THE UNIVERSITY OF WESTERN AUSTRALIA

The University of Western Australia

Design and Construction Standards

STRUCTURAL WORKS

H

DOCUMENT CONTROL

REVISION LOG

Current Issue

UWA Design and Construction Standards: Structural Works - H, Version 1.0 (September 2016)

Previous issues

Version	Author(s)	Description	Date completed
1.0	Campus Management	UWA Design and Construction Standards: Structural Works - H	

REVISION MANAGEMENT

It is envisaged that revisions to this document will be undertaken at intervals of not more than two (2) years.

ENDORSEMENT BODY

To be determined.

OWNER

Director, Campus Management

AUTHOR(S)

The Standards have been developed by Campus Management with the assistance of UWA staff, external consultants, contractors and colleagues from other education institutions.

CONTACT PERSON

Associate Director Capital Works, Campus Management

COPYRIGHT

TABLE OF CONTENTS

1 Introduction

1.1 PURPOSE

The UWA Design and Construction Standards (the *Standards*) outline UWA's expectations for its built forms in order to achieve consistency in the quality of the design and construction of those built forms. They are aligned with the UWA's *Campus Plan 2010* planning principles and UWA's requisites for aesthetic appeal, maintainability and environmental sustainability, while ensuring that there is sufficient scope for innovation and technological advancements to be explored within each project.

The Standards are intended for use by any parties who may be involved in the planning, design and construction of UWA facilities. This includes external consultants and contractors, UWA planners, designers and project managers as well as faculty and office staff who may be involved in the planning, design, maintenance or refurbishment of facilities. These Standards also provide facility managers, maintenance contractors and other service providers with an understanding of UWA services in order to assist in the maintenance and operation of facilities.

1.2 SERVICES

The UWA Design and Construction Standards for **Structural Works** (this document) are a part of UWA Design and Construction Standards set of documents (the Standards). The Standards are divided into the following service documents for ease of use, but must be considered in its entirety, regardless of specific discipline or responsibilities:

A Building and Architecture
B Mechanical Services
C Electrical Services
D Communication Services
E Hydraulic Services
F Security Services
G Fire Services and Fire Safety Engineering
H Structural Works (this document)
I Civil Works
J Irrigation Services
K Sustainability
L Vertical Transport

1.3 RELATED DOCUMENTS

1.3.1 University Documents

The Standards are to be read in conjunction with the following relevant University documents:

- UWA General Preliminaries Document
- UWA Specification for As-Constructed Documentation
- Relevant UWA planning and policy documents such as the *UWA Campus Plan*, *Commercial Masterplan*, *Landscape Vision* and *Integrated Infrastructure Strategy*, *University Policy on Alterations to University Buildings*, etc.
- Relevant UWA operational and maintenance documents such as preferred vendors lists, room data sheets, operational and maintenance manuals, etc.
- Other documents as referenced within the UWA Design and Construction Standards.

1.3.2 Relevant Legislation

The planning, design and construction of each UWA facility must fully comply with current relevant legislation, including but not limited to:

- Relevant Australian or Australian / New Zealand Standards (AS/NZS),
- National Construction Code (NCC),
- Occupational Safety and Health (OSH) legislation,
- Disability Discrimination Act (DDA),
- Accessibility Aspiration Design Factors, and
- Local council and authority requirements.

1.3.3 Manufacturer Specifications and Data Sheets

All installation must be carried out in accordance with manufacturer specifications and data sheets to ensure product performance over its intended life and so as not to invalidate any warranties.

1.3.4 Project Specific Documentation

Requirements specific to a particular project, campus or other variable, will be covered by project specific documentation, such as client briefs, specifications and drawings. These Standards will supplement any such project specific documentation.

The Standards do not take precedence over any contract document, although they will typically be cross-referenced in such documentation.

Extracts from the Standards may be incorporated in specifications, however it must remain the consultant's and contractor's responsibility to fully investigate the needs of the University and produce designs and documents that are entirely 'fit for purpose' and which meet the 'intent' of the project brief.

1.4 DISCREPANCIES

The Standards outline the University's generic requirements above and beyond the above mentioned legislation. Where the Standards outline a higher standard than within the relevant legislation, the Standards will take precedence.

If any discrepancies are found between any relevant legislation, the Standards and project specific documentation, these discrepancies should be highlighted in writing to the Associate Director Capital Works, Campus Management.

1.5 DEPARTURES

The intent of the Standards is to achieve consistency in the quality of the design and construction of the University's built forms. However, consultants and contractors are expected to propose 'best practice / state of the art' construction techniques, and introduce technological changes that support pragmatic, innovative design.

In recognition of this, any departures from relevant legislation, or the Standards, if allowed, must be confirmed in writing by the Associate Director Capital Works, Campus Management.

Any departures made without such written confirmation shall be rectified at no cost to UWA.

1.6 PROFESSIONAL SERVICES

For all works, it is expected that suitably qualified and experienced professionals are engaged to interpret and apply these Standards to UWA projects. Works cannot be carried out by unqualified and unlicensed consultants or contractors.

1.7 STRUCTURE OF DOCUMENT

This document is structured into 4 parts:

Part 1 Introduction (this Section)

Part 2 General Requirements – outlines the general requirements or design philosophies adopted at UWA

Part 3 Checklist for project team (if applicable) – checklist of items for consideration at various stages of a project

Part 4 Specifications (if applicable) – materials specifications and/or preferred lists for materials, processes or equipment used by UWA.

1.8 DEFINITIONS

For the purpose of this document, the following definitions apply:

Can: Implies a capability of possibility and refers to the ability of the user of the document, or to a possibility that is available or might occur.

May: Indicates the existence of an option.

Shall: Indicates that a statement is mandatory.

Should: Indicates a recommendation.

2 General Requirements

2.1 BUILDING WORKS SCOPE

This document sets out the requirements for structural engineering services associated with building works for UWA, including:

- New buildings
- Additions and/or extensions to existing buildings
- Refurbishment of existing buildings
- Retention walls
- Screen walls
- Free-standing shelters and canopies
- Foundations, plinths and platforms for plant

The requirements of this document can also be adopted for structural engineering services associated with other elements where appropriate, e.g., tanks, signs, poles, balustrades, pavement.

2.2 OBJECTIVES

The structural works, including the materials and components used, shall be capable of performing over the planned life at the prescribed level of safety and serviceability under all actions to which they may reasonably be subjected.

2.3 STANDARDS AND CODES

Design and construction of the structural works shall comply with all relevant statutory and UWA requirements, including the UWA *Design and Construction Standards* of other services.

A list of Standards and Codes are provided within the *References* section of this document. This does not represent an exhaustive list, and additional Standards and Codes shall be adopted as necessary to suit individual project requirements.

Care shall be taken to ensure current editions of all relevant Standards and Codes are adopted for the Structural Works.

All documents referenced by the relevant Standards and Codes shall be considered integral for compliance purposes.

2.4 STRUCTURAL ENGINEER

The adequacy of all structural works must be assessed and certified by a structural engineer.

The structural engineer responsible for overall structural design and certification shall:

- Be eligible for membership of the Institution of Engineers Australia, as either a Corporate Member or a Graduate Member.
- Have practical design and construction experience for buildings and elements commensurate with the value, usage and complexity of the works.
- Have been actively engaged in structural engineering design of buildings during the preceding 3 years.
- Have worked with Australian design standards and regulations, current at the time, for the preceding 12 months.

2.5 DESIGN REQUIREMENTS

2.5.1 Recording of Design Data

The structural works, including the materials and components used therein, shall be capable of performing over the planned life at the prescribed level of safety and serviceability under all actions to which they may reasonably be subjected.

Structural design standards relevant to a project shall be listed on at least one sheet of the structural drawings. The Australian Standard number and year of Code issue must be recorded for all standards used in the design.

If an Australian Standard has not been issued for particular design criteria then an international standard shall be adopted (such as a British or New Zealand Standard) which is most closely aligned with the principles of Australian design practice. Where design criteria are used which are not sourced from Australian Standards, they are to be included with the information required.

In addition to listing the design standards, specific design information identified within this section must also be recorded on the structural drawings.

This information is required to guide future planning where:

- an existing structural design is being considered for use in a new location;
- an existing project is to be altered or additions are to be made;
- changes to building or room occupancies require an evaluation of floor load capacities; or
- cost estimates for a new building in a similar location are to be prepared.

The inclusion of the above information on a structural drawing does NOT relieve future users of such information of their responsibilities under their conditions of engagement.

2.5.1.1 Imposed Loads (Live Loads)

Imposed loads shall be recorded for structural elements based on the intended activity/occupancy and specific usage, including (but not limited to):

- Floors - including balconies, walkways and mezzanines
- Stairs and landings
- Roofs - including awnings and canopies
- Barriers - including pedestrian barriers (balustrades and railings), vehicle barriers and parapets
- Retaining wall surcharge
- Pavements – pedestrian and vehicular traffic

Special attention is required for recording imposed actions for floors subject to defined heavy loads, for example:

- Storage Areas: design actions based on available storage height, shelving units, compactus or vaults.
- Plant Areas: design actions for plant, equipment, machinery, tanks, vessels, generators, transformers etc.

The loads shall be referenced in terms of the appropriate actions, including:

- Uniformly distributed actions (kPa)
- Concentrated actions (kN)
- Line/edge actions (kN/m)

2.5.1.2 Wind Actions

The following shall be recorded for each project:

- Wind Region
- Regional Wind Speed and Return Period
    - Strength
    - Serviceability
- Terrain Category
- Shielding Multiplier
- Topographical Multiplier

Where different terrain categories or multipliers have been assumed in the design, depending on wind direction, each of the different combinations of terrain category and multipliers used are to be noted together with the wind direction(s) to which they apply.

2.5.1.3 Earthquake Actions

The following shall be identified when designing for earthquake loads:

- Importance Level
- Annual Probability of Exceedance
- Probability Factor

- Hazard Factor
- Site Sub-soil Class
- Earthquake Design Category

2.5.1.4 Concrete Durability

Exposure classifications shall be identified for the various concrete surfaces and exposure environments.

2.5.1.5 Geotechnical Data

The following shall be recorded for each project:

Site Classification in accordance with *AS 2870*, for projects to which this standard can be considered appropriate.

If the classification varies across the site, the extent of each soil class must be shown or noted on an appropriate structural drawing.

2.5.1.6 Soil Bearing Capacity

The maximum allowable or ultimate soil bearing pressures (state which) used in footing design. If different footings have been designed using different bearing pressures, the design bearing pressure for each footing type or size must be recorded.

2.5.1.7 Retained Earth Properties

Soil material properties in accordance with *AS 4678*, including (but not limited to):

- Bulk Density
- Internal friction angle
- Cohesion (if applicable)
- Peak Groundwater Level

2.5.2 Design Criteria Example

The following is an example of the preceding requirements.

(Example: information included on drawing S.01 'General Notes').

DESIGN CRITERIA

Imposed Loads: (in accordance with *AS 1170.1-2002*)

ELEMENT	UDL	CONCENTRATED
Ground Slab – Loading Area	5.0kPa	31.0kN
Level 01 - Offices	3.0kPa	4.5kN
Stairs & Landings	4.0kPa	4.5kN
Roofs (metal sheet)	0.25kPa	1.4kN
Balustrades	0.75kN/m	0.6kN
Retention Wall Surcharge	5.0kPa	-

Wind Loads: (in accordance with *AS 1170.2-2011*)

WIND REGION: 'A1'

REGIONAL WIND SPEED AND RETURN PERDIOD: STRENGTH: V_{500} = 45m/s

SERVICEABILITY: V_{25} = 37m/s

Wind from North and West:

TERRAIN CATEGORY: 3

SHIELDING MULTIPLIER: 1.0

TOPOGRAPHIC MULTIPLIER: 1.0

Wind from South and East:

TERRAIN CATEGORY: 2

SHIELDING MULTIPLIER: 1.0

TOPOGRAPHIC MULTIPLIER: 1.1

Earthquake Loads: (in accordance with *AS 1170.4-2007*)

Importance Level: 2

Annual Probability of Exceedance: 1/500

Probability Factor: $k_p = 1.0$

Hazard Factor: a = 0.09

Site Sub-soil Class: C_e

Earthquake Design Category: II

Concrete Durability: (in accordance with *AS 3600-2009*)
Surfaces within Interior Environments: A1
Surfaces in Exterior Environments: B1

Geotechnical Data

Site Classification (in accordance with *AS 2870*): 'A'

Allowable Bearing Pressures:

Pad Footings:	up to 1m x 1m, 150kPa
	2m x 2m, 200kPa
Strip Footings:	up to 0.6m wide, 150kPa
	2m wide, 200kPa

Retained Earth Pressures (in accordance with *AS 4678-2002*):

Soil Density (saturated)	18kN/m^3
Internal Friction Angle	33deg

(End of example)

2.5.3 Future-Proofing and Flexibility

The structural works shall consider provisions for future development or variation in occupancy or usage. Design of the structure shall provide:

- Structural grids accommodating column and wall free space, minimising constraints to future space planning changes
- Allowances in nominated floor design imposed loadings
- Structural floor systems that are cognisant of horizontal services distribution required and compatible with installation of future service openings
- Interface details suitable for future expansion.

The design of the structure should recognise that future floor penetrations will be required and the selected systems should not unreasonably limit this requirement.

2.5.4 Assessment of Modifications to Existing Structures

Works that involve modifications to existing structures shall be subject to structural assessment which encompasses implications to the overall structure, and not just the part or portion being modified, i.e., global assessment of the structure shall be performed rather than just localised assessment.

Existing structures and buildings may have been subject to previous modifications, which need to be considered in conjunction with the proposed Works, for example:

- The original load path may have been altered by previous works, such as the removal of a column and replacement with transfer elements.
- Elements may be non-loadbearing, but contribute to lateral stability of adjacent members/elements.
- Penetrations or openings may have been added to structural elements which have implications for proposed modifications.

Assessment of modifications to existing structures shall include the following:

- Review of original drawing records held in UWA archives
- Visual inspection and examination of the as-built structure to confirm the accuracy of original drawings and to identify the nature of any subsequent modifications.

2.5.5 Ecologically Sustainable Design

Generally, the structural works shall support the requirements necessary to achieve the nominated ESD requirements for the project. Reference shall be made to UWA *Design and Construction Standards - Sustainability'*.

2.5.5.1 Thermal Performance of Structural Framing

Where required the thermal mass and thermal performance properties of the structural framing materials is to be integrated into the heating and cooling processes for the buildings.

2.5.5.2 Structural Materials

Structural Steelwork

Structural steelwork shall be manufactured from steel with inherent high recycled content.

Concrete

The use of structural concrete containing GB cement shall be considered for the maximum extent practical, acknowledging that structural concrete containing GB cements gains strength more slowly than concretes with GP cement and extended formwork stripping times are required. On this basis special consideration is required regarding use of GB cement in suspended floor slab construction.

Concrete containing GB cements from blast furnace slag are generally considered suitable for use in concrete elements such as foundations, columns and core walls.

Recycled concrete is not permitted for use in structural elements. Recycled concrete can be considered for use in hard landscaping e.g., paving, low traffic areas, etc.

Concrete Reinforcement

The majority of steel reinforcement used in the concrete works shall be manufactured from recycled steel.

2.5.6 Safety in Design

Incorporate design solutions that minimises the potential for danger during construction as well as during occupation and maintenance.

Regular reviews shall be undertaken progressively through the various stages of design to facilitate optimal solutions to minimise unsafe risk issues. The opportunity for UWA staff to be involved in such workshops and reviews shall be provided.

2.6 PERFORMANCE REQUIREMENTS

2.6.1 Design Working Life

The 'Design Working Life' is defined by *AS 1170.0* as being:

> *Duration of the period during which a structure or structural element, when designed, is assumed to perform for its intended purpose with expected maintenance but without major structural repair being necessary.*
>
> *It is a concept used to select the probability of exceedance of different actions. This does not mean that when the design working life is reached the structure will fail; nor does it mean that the design working life has to correspond exactly with the intended useful life the designer has in mind or with the durability of the construction materials.*

All works associated with normal structures shall have a minimum design working life of 50 years.

A design working life less than 50 years may be considered appropriate for structural works associated with:

- Refurbishment of existing buildings and structures, where is it accepted by UWA that the design working life for the overall building/structure is no greater than 25 years
- Minor structures, where failure is not likely to endanger human life. Such structures are generally isolated, rarely contain people, and are not required as part of normal infrastructure
- Short-term or temporary structures, e.g., structures intended for a single event only.

Structures for which failure might result in loss of human life shall not be designed for less than a 25 year life.

In situations where a design working life less than 50 years is considered appropriate, it shall be determined in accordance with *AS 1170.0* and the BCA, and must be endorsed by the Structural Engineer in writing for acceptance by UWA.

2.6.2 Durability

2.6.2.1 General

All structural elements shall have adequate durability to achieve the design working life period as a minimum, without need for undue maintenance that would not otherwise be required for a building or element with comparable function, scale/size, and environment within Australia, built in accordance with best industry practice.

Durability is to be incorporated into the structure works through materials with properties complying with the durability recommendations specified in the relevant Australian Standard, along with attention to design details and good construction practices.

2.6.2.2 Inaccessible Elements

Special attention is required for deterioration of elements which cannot be easily accessed for maintenance or repair, e.g., foundations, basement walls and other buried structural elements. The durability for inaccessible elements shall be sufficient to reliably achieve the design working life period without maintenance.

Where the required durability cannot be achieved by the material properties of the structural element alone, then protective coatings shall be provided.

2.6.2.3 Concrete

Durability Design Standards

All concrete elements shall comply with the durability provisions of *AS 3600* as a minimum.

The following standards shall be adopted for durability design if they are considered relevant to the scope of the Structural Works:

- *AS 3735* Concrete Structures Retaining Liquids
- *AS 4997* Guidelines for Design of Maritime Structures
- *AS 5100* Bridge Design

Durability Design Considerations

The following issues shall be assessed as part of the overall design for concrete durability:

- Exposure classification (including assessment for aggressive soil conditions)
- Abrasion from traffic
- Freezing and thawing
- Crack control
- Cover for concrete placement (minimum cover to ensure proper concrete placement and compaction around reinforcement, tendons and ducts)

Documentation for Concrete Durability

The structural documentation shall clearly state the concrete durability requirements, including but not limited to the following:

- Concrete class - normal or special class
- Concrete strength - characteristic compressive cylinder strength at 28 days
- Minimum cement content and cement type (for special class concrete)
- Restrictions on chemical content in concrete
- Cover to reinforcement and tendons/ducts
- Requirement for rigid formwork and intense compaction
- Curing period (or minimum compressive strength at end of curing period)

2.6.2.4 Structural Steelwork

Protective coatings appropriate to the exposure conditions and Architectural requirements shall be provided so that the structural steelwork has adequate durability without need for undue maintenance throughout the design working life.

Protective Coating Durability

The protective coating durability is defined as the coating life to first major maintenance for the relevant corrosivity category.

For buildings and structures with a design working life of 50 years, the major maintenance periods are expected to be after 25 years and 40 years. On this basis, the protective coating durability shall be ‘Extra Long term (EL)’ in accordance with *AS/NZS 2312* durability classifications.

The protective coating durability classification is subject to project specific assessment, including consideration of the following:

- Relevant design working life
- Importance of coating appearance and aesthetics
- Function and usage of the building/elements
- Preferred coating type(s)
- Acceptable maintenance periods
- Access for maintenance and ease with which maintenance can be undertaken
- Coating costs relative to overall project cost
- Whole of life costs for coating

Corrosivity Category

The atmospheric corrosivity category (macro-climate) shall be determined in accordance with *AS 4312*.

Micro-climates arising from local environmental effects shall be assessed in accordance with *AS/NZS 2312* to establish the relevant corrosivity category. Special consideration shall be given to the following micro-climatic circumstances:

- Elements exposed to atmospheric contaminants but protected from cleansing rain
- Surfaces that can remain damp for an extended period, such as where surfaces are not freely drained or are shaded from sunlight
- Exposure to acidic or alkaline fallout, industrial chemicals and solvents, airborne fertilisers and chemicals
- Exposure to prevailing winds which transport contamination
- Surfaces exposed to abrasion and impact.

Dissimilar Metals

Contact between dissimilar metals shall be avoided to prevent galvanic corrosion. Special attention is required to reliably achieve isolation between dissimilar metal surfaces using inert spacers, washers, sleeves and bushes.

Inaccessible Elements and Surfaces

All steel elements and surfaces which are not accessible after assembly should be provided with a corrosion protection system to *AS/NZS 2312* that will remain effective for the design working life of the building or structure. If this cannot be achieved by means of a protective coating system, other appropriate measures shall be taken, for example:

- Adopting corrosion resistant material(s)
- Designing for replacement
- Designing with provision for suitable corrosion allowance

Repairs to Coating Protection

Corrosion protection which has been damaged during the course of the works shall be repaired or restored before the structure is put into service.

Specialist Corrosion Consultant

For projects where the atmospheric corrosivity classification is C3, C4 or C5 in accordance with *AS/NZS 2312* and *AS 4312*, then corrosion protection requirements for the project shall be addressed by a NACE (National Association of Corrosion Engineers) accredited consultant.

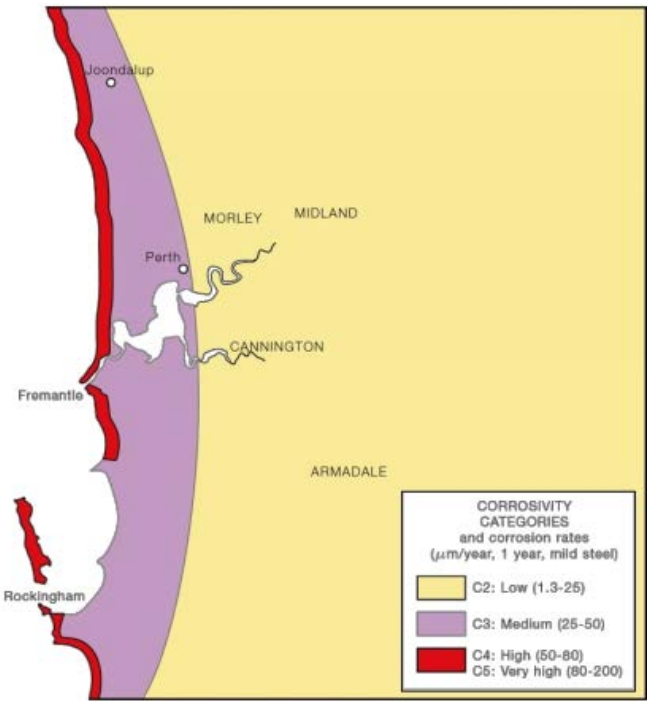
Reference shall be made to figure below for corrosivity classifications relevant to external environments in Perth as a guide.

The need for specialist corrosion consultant services can be omitted at the discretion of UWA subject to assessment of project specific issues, including:

- Design working life less than 50 years
- Protective coating durability performance less than 25 years

The role of the specialist corrosion consultant shall include:

- Assessment of the appropriate corrosivity classification(s)
- Recommendations regarding the appropriate materials and protective coating durability
- Review and input towards steelwork detailing to ensure best practice for durability performance
- Specification of protective coatings which are:
    - Appropriate for the corrosivity classification
    - Incorporating architectural preferences for appearance
    - Compliant with the relevant standards
    - Consistent with manufacturer's recommendations and warranties
- Specification of hold/witness points to be addressed during the protective coating works, e.g. verification of material properties, surface preparation procedures/tests, verification of coating products, coating application procedures/tests, coating thickness tests.
- Specification of protective coating warranties to be provided by the Contractor.
- Document any warranty conditions and required maintenance regimes for submission to the Superintendent. Review this document with UWA to ensure clear understanding of any warranty limitations and acceptance/commitment to the required maintenance regime.
- Review of test results submitted by the Contractor for compliance with specified hold points.
- Attendance at coating works being undertaken by the Contractor for compliance with specified witness points.
- Attendance to site following erection of structural steelwork for compliance with specified hold/witness points for repairs and/or restoration of damaged coatings.



Corrosivity Categories for Perth

2.6.2.5 Masonry

Generally, masonry structures and elements shall comply with the requirements of *AS 3700* for durability.

All masonry materials, accessories, and built-in items shall be selected and combined to suit:

- the relevant exposure classification (determined based on proximity to coastline or industrial activity, and climate zone), and
- the location, i.e., exterior, exterior-coated, interior.

Wall Ties

Special attention is required for documentation and selection of the appropriate durability classification for wall ties, which are addressed as 'built-in items' within *AS 3700*. The durability classification of the wall ties supplied to site shall be clearly marked on the packaging.

Reinforcement and Tendons

Special attention is required for durability of reinforced or prestressed masonry for the relevant exposure classification and location, including:

- Cover to reinforcement and tendons
- Durability class of reinforcement and tendons
- Cement type and content for grout required to protect reinforcement and tendons
- Support requirements for horizontal reinforcement in grouted hollow-unit masonry incorporating flush ended blocks.

2.6.2.6 Structural Timber

All elements of timber structures (including timber, metal, adhesives and other structural material) shall be designed to satisfy the strength, stability and serviceability requirements for the design life of the structure.

Timber Durability

Generally, structural timber shall have the level of durability appropriate for the climate, design working life, and exposure to conditions which could lead to decay, e.g., insect attack, fungal attack and moisture.

As a minimum, design for timber durability shall be in accordance with *AS 1684.2* Appendix B 'Durability' for determination of the following:

- Type and level of hazard to which the timber is exposed
- Natural durability of the heartwood of the particular species
- Type and level of preservative treatment
- Supplementary preservative maintenance

- Protective coatings and their ongoing maintenance

The provisions of *AS 1684.2* Appendix B 'Durability' shall be adopted as a 'mandatory' requirement as part of this document (rather than 'informative' as otherwise permitted by the Standard).

Detailing

Sound timber detailing and construction practices contribute significantly to the overall durability performance of timber structure by reducing exposure to hazards. Reference shall be made to *AS 1684.2* Appendix B and relevant timber industry publications (e.g., NAFI). Special consideration shall be given towards:

- Shielding external timber from the weather, e.g., roof overhangs, screens, cappings
- Isolation from moisture sources, e.g., steel post anchors to avoid ground contact with posts, flashings to prevent contact with concrete and masonry
- Protecting timber end grain, e.g., fascias and barges
- Reducing end grain exposure, e.g., sloping cuts, bevelled ends
- Ventilation to prevent exposure to high humidity and to promote drying, e.g., subfloor areas, roof spaces, wall cavities.

External Timber

Structural timber members that are in ground contact or that are not protected from weather exposure and moisture ingress shall be of in-ground durability class 1 or 2 as appropriate (refer *AS 1720.2* and *AS 5604*), or shall be adequately treated with preservative in accordance with *AS/NZS 1604* series.

Fasteners

All metal used in timber connections (e.g., nails, screws, bolts, nailplates, framing anchors, brackets, post anchors, straps) shall be provided with corrosion protection appropriate for the conditions of use. The level of corrosion protection shall take into account weather exposure, timber treatment, moisture and presence of salt.

Floor and Deck Construction

Ground clearance and subfloor ventilation shall be provided in accordance with the provisions of the *Building Code of Australia*.

Termite Management

Protection against termites shall be provided in accordance with the provisions of the *Building Code of Australia*.

Maintenance

Regular and ongoing maintenance is typically required for timber structures to ensure the protective systems/treatments remain functional. The maintenance program required for the design working life of the structure shall be summarised by the Structural Engineer and submitted to UWA for acceptance prior to proceeding with final documentation.

2.6.3 Maintainability

All structural elements which require maintenance must be provided with a means of safe and efficient access to undertake maintenance works.

The structural works shall also be capable of supporting the access provisions and systems required to maintain other services, e.g. plant and equipment, lighting, decorative linings/finishes.

Design, construction and installation for elements associated with maintenance access (e.g., walkways, platforms, ladders) shall be in accordance with *AS 1657* as a minimum.

2.6.4 Structural Design Actions

2.6.4.1 General

Structural design actions shall be determined in accordance with the Australian Standards and the *Building Code of Australia*. Additional design actions or higher values of specified loads may be nominated according the requirements of individual projects.

The design actions, values and reliability parameters included in this section represent the minimum requirements. All relevant design actions shall be assessed and combinations of actions determined in accordance with the Australian Standards.

In situations where information regarding design actions is not available from the Australian Standards, *BCA* or UWA, then 'special studies' shall be undertaken in accordance with *AS/NZS 1170.0* Appendix A.

Testing may be used to determine data for design in accordance with *AS/NZS 1170.0* Appendix B. Examples of information determined by testing include:

- Values for an action at a particular site (including reliability parameters)
- Design parameters, e.g., wind pressure factors

2.6.4.2 Permanent Actions (Dead Load)

Self-weight

The self-weight of the structure shall be determined based on actual material weights. Reference should be made to *AS 1170.1*, Appendix A for unit weights of materials.

Super-imposed Dead Loads

Super-imposed dead load allowances shall be determined based on the known material weights of:

- All other materials incorporated into the structure, including but not limited to:
    - Building envelope (e.g., façade and roof cladding)
    - Walls
    - Floors (e.g., toppings, screeds, plinths, finishes)
    - Landscaping
    - Ceilings
    - Access walkways and platforms
- Permanent equipment, including but not limited to:
    - Services (e.g., pipes, ductwork, cabling, support trays)
    - Fixtures and fittings (e.g., lights, fans, plant, switchboards and equipment)
    - Partition walls, including:
    - Permanent partitions (e.g., masonry)
    - Operable walls
    - Lightweight framed walls

The minimum provision for movable partitions is 0.5kPa in accordance with *AS/NZS 1170.1*.

2.6.4.3 Imposed Actions (Live Load)

The imposed actions shall be not less than the greater of the following:

- The actions resulting from the intended use or occupancy of the structure
- The imposed actions prescribed within *AS/NZS 1170.1* and its referenced documents.

2.6.4.4 Robustness

A structure shall be designed and constructed so that it will not be damaged to an extent disproportionate to the original cause, by events such as fire, explosion, impact or consequences of human errors.

As a minimum, the structure and its components shall be designed and detailed in accordance with the requirements of *AS/NZS 1170.0* for structural robustness.

For buildings and elements which represent major structures (affecting crowds) with high consequences of failure, consideration shall be given to selecting a structural form and design that can survive adequately the accidental removal of an individual element or a limited part of the structure or the occurrence of acceptable localised damage.

Structural systems which may collapse without warning shall be avoided.

Special consideration is required for structural systems which are susceptible to progressive collapse, e.g., low-

rise buildings with load-bearing concrete wall panels. Progressive collapse shall be prevented by providing more than one means of lateral stability, i.e., the structure should be left with some temporary stability if a member is removed.

2.6.4.5 Wind Actions

Wind actions shall be determined generally in accordance with *AS/NZS 1170.2*.

Wind loads for housing can be determined in accordance with *AS 4055*, subject to compliance with the geometric limits specified within the Standard.

2.6.4.6 Earthquake Actions

Earthquake actions shall be determined in accordance with *AS 1170.4* for structures generally. For earth-retaining structures the earthquake actions shall be determined in accordance with *AS 4678*.

Geotechnical Assessment

The following information shall be determined by a Geotechnical Consultant:

- The site sub-soil class, and
- The potential for liquefaction of soil during an earthquake

Existing Buildings

Assessment for earthquake resistance of existing buildings should be undertaken in accordance with *AS 3826* where it is accepted by UWA and the relevant certifying authority that compliance with *AS 1170.4* is not required.

In the event that the need for compliance with *AS 1170.4* has not been established for an individual project, the Structural Engineer shall provide technical information regarding the scope and context of *AS 3826* and identify the implications for non-compliance with *AS 1170.4* for review and assessment by UWA and the relevant certifying authority.

2.6.4.7 Earth Pressure and Ground Water Actions

Actions associated with earth pressure and ground water shall be determined in accordance with *AS/NZS 1170.1* and *AS 4678*.

The relevant soil parameters and ground water levels shall be determined by a Geotechnical Consultant.

2.6.4.8 Construction Actions

Actions arising from construction and temporary works shall be controlled so the design imposed actions are not exceeded.

Allowance should be included for special actions which could foreseeably arise during construction.

2.6.4.9 Movement Effects

Actions on structures resulting from movement shall be allowed for where appropriate, including but not limited to:

- Expansion or contraction of construction materials, such as those due to creep, temperature or moisture content changes
- Expansion or contraction at the interface between materials having different properties, such as those with differential response to temperature or moisture content changes
- Differential ground settlement

2.6.5 Serviceability Deflections

Design and construction of the structural works shall ensure that deformations, deflections and movements of structural elements and the overall structure are controlled so that all components of the works will perform adequately when subject to normal use under all expected actions over the design working life.

2.6.5.1 Deflection Limits

The appropriate limits for deflection of structural elements shall be determined to ensure adequate serviceability performance of:

- Individual structural elements
- Components supported by the structural elements
- The overall structure or building

The serviceability response shall be assessed as a ratio of the element length (e.g., span, cantilever projection or height) and the total magnitude.

The following serviceability issues shall be assessed when establishing the appropriate deflection limits:

- Visual sagging which may give the incorrect impression when viewed by the public that an element is overstressed or unsafe. The context of the element (e.g., proximity and relationship to other elements or surfaces with true alignment) and the environment of the public are important considerations in this regard

- Prominent elements subject to high levels of visual scrutiny. Members subject to deflection within the minimum specified limits may still have discernible sag or misalignment which draws undesirable attention from observers. More stringent deflection criteria shall be adopted for:
  - Elements which are particularly prominent (e.g., façade or feature members)
  - Elements adjacent visual cues for observers to gauge linearity
  - Elements with glossy or reflective surfaces which tend to amplify sag or rippling.
- Damage to non-structural members. Excessive deflection can lead to unsightly cracking in partitions or brittle partitions
- Damage to glazing. Deflecting members can impose loads on glazing
- Jamming of doors. Deflecting members can distort door frames
- Interference with deflection-sensitive machinery or apparatus. Deflections must not exceed manufacturer's tolerances
- Ponding on floors or roofs
- Damage to finishes or suspended services due to incremental deflections
- Damage to the building envelope from incremental deflections and/or interstorey horizontal movements.

2.6.5.2 Minimum Requirements

The deflection limits adopted for design shall as a minimum comply with the suggested serviceability limits from the following documents:

- *AS/NZS 1170* Appendix C 'Guidelines for Serviceability Limit States;
- *AS 3600* Item 2.3 'Design for Serviceability'
- *AS 4100* Appendix B 'Suggested Deflection Limits'

2.6.6 Dynamic Performance

The dynamic response of structural elements shall be controlled so that all structural elements will perform in a manner appropriate for the intended function and purpose over the design working life.

Consult with the relevant Faculty / Section or their nominated representatives to establish whether the proposed usage is sensitive to vibration.

Determine appropriate limits for the dynamic response of structural elements to ensure adequate serviceability performance.

The structural framing shall be capable of integrating any additional vibration controls such as vibration isolation mounts and the like such as may be needed for highly sensitive equipment which require more onerous vibration control.

2.6.6.1 Vibration Limits

Vibration shall be limited to avoid:

- Discomfort to occupants or users
- Damage to non-structural elements
- Impairment to the function of equipment

Acceptance Criteria for Human Comfort

As a minimum the vibration limits must comply with the suggested serviceability limits as outlined within *AS 2670.2* Table 2, and the illustrated combined direction curves Figures 5a, 5b and 5c given in Annex A.

Vibration Criteria for floors supporting Sensitive Equipment:

In absence of supplier criteria, comply with ASHRAE acceptance criteria (Figure 1 and Table 1 as follows):

- General floor area – comply with VC-A curve.
- Floor directly below item – comply with VC-B curve.

These criteria apply to footfall-induced vibrations. The same criterion values apply to mechanical disturbances at a single frequency or at a number of widely separated frequencies. For disturbances at multiple, closely spaced frequencies, the criterion apply to disturbances observed in one-third-octave bands.

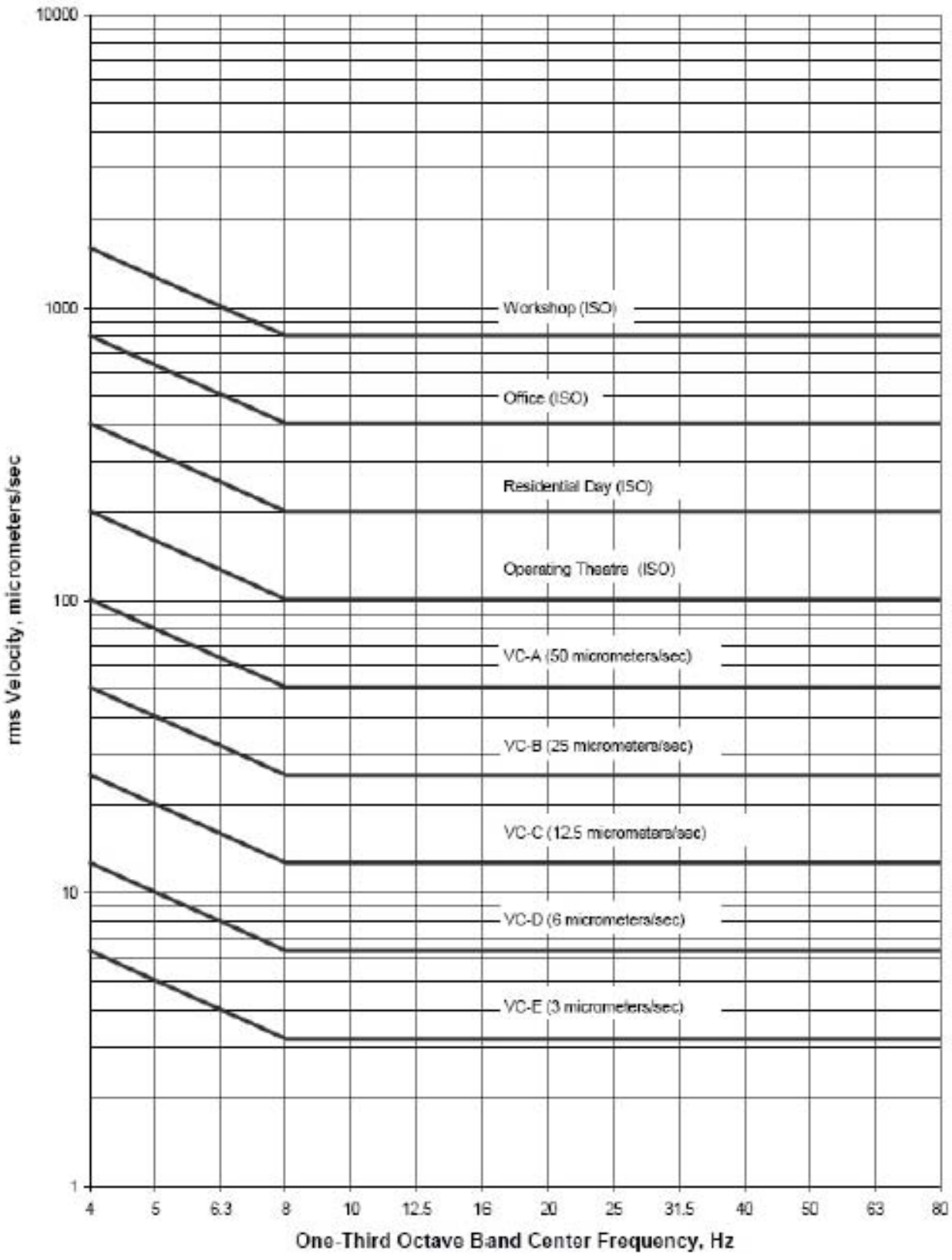


Figure 1. ASHRAE CURVES for Vibration Acceptance Criteria

Table 1: Application and interpretation of the generic vibration criterion (VC) curves (as shown in Figure 1)

Criterion Curve (see Figure 1)	Max Level (1) micrometers/ sec,rms	Detail Size (2) microns	Description of Use
Workshop (ISO)	800	N/A	Distinctly feelable vibration. Appropriate to workshops and nonsensitive areas.
Office (ISO)	400	N/A	Feelable vibration. Appropriate to offices and nonsensitive areas.
Residential Day (ISO)	200	75	Barely feelable vibration. Appropriate to sleep areas in most instances. Probably adequate for computer equipment, probe test equipment and low-power (to 20X) microscopes.
Op. Theatre (ISO)	100	25	Vibration not feelable. Suitable for sensitive sleep areas. Suitable in most instances for microscopes to 100X and for other equipment of low sensitivity.
VC-A	50	8	Adequate in most instances for optical microscopes to 400X, microbalances, optical balances, proximity and projection aligners, etc.
VC-B	25	3	An appropriate standard for optical microscopes to 1000X, inspection and lithography equipment (including steppers) to 3 micron line widths.
VC-C	12.5	1	A good standard for most lithography and inspection equipment to 1 micron detail size.
VC-D	6	0.3	Suitable in most instances for the most demanding equipment including electron microscopes (TEMs and SEMs) and E-Beam systems, operating to the limits of their capability.
VC-E	3	0.1	A difficult criterion to achieve in most instances. Assumed to be adequate for the most demanding of sensitive systems including long path, laser-based, small target systems and other systems requiring extraordinary dynamic stability.

Notes:

(1) As measured in one-third octave bands of frequency over the frequency range 8 to 100 Hz.

(2) The detail size refers to the line widths for microelectronics fabrication, the particle (cell) size for medical and pharmaceutical research, etc. The values given take into account the observation that the vibration requirements of many items depend upon the detail size of the process.

2.6.7 Joints

2.6.7.1 Building Movement Joints

Movement joints passing through the whole structure in one plane shall be provided to control the effects of movement caused by wind, earthquake, linear shrinkage, temperature variations, creep and settlement.

The structure must be independently supported (framed) on both sides of the joint or have sliding bearings which transfer vertical loads whilst allowing appropriate movement in the structure.

Movement joints shall be:

- Continuous through facade elements, floor and wall finishes and shall facilitate the articulation of the structure for expected differential settlements and lateral movements
- Selected to minimise ongoing maintenance
- Selected so as not to represent a slip and trip hazard
- Suitably robust to withstand vehicular and pedestrian traffic
- Able to prevent the passage of fire, smoke, noise and moisture where required
- Avoided within plant rooms and wet areas.

Where movement joints occur in areas which are sensitive to water ingress or damage, then drained joints shall be provided.

Slipjoints and bearings incorporated within joints shall have a minimum design working life of 50 years.

2.6.7.2 Control Joints

Control joints shall be provided in concrete and masonry elements to minimise the effects of linear shrinkage, temperature variations, creep and subgrade movement.

2.6.8 Settlement

2.6.8.1 Generally

Settlement shall be controlled so that all structural elements will perform in a manner appropriate for the intended function and purpose over the design working life.

Appropriate limits for the settlement of structural elements shall be determined to ensure the functional performance of the individual structural element as well as the functional performance of any element which the structure supports is adequate.

Total and differential settlement of foundations must be limited to ensure the serviceability performance of the superstructure meets the functional performance requirements.

Settlement limits shall be selected which are appropriate to the structural system supported by the foundation to limit any detrimental secondary effects induced by settlement.

As a minimum, the following settlement movements must be incorporated into the design:

- individual foundation settlements
- differential settlement between adjacent columns
- differential settlement between ground bearing slabs/pavements/hard landscaping and piled foundations.

2.6.8.2 Recommended Settlement Limits

The following settlement limits shall be adopted as the maximum allowable unless otherwise supported by the Geotechnical consultant and justified in writing to the Project Manager for acceptance:

- Total Settlement:
  Shallow Foundations - 25mm.

  Deep Foundations - 15mm.
- Differential Settlement:
  Differential settlement between adjacent vertical load bearing elements is not exceed to span / 500 or 5mm whichever is the greater.
- Horizontal Movements.
  Horizontal movements are to be maintained within 10mm in any direction.

2.7 GEOTECHNICAL SCOPE

2.7.1 Review of Existing Information

Review any geotechnical reports previously prepared for the project or pertaining to sites within close proximity and determine whether such geotechnical information is relevant.

2.7.2 Geotechnical Scope Definition

In the event that no geotechnical report is available, or if existing information is considered incomplete or not appropriate, the Structural Engineer shall define the technical scope of work required by a Geotechnical Consultant. This document shall be submitted to UWA for the purpose of procuring geotechnical consultancy services.

The Geotechnical workscope shall identify the specific requirements to be addressed within the Geotechnical Report which are relevant to the project, including but not limited to:

- Assessment of soil and groundwater conditions, including likely seasonal variations, across the site
- Recommendations on suitable footing systems
- Geotechnical design parameters for the recommended foundation systems
- Estimates for total and differential settlements of the foundations

- Recommendations and geotechnical design parameters for earth retaining structures in accordance with *AS 4678*
- Site classification in accordance with *AS 2870*
- Assessment of the site factor for earthquake design in accordance with *AS 1170.4*
- Provide geotechnical parameters for pavement design, including CBR
- Recommendations on site preparation requirements, including groundwater control, suitability of in-situ material for re-use as fill, placement of fill, compaction criteria and testing requirements
- Protection to existing buildings, adjoining structures and any underpinning works.
- Design, selection, installation, monitoring and reporting of instrumentation for the monitoring of movements, stresses, strains, groundwater levels and pore pressures and vibrations due to the effects of the works on existing structures, buildings, utilities and services and infrastructure.

In consultation with other services consultants, establish a complete geotechnical workscope summary appropriate for all engineering disciplines, for example:

- **Environmental**: Assessment as to the potential for Acid Sulphate Soils across the site.
- **Civil**: Assessment of near surface subsoil drainage characteristics for the potential disposal of storm water by infiltration.

2.7.3 Geotechnical Report

The structural design and documentation shall be based upon the Geotechnical Report prepared or adopted.

3 Checklist for Project Team

ACTIVITY	RESPONSIBILITY	STAKEHOLDER(S)	TIMEFRAME
Review of existing Geotechnical Report for adequacy, or scope definition for procurement of Geotechnical Services.	Structural Consultant	CM (Engineering Services) / CM (Capital Works)	Gate 2 Feasibility
Specification of protective coatings for structural steel within 'Medium' to 'High' Corrosivity Categories by Specialist Corrosion Consultant	Structural Consultant		Gate 3 Planning
Provisions for future re-planning or alternate occupancy/use.	Structural Consultant	CM (Capital Works) / Client Faculty	Gate 2 Feasibility
Specific project requirements for vibration sensitive equipment or activities.	Structural Consultant	CM (Capital Works) / Client Faculty	Gate 2 Feasibility
Modifications to existing buildings to include assessment for implications to the overall structure	Structural Consultant		Gate 2 Feasibility
ESD requirements or initiatives.	Structural Consultant	CM (Engineering Services) / CM (Capital Works)	Gate 3 Planning

Abbreviations

ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers
BCA	Building Code of Australia
CBR	California Bearing Ratio
CM	Campus Management
ESD	Ecologically Sustainable Design
GB	General Blended (cement)
GP	General Purpose (cement)
NACE	National Association of Corrosion Engineers
NAFI	National Association of Forest Industries
UDL	Uniform Distributed Load
UWA	The University of Western Australia

References

AS/NZS 1170	Structural design actions
AS/NZS 1604	Specification for preservative treatment
AS 1657	Fixed platforms, walkways, stairways and ladders
AS 1684	Residential timber framed construction – Non-cyclonic areas
AS 1720	Timber structures
AS 2159	Piling – Design and installation
AS/NZS 2312	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings
AS 2670	Evaluation of human exposure to whole-body vibration
AS 2870	Residential slabs and footings
AS 3600	Concrete structures
AS 3610	Formwork for concrete
AS 3700	Masonry structures
AS 3735	Concrete structures retaining liquids
AS 3826	Strengthening existing buildings for earthquake
AS 4055	Wind loads for housing
AS 4100	Steel structures
AS 4312	Atmospheric corrosivity zones in Australia
AS 4678	Earth-retaining structures
AS 4773	Masonry in small buildings
AS 4997	Guidelines for design of maritime structures
AS 5100	Bridge design
AS 5604	Timber - Natural durability ratings
BCA	Building Code of Australia

THE UNIVERSITY OF WESTERN AUSTRALIA

Campus Management

The University of Western Australia
M458, Perth WA 6009
Tel: +61 8 6488 2025
cm.uwa.edu.au