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Timbercrete Pty Ltd

Design of Partially Reinforced Timbercrete for Out-of-Plane Face Loads

This report has been prepared on behalf of **ELECTRONIC BLUEPRINT** by:

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Scope
This report considers the design of partially reinforced Timbercrete masonry for simple bending due to out-of-plane face loads, with particular reference to Ensis Test Report TE06-001b.

The report is in three parts:
Part 1- Behaviour Similar to Conventional Partially Reinforced Masonry
Part 2- Design Based on Tests Reported in Ensis Test Report TE06-001b
Part 3- Design Based on AS 3700-2001

Background
All building design must comply with the relevant State Building Regulations, which are set out in the BCA (Building Code of Australia) Volumes 1 and 2. The BCA defines the performance requirements, generally in very broad terms, and the means of compliance through:

- Deemed-to-Satisfy Provisions, which may include:
  - Acceptable Construction Manuals (e.g. nominated Australian Standards, AS 3700)
  - Acceptable Construction Practice (e.g. forms of construction reproduced in the BCA itself

- Alternative Solutions (e.g. Designs based on test results and engineering principles).

Each of these paths to compliance has equal status under the BCA. This report deals with the "Alternative Solutions" path.

In all but the rarest of cases, structural engineers will design using the Deemed-to-Satisfy Solution by:
- Determining loads using AS/NZS 1170 (Parts 0, 1, 2, 3) and AS 1170.4; and,
- Determining resistance using AS 4100, AS 3600, AS 3700, AS 1720, AS 1684, AS 2870 etc.

However, structural engineers are often asked to incorporate new products into their designs. The performance of such products is justified by test because they are outside the scope of the various Australian Standards specified by the BCA as Deemed-to-Satisfy. The requirements are set out in BCA Vol 1 Clauses A0.8, A0.9 and A0.10, and BCA Vol 2 Clauses 1.0.8, 1.0.9 and 1.0.10. When dealing with structural components, the following procedure is appropriate.

1. Determine the performance requirements using BCA Vol 1 Part B1 or BCA Vol 2 Part B.

2. Determine the loads using AS/NZS 1170 (Parts 0, 1, 2 3) and AS 1170.4.

3. Determine the relevant properties by test e.g. stability, strength, deflection etc.

4. Use AS/NZS 1170.0 :2002 Appendix B to assess the test data and obtain design values. Although this Appendix is informative, and therefore not formally part of the BCA Deemed-to-Satisfy path, it provides a reliable component of "Expert Judgement".

5. Use the design values so derived in the context of the normal structural design standards. It should be noted that such design values include allowance for reductions normally associated with the capacity reduction factors, φ.

Part 1- Behaviour Similar to Conventional Partially Reinforced Masonry

Height of simply supported wall
H = 2.380 m

Maximum design H/Δ
H/Δ_{max} = 150

This value is recommended in Draft AS 4773.1 as the maximum deflection ratio for masonry walls

Maximum permissible mid-height deflection
Δ = $H / H/\Delta_{max}$
= 2.380 / 150
= 15.9 mm

Maximum horizontal load capacity at maximum permissible deflection of 15.9 mm
P = 6.2 kN

This value has been read from the plot of load versus deflection.

This is near the maximum load and deflection measured.

Up to this point, there has been a gradual decrease in the slope of the load/deflection curve, probably indicating a progressive reduction in the masonry elastic modulus. Because there is no clear levelling of the curve, it is not clear whether the steel has yielded.

The plot of load versus deflection represents a reasonable test of the wall to its practical design limit, based on deflection.

Part 2- Design Based on Tests Reported in Ensis Test Report TE06-001
Number of samples tested
N = 1

Minimum failure load
P_{min} = 6.2 kN

Minimum failure bending moment
M_{min} = P_{min} L / 4
= 6.2 x 2.38 / 4
= 3.69 kN.m

Reduction factor
k_1 = 1.79
Based on AS 1170.0:2002 Table B1, for one sample tested and assumed coefficient of variation of 15%

Design capacity
φ M = M_{min} / k_1
= 3.69 / 1.79
= 2.06 kN

Note:
If the number of identical tests were increased to (say) five, assuming that the minimum value was 95% of the single test, it could be reasonably expected that this value would increase to:
φ M_{pred} = 3.69 x 0.95 / 1.46
= 2.40 kN.m

Part 3- Design Based on AS 3700-2001

Wall thickness
D = 190 mm

Effective depth
d = D / 2
= 95 mm

Threaded bar nominal diameter
D_{dia} = 12 mm

Area of tensile steel threaded bar
A_s = 84.3 mm^2
This value allows for the depth of thread.

Tensile strength of threaded bar
f_{sy} = 500 MPa Assumed value – should be verified by testing laboratory.

Effective compression width, based on AS 3700.
b = 4 t
= 4 x 190
= 760 mm
This value is probably conservative

Masonry unit characteristic unconfined compressive strength
f'_{uc} = 3.0 MPa

Block type factor
k_m = 1.4
Units are solid

Equivalent brickwork strength
f'_{mb} = k_m $(f'_{uc})^{0.5}$
= 1.4 $(3.0)^{0.5}$
= 2.42 MPa

Mortar joint height
h_j = 10 mm

Masonry unit height
h_b = 190 mm

Ratio of block to joint thickness
h_b/h_j = 190/10
= 19.0

Block height factor
k_h = 1.3

Characteristic masonry strength
f'_m = k_h f'_{mb}
= 1.3 x 2.42
= 3.15 MPa

Design area of main tensile reinforcement

A_{sd} = min [0.29 (1.3 f'$_m$) b d / f_{sy} , A_{st}] AS 3700 Clause 8.5

= min [(0.29 x 1.3 x 3.15 x 760 x 95 / 500) , 84.3]

= min [171 , 84.3]

= 84.3 mm^2

Capacity reduction factor

Φ = 0.75

Moment capacity based on steel strength

M = φ $f_{sy} A_{sd}$ d (1 – 0.6 $f_{sy} A_{sd}$ / (1.3 f'$_m$ b d) AS 3700 Clause 8.5

= 0.75 x 500 x 84.3 x 95 x (1 – [0.6 x 400 x 84.3 /(1.3 x 3.15 x 760 x 95)])

= 2.79 kN.m

Conclusions

1. The test is consistent with the expected behaviour of partially reinforced masonry.

2. When the rest result is analyzed in accordance with AS/NZS 1170.0 Appendix B Clause B3, a design bending moment capacity of 2.06 kN.m is derived.

3. Further identical tests would enable this value to be increased. Typically, if the number of identical tests were increased to (say) five, it could be reasonably expected that this value would increase to approximately 2.40 kN.m.

4. Using AS 3700-2001, the design bending moment capacity is 2.79 kN.m.

5. Therefore, it is recommended that further tests are not necessary and that design should be based on AS 3700-2001.

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