RAPIDWALL®

ENGINEERING DESIGN GUIDELINES

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1. INTRODUCTION

Designed for use by professional structural design engineers these technical guidelines and recommendations were specifically developed by structural engineers Dare Sutton Clarke Pty Ltd as a guide to the design of buildings deploying the Rapidwall®structural walling system.

Other data relating to building design, such as fire resistance, sound transmission and water resistance are also included in the guidelines. The guidelines are presented in sections each covering a specific property of Rapidwall® .

As a guide to designers simple design calculations are included in some sections as appropriate. At the end of the guidelines a comprehensive detailed example is provided for the design of a multi-storey building utilising load-bearing Rapidwall® where the building is subjected to seismic loadings. All calculations and designs in this manual are in accordance with the following Australian Codes of Practice:-

- AS 1170.1 – 1989 SAA Loading Code –Part 1: Dead and Live Loads and Load Combinations
- AS 1170.4 – 1993 Minimum Design Loads on Structures – Part 4: Earthquake Loads
- AS 3600 – 2001 Concrete Structures

All the design data and design charts provided in these guidelines are based upon the results of regular university testing undertaken for Rapid Building Systems Pty Ltd since 1990.

A new and comprehensive test program was undertaken in 2002 from which the current design guidelines were developed. The technical paper presenting the results and the derived design theory *'A 2002 Report into the Physical Testing and the Development of Design Guidelines for the Structural Application of Rapidwall® in Building Construction'* can be obtained on request from Rapid Building Systems Pty Ltd.

Rather than a strict code of practice the design methodologies are presented as a set of guidelines for the safe and efficient structural use of Rapidwall® in general building construction.

The guidelines are for use by appropriately experienced and qualified structural engineers who should satisfy themselves as to relevance of these design guidelines and their development as presented in *'A 2002 Report into the Physical Testing and the Development of Design Guidelines for the Structural Application of Rapidwall® in Building Construction'*

The information presented is supplied in good faith and was accurate at the time of its preparation. Neither Dare Sutton Clarke Pty Ltd nor Rapid Building Systems Pty Ltd will accept responsibility for the incorrect use or interpretation of the data and guidelines presented.

2. NOTATION

A = Cross-sectional area

A_{cr} = Area of crack interface in shear

A_{cv} = Area of concrete section resisting shear transfer

A_g = Gross area of shear plane

A_s = Area of steel bars

A_{s1} = Area of steel bars in unit width of cross-section

A_t = Additional amount of reinforcement resisting tension across shear plane

A_{vf} = Area of shear friction reinforcement

b = Breadth of a section

c = cohesion stress

D = Depth or width of cross-section

d = Effective depth of cross-section

DL = Dead load

ECC = Eccentricity

f_c' = Characteristic compressive concrete strength

f_{sy} = Yield strength of steel

G = Dead load

EI = Flexural rigidity

I = Second moment of area

k_u = Neutral axis parameter, refer to AS 3600-2001

L = Span length

LL = Live load

$M*$ = Design moment

M_{uo} = Ultimate bending moment of beam

N = Compressive load

$N*$ = Design axial load

N_t = Tension axial load acting across the shear plane

p = Unit ultimate compressive strength of wall

Q = Live load

$q*$ = Design shear flow

R_f = Structural response factor in accordance with AS 1170.4-1993

$S*$ = Design action effect

T = Total tensile force

t = Thickness of wall

UDL = Uniformly distributed load

V^* = Design shear force

v_r = Factored resisting shear stress at wall-slab joint

w = UDL intensity

x = Compression zone depth

y = Distance to centroid of cross-section

Δ = Deflection

ϕ = Strength reduction factor

ϕ_c = Frictional shear strength reduction factor

ϕR = Design load capacity

ϕ_s = Tensile strength reduction factor at frictional shear plane

γ = Ratio of depth of rectangular stress block to $k_u d$.

φ_s = Short term live load factor for serviceability limit state

μ = Coefficient of friction

ρ_v = Ratio of shear friction reinforcement

σ = Stress

σ_e = Effective normal stress

3. DESIGN PHILOSOPHY

The design capacities given in these guidelines are based on ultimate strengths determined from tests.

In accordance with Table B4.3 of Australian Standard AS 3600-2001, the ultimate strengths have been determined allowing a safety margin (mean strength divided by safety factor *k*) to account for the variations or scattering in the test results. Accordingly this provides a safety index of 3.0 for a confidence level of 90%.

For strength design a reduction factor ϕ is further applied to the ultimate strength capacities obtained from the tests. This design strength reduction factor has been included in the various design charts presented. The strength reduction factors used are generally in accordance with AS 3600-2001 but with some minor modifications to account for the differences between Rapidwall® panel design and concrete structural design. Table 3.1 lists the design strength reduction factors ϕ that are adopted in this manual.

Table 3.1 Design strength reduction factors ϕ

Type of action effect	**Strength reduction factor ϕ**
Concentric or eccentric axially loaded walls	0.6
Bending without axial load	0.8
Shear strength	0.6
Flexural in-plane strength of walls	0.7
Compressive strength of wall cross-section	0.6
Tensile strength of wall cross-section	0.8

The structural capacity of a Rapidwall® member shall be checked using the following equation

$$S^* \le \phi R \qquad (3.1)$$

where S^* is the design action effect due to the design load calculated in accordance with Clause 2.3, AS 3600 – 2001; and
ϕR is the **design load capacity** given in the design charts

Design Example: A 2.85m high Rapidwall® panel filled with 25 Mpa concrete is loaded with 100kN/m live load and 200kN/m dead load. The load is applied at the pinned support at the top of the wall with an eccentricity of 20mm. The bottom of the wall is considered as fixed end. Check strength capacity.

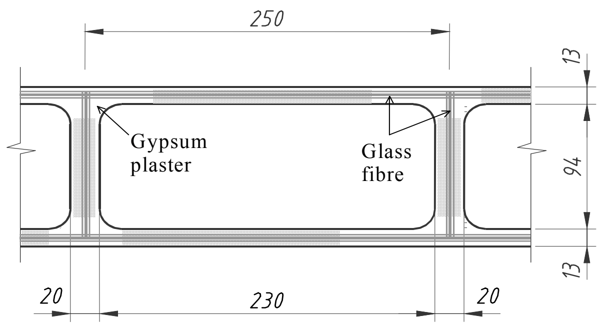
Design load $S^* = 1.25 \times 200 + 1.5 \times 100 = 400$ (kN/m)

From Fig.11.3, the design load capacity of the wall with the support conditions of one pinned end and one fixed end for ECC = 20mm is $\phi R = 425$ (kN/m)

$S^* \le \phi R$, OK.

4. PRODUCT DIMENSIONS

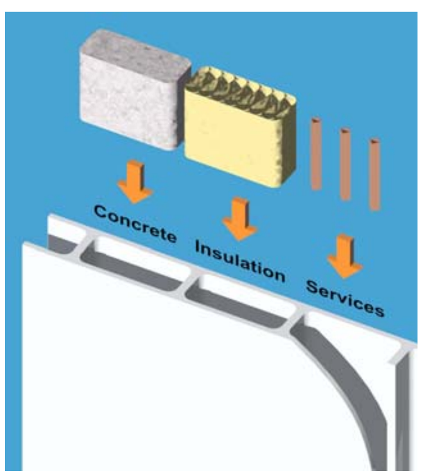
The design guidelines are applicable to Rapidwall® panels manufactured by Rapid Building Systems Pty Ltd or its licensees in accordance with the Product Specification RW-S 1001. The typical dimensions of Rapidwall® panelling is shown in Fig.4.1(a). Reinforcement in the form of 300-350mm long glass fibre rovings is located randomly but centrally within the panel faces and their connecting ribs.



(a) Cross-section

Fig 4.1 (b) indicates the various uses of the Rapidwall® cells. Rapidwall® panels are generally used structurally in six ways:-

1. *As a lightweight load-bearing walling product in cottage construction*- the panels can be used with or without non-structural core-filling such as insulation, sand, polyurethane or lightweight concrete;
2. *As prefabricated lost-formwork for high capacity vertical and shear load-bearing structural walling*- the panel's cores are filled with concrete, either reinforced or not, to provide load-bearing walls in medium-rise residential constructions of up to twenty storeys;
3. *As partitions*- the panels can be insulated for use in hospitals and offices;
4. *As fencing*- the panels can be used from ground level with inserted SHS structural posts embedded into the ground. Alternatively the Rapidwall® panels can be trenched and filled with sand without a need for foundations;
5. *As cladding*- for industrial buildings or sports facilities etc..
6. *As suspended slab formwork*- used in this way the panels become the flush plaster ceiling.



(b) Isometric View

Fig.4.1 Rapidwall® panel details

5. MECHANICAL PROPERTIES OF RAPIDWALL®

Table 5.1 provides the various mechanical properties of Rapidwall® panel when used empty and when concrete filled.

Table 5.1 Mechanical Properties of Rapidwall®

Property name		**Value**	**Note**
Unfilled Rapidwall® panels	Uni-axial compressive strength ϕR_u	100 kN/m	Strength obtained from longitudinal compression/tension tests with ribs extending in the longitudinal direction
	Uni-axial tensile strength ϕR_u	28.8 kN/m	
	Out-of-plane flexural rigidity *EI*, rib parallel to span	3.5×10^{11} Nmm^2/m	
	Out-of-plane flexural rigidity *EI*, rib perpendicular to span	1.7×10^{11} Nmm^2/m	
	Unit weight	40 kg/m^2	
	Thermal expansion coefficient	12×10^{-6} mm/mm/°C	
	Water absorption	<5%	Water absorption by weight % after 24 hours of immersion
	Mohr Hardness	1.6	
Rapidwall® panels filled with 25 MPa concrete in all the cores	Uni-axial compressive strength ϕR_u	890 kN/m	Obtained from longitudinal compression tests with ribs in the longitudinal direction

6. FIRE RESISTANCE

The fire resistance levels (FRL) of Rapidwall® are listed in Table 6.1. Copies of the test certificates are available by request from Rapid Building Systems Pty Ltd.

Table 6.1 Fire Resistance Levels

Description		**FRL**
Non-load bearing walls	Single leaf unfilled Rapidwall® panel	180/120/60*
	Single leaf panel filled with 12mm scoria aggregate	180/90/90*
Load bearing walls	Single leaf panel filled with Rockwool batts	30/30/30*
	Single leaf panel filled with no fines scoria	120/120/120*
	Single leaf panel filled with 32 MPa concrete	240/240/240*
	Double leaf panel filled with cellulose fibre inside the cores	180/180/180*

Note:

1. The three figures in the right hand column refer to fire-resistance periods for satisfying structural adequacy, integrity and insulation, respectively.
2. FRL ratings with an asterisk "*" are test results from previous 100mm thick Rapidwall® panels. These results are deemed be applicable to 120mm thick Rapidwall® .

7. SOUND TRANSMISSION

Sound Transmission Coefficients, STC, have been determined for a number of Rapidwall® construction options. The coefficients from tests on 120mm thick panels are provided in Table 7.1. Other types of constructions have been investigated and the acoustic opinions are available on request from Rapidbuilding Systems Pty Ltd. STC test results on former 100mm thick panels, including double leaf walls, are also available on request from Rapidbuilding System Pty Ltd.

Table 7.1 STC values for various forms of Rapidwall® construction

Construction				STC
Main element of wall	**Additional lining**	**Attachment method**	**Total thickness (mm)**	
Single leaf Rapidwall® unfilled	-	-	120	28
Single leaf Rapidwall® filled with 60kg/m^3 cellulose fibre insulation	-	-	120	31
Single leaf Rapidwall® filled with 90kg/m^3 cellulose fibre insulation	-	-	120	33
Single leaf concrete-filled Rapidwall®	-	-	120	45
Single leaf Rapidwall® filled with 90kg/m^3 cellulose fibre insulation	13mm Gyprock	Direct-fixed with screws and thin glue daubs	133	36
Single leaf Rapidwall® filled with 90kg/m^3 cellulose fibre insulation	13mm Gyprock and Tontine TSB3 polyester insulation	Standard 28mm Rondo 129 furring channels	161	45
Single leaf concrete filled Rapidwall®	13mm Gyprock and Tontine TSB3 polyester insulation	Heavy gauge (1.2mm) Rondo 38mm top hat sections	171	54
Single leaf concrete-filled Rapidwall®	13mm Gyprock and Tontine TSB3 polyester insulation	Standard 28mm Rondo 129 furring channels and CSR Gyprock Resilient Mounts	173	55
Single leaf concrete-filled Rapidwall®	13mm Gyprock and Tontine TSB3 polyester insulation	Separate row of 51mm steel studs spaced 10mm from Rapidwall	194	55

8. THERMAL INSULATION

The thermal transmission properties have been determined for a number of Rapidwall® construction options. The thermal resistance (R_rating) from laboratory tests on 120mm thick panels are provided in Table 8.1. Theoretical thermal opinions for some other types of constructions may also be available on request from Rapidbuilding Systems Pty Ltd.

Table 8.1 Thermal resistance for various forms of Rapidwall® construction

Construction			**R (m^2K/W)**
Main element of wall	**Additional coat or lining**	**Total thickness (mm)**	
Single leaf Rapidwall® unfilled	NA	120	0.36
Single leaf Rapidwall® filled with 20MPa normal concrete	NA	120	0.25
Single leaf Rapidwall® filled with light weight concrete	NA	120	0.6
Single leaf Rapidwall® filled with 35kg/m^3 and R2.5 rockwool batts	With standard texture finishing coats (ASTEC) on both external faces	120	1.63

9. OUT-OF-PLANE BENDING OF UNFILLED RAPIDWALL® PANELS

The out-of-plane flexural properties are given in Table 9.1

Table 9.1 Out-of-plane flexural properties of unfilled Rapidwall® panels

	Ribs parallel to span	**Ribs perpendicular to span**
Design moment capacity ϕM	1.6 kNm/m	0.7 kNm/m
Flexural rigidity *EI*	3.5×10^{11} Nmm^2/m	1.7×10^{11} Nmm^2/m

The ultimate uniformly distributed applied load for simply supported spans of Rapidwall® are provided in Fig.9.1 and Fig.9.2.

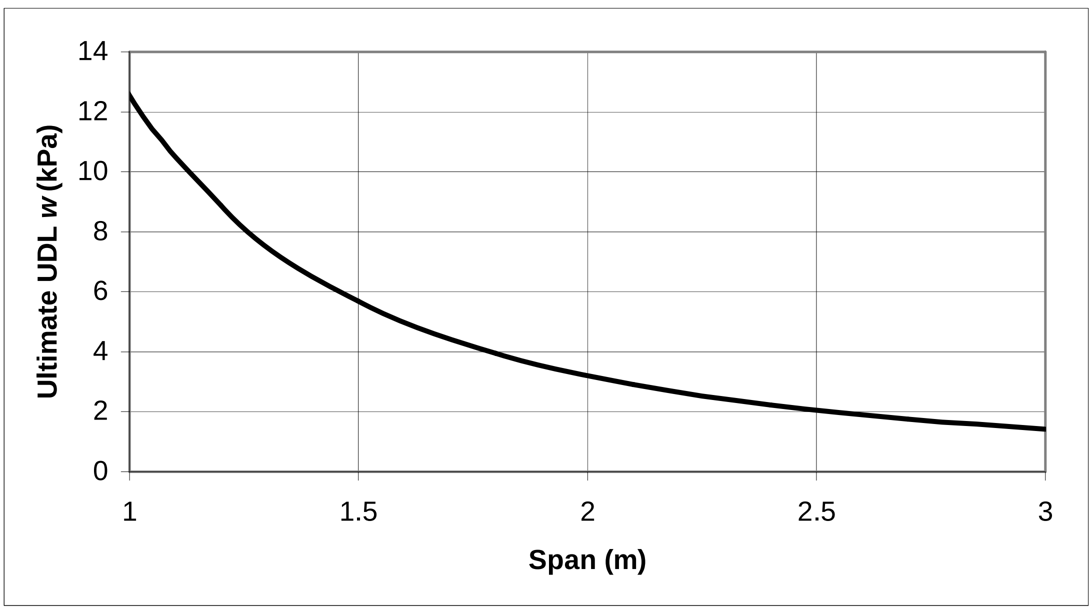


Fig.9.1 Ultimate uniformly distributed load for simply supported Rapidwall® panels Ribs parallel to span

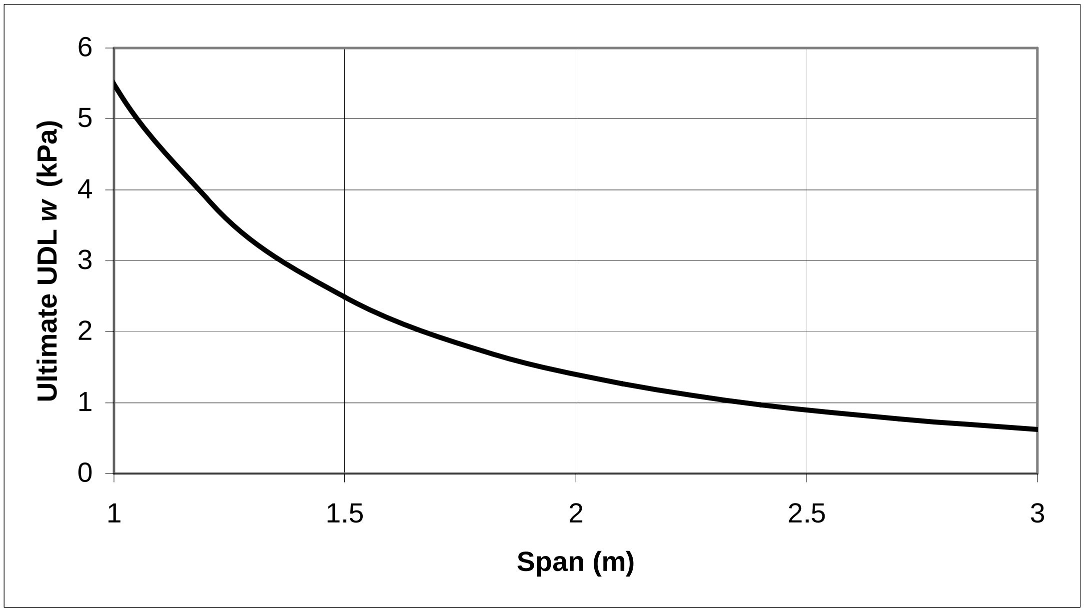


Fig.9.2 Ultimate uniformly distributed load for simply supported Rapidwall® panels Ribs perpendicular to span

Design Example:

Rapidwall® panels are used as formwork for the construction of a 2.5m span concrete slab. The construction dead and live load on the formwork are 3.5kPa and 1.0kPa, respectively. The maximum allowable deflection of the formwork is $L/250$. If the Rapidwall® formwork is supported at both ends of the span - *check the adequacy of the formwork design.*

The design UDL for serviceability and ultimate limit states are respectively

$$w_s = G + \varphi_s \cdot Q = 3.5 + 0.7 \times 1.0 = 4.2 \text{ kPa}$$

$$w_u = 1.25G + 1.5Q = 1.25 \times 3.5 + 1.5 \times 1.0 = 5.9 \text{ kPa}$$

The mid-span deflection of the Rapidwall® panel is given by

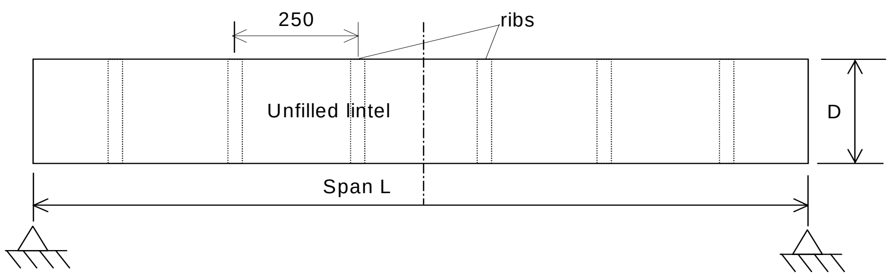
$$\Delta = \frac{5wL^4}{384EI} = \frac{5 \times 4.2 \times 2500^4}{384 \times 3.5 \times 10^{11}} = 6.1 \text{ (mm)},$$

$$\frac{\Delta}{L} = \frac{1}{410} < \frac{1}{250} \text{ Ok}$$

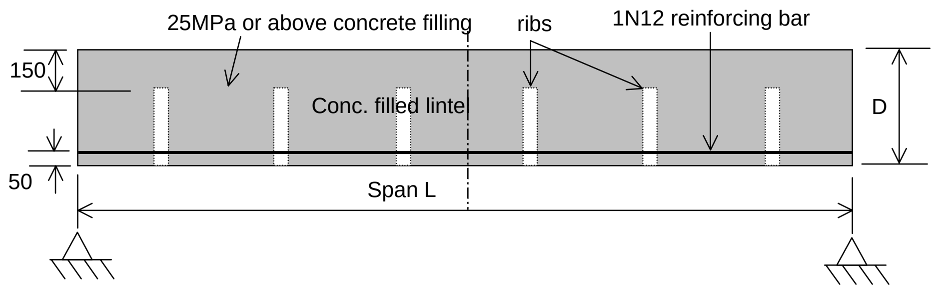
The UDL for strength design is obtained from Fig.9.1 to be 2.0 kPa that is less than 5.9kPa. Accordingly the strength capacity of the wall panel is insufficient and one more prop at the mid-span is needed.

10. LINTEL DESIGN

Rapidwall® panel above window and door cut-outs can be used as lintels to support superimposed loads. These design guidelines are based upon experimental results of simply supported lintels as shown in Fig.10.1. For lintels that are actually a frame above an opening to limit creep deflection they should be considered as simply supported.



(a) Unfilled Lintel



(b) Concrete Filled Lintel

Note: To maintain a continuous concrete compression zone the top 150mm of connecting ribs must be removed.

Fig. 10.1 Details of lintels

10.1 UNFILLED LINTELS

The design moment capacities of unfilled lintels are given in Fig.10.2. Shear strength checks are not required for beams with aspect ratios (D/L) of less than 0.5.

The displacement of lintels can be calculated with the flexural rigidity *EI* provided in Fig.10.3. Note: Due to the variable influence of the connecting ribs <u>*EI* varies with both depth and span of the lintel</u>.

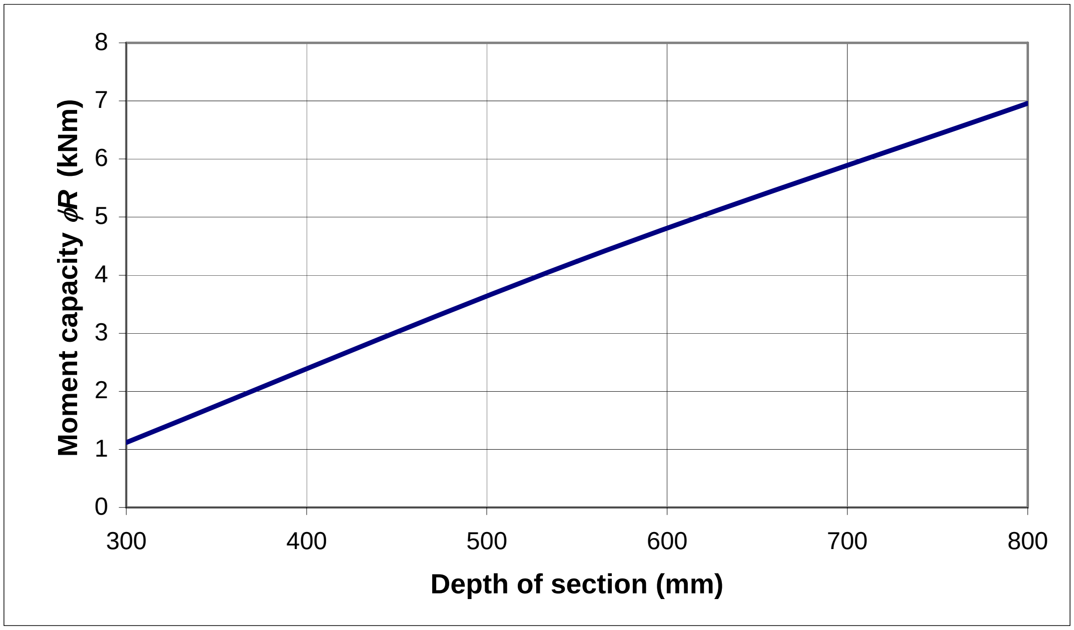


Fig.10.2. Moment capacity of unfilled lintels

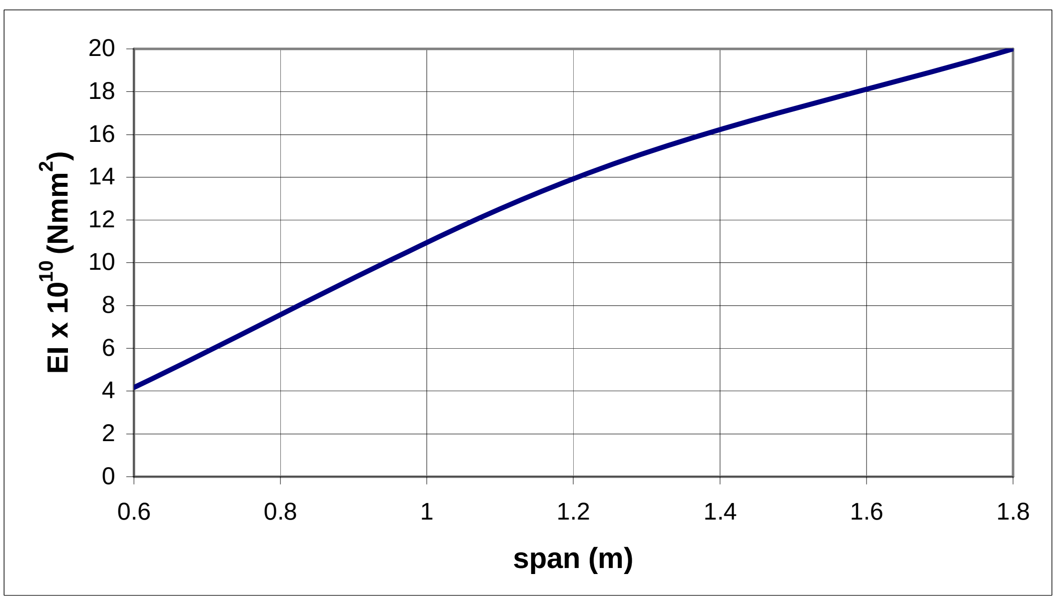


Fig.10.3 (a) Elastic rigidity *EI* of unfilled lintels 300 mm deep

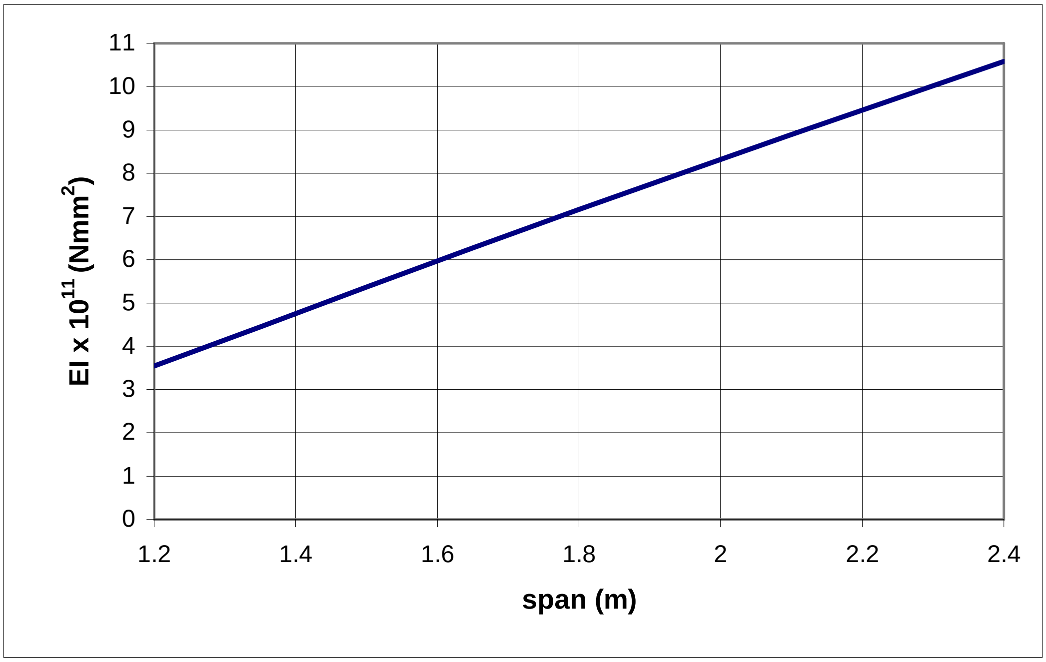


Fig.10.3 (b) Elastic rigidity *EI* of unfilled lintels 550mm deep

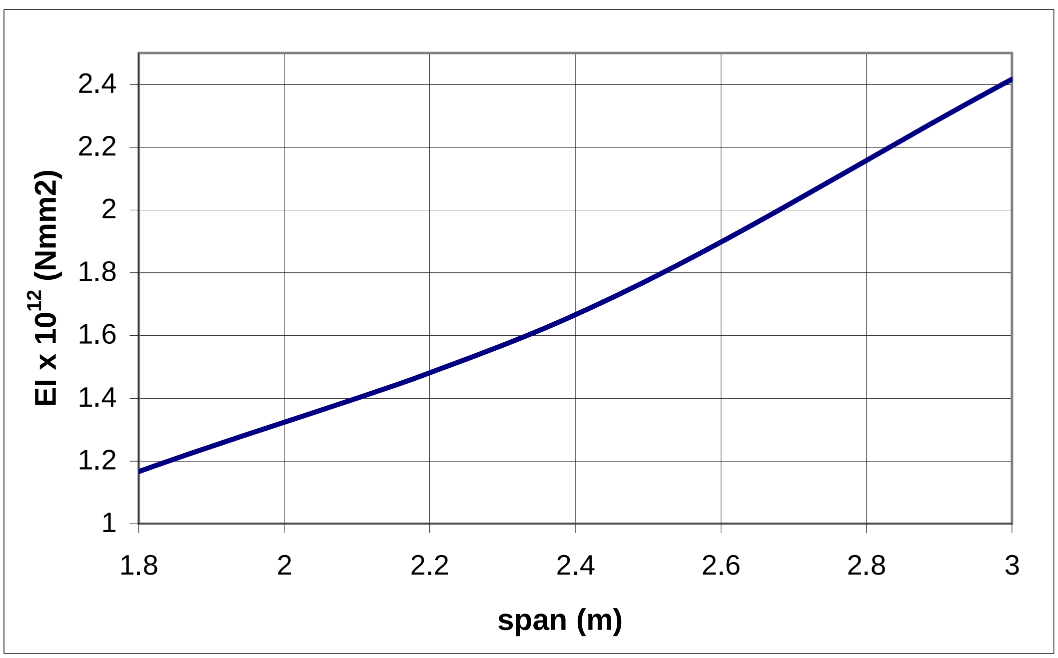


Fig.10.3 (c) Elastic rigidity *EI* of unfilled lintels 800mm deep

10.2 CONCRETE FILLED LINTELS

10.2.1 Flexural strength

The flexural strength of lintels shall be calculated in accordance with AS 3600-2001 based upon the cross-section shown in Fig.10.4 below.

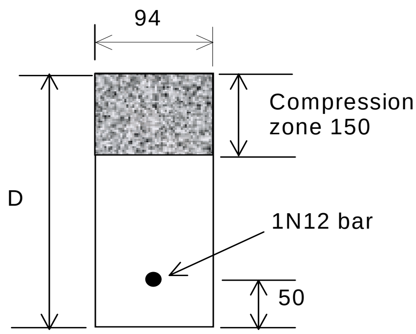


Fig. 10.4 Lintel cross-section for flexural strength calculation

10.2.2 Shear strength

The typical shear failure mode for concrete filled lintels is illustrated Fig.10.5.

The ultimate design shear strength at any shear plane is ϕR=25kN.

This lintel ultimate shear strength is applicable for all values of depth *D*.

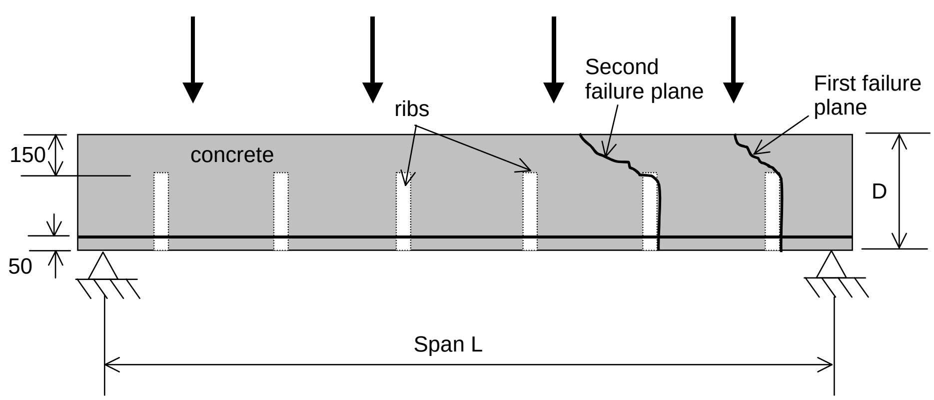


Fig.10.5 Typical shear failure mode

Design Example:

A three metre long simply supported lintel filled with 25MPa concrete has an ultimate UDL of 15kN/m. The yield strength of the 1-N12 bar is f_{sy} = 550MPa. Check the structural strength.

The maximum shear force at the first shear plane

$V^* = 0.5 \times 3 \times 15 = 22.5$ (kN)
$V^* < \phi R$=25kN, shear strength ok.

The design moment $M^* = \frac{1}{8} \times 15 \times 3.0^2 = 16.9$ (kNm)
Design ultimate moment capacity of the cross-section:
d = 300-50 = 250 (mm), b = 94 mm
γ = 0.85

$$k_u = \frac{A_s \cdot f_{sy}}{0.85 f_c^{'} \gamma d b}$$

$$= \frac{113 \times 550}{0.85 \times 25 \times 0.85 \times 250 \times 94}$$

$$= 0.15$$

$$\phi M_{u0} = \phi \cdot 0.85 f_c^{'} \gamma k_u (1 - \frac{1}{2} \gamma k_u) b d^2$$

$$= 0.8 \times 0.85 \times 25 \times 0.85 \times 0.15 (1 - 0.5 \times 0.85 \times 0.15) \times 94 \times 250^2$$

= 11.9 (kNm)

< M^*, the flexural strength is insufficient.

11. AXIAL LOAD CAPACITY OF RAPIDWALL

The axial load capacities for unfilled and concrete filled (≥25Mpa) Rapidwall® panels are provided in Figs.11.1, 11.2 and 11.3.

These three charts were developed from experimental tests and therefore take into account the primary and secondary moments and buckling of the wall. Designers need only consider the appropriate support conditions and eccentricity (ECC) and the design axial load capacity ϕR can be found from the appropriate chart.

The support conditions are specified in each chart. Fig.11.2 and Fig.11.3 are applicable to panels filled with concrete of strength equal to or greater than 25 Mpa and with or without reinforcement bars.

Note: The inclusion of reinforcing bars centrally within the concrete filled cores of Rapidwall® panels will not increase its ultimate axial load capacity.

These following three charts provide axial load capacities for Rapidwall® panelled walls for all heights up to and including three metres. For very squat (≤ one metre) walls under concentric load the cross-sectional capacities (uni-axial compressive strength) given in Table 5.1 can be used.

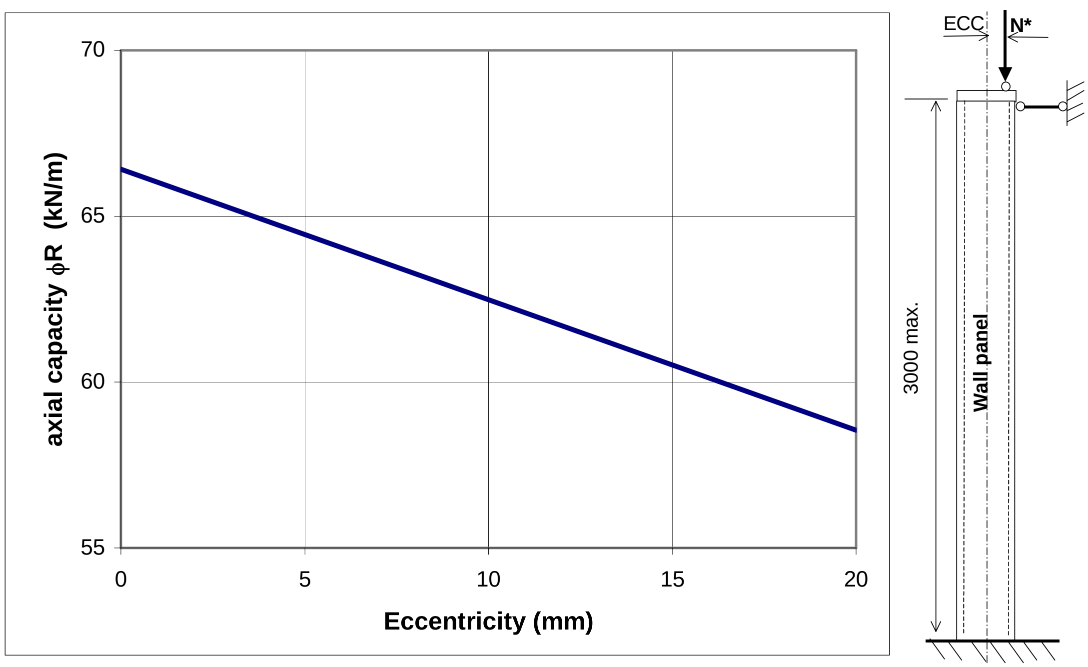


Fig.11.1 Axial load capacity of unfilled Rapidwall® for all heights of walls ≤ 3.0m One end fixed and one end pinned

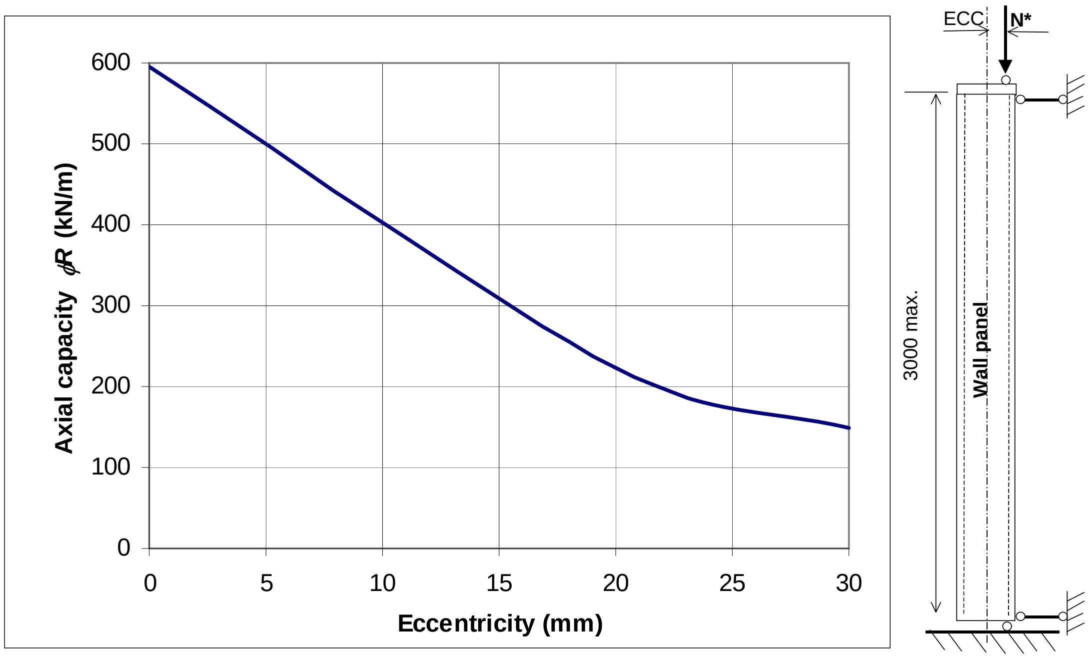


Fig.11.2 Axial load capacity for concrete filled (≥25Mpa) Rapidwall® for all heights of walls ≤ 3.0m – Both supports pinned

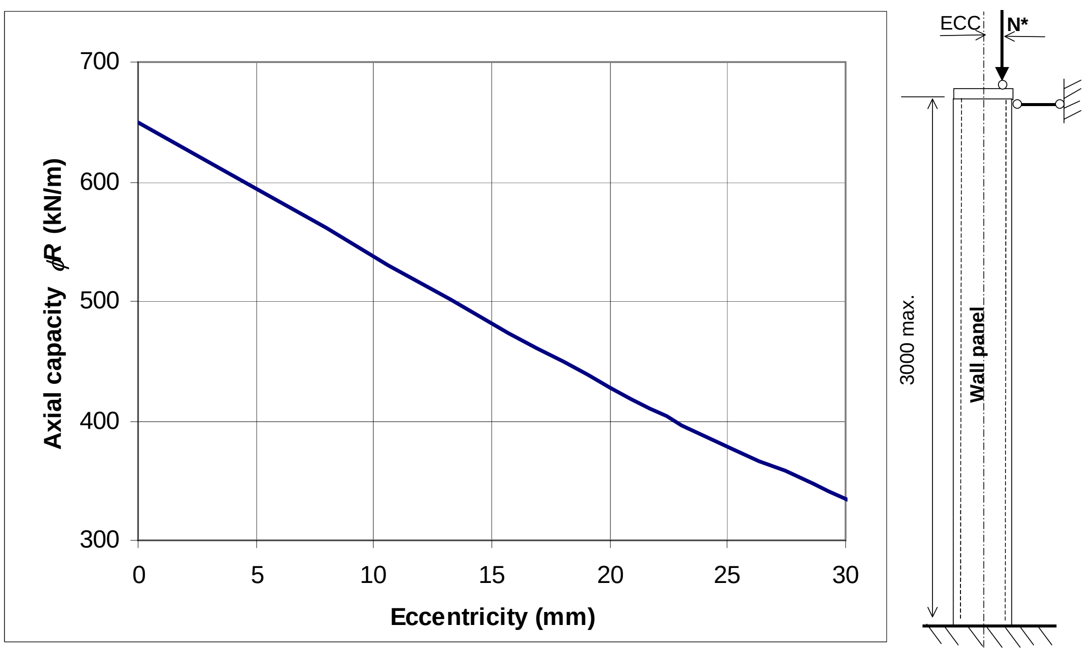


Fig.11.3 Axial load capacity for concrete filled (≥25Mpa) Rapidwall® for all wall heights ≤ 3.0m - one support pinned and one fixed

Design Example:

An external Rapidwall® panel 2.85m high filled with 25Mpa concrete supports a roof load of DL=180kN/m and LL=120kN/m - check the strength capacity.

From Clause 11.4.1 of AS 3600-2001, the vertical load transmitted to a wall by a discontinuous concrete floor or roof shall be assumed to act at one-third the depth of the bearing area measured from the span face of the wall.
Therefore, the corresponding eccentricity is

$$\text{ECC}=\frac{1}{2}t-\frac{1}{3}t=\frac{1}{6}t=20\ \text{(mm)}.$$

This eccentricity is applied at the top of the wall and the bottom of the Rapidwall® panel can be considered as fixed end.

The ultimate axial load on the wall panel

$N^*= 1.25\times180+1.5\times120=405\ \text{(kN/m)}$

From Fig.11.3, when ECC=20mm

ϕR=430 kN/m

> N^*=405, ok.

12. SHEAR STRENGTH OF RAPIDWALL®

The shear strength capacity of a Rapidwall® panel is given in Table 12.1. The ultimate shear strength of a Rapidwall® panel equals the unit shear strength given in Table 12.1 multiplied by the length of the Rapidwall® load-bearing wall under consideration.

Table 12.1 Shear strength of vertical walls

Application	Shear Capacity ϕR (kN/m)
Unfilled Rapidwall® Panel	10.5
Rapidwall® Panel Filled with 25MPa Concrete	28.5

NOTE: Refer also section 14 for further guidelines for the design of Rapidwall® panels in shear. Full height reinforcement may be required for reasons other than shear resistance. However for all Rapidwall® panels in shear starter bars, and if appropriate finisher bars, of at least 1-N12, is required in each cell embedded 400 millimetres.

12.1 FRICTIONAL SHEAR AT WALL-SLAB JOINT

Frictional shear at wall-slab joint can be evaluated by appropriate published guidelines, assuming the concrete filled Rapidwall® is a precast wall panel. Guidelines from *Precast Concrete Handbook* published by National Precast Concrete Association Australia are adopted in this manual and provided blow.

The factored resisting shear stress v_r at the wall/slab joint with reinforcing bars perpendicularly passing through the joint can be calculated with Eq.12.1 as follows:

$$v_r = \phi_c \cdot (c + \mu\sigma_e) \qquad (12.1)$$

but shall not exceed $0.25\phi_c \cdot f_c^{'}$

nor $7.0\phi_c$ MPa

where: c = cohesion stress

σ_e = effective normal stress

μ = coefficient of friction

ϕ_c = 0.65

Values of c and μ for certain crack interface conditions are shown in Table 12.2.

Table 12.2Values for c and μ for given interface conditions

Crack interface condition	μ	c (MPa)
Concrete placed against hardened concrete with surface clean but not intentionally roughened	0.6	0.25
Concrete placed against hardened concrete with surface clean and intentionally roughened to an amplitude of 5 mm	1.0	0.5
Concrete placed monolithically	1.4	1.0
Concrete anchored to as-rolled steel by headed studs or reinforcing bars	0.6	0

The effective normal stress σ_e is calculated by

$$\sigma_e = \rho_v \cdot f_{sy} + N / A_g \qquad (12.2)$$

where: A_g = gross area of the shear plane

f_{sy} = specified yield strength of reinforcement

N = unfactored permanent compressive load perpendicular to the shear plane

ρ_v = ratio of shear friction reinforcement

The ratio of shear friction reinforcement ρ_v is given by

$$\rho_v = A_{vf} / A_{cv} \qquad (12.3)$$

where: A_{cv} = area of concrete section resisting shear transfer

A_{vf} = area of shear friction reinforcement

The area of shear friction reinforcement A_{vf} should not be less than

$$A_{vf\,(\min)} = 0.9A_{cr} / f_{sy} \qquad (12.4)$$

where: A_{cr} = area of crack interface

Tension N_t acting across the shear plane should be resisted by an additional amount of reinforcement computed by

$$A_t = \frac{N_t}{\phi_s \cdot f_{sy}} \qquad (12.5)$$

where: A_t = additional amount of reinforcement resisting tension across shear plane

$\phi_s = 0.85$

All reinforcement on both sides of the assumed crack plane should be properly anchored by development length.

13. IN-PLANE FLEXURAL STRENGTH OF RAPIDWALL®

The following procedure should be used to calculate the ultimate in-plane flexural strength of Rapidwall® panels.

1. Assess the stress distribution in a cross-section of the wall based on linear elastic assumption, i.e.
   $\sigma = \frac{N^*}{A} \pm \frac{M^* \times y}{I}$.
2. Based on the stress distribution from step 1, there are two different cases to consider:
   (a) If the whole cross-section is under compression or there is no tensile stress in the cross-section, compare the maximum unit force (kN/m) in the cross-section calculated from step 1 with the compressive strength of walls given in Section 11.

   If the calculated unit force is less than the compressive strength of the wall, the design is safe. Otherwise, the design is not safe and should be changed.

   (b) If tension exists in the cross-section, go to step 3.

   The unfilled Rapidwall® and concrete filled Rapidwall® panels without continuous reinforcement in the cores are not able to transmit tension between floors. Therefore case (b) is not applicable to unfilled Rapidwall® or concrete filled Rapidwall® without continuous longitudinal bars.

3. When tension exists in the cross-section, the flexural strength can be calculated using the following assumptions: -
   i) The compression stress distribution is represented with a rectangular stress block;
   ii) The unit compression force in the compression zone is the compression strength of concrete filled wall as given in Section 11 without including capacity reduction factor ϕ;
   iii) Tension reinforcement (full length bars) fully yields in the whole tension zone, and the concrete and glass-reinforced plaster of the Rapidwall® are assumed to take no tension.

   The forces in the cross-section of a concrete filled Rapidwall® are shown in Fig.13.1. The compression zone depth can be calculated with Eq.13.1:

$$x = \frac{N^* + D \cdot f_{sy} \cdot A_{s1}}{p + f_{sy} \cdot A_{s1}} \qquad (13.1)$$

where A_{s1} is the total reinforcement area inside a unit length of wall and p is the unit compression strength of wall, excluding ϕ

From Fig.11.3 p = 1100 kN/m

The design moment capacity is given by

$$\phi M_u = \phi \cdot \frac{x}{2}(p \cdot D - N^*) \tag{13.2}$$

where the design capacity reduction factor ϕ =0.7.

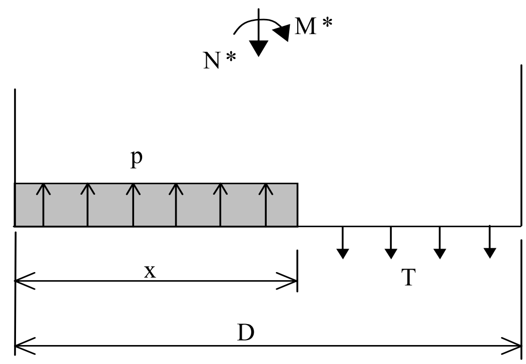


Fig.13.1 Ultimate forces in a cross-section of wall under bending

Design Example:

Design of a three metre long wall of Rapidwall® whose cross-section is subjected to the design ultimate forces of

- In-plane Moment M^*=500 kNm
- Axial force N^*=300 kN, and
- Shear force V^*=35 kN

All cores of the Rapidwall® are filled with 30 MPa concrete.

(1) Check shear strength

From Table 12.1, the design shear capacity
ϕR = 28.5 kN/m
The total shear strength of the wall is given by
V_c=28.5×3=85.5 > V^*=35 kN, shear strength ok.

(2) Flexural design

Based on the design moment and the axial load, tensile stress exists in the cross-section. Therefore, design flexural strength in accordance with step 3 of this section.

From Eq.13.2

$$M^* = \phi M_u = \phi \cdot \frac{x}{2}(p \cdot D - N^*)$$

Therefore,

$$x = \frac{2M^*}{\phi \cdot (p \cdot D - N^*)}$$

$$= \frac{2 \times 500 \times 10^6}{0.7 \times (1100 \times 3 - 300) \times 10^3}$$

$$= 476.2 \text{ (mm)}$$

Use mild steel bars f_{sy}=250 MPa, and the tensile reinforcement required can be calculated by re-arranging Eq.13.1 to get

$$A_{s1} = \frac{x \cdot p - N^*}{f_{sy}(D - x)}$$

$$= \frac{476.2 \times 1100 - 300 \times 10^3}{250 \times (3000 - 476.2)}$$

$$= 0.355 \text{ (mm}^2\text{/mm)} = 355 \text{ (mm}^2\text{/m)}$$

Provide 1-R12 in each core,

A_{s1} (provided) = 113×4

=452 (mm^2/m)

14. DESIGN PROCEDURE FOR RAPIDWALL® BUILDINGS

The following procedure is recommended for the structural design of a Rapidwall® building supporting lateral loads: -

1. For seismic load analysis the base shear method is recommended in accordance with AS 1170.4-1993, treating the concrete filled Rapidwall® building as a bearing wall system similar to that of a reinforced concrete shear wall system. The corresponding structural response factor R_f for reinforced concrete shear walls is adopted;

2. Distribute the base shear to each individual concrete filled Rapidwall® shear wall in accordance with AS1170.4-1993, where the *EI* for in-plane bending of the concrete filled Rapidwall® is calculated based on the infill concrete only, ignoring the Rapidwall® panel;

3. Check the shear strength of each individual wall in accordance with Section 12 to ensure that shear failure does not occur;

4. Design flexural strength of walls by the procedure described in Section 13.

Care must be exercised in all designs utilizing a new technology and using the Rapidwall® structural system in building design is no exception. A building composed of Rapidwall® panel elements cannot be treated as though it is a monolithic cast-insitu reinforced concrete walled structure. The integrity of a building composed of Rapidwall® structural elements is similar to that of a building composed of precast concrete wall panels. Accordingly similar considerations on structural integrity should be given to prevent progressive collapse mechanisms occurring.

For multi-storey Rapidwall® buildings, the Rapidwall® panel is discontinuous at floor level and the continuity of the steel reinforcement through the joint is therefore important to maintain structural integrity. Also, if in an earthquake there is net uplift on any structural Rapidwall® panel, full height tensile reinforcement should be used through the panel.