Proposal Form - Standards Development Projects

Version: 3.6
Issued: 14 June 2013

This form is to be completed for proposals to initiate projects to produce Australian or Australian/New Zealand Standards or other documents published by Standards Australia. This includes significantly modified adoptions of International Standards. For identical adoptions of International Standards please complete the Proposal Form – Direct Text Adoptions.

Proposals for participation in international Standards development should use the Proposal Form - Participation in International Standards Development Programs.

This form will take some time and care to complete. It is important that all sections are completed, and that stakeholder consultation is conducted and their input is incorporated. This ensures that Standards Australia is presented with the best information on which to prioritise its efforts across a range of sectors and proposals. It also helps to ensure that there is consensus from appropriate communities of interest on the need for and the importance of the Standard, and on the expectations, timetable and direction of the project. All these elements contribute to producing a quality document in the most efficient and quickest manner.

If the proposal includes new or revised joint Australian/New Zealand Standards, Standards Australia will contact Standards New Zealand to ensure appropriate consultation with New Zealand stakeholders.

Please submit completed forms to mail@standards.org.au by the closing date advertised at: http://www.standards.org.au/StandardsDevelopment/Developing_Standards/Pages/Proposing-a-project.aspx
GUIDANCE

What information do I need to provide?

<table>
<thead>
<tr>
<th>Section &amp; Title</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Proponent Details</strong></td>
<td>All proposals need to be submitted by an individual, preferably supported by a national organisation. Provide contact details to be used in any correspondence regarding the proposal.</td>
</tr>
<tr>
<td>1. <strong>Proposal Details</strong></td>
<td>Specify the title, type, relevant sector(s) and type of work being proposed. If a program of work, further information should be provided in the appendix or attachments.</td>
</tr>
<tr>
<td>2. <strong>Summary and Demonstration of Net Benefit</strong></td>
<td>Outline the need for, and Net Benefit impact of, the proposed work on the Australian community.</td>
</tr>
<tr>
<td>3. <strong>Harmonisation and Alignment</strong></td>
<td>List existing related documents and alignment of proposed work to these documents.</td>
</tr>
<tr>
<td>4. <strong>Pathways for Standards Development</strong></td>
<td>State the desired development pathway and who will fund the proposed work.</td>
</tr>
<tr>
<td>5. <strong>Stakeholder Support</strong></td>
<td>Provide details of relevant stakeholders across interest groups, the consultation process undertaken and whether they support the proposal.</td>
</tr>
<tr>
<td>6. <strong>Risks and Dependencies</strong></td>
<td>Highlight known risks and any dependencies that may impact successful completion of the proposed project/program.</td>
</tr>
<tr>
<td>7. <strong>Additional Information</strong></td>
<td>Provide any additional information which may assist in consideration of the proposal.</td>
</tr>
<tr>
<td>8. <strong>Declaration</strong></td>
<td>Confirm that all information within the proposal form is true and accurate.</td>
</tr>
<tr>
<td><strong>Appendix A: Stakeholder Consultation</strong></td>
<td>Identify the relevant Australian stakeholder organisations which may have an interest in this proposal and provide evidence of consultation and support.</td>
</tr>
<tr>
<td><strong>Appendix B: Details of projects within a proposed program of work</strong></td>
<td>Where required, provide details of projects in order of priority for development where multiple projects or a program of work is being proposed.</td>
</tr>
<tr>
<td><strong>Appendix C: Project Complexity Matrix</strong></td>
<td>Used for calculation of project complexity in Section 1 and Appendix B.</td>
</tr>
</tbody>
</table>

How do I submit a completed proposal?

1. Complete a pre-submission check to ensure that:
   - All sections of the form are complete.
   - The Net Benefit case is fully articulated and, where possible, quantified.
   - Full stakeholder consultation has been conducted with evidence provided.
   - The declaration is complete.
   - All supporting documentation is attached to the proposal.

2. Submit completed proposal along with all supporting documentation by email to mail@standards.org.au

3. If for any reason, you are unable to submit this form by email, please contact Standards Australia (1800 035 822).
PROPOSAL FORM FOR STANDARDS DEVELOPMENT PROJECTS

<table>
<thead>
<tr>
<th>Proposal Reference Number</th>
<th>Standards Australia to Complete</th>
</tr>
</thead>
</table>

Proponent Details

<table>
<thead>
<tr>
<th>Your name</th>
<th>Dr. Daniela Ciancio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>Associate Professor</td>
</tr>
<tr>
<td>Name of employer</td>
<td>University of Western Australia</td>
</tr>
<tr>
<td>Address</td>
<td>School of Civil and Resource Engineering M051, UWA, 35 Stirling Hwy</td>
</tr>
<tr>
<td>Suburb</td>
<td>Crawley</td>
</tr>
<tr>
<td>State</td>
<td>WA</td>
</tr>
<tr>
<td>Postcode</td>
<td>6009</td>
</tr>
<tr>
<td>Phone number</td>
<td>8 6488 3892</td>
</tr>
<tr>
<td>Fax number</td>
<td></td>
</tr>
<tr>
<td>Mobile number</td>
<td></td>
</tr>
<tr>
<td>Email address</td>
<td><a href="mailto:daniela.ciancio@uwa.edu.au">daniela.ciancio@uwa.edu.au</a></td>
</tr>
<tr>
<td>Web address</td>
<td></td>
</tr>
</tbody>
</table>

Supporting/Nominating Organisation Details (if applicable)

<table>
<thead>
<tr>
<th>Name of proponent's national organisation supporting this proposal</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Western Australia?</td>
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<tr>
<td>Australian Research Council?</td>
<td></td>
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<tr>
<td>Government of Western Australia Department of Housing?</td>
<td></td>
</tr>
<tr>
<td>EBAA?</td>
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</tr>
</tbody>
</table>

Contact officer at national organisation

Contact details

NOTE:

Standards Australia reserves the right to make public information relating to Standards development projects, including information contained within submitted proposal forms and the attached Net Benefit Case in part or in full.

In the event that Standards Australia publishes proposals on its website, this section and stakeholder contact details provided at Appendix A will not be included. However, with prior agreement, your contact details may be provided to interested parties wishing to contribute or comment on the proposal or the proposed project.
1. Proposal Details

<table>
<thead>
<tr>
<th>Proposal title</th>
<th>Development of Standards for the testing of rammed earth soils for engineering purposes (Complete revision of testing methods given in HB 195 The Australian Earth Building Handbook)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Scope</td>
<td>Complete revision of testing methods given in HB 195 in order to keep pace with recent research in the field of earthen construction materials. There is a need to develop a set of Standards for the testing of rammed earth soils for engineering purposes in order to provide regulation for a rapidly growing industry.</td>
</tr>
<tr>
<td>Project or program</td>
<td>Project</td>
</tr>
<tr>
<td>Project type</td>
<td>New documents (complete revision of testing methods given in HB 195 The Australian Earth Building Handbook).</td>
</tr>
<tr>
<td>Product type</td>
<td>Standard</td>
</tr>
<tr>
<td>Committee</td>
<td>Standards Australia Committee BD-083, Earth Building</td>
</tr>
<tr>
<td>Scale of proposed work</td>
<td>• Small</td>
</tr>
</tbody>
</table>

Proposal Reference Number | Standards Australia to Complete

Proposal title
Please provide the full and correct title of the proposed document(s).

Project Scope
Briefly summarise what is being requested within this proposal. Please summarise the scope of the Standard(s) to be produced. Please outline any specific inclusions and exclusions. *For programs of work, please include the scope of each project in sufficient detail at Appendix B.*

Project or program
Please specify if this proposal covers a single project or multiple projects. If a program of work is proposed that covers multiple projects, please include details of each project in Appendix B.

Project type
Please indicate whether the project is a new document, amendment, revision or other. If other, please specify. If applicable, please provide the existing Australian or International Standard number and full title of the standard (e.g. AS, AS/NZS, ISO, IEC or other).

Product type
Please indicate whether the output of this project is to be a Standard, handbook, or other type of document.

Committee
Are you aware of an Australian or International technical committee working in this field? Please provide details, including any related committees that may be affected by this proposal.

Scale of proposed work
Please indicate the size/complexity rating of the proposed project/program, taking account of the size of the document, changes required, expected level of comment etc. For further information, please refer to Appendix C to this form.
<table>
<thead>
<tr>
<th>Sector</th>
</tr>
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<tbody>
<tr>
<td>Please delete any non-relevant sectors. Select one or more from:</td>
</tr>
<tr>
<td>• Building and Construction</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relationship to legislation</th>
</tr>
</thead>
<tbody>
<tr>
<td>If the document is referenced in legislation in Australia (or New Zealand for joint documents), please provide details here. If so, is this as a primary or secondary reference?</td>
</tr>
<tr>
<td>None known</td>
</tr>
</tbody>
</table>

*Note: If this Standard is a primary or secondary reference in the National Construction Code, please refer to the Protocol for the development of National Construction Code referenced documents available at: [http://www.abcb.gov.au](http://www.abcb.gov.au)*

<table>
<thead>
<tr>
<th>Conformity assessment</th>
</tr>
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<tbody>
<tr>
<td>Does this proposal include any conformity assessment requirements?</td>
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<tr>
<td>No</td>
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</tbody>
</table>

*Note: If conformity assessment requirements are being considered for inclusion, please note that an additional miscellaneous publication will be required, and should be included as a separate project item in Appendix B – conformity assessment requirements are not included in Australian Standards. Please see [SG-006 Rules for the structure and drafting of Australian Standards](http://www.standards.org.au) for further information.*

If yes, please provide additional details as an attachment to this form. The request is to include:

- the reason for the inclusion;
- why regulation is not addressing the matter;
- the benefits to the Australian community from a safety aspect;
- the benefits to the industry sector;
- the cost to the community and to manufacturers;
- the risk of its non-inclusion;
- technical barriers to trade implications.
2. Summary and Demonstration of Net Benefit

All Australian Standards developed by Standards Australia must demonstrate a Net Benefit, i.e. the Standard must have an overall positive benefit to the Australian community. All proposals for new work must describe a clear need for a Standards solution and the anticipated Net Benefit in the form of a Net Benefit case. Further guidance is available within the Standards Australia Guide to Net Benefit.

Note: Where a more detailed Net Benefit case is required, this may be attached separately.

<table>
<thead>
<tr>
<th>Need for the proposed work</th>
<th>Problem to be addressed: lack of proper code slows down rammed earth construction and stops potential growth of this industry sector. Goals: provide Australia-wide accepted guidelines for soil analysis and material characterization for rammed earth construction. Demonstration of justified work and its implementation: ARC supported a 3-year project to develop new and validate existing testing methods for soil assessment in rammed earth constructions. The project has been already implemented.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment with national public policy</td>
<td>national or public policy interest: desire of more sustainable, affordable and Australian climate suitable construction techniques.</td>
</tr>
</tbody>
</table>
| Net Benefit | • Public Health and Safety  
• Social and Community Impact  
• Environmental Impact  
• Competition  
• Economic Impact |
### 3. Harmonisation and Alignment

**Related documentation**

Please research and list any known industry, domestic, regional, other national or international standards, guides, codes and research related to the proposal.

<table>
<thead>
<tr>
<th>No Australian Standards are related to the proposal. HB 195, in conjunction with CSIRO Bulletin 5, is currently used to inform testing of rammed earth materials. HB 195 and CSIRO Bulletin 5 make reference to several Australian Standards for various testing methods. These Standards would not be affected by the development of the proposed Standard.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Related National (non-Australian) Standards:</td>
</tr>
<tr>
<td>NZS 4297. Engineering design of earth buildings, Standards New Zealand.</td>
</tr>
<tr>
<td>NZS 4298. Materials and workmanship for earth buildings, Standards New Zealand.</td>
</tr>
<tr>
<td>NZS 4299. Earth buildings not requiring specific design, Standards New Zealand.</td>
</tr>
<tr>
<td>SAZS 724. Rammed earth structures, Standards Association of Zimbabwe.</td>
</tr>
</tbody>
</table>

**Avoidance of duplication**

How will the proposed document relate to any of the existing material listed above? Please address any apparent or actual duplication between the existing material and the proposed document(s).

| The proposed Standard aims to build on those methods contained within HB 195 and CSIRO Bulletin 5 (and documents referenced therein) to reflect recent advances made in the understanding and testing of soils for rammed earth testing. Although testing of stabilised soils is discussed in AS 1289 and AS 5101, amongst others, there are several situations unique to rammed earth materials that require new methods to be defined. |

**Alignment with International Standards**

If there is an existing International Standard that covers the scope of this proposal, but is not being adopted, please clarify this position.

| None |

### 4. Pathway for Standards Development

**Preferred development pathway**

Please select one. If Other, please provide details of discussions with Standards Australia.

| Externally Funded |

**Committee capability and capacity**

If there is an existing Standards Australia committee working in this field, please specify their capability and capacity to take on additional work.

| Standards Australia Committee BD-083, Earth Building was involved in the production of HB 195. It is unknown whether this committee has been active since the |
projects relating to this proposal, particularly relating to programs of work described at Appendix B.

Standards Australia process to be funded by

<table>
<thead>
<tr>
<th>Please select one.</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Proponent</td>
</tr>
</tbody>
</table>

Note: For information on the various standards development pathways refer to:

5. Stakeholder Support

Consultation process

Provide details on the consultation process undertaken in development of this proposal, including identified stakeholder groups and the outcomes.

Please complete Appendix A and provide evidence of stakeholder support.

Work necessary for the production of a Standard for the testing of rammed earth materials has been conducted as part of an ongoing Linkage Project (LP110100251), jointly funded by the Australian Research Council (ARC) and the Government of Western Australia Department of Housing (WADoH). The project's working group comprises rammed earth research, engineering, architecture and building experts who each represent the key stakeholders. As such, all input required for document development will include stakeholder consultation. This will happen during the ICREC2015 workshop.

6. Risks and Dependencies

Risks

Are there any key risks that you know of that may impact this project?

Note: Project risk does not include Standards Australia failing to approve this proposal.

Dependencies

Are there any fundamental dependencies on this e.g. changes to legislation, publication or revision of a related Standard or the need to publish concurrently with an Australian or International Standard?

Indicative timelines

Taking into account the risks and dependencies identified above, and an average publication cycle of 12 months, please provide estimates of the duration of key project stages.

Estimated time to complete draft for public comment from project initiation:

6 months

Estimated time to publication from project initiation:

12 months
7. Additional Information

<table>
<thead>
<tr>
<th>Comments</th>
<th>In attachment:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Please provide comments (if any) which support this proposal or assist its consideration.</td>
<td>Net Benefit Case</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Funding declaration</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are you aware of any direct or indirect funding for this proposed work, other than employer support to attend and participate in meetings?</td>
<td></td>
</tr>
</tbody>
</table>

8. Declaration

Please check your proposal is complete, read and complete the declaration, then forward this proposal and any attached documents to Standards Australia at mail@standards.org.au. The named proponent is deemed to have approved the information contained within this proposal and this declaration. This is required prior to formal consideration of this proposal.

<table>
<thead>
<tr>
<th>Name of Proponent</th>
<th>Dr. Daniela Ciancio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of Nominating Organisation representative (if supported by a suitable national organisation)</td>
<td>UWA? EBAA?</td>
</tr>
</tbody>
</table>

| Date | |

* As defined in Standard Australia’s Guide to Net Benefit.
Appendix A: Stakeholder Consultation

Please identify the relevant Australian stakeholder organisations which have been consulted or which may have an interest in this proposal. All categories of stakeholders should be considered for consultation and participation, but all are not required. Evidence of consultation and stakeholder responses **must** be provided (organisation/company emails or letterhead only). If the proposal includes new or revised joint Australia/New Zealand Standards, Standards Australia will contact Standards New Zealand to ensure appropriate consultation with New Zealand stakeholders.

<table>
<thead>
<tr>
<th>Key stakeholder groups</th>
<th>Organisation Name</th>
<th>Contact name</th>
<th>Position</th>
<th>Email</th>
<th>Do they agree with this proposal (Y/N)?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research and academic organisations</td>
<td>University of Western Australia</td>
<td>Dr. Daniela Ciancio</td>
<td>Assistant Professor</td>
<td><a href="mailto:daniela.ciancio@uwa.edu.au">daniela.ciancio@uwa.edu.au</a></td>
<td>Y</td>
</tr>
<tr>
<td>Consumer interests</td>
<td></td>
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<tr>
<td>Government organisations</td>
<td>WA DoH</td>
<td>Mr. David Carpenter</td>
<td>Manager Country Construction &amp; Special Projects</td>
<td><a href="mailto:David.CARPENTER@housing.wa.gov.au">David.CARPENTER@housing.wa.gov.au</a></td>
<td>Y</td>
</tr>
<tr>
<td>Regulatory and controlling bodies</td>
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<tr>
<td>Technical associations</td>
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<tr>
<td>Professional associations</td>
<td>Earth Building Association of Australia</td>
<td>Mr. Stephen Dobson</td>
<td>Owner, Director RAMTEC plc.</td>
<td><a href="mailto:mail@ramtec.com.au">mail@ramtec.com.au</a></td>
<td>Y</td>
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<tr>
<td>Manufacturers’ associations</td>
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<td>Suppliers’ associations</td>
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<tr>
<td>User and purchasing bodies</td>
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</tr>
<tr>
<td>Testing bodies</td>
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<td>Auditing bodies</td>
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<td>Certification bodies</td>
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<tr>
<td>Employer representative bodies</td>
<td>Unions and employee associations</td>
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<tr>
<td>Independent</td>
<td>Scott Smalley Partnership</td>
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<tr>
<td></td>
<td>Mr. William Smalley</td>
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<td></td>
<td>Partner</td>
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<tr>
<td></td>
<td><a href="mailto:smalleyw@sspeng.com.au">smalleyw@sspeng.com.au</a></td>
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<td></td>
<td>Y</td>
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</tbody>
</table>

New Zealand
Appendix B: Details of projects within a proposed program of work

Where a program has been specified in Section 2, please provide details of projects in order of priority for development. If preferred, details can be provided in a separate file and attached to this proposal.

<table>
<thead>
<tr>
<th>Priority</th>
<th>Title</th>
<th>Committee</th>
<th>Pathway</th>
<th>Designation</th>
<th>Complexity Rating</th>
<th>Project type</th>
<th>Product type</th>
<th>Brief project scope and dependencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g.</td>
<td>Information Technology – Personal Computers – Hard Drives</td>
<td>AB-123</td>
<td>Committee Driven</td>
<td>AS/ISO 1234</td>
<td>Small</td>
<td>Revision</td>
<td>Standard</td>
<td>Adoption of ISO 1234 as an Australian Standard. This Standard relies on the publication of AS1233.</td>
</tr>
<tr>
<td>1</td>
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</table>
### Appendix C: Project Complexity Matrix

- Use this matrix to complete an initial assessment of project complexity.
- For each question, review the criteria and enter the appropriate Rating (1 to 5) for the project in the far right column.

<table>
<thead>
<tr>
<th>#</th>
<th>Factor</th>
<th>Rating Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>What is the anticipated duration of the project?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 3 months</td>
<td>3 - 6 months</td>
<td>6 - 24 months</td>
<td>2 - 3 years</td>
<td>&gt; 3 years</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>What overall level of risk (technical risk, political risk and consensus risk) is associated with the project in the context of the committee?</td>
<td>Very Low</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>Very High</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>What level of overall technical complexity does the project have?</td>
<td>Very Low</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>Very High</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>What is the size of (the change to) the standard or the consensus document?</td>
<td>1-2 pages</td>
<td>2 - 20 pages</td>
<td>20-100 pages</td>
<td>100 - 300 pages</td>
<td>&gt;300 pages</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>What is the expected level of public comment/adverse reaction to the project?</td>
<td>Very Low</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>Very High</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL** 9

### COMPLEXITY RATING

- **Small**
- **Simple Complexity**
  - Adoption, endorsement of an ISO standard with high consensus.
- **Small Complexity**
  - Technical report with low complexity, low risk and low profile.
- **Medium Complexity**
  - New standard or revision with moderate complexity and risk.
- **Large Complexity**
  - New standard or revision with high complexity and risk.
- **Complex Complexity**
  - New standard or revision with very high complexity, profile, risk and major references in legislation e.g. Wiring Rules Standard
INDEX of Sections

• Rammed earth soil compaction and density tests—Determination of the dry density/moisture content relation of rammed earth using modified compactive effort

• Determination of drying shrinkage of compacted rammed earth materials

• Method for securing and testing cores from hardened rammed earth for compressive strength

• Unconfined compressive strength of compacted rammed earth materials

• Determination of flexural tensile strength of rammed earth beams (bending or flexure test)

• Determination of indirect tensile strength of rammed earth cylinders (‘Brazil’ or splitting test)
Methods of testing rammed earth soils for engineering purposes

Method x.x.x: Rammed earth soil compaction and density tests—Determination of the dry density/moisture content relation of rammed earth using modified compactive effort

1 SCOPE
This Standard sets out a method for the determination of the relationship between the moisture content and the dry density of a soil for use for rammed earth construction, when compacted using modified compactive effort (2703 kJ/m$^3$) in the presence or absence of cementitious stabilising binders such as lime, blended lime mixtures, cement, blended cements, bituminous or other materials. Compaction is conducted over a range of moisture contents to establish the maximum mass of dry soil per unit volume achievable for this compactive effort, and its corresponding moisture content. The procedure is applicable to that portion of a soil that passes the 37.5 mm sieve. Soil that passes the 19.0 mm sieve is compacted in a 105 mm diameter mould. Soil that contains more than 20% of material retained on the 19.0 mm sieve is compacted in a 152 mm diameter mould.

NOTES:

1. Corrections for oversize material are not made in this method but may be made using AS 1289.5.4.1 when required for compaction control.
2. The binders usually used for stabilized rammed earth construction are covered by the following Standards:
   (a) Limes, AS 1672.1.
   (b) Cements, AS 3972.
   (c) Bitumens, AS 1160 and AS 2157.
3. Compaction regime used on-site is likely to be different to that specified in this method. It is the user’s responsibility to account for these differences for design purposes.

2 REFERENCED DOCUMENTS
The following documents are referred to in this Standard:

AS

1160 Bitumen emulsions for construction and maintenance of pavements
1672 Limes and limestones
1672.1 Part 1: Limes for building
2157 Cutback bitumen
3972 Portland and blended cement
1289.0 Method 0 General requirements and list of methods
1289.1.1 Method 1.1 Sampling and preparation of soils—Preparation of disturbed soil samples for testing
1289.2.1.1 Method 2.1.1 Soil moisture content tests—Determination of the moisture content of a
3 APPARATUS
In accordance with AS 1289.5.2.1.

4. PROCEDURE

4.1 Determination of the dry density/moisture content relation of a rammed earth soil using modified compactive effort in the absence of cementitious stabilising binders.

The procedure shall be as follows:

(a) Prepare the sample in accordance with AS 1289.1.1.
(b) Determine the dry density/moisture content relation in accordance with AS 1289.5.2.1.

4.2 Determination of the dry density/moisture content relation of a rammed earth soil using modified compactive effort in the presence of cementitious stabilising binders.

The procedure shall be as follows:

(a) Dry the sample and cementitious stabilising binders in the oven at 105°C to 110°C to constant mass (see Notes below).
(b) When the sample has been dried sufficiently, remove from the oven and allow cooling to touch.

NOTES:

1. Drying time of soils A drying time of 16 h to 24 h is usually sufficient for most soils, but certain soil types and large or very wet samples will require longer. The drying time will also depend on the total amount of material in the oven.
2. Soils containing gypsum  Gypsum loses water of crystallization on heating. Therefore, a moisture content determined by this method will increase by approximately 0.2% for each 1% of gypsum. If it is suspected that gypsum is present in the soil, the sample should be dried at a temperature of not more than 80°C for a longer time and the change in procedure reported.

(c) Screen the prepared material over a 19.0mm sieve. If necessary, brush fine material from the material retained on the sieve. Determine the mass of the retained material and calculate the percentage retained on the 19.0mm sieve from the equation:

\[ P_0 = \frac{100m_0}{m} \]  

where

\[ P_0 = \text{percentage by mass of + 19.0mm (oversize) material} \]
\[ m_0 = \text{dry mass of +19.0mm (oversize) material, in grams} \]
\[ m = \text{dry mass of total sample, before screening, in grams} \]

If \( P_0 \) is greater than 20%, screen the retained 19.0 mm material over a 37.5 mm sieve. Determine the mass of the retained 37.5 mm material and calculate the percentage retained on the 37.5 mm sieve using the above equation, substituting +37.5 mm for +19.0 mm in the equation notation. If required, keep the material retained on the 19.0 mm, or 19.0 mm and 37.5 mm sieves for dry mass and volume determinations.

NOTE: It is necessary that the dry mass and volume of oversize material be determined if a correction is required to the maximum dry density and optimum moisture content as detailed in AS 1289.5.4.1.

(d) Select the size fraction and mould to be used in the compaction test using the criteria in Table 2. Record the mould used; that is, A or B. When necessary, recombine the material passing the 37.5 mm sieve and that passing the 19.0 mm sieve and thoroughly mix.

TABLE 1

<table>
<thead>
<tr>
<th>Percentage retained</th>
<th>Test method</th>
<th>Portion to be tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5 mm sieve</td>
<td>19.0 mm sieve</td>
<td></td>
</tr>
<tr>
<td>&gt; 20</td>
<td>B</td>
<td>All material passing 37.5 mm sieve</td>
</tr>
<tr>
<td>\leq 20</td>
<td>A</td>
<td>All material passing 19.0 mm sieve</td>
</tr>
</tbody>
</table>

(e) Split out four or more representative portions of the sieved soil, each of sufficient quantity to produce a compacted volume in excess of the volume of the mould.

NOTE: For material compacted in a 105 mm diameter mould, a mass of 2.5 kg will be adequate for most soils. A gravel may, however, require up to 3 kg, whilst it may be possible to use as little as 2 kg with a heavy clay. For material compacted in 152 mm diameter mould about 2.5 times the mass of the material required for a 105 mm diameter mould will be required.
(f) Take the portions of the soil as prepared in Step (e). Thoroughly mix each portion with the required amount of dry binder for a minimum of 5 minutes.

(g) Clean the mould, collar and baseplate. Inspect and clean the rammer and ensure that it is free in the guide.

(h) Determine the mass \( m_1 \) of the mould plus baseplate attached to the compaction block. In such cases determine the mass of the mould alone.

(i) Assemble the mould, collar and baseplate and place the assembly on the rigid foundation.

(j) Determine a mass \( w_i \) of water to be added to sample portion \( i \) so that the optimum moisture content is judged to be straddled. Use essentially equal increments of water between portions and ensure that the water steps are not excessive for the soil type.

**NOTE:** As a guide, suitable intervals of water content range between 1% for crushed rock and gravel and 2% to 3% for clays.

(k) Compact the specimen as follows (the procedure depends upon the size of the materials):

(i) **Testing material passing the 19.0 mm sieve only (Mould A)**

   Take sample portion \( i \) and mix it thoroughly with a mass of water \( w_i \) for a minimum of 1 minute. Compact into the mould in five layers, so that the compacted height of soil in the mould is 23 mm to 28 mm in the first layer, 47 mm to 52 mm in the second layer, 70 mm to 75 mm in the third layer, 93 mm to 98 mm in the fourth layer and 116 mm to 120 mm in the fifth layer. Specimens that do not meet these tolerances shall be discarded. Material from a previously compacted specimen shall not be reused.

   Compact each layer by 25 uniformly distributed blows of the rammer falling freely from a height of 450 mm. Use only sufficient soil, which is representative of the portion, to meet the layer heights above.

   **NOTES:**

   1. It is necessary to control the total amount of soil compacted since, if the amount of soil struck off after removing the collar is too great, the test results will be inaccurate as the energy input will not be within the required tolerances. Some large particles may protrude a little more than 5 mm above the surface for the passing 37.5 mm material. Suitable allowances in the trimming process must be made for these particles but the average height of the compacted specimen before trimming should not exceed 5 mm above the mould.

   2. Step (k) must be completed within 45 minutes of the addition of water mass \( w_i \) to sample portion \( i \) in order to prevent cementation from interfering with compaction. Discard specimens that do not meet this requirement.

(ii) **Testing material passing the 37.5 mm sieve (Mould B)**

   Take sample portion \( i \) and mix it thoroughly with a mass of water \( w_i \) for a minimum of 1 minute. Compact it into the mould in three layers, so that the compacted height of the soil in the mould is 44 mm to 49 mm in the first layer, 89 mm to 94 mm in the second and 133 mm to 138 mm in the third layer. Specimens that do not meet these tolerances shall be discarded. Material from a previously compacted specimen shall not be reused.

   Compact each layer by 100 uniformly distributed blows of the rammer falling freely from a height of 450 mm. Use only sufficient soil, which is representative of the portion, to meet the layer heights above (see Notes to Step (j)(i) above).

(l) Free the material from around the inside of the collar and then carefully remove the collar.
(m) Trim the surface of the specimen while the mould is still attached to the baseplate as follows (the procedure depends upon the characteristics of the soil):

(i) **Essentially fine-grained soil** Trim the compacted soil level with the top of the mould by means of the straightedge; use smaller size material to patch any holes developed in the surface from removal of coarse material during trimming.

(ii) **Soil containing stones** Trim the compacted soil in the mould ensuring that portions of stones standing above the top of the mould are compensated by hollows of about the same volume below the top of the mould.

(n) Determine the mass \(m_2\) of the mould and the soil, with baseplate if appropriate.

(o) Immediately remove the soil specimen from the mould.

**NOTE:**

1. The water content \(w_{oven}\) of the specimen or a representative sample of the full specimen height can be determined in accordance with AS 1289.2.1.1 or one of the subsidiary methods AS 1289.2.1.2, AS 1289.2.1.4, AS 1289.2.1.5 or AS 1289.2.1.6 for which a correlation has been established in accordance with AS 1289.2.3.1.

2. It should be noted that \(w_{oven} \neq w_t\) due to hydration of the cementitious binder on exposure to elevated temperatures.

(p) Discard the used soil. Soil from a previously compacted specimen shall not be reused.

(q) Repeat Steps (g) to (p) excluding Step (h) with the other portions of prepared soil to obtain at least four points, at least two of which shall be dryer, and one wetter, than optimum moisture content to satisfactorily define the dry density/moisture content relationship.

(r) If the optimum moisture content has not been straddled or is imprecisely defined, use additional soil portions prepared in the same manner as in Steps (a) to (c) and compact these at appropriate moisture contents as in Steps (d) to (p).

**NOTE:** If, with increasing moisture content, the wet mass of compacted soil markedly increases and then starts to decrease, the optimum moisture content probably has been straddled adequately. For soils with low plasticity and high permeability, points wetter than optimum moisture content may not be achieved due to loss of water during compaction.

### 5 CALCULATIONS

Calculate as follows:

(a) For each specimen, density of wet soil \((\rho)\) from the following equation:

\[
\rho = \frac{(m_2 - m_1)}{V} \quad [2]
\]

where

\[
\begin{align*}
\rho & = \text{density of wet soil, in tonnes per cubic metre} \\
 m_2 & = \text{mass of mould plus baseplate plus specimen, in grams} \\
 m_1 & = \text{mass of mould plus baseplate, in grams} \\
 V & = \text{the measured volume of the mould, in cubic centimetres}
\end{align*}
\]

(b) For each specimen \(i\), density of dry soil \((\rho_d)\) from the following equation:
$$\rho_d = \frac{100\rho}{100 + w_i} \tag{3}$$

where

- $\rho_d$ = dry density of wet soil, in tonnes per cubic metre
- $\rho$ = density of wet soil, in tonnes per cubic metre
- $w_i$ = water content of sample portion $i$, in percent

(c) Calculate points for the chosen air voids line (see Note) from the soil particle density, either assumed or determined in accordance with AS 1289.3.5.1, from the following equation:

$$\rho_d = \frac{1 - V_a/100}{1/\rho_s + w/100} \tag{4}$$

where

- $\rho_d$ = dry density of wet soil, in tonnes per cubic metre
- $V_a$ = volume of air voids in the soil, expressed as a percentage of the volume of the undried material
- $\rho_s$ = density of wet soil, in tonnes per cubic metre
- $w_i$ = water content of sample portion $i$, in percent

Plot the air voids line in accordance with AS 1289.0 (see Note)

(d) Plot the dry densities obtained for the compacted specimens against their corresponding water contents. Draw a smooth curve of best fit through the resulting points with the wet leg of the curve tending parallel to the air voids line (see Note).

NOTE: Plotting the curve The value of soil particle density for calculating the air voids lines may be obtained using the method described in AS 1289.3.5.1 or assumed on the basis of previous tests. A rough check is to select a dry density equal to that of the wettest data point, nominate a percent air voids (2% often gives a satisfactory result), and calculate an apparent particle density for a point 1% wetter than the wettest data point using Equation 4. The soil particle density so derived is taken as the assumed value. A curve-fitting calculator or computer program that plots throughout the points, such as those based on the cubic spline techniques, may also be used to determine the coordinates of the peak point of the curve.

6 PRECISION

The precision of the test is shown in Table 2.

<table>
<thead>
<tr>
<th>Results</th>
<th>Maximum density</th>
<th>Optimum moisture content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeatability, single operator</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Reproducibility, multi-laboratory</td>
<td>4</td>
<td>20</td>
</tr>
</tbody>
</table>

NOTE: These values, in 95% of cases, should not be exceeded by the difference between any two results, expressed as a percentage of the average value.
7 TEST REPORT

Report the following values:

(a) The dry density corresponding to the maximum point on the moisture content/dry density curve as the ‘modified maximum dry density’ in tonnes per cubic metre to the nearest 0.01 (see Notes 1 and 2).

(b) The percentage moisture content corresponding to the maximum dry density on the moisture content/dry density curve, as the ‘modified optimum moisture content’ to the nearest 0.5 (see Notes 1 and 2).

(c) The percentage of oversize material retained on the 19.0 mm sieve or the 37.5 mm sieve and the sieve on which the material is retained, whichever is applicable to the nearest 1.

(d) When required, the plot of dry density against moisture content.

NOTES:

1. When the results are to be used for further calculations such as dry density ratio values and in the assignment of values for maximum dry density and optimum moisture content, and for statistical analysis, the values may be used to the nearest 0.001 t/m$^3$ for maximum dry density and 0.1% for optimum moisture content.

2. If a subsidiary method for determination of moisture content has been used, the accuracy to which moisture content and values calculated using moisture content may be reported will depend upon the correlation established using AS 1289.2.3.1.
Methods of testing rammed earth soils for engineering purposes

Method x.x.x: Determination of drying shrinkage of compacted rammed earth materials

1 SCOPE

This Standard sets out the method for determining the drying shrinkage of compacted specimens of unbound, bound and self-cementing rammed earth materials.

This method is applicable to the control testing of field or plant mix materials and for the assessment of the drying shrinkage of materials mixed in the laboratory.

The test is conducted on that portion of the material that passes the 10.0 mm sieve.

NOTES:

1. The exclusion of a large proportion of stone coarser than 10.0 mm may have a major effect on the drying shrinkage determined compared with that obtainable with the material as a whole.
2. The binders usually used for stabilized rammed earth construction are covered by the following Standards:
   (a) Limes, AS 1672.1.
   (b) Cements, AS 3972.
   (c) Bitumens, AS 1160 and AS 2157.
3. Compaction regime used on-site is likely to be different to that specified in this method. It is the user’s responsibility to account for these differences for design purposes.

2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

1152 Specification for test sieves
1160 Bitumen emulsions for construction and maintenance of pavements
1672 Limes and limestones
1672.1 Part 1: Limes for building
2103 Dial gauges and dial test indicators (metric series)
2139 Calibration and classification of force-measuring systems
2157 Cutback bitumen
3972 Portland and blended cement
xxxx Method x.x Rammed earth soil compaction and density tests—Determination of the dry density/moisture content relation of rammed earth using modified compactive effort
xxxx Method x.x Rammed earth sampling?
1141.1 Method 1 Definitions
3 PRINCIPLE
The method comprises the determination of drying shrinkage of prismatic test specimens 40 mm × 40 mm × 450 mm in size.

The specimens in the mould are stored in an atmosphere representative of that present on-site during construction. Measurement of the specimen length is carried out at the age of 0 d, 1 d, 3 d, 5 d, 7 d, 14 d, 21 d and 28 d from moulding.

4 DEFINITIONS
For the purpose of this Standard, the definitions in AS 1141.1 and those below apply.

4.1 Bound material
A material to which a binder, such as lime, cement, bitumen, or other binding agent has been added to produce structural stiffness.

4.2 Laboratory density ratio
The ratio of the dry density of a test specimen to the maximum dry density of that material as determined by test in accordance with AS xxxx (Rammed earth soil compaction and density tests), expressed as a percentage.

4.3 Laboratory moisture ratio
The ratio of the moisture content of a test specimen to the optimum moisture content of that material as determined by test in accordance with AS xxxx (Rammed earth soil compaction and density tests), expressed as a percentage.

4.4 Unbound material
A material that is not self-cementing and does not contain a binder.

5 APPARATUS
The following apparatus, complying with the relevant provisions of AS 1141.2, is required:

(a) Balance—of sufficient capacity, with a limit of performance not exceeding ±5 g.
(b) Base—a level rigid foundation on which to compact the specimen; for example, a sound concrete floor about 100 mm or more in thickness or a cubical concrete block of at least 100 kg mass.
(c) Cabinet—a humidity cabinet capable of maintaining a humidity and temperature equal to the average expected on-site environment or of not less than 90% at a temperature within the range required by the curing regime (usually 21°C to 25°C). Alternatively, a suitable room in which these conditions can be maintained can be used.
(d) Dishes—metal dishes.
(e) Displacement measurement—shrinkage of the specimen shall be measured by a system of dial gauges or electrical transducers in conjunction with a reference frame in order to provide an accurate measure of absolute displacement. The displacement measuring devices shall—
   (i) be accurate to within the lesser of 0.1% of the specimen length and 0.1mm;
   (ii) have sufficient travel to accommodate the maximum specimen displacement or the required differential displacement between the specimen and the reference frame;
(iii) be shielded from direct sunlight or other environmental influences.

(f) Mixing apparatus—such as a trowel, palette knife and metal quartering plates.

(g) Mould—a cuboidal metal mould and inserts as shown in Figure 1 having dimensions given in Table 1. The mould should be of sufficient external length to allow for the fixing of measurement gauges and should be able to be prised free of the specimen.

(h) Oil—to ease the removal of mould inserts and to reduce friction between the mould and the specimen.

(i) Rammer—a suitable electric or pneumatic vibrating hammer may be used in conjunction with a fixed-volume compaction head as shown in Figure 2 having dimensions given in Table 1 when compacting to a predetermined laboratory density ratio.

(j) Reference frame—specimen displacement should be measured relative to a reference frame incorporated into the mould and independent of the specimen as shown in Figure 1. The reference frame shall be—

(i) shielded from direct sunlight or other environmental influences;

(ii) sufficiently robust to minimise distortion due to temperature differences.

(k) Rule—300 mm readable to 1.0 mm.

(l) Sieves—10.0 mm, in accordance with AS 1152.

(m) Tray—a metal mixing and quartering tray of adequate size.

### TABLE 1

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MOULD</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal height, mm</td>
<td>100.0</td>
<td>±0.5¹</td>
</tr>
<tr>
<td>Internal width, mm</td>
<td>45.0</td>
<td>±0.5²</td>
</tr>
<tr>
<td>Internal length, L, mm</td>
<td>450.0</td>
<td>±0.5</td>
</tr>
<tr>
<td>Wall thickness, mm</td>
<td>5.0</td>
<td>±0.5</td>
</tr>
<tr>
<td>Securing bolt (centre-to-centre), mm</td>
<td>90.0</td>
<td>±0.5</td>
</tr>
<tr>
<td>Securing bolt (shaft)</td>
<td>M10³</td>
<td></td>
</tr>
<tr>
<td><strong>MOULD INSERTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height, mm</td>
<td>100.0</td>
<td>±0.5</td>
</tr>
<tr>
<td>Width, mm</td>
<td>44.5</td>
<td>±0.5²</td>
</tr>
<tr>
<td>Thickness, mm</td>
<td>10.0</td>
<td>±0.5</td>
</tr>
<tr>
<td><strong>FIXED-VOLUME RAMMER HEAD</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width (foot), mm</td>
<td>44.0</td>
<td>±0.5</td>
</tr>
<tr>
<td>Length (foot), mm</td>
<td>100.0</td>
<td>±0.5</td>
</tr>
<tr>
<td>Thickness (foot), mm</td>
<td>10.0</td>
<td>±0.5</td>
</tr>
<tr>
<td>Diameter (shaft), mm</td>
<td>20.0</td>
<td>±0.5</td>
</tr>
<tr>
<td>Length (top plate to base of foot), mm</td>
<td>55.0</td>
<td>±0.5¹</td>
</tr>
</tbody>
</table>

**NOTES:**

1. Either but not both of the tolerances may be exceeded.
2. Either but not both of the tolerances may be exceeded.
3. Use of bolts of this size has been found to be satisfactory but alternative sizes may be employed.

NOTE: This design has been found satisfactory, but alternative designs may be employed provided that the essential dimensions in Table 1 are met.

FIGURE 1 DETAILS OF TYPICAL MOULD

NOTE: This design has been found satisfactory, but alternative designs may be employed provided that the essential dimensions in Table 1 are met.

FIGURE 2 DETAILS OF TYPICAL FIXED-VOLUME RAMMER HEAD
5 SAMPLING
Samples shall be obtained from the field in accordance with AS xxxx.x.x (Rammed earth sampling?). Samples shall be taken at the point of use as soon as practicable after completion of mixing. The samples shall be cured and compacted in the field or immediately placed in an airtight container and transported to the laboratory for immediate processing. The time of the addition of the binder and the time of sampling shall be recorded.

Samples from the laboratory shall be taken from the mixing bowl or the curing container.

6 PREPARATION OF TEST PORTIONS

6.1 General
A minimum of three test portions shall be prepared for each drying shrinkage test.

6.2 Field samples

6.2.1 Preparation of test portions of unbound material
Test portions shall be prepared as follows:

(a) Reduce the sample by quartering or riffling to provide at least 10,000 g of material that would pass a 10.0 mm sieve. Screen on a 10.0 mm sieve and determine mass of materials passing and retained on the sieve. Determine the amount of material retained as a percentage of total (wet) mass. Discard material retained on the sieve.
(b) Thoroughly mix all material passing the 10.0 mm sieve.
(c) Obtain by quartering or riffling three test portions, each of about 3000 g mass.

6.2.2 Preparation of test portions of bound material
Test portions must be secured and test specimens manufactured following the required method as per Clause 7 within 45 minutes of the addition of water to the material containing the cementitious binder.

Test portions shall be prepared as per Clause 6.2.1.

6.3 Laboratory samples
Laboratory samples shall be prepared as follows:

(a) Unbound material Dry the material for a minimum of 24 hours in the oven at 105°C to 110°C to constant mass (see Note below). Screen the material over a 10.0 mm sieve and subdivide the material by quartering or riffling to obtain a test portion of about 3500 g. Screen material passing the 10.0 mm sieve over a 1.18 mm to obtain a screed portion of about 50 g for use as per Clause 7.4.

NOTE: A drying time of 16 h to 24 h is usually sufficient for most soils, but certain soil types and large or very wet samples will require longer. The drying time will also depend on the total amount of material in the oven.

(b) Unbound material to which cementitious stabilising binders will be added Dry the material for a minimum of 24 hours in the oven at 105°C to 110°C to constant mass (see Note to Step (a) above). Screen the material over a 10.0 mm sieve and subdivide the material by quartering or riffling to obtain a test portion of about 3500 g. Screen material passing the 10.0 mm sieve over a 1.18 mm to obtain a screed portion of about 50 g for use as per Clause 7.4. Thoroughly mix each test portion with the required amount of dry binder for a minimum of 5 minutes.
6.4 Curing prior to compaction

6.4.1 Curing of unbound material

(a) Determine a mass \((w)\) of water to be added to test portion so that the optimum water content of the material determined as per AS xxxx.x.x (Rammed earth soil compaction and density tests) is achieved.

(b) Allow the test portions to cure for an appropriate time for the soil type. Record the time of curing.

NOTE: It is important that the water is thoroughly mixed into and uniformly distributed through the soil since adequate mixing gives rise to variable test results. It is desirable to keep the mixed soil in a sealed container to allow the water to become more uniformly distributed throughout the soil before compaction. For materials of low plasticity and high permeability, little curing is required, but if the soil is a completely dry heavy clay up to seven days curing maybe required before testing. The more clayey a soil, the more time required for the water to be uniformly distributed through it. Normally, soils should be cured for a minimum of 2 h.

6.4.1 Curing of bound material

Material shall not be allowed to cure.

7 PREPARATION OF TEST SPECIMENS

7.1 General

For each test portion a test specimen shall be prepared. The method used will depend on the compaction required. The underlying layer shall be scarified prior to placement of the subsequent layer.

7.2 Compaction to a specified laboratory density ratio with a specified laboratory moisture content

7.2.1 Compaction of unbound material to a specified laboratory density ratio

The procedure shall be as follows:

(a) Calculate the amount of material required to fill the mould in one layer when the material is compacted to the required laboratory density ratio.

(b) Place the mould inserts into the mould.

(c) Insert and tighten the securing bolts ensuring that the mould walls remain vertical.

(d) Oil the mould and mould inserts.

(e) Compact the test portion into the mould in one layer using both the pneumatic or electric hammer and the fixed-volume rammer head.

NOTE:

A device other than a pneumatic or electric hammer can be used to compact the material, provided that it is able to deliver sufficient compactive effort to compact the material to the required layer thickness.

(f) Determine the moisture content of the remaining material in the test portion in accordance with AS 1289.2.1.1.
7.2.2 Compaction of bound material to a specified laboratory density ratio

The procedure shall be as follows:

(a) Determine a mass \((w)\) of water to be added to the dry test portion so that the optimum water content of the material is achieved.

(b) Calculate the amount of material required to fill the mould in one layer when the material is compacted to the required laboratory density ratio.

(c) Thoroughly mix one portion of material with mass of water \(w\) for a minimum of 1 minute. Record the time of wetting.

(d) Place the mould inserts into the mould.

(e) Insert and tighten the securing bolts ensuring that the mould walls remain vertical.

(f) Oil the mould and mould inserts.

(g) Compact the test portion into the mould in one layer using both the pneumatic or electric hammer and the volume-controlled rammer head, so that the compacted height of the material in the mould is 45 mm ±0.5mm. Discard specimens that do not meet these tolerances. Do not re-use material from a previously compacted specimen.

NOTES:

1. A device other than a pneumatic or electric hammer can be used to compact the material, provided that it is able to deliver sufficient compactive effort to compact the material to the required layer thickness.

2. Step (f) must be completed within 45 minutes of the addition of water mass \(w\) to the test portion in order to prevent cementation from interfering with compaction. Discard specimens that do not meet this requirement.

3. Material moisture content cannot be verified through drying due to hydration of the cementitious binder. The moisture content of the material is therefore to be taken as the mass \(w\) from Step (a).

7.4 Trimming the compacted specimens

Specimens shall not be trimmed.

8 CURING OF TEST SPECIMENS

Specimens shall not be cured.

9 EXPOSURE AND MEASUREMENT OF SPECIMENS

9.1 Laboratory

The air within the laboratory, humidity-controlled room or cabinet where measurement takes place shall be maintained at—

(i) a temperature and relative humidity equal to the average expected on-site curing environment;

(ii) a temperature and relative humidity of not less than 90% at a temperature within the range required by the curing regime (usually 21°C to 25°C).

9.2 Initial measurements

The procedure for taking initial measurements is as follows:

(a) Within 5 minutes of compaction, release the securing bolts and extract the mould inserts.
(b) Prise the mould walls free of the specimen surfaces.
(c) Fix the measurement gauges to the base of the mould and record the initial readings.

9.3 Subsequent measurements
The procedure for taking subsequent measurements is as follows:

(a) Take the length measurement for each specimen at the age of 1d, 3d, 5d, 7d, 14d and 28d. A single measurement for each specimen will normally be adequate.
(b) Determine the moisture content at the completion of testing ($w_f$) by drying the whole specimen as specified in AS 1289.2.1.1.

10 CALCULATIONS
Drying shrinkage of each specimen at any age is the difference ($\Delta L$) between the initial length measurement taken in Clause 9.2(a) (in millimetres) and the length reading at a particular age (in millimetres). The following shall be calculated:

(a) The dry density ($\rho_d$) of the test specimens as compacted from the following equation:

$$\rho_d = \frac{100\rho}{100 + w_i} \quad [1]$$

where

$\rho_d$ = dry density of wet soil, in tonnes per cubic metre
$\rho$ = density of wet soil, in tonnes per cubic metre
$w_i$ = moisture content of the specimen at compaction, in percent

(b) The dry density ($\rho_d$) of the test specimens at the completion of testing from the following equation:

$$\rho_d = \frac{100\rho}{100 + w_f} \quad [2]$$

where

$\rho_d$ = dry density of wet soil, in tonnes per cubic metre
$\rho$ = density of wet soil, in tonnes per cubic metre
$w_f$ = moisture content of the specimen at the completion of testing, in percent

(c) The shrinkage shall be expressed according to the following equation:

$$\frac{\Delta L}{L} \times 10^6, \text{ in microstrain} \quad [3]$$

where

$L = 450 \text{ mm}$

11 DEFINITION OF TEST RESULT
A test result is defined as the arithmetic mean of the three shrinkage determinations made on one batch of three specimens for that age.

If one determination varies by more than ±10% from the mean of the three determinations for that age, discard this determination and calculate the mean of the remaining determinations. If a further determination varies by more than ±10% of the recalculated mean, discard this result.
Where the results of more than one age are required and the results at any one of those ages are discarded, then the test shall be repeated.

12 RECORDS
The following shall be recorded:

(a) Identification of sample in accordance with AS xxxx.x.x (Rammed earth sampling?), if applicable.
(b) Identification of specimens.
(c) Identification of analyst.
(d) Date specimens were moulded and dates of subsequent measurements.
(e) Each of the consecutive initial length readings of each specimen and the mean of the consecutive readings to the nearest 0.001mm.
(f) Subsequent lengths of each specimen at each age to the nearest 0.001mm.
(g) Drying shrinkage for each specimen and the mean for each set, at each age, and the mean of the results to the nearest 10 microstrain.
(h) Range of drying room of chamber temperature and humidity during the test period to the nearest 0.1°C and 1%, respectively.
(i) Any other relevant comments or observations.
(j) Number of this standard, i.e. AS xxxx.x.x (Determination of drying shrinkage of compacted rammed earth materials).

13 REPORTING
The following data shall be reported:

(a) Identification of sample in accordance with AS xxxx.x.x (Rammed earth sampling?), if applicable.
(b) Moisture content of each specimen on completion of testing, in percent to the nearest 0.5.
(c) Dry density of each specimen as compacted, to the nearest 0.01 t/m³ or, if required, the laboratory density ratio to the nearest 1%.
(d) If required, the laboratory moisture ratio of the material prior to compaction to the nearest 1%.
(e) If not in accordance with either AS xxxx.x.x, the method of compaction and number of layers.
(f) Description of the stabilized soil.
(g) If applicable, the amount of material retained on the 19.0 mm sieve as a percentage of the moist mass in the original sample, to the nearest 1.
(h) Bound material: the elapsed time between addition of the binder and compaction of the specimens.
(i) The calculated mean drying shrinkage for each set at the nominated age to the nearest 10 microstrain.
(j) Whether any determination has been discarded in accordance with Clause 11.
(k) Number of this standard, i.e. AS xxxx.x.x (Determination of drying shrinkage of compacted rammed earth materials).
Methods of testing rammed earth soils for engineering purposes

Method x.x.x: Method for securing and testing cores from hardened rammed earth for compressive strength

1 SCOPE
This Standard sets out a method for the securing and testing of cylindrical cores from hardened bound or unbound rammed earth for the determination of compressive strength for an estimate of the in-service strength of a structure or part thereof.

NOTE: Because of the increased variability associated with core strengths, it is not recommended that rammed earth cores be used for direct quality control purposes.

2 REFERENCED DOCUMENTS
The following documents are referred to in this Standard:

AS
1152 Specification for test sieves
xxxx Method x.x Rammed earth soil compaction and density tests—Determination of the dry density/moisture content relation of rammed earth using modified compactive effort
xxxx Method x.x Unconfined compressive strength of compacted rammed earth materials
1289.3.6.1 Method 3.6.1 Soil classification tests—Determination of the particle size distribution of a soil—Standard method of analysis by sieving

3 DEFINITIONS
For the purpose of this Standard, the following definitions apply.

3.1 Designer
The person, persons or organization responsible for the design of the structure.

3.2 Location
A region of concrete that is being assessed and that for practical purposes is assumed to be of uniform quality.

3.3 Bound material
A material to which a binder, such as lime, cement, bitumen, or other binding agent has been added to produce structural stiffness.

3.6 Unbound material
A material that is not self-cementing and does not contain a binder.
4. PRINCIPLE

Cores are secured from the hardened rammed earth by using a core drill, then trimmed, conditioned and tested for compressive strength in accordance with AS xxxx.x.x.

5 APPARATUS

The following apparatus is required:

(a) Balance—of sufficient capacity, with a limit of performance not exceeding ±5 g.
(b) Core drill—with the facility for the application of water as a cooling fluid to the cutting edge.
(c) Equipment for measuring test specimens—accurate to the nearest 0.5 mm.
(d) Facilities for conditioning in air at a temperature (±5°C) and a relative humidity (±5%) equal to that typical for the location for seven days immediately before testing.
(e) Facilities for capping and testing the cores in accordance with AS xxxx.x.x.
(f) Masonry or diamond saw—for trimming the cores.
(g) Mixing apparatus—such as a trowel, palette knife and metal quartering plates.
(h) Sieve—1.18 mm, in accordance with AS 1152.
(i) Steel straightedge—a suitable size being about 300 mm long, 25 mm wide and 3 mm thick, preferably with a bevelled edge.

6. PROCEDURE

6.1 General

The procedure for securing and preparing the cores is as follows:

(a) Secure the core from the hardened rammed earth.
(b) Check the core for acceptance.
(c) Prepare the core for testing by trimming and conditioning it.

Compressive testing is then carried out in accordance with AS xxxx.x.x.

6.2 Securing the cores

6.2.1 General

The aim is to secure cores with a ratio of length/diameter after trimming of approximately 2:1 and surfaces that are smooth, cylindrical and free from steps, ridges and grooves.

The diameter of cores shall be not less than the greater of 100 mm or 3 times the nominal size of coarse aggregate in the concrete, measured in accordance with AS 1289.3.6.1.

6.2.2 Procedure

The procedure for securing cores is as follows:

NOTE: Appendix A gives guidelines on securing cores.

(a) Take the cores from a location and at a time as specified by the designer or delegate, where possible avoiding the reinforcement.
(b) Secure the test cores by carefully using a core drill so that the concrete will not be weakened by shock or by heating. During the drilling process apply water as a cooling fluid to the cutting edge.
(c) Record the location and direction of coring for each core secured.

6.3 Acceptance of cores

6.3.1 General

Core specimens shall be accepted for testing if they have been secured in accordance with Clause 6.2 and appear to be free from defects likely to affect their strength.

The cores are examined for acceptance as follows:

   (a) Handle the cores carefully to avoid damage.
   (b) Note and record the size and position of any significant voids or areas of poor compaction.
   (c) Examine for cracks prior to conditioning. If any such cracks are found, saw off that part of the core so that the sawn-off piece extends beyond any visible crack.
   (d) Note all apparent defects as required by Clauses 9 and 10.

6.3.2 Rejection criteria

Uncapped cores shall be liable to rejection if any of the following criteria apply:

   (a) A diameter less than 100 mm.
   (b) The diameter at any cross-section deviates from either end diameter by more than 2 mm.
   (c) The length of the core when ready for capping is less than the diameter.
   (d) Any edge is broken away in such a manner that the radial or vertical break is more than 10 mm from the edge line and the corresponding circumferential break (or sum of circumferential breaks) exceeds 10% of the circumference of the core.
   (e) Either end of the core is not at right angles to the axis and the departure from squareness exceeds 2 degrees (approximately 5 mm in 150 mm).
   (f) There is an apparent defect likely to affect the test result.
   (g) The core contains any reinforcement.

NOTES:

   1. The core may be retrimmed to conform to these criteria.
   2. In view of the difficulties associated with obtaining cores and duplicating them, it may be necessary to test cores which do not comply with the requirements of Clause 6.3.2. The results may be used for acceptance criteria if they exceed the strength values required. The level of non-compliance should be assessed if results are to be used for rejection criteria.

6.4 Preparation of test cores

The cores shall be prepared for testing as follows:

   (a) Trimming Trim the ends of the core so that the length/diameter ratio is as near to 2:1 as possible.

       NOTE: Trimming of unbound rammed earth using a water cooled masonry or diamond saw is not recommended. Instead, trimming should be conducted in the absence of coolant.

   (b) Bulk density Measure the core wet density as per Clause 7(x).

   (c) Capping If deemed necessary, prepare a screed portion of material and smooth the surface of the core in a mould of suitable dimensions as per AS xxxx.x.x.
(d) **Preconditioning** Store in air at a temperature and humidity equal to that typical for the location in accordance with Clause 5(d) for seven days immediately before testing.

(e) **Inspection** Prior to testing, inspect the cores and record details of any defects such as voids or scoring of the surface.

(f) **Testing** Testing of the cores is carried out in accordance with AS xxxx.x.x. The maximum applied force, in kilonewtons, indicated by the testing machine shall be recorded.

(g) **Drying** The crushed core material shall be dried and the dry density calculated in accordance with AS xxxx.x.x.

7. **CALCULATIONS**

The following shall be calculated:

(a) The core strength of the specimens is calculated from the following equation:

\[
\text{Core strength} = \frac{1000F}{A} \quad \text{[1]}
\]

where

- \( F \) = maximum applied force, in kilonewtons (see Clause 6.4)
- \( A \) = cross-sectional area, in square millimetres, as calculated according to AS xxxx.x.x

**NOTES:**

1. When tested according to AS xxxx.x.x, correction factors for length/diameter ratios less than 2:1 are not required as long as conditions required in Clause 6.3.2 are met.
2. Other factors listed in Appendix B may influence the calculation of compressive strength.

8. **PRECISION**

For a group of three cored specimens secured from the same location, cured and conditioned under similar conditions and tested at age 28 days or more, the accuracy expressed as a percentage of the mean of the strengths obtained, is +7% at the 95% probability level, subject to a length/diameter ratio of 2:1. As this ratio decreases, the repeatability of the test also increases in value.

9. **REPORT**

The following information concerning each test core shall be recorded:

(a) Identification of core.
(b) Details of location and direction of coring.
(c) Date of test.
(d) Age of rammed earth in core at testing, where known.
(e) Results of inspection of the core before and after testing.
(f) Dimensions of core.
(g) Position of any ramming planes, if present.
(h) Bulk density, expressed in accordance with AS xxxx.x.x.
(i) Preconditioning temperature and humidity, correct to ±5°C and ±5% respectively.
(j) Any defects in core before testing.
(k) Calculated core strength, to the nearest 0.1 MPa.
(l) Dry density of the core material, expressed in accordance with AS xxxx.x.x.
(m) The number of this Australian Standard, i.e. AS xxxx.x.x.
(n) Any other significant factors noted before or after testing.
APPENDIX A

GUIDANCE ON SECURING CORES

Cores are taken for a number of reasons, including estimation of the compressive strength of the rammed earth in the structure. The sampling and interpretation of core tests is by no means as simple as it might appear. Cores should not be used to assess the compliance of rammed earth with AS xxxx.x.x, as compliance is achieved only by the testing of cylinder specimens. Cores can assist in determining subsequent action, however, if the rammed earth does not comply. Cores are also useful in resolving doubt about the structure caused by accidental damage, chemical attack or poor construction methods.

The practice of securing and testing cores should take into account the following:

(a) **Location** The following should be considered when selecting the location for coring:
   (i) As coring may weaken the structure, a non-critical location should be selected.
   (ii) Non-destructive testing can assist in the location of defective areas.
(b) **Number** Increased accuracy is obtained in estimating the strength of the element when more cores are secured. At least three cores should be taken for each sample.
(c) **Size** The diameter and length/diameter ratio should be within the specified limits.
(d) **Direction of coring** The direction of coring may be either vertical or horizontal:
   (i) **Vertical coring** The cores will likely intersect a ramming plane, which will represent a plane of weakness. Additional care should be taken when handling these samples. The compressive strength of vertically-cored samples is representative of the compressive strength of multiple rammed earth layers.
   (ii) **Horizontal coring** Cores should be taken from locations such that they do not intersect any ramming planes. The compressive strength of horizontally-cored samples is representative of the compressive strength of a single rammed earth layer.
(e) **Drilling procedures** A rigidly positioned water-cooled drill with diamond-impregnated bit should be used. The total depth should be checked before break-out.
(f) **Age** The basis of design and comparison is usually the 28-day strength. If cores are taken at ages greatly differing from this, some correction will be needed.
(g) **Moisture condition** AS xxxx.x.x requires that the cores be equilibrated and tested under conditions representative of those encountered in service.
(h) **Top layer** The top layer of a rammed earth member should be avoided as it usually is of lower strength than the bulk of the material.
(i) **Making good** When the cores have been secured all core holes should be repaired using a similar material to the parent material and compacted as per AS xxxx.x.x.
B1 INTRODUCTION

There are many factors which influence the compressive strength of cores. Chiefly these are as follows:

(a) Physical factors relating to the securing of the core itself.
(b) Properties of the rammed earth supplied.
(c) Factors related to the compaction and the curing of the rammed earth provided.

It should be recognized that most core results used as an estimate of the in-service strength of a structure will be affected by all of the above factors. The following notes summarize the available information and are included to assist in the interpretation of the results obtained from coring.

B2 FACTORS WHICH INFLUENCE THE STRENGTH OF CORES

The main factors which influence the strength of cores are related to the production and properties of the rammed earth and the securing of the core itself. The variability of core results is, however, higher than that obtained from moulded specimens manufactured as per AS xxxx.x.x. For example, when only three cores are secured, less reliance can be placed on the average strength result than for the same number of moulded specimens.

There can be a strength gradient within the rammed earth, increasing with depth below the surface resulting from curing and confinement effects, which should be considered.
Methods of testing rammed earth soils for engineering purposes

Method x.x.x: Unconfined compressive strength of compacted rammed earth materials

1 SCOPE

This Standard sets out the method for determining the unconfined compressive strength of compacted specimens of unbound, bound and self-cementing rammed earth materials.

This method is applicable to the control testing of field or plant mix materials and for the assessment of the strength of materials mixed in the laboratory.

The test is conducted on that portion of the material that passes the 10.0 mm sieve.

NOTES:

1. The exclusion of a large proportion of stone coarser than 10.0 mm may have a major effect on the unconfined compressive strength determined compared with that obtainable with the material as a whole.

2. The binders usually used for stabilized rammed earth construction are covered by the following Standards:
   (a) Limes, AS 1672.1.
   (b) Cements, AS 3972.
   (c) Bitumens, AS 1160 and AS 2157.

3. Compaction regime used on-site is likely to be different to that specified in this method. It is the user’s responsibility to account for these differences for design purposes.

2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

1152   Specification for test sieves
1160   Bitumen emulsions for construction and maintenance of pavements
1672   Limes and limestones
1672.1 Part 1: Limes for building
2139   Calibration and classification of force-measuring systems
2157   Cutback bitumen
3972   Portland and blended cement
xxxx   Method x.x Rammed earth soil compaction and density tests—Determination of the dry density/moisture content relation of rammed earth using modified compactive effort
xxxx   Method x.x Method for securing and testing cores from hardened rammed earth for compressive strength
3 DEFINITIONS
For the purpose of this Standard, the definitions in AS 1141.1 and those below apply.

3.1 Bound material
A material to which a binder, such as lime, cement, bitumen, or other binding agent has been added to produce structural stiffness.

3.2 Laboratory density ratio
The ratio of the dry density of a test specimen to the maximum dry density of that material as determined by test in accordance with AS xxxx (Rammed earth soil compaction and density tests), expressed as a percentage.

3.3 Laboratory moisture ratio
The ratio of the moisture content of a test specimen to the optimum moisture content of that material as determined by test in accordance with AS xxxx (Rammed earth soil compaction and density tests), expressed as a percentage.

3.4 Unbound material
A material that is not self-cementing and does not contain a binder.

4 APPARATUS
The following apparatus, complying with the relevant provisions of AS 1141.2, is required:

(a) Balance—of sufficient capacity, with a limit of performance not exceeding ±5 g.
(b) Base—a level rigid foundation on which to compact the specimen; for example, a sound concrete floor about 100 mm or more in thickness or a cubical concrete block of at least 100 kg mass.
(c) Cabinet—a humidity cabinet capable of maintaining a humidity and temperature equal to the average expected on-site environment or of not less than 90% at a temperature within the range required by the curing regime (usually 21°C to 25°C). Alternatively, a suitable room in which these conditions can be maintained can be used.
(d) Dishes—metal dishes.
(e) Equipment for measuring test specimens—accurate to the nearest 0.5 mm.
(f) Mixing apparatus—such as a trowel, palette knife and metal quartering plates.
(g) Mould—a cylindrical metal split mould with a cylindrical collar as shown in Figure 1 having dimensions given in Table 1.
(h) Rammer—in accordance with AS xxxx (Rammed earth soil compaction and density tests).

NOTE: A mechanical compactor may be used, provided the essential dimensions are adhered to and the rammer has a free vertical fall of the correct height. It is also essential that the design of the machine is such that the mould rests on a solid base.

Alternatively, a suitable electric or pneumatic vibrating hammer may be used in conjunction with a fixed-volume compaction head as shown in Figure 2 having dimensions given in Table 1 when compacting to a predetermined laboratory density ratio.
(i) Rule—300 mm readable to 1.0 mm.

(j) Sample extractor—jack, level and frame, or other device, suitable for extruding compacted specimens from the mould (optional if split mould is used).

(k) Sieves—10.0 mm and 1.18 mm, in accordance with AS 1152.

(l) Steel straightedge—a suitable size being about 300 mm long, 25 mm wide and 3 mm thick, preferably with a bevelled edge.

(m) Teflon sheets—minimum 100.0mm by 100.0mm by 5.0mm thick.

(n) Testing machine—a compression testing machine complying with the requirements for Grade B of AS 2193, with the upper bearing block of the machine having a spherical seat. The capacity of the testing machine shall be sufficient to test the strongest test specimen (a minimum capacity of 50 kN is recommended).

The testing machine shall be power operated and capable of applying the load to travel at a speed of 0.3±0.1 mm per minute whilst under load.

(o) Tray—a metal mixing and quartering tray of adequate size.

**TABLE 1**

DIMENSIONS AND TOLERANCES FOR SUITABLE MOULDS AND FIXED-VOLUME RAMMER HEAD

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MOULD</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal diameter, mm</td>
<td>100.0</td>
<td>±0.5¹</td>
</tr>
<tr>
<td>Height, mm</td>
<td>200.0</td>
<td>±0.5¹</td>
</tr>
<tr>
<td><strong>COLLAR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal diameter, mm</td>
<td>100.0</td>
<td>±0.5¹</td>
</tr>
<tr>
<td><strong>FIXED-VOLUME RAMMER HEAD</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (round foot), mm</td>
<td>99.0</td>
<td>±0.5</td>
</tr>
<tr>
<td>Diameter (shaft), mm</td>
<td>20.0</td>
<td>±0.5</td>
</tr>
</tbody>
</table>

NOTES:

1. Either but not both of the tolerances may be exceeded
NOTE: This design has been found satisfactory, but alternative designs may be employed provided that the essential dimensions in Table 1 are met.

FIGURE 1 DETAILS OF TYPICAL MOULD
NOTE: This design has been found satisfactory, but alternative designs may be employed provided that the essential dimensions in Table 1 are met.

FIGURE 2 DETAILS OF TYPICAL FIXED-VOLUME RAMMER HEAD
5 SAMPLING

Samples shall be obtained from the field in accordance with AS xxxx.x.x (Rammed earth sampling?). Samples shall be taken at the point of use as soon as practicable after completion of mixing. The samples shall be cured and compacted in the field or immediately placed in an airtight container and transported to the laboratory for immediate processing. The time of the addition of the binder and the time of sampling shall be recorded.

Core samples shall be obtained from the field in accordance with AS xxxx.x.x (Method for securing and testing cores from hardened rammed earth for compressive strength).

Samples from the laboratory shall be taken from the mixing bowl or the curing container.

6 PREPARATION OF TEST PORTIONS

6.1 General

A minimum of three test portions shall be prepared for each unconfined compressive strength test.

6.2 Field samples

6.2.1 Preparation of test portions of unbound material

Test portions shall be prepared as follows:

(a) Reduce the sample by quartering or riffling to provide at least 10500 g of material that would pass a 10.0 mm sieve. Screen on a 10.0 mm sieve and determine mass of materials passing and retained on the sieve. Determine the amount of material retained as a percentage of total (wet) mass. Discard material retained on the sieve.

(b) Thoroughly mix all material passing the 10.0 mm sieve.

(c) Obtain by quartering or riffling three test portions, each of about 3500 g mass.

6.2.2 Preparation of test portions of bound material

Test portions must be secured and test specimens manufactured following the required method as per Clause 7 within 45 minutes of the addition of water to the material containing the cementitious binder.

Test portions shall be prepared as per Clause 6.2.1.

6.3 Laboratory samples

Laboratory samples shall be prepared as follows:

(a) Unbound material Dry the material for a minimum of 24 hours in the oven at 105°C to 110°C to constant mass (see Note below). Screen the material over a 10.0 mm sieve and subdivide the material by quartering or riffling to obtain a test portion of about 3500 g. Screen material passing the 10.0 mm sieve over a 1.18 mm to obtain a screed portion of about 50 g for use as per Clause 7.4.

NOTE: A drying time of 16 h to 24 h is usually sufficient for most soils, but certain soil types and large or very wet samples will require longer. The drying time will also depend on the total amount of material in the oven.

(b) Unbound material to which cementitious stabilising binders will be added Dry the material for a minimum of 24 hours in the oven at 105°C to 110°C to constant mass (see Note to Step (a) above). Screen the material over a 10.0 mm sieve and subdivide the material by quartering or riffling to obtain a test portion of about 3500 g. Screen material passing the 10.0 mm sieve over a 1.18 mm to obtain a
screed portion of about 50 g for use as per Clause 7.4. Thoroughly mix each test portion with the required amount of dry binder for a minimum of 5 minutes.

6.4 Curing prior to compaction

6.4.1 Curing of unbound material

(a) Determine a mass \( (W) \) of water to be added to test portion so that the optimum water content of the material determined as per AS xxxx.x.x is achieved.

(b) Allow the test portions to cure for an appropriate time for the soil type. Record the time of curing.

NOTE: It is important that the water is thoroughly mixed into and uniformly distributed through the soil since adequate mixing gives rise to variable test results. It is desirable to keep the mixed soil in a sealed container to allow the water to become more uniformly distributed throughout the soil before compaction. For materials of low plasticity and high permeability, little curing is required, but if the soil is a completely dry heavy clay up to seven days curing maybe required before testing. The more clayey a soil, the more time required for the water to be uniformly distributed through it. Normally, soils should be cured for a minimum of 2 h.

6.4.1 Curing of bound material

Material shall not be allowed to cure.

7 PREPARATION OF TEST SPECIMENS

7.1 General

For each test portion a test specimen shall be prepared. The method used will depend on the compaction required. The underlying layer shall be scarified prior to placement of the subsequent layer.

7.2 Compaction to a constant compactive effort

7.2.1 Compaction of unbound material to a constant compactive effort

The procedure shall be as follows:

(a) Clean the mould, collar and baseplate. Inspect and clean the rammer and ensure that it is free in the guide.

(b) Determine the mass \( (m_1) \) of the mould plus baseplate, except that where the mould has the baseplate attached to the compaction block, determine the mass of the mould alone.

(c) Assemble the mould, collar and baseplate and place the assembly on the rigid foundation.

(d) Take one portion of material, mix it thoroughly and compact it into the mould in five layers, so that the compacted height of the material in the mould is 40 mm to 45 mm in the first layer, 81 mm to 86 mm in the second layer, 121 mm to 126 mm in the third layer, 161 mm to 166 mm in the fourth layer and 201 mm to 206 mm in the fifth layer. Discard specimens that do not meet these tolerances. Do not re-use material from a previously compacted specimen. Compact each layer by 25 uniformly distributed blows of the rammer falling freely from a height of 450 mm. Use only sufficient material, which is representative of the portion, to meet the layer heights specified in this Item.

(e) Determine the moisture content of the remaining material in the test portion in accordance with AS 1289.2.1.1.
7.2.2 Compaction of bound material to a constant compactive effort

The procedure shall be as follows:

(a) Determine a mass \(w\) of water to be added to the dry test portion so that the optimum water content of the material is achieved.

(b) Clean the mould, collar and baseplate. Inspect and clean the rammer and ensure that it is free in the guide.

(c) Determine the mass \(m_1\) of the mould plus baseplate, except that where the mould has the baseplate attached to the compaction block, determine the mass of the mould alone.

(d) Assemble the mould, collar and baseplate and place the assembly on the rigid foundation.

(e) Thoroughly mix one portion of material with mass of water \(w\) for a minimum of 1 minute. Record the time of wetting.

(f) Compact the test portion into the mould in five layers, so that the compacted height of the material in the mould is 40 mm to 45 mm in the first layer, 81 mm to 86 mm in the second layer, 121 mm to 126 mm in the third layer, 161 mm to 166 mm in the fourth layer and 201 mm to 206 mm in the fifth layer. Discard specimens that do not meet these tolerances. Do not re-use material from a previously compacted specimen. Compact each layer by 25 uniformly distributed blows of the rammer falling freely from a height of 450 mm. Use only sufficient material, which is representative of the portion, to meet the layer heights specified in this Item.

NOTE: Step (f) must be completed within 45 minutes of the addition of water mass \(w\) to the test portion in order to prevent cementation from interfering with compaction. Discard specimens that do not meet this requirement.

7.3 Compaction to a specified laboratory density ratio with a specified laboratory moisture content

7.3.1 Compaction of unbound material to a specified laboratory density ratio

The procedure shall be as follows:

(a) Calculate the amount of material required to fill the mould in five equal layers when the material is compacted to the required laboratory density ratio.

(b) Compact the test portion into the mould in five layers using both the pneumatic or electric hammer and the fixed-volume rammer head.

NOTES:

1. The calculated mass of material to be placed in each layer should be measured to ensure uniform compaction.

2. A device other than a pneumatic or electric hammer can be used to compact the material, provided that it is able to deliver sufficient compactive effort to compact the material to the required layer thickness.

(c) Determine the moisture content of the remaining material in the test portion in accordance with AS 1289.2.1.1.

7.3.2 Compaction of bound material to a specified laboratory density ratio

The procedure shall be as follows:
(a) Determine a mass \( (w) \) of water to be added to the dry test portion so that the optimum water content of the material is achieved.

(b) Calculate the amount of material required to fill the mould in five equal layers when the material is compacted to the required laboratory density ratio.

(c) Thoroughly mix one portion of material with mass of water \( w \) for a minimum of 1 minute. Record the time of wetting.

(d) Compact the test portion into the mould in five layers using both the pneumatic or electric hammer and the fixed-volume rammer head, so that the compacted height of the material in the mould is 40 mm to 45 mm in the first layer, 81 mm to 86 mm in the second layer, 121 mm to 126 mm in the third layer, 161 mm to 166 mm in the fourth layer and 201 mm to 206 mm in the fifth layer. Discard specimens that do not meet these tolerances. Do not re-use material from a previously compacted specimen.

NOTES:

1. The calculated mass of material to be placed in each layer should be measured to ensure uniform compaction.

2. A device other than a pneumatic or electric hammer can be used to compact the material, provided that it is able to deliver sufficient compactive effort to compact the material to the required layer thickness.

3. Step (d) must be completed within 45 minutes of the addition of water mass \( w \) to the test portion in order to prevent cementation from interfering with compaction. Discard specimens that do not meet this requirement.

4. Material moisture content cannot be verified through drying due to hydration of the cementitious binder. The moisture content of the material is therefore to be taken as the mass \( w \) from Step (a)

### 7.4 Trimming the compacted specimens

The procedure shall be as follows:

(a) Free the material from around the inside of the collar then carefully remove the collar.

(b) Determine a mass of water \( w_s \) to be added to the dry screed portion so that a water content equal to the optimum water content of the test portion is achieved.

(c) Thoroughly mix the screed portion with mass of water \( w_s \) for a minimum of 1 minute.

(d) If required, trim the compacted specimen level with the top of the mould by means of the straightedge; use smaller size material to patch any holes developed in the surface from removal of coarse material during trimming.

(e) Place a thin layer of wet screed portion material on the surface of the compacted specimen using the palette knife. Repeat Steps (d) and (e) until a smooth surface is achieved.

(f) Determine the mass \( (m_2) \) of the mould and compacted material, with baseplate if appropriate.

(g) Carefully remove the compacted specimen from the mould and examine the specimen for any defects. Immediately commence curing in accordance with Clause 8. If the specimen has cracked, discard it and mould a replacement specimen.

NOTE: If the use of impermeable caps (e.g., plaster of paris, double plaster or sulphur) is required, the capping process should occur after the standard curing times and the specimens shall be allowed to stand in a sealed container for 1 h until the cap material has suitably set.
8 CURING OF TEST SPECIMENS

The curing regime shall be recorded. Unless otherwise specified the specimens shall be cured using one of the following procedures, as appropriate:

(a) Unbound material Stand the compacted specimen on a wire rack and place in a humidity cabinet (see Clause 4(c) and Note 1 to Step (b) below). Determine the mass of the compacted specimen \( m_3 \) after 48 hours and again every subsequent 24 hours. Allow to cure until \( m_3 \) remains unchanged for three consecutive readings.

(b) Bound material Stand the compacted specimen on a wire rack and place in a humidity cabinet (see Clause 4(c)). Leave the specimen to cure for the required period; normally, 28 d are specified. Determine the mass of the compacted specimen \( m_3 \) after the curing period.

NOTES:
1. A room capable of maintaining the same conditions as per Clause 4(c) can be used in place of the humidity chamber.
2. Specimens should be cured and tested under conditions equal to the average expected humidity and temperature on site. Alternatively, specimens can be tested under curing conditions given in Clause 4(c).
3. Conditions during the curing process must be recorded.
4. Handle uncured specimens with care as they may disintegrate.

9 COMPRESSION TESTING

Each test specimen shall be tested in compression as follows:

(a) Remove the specimen from the curing environment. Examine the specimen for any defects. If the specimen has cracked at the compaction layer or on any of the surfaces, discard it.

(b) End surfaces shall be plane and be at right angles to the axis of the cylinder.

NOTE: If required, cap the ends of the specimen. The use of a jig will facilitate the capping process. Uncapped ends should not be more than 2° out of square from the axis nor have irregularities or depressions that will cause the load to be applied over less than 90% of the area of the specimen.

(c) If capping is required, allow the test specimen to stand in a sealed container for 1 h after capping to allow the cap to gain strength (see also Note to Clause 7.4(g)).

(d) Determine the average diameter \( D_{av} \) of the test specimen to the nearest 0.5 mm from two diameters measured at right angles to each other near the centre of the height of the cylinder.

(e) Place a Teflon sheet on the lower bearing block of the compression testing machine, making sure that its centre is aligned to the centre of the thrust of the upper bearing block. See Note to Step (f) below.

(f) Place the test specimen on the Teflon sheet on lower bearing block of the compression testing machine, making sure that the vertical axis of the test specimen is aligned with the centre of the thrust of the upper bearing block. Place a Teflon sheet above the test specimen, making sure that its centre is aligned to the centre of the thrust of the upper bearing block. Gently bring the upper bearing block to bear on the test specimen and ensure that uniform seating is obtained.

NOTE: A suitable low-friction material other than Teflon can be used in place of the Teflon sheets. Substituted materials must have the minimum dimensions as per Clause 4(m).
(g) Apply the load at a constant rate by setting the moveable platen to travel at a speed of 0.3 ±0.1 mm/min or increase the load at a uniform rate of 20 ±2 kN/min. Record the load at failure (P) of the test specimen to the nearest 0.1 kN.

(b) Determine the moisture content (w_f) by drying the whole specimen as specified in AS 1289.2.1.1, taking care to first remove any capping material.

10 CALCULATIONS
The following shall be calculated:

(a) The wet density (\( \rho_w \)) of the test specimens as compacted from the following equation:

\[
\rho_w = \frac{m_2 - m_1}{V}
\]

where

\( \rho_w \) = density of wet soil, in tonnes per cubic metre
\( m_2 \) = mass of mould plus compacted specimen, in grams
\( m_1 \) = mass of mould, in grams
\( V \) = the measured volume of the mould, in cubic centimetres

(b) The dry density (\( \rho_d \)) of the test specimens as compacted from the following equation:

\[
\rho_d = \frac{100\rho}{100 + w_i}
\]

where

\( \rho_d \) = dry density of wet soil, in tonnes per cubic metre
\( \rho \) = density of wet soil, in tonnes per cubic metre
\( w_i \) = water content of the specimen at compaction, in percent

(c) The unconfined compressive strength (\( UCS \)) of the test specimens from the following equation:

\[
UCS = \frac{F \times 1273}{(D_{av})^2}
\]

where

\( UCS \) = unconfined compressive strength, in megapascals
\( F \) = load at failure, in kilonewtons
\( D_{av} \) = Average diameter, in millimetres

NOTE: 1273 = \( \pi / 4 \times 1000 \)

NOTE: \( \pi / 4 \) is the constant in the formula for the surface area of the specimens and 1 kN/mm\(^2\) = 1000 MPa.

(d) The average value of the minimum of three determinations of (\( UCS \)).

11 REPORT
The following data for the three test specimens shall be reported:

(a) Unconfined compressive strength, as the average of the strengths of the test specimens, to the following precision:
(i) For UCS less than 1.0 MPa, to the nearest 0.05 MPa
(ii) For UCS between 1.0 and 2.0 MPa, to the nearest 0.1 MPa
(iii) For UCS greater than 2.0 MPa, to the nearest 0.2 MPa.

(b) The age of the test specimens, in days taken from the time of compaction of the specimens to the time of testing, in days.

(c) Moisture content of each specimen on completion of testing, in percent to the nearest 0.5.

(d) Dry density of each specimen as compacted, to the nearest 0.01 t/m³ or, if required, the laboratory density ratio to the nearest 1%.

(e) If required, the laboratory moisture ratio of the material prior to compaction to the nearest 1%.

(f) If not in accordance with either AS xxxx.x.x (Rammed earth soil compaction and density tests), the method of compaction and number of layers.

(g) Description of the stabilized soil.

(h) Details of curing.

(i) If applicable, the amount of material retained on the 19.0 mm sieve as a percentage of the moist mass in the original sample, to the nearest 1.

(j) Bound material

   (i) the elapsed time between addition of the binder and compaction of the specimens; and

   (ii) the method of preparation of the test sample.

(k) Reference to this Australian Standard, i.e., AS xxxx.x.x (Unconfined compressive strength of compacted rammed earth materials).
Methods of testing rammed earth soils for engineering purposes

Method x.x.x: Determination of flexural tensile strength of rammed earth beams (bending or flexure test)

1 SCOPE

This Standard sets out a method for determining the flexural tensile strength of bound or unbound rammed earth test specimens prepared in accordance with AS xxxx.x.x tested as simple beams compacted laterally or longitudinally with third-point loading.

This method is applicable to the control testing of field or plant mix materials and for the assessment of the strength of materials mixed in the laboratory.

The test is conducted on that portion of the material that passes the 10.0 mm sieve.

NOTES:

1. The exclusion of a large proportion of stone coarser than 10.0 mm may have a major effect on the unconfined compressive strength determined compared with that obtainable with the material as a whole.
2. The binders usually used for stabilized rammed earth construction are covered by the following Standards:
   (a) Limes, AS 1672.1.
   (b) Cements, AS 3972.
   (c) Bitumens, AS 1160 and AS 2157.
3. Compaction regime used on-site is likely to be different to that specified in this method. It is the user’s responsibility to account for these differences for design purposes.

2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

1152 Specification for test sieves
1160 Bitumen emulsions for construction and maintenance of pavements
1672 Limes and limestones
1672.1 Part 1: Limes for building
1984 Vernier callipers (metric series)
2139 Calibration and classification of force-measuring systems
2157 Cutback bitumen
3972 Portland and blended cement
1141.1 Method 1 Definitions
1141.2 Method 2 Basic testing equipment
1289.2.1.1 Method 2.1.1 Soil moisture content tests—Determination of the moisture content of a soil—Oven drying method (standard method)
3 DEFINITIONS
For the purpose of this Standard, the definitions in AS 1141.1 and those below apply.

3.1 Bound material
A material to which a binder, such as lime, cement, bitumen, or other binding agent has been added to produce structural stiffness.

3.2 Unbound material
A material that is not self-cementing and does not contain a binder.

4 ACCEPTANCE OF TEST SPECIMENS
Moulded flexure test specimens shall be accepted for testing if they have been moulded in accordance with the provisions of AS xxxx.xx (manufacturing), and if they are free from defects likely to affect their strength.

(a) Bound specimens Bound specimens cured for a period of less than 28 days should not be tested.
(b) Unbound specimens Unbound specimens not already cured under known conditions for a minimum of 7 days should not be tested.

Where specimens liable to rejection are tested, all apparent defects shall be noted in accordance with Clauses 10 and 11 of this Standard. Specimens shall be liable to rejection if any of the following conditions exist:

(i) Chipped edges, surface cracking or honeycombing are apparent anywhere in the tested span.
(ii) The surfaces of the specimen are out of plane such that any of the lines of contact between the bearing surfaces on which the rollers bear are out of plane by more than 0.1 mm.
(iii) Failure of the specimen does not occur within the middle third of the specimen’s tested length L (see Note 3 to Clause 8(a)).

5 APPARATUS

5.1 Testing machines
The testing machine shall comply with the following requirements:

(a) It shall meet the requirements for Grade A machines, as defined in AS 2193 for the relevant range of compressive forces.
(b) It shall be power operated and capable of applying compressive forces increasing continuously at the rate of loading and in the manner specified in Clause 7.
(c) It shall be fitted with a device for controlling the rate of displacement, which shall be capable of operating at the rate of displacement specified in Clause 7(d).

NOTE: If a machine with a controlled rate of displacement is not available, a machine with a controlled rate of loading can be used provided that the rate of loading is controlled to ensure that the required rate of displacement is maintained.

5.2 Flexure testing apparatus
The force shall be applied to the specimen through a frame containing two supporting rollers and two loading rollers. The frame shall consist of two parts (upper and lower) each of which shall be precisely located in the testing machine so that loading is applied evenly and precisely at the third points of the span. This frame may be
incorporated either in the testing machine or in an accessory that can be used with, or between, the platens of a suitable compression-testing machine.

The application of the force shall be through the spherical seat or a loading ball (see Figure 1) that is centrally placed between the loading rollers.

The rollers shall be suitably articulated to ensure that:

(a) The force is divided equally between the loading rollers;
(b) The force is applied normal to the specimen surface; and
(c) The specimen is not restrained or subject to torsion.

NOTE: This may be achieved by incorporating a suitable system of transverse rollers and either a spherical seat or a ball in both the supporting group and loading group of rollers.

A suitable arrangement of the loading apparatus is illustrated in Figure 1.

The dimensions and spacing of the rollers shall comply with the following requirements:

(i) Two hardened steel rollers of 38 mm to 40 mm nominal diameter shall be provided to support the specimen. The centre-to-centre distance of the supporting rollers ($L$) shall be in accordance with Table 1.
(ii) Two hardened steel rollers of 38 mm to 40 mm nominal diameter shall be used to apply the load at the third points of the supporting span. The centre-to-centre distance of the loading rollers ($l$) shall be in accordance with Table 1.
(iii) The length of both the supporting and loading rollers shall be at least equal to the width of the specimen being tested.

To ensure that the rollers bear uniformly on the width of the specimen, the surface of the rollers along any contact edge shall not deviate from a straight line by more than $\pm 0.02$ mm in 150 mm.

5.3 Measuring apparatus

A Vernier calliper readable to at least 0.2 mm and complying with the requirements of AS 1984 or a ruler at least 400 mm long with a scale interest of 0.5 mm.

5.4 Drying apparatus

(a) A plastic or wooden mallet of suitable strength to crush failed specimen material. A metal-headed mallet shall not be used.
(b) Trays of suitable size to contain and dry crushed specimen material.

6 CONDITIONING OF TEST SPECIMENS PRIOR TO TEST

The specimen shall be cured in accordance with AS xxxx.x.x (manufacturing). The surfaces of the specimens that are loaded shall be free from grit, and all surfaces shall be wiped, if necessary, to remove surplus water.
CENTRE-TO-CENTRE DISTANCES OF THE SUPPORTING AND LOADING ROLLERS

<table>
<thead>
<tr>
<th>Nominal size of specimens</th>
<th>Centre-to-centre distance of rollers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Supporting rollers (L) mm</td>
</tr>
<tr>
<td>150 x 150</td>
<td>450 ± 10, 5</td>
</tr>
<tr>
<td>100 x 100</td>
<td>300 ± 8, -3</td>
</tr>
</tbody>
</table>

7 PROCEDURE

The procedure shall be as follows:

(a) Remove grit from the surface of the specimen that is loaded and, if necessary, wipe to remove the surplus water.

(b) Centre the specimen on the supporting rollers. Although it is necessary to locate the specimen centrally with respect to its width, it is neither necessary nor always desirable that it be located centrally with respect to its length. The position of the specimen may be arranged such as to avoid any defects that may occur near one end.

NOTE: Laterally-compacted specimens should be placed so that the compaction plane is perpendicular to the axis of loading.
(c) Bring the loading rollers into contact with the top, apply a seating load not exceeding 50 N, check the uniformity of bearing of the rollers, and mark their position on the sides of the specimen before proceeding with the loading.

(d) Apply the force without shock and increase continuously at a displacement rate of 0.3mm/min until no increase in force can be sustained (see Note to Clause 5.1(c)). Record the maximum force applied to the specimen as indicated by the testing machine.

(e) Determine the average width and average depth of the specimen at the section of failure to the nearest 1 mm.

(f) Note the appearance of the rammed earth and the type of fracture, if the fracture is unusual.

(g) If the fracture occurs outside the middle third of the span length, do not calculate the modulus of rupture but measure and record the distance from the nearest supporting roller to the section of failure.

(h) Determine the moisture content \((w)\) by drying the whole specimen as specified in AS 1289.2.1.1, taking care to first remove any capping material.

**NOTES:**

1. If drying of the entire specimen is not feasible then a smaller portion of mass no less than half of the total specimen mass can be used to determine the moisture content \((w)\).
2. Use of oven drying as per AS 1289.2.1.1 is not recommended for bound specimens cured for less than 28 days. It is recommended that alternative drying methods, for example freeze drying or critical point drying, be used if an accurate value of \((w)\) is required.

**8 CALCULATION**

The following shall be calculated:

(a) When the fracture occurs within the middle third of the specimen, the flexural tensile strength \(f_{cf}\) of the specimen shall be calculated from the following equation:

\[
f_{cf} = \frac{1000PL}{BD^2} \tag{1}
\]

where

\[
\begin{align*}
f_{cf} & = \text{flexural tensile strength, in megapascals} \\
P & = \text{maximum applied force indicated by the testing machine, in kilonewtons} \\
L & = \text{span length, in millimetres} \\
B & = \text{average width of the specimen at the section of failure, in millimetres} \\
D & = \text{average depth of the specimen at the section of failure, in millimetres}
\end{align*}
\]

**NOTES:**

1. *Laterally compacted specimens* Calculated values of \(f_{ct}\) represent the flexural tensile strength of a single compacted layer.
2. *Longitudinally compacted specimens* Calculated values of \(f_{ct}\) represent the flexural tensile strength of two adjoining compacted layers.
3. Provided that fracture occurs within the middle third of the specimen, Equation 1 can be used for both laterally compacted and longitudinally compacted specimens. If failure does not occur within the middle third of the specimen then the specimen should be rejected.
9 PRECISION STATEMENT

For pairs of beams made from the same sample, cured in similar conditions and tested in accordance with this standard, the repeatability expressed as a percentage of the mean of the two strengths obtained, is 18 percent at the 95 percent probability level.

NOTE: This statement on repeatability is based on limited Australian data and may be amended when more data is collected.

10 RECORDS

The following information shall be recorded for each test specimen:

(a) Identification of the rammed earth.
(b) Job site or laboratory where tested.
(c) Date and time of test.
(d) Age of specimen at date of test, if known.
(e) Moisture condition of specimen.
(f) Any apparent defects of the specimen, as received.
(g) Curing history of the specimen.
(h) Failure load.
(i) Span length.
(j) Average width and depth of the specimen at the section of failure.
(k) Flexural tensile strength, calculated to the nearest 0.05 MPa, or the position of the fracture, if it occurs outside the middle third of the span length.
(l) Appearance of the concrete in the fracture surface and the type of fracture, if these are unusual.
(m) Any other significant factors noted before, during or after testing.
(n) Identification of the testing operator.
(o) Reference to this Standard, i.e. AS 1012.11.

10 REPORT

The following information shall be reported:

(a) Identification of the concrete.
(b) Date and location of test.
(c) Age of specimen at the date of test, if known.
(d) Nominal size of specimen.
(e) Flexural tensile strength, calculated to the nearest 0.05 MPa, or the position of the fracture if it occurs outside the middle third of the span length.
(f) Moisture content of the specimen, calculated to the nearest 0.1%.
(g) Dimensions of the specimen.
(h) Curing history of the specimen.
(i) Any apparent defects, any relevant comments on the moisture condition of the specimen, as received, or any other significant factor(s) noted before, during or after testing.
(j) Reference to this Standard, i.e. AS xxxx.x.x.
(k) Such other information contained in the sampling records as may be requested.
Methods of testing rammed earth soils for engineering purposes

Method x.x.x: Determination of indirect tensile strength of rammed earth cylinders (‘Brazil’ or splitting test)

1 SCOPE
This Standard sets out a method for determining the indirect tensile strength of standard bound and unbound rammed earth cylinders, prepared in accordance with AS xxxx.x.x.

This method is applicable to the control testing of field or plant mix materials and for the assessment of the strength of materials mixed in the laboratory.

The test is conducted on that portion of the material that passes the 10.0 mm sieve in accordance with AS 1152.

NOTES:

1. The exclusion of a large proportion of stone coarser than 10.0 mm may have a major effect on the indirect tensile strength determined compared with that obtainable with the material as a whole.
2. The binders usually used for stabilized rammed earth construction are covered by the following Standards:
   (a) Limes, AS 1672.1.
   (b) Cements, AS 3972.
   (c) Bitumens, AS 1160 and AS 2157.
3. Compaction regime used on-site is likely to be different to that specified in this method. It is the user’s responsibility to account for these differences for design purposes.

2 REFERENCED DOCUMENTS
The following documents are referred to in this Standard:

AS

1152 Specification for test sieves
1160 Bitumen emulsions for construction and maintenance of pavements
1672 Limes and limestones
1672.1 Part 1: Limes for building
1984 Vernier callipers (metric series)
2139 Calibration and classification of force-measuring systems
2157 Cutback bitumen
2458 Hardboard
3972 Portland and blended cement
xxxx Method x.x Method for securing and testing cores from hardened rammed earth for compressive strength
xxxx Method x.x Rammed earth soil compaction and density tests—Determination of the dry density/moisture content relation of rammed earth using modified compactive effort
3 DEFINITIONS
For the purpose of this Standard, the definitions in AS 1141.1 and those below apply.

3.1 Bound material
A material to which a binder, such as lime, cement, bitumen, or other binding agent has been added to produce structural stiffness.

3.2 Unbound material
A material that is not self-cementing and does not contain a binder.

4 TEST SPECIMENS

4.1 Acceptance of specimens
Cylinder specimens shall be accepted for testing if they have been moulded and cured in accordance with the provisions of AS xxxx.x.x or obtained via coring as per AS xxxx.x.x, and if they are free from defects likely to affect their strength.

(a) Bound specimens
Bound specimens cured for a period of less than 28 days should not be tested.

(b) Unbound specimens:
   (i) Unbound specimens not already cured under known conditions for a minimum of 7 days should not be tested.
   (ii) Unbound specimens showing deformations greater than \( \frac{a}{y} > 0.27 \) where \( a \) is the width of the flattened portion in millimetres and \( y \) is the distance between flattened portions in millimetres after testing should be rejected.

   **NOTE:** Definitions of \( a \) and \( y \) are shown in Figure 2.

Where specimens liable to rejection are tested, the specimen age and all apparent defects shall be noted in accordance with Clauses 9 and 10 herein.

Specimens shall be liable to rejection if no suitable plane of loading (see Clause 4.2) can be found which complies with the following tolerances when measured in accordance with Clause 6(a):

(c) Difference of any diameter on the plane of loading with respect to end diameter .......................................................... \( \pm 1 \text{ mm.} \)

(d) Difference in length between upper and lower loading lines ....................................................................................... \( \pm 2 \text{ mm.} \)

4.2 Selection of plane of loading
The best position for the plane of loading shall be selected before the cylinder is tested. The plane of loading shall be such that the lines of contact with the bearing strips are the most nearly straight and parallel that can be found. A straightedge shall be used to find the best lines. The selected plane shall be marked by drawing a
diametral line upon each end of the cylinder. The lines shall be drawn using a suitable device that will ensure that they are in the same axial plane.

5 APPARATUS

5.1 Testing machines
The testing machine shall comply with the following requirements:

(a) It shall meet the requirements of Grade A machines as defined in AS 2193, for the relevant range of compressive forces.
(b) It shall be power operated and capable of applying compressive forces increasing continuously at the rate of displacement in the manner specified in Clause 6(e) (see Note to item (c) below).
(c) It shall be fitted with a device for controlling the rate of displacement, which shall be capable of operating at the rate of displacement specified in Clause 6(e).

NOTE: If a machine with a controlled rate of displacement is not available, a machine with a controlled rate of loading can be used provided that the rate of loading is controlled to ensure that the required rate of displacement is maintained.

(d) It shall be fitted with two steel compression platens. If the relevant dimension of either of the platens of the testing machine is less than the length of the specimen, or if the relevant dimension of the upper platen is longer than the testing jig when used, a supplementary bearing plate or bar of machined steel shall be placed between the particular platen and the jig.
(e) If the bearing surface of either platen departs from plane by 0.1 mm at any time during service, a supplementary bar or plate placed as described in Clause 5.3 shall be used.
(f) The centre of curvature of the spherical seat shall be on the vertical axis of the upper platen and shall be within 6 mm of its bearing surface. The upper platen shall be capable of limited movement and tilting by at least 3 degrees in any direction. The spherical seat shall be free from grit and other foreign matter and shall be lubricated at all times (see Note).

NOTE: Where the spherical seating is accessible, it should be cleaned regularly and should be lubricated with a thin film of light non-polar oil. Where the spherical seating is sealed, the manufacturer’s recommendation for correct maintenance of the seating should be followed.

5.2 Testing jig
An appropriate steel testing jig may be used when testing the specimen. A jig of suitable design is illustrated in Figure 1.

The design of the jig shall be such that it ensures that the specimen can be located centrally on the lower platen of the testing machine, with the bearing strips aligned in a vertical plane passing through the axis of the specimen.

(a) The jig shall not constrain the specimen, the platens, or supplementary bearing bars or plates, while the load is being applied.
(b) Each bearing surface of the testing jig shall not depart from plane by more than 0.02 mm.
(c) The bearing surfaces shall be parallel within 1 degree.
(d) The thickness of the jig bearing plate shall be approximately 20 mm.
5.3 Supplementary bearing bar or plate
Where required, the supplementary steel bearing bar or plate shall have a width of at least 50 mm and a thickness not less than the distance from the edge of the platen to the end of the specimen; or where the upper platen is longer than the test jig, the thickness shall be approximately 20 mm. It shall be at least as long as the specimen.

Each bearing surface of the bar or plate shall not depart from plane by more than 0.1 mm. Each bar or plate shall be used in such a manner that the load will be applied over the entire length of the specimen.

The bearing surfaces shall be parallel within 1 degree.

5.4 Bearing strips
Two bearing strips of tempered grade hardboard, complying with AS 2458, shall be provided. They shall be free from defects, nominally 5 mm thick, 25 mm wide and at least as long as the specimen. Bearing strips shall not be re-used.

5.5 Vernier calliper
A Vernier calliper readable to at least 0.2 mm and complying with the requirements of AS 1984.

5.6 Ruler
A ruler at least 400mm long with a scale interest of 0.5mm.

5.7 Mallet
A plastic or wooden mallet of suitable strength to crush failed specimen material. A metal-headed mallet shall not be used.

5.8 Trays
Trays of suitable size to contain and dry crushed specimen material.
NOTE: This design has been found satisfactory, but alternative designs may be employed provided that the essential dimensions are met.

FIGURE 1 DETAILS OF TYPICAL TESTING JIG FOR LOCATING 100mm DIAMETER RAMMED EARTH TEST CYLINDERS FOR INDIRECT TENSILE TEST

6 PROCEDURE

The procedure shall be as follows:

(a) Determine the diameter of the test specimen in the test plane to the nearest 0.2 mm by averaging three diameters measured near the ends and the middle of the specimen. Determine the length of the test specimen to the nearest millimetre by averaging at least two length measurements. Make length measurements along the lines in contact with the bearing strips.

(b) Align the hardboard bearing strips between the top and bottom platen of the specimen.

(c) Where necessary, position the supplementary apparatus in the testing machine, so that the specimen is centred over the lower platen.

(d) Apply a small initial force and remove any side constraint (by lowering the side plates in the case of the testing jig illustrated in Figure 1).

(e) Apply the force without shock and increase continuously at a constant displacement rate of 0.3±0.1 mm per minute until no increase in force can be sustained. Record the maximum force applied to the specimen as indicated by the testing machine.

(f) Note the appearance of the rammed earth and the type of fracture, if the fracture is unusual.

(g) Determine the moisture content (w) by drying the whole specimen as specified in AS 1289.2.1.1, taking care to first remove any capping material.

NOTES:
1. If drying of the entire specimen is not feasible then a smaller portion of mass no less than half of
the total specimen mass can be used to determine the moisture content (w).
2. Use of oven drying as per AS 1289.2.1.1 is not recommended for bound specimens cured for less
than 28 days. It is recommended that alternative drying methods, for example freeze drying or
critical point drying, be used if an accurate value of (w) is required.

7 CALCULATION
The following shall be calculated:

(a) The indirect tensile strength (T) of the specimen shall be calculated from the following equation:

\[ T = \frac{2000P}{\pi LD} \]  

[1]

where

\( T \) = indirect tensile strength, in megapascals
\( P \) = maximum applied force indicated by the testing machine, in kilonewtons
\( L \) = length, in millimetres
\( D \) = diameter, in millimetres

8 PRECISION STATEMENT
For pairs of bound or unbound 100 mm diameter \( \times \) 200 mm long cylinders, made from the same material, cured
in similar conditions and tested in accordance with this Standard, the repeatability expressed as a percentage of
the mean of the two strengths obtained, is 14 percent at the 95 percent probability level.

NOTE: The same precision is required of bound and unbound rammed earth core samples obtained according to
procedures given in AS xxxx.x.x.

9 RECORDS
The following information shall be recorded for each test specimen:

(a) Identification of rammed earth.
(b) Job site or laboratory where tested.
(c) Date and time of test.
(d) Age of specimen at date of test, if known.
(e) Moisture content of specimen.
(f) Any apparent defects of the specimen.
(g) Dimensions of specimen.
(h) Curing history of specimen.
(i) Force at failure.
(j) Indirect tensile strength, calculated to the nearest 0.1 MPa.
(k) Appearance of concrete in fracture surfaces, and type of fracture, if these are unusual.
(l) Any other significant factors noted before, during or after testing.
(m) Identification of the operator carrying out the test.
(n) Reference to this Standard, i.e. AS xxxx.x.x.

10 REPORT
The following information shall be reported:
(a) Identification of concrete.
(b) Date and location of test.
(c) Age of specimen at date of test, if known.
(d) Indirect tensile strength, calculated to the nearest 0.05 MPa.
(e) Moisture content of the specimen, calculated to the nearest 0.1%.
(f) Dimensions of specimen.
(g) Curing history of specimen.
(h) Any apparent defects, any relevant comments on the moisture condition of the specimen, as received, or any other significant factor(s) noted before, during or after testing.
(i) Reference to this Standard, i.e. AS xxxx.x.x.
(j) Such other information contained in the sampling records as may be requested.