2) SA Water
5	Quality Systems of Construction & Material Supply	• Monitor construction procedures on an as needed basis. • Monitor materials supplied using ITPs of sufficient detail to determine durability compliance; noting that variations may occur without causing non-compliance. • The Constructor, Designer and SA Water will initiate any required independent (3rd party) Durability Consultant reviews based on the DAR:DD.	**Who** Constructor **When** During construction	1) Durability Consultant *(for Constructor)* 2) SA Water 3) Independent Durability Consultant (3rd party)

Item	Process	Design Tasks	By	Reviewed By
6	Verification of Construction Procedures and Material Supply	• Inspection and approval of staged completion will be carried out during the Works, including review of completed ITP's. Any non-compliant Works will have the cause of defect determined to prevent reoccurrence. • Methods of repair will comply with project requirements including compliant repair works. • Constructor, Designer and SA Water will initiate any required Durability Consultant reviews based on the DAR:DD, including audit site inspections. • Specification non-compliance that may impact the future durability and/or water tightness of the Works will be reviewed by the Durability Consultant.	**Who*** Constructor Durability Consultant *(for Constructor)* **When** During construction **SA Water will undertake verification activities at its discretion*	1) Durability Consultant (for Constructor) 2) SA Water
7	Durability Assessment: Verification of Finished Product (DAR:VR)	• Verification that all completed Works are in accordance with the DAR:DD by review of ITP's non-compliance, non-compliance reports (NCR's), design change requests (DCR's), field change requests (FCR's) and repair records at the end of construction. • The Constructor will provide a concise summary and the individual records to the Durability Consultant for the durability review. • Durability Assessment Report: Verification Report (DAR:VR) completes the verification. Constructor, Durability Consultant and SA Water to agree DAR:VR contents to the approval of SA Water. • Review the Operations and Maintenance Manual (O&M Manual), Asset Maintenance Manual and other project manuals to check relevant durability matters from DAR:DD and DAR:VR have been included.	**Who** Durability Consultant *(for Constructor)* **When** Prior to practical completion	1) SA Water

4.2 Durability Report Deliverables

The key deliverables for a complete Durability Plan are described in Table 3, which indicates future durability matters that will require further assessment.

A Durability Plan is a procedure by which the quality and suitability of all processes and materials involved in the production of the final end product are continuously assessed. It involves the preparation of a number of Durability Assessment Reports (DAR) that outline the requirements for durability and the assessment of compliance with the requirements of the final design, construction process and end product.

Where a Durability Plan is required (refer Section 2.3), a single DAR deliverable that incorporates all required structures will be provided at each project stage. Table 3 identifies these deliverables, <u>each of which</u> represents a **HOLD POINT** under this Technical Standard.

Table 3 – Durability Assessment Report Deliverables

Deliverable	Scope	By Whom
Durability Assessment Report: Concept Design (DAR:CD) (for all parties)	• DAR is at concept design stage with available environmental information and highlights durability issues that will require Constructor's consideration and assessment during detailed design process.	SA Water or their appointed Durability Adviser at concept
Durability Assessment Report: Detailed Design (DAR:DD) (for all parties)	• DAR to reflect the detailed design stage. Considers potential durability issues for final design details, construction method and all environmental information available. • Review and comment on durability compliance of design, drawings and specifications. • Durability requirements for construction stage Constructor method statements and procedures for doing the Works. • DAR multiple revisions are required for design development in progress and reviews until the final design DAR:DD	Durability Consultant *(for Constructor)* prior to construction
Durability Assessment Report: Verification Report (DAR:VR) (for all parties)	• Verification that all completed Works are in accordance with the DAR:DD by review of ITP's non-compliance, NCR's, DCR's, FCR's and repair records at the end of construction. • Constructor, Durability Consultant and SA Water to agree DAR:VR contents to the approval of SA Water.	Durability Consultant *(for Constructor)* prior to practical completion

4.3 Durability Assessment Report Contents

The Durability Assessment Report contents shall include the sections described below unless agreed otherwise with SA Water via a TDRF:

1. **Introduction**
   - Background
   - Scope of the Durability Assessment Report
   - Description of the project.
   - Plan compliance with SA Water Specifications.
   - Relation with the Design Report and other Project Plans.
   - Durability Reviewer named if required for project (refer Section 4.1).
2. **Abbreviations**
3. **References**
4. **Definitions**
5. **Limitations**
6. **Project Assets**
   - List of structures, assets and equipment assessed for durability.
   - List of assets and equipment not assessed for durability based on acceptable Designer review and well defined by SA Water Technical Standards, Australian Standards and project Specifications.
   - Accessibility of structures, assets and equipment for maintenance or replacement.

- List of assets with requirement for AS/NZS 4020 compliance for water retaining structures.
- Lessons learnt from prior projects.

7. Durability Design Process

- Design life and maintenance requirements confirmed for project.
- Atmospheric, soil, groundwater and process environmental conditions determined by testing or reference to verified data.
- Exposure classifications (external, internal and process water) determined for assets and elements.
- Durability assessment of structures and equipment.
- Durability Assessment Reports prior to construction.
- Durability Verification Report prior to Practical Completion.

8. Input Documents

- Design documents such as drawings and specifications.
- Source of information such as SA Water project requirements, test records, geotechnical reports/tests, Bureau of Meteorology (BOM) data etc.
- Standards and references

9. Implementation of Durability Assessment

- Exposure conditions
- Deterioration processes for exposure classifications.
- Durability Design for:
- Structural concrete
- Metal structural elements and protective coatings
- Waterproofing including at construction joints
- Coatings and sealants
- Non-structural components
- Electrical and mechanical components
- Pipework, pumps and valves.

10. During Construction

- Quality Assurance and control
- ITP's and testing plans
- Trial mixes and samples
- Analysis and controls for concrete early age thermal cracking
- Project specifications for items including, but not limited to,
- Concrete cover depth, quality, mix design, reinforcement requirements, joint placement and curing in TS 0710
- Coating systems, surface preparation and curing conditions per TS 146b, TS 0230 and TS 0400
- Architectural finishes
- Details of Non-conformances:
- Root cause analysis

- Rectification actions/verification of work
- Assessment of the impact of repaired non-conformance on future durability.

11. After Construction before Practical Completion

- Close out of non-conformances.

12. Maintenance Documents

- Definition of maintenance requirements and intervention levels
- List of elements with maintenance requirements
- Inspection and Maintenance schedules
- Criteria for initiating expected maintenance interventions or changes to increase/decrease frequency of inspection schedules.

13. Durability Design Summary Table

- Refer to Appendix H.

5 Design for Durability

5.1 General

In designing for durability using the limit-states method, the structure environment (the macro-environment) contains influences outside the structure (atmospheric and ground conditions, including pollution) and inside the structure (indoor atmosphere and materials), that are transformed into one or more agents on the surface of or within a component (the micro-environment) causing environmental action.

Table 4 lists the most common influences in the structure environment affecting the durability of structures and their components. Table 5 lists the most common agents causing environmental actions that affect the durability of components.

Table 4 – Common Environmental Influences

Location	Influence
External: Atmosphere	• Rain, snow or ice • Air constituents • Air contaminants (e.g., salt spray) or pollutants • Wind • Temperature and humidity • Sun
External: Ground or water	• Water • Soil constituents • Soil spills/leaks
Internal	• Humidity and temperature • Contaminating materials • Water and sewage • Stored chemicals • Activities causing wear

Table 5 – Environmental Influence Agents and Examples

Influences	Agents	Examples of parameters
Moisture constituents	• Solid (ice, snow) • Liquid (rain, condensation) • Gas (water vapour)	• Time of wetness • Relative humidity
Moisture contaminants	• Chlorides, acids, sulfates	• Time of exposure • Relative humidity • pH • Concentration
Air constituents	• O_2, CO_2	• Time of exposure • Relative humidity • pH • Concentration
Air contaminants	• Oxides, particulates, sea spray	• Time of exposure • Concentration

Influences	Agents	Examples of parameters
Ground constituents	• Sulfates and other salts • Acids (from decomposition of organics)	• Time of exposure • Relative humidity • pH • Concentration
Ground contaminants	• Chemicals from spills and leaks • Chlorides from road salt • Induced electric currents	• Time of exposure • Relative humidity • pH • Temperature • Concentration
Biological life	• Microorganisms, insects, animals, plants	• Time of witness • Relative humidity • Temperature • Geographical
Temperature	• Freeze-thaw cycles	• Freeze-thaw cycles • Temperature • Time
Solar radiation	• UV radiation, Infrared radiation	• Time of exposure • Relative humidity • Temperature
Incompatible chemicals	_	• Time of exposure • Concentration
Use or exposure	• Wear, abrasion	• Time of exposure • Load

5.2 Project Assets Design Life

Design and Service Life definitions and guidance for SA Water infrastructure can be obtained from TS 0109.

CIA Z7/01 provides guidance including reviews of design life in Australian Standards and the durability assessment approach to achieve a project specific design life.

5.2.1 Predicted Service Life

The predicted service life of the components or the structure as a whole shall be assessed based on experience, modelling and testing, as follows:

- Experience may be applied where identical assemblies have been used successfully and in the same environments.
- Modelling and experience should be applied where:
- A similar component or assembly has been used successfully in the same environments, or
- Proven components or assemblies have been used successfully, but in moderately different environments.
- Modelling and testing should be applied where:
- Innovative components and assemblies are going to be used, or
- Proven components or assemblies are going to be used in significantly different environments.

5.3 Materials in Contact with Drinking Water

All materials used that are in contact with drinking water shall satisfy the requirements of TS 0800 before use, unless a TDRF is sought and approved by SA Water in accordance with TS 0800.

5.4 Exposure Classification

The project exposure classifications can consider exposure as expressed in:

- AS 1664.1 – Aluminium structures
- AS 1720.1 & 2 – Timber Structures and Properties
- AS 2159 – Piling Design and installation
- AS/NZS 2312.1 – Structural Steel Paint Coating Systems
- AS/NZS 2312.2 – Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings Hot dip galvanizing
- AS 3571.1 & 2 - Plastics piping systems - Glass reinforced thermoplastics (GRP) system
- AS 3600 – Concrete Structures
- AS 3700 – Masonry structures
- AS 3735 – Concrete Structures for Retaining Liquids
- AS 4312 – Atmospheric corrosivity zones in Australia
- AS4673 – Cold formed stainless steel structures
- Project specific geotechnical investigations of surface and groundwater
- Field testing of site conditions
- Other documents that may be applicable.

The exposure classifications in the durability design sections of the design codes provide an assessment of the potential aggressiveness of the local macro-and micro-environments toward the durability of a structure component.

The basis of the project specific exposure classifications for SA Water infrastructure shall be assessed by specific investigations of exposure conditions, which duly consider the nature in which SA Water infrastructure operates, using the test methods shown in the following Table.

Table 6 – Methods for Assessment of Exposure Conditions[1]

Exposure	Aggressive Condition	Test/Assessment Method
Water/Wastewater networks	Fatigue	TS 0622
Wastewater	Biogenic sulfide corrosion	Field test
	Metal corrosion	TS 0400 Field test
	Concrete degradation	AS 3735
Corrosive and Acidic Chemicals	Concrete degradation	AS 3735
	Metal Corrosion	TS 0400
Ground and Groundwater	Acid-sulfate soil (ASS)	BRE SD1
	Chlorides	Field test
	Potential acid-sulfate soil (PASS) Sulfate content in groundwater	AS 3600 Geotechnical testing/maps
	pH of groundwater	Field test
	Biogenic Sulfide corrosion	Field test
Atmospheric	Carbon dioxide ingress, Chloride ingress/Reinforcement corrosion	CIA Z7/05 Fib 34 section 3.2 AS 3600
	UV degradation	TS 0109 TS 0400
	Metal corrosion	AS 4312 Bureau of Meteorology data
Process Water	Soft water leaching of concrete	Langelier saturation index (LSI)
	Abrasion/erosion of concrete	AS 3600
	Metal corrosion	TS 0400 Field test
	Biogenic sulfide corrosion	Field test
Seawater or Inland Saline	Concrete carbonation/Reinforcement corrosion	CIA Z7/05 fib 34 section 3.2 AS 3600
	Metal corrosion	AS 4036:2006

Note: *1) Exposure classes for bridges shall be assessed using AS 5100.5 with similar tests*

5.5 Durability Limit States

This Standard recommends the use of the limit-states method for the design and verification of structures for durability. For any component of the structure, this requires an understanding of the structure environment, the transfer mechanisms, the environmental action, leading to action effects that can result in the failure of the component.

5.5.1 Structure Environment

The structure environment contains influences, such as air, rain, contaminants, temperature, biological life and solar radiation, that provide agents such as moisture and oxygen that can affect the durability of components. These influences occur outside (climate, ground or body of water) or inside (climate, chemicals) the structure.

5.5.2 Transfer Mechanisms

Transfer mechanisms, such as gravity, condensation and drainage, promote or prevent transfer of environmental influences into agents causing environmental action on or within the components of the structural system.

For examples of transfer mechanisms, refer 0.

5.5.3 Environmental Action

An environmental action, such as corrosion, decay or shrinkage, is a chemical, electrochemical, biological (e.g., insect attack), physical (e.g., UV) or mechanical action causing material deterioration or deformation.

Except for mechanical action, an environmental action is the consequence of the expected environmental agents, such as moisture, oxygen and temperature, the chemical, electrochemical and physical properties of the materials of the components, and the interaction of the different components, including electrochemical (e.g., galvanic corrosion) and physical (e.g., deformation) interactions. Environmental actions, such as corrosion of steel, decay of wood, shrinkage or freeze-thaw of cement-based materials such as masonry or concrete, can result in loss of performance.

For examples of agents affecting different materials, refer Appendix B.

5.5.4 Action Effects

Action effects include damage, loss of resistance, internal force/stress or unacceptable appearance due to material deterioration, or displacement due to material deformation. An action effect can result in the loss of performance as defined by one or more of the limit states given in 5.5.5 to 5.5.7.

For examples of action effects, refer B2.2.

5.5.5 Ultimate Limit State

For material deterioration resulting in failure due to loss of resistance, the ultimate limit state is defined when the resistance of the component or structure becomes equal to, or less than, the internal mechanical force.

5.5.6 Serviceability Limit States

For material degradation, the serviceability limit states are defined by:

- Local damage (including cracking) or change in appearance that affects the function or appearance of structural or non-structural components.
- Relative displacements that affect the function or appearance of structural or non-structural components.

5.5.7 Initiation Limit State

This limit state is defined by the initiation of deterioration of a component that precedes the occurrence of the serviceability or ultimate limit states.

5.6 Climate Resilient Durability Design

The durability of a structure is determined largely by its deterioration over time which is affected by the environment. Climate change may alter this environment, especially in a longer term, causing an acceleration of deterioration processes and consequently adversely affect safety, serviceability, and durability of structures.

The climate of South Australia is changing with increases in average temperatures, a greater frequency of very hot days, declining rainfall and rising sea levels. New climate projections indicate these changes will continue over coming decades, increasingly affecting communities, industries, infrastructure. Reference shall be made to TS 0109 and The Department for Environment and Water "Guide to Climate Projections for Risk Assessment and Planning in South Australia 2022", which provide a summary of the likely changes to key climate variables.

The significant daily processes of weathering that contribute to premature degradation of the exterior of structures include wind-driven rain, temperature fluctuations, freeze–thaw cycling, frost effects, wetting and drying of porous materials, the action of solar and ultraviolet (UV) radiation, and chemical deposition on metals from the atmosphere. The climate sensitivity of different weathering mechanisms for materials shown in Table 7 indicate that materials durability will be impacted by climate change.

Table 7 – Climate Sensitivity & Durability of Generic Materials

Material Type	Durability Issues	Climate Dependence
Brick and Ceramics	Frost damage Shrinkage of unfired materials Salt staining	Freeze-thaw cycles Precipitation and drying Precipitation and drying
Stone	Weathering & erosion Acid deposition Salt attack	Temperature, precipitation Precipitation (with pollution) Precipitation and drying
Wood	Biological deterioration Warping & structural movement	Temperature and precipitation Uneven drying
Metals	Various corrosion mechanisms	Temperature, precipitation
Concrete	Corrosion of reinforcement Chemical and salt attack	CO_2, temperature, drying Precipitation, Temperature and drying

The deterioration of concrete structures can be affected directly or indirectly by climate change that is linked to the change in carbon dioxide (CO_2) concentration, temperature and relative humidity, as shown in Table 8.

Table 8 – Consequences of Climate Change for Concrete

Climate Change	Implications
Increase of carbon concentration	Elevated carbon concentration accelerates carbonation and increases carbonation depth in concrete, which increases the likelihood of concrete structures exposed to carbonation-induced reinforcement corrosion initiation and structural damage
Change of temperature	Elevated temperature accelerates carbonation, chloride penetration and corrosion rate of reinforcement that exacerbates corrosion initiation and structural damage
Change of humidity	Lowered relative humidity may reduce or even stop carbonation and chloride penetration in areas with yearly average RH currently above 40–50%, while increased humidity may allow carbonation and chloride penetration in regions where they are now negligible

Therefore, design for durability shall consider climate changes with infrastructure climate resilience pertaining to the ability of a building material, component or element to maintain its function if subjected to the effects of climate loads as may occur in the future under different climate change scenarios as compared to those effects arising from loads sustained under current historical climate conditions.

5.7 Durability for Concrete

5.7.1 General

Specific durability actions for concrete asset elements will depend on the environmental exposure category for macro and micro-climates and the design life.

To achieve the required durability, specific durability measures shall be provided. These may include, but are not limited to the following:

- Resistance to attack from aggressive agents such as biogenic acid, process or treatment chemicals/products, sulfates, magnesium, backfill/soil chemicals or soft water. Required protective measures may include increased cover, specific cement type or coatings/linings.
- Penetration resistance requirement for carbonation and chloride ingress (external exposure and process water) to prevent premature corrosion of reinforcement.
- Cover to reinforcement.
- Resistance to concrete degradation including from alkali aggregate reaction (AAR), Acid Sulfate Soils (ASS) and Delayed Ettringite Formation (DEF).
- Control of early age thermal cracking.
- Detailing of joints to facilitate maintenance of sealants as required.

5.7.2 Application of Codes for Concrete Infrastructure

A durability evaluation for concrete water/wastewater infrastructure is undertaken through consideration of several Australian Standards, not all of which are specific to water industry infrastructure.

Specific guidance on the application of these codes to this Technical Standard is provided below.

5.7.2.1 AS 3735: 2001 – Concrete structures for retaining liquids

AS 3735 uses exposure classifications for water products contained in the structures. Clause 4 requires concrete elements to be in accordance with Clauses 4.3 and 4.4 for exposure classifications in Table 4-1 and from AS 3600 for the most severe environment or use during the operational life.

There is no stated design life in years in AS 3735 so AS 3600 applies.

AS 3735 has no requirements to comply with AS 5100.5.

5.7.2.2 AS 3600: 2018 – Concrete Structures

Based on Clause 4.1 items 1 and 2 of AS 3600, a 100 year design life can be achieved by evaluating the AS 3600 requirements with durability assessment of the project specific durability conditions in accordance with this Technical Standard.

5.7.2.3 AS 5100.5: 2017 – Bridge Design – Concrete

AS 5100.5 Section 4 provides guidance on requirements for a design life of 100 years, but constraints should not be applied for water/wastewater infrastructure as:

- Design of bridge structures are focused more on ultimate limit states than serviceability limit states while liquid retaining structures are primarily serviceability limit state design.
- Requirements are not designed for water structures and are not optimal for water structures.

5.7.2.4 AS 2159: 2009– Piling

AS 2159: Piling – design and installation has a stated design life of 100 years and is applicable to foundation designs.

5.8 Durability for Steel

The specific durability actions for steel asset elements will depend on the design life, the maintainability or maintenance class of the structure and the environmental exposure category.

To achieve the required durability, specific durability measures shall be provided. These may include, but are not limited to the following:

- Avoidance of corrosion prone detailing
- Substitution with more corrosion resistant materials
- Protective coating with long time to first maintenance
- Isolation of dissimilar metals
- Corrosion allowance
- Cathodic protection (only for immersed or buried items).

5.9 Durability for Polymers

Polymer based materials include waterproofing membranes, geo-membranes, sealants, coatings, bearings, piping, covers and access equipment.

- Waterproofing such as sheet membranes (below concrete slabs) and water stops are generally protected from aggressive agents so are expected to meet the design life of the asset.

Polymers such as joint sealants and coatings may have short service life compared to concrete and metals when exposed to aggressive conditions so must be:

- Selected to provide adequate design life
- Protected from aggressive agents by shielding or coating
- Able to be accessed for maintenance or replacement at specific age, per TS 0109.

Access equipment made from GRP and FRP may include stairs, walkways, handrails, and associated support beams and structures. These materials can have extended design life.

5.10 Durability for Equipment

This category includes electrical and mechanical equipment provided as a proprietary item.

Equipment may not have been originally designed for a specific exposure environment, and will generally have a shorter service life compared to concrete and metals when exposed to aggressive conditions so must be:

- Selected to provide adequate design life
- Protected from aggressive agents by shielding or suitable type of coating
- Accessible for maintenance or replacement at specific ages.

SA Water provides technical standards which provide additional information and requirements for electrical, mechanical and hydraulic equipment. These shall be incorporated into the Durability Design process and measures captured and documented.

6 Inspection and Maintenance

The Durability Plan shall nominate the required maintenance inspections and provide details of:

- Components requiring inspection
- The frequency of inspection required
- How inspections are to be undertaken (including access provisions and operational considerations)
- Condition thresholds for components to be repaired/replaced
- How repair/replacement activities are to be undertaken
- Hazards associated with any of the foregoing.

Inspection of SA Water infrastructure and components is undertaken in accordance with TG 0102, which may be used to assist development of inspection and maintenance plans in the Durability Plan.

The Durability Plan shall include appropriate reference to technical society recommended practices and guidance documents readily available.

6.1 Maintenance

6.1.1 General

Maintenance during the design life of infrastructure (and its constituent components) shall be suitably considered and documented in accordance with TS 0132 and this Technical Standard.

The following sections provide general considerations for maintenance schedules. However, these shall not be treated as an exhaustive list of durability and maintenance considerations. The Designer and Durability Consultant are expected to determine the relevant requirements applicable to the infrastructure for which they are preparing the design.

Maintenance schedules shall be included in the Durability Assessment Report: Detailed Design (DAR:DD).

6.1.2 Equipment and Electrical Maintenance

Maintenance schedules and requirements will be in accordance with the requirements of the manufacturer.

6.1.3 Concrete Structures

Concrete structures are designed to achieve a long service life with little or no maintenance. Maintenance may consist of repair of minor degradation or defects that occur during construction or later or may consist of application of protection in the form of a penetrant or coating. Information on mechanisms of degradation, test methods and methods for repair or protection of concrete structures are given in industry publications including CIA Z7/01, CIA Z7/05, CIA Z7/06, CIA Z7/07 and SA HB 84.

SA Water's TS 0711 series also provides detailed guidelines on concrete repair methods for water and wastewater assets based on accepted principles to repair and prevent further deterioration of concrete structures as described in EN 1504-9.

6.1.4 Metal Assets

Metal assets are generally proprietary materials including structural sections, access equipment and support structures. A wide range of metals are used with the type of metal chosen to provide economic service and durability. Some metals are inherently durable while other require a protective coating to achieve durability. These include:

- Aluminium alloy in proprietary products generally have a long service life without protection. Maintenance requirements are dictated by the manufacturer, operational factors and if the aluminium is coated.
- Carbon steel is usually protected by a protective coating or by a cathodic protection system, both of which require periodic inspection and maintenance.
- Stainless steels are specified to maximise service life and minimise maintenance of components in aggressive or inaccessible environments. Uses with high abrasion such as pumps may require maintenance.

Protective coatings are considered in Sections 6.1.5 and 6.1.6.

6.1.5 Hot Dip Galvanised Steel Products

HDG products can achieve an extended service life with good cleaning and maintenance measures. Maintenance of HDG steel is reduced if the following conditions are met:

- Exposure conditions have pH between 6 and 12.
- Avoid contact with dissimilar metals such as brass or copper. Use an insulator between dissimilar metals.
- Avoid constant abrasion or abrasive cleaning.
- Clean with a water-based emulsifier, alkaline-based cleaners with a pH of 12 or lower or organic solvents. Then rinse the area with fresh water and wipe clean with a soft cloth.
- Avoid use in damp and poorly ventilated conditions. Ensure the location is dry and there is effective ventilation.
- If physical damage occurs e.g., coating is chipped, repair damaged areas in accordance with AS/NZS 4680.

6.1.6 Protective Coatings and Linings

Protective coatings and linings have a limited service life so may require maintenance in the form of overcoating or replacement during the service life of the facility.

Protective coatings may be applied to:

- Structural steel
- Concrete structures
- Sheeting for walls and roof
- Plastic and polymer pipes and access equipment to protect from ultra-violet light.

Installation and maintenance of coating systems shall comply with the requirements of TS 0400, TS 0711.5, the manufacturer and the durability consultant's instructions and will consist of:

- Touch up of damage.
- Overcoating at times specified by the manufacturer.
- Removal and replacement of paint or linings at specified times.

6.1.7 Cathodic Protection

Cathodic protection systems consist of sacrificial anodes or impressed current systems. Impressed current and sacrificial anode systems are often used in conjunction with protective coatings to reduce the electrical protection required. The protective coatings require regular maintenance while the anodes have a finite life and may have to be replaced at fixed intervals (refer TS 0440).

Impressed current CP systems are complex and require regular maintenance of the various physical components, electrical systems and control systems.

6.1.8 Sealants

Sealants have a limited service life so generally require replacement during the service life of the structure. Maintenance should comply with TS 0711.2 and the manufacturer's instructions.

6.1.9 Plastics

Plastics cover a broad range of materials and components that may include the following:

- GRP access systems (grating, handrails, etc) and pipes.
- Linings or coatings
- Pipes made of common materials include:
- Polyvinyl chloride (PVC)
- Chlorinated polyvinyl chloride (CPVC)
- High-density polyethylene (HDPE)
- Low-density polyethylene (LDPE)
- Acrylonitrile butadiene styrene (ABS)
- Polyethylene (PE).

These components are selected to suit the purpose and exposure conditions.

Plastics can have an extended service life but may require coatings for protection from UV. Coatings are considered in section 6.1.6. Additives are used in some plastics to improve durability such as hindered amine light stabilizers (HALS) and carbon black in PE.

7 Durability Design Summary Table

7.1 General

Successful implementation of Durability Design outcomes in infrastructure requires appropriate information to be conveyed to operators to ensure:

- Durability measures adopted are known and understood
- Inspection, maintenance and remediation requirements are documented and planned for
- The design and operation of the asset adequately allows for inspection, maintenance and remediation activities to occur
- Relevant access and hazard information is articulated to those undertaking inspection, maintenance and radiation works.

To achieve these objectives, a Durability Design Summary Table (DDST) shall be provided with the Durability Plan and is to be included with any Operation and Maintenance Manual prepared for a project per TS 0132.

The DDST is intended to succinctly provide the key outcomes and durability design described in detail within the Durability Plan. The DSST, along with the DAR, shall be updated throughout the progression of design in accordance with Section 4 of this Technical Standard.

7.2 Content

The DDST is subdivided into five sections as described below, and the information nominated must be provided to ensure appropriate information transfer to SA Water operators:

1) **Asset Information**

   Provides specific information on the asset (and component/sub-component) and minimum design life.

2) **Durability Design Factors**

   Summarises exposure conditions, durability and deterioration issues and their associated risk rating to highlight factors on which the Durability Design is based.

3) **Durability Design Outcomes**

   Summarises the durability design measures adopted, along with details of any proprietary products specified in the design.

4) **Inspection and Maintenance Requirements**

   Summarises the inspection and maintenance activities required at component level, while also stipulating the condition state at which remedial actions are required, along with detail of what these actions are.

   In addition, the access provisions required (both physical and operational) to undertake these activities are also to be identified.

5) **Safety Hazards**

   Details of hazards associated with the inspection, maintenance and remedial activities provided in the DDST are to be provided, along with mitigation measures and any residual hazards remaining after the mitigations are applied.

A template and example are provided in Appendix H.

Appendix A – Examples of Transfer Mechanisms

A1 General

Environmental action is caused by micro-environmental agents, acting alone or in combination, over time, resulting in deterioration or deformation of a given material. These agents generally occur as a result of influences in the structure environment outside or within the structure being transferred on, into or through an assembly of components. Table 7 contains a list of these transfer mechanisms.

Although little can be done to modify the structure environment (except indoors), the agents causing degradation can be controlled. Their control can be achieved from a fundamental understanding of the transfer mechanisms listed in Table 8. The mechanisms of most concern are those that govern the flow of water, air, and heat.

In designing for durability, one can either select a material to resist degradation caused by the expected environmental action, or the environmental action must be altered to suit the material. Table 9 provides simple examples of the application of an understanding of the transfer mechanisms to the design of an assembly and its components.

Table 9 – Transfer Mechanisms

Transfer mechanisms that usually promote environmental action	Transfer mechanisms that reduce environmental action
• Direct exposure to environmental action • Gravity • Air and vapour pressure • Capillarity (surface tension) • Kinetic energy (driving rain) • Permeation • Convection • Condensation • Diffusion	• Barrier • Drainage • Ventilation • Combination of a barrier and drainage

Table 10 – Mechanism Examples

Transfer mechanism	Examples
Direct exposure	• UV on exterior surface materials • Rain on roof or wall surfaces • Ground moisture (plus contaminants) on foundation surfaces
Gravity	• Water traps in lap joints, channels, column base, crevices • Ponding on “flat” surfaces • Rain penetration into building envelopes (especially roofs) • Staining of building face by water runoff
Air/vapour pressure	• Rain penetration into building envelopes (especially walls) • Condensation in building envelopes due air leakage and vapour diffusion
Capillarity or surface tension	• Penetration of rain and groundwater through porous materials (capillarity) or at joints (surface tension) • Migration of salts within porous materials
Kinetic energy	• Driving rain on wall surfaces and penetration through openings

Transfer mechanism	Examples
Permeation	• CO_2 ingress into concrete • Vapour transmission through building envelope materials
Convection	• Air leakage through gaps in building envelopes
Condensation	• Onto surfaces whose temperature is below the dew point of adjacent air
Diffusion	• Chloride ingress into concrete

Table 11 – Mechanism prevention/mitigation

Transfer Mechanism Prevention/Mitigation	Examples
Barrier	• Coatings: zinc on steel, paint on wood • Preservatives: treated wood • Sealants (joints and surfaces) • Damp-proofing and waterproofing (foundations) • Membranes: concrete parking garages and bridge decks • Air/vapour barrier system in building envelopes
Drainage	• Detailing to avoid water traps • Detailing to avoid rain penetration in building envelopes • Drips to deflect moisture away from lower components • De-watering systems
Ventilation	• Detailing to promote escape of moist air in building envelopes
Combination of a barrier and drainage	• Rain-screen in building envelopes • Two-stage joint in building envelopes • Sheltering (roofing, cover) of highly exposed parts (joints, wooden ends)

Appendix B – Environmental Actions & Control

This Appendix gives examples of environmental actions and action effects in structural materials that resulted in failures, along with a description of the agents and conditions causing degradation and design options currently used.

B1 Agents Causing Environmental Action

B1.1 General

Chemical action takes place continuously in many component materials. These actions may be beneficial (e.g., increase of concrete strength during and after curing) or detrimental (embrittlement of plastics exposed to UV radiation). Chemical actions depend on material constituents of a component and agents such as moisture, temperature and oxygen. Frequently, the environmental action due to one agent is dependent on the presence of another, for example moisture combined with oxygen.

Physical action, such as temperature and moisture fluctuation, can result in damage or separation of components that allow transfer of moisture or humid air, increasing the risk of failure due to material deterioration.

B1.2 Moisture and Contaminants

Water in the atmosphere in its various states (gas, liquid or solid) interacts with material surfaces in several forms: adsorbed moisture (low relative humidity); condensed water (high relative humidity, e.g., dew); and precipitation (e.g., fog, rain, snow).

Water plays a major role in the corrosion of metals, the decay of wood and the deterioration of other materials, either as an active agent or as a means for transfer of other agents.

Most organic and many inorganic materials are porous and permit ingress of moisture to varying degrees. Porous materials with high moisture levels can be fractured by the expansive forces exerted when the contained water freezes. Fluctuations in the moisture content of porous materials can cause them to expand and contract as moisture is absorbed and given off. These deformations can result in damage to components and loss of performance. Organic materials, such as wood, also decay if exposed to excessive moisture in the presence of oxygen and fungi.

The formation and growth of ice lenses in moist, fine-grained soils can cause serious damage through frost heave of foundations or by lateral displacement of retaining walls. The source of water can be from rain, moisture migration from the ground or from the interior of a building or melt water when frost or ice formed on a surface melts.

Chloride contaminants are found in abundance and are a major cause of much deterioration. They can also originate from industrial sources, such as hydrochloric-acid manufacturing plants and from the combustion of coal, paper and chlorine-containing plastics.

Acid rain (or snow or mist) is caused by the introduction of sulfur and nitrogen oxides into the air, primarily from the burning of coal, gasoline and oil, and from motor-vehicle traffic. This new climatic situation in the atmosphere produces a number of problems, including deterioration of structures (e.g., limestone buildings), in addition to affecting life itself.

B1.3 Air and Contaminants

Air, like water, is both an active agent and a means for transfer of other agents.

Atmospheric oxygen, when present with moisture, acts as an agent that causes corrosion and allows decay to develop in the presence of fungi. Carbon dioxide acts as an agent of corrosion of reinforcing steel by reducing the alkalinity of concrete (carbonation) and, as a consequence, the passivity against corrosion of concrete reinforcement.

Air provides a means for transfer of other agents, such as moisture and chlorides (sea spray). Air leakage through assemblies (e.g., the building envelope) is a major cause of problems, including condensation and rain penetration.

Particulate matter in the air deposited on surfaces can contribute to material deterioration, both physical and cosmetic. Hygroscopic deposits (e.g., salts, dusts, pollen) on material surfaces have been found to decrease the relative humidity at which a moisture film forms on a surface. The deposits depend on wind flow near the surface and the shape of the surface.

Chlorides in sea spray act as contaminants that contribute to atmospheric corrosion and stone deterioration in maritime regions. Since sodium chloride can take up water from the atmosphere at a low relative humidity, sea-salt deposits can pose severe durability hazards to metal cladding, especially on surfaces sheltered from rain.

B1.4 Soils and Ground Contaminants

Any material placed in contact with soils and groundwater can be affected by the presence of contaminants. The effect of soil contaminants depends on their combination, concentration and type of soil. Contaminants such as solvents (e.g., gasoline) and oxidizing agents (e.g., acids) can react chemically and dissolve or degrade plastics. Bacterial activity can affect directly or indirectly the deterioration of materials in soils. Sulfate-reducing bacteria, found mostly on wet clay, boggy soils and marshes, are a typical example of bacteria affecting corrosion of metals.

Naturally occurring constituents of the soil promote deterioration, particularly in moist conditions. Salts dissolved in groundwater migrate in porous materials in contact with the ground and cause efflorescence, a common problem with masonry in contact with soil. Naturally occurring sulfates in some soils require the use of specially formulated concrete and mortar mixes to avoid their destruction due to deterioration.

Stray electrical currents in the ground can accelerate corrosion of a metallic object at points where current leaves the object and enters the soil. This effect is pronounced in densely populated oil-production fields and within industrial complexes containing numerous buried pipelines.

B1.5 Biological Agents

Component materials can deteriorate from the direct action of living organisms (e.g., decay of wood by fungi) or from the action of by-products of plant or animal life (e.g., corrosion of metals by the action of sulfate-reducing bacteria).

Microorganisms are usually classified according to their ability to grow in the presence or absence of oxygen. Fungi that cause deterioration of timber need oxygen and moisture. A moisture content of less than about 20 % in timber is usually sufficient to prevent fungi from flourishing. Sulfate-reducing bacteria are most prevalent in environments depleted of oxygen.

The predominant insect problem is termite attack of wood and wood-based materials. Rodents such as mice and rats cause considerable damage by gnawing organic materials and PVC casings to electric cables. Birds and their nests and droppings can cause either mechanical damage (by pecking of soft materials) or chemical damage (corrosion of steel bridges exposed to bird droppings).

A major cause of damage from plants is the clogging of drains and gutters by roots and leaves, which leads to water damage of building components. Trees absorb water from the soil which, for some soils, can result in differential settlement.

B1.6 Temperature

One of the most significant effects of temperature is the deformation of materials subject to variations in temperature. These deformations can result in damage to components and loss of performance. Above-ground pipework, roofing and cladding components are subjected to high temperatures in summer and cold temperatures in winter, and they should be allowed to expand and contract with temperature cycles. Thermal stresses cause buckling, bowing and sometimes breakage of components.

Although most chemical processes are accelerated by an increase in temperature, some are accelerated by a decrease in temperature. This occurs in the corrosion of metals, where low surface temperatures promote condensation on the surface, providing an environment favourable to corrosion. However, if the surface temperature is high, drying of the surface impedes corrosion.

B1.7 Solar Radiation

Organic materials such as polymers and wood can deteriorate if exposed to solar radiation. If radiation contains enough energy, however, it can cause a chemical reaction that results in a gradual change of the material properties, such as embrittlement, yellowing or fading of the colour. Sealants can either crack or lose adhesion at the interface.

Before solar radiation can affect a material, it is necessary for the radiation to be absorbed. The opacity, texture and colour of the surface, and its slope to the sun, considerably affect the ability of materials to absorb radiation. Also, the amount of high-energy UV reaching the ground decreases as the sun angle decreases.

UV radiation also interacts with other agents, such as temperature and moisture, to greatly increase deterioration.

The daily cycle of solar radiation can cause exposed surfaces to experience large temperature swings. This results in cyclic dimensional changes and can also increase the number of freeze-thaw cycles.

B1.8 Chemical Incompatibility

Two materials in contact can cause or accelerate deterioration as a result of chemical interaction. Some examples are:

- Galvanic corrosion between dissimilar metal
- Accelerated corrosion of steel and zinc in certain woods and wood containing certain preservative chemicals
- Corrosion of lead and some aluminium alloys in contact with moist concrete or mortar
- Crazing or fracture of plastic in contact with certain sealants.

B2 Structure Environment, Environmental Action & Control Parameters

B2.1 Structure Environment

Acidity of Precipitation

This is important for material deterioration, including corrosion. Normal rain is slightly acidic with a pH of approximately 5,6 (caused by CO_2 in the air). Organic acids and air pollution can further reduce the pH of rain to less than 5,0.

Driving rain index

The driving rain index (DRI), the product of the annual rainfall, expressed in metres, and the average wind speed, expressed in metres per second, is an indicator of the likelihood of rain wetting and penetrating external walls of buildings. It is usually classified into sheltered (DRI of 3 or less), moderate, and severe (DRI of 7 or more).

B2.2 Environmental Action

Time of Wetness (TOW)

Time of wetness is one of the most important parameters for material deterioration. Corrosion, for example, takes place when a metal surface exposed to the atmosphere is covered by a film of water. The presence of such a film occurs when the relative humidity is above 80 % to 90 % and the temperature is above freezing. Also, time of wetness depends on design details (e.g., retention of moisture between surfaces, gravity water traps). This parameter can be improved by the inclusion of other parameters such as temperature.

Time of Exposure (TOE)

This is a generalization of time of wetness applied for a more specific agent causing environmental action, such as UV on plastic materials, or the concentration of chlorides in concrete adjacent to the reinforcement.

Freeze-thaw cycles (F-T)

This parameter is similar to the number of stress cycles causing fatigue damage to structural materials. The degradation mechanism, however, is different than for fatigue.

Table 12 – Environmental Actions and Control Options

Material	Environmental action	Action effects	Agents, conditions	Design options
Ground soil	Frost heave	Damage to foundation or fabric, floor slope	Fine-grained soils and ground temperature < 0 °C	Foundation location, type of soil
	Swelling and shrinkage of soils	Damage to foundation or fabric, floor slope	Expansive clays and changes in soil moisture content	Control soil moisture changes through paving, drainage and vegetation controls. Design footings to resist movements. Incorporate movement joints.
Timber	Fungal decay	Loss of material, strength, appearance	Sustained moisture and oxygen with temperature ranging from 5 °C to 40 °C	Drainage *(avoid water traps)*, preservatives, ventilation, naturally resistant species
	Subterranean termites	Loss of material, strength	Access from ground, oxygen, temperature > 5 °C	Preservatives, barriers, bait blocks
	Marine borers	Strength, loss of material	Salty or brackish water (e.g., piles)	Preservatives

Material	Environmental action	Action effects	Agents, conditions	Design options
	Drying shrinkage perpendicular to grain	Splitting, damage to other components, floor misalignment, nail popping	High initial moisture content, accumulated thicknesses perpendicular to grain *(beams, stringers, plates)*	Use seasoned timber, compatible materials, design to allow movement
Masonry: see table entries for stone, clay brick, concrete, concrete block and mortar, steel and stainless steel.				
Stone	Acid attack *(leaching)*	Disintegration, disfigurement	Carbonates in stone *(e.g., limestone or sandstone)*, acid rain, lack of drainage, orientation	Choice of stone, pointing of mortar, protective coating
	Movements due to moisture change	Bowing of panels	Type of stone (e.g., marble), thickness	Use thicker section or stiff backing
Clay brick	Freeze-thaw	Spalling, disintegration	Lack of drainage, high moisture content during freeze-thaw cycles, aggravated by non-breathing surface coatings	Manufacturing process, drainage details, breathable coatings, moisture barriers, well-made *(detailed to reduce water ingress)* mortar joints
	Salt crystallization	Efflorescence, occasionally spalling	High moisture content and presence of salts in brick, mortar, or adjacent materials	Low salts in bricks and mortar, drainage details, well-made mortar joints
	Movements due to moisture or temperature variations	Cracking	Restraints	Movement joints
Concrete, concrete block, and mortar	Freeze-thaw cycles	Disintegration, appearance	High moisture content during freeze-thaw cycles, aggravated by chlorides and lack of drainage	Air entrainment, mix design, choice of aggregates, drainage details
	Sulfate attack	Expansion followed by disintegration	Sulfates in groundwater, bricks, coal stockpiles or sea water	Type of cement, mix design, drainage, low sulfate in brick
	Alkali-aggregate reaction	Expansion followed by disintegration	Silica or dolomite aggregates, require moisture	Type of aggregate, type of cement (e.g., low alkali or composite cement) or cement additives, control of moisture
	Shrinkage	Cracking, damage of adjacent components *(e.g., brick veneer)*	High w/c ratio, high moisture content during construction *(concrete blocks)*	Mix design, construction sequence, control joints, reinforcement, curing and moisture control prior to use
For chloride attack and carbonation, see “Steel” and “Corrosion of reinforcement in concrete.”				
Metals (all)	Galvanic corrosion	A wide variety of failures	Electrolyte *(moisture-filled porous material)*, metals electrically connected	Choice of materials, electrical disconnection of adjoining metals
Steel	Corrosion in atmospheric environment	Connector failures, appearance, damage due to rust expansion	Sustained moisture, oxygen, aggravated by acid and hygroscopic impurities	Drainage *(avoid water traps)*, ventilation, protective coatings
	Corrosion in marine environment	Corrosion of piles in splash zone	Sustained moisture, oxygen, aggravated by chlorides	Protective coating, cathodic protection
	Corrosion in soil environment	Pile failures, pipe failures	Sustained moisture, oxygen or anaerobic bacteria, aggravated by soluble salts, stray electric currents	Type of soil *(test for resistivity, bacteria, etc.)*, protective coating, cathodic protection

Material	**Environmental action**	**Action effects**	**Agents, conditions**	**Design options**
	Corrosion of reinforcement in concrete environment	Loss of bond, failure of reinforcement, cracking and delamination of concrete	Sustained moisture, oxygen, chlorides or pH reduced by carbonation	Protective barriers, concrete mix, drainage details
	Corrosion of reinforcement in masonry environment	Failure of connectors, cracking of masonry	Sustained moisture, oxygen, aggravated by salts	Zinc coatings, stainless steel
	Corrosion in timber environment	Failure of connectors and surrounding timber	Sustained moisture, oxygen	Drainage *(avoid water traps)*, ventilation, protective coatings
Weathering steel	Corrosion: atmospheric environment	Connection failures, damage due to rust	Retention of water between surfaces, sea water	Detailing to avoid accumulation of water between surfaces
Stainless steel	Pitting/crevice corrosion, intergranular corrosion, stress corrosion cracking	Connector failures	Type of stainless steel, aggravated by warm chlorinated atmospheres, high stress	Type of stainless steel
Aluminium alloys	Corrosion *(dark pitted appearance)*	Downgrading of appearance, connector failures	Type of alloy, surface finish, contact with alkaline solution, contact with copper, copper-containing solution, or other metals	Drainage *(avoid contact with alkaline solutions or damage from large dissimilar metal surface area)*, protective coatings
Copper and alloys	Dezincification of brass	Failure of fasteners by loss of strength or cracking	Type of brass	Material selection (brass with less than 20 % zinc
	Stress corrosion cracking	Failure of fasteners, cracking	High humidity, composition of brass	Annealing to reduce residual stresses
Glass	Thermal stress	Cracks starting at edge	Unequal solar heating *(centre hot, edges cold)*; shadows, heat-absorbent glass, indoor heat	Avoid heat traps and strong shading; produce clean-cut edges or finish them well; heat strengthening
	Etching, leaching	Hazy appearance, milky or scummy deposit, darkening	Alkaline runoff from masonry or concrete; acid rain or water that leaches alkalis	Drain contaminated runoff away from glass
Polymers *(natural and synthetic rubbers, sealants, roof membranes)*	Chemical degradation, oxidation, ozonation	Loss of strength, cracking	Contact with oils and the atmosphere	Avoid contact with oils, selection of suitable synthetic rubber
Plastics, GRP	Moisture absorption	Fibre “pop-out”, loss of toughness	Presence of moisture	Drainage, cut edges should be sealed
GRP/FRP, other plastics	Chemical attack under tensile stress	Crazing and possible fracture	Exposure to solvents or contact with some sealants, tensile stresses	Avoid use of solvents, select compatible sealant
	Fatigue induced by temperature and moisture fluctuation	Surface cracking, degradation of mechanical properties	Exposure to temperature and humidity fluctuation, UV light	Surface protection from UV exposure
	Oxidation and photo-oxidation	Degradation of mechanical properties, discolouration, hazing, dullness	Exposure to UV light	Use of surface coating and/or UV absorber

Appendix C – Durability Process Across the Asset Lifecycle

Credit: Concrete Institute of Australia Z7/01

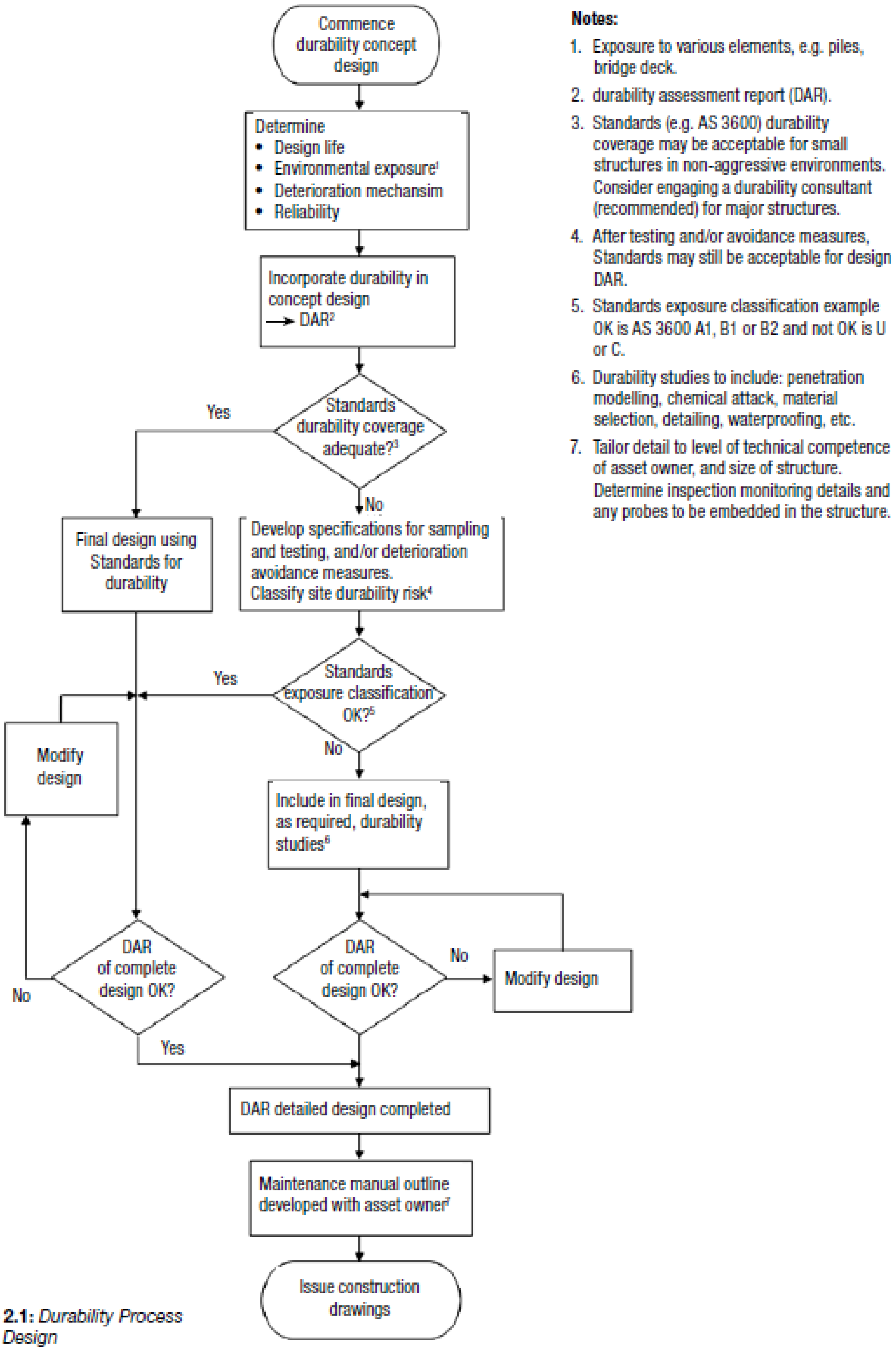
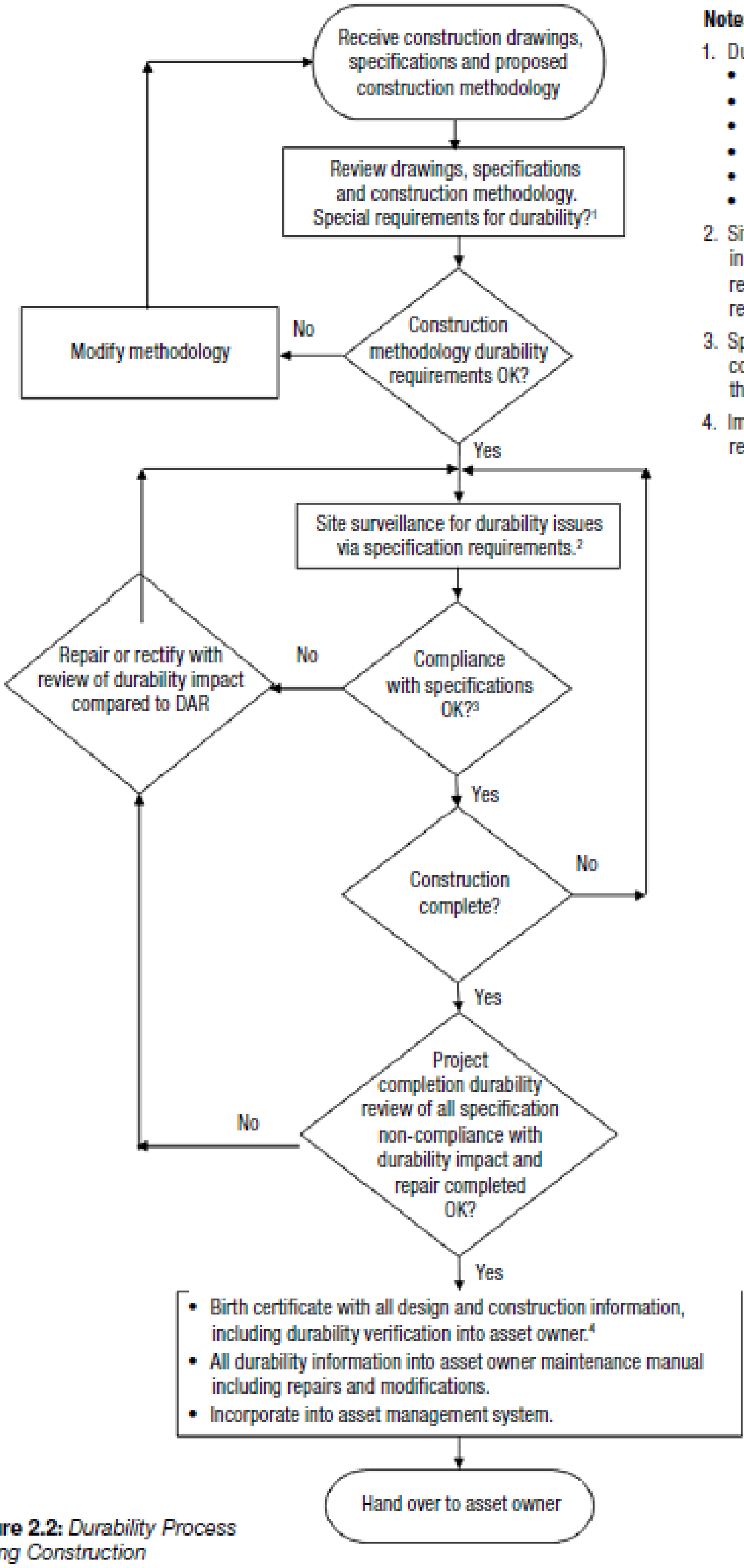


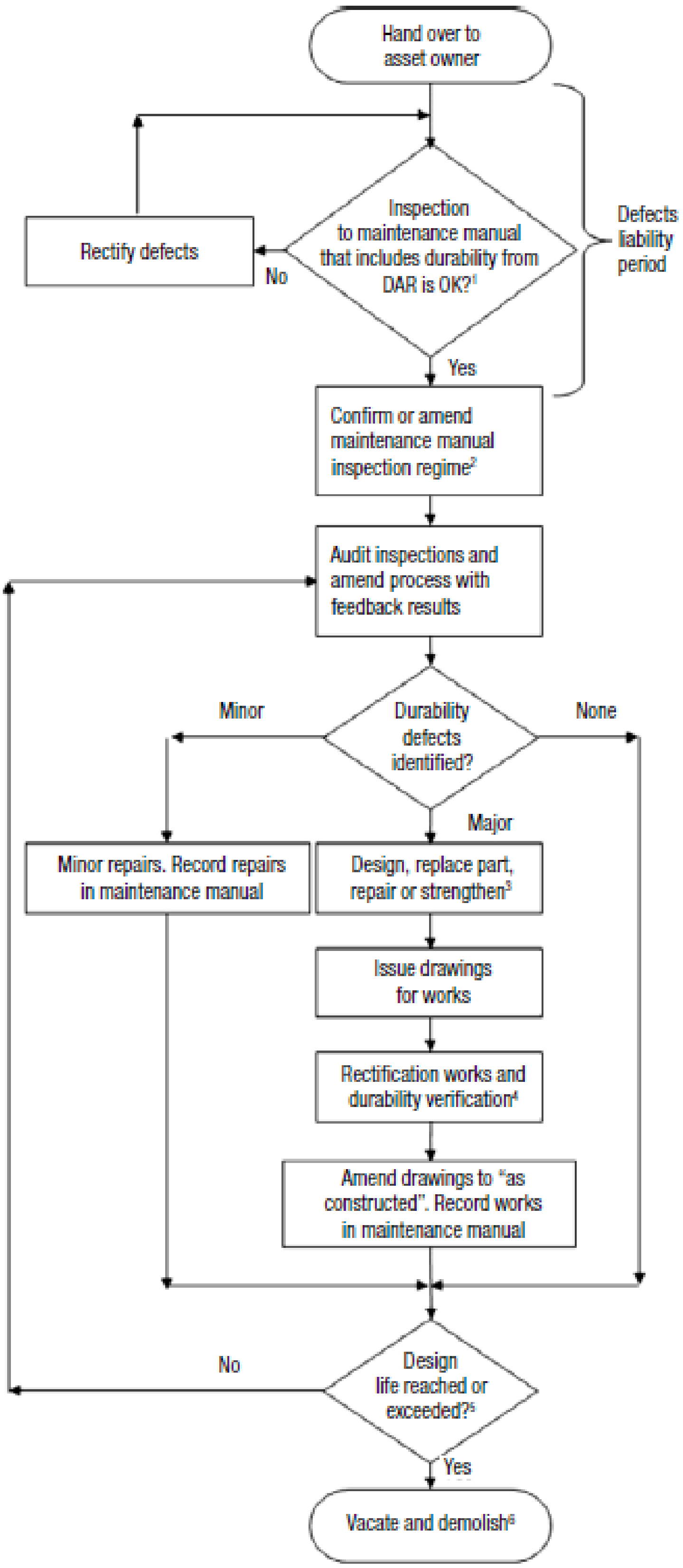
Figure 2.1: *Durability Process During Design*



Notes:

1. Durability requirements include:
   - Compaction possible
   - Cover
   - Curing
   - Construction sequence
   - Construction joints
   - Waterproof details
2. Site surveillance and durability input in QA/QC, inspection and test plan (ITP), request for information (RFI), non-compliance report (NCR), etc.
3. Specification non-compliance examples are concrete cracks or voids and water leakage that need repair.
4. Important for future maintenance, repair, part replacement or strengthening.

Figure 2.2: *Durability Process During Construction*



Notes:

1. Asset owner and/or a representative does inspection. They use maintenance manual and DAR for future reference.
2. Frequency depends on infrastructure type and risks of failure (e.g. fixed schedule for bridge routine, general, detailed and special investigations).
3. Follow durability design flow chart.
4. Follow durability construction flow chart.
5. Design life may be extended with regular maintenance.
6. If structure is unsafe and repair not viable, it should be decommissioned and/or demolished.

Figure 2.3: *Durability Process During Service Life*

Appendix D – Schedule of Hold Points

Table 13 – Schedule of Hold Points*

Type	Description
Hold Point	Concept Design Report
Hold Point	Durability Assessment Report: Concept Design
Hold Point	Detailed Design Report
Hold Point	Durability Assessment Report: Detailed Design
Hold Point	Durability Assessment Report: Verification Report
Hold Point	Refer Note*

***Note: ****The Durability Design shall nominate additional relevant durability **HOLD POINTS** during design, which are to be provided in the Durability Assessment Report: Detailed Design (DAR:DD).*

Appendix E – Example DAR for Water Storage Tank

Table 14 – Durability Assessment Report Example Contents

Item	Description
E1	General
E2	Design Life
E2.1	Project Assets and Component Design Life
E2.2	Expected Maintenance during Design Life
E3	Reinforced Concrete Early-age Temperature and Crack Risk Assessment
E3.1	Assessment Methods
E3.2	Assessment Outcomes
E4	Durability Assessment of Reinforced Concrete
E4.1	General
E4.2	Concrete Specification
E4.3	Concrete Mix Design
E4.4	Acceptable Crack Widths
E4.5	Formwork and Insulation
E4.6	Curing General
E4.7	Site Crack Inspection
E4.8	Site Concrete Cover Measurements
E4.9	Concrete Placement
E4.10	Concrete Wall Compaction Testing
E4.11	Crack Repair
E4.12	Bar Chairs and Reinforcement Spacers
E4.13	Ready Mixed Concrete Supply
E4.14	Protective Coatings for Concrete
E5	Metal Structural Elements
E5.1	Structural Steelwork
E5.2	Roof and Wall Cladding
E5.3	Roofing Watertightness Test
E6	Pipework, Fasteners, Grouting, Valves and Pumps
E7	Access Infrastructure
E8	Waterproofing
E9	Building Secondary Containment Bund
E9.1	Precast Building Wall Panels
E9.2	Constructor Waterproofing Method Statement
E9.3	Watertightness Testing Liquid Retaining Structures
E10	Concrete Crack & Joint Construction Assessment Process and Repair Criteria
E11	Form Ties
E12	Building Envelope
E13	Construction Phase Compliance Assessment
E14	Future Durability Plan Program

E1 General

Example outputs of a Durability Assessment Report are provided below, with all examples related to a water storage tank.

Table 15 – Example Outcomes & Recommendations Summary

Critical Structural Elements	Targeted Design Life Example Values Used (Report Section ??)	Significant Reinforced Concrete and Metal Elements Durability Considerations (Report Sections ??)	Exposure Conditions (Report Section ??)	Specific Criteria (Report Sections ??)	Recommended Design Solutions (Report Sections ??)
15ML Tank					
Reinforced Concrete Floor Slab and Ring Beam below Walls ?? and ?? mm thick slab, ?? mm thick ring beam	100	Cracking Reinforcement Corrosion Deterioration of concrete due to water chemistry Deterioration of concrete due to water chemistry Concrete QC (e.g., curing)	Water Submerged Contact: Depends on water conditions that must be checked for this Tank. Category ?? AS 3735:2001. Atmospheric Exterior: Category ?? AS 3600:2018 Ground: Category ?? AS 3600:2018 ?? AS 2159:2009	Design target crack width ≤ ?.? mm	Mix Design: ?? Min. Reinforcement Cover (exterior): ?? mm Min. Reinforcement Cover (interior): ?? mm Reinforcement at ?? & ?? mm thick concrete: Reinforcement is unknown. Concrete early-age thermal/restraint and shrinkage assessment at design and construction can be completed once the reinforcement details and construction sequence are known prior to construction.
Reinforced Concrete Walls ?? mm thick	100	Cracking Reinforcement Corrosion Deterioration of concrete due to water chemistry Concrete QC (e.g., wall compaction)	Water Submerged Contact: Depends on water conditions that must be checked for this Tank. Category ?? AS 3735:2001. Water Wetting Contact: Depends on water conditions that must be checked for this Tank. Category ?? AS 3735:2001. Atmospheric Exterior: Category ?? AS 3600:2018 Atmospheric Interior: Category ?? AS 3735:2001 ?? AS 3600:2018	Design target crack width ≤ ?.? mm	Mix Design: ?? Min. Reinforcement Cover (exterior): ?? mm Min. Reinforcement Cover (interior): ?? mm Reinforcement at ?? & ?? mm thick concrete: Reinforcement is unknown. Concrete early-age thermal/restraint and shrinkage assessment at design and construction can be completed once the reinforcement details and construction sequence are known prior to construction.
Precast Concrete Columns ?? mm × 400mm	100	Cracking Reinforcement Corrosion Concrete QC (e.g., column compaction) Precast handling and transport	Water Submerged Contact: Depends on water conditions that must be checked for this Tank. Category ?? AS 3735:2001. Water Wetting Contact: Depends on water conditions that must be checked for this Tank. Category ?? AS 3735:2001. Atmospheric Interior: Category ?? AS 3735:2001 ?? AS 3600:2018	Design target crack width ≤ ?.? mm	Mix Design: ?? Min. Reinforcement Cover: ?? mm
Roof Sheeting & Fasteners	25, check fasteners at 10 years intervals	Metal corrosion Metal QC (e.g., coating thickness and defects)	Atmospheric Internal: Category ?? (AS/NZS 2312:2002) Atmospheric External: Category ?? (AS/NZS 2312:2002)	Protective Coatings	Roof sheeting: ?? roof sheeting with minimum BMT of ?.? mm and coated in accordance with AS 1397 Class Z??. Fasteners: Fasteners plus seals in accordance with ???? roof sheeting manufacturer recommendations and fasteners in accordance with AS 3566.2 Corrosion Resistance Class ??.

Critical Structural Elements	Targeted Design Life Example Values Used (Report Section ??)	Significant Reinforced Concrete and Metal Elements Durability Considerations (Report Sections ??)	Exposure Conditions (Report Section ??)	Specific Criteria (Report Sections ??)	Recommended Design Solutions (Report Sections ??)
Roof Steel Support Beams & Fasteners	100, major maintenance at 25 year intervals and check fasteners at 10 years intervals	Metal corrosion Metals QC (e.g., galvanising thickness)	Atmospheric Internal: Category ?? (AS/NZS 2312:2002)	Galvanising	Roofing structural steel beams including fasteners: Beams and fasteners hot-dip galvanised in accordance with AS 4680 for beams and AS 1214 for fasteners.
Roof Purlins & Fasteners	100, coating maintenance and check fasteners at 10 years intervals	Metal corrosion Metal QC (e.g., coating thickness and defects)	Atmospheric Internal: Category ?? (AS/NZS 2312:2002)	Protective Coatings & Galvanising	Purlins: Purlins plus bridging coated in accordance with AS 1397 Class Z??. Fasteners: Fasteners in accordance with the purlin manufacturer recommendations and to be hot-dip galvanised in accordance with AS 1214.
Pipelines					
MSCL Pipes within Tank Boundary	80	Metal Corrosion Metal QC (e.g., coating thickness and defects) Cement Liner QC (e.g., crack and debond defects) Cathodic Protection QC (e.g., electrical continuity and interference) Acid Sulphate Soils	Buried External: Within selected fill surrounding the pipe, or mass concrete encasement with Grade ?? (typical assumption). Water Internal: Based on local previous water supply data, assumed water quality is Category ?? (AS 3735:2001)	-	Pipes Below Ground External (from isolation joint at tank floor to end of concrete encasement): Bare pipe embedded in mass concrete encasement of Grade ??. ?? protective coating applied to first ?? mm of pipe in concrete encasement. Pipes Buried External (from end of concrete encasement within tank boundary): ?? protective coating. Pipes in selected fill free of chemical contamination and high soil resistivity (>150 ohm.m). CP protection is/is not?? required based on available information. Pipeline Internal: Cement Mortar Liner (CML).
Stainless Steel Pipe fittings inside the tank and concrete floor slab (i.e., flanges and nozzle, overflow, outlet and scour) and outside the tank (i.e., inlet pipe riser)	80	Metal Corrosion Metal QC (e.g., fabrication and installation defects)	Water Internal: Based on local previous water supply data, assumed water quality is Category ?? (AS 3735:2001) Water External: Based on local previous water supply data, assumed water quality is Category ?? (AS 3735:2001) Atmospheric External: Category ?? (AS/NZS 2312:2002)	-	Stainless Steel Grade 316 or “L” if welded.
PE Pipes	80 (if used above ground portions potential UV damage major refurbishment/replacement at 50+ years)	Degradation Placement and Handling QC (e.g., Mechanical Impact Damage)	Buried External Water Internal & External		PE Pipeline should be supplied and installed in accordance with SA Water requirements. If PE pipeline was to be used above ground it should be supplied with a UV resistant outer layer complying AS 4130 or protected from direct sunlight exposure (no above ground use presently intended).

Note: “??” is used to indicate details to be inserted.

E2 Design Life

E2.1 Project Assets & Component Design Life

A table with all project assets and components listed together with their respective design life is to be included in the DAR. An example table is provided below for water tank project assets and components design lives.

Note: These values are from TS 0109 and shall be checked for the specific project.

Table 16 – Project Asset Design Life

Project Assets	Minimum Design Life (years)
Building	100
Mechanical assets	25
Cranes	50
Valves	50
Instrumentation & Control	15

Table 17 - Project Component Design Life

Component	Minimum Design Life (years), all with appropriate maintenance
Tank Reinforced Concrete Components: Footings, Floor Slabs, Walls and Precast Columns	100
Wall & Floor Construction Joint with flexible sealant	25
Wall & Floor Construction Joint with encased Waterstop	100
Roof Sheeting & Fasteners	60
Roof Steel Support Beams & Fasteners	100
Walkways, ladders and stairways	50
MSCL – Tank Inlet, Outlet, Scour and Overflow Pipes	100
Stainless Steel – Tank Inlet Pipe Riser	100
HDPE, PVC (buried)	100

E2.2 Expected Maintenance during Design Life

Use Section 6 with any changes to be approved by SA Water via a TDRF.

A table with all project assets and components listed together and the respective expected maintenance during the design life for design expected operating conditions shall be included in the DAR.

An example table is provided below for a water tank, **which are not SA Water approved values for standard use.**

Table 18 - Project Component Expected Maintenance

Component	Expected Maintenance during Design Life
Reinforced Concrete Floor Slab	• Nil. • Inspect when any interior visits and when the tank is water emptied.
Reinforced Concrete Walls	• Nil. • Inspect when any interior visits, for above water level and the entire wall when the tank is water emptied. • Inspect exterior when visiting to inspect other components.
Wall & Floor Construction Joint with surface Sealant	• 25 years before major joint seal replacement. • Inspect wall joints when any interior visits for above water level. Inspect all floor and wall joints when the tank is water emptied. • Replace sealant when damaged. • Material manufacturers will not provide a long-term life expectancy for surface sealant products, with a warranty to 10 years available. Service life from 10 to 25 years is primarily influenced by the initial installation and secondly the operational conditions (normal stable in water tanks).
Wall & Floor Construction Joint with encased Waterstop	• 100 years with no expected waterstop replacement. • No inspection possible with waterstop encased in the concrete. Material manufacturers will not provide a long term life expectancy for waterstop products. The common present day used products when appropriately installed are not subject to materials deterioration (e.g., no ultraviolet light to degrade the PVC material). Fatigue cycling is not expected to initiate failure in the normally expected environment and dewatering the tank for operational cleaning will not significantly change the slab base moisture condition.
Precast Concrete Columns	• Nil. • Inspect when any interior visits for above water level and the entire column when the tank is water emptied.
Steel Roof Sheeting & Fasteners	• Coating maintenance at 10 years intervals. • 60 years before major replacement. • Fasteners inspection at 10 years intervals and inspect other components during this visit.
Steel Roof Steel Support Beams & Fasteners	• Major re-coating/maintenance of structural steel and fasteners at 25 years intervals. • 100 years before major replacement. • Fasteners inspection at 10 years intervals and inspect other components during this visit.
Steel Roof Purlins & Fasteners	• Coating maintenance at 10 years intervals. • 100 years before major replacement. • Fasteners inspection at 10 years intervals and inspect other components during this visit.
Steel Access Facilities and Landings	• Coating maintenance at 10 years intervals. • 50 years before major replacement. • Fasteners inspection at 10 year intervals and inspect other components during this visit.

Component	Expected Maintenance during Design Life
Mild Steel Pipes – Tank Inlet, Outlet, Scour & Overflow below the Tank	• Buried Pipes (concrete encased): • Nil. Mass concrete encasement of Grade ?? concrete provides corrosion protection. • Buried Pipes (Sintakote, small portion not concrete encased): • Nil. Sintakote coating or tape wrapping in fill free of chemical contamination and high soil resistivity (>150 ohm.m) provides corrosion protection. • Cathodic protection (CP) system audits if a CP system is applied to the pipeline. • Internal: • Cement mortar liner assumed remains intact.
Stainless Steel Pipes – Tank inlet pipe riser	• Nil. • Inspect when visiting to inspect other exterior components and no replacement expected.
FRP Pipes – Tank overflow pipe riser	• Nil. • Inspect when visiting to inspect other interior components and no replacement expected.
PE Pipelines	• Nil.

Table 19 – Project Exposure Classification Summary

Material & Component	**Exposure Assessment**	**Exposure Classification to AS 2159, AS 2312.1, AS 3600 and AS 3735**
Reinforced Concrete Cast on polythene sheeting and blinding concrete.	The subbase will be minimum ??? mm thick compacted sand free from high levels of chlorides or sulfates (classified as non-aggressive to AS 2159). A 0.2 mm polythene sheeting (expected taped at all joints) to be placed over the ?? mm thick blinding concrete prior to casting concrete floor slabs. This will stop moisture loss from fresh placed concrete onto the substrate.	AS 3600: ??
Reinforced Concrete In contact with soil or fill.	The backfill will be clean imported fill or re-used site material classified as non-aggressive to AS 2159. Site native soil is ?????, typically non-aggressive/aggressive??. Site testing for shallow AASS/PASS does not/does ??? indicate presence of AASS/PASS. Fill to be non-aggressive, comply with AS 4678 Table D6 ????. All structures will be constructed above ground water table???.	AS 3600: ?? AS 2159: ??
Reinforced Concrete Exterior in contact with the atmosphere, not subject to splash or spray wetting by process water.	The site is situated in a near-coastal temperate urban location, approximately ?? km from the nearest coastline. The site is remote from significant sources of industrial pollution.	AS 3600: ??
Reinforced Concrete Dominantly submerged in process water.	Process water quality is generally expected to be calcium deficient, soft water leaching is expected. Flowing water in Aerator basin and sump.	AS 3735: ?? (general) AS 3735: ?? (Aerator) AS 3600: ??
Reinforced Concrete Above water level, subject to splash or spray wetting by process water.	Process water quality is generally expected to be/not to be ?? calcium deficient, soft water leaching is expected/not expected ?? in splash or spray exposures.	AS 3735: ?? AS 3600: ??
Reinforced Concrete Containment Bund.	No/low/medium/severe ????? chemical exposure in event of spill. Protection by ??? coatings required to surfaces potentially subject to immersion, splash or spray. ???? sealant in construction joints potentially subject to immersion, splash or spray.	AS 3735: ??? AS 3600: ???
Metal External in contact with the atmosphere.	The site is approximately ?? km from the nearest coastline/inland saline water??. The site is remote from significant sources of industrial pollution.	AS 2312.1: ???

Material & Component	Exposure Assessment	Exposure Classification to AS 2159, AS 2312.1, AS 3600 and AS 3735
Metal Subject to splash or spray wetting by process water.	Aerator screen wall supports. No/continuous ?? exposure to process water spray???. The site is approximately ?? km from the nearest coastline/inland saline water??. The site is remote from significant sources of industrial pollution????.	AS 2312.1: ??
Metal Internal in contact with headspaces above process water, no splash or spray.	The site is approximately ?? km from the nearest coastline/inland saline water??. The site is remote from significant sources of industrial pollution????.	AS 2312.1: ???
Metal In contact with soil or fill.	Soil ????, expected typically low/medium/high??? in chloride and sulfate. Native soil pH ???. Evidence/no evidence ??? of AASS/PASS. Fill to be non-aggressive, comply with AS 4678 Table D6???.	AS 2159: ?????

Note: “??” is used to indicate values to be inserted.

E3 Concrete Early-Age Temperature & Crack Risk Assessment

E3.1 Assessment Methods

The assessment method is in accordance with TS 0710.

Review, determine and list the concrete elements that require concrete early-age thermal/restraint and shrinkage modelling of concrete temperature and crack risk.

E3.2 Assessment Outcomes

Provide summary outcomes of the concrete early-age crack assessment, in particular for potential water leakage.

The crack assessment is likely to be in a separate report because then assessment updates for any design changes can occur until the drawings are issued for construction. The Durability Assessment Report can be completed separately.

E4 Durability Assessment of Reinforced Concrete

E4.1 General

Provide general comments on durability assessment of the reinforced concrete for the project.

Complete assessment for all project reinforced concrete exposure conditions including atmosphere, soil, water and chemicals.

E4.2 Concrete Specification

Reference will be made to the Concrete Specification, which may be TS 0710 or a project specific Concrete Specification as approved by SA Water.

E4.3 Concrete Mix Design

The concrete mix designs selected for the concrete specification requirements shall comply with the requirements of TS 0710 and will be listed in a table with ongoing review as the design develops.

E4.4 Acceptable Crack Widths

Review concrete crack widths that will be acceptable in accordance with TS 0710 requirements and provide guidance for investigations during construction if non-compliant cracks are identified.

E4.5 Formwork and Insulation

Review formwork and insulation to be used by the Constructor, noting formwork requirements per TS 0712.

E4.6 Curing General

Review curing of concrete to be used by the Constructor, which shall be in accordance with TS 0710.

E4.7 Site Crack Inspection

Constructor site crack inspections to be undertaken during construction with feedback to the Durability Consultant and Designer for review.

E4.8 Site Concrete Cover Measurements

Review Constructor site concrete cover measurements undertaken during construction.

E4.9 Concrete Placement

Review Constructor site concrete placement method statement, including dosing regimen for any admixtures to be used, quality assurance procedures of the Constructor, and locations posing higher risks of non-conformances that may negatively impact durability outcomes.

E4.10 Concrete Wall Compaction Testing

Review Constructor site concrete wall compaction testing undertaken during construction.

E4.11 Crack Repair

Review concrete crack repair methods (considered alongside the requirements of TS 0710 and TS 0711) and provide guidance for repair methods and materials during construction if non-compliant cracks are identified.

E4.12 Bar Chairs & Reinforcement Spacers

Review the bar chairs and reinforcement spacers to be used by the Constructor.

E4.13 Ready Mixed Concrete Supply

Review available ready mix concrete supply readily available for the project location, which shall be in accordance with TS 0710.

E4.14 Protective Coatings for Concrete

Review and determine if any protective surface coatings or treatments need to be applied to concrete surfaces in accordance with TS 0711.

E5 Metal Structural Elements

E5.1 Structural Steelwork

The major deterioration risk for steelwork is atmospheric corrosion unless other project specific issues are identified.

Steelwork can be acceptably protected using appropriate hot dip galvanised systems in accordance with AS/NZS 4680 to give the required minimum period until first maintenance. The use of specific hot dip galvanized elements that must be determined for the structural steel is considered acceptable, on the basis:

- The steel pipe supports, access platforms and grating are generally accessible for inspection and maintenance.
- Any existing steelwork on the project that has been constructed from galvanized mild steel with no known significant corrosion issues.

The structural steelwork will be durability reviewed and the appropriate hot dip galvanised systems determined in accordance with AS/NZS 4680.

E5.2 Roof & Wall Cladding

Metal roof and wall cladding will be generally exposed to a specific corrosivity Category to be determined for the project location both internally and externally to AS 4312. Cladding is to comply with requirements in TS 0721.

For the purposes of durability assessment and design life compliance, supporting elements such as purlins, girts, bridging, and attendant fastenings are typically considered to be part of the cladding unless other project specific issues are identified.

The wall and roof sheeting will be durability reviewed to determine:

- Roof sheeting base metal and coating system, BMT thickness in mm based on manufacturer's information, AS 2312 and roof structural design.
- Protective coating to purlins, girts and bridging pieces are to be minimum category Z values to AS 1397.
- All fasteners and seals for roof sheeting to be in accordance with the roof sheeting manufacturer's recommendations, with fasteners in accordance with AS 3566.2 Corrosion Resistance Class to SA Water requirements and EPDM seals.
- Ventilation and condensation barriers to be provided as required.

E5.3 Roofing Watertightness Test

All roof sheeting to be tested once completed for water tightness, with testing and success criteria to be in accordance with TS 0600.

E6 Pipework, Fasteners, Grouting, Valves & Pumps

Complete assessment for all items for exposure conditions below, noting testing requirements per TS 0210.

Assess the requirement for cathodic protection to be applied to underground MSCL pipelines, which shall be in accordance with TS 0440.

- MSCL Pipes
  - MSCL Pipes – External Exposed to Atmosphere
  - MSCL Pipes – External below Ground
  - MSCL Pipes – External below Ground Cathodic protection
  - MSCL Pipes – Internal
- Stainless Steel Pipe Fittings
- PE Pipelines and uPVC Pipelines
- GRP / FRP Pipelines
- CPVC Pipelines
- Fasteners
  - Fasteners in Tanks
  - Fasteners – Stainless Steel Pipelines
  - Fasteners – In Bore Fittings and Fixings

Provide a summary of all pipelines used on the project, materials durability acceptable for the required design life and any special protection requirements.

Provide general details for grouting to be used on the project.

Review and provide general details for grouting of metal and concrete elements.

Complete assessment for pumps and if any special requirements apply for the project exposure conditions.

Complete assessment for values and if any special requirements apply for the project exposure conditions.

Complete assessment of any other matters for pipes, valves and pumps not adequately described above.

E7 Access Infrastructure

Complete assessment for access infrastructure elements and materials, which shall be in accordance with TS 0720.

E8 Waterproofing

Provide a summary Waterproofing Plan for the project covering:

- General comments on the waterproofing for the project.
- Installation of waterproofing barriers
- Review Constructor intended installation of waterproofing barriers.
- Review and assessment of all water proofing barrier methods
- Joint Waterproofing Details
- Review and assess all water proofing details including but not limited to pipe penetrations.

E9 Building Secondary Containment Bund

E9.1 Precast Building Wall Panels

Review durability for precast panels, inserts and fasteners.

E9.2 Constructor Waterproofing Method Statement

Review the Constructor waterproofing method statement.

E9.3 Watertightness Testing Liquid Retaining Structures

Review testing for liquid tightness of liquid retaining structures, to be completed in accordance with TS 0600.

E10 Concrete Cracking & Joint Construction - Assessment & Repair

Review crack and joints construction assessment and repair criteria as a guide for the approach to be adopted if defects and non-compliance occurs during the Works.

E11 Form Ties

Review form ties to be used to ensure compliance with the requirements of TS 0710 and that durability outcomes are achieved, which is of particular importance for liquid retaining structures.

E12 Building Envelope

Building envelopes will be designed and detailed to be sufficiently watertight to prevent water damage and corrosion of internal components, creation of safety hazards, or damage to equipment that results in compromise of operations. Necessary penetrations such as ventilation fixtures should be designed and installed in a manner that does not allow water penetration.

All cladding elements should be provided with appropriate flashings and seals at terminations, joints and penetrations (doors, windows, utilities/services) to maintain the building envelope in a watertight condition for the life of the cladding.

Detailing must be such that the durability of the flashing, cladding or seal is not adversely affected by condensation or pooling water, or by retention of moisture in interstices such as interlayer gaps.

Stormwater handling to prevent water accumulation and bypassing of building envelope waterproofing components will be an integral part of the building envelope waterproofing strategy.

E13 Construction Phase Compliance Assessment

Durability compliance will be in accordance with the requirements of the Durability Plan Process and Durability Assessment Report Deliverables in Tables 1 and 2 of TS 0110 respectively.

The inspection and testing shall be in project specifications and/or comply with SA Water requirements for the structure and elements (e.g., TS 0710 for concrete).

Durability review will be completed for inspection and testing plans for construction, in particular for durability critical elements of materials and workmanship.

E14 Future Durability Plan Program

Durability compliance will be in accordance with the requirements of the Durability Plan Process and Durability Assessment Report Deliverables in Tables 1 and 2 of TS 0110 respectively.

Durability review will be completed for operational and maintenance requirements including inspection and testing plans, corrosion monitoring of reinforced concrete structures, coupons for corrosion of steel structures, performance monitoring for structure type, etc.

Appendix F – Potential Concrete Durability Issues

F1 General

This Section outlines potential durability issues for reinforced concrete elements.

F2 Concrete Degradation

Alkali Aggregate Reaction (AAR): AAR deterioration of concrete can occur with certain aggregate types, which react and decompose in the presence of moist alkaline conditions (within concrete). Using non-reactive aggregate and/or low alkali cements alleviates the potential for this form of deterioration. The concrete premix supplier must submit AAR test results for coarse and fine aggregate prior to the start of concrete works, to confirm the aggregate is acceptable for use in concrete.

Backfill & Soil Chemical Induced Deterioration: The concentration of sulfate, as well as highly alkaline or highly acidic conditions of the proposed back fill materials may be harmful to concrete. Additionally, microbiological activity within the soil or the concrete is known to cause damage to concrete. These problems are addressed by chemical analysis of the proposed fill materials and the local soil conditions. The Constructor to check that fill materials are free from high levels of chlorides or sulfates and that the concrete will be cast on the polythene sheeting membrane, which will avoid concrete damage from the soil.

Delayed Ettringite Formation (DEF): DEF is a potential degradation mechanism that may occur in steam cured precast reinforced concrete elements. It is generally accepted that to effectively prevent concerns relating to DEF, the temperature of the concrete during steam curing has to be monitored, rather than the steam temperature, and that for concrete temperatures of 70°C for cement type GP and 80°C for cement type LH or less, DEF is not likely with normally available cements. The precast concrete must comply with these temperature limits.

Acid Sulfate Soils (ASS): ASS are naturally occurring soils containing pyrites, or chemical precursors of pyrite, which have begun to oxidise through exposure to oxygen. When water passes through ASS, sulfuric acid is leached out. Potential Acid Sulfate Soils (PASS) are similar to ASS in nature but are in an unoxidised state. Engineering operations on ASS and PASS, such as excavation, dredging and draining accelerate the exposure of pyritic material to air and speeds up the production of acidic waters. These problems are addressed by chemical analysis of the proposed fill materials and the local soil conditions.

Soft Water Attack: The form of chemical attack on the concrete known as “soft water attack” occurs from water deficient in calcium. In soft water attack, the water that is in contact with the concrete progressively dissolves the calcium hydroxide phase from the cement matrix. The loss of calcium hydroxide and resultant reduction in pH results in destabilisation of the calcium silicate hydrates that form the binding component of the cement. As these silicates break down, integrity of the cement matrix is lost, and the aggregate is released from the surface with sufficient cement matrix loss. Water quality test data for the project to be assessed to determine the level of soft water attack that will be considered for the concrete structures.

Biogenic Acidic Concrete Damage and Reinforcement Corrosion: Sewage, both fresh and stale is essentially non-aggressive to concrete and, in general, concrete submerged in sewage deteriorates at a very slow rate. Under anaerobic conditions however, such as slowly moving or stagnant conditions, hydrogen sulfide gas (H_2S) is generated by bacteria in the submerged slime layers and is released further downstream into the space above the sewage. Turbulence increases the release of hydrogen sulfide gas. In dry conditions, the hydrogen sulfide may oxidise to elemental sulfur. In moist conditions, which is the usual case, the hydrogen sulfide dissolves in water condensed on the surface of the sewer pipe and through aerobic bacterial reaction with oxygen (which include various types of Thiobacillus bacteria), is oxidized to form sulfuric acid. Due to the porous nature of concrete this acid is absorbed (to a greater or lesser extent, depending on concrete quality) into the capillary pores. From here it can attack the cement paste from within. The rate at which this occurs depends not only on the quality of the concrete but the concentration of hydrogen sulfide in the air and the humidity. Given this attack mechanism, the sewage asset surfaces most at risk are atmospheric headspaces where condensation will occur, typically the underside of slabs in pits or tanks, and the crown close to the dry weather flow water line in pipes. The acid can also attack exposed metals or protective coatings and can cause very severe damage where ventilation is poor. The degradation is visually apparent as loss of surface cement paste, staining and exposure of aggregates, or corrosion of metal surfaces. The extent of acidification can be determined by pH tests of concrete surfaces and the significance of the attack is assessed in relation to original structure section, depth of acidification and depth of reinforcement.

Chloride ingress: Process water quality, for precast columns in water tanks and reservoirs in particular, creates chloride induced reinforcement corrosion risk just above the water level primarily due to capillary rise/evaporation cycle mechanism that can deposit chlorides into the concrete from relatively low chloride concentrations in water.

F3 Reinforcement Corrosion

The potential mechanisms for initiation of reinforcement corrosion in concrete structures are:

Carbonation: Atmospheric carbon dioxide (CO_2) in the presence of moisture, reacts with hydrated cement minerals (primarily $Ca(OH)_2$) in the cement paste to reduce the pH of concrete (normally between 12.5 and 13.5) to pH 11 or below. Consequently, as the carbonation front advances and reaches the steel reinforcement it changes the alkaline and passivating environment of the cement paste to one in which the steel may become active and corrode in the presence of moisture. Durability design stage modelling of carbonation induced reinforcement corrosion can be completed (refer CIA Z7/05).

Chloride ingress: The chloride concentration present in concrete is particularly important with respect to reinforcement corrosion. The presence of chloride ions can depassivate steel reinforcement in concrete and promote corrosion (together with carbonation, this is the most common mechanism of initiating reinforcement corrosion). Chloride contamination may originate from wind-borne aerosols depositing on the external atmospheric exposed concrete surfaces from the coast or inland salinity or less likely from concrete mix constituents (e.g., mix water, sea sand, curing water or accelerating agent). The chloride ion content of the concrete is therefore particularly important with respect to reinforcement corrosion. The presence of chloride ions can depassivate the steel and promote corrosion. Chloride levels as low as 0.02% by weight of sample are enough to activate steel corrosion in concrete. The commonly quoted threshold value for typical widespread initiation of reinforcement corrosion by chloride ions is 0.06% by weight of concrete sample. This deterioration mechanism is heightened by cracking, low cover depth, inappropriate material selection or workmanship. Durability design stage modelling of chloride induced reinforcement corrosion can be completed (refer CIA Z7/05).

Chloride ingress due to process water quality for precast columns in water tanks and reservoirs needs to consider the chloride induced reinforcement corrosion risk just above the water level primarily due to capillary rise/evaporation cycle mechanism that can deposit chlorides into the concrete from relatively low chloride concentrations in water. Risk assessment is to be based on the expected chemistry of the stored water, in particular the chloride concentration. This mechanism can also affect walls at the same height and should be design assessed however, columns have significantly earlier corrosion damage due to the bi-axial chloride deposition at corners.

Non-liquid retaining structures are similarly not expected to have carbonation or chloride induced reinforcement corrosion for the design life using an appropriate concrete grade with designated maximum water/cement typical exterior/interior concrete cover.

F4 Construction Joints

Where construction joints are not intended to be movement joints, a monolithic joint is required for structural and durability performance. A monolithic joint with proper concrete compaction and bond will be as watertight as the surrounding concrete, and therefore provides the primary water barrier at the joint. Any installed waterstop or other waterproofing system provides the second barrier.

Wall and slab concrete that is cast against prior cast concrete may use a durability consultant approved hydrophilic swellable waterstop. The waterstop is protected by concrete from damage by ultraviolet light. Attention is required to cover requirements for the waterstop, insufficient cover can result in spalling damage to the concrete if the swelling component is activated (minimum 100 mm cover required). Good concreting practice is required, as this type of seal cannot seal voided, cracked, or poorly compacted concrete.

Provided all waterstops are correctly installed in properly compacted concrete, and not damaged the joint is expected to be watertight and is expected to meet the 100 years design life.

The position of all water stops is critical and the ITP should confirm the position installed in accordance with the Concrete Specification, Drawings and material manufacturers recommendations.

Concrete wall pours on the project can achieve acceptable waterproofing at wall construction joints with reasonable construction methods in accordance with TS 0710 and refer to CIA Z7/04 for guidance.

F5 Early-age Thermal/Restraint Cracking

The hydration reaction that takes place when cement is mixed with water is exothermic and the volume of concrete will expand and contract as it heats up and then cools back down to the ambient temperature. If the concrete is restrained (unable to move freely) in certain locations, this expansion and contraction may result in the concrete cracking.

Commonly the highest risk locations for crack formation are:

- Vertical cracks in the walls from restraint by a prior cast floor, primarily forming from the floor base up the wall and between prior cast wall segments.
- Cracks in the roof from restraint by prior cast walls, forming from the wall's perpendicular inwards and between parallel walls.
- Cracks in floor slabs from restraint by prior cast floor segments, forming from the prior cast floor perpendicular inwards and between prior cast parallel floor segments.

Concrete early age thermal/restraint crack risk modelling to be evaluated in accordance with TS 0710.

F6 Cracking effect on Water Penetration

Not all cracks in concrete will necessarily leak. A number of cracks that appear wide at the surface may not penetrate the full depth of the section. Others may follow an irregular path that limits the flow of moisture or may be blocked by contaminants.

Cracks as narrow as 0.1 mm can allow the penetration of moisture under piezometric head. The rate of flow will depend on the piezometric head, thickness of section and tortuosity of the crack.

Where cracks form at an early age (or minor gap opening at a construction joint) some level of sealing will occur due to a process known as autogenous healing or self-healing. This process will occur at early-age and after filling a liquid retaining structure. The extent of such self-healing is difficult to predict being dependent on a number of factors including the crack width, cement binder type, rate of flow, water composition, time of water flow through the crack, etc. Concrete crack widths up to 0.15 mm normally autogenously heal. However, self-healing can be confirmed by core sampling and examination of the retrieved concrete core, and/or observation of water leakage through cracks over time (i.e., whether self-healing seals the crack). Refer to TS 0710 for the design crack width.

Cracks (or minor gap opening at a construction joint) with water leakage consisting of flow through the crack, moisture can be felt on the concrete surface at the crack or the concrete adjacent to the crack is a darkened colour from water penetration through the crack may be sealed by a variety of methods.

Inspection requirements to be in accordance with TS 0710 and guidance is provided in CIA Z7/07.

F7 Construction Joints Restraint Induced Concrete Cracks

Vertical and horizontal construction joints in cast in situ reinforced concrete will create restraint for the concrete element cast against prior cast concrete. The concrete pour sizes will be selected to practically minimise the number of construction joints.

F8 Other Matters

The durability review to consider any other matters understood to be of most significance at the Detailed Design stage of the project.

Appendix G – Construction Phase Guidelines

Item	Description
G1	General
G2	Concrete: Mix Design
G2.1	Premix Concrete Supply
G2.2	General Plastic Properties
G2.3	Plastic & Drying Shrinkage
G2.4	Alkali Aggregate Reactivity (AAR)
G2.5	Delayed Ettringite Formation (DEF)
G3	Concrete: Construction Issues
G3.1	General
G3.2	Constructor Work Method Statement for Concrete
G3.3	Concrete Construction for Clay Soil Conditions
G3.4	Concrete Curing
G3.5	Sectional Details
G3.6	Concrete Crack Inspection
G3.7	Wall Concrete Compaction
G3.8	Cover Surveys
G3.9	Concrete Supply and Placement
G3.10	Water Testing Liquid Retaining Structures
G3.11	Concrete Crack/Joint Assessment Process & Repair Criteria
G4	Base Fill and Back Fill Materials
G4.1	Material Quality Control
G5	Wall Construction – Joint Seal & Waterstop Hydrophilic Seal Materials
G6	Wall Construction – Joint Grout
G7	Wall Seating – Joint Seal Material
G8	Pipeline
G8.1	Pipeline Placement
G8.2	Cathodic Protection (CP)
G9	Welding
G10	Coatings
G10.1	General
G10.2	Painted Coatings
G10.3	Galvanised Coatings
G10.4	Proprietary Coating Systems
G11	Roofing System
G12	Fasteners and Joints
G13	Grout

The Constructor will implement Method Statements and Inspection Test Plans (ITP) in accordance with the DAR: DD authored by the Durability Consultant. Guidelines are given in this Section for consideration by the Constructor. Notwithstanding the contents of this section, it is the responsibility of the Constructor to consider all durability requirements of the design during construction.

G1 General

Compliance with the requirements of the DAR during the construction phase will be achieved through reliance upon the Constructor's work practice procedures, quality assurance procedures and by undertaking Durability Audit visits during the course of the works.

The works procedures will incorporate requirements for critical construction phase procedures identified in this report, and quality audits will assess compliance with the requirements of the DAR and compliance with the Constructor's work method statements. During the Durability Audit visits, site practices will be assessed, and the appropriateness of the quality systems and their capacity to detect relevant non-compliances determined.

The construction phase compliance assessment will primarily focus on issues presented within this section of the report. The details of the requirements and the methods of testing for compliance will be captured as part of the ITP compiled as part of the Quality Systems.

G2 Concrete: Mix Design

G2.1 Premix Concrete Supply

Constructor will need to review and plan with premix concrete suppliers well in advance to determine availability and cost of the concrete supply alternatives and ensure compliance with TS 0710.

Concrete mix design for wall infill concrete between precast panels should consider use of an integral waterproofing admixture or approved equivalent, shrinkage reduction admixture, high workability to improve concrete compaction and/or 10 mm or 14 mm maximum sized aggregate, all to Durability Consultant approval.

G2.2 General Plastic Properties

- Compliance with the requirements of the concrete specification will be determined by ongoing visual assessment of characteristics such as bleed, slump, pumpability and general workability.
- Where non-compliance occurs, batch records to be assessed to determine whether a gross batching error may be responsible. Where continuous non-compliance occurs, adjustments to be made to concrete mix designs.
- Additional information to be obtained by the regular monitoring of variations in constituent materials such as cement and aggregates. Modifications to the mix design will be required to maintain desired properties in accordance with changes in constituent materials and seasonal variations.
- Approval from the Durability Consultant, endorsed by the SA Water Representative, shall be sought for any change from the approved mix design. Where such changes are significant the Premix Concrete supplier may be required to perform further mix trials. Modifications accepted by SA Water shall be incorporated into the concrete specification.

G2.3 Plastic & Drying Shrinkage

- It is not practicable to conduct testing of concrete drying shrinkage for this project prior to concrete used in the works (i.e., due to time delay from trial mix concrete to test value available in accordance with relevant Australian Standard). Premix concrete suppliers are expected to have typical values available for concrete to be supplied to the project. Compliance testing to be related to the visual appearance of the mix and level of visible plastic cracking. The premix concrete supplier to be required to supply shrinkage test data completed on concrete supplied from the region of the project for review and approval prior to any concrete is used in the works, data from any grade of concrete can be assessed for project concrete where data on the Specification concrete grade is not available.
- All concrete sections to be inspected as soon as practicable after placement and at subsequent times during the construction process. Acceptability of the adequacy of the specified maximum coefficient of drying shrinkage to be assessed by measurement of crack widths in completed sections.
- The construction procedures to include provision for documenting the location, widths and time of occurrence of all significant cracks. There shall be contingency procedures for modifying materials and construction procedures where the crack widths exceed specified limits. Careful notice is to be taken of cracking of temporarily unrestrained slabs where future pours are likely to impose restraint and cracking may be exacerbated.

G2.4 Alkali Aggregate Reactivity (AAR)

- There is a reasonable possibility that AAR susceptible aggregates can be found in association with typically sound aggregates. The regular monitoring of aggregates (typically done by the premix concrete suppliers and/or aggregate suppliers) and/or the use of cement replacements as appropriate is the normal method to reduce the potential risk of AAR attack.
- The premix supplier should complete AAR compliance testing as part of normal quality control prior to awarding the concrete supply contract. If premix concrete supplier testing of aggregates for AAR is inadequate then specialised testing laboratories can undertake separate testing of the aggregates.

G2.5 Delayed Ettringite Formation (DEF)

The concrete maximum temperature for in situ and precast concrete should not exceed 70°C except where at least 20% fly ash, 40% slag or 8% silica fume by mass of binder is incorporated, in which case the maximum temperature to not exceed 80°C.

G3 Concrete: Construction Issues

G3.1 General

Inappropriate construction practices can produce concrete structures with reduced resistance to deterioration. Some examples of inappropriate construction practices include:

- Highly cohesive concrete leading to plastic cracking issues.
- Excessive water content, or inappropriate mix design leading to excessive concrete shrinkage or bleeding.
- Hydration related thermal stresses arising from excessive cement contents or significant restraint.
- Inappropriate pour geometry, placement and/or fall height.
- Unworkable concrete leading to poor compaction.

- Reinforcement and cast-in detailing which makes correct reinforcement and concrete placement difficult.
- Poor construction joint preparation before commencing pours, resulting in poor bonding across the joint.

Actual site practices to be reviewed by the Durability Consultant on a regular basis to assess compliance with previously approved written procedures. Where the desired level of quality is not achieved for a particular component, a non-conformance shall be raised, and site practices shall be reviewed and modifications made (where appropriate) to prevent reoccurrence of the defect.

G3.2 Constructor Work Method Statement for Concrete

The Constructor to provide concrete supply and placement practice details in accordance with a Constructor Work Method Statement in TS 0710.

G3.3 Concrete Construction for Clay Soil Conditions

All works associated with provisions for expansive and reactive clay soil conditions will be subject to particular and separate ITP.

G3.4 Concrete Curing

Compliance with the specified requirements for concrete curing in TS 0710 to be verified by recording the method and period of curing employed. The effectiveness of curing to be determined by testing the performance properties of concrete components after curing. The properties to be assessed to include (but is not limited to):

- Presence of cracking.
- Visual appearance.

G3.5 Sectional Details

The acceptability of sectional details shall be confirmed by visual assessment of the quality of completed structures. Where poor compaction or low cover (as determined by regular cover meter surveys) is observed, the constructability of sectional details shall be reviewed by the Designer, Constructor and Durability Consultant and adjusted where considered appropriate.

The typical parameters used to assess the constructability include, but are not limited to:

- Concrete slump.
- Concrete workability.
- Reinforcement congestion.
- Concrete compaction method.
- Concrete placement method.

G3.6 Concrete Crack Inspection

A site crack inspection to be completed on all interior and exterior concrete surfaces in accordance with TS 0710 with guidance in CIA Z7/07.

G3.7 Wall Concrete Compaction

Concrete compaction at the base of walls has the greatest risk of inadequate compaction and to be inspected and tested after concrete placed in accordance with TS 0710.

G3.8 Cover Surveys

Site concrete cover inspection after concrete placed in accordance with TS 0710.

G3.9 Concrete Supply & Placement

There can be limited capacity to support the construction activities if difficulties arise during a major concrete pour. It is therefore recommended that prior to each major pour that contingency plans be assessed. Factors to consider would include:

- Concrete batch Plant and agitator fleet capacity including effect of breakdowns.
- Placement procedures (pump or crane) including effect of breakdown.
- Placing equipment including vibrators, including effect of breakdown and fatigue
- Curing membrane.

G3.10 Water Testing Liquid Retaining Structures

Testing for liquid tightness of liquid retaining structures shall be completed in accordance with TS 0600.

G3.11 Concrete Crack/Joint Assessment Process & Repair Criteria

The recommended crack and joint repair criteria are:

- Crack inspection to identify cracks, water leakage at cracks and water leakage at joints to be completed in accordance with TS 0710 on liquid retaining or excluding structures.
- Crack width limits are given in TS 0710.
- Crack and water leakage repair to be in accordance with TS 0710 and TS 0711 with review required by SA Water and the Durability Consultant as stated in TS 0710.

G4 Base Fill & Back Fill Materials

G4.1 Material Quality Control

Intended base fill and back fill materials to be tested for compliance to the specification. These materials should be free from significant levels of chlorides and sulphates. As a minimum these tests relevant for reinforced concrete to include:

- pH.
- Chloride content.
- Resistivity.
- Sulphate content.

G5 Wall Construction – Joint Seals, Waterstops & Hydrophilic Seals

Waterstop requirements are provided in TS 0464 and TS 0710, and the product shall be suitable for encasement in concrete and installed in accordance with the material manufacturer's recommendations.

G6 Wall Construction – Joint Grout

Joint grout, where used in this project, shall be installed in accordance with the material manufacturer's recommendations.

G7 Wall Seating – Joint Seal Material

The product will be installed in accordance with the material manufacturer's recommendations.

G8 Pipelines

G8.1 Pipeline Placement

Transportation, lifting, handling and placement of pipelines both above and below ground to comply with the specification, manufacturer's recommendations and TS 0622.

The risk of damage to coatings or pipe structure during the transportation and placement of pipes is significant. Full defect inspections (including internal) of all pipes must be conducted by a suitable qualified inspector prior to backfilling of the pipes. Repairs to the external coatings or the cement lining must be conducted in accordance with the manufacturer's recommendations and SA Water Technical Standards TS 0400 and TS 0465

G8.2 Cathodic Protection

Cathodic Protection (CP) to be applied to new pipes after assessment for the need to use CP with appropriate isolation to other pipes.

G9 Welding

All welding is to be completed and inspected in accordance with TS 0420 and be approved by the Durability Consultant.

A separate ITP is to be prepared for each welded element. For example, wall shell plates, floor plates and roof beams.

G10 Coatings

G10.1 General

All coating applications shall comply with the specified system for each element and be in accordance with TS 0400. The following sections outline the key construction phase durability compliance issues that should be captured by the various Durability Plan Process coatings specifications, ITPs and inspections, completed by the responsible parties. Personnel completing the tasks will be suitably qualified coatings Engineers/Inspectors and shall be approved by the SA Water Representative.

G10.2 Painted Coatings

The key construction phase durability compliance issues are:

- Access.
- Surface preparation procedures.
- Acceptable ambient application conditions.
- Coating material acceptance, quality, identification and storage.
- Application procedures.

- Dry film thickness (DFT) survey.
- Holiday detection.
- Defect repairs.

G10.3 Galvanised Coatings

The key construction phase durability compliance issues are:

- Preparation.
- Masking.
- Pickling.
- Application procedures.
- Defect inspection.
- Defect repairs.

G10.4 Proprietary Coating Systems

The key construction phase durability compliance issues are:

- Manufacturer QA/QC data submitted to confirm product delivery compliance with the manufacturers specified performance data.
- Defect inspection.
- Defect repairs.

G11 Roofing System

The construction of the roofing metal components to be conducted in accordance with the manufacturer's recommended instructions and comply with the clauses of the manufacturer's warranty. On completion of construction the roof to be tested for water tightness to the satisfaction of the SA Water.

G12 Fasteners & Joints

The durability of structural elements at the points where they are joined will be reliant on the following points:

- Materials selection.
- Joint design.
- Insulation/isolation.

All fixing materials should be selected to minimise the risk of detrimental galvanic corrosion. All fixing materials shall be reviewed by the Durability Consultant and be submitted to SA Water for review.

Where elements lap or are joined, suitable measures to be specified to minimise the risk of crevice corrosion. At the time of construction, ITPs to include additional QA/QC checks by the Designer and Constructor to confirm the correct installation of fixing materials and insulating materials. In particular, QA/QC checks are required on tank internal fasteners for the use of hot dip galvanised fasteners above TWL and stainless steel 316 fasteners below TWL in accordance with TS 0721, which must take account of the normal operating range for the tank.

G13 Grout

All grout is to be a proprietary cementitious shrinkage compensating grout compliant with TS 0711 and be approved by the SA Water Representative and used strictly in accordance with manufacturer's recommendations. The key construction phase durability compliance issues are:

- Selection to grout manufacturer present day recommended thickness.
- Surface preparation.
- Surfaces cleaned of all laitance, debris, loose or defective concrete, etc. and thorough potable water washed.
- Concrete surfaces to be potable water wetted to achieve a saturated surface dry condition before placing the grout (e.g., kept moist for 24 hours immediately prior to grouting).
- Acceptable consistency of stiff, plastic, flowable, fluid, etc. to grout manufacture recommendations for specific requirements.
- Batched and mixed to manufacture instructions.
- Applied within open time.
- Applied so space is completely filled.
- Cured.
- Acceptable bond adhesion, no cracks and no delaminations.
- All above controlled by ITP and QA/QC.

Appendix H – Durability Design Summary Table

Note: This Appendix is provided to demonstrate the intent and application of the DDST. Content of the table below **shall not be used** in place of Durability Design per TS 0110.

Durability Design Summary

Client	SA Water	**Project Number**	XXXX
Project Title	Example Wastewater Rising Main	**Current Revision**	1.0

Asset Information				Durability Design Factors				Durability Design Outcomes			Inspection & Maintenance Requirements					Safety Hazards		
Asset	Asset Component	Asset Sub-Component	Minimum Design Life *(years)*	Exposure Condition	Durability Issue	Deterioration Mechanism	Risk Rating *(normal/increased/extreme)*	Durability Measures Adopted	Manufacturer Details	Product Reference	Inspection Requirements	Maintenance Requirements	Condition State for Remedial Action	Remedial Action	Access Provisions *(physical/operational)*	Description	Mitigation	Residual Hazards
Rising Main	Pipeline	Pipe	100	Elevated H_2S levels	Biogenic Acidic Attack	Concrete lining damage Steel Corrosion	Extreme	Use of MSCACL Pipe Isolation valve branch into adjacent gravity main Duplicated rising main	SteelMains	Sintalock DN450 MSCACL pipe	Inspected 5 yearly	Rising main flushed when taken offline	Complete degradation of CACL lining	Spiral wound lining	Operational Use of dual rising mains Physical Maintenance holes provided at 500m centres *(physical)*	High traffic volumes	Rising main route situated away from main roads Appropriate traffic management	Traffic, at lower volumes
																Operational windows to safely conduct works Exposure to wastwater Customer impacts	Duplication of rising main Flushing of main when taken offline	Exposure to dilute wastewater
		Isolation valve branch	25	Elevated H_2S levels	Biogenic Acidic Attack	Steel Corrosion	Extreme	Duplicated rising main Valves situated in street boxes for improved access	AVK	Series 29 hydrant	Inspected 2 yearly	Operated annually, inclusive of rising main recharges (if applicable)	Valves exhibiting signs of substantial degradation and loss of performance	Replace ment	Operational Use of dual rising mains Physical Valves located in Street Box	As for pipe		