part 1.
introduction

Pronto Block walls are built with dry-stack concrete blocks that are filled with concrete, the dry-stack concrete blocks being precision hollow concrete blocks that are laid without the use of mortar in either the bed joints or the perpends. In Pronto Block construction hollow concrete blocks are interconnected by means of plastic connectors that have the following functions:
– they firmly secure blocks to each other end to end,
– they help correctly position the blocks in the overlying courses, and
– they accurately support horizontal and vertical reinforcement in its correct location.

Pronto Block load bearing walls use specially shaped hollow concrete blocks to construct solid concrete walls. The blocks are essentially used as permanent formwork that contributes some strength to the finished wall. All Pronto Block walls are reinforced and core filled with concrete.

Part 1 of the design manual summarises the provisions of AS 3600:2009 that apply to the design of Pronto Blocks, outlines how it has been applied to the design of Pronto Block walls when preparing the design aids, and provides guidance on all aspects of the structural design.

Parts 2 and 3 of the design manual contain design tables and charts for walls constructed from the range of Pronto Block products. The design aids have been specifically prepared for Pronto Block walls and are not applicable to walls constructed with alternative products.

Disclaimer
This Pronto Block design manual has been compiled to assist structural engineers quickly and efficiently prepare designs and details of load-bearing Pronto Block wall structures and elements. Numerous design aids are provided and these cover a broad range of typical design applications. While every care has been taken to ensure the information provided is accurate and complete for the design situations and actions covered, the information should only be used by experienced practicing structural engineers, and all engineers should familiarise themselves with the full contents of the applicable Standards to ensure no requirement is overlooked. Mortarless Pty Ltd, its licensees and the author accept no liability whatsoever arising out of the use or misuse of the information provided in this design manual.
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section 1.2
scope of AS 3600:2009

AS 3600:2009 sets out the minimum requirements for the design and construction of plain and reinforced concrete structures and members. For the purposes of the Standard plain concrete structures are those where the reinforcement, if provided, is ignored for the determination of strength of the structure or member. This is precisely the approach taken for the design of Pronto Block walls in compression.

When designing Pronto Block members to AS 3600, the masonry units are merely considered permanent formwork units that contribute just a little to the strength of the member.

When making calculations for the load tables and diagrams in this manual a small portion of the face shells of the masonry units has been taken as acting in compression and bending. The design thickness of the wall is the overall width of the core fill grout and this is tabulated in Section 1 of Parts 2 and 3. It is this width that has also been used when calculating slenderness ratios.

The core fill concrete in any wall must be of compressive strength at least equal to the unconfined compression strength of the blocks even though that is considered to be possibly conservative. For the purposes of the strength calculation in the design aids in this manual it has been assumed that the grout $f'_c$ is at least equal to the strength of the blocks. Grout of greater strength however may be used.
section 1.3
design procedures

AS 3600 Section 2 outlines the requirements for design procedures, actions and loads.

Clause 2.1 sets out the requirements when designing for strength and serviceability, earthquake actions, robustness, durability and fire resistance.

Clause 2.1.1 states that structures shall be designed for ultimate strength and serviceability limit states in accordance generally with the provisions of AS/NZ 1170.0 and the specific requirements of AS 3600 Clauses 2.2 and 2.3.

The limit state method has been used in the generation of all tables and other design aids in this manual.

1.3.1 Design for strength

Clause 2.2 outlines the various options for designing members and structures for strength. It is mentioned in Clause 2.2.1 that it is permissible to use different strength check procedures for different members in the one structure, and the structure as a whole, provided it can be shown that all external actions and forces and calculated internal stress resultants are consistent with the requirements for equilibrium and compatibility of the entire structure.

Clause 2.2.2 states that the strength check procedure for use with linear elastic methods of analysis, with simplified methods of analysis, and for statically determinate structures shall be that

\[ R_u \geq E_d \]

Where

- \( R_u \) is the ultimate strength of a member
- \( R_d \) is the design capacity (= \( \varnothing R_u \)), and
- \( E_d \) is the design action effect

This condition must be satisfied at all critical cross sections and regions.

The capacity reduction factors \( \varnothing \) are given in AS 3600 Table 2.2.2.

The ultimate strength of a member \( (R_u) \) is to be determined in accordance with AS 3600 using characteristic values for material strengths.

The design action effect \( (E_d) \) is to be determined for critical combinations of factored actions specified in AS 1170.0 and AS 3600 Clause 24 by one of the following methods of analysis:

- Linear elastic analysis in accordance with AS 3600 Clause 6.2
- Linear elastic analysis incorporating secondary bending moments due to lateral joint displacement in accordance with AS 3600 Clause 6.3
- One of the simplified methods of analysis in accordance with AS 3600 Clauses 6.9 and 6.10.
- Equilibrium analysis of a statically determinate structure.

For strength checks using other methods of analysis refer to AS 3600 Clauses 2.2.3 – 2.2.6, 6.1.1 – 6.1.3 and 6.2 – 6.10.

1.3.2 Design for serviceability

Clause 2.3.1 notes that it is a general requirement that design checks shall be carried out for all appropriate service conditions to ensure the structure will perform in a manner appropriate for its intended function and purpose.

There are no limiting values given for the deflection of walls but limiting values for the deflection of beams are given in Table 2.3.2.

Clause 2.3.2 b) states that members shall be designed such that under serviceability design loads the deflections shall not exceed the deflection limits given in Table 2.3.2. It further states that the deflection may be controlled by limiting the span to depth ratios in accordance with Clause 8.5 for beams and Clause 9.3 for slabs.
Clause 2.3.3 states that cracking shall be controlled such that structural performance, durability and appearance are not compromised. These rules do not generally apply to walls.

1.3.3 Design for robustness
Clause 2.1.3 requires that concrete structures be designed to be robust in accordance with the procedures and criteria given in AS 1170.0 Section 6.
AS 1170.0 Section 6 requires structures to be detailed such that all parts of the structure are tied together in both the horizontal and vertical planes so that the structure can withstand an event without being damaged to an extent disproportional to the event. It is further stated in Clause 6.2.1 that this requirement applies to non-structural components as well.
This is a condition that can be readily satisfied with load bearing Pronto Block construction, but a condition that is often not satisfied in column and beam structures and in traditionally detailed residential/domestic structures.
AS 1170.0 Clause 6.2.5 states that:

     Walls shall be connected to the structure to provide horizontal resistance to face loads. The connection between the walls and the structure shall be capable of resisting the forces of 5% of G.

It should be borne in mind that this requirement applies to interconnection of the walls to all structural elements including the footings.

1.3.4 Design for durability and fire resistance
Clause 2.1.4 requires concrete structures to be designed such that they are fire resistant in accordance with the procedures and criteria given in Section 5.
All permanent, imposed and other actions are to be in accordance with AS 1170.1.
All wind actions are to be in accordance with AS 1170.2.
All earthquake actions are to be in accordance with AS 1170.4.
All combinations of actions are to be in accordance with AS 117.0 Section 4.
section 1.4
design actions

1.4.1 Combinations of actions for Strength Limit State
Basic combinations:

i) $E_d = 1.35G$ permanent action only
ii) $E_d = 1.2G + 1.5Q$ permanent and imposed action
iii) $E_d = 1.2G + 1.5\psi_lQ$ permanent and long term imposed action
iv) $E_d = 1.2G + W_u + \psi_sQ$ permanent, wind and imposed action
v) $E_d = 0.9G + W_u$ permanent and wind action reversal
vi) $E_d = G + E_u + \psi_sQ$ permanent, earthquake and imposed action
vii) $E_d = 1.2G + S_u + \psi_sQ$ permanent action, actions given in AS 1170.0 Clause 4.2.3 and imposed action

where $G$, $Q$, $W_u$ and $E_u$ are the permanent action, imposed action, ultimate wind action, and ultimate earthquake action respectively.

and where for distributed imposed actions $Q$

$\psi_s$ and $\psi_l$ = 0.4 for domestic, office, parking, retail floors
= 0.6 for storage and other floors
= 0.4 for trafficable roofs
= 0.0 for non-trafficable roofs

$\psi_s$ = 0.3 for domestic, office, parking, retail floors
= 0.6 for storage and other floors
= 0.3 for trafficable roofs
= 0.0 for non-trafficable roofs

Refer to AS 1170.0 Table 4.1 for the factors applicable to concentrated imposed actions.
Refer to AS 1170.0 Clause 4.2.3 for $S_u$.

1.4.2 Combinations of actions for Stability Limit State
For combinations that produce net stabilizing effects ($E_{sta}$):

$E_{sta} = 0.9G$ permanent action only

For combinations that produce net destabilizing effects ($E_{das}$):

i) $E_{das} = 1.35G$ permanent action only
ii) $E_{das} = 1.2G + 1.5Q$ permanent and imposed action
iii) $E_{das} = 1.2G + W_u + \psi_sQ$ permanent, wind and imposed action
iv) $E_{das} = G + E_u + \psi_sQ$ permanent, earthquake and imposed action
v) $E_{das} = 1.2G + S_u + \psi_sQ$ permanent action, actions given in AS 1170.0 Clause 4.2.3 and imposed action

1.4.3 Combinations of actions for Serviceability Limit State
For short-term and long-term effects, combinations that include one or more of the following:

i) $G$
ii) $\psi_sQ$
iii) $\psi_lQ$
iv) $W_u$
v) $E_u$
vi) Serviceability values of other actions, as appropriate.

Where $\psi_s$ and $\psi_l$ are the short-term and long-term imposed action factors respectively, which are given in AS 1170.0 Table 4.1.
section 1.5
structural properties

1.5.1 Characteristic compressive strength of mortarless walls
The adopted value for the compressive strength of the composite masonry unit and the core fill concrete is the characteristic compressive (cylinder) strength of the core fill concrete but not greater than the unconfined compressive strength of the masonry face shells. Note that the minimum cylinder strength of the core fill concrete (grout) is to be not less than the unconfined compressive strength of the face shells of the blocks.

1.5.2 Characteristic yield strength of reinforcing steel, $f_{sy}$
The design tables in this manual are based on the use of reinforcing steel with a characteristic yield strength of 500 MPa.

1.5.3 Elastic Moduli
The modulus of elasticity of the core fill grout ($E_c$) at 28 days is as follows (Clause 3.1.2):

- $E_c = 20,500$ MPa for 15MPa Grout
- $E_c = 24,000$ MPa for 20MPa Grout
- $E_c = 26,700$ MPa for 25MPa Grout

It is noted in Clause 3.1.2 that consideration should be given to the fact that the above values have a range of +/- 20%.

The elastic modulus of steel reinforcement $E_s = 200,000$ MPa.
Mortar is not generally used with Pronto Block, however it is recommended that the first course of blocks be always bedded in mortar in order to correct any unevenness or level issues in the slab or footings and to provide the maximum bearing width at the base of the wall. Mortar type M4 (refer Table 10.1 in AS 3700) should be used for this purpose.

In situations where loads are minimal it may not be necessary to bed the bottom course. This is the exception however rather than the rule.
section 3. reinforcement

The reinforcement in Pronto Block walls designed to AS 3600:2009 needs to comply with the minimum requirements outlined in Clause 11.7. When calculating the minimum reinforcement requirements the thickness of the Pronto Block wall should be taken as the design thickness given in the Properties Table in Section 1 of the subsequent parts of this manual.

3.1 Vertical reinforcement
The vertical reinforcement is not considered as contributing the compression load capacity of a Pronto Block wall and that is because it cannot be tied in the way that prevents premature buckling of the bars (refer Clauses 10.7.2 and 10.7.4). Note however that Clause 11.7.4 states that it is not necessary to restrain the vertical reinforcement if:

\[ N^* \leq 0.5 \varnothing N_u \], or

the vertical reinforcement is not used as compressive reinforcement, or

the vertical reinforcement ratio is not greater than 0.01 and a minimum horizontal reinforcement ratio of 0.0025 is provided.

This means that generally, in terms of compliance with AS 3600, the vertical reinforcement could be considered to contribute to the axial load capacity of a Pronto Block wall and therefore the values in the load tables are generally a little conservative.

Clause 11.7.1 requires a minimum reinforcement ratio of 0.0015, i.e. 0.15% of the cross sectional area (refer first paragraph above). The area of reinforcement however must be adequate to satisfy the strength requirements.

3.2 Horizontal reinforcement
Clause 11.7.1 requires a minimum reinforcement ratio of 0.0025, i.e. 0.25% of the cross sectional area (refer first paragraph above). As for the vertical reinforcement however the area of reinforcement must also be adequate to satisfy the strength requirements.

It is noted in 11.7.1 that the minimum ratio may be reduced to 0.0015 if the wall is being designed for one-way buckling using Clause 11.4(a). It further states that the minimum reinforcement ratio may be reduced to zero when there is no restraint to horizontal shrinkage or thermal movements and the length of the wall is less than 2.5m, or 0.0015 when there is no restraint against horizontal shrinkage or thermal movements and the length of the wall is equal to or greater than 2.5m.

Clause 11.7.2 provides further requirements for minimum reinforcement ratios in terms of exposure classifications and crack control. The requirements are as follows:

<table>
<thead>
<tr>
<th>Reinf't Ratio</th>
<th>Exposure Classification</th>
<th>Degree of control over cracking</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0025</td>
<td>A1 &amp; A2</td>
<td>Minor</td>
</tr>
<tr>
<td>0.0035</td>
<td>A1 &amp; A2</td>
<td>Moderate and where cracks are inconsequential or hidden from view</td>
</tr>
<tr>
<td>0.006</td>
<td>A1 &amp; A2</td>
<td>Strong – for appearance and where cracks may reflect through finishes</td>
</tr>
<tr>
<td>0.006</td>
<td>B1, B2, C1, C2</td>
<td>All</td>
</tr>
</tbody>
</table>

It is also noted in Clause 11.7.2 that additional horizontal crack control reinforcement may be needed at the base of the wall to control thermal cracking during hydration for walls longer than 8m. The author is of the opinion that this is not applicable to Pronto Block walls.

3.3 Spacing of reinforcement
Clause 11.7.3 gives guidance on the maximum spacing of reinforcement. The maximum clear spacing is given as the lesser of 2.5\(t_w\) and 350mm. As mentioned above the design thickness of a Pronto Block wall (\(t_d\)) is the value given in the section properties tables in the subsequent Parts of this manual and for the purposes of this calculation \(t_w\) should be substituted for \(t_d\).

With Pronto Block construction the spacing of vertical and horizontal reinforcement can only be in increments of 200mm, i.e. 200, 400, 600 etc. This is something the
designer needs to come to terms with and decide whether the maximum spacing provisions of AS 3600 will be stretched a little. It is the opinion of the author that due to the unique nature of Pronto Block construction for concrete walls, the maximum spacing of reinforcement can readily be increased to 400mm without detriment to the wall.

In view of all of the above the minimum reinforcement requirements of Pronto Block walls can be summarized as follows:

As can be seen in Table 3.3.1 above, the maximum spacing provisions will control the selection of vertical reinforcement for all walls being designed for axial compression loads only, and it is the author’s recommendation that N12-400 be adopted as the minimum vertical reinforcement despite this slightly exceeding the literal interpretation of the maximum spacing provisions of AS 3600.

It is the author’s opinion that N12-300 (N12 at alternating 400mm and 200mm centres) should also be adopted as the minimum horizontal reinforcement and this is because the design thickness of a Pronto Block wall is more than 20% greater than the actual average thickness of the grout (i.e. the fresh concrete). The minimum reinforcement ratios given in AS 3600 should arguably be applied to this thickness rather than the design thickness, and if so the minimum horizontal reinforcement in a 200 Pronto Block wall would be N12-330 rather than N12-250 as tabulated above. Note that it is the Author’s experience also that N12-400 horizontal is generally adequate for all walls as minimum horizontal reinforcement.

The options for the design engineer are:

- Be conservative and adopt N12-200 horizontal reinforcement,
- Be less conservative and adopt alternating N12-200 and 400 horizontal reinforcement,
- Take into consideration the provisions of AS3700 and adopt N12-400 or even greater.

Over and above this the engineer should give consideration to the degree of crack control required and therefore to the provisions of Clause 11.7.2.

An alternative for any engineer is to design Pronto Block walls to the provisions of AS 3700 in lieu of AS 3600 but this will result in reduced load capacities.

### 3.4 Position of reinforcement

Clause 11.7.3 states that reinforcement must be provided in both faces of a wall if:

- The wall is greater than 200mm thick,
- If the tension in the wall exceeds the tensile capacity of the concrete under the design ultimate loads,
- The walls are designed for two way buckling (Clauses 11.4(b) and 11.4(c)).

<table>
<thead>
<tr>
<th>Pronto Block</th>
<th>Design Thickness (t) (mm)</th>
<th>Minimum Vertical Reinforcement 0.15%</th>
<th>Minimum Horizontal Reinforcement 0.25%</th>
<th>Maximum Spacing (mm) 350 or 2.5(t)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AS 3600</td>
<td>Suggested</td>
<td>AS 3600</td>
</tr>
<tr>
<td>140 Unchamfered</td>
<td>114</td>
<td>N12-640</td>
<td>N12-600</td>
<td>N12-310</td>
</tr>
<tr>
<td>200 Chamfered</td>
<td>164</td>
<td>N12-450</td>
<td>N12-400</td>
<td>N12-270</td>
</tr>
<tr>
<td>200 Unchamfered</td>
<td>174</td>
<td>N12-420</td>
<td>N12-400</td>
<td>N12-250</td>
</tr>
</tbody>
</table>

**TABLE 3.3.1**
3.5 Laps in reinforcement

The lap length for splicing bars in tension is given in Clause 13.2.2 as follows:

\[ L_{sy,\text{lap}} = k_7 \cdot L_{sy,t} \geq 29k_1d_b \]

Where:

- \( L_{sy,t} \) is calculated in accordance with Clause 13.1.2.1, and
- \( k_7 \) is to be taken as 1.25 unless the area of steel provided is at least twice the area required and no more than half of the reinforcement at the section spliced in which case it can be taken as 1.

Accordingly a minimum lap length of 36.25 bar diameters applies and for N12 bars this is 435mm but say 450mm.

When calculating the basic development length in accordance with Clause 13.1.2.2 the following values result:

### Development length \( L_{sy,b} \) calculated in accordance with Clause 13.1.2.2

<table>
<thead>
<tr>
<th></th>
<th>20MPa concrete</th>
<th>25MPa concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>N12 vertical bars</td>
<td>390</td>
<td>350</td>
</tr>
<tr>
<td>N12 horizontal bars</td>
<td>510</td>
<td>455</td>
</tr>
<tr>
<td>N16 vertical bars</td>
<td>540</td>
<td>485</td>
</tr>
</tbody>
</table>

Assuming \( k_7 = 1.25 \) as is normally the case, the minimum lap lengths are as follows:

### Lap length \( L_{sy,\text{lap}} \) Calculated in accordance with Clause 13.2.2 (mm)

<table>
<thead>
<tr>
<th></th>
<th>20MPa concrete</th>
<th>25MPa concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>N12 vertical bars</td>
<td>490</td>
<td>440</td>
</tr>
<tr>
<td>N12 horizontal bars</td>
<td>640</td>
<td>570</td>
</tr>
<tr>
<td>N16 vertical bars</td>
<td>675</td>
<td>605</td>
</tr>
</tbody>
</table>

Clause 13.2.2 states that the tabulated lap lengths apply to both contact and non-contact splices. Note that Clause 13.2.1 states that lap splices shall not be used in tension tie members; in these members splices must be made only by welding or mechanical means.
section 4.
cover to reinforcement

A fundamental and most critical aspect of the durability of any reinforced concrete member or any masonry member containing reinforcement is the provision of adequate cover. Adequate cover is also an important aspect of achieving the necessary fire resistance period (FRP) with respect to structural adequacy.

Clause 4.10.1 states that the cover to any bar shall be the greatest of the values determined for proper concrete placement, durability and fire protection.

4.1 Cover for concrete placement

Clause 4.10.2 states that the cover shall be adequate to ensure concrete can completely fill the formwork and closely surround the reinforcement. In general, this means that cover shall not be less than the larger of the size of the reinforcing bar or the maximum nominal aggregate size.

4.2 Cover for durability

Cover to reinforcement must be adequate to provide corrosion protection to the reinforcement and to afford adequate protection to reinforcement in members that are in contact with aggressive soils. (Clauses 4.10.3 and 4.8.1)

The minimum cover for corrosion protection is tabulated in AS 3600 Table 4.10.3.2 and this varies according to the characteristic strength of the concrete and the exposure classification. The minimum cover is 20mm for both 20 and 25MPa concretes and the maximum is 60mm.

It should be noted that 20MPa concrete can only be used for exposure classifications A1 and A2, and 25MPa concrete can only be used for exposure classification A1, A2 and B1.

When designing the blocks for Pronto Block masonry units a great deal of attention was paid to achieving

Plan view on connector joining two 200 Pronto Block masonry units and supporting two horizontal bars, showing the shaping of the ends of the blocks to maximize grout penetration into the perpends.
satisfactory cover to the embedded reinforcement. This is a most important structural aspect that is overlooked in all similar dry-stack systems.

Most dry-stack systems provide totally inadequate cover in the vicinity of the perpends and many also provide totally inadequate cover in the vicinity of the bed joints but this issue has been addressed in the internal shaping of Pronto Block masonry units.

4.3 Cover requirements for fire resistance

AS 3600 Clause 5.7 outlines the requirements for walls when assessing the FRP.

Insulation:

AS 3600 Table 5.7.1 gives the FRP for walls of various effective thicknesses. 140 Pronto Block walls would achieve an FRP of 120 minutes and 200 Pronto Block walls would achieve an FRP of 240 minutes without the addition of suitable insulation material (refer Clause 5.8.1).

Structural Adequacy:

The values for the full range of FRPs are given in AS 3600 Table 5.7.2 and these are for walls exposed to fire on either one or both sides.

To satisfy the structural adequacy provisions a wall must have an axis distance of 10mm for 30 minutes FRP and 55mm or 60mm for 240 minutes FRP. The axis distance is the cover to the longitudinal steel plus half of the bar diameter. Pronto Block masonry units are designed to achieve the maximum required axis distance for all reinforcement.

It should be noted that the required thickness of a wall for any particular FRP increases as the ratio of the applied load to the load capacity increases.

For compliance with Table 5.7.2 a 140 Pronto Block wall would not achieve an FRP greater than 90 minutes and a 200 Pronto Block wall would not achieve an FRP greater than 180 minutes.

Maximum Slenderness Ratio:

Clause 5.7.3 states that any wall required to have an FRP must have a slenderness ratio (ratio of effective height to thickness) not exceeding 40.

Clause 5.7.4 outlines the effect that chases have on the FRP of any wall. The design engineer needs to give careful consideration to walls designed as spanning in two directions.
section 5.
core fill grout and grouting

All Pronto Block walls and piers must be fully grouted regardless of whether or not they are reinforced, as it is the grout that permanently bonds the masonry units to each other. Although most Pronto Block elements will contain reinforcement, minor structures such as drainage pits and temporary in-ground works may not need to be reinforced.

Core filling grout must be a free flowing concrete with a small sized coarse aggregate. Typically core filling grout is specified as 20MPa or 25MPa with maximum 5mm or 7mm coarse aggregate and about 230 slump. This is achieved by means of a super plasticiser additive.

Concretes with such a high slump are sometimes more appropriately specified with a spread rather than a slump and a spread of about 600mm is the equivalent.

The 28-day cylinder strength of the grout should be at least equal to the unconfined compressive strength of the face shells of the masonry units but may be increased for enhanced corrosion protection and it is recommended that a minimum 20MPa grout be used in any Pronto Block wall.

The grout must have pouring consistency that enables the cores or cavities to be completely filled and reinforcement to be completely surrounded without segregation of the constituents. The super plasticised mix readily achieves this objective and thoroughly wetting the block cores immediately prior to grouting is also essential.

Grout should not be compacted by mechanical vibration as this can result in failure of face shells. As stated above it is recommended that all block cores be thoroughly wetted down immediately prior to grouting and it is also recommended that the grout be compacted by rodding only to remove any trapped air.

Upon completion of the last lift of Pronto Block walling, the grout should be topped up after a waiting period of 10 to 30 minutes and lightly rodded to merge the top up grout with the previous pour.
section 6. slenderness ratio

Slenderness ratio of a wall is the ratio of the effective height of a wall divided by the thickness. It provides a means of measuring the robustness of a wall and it is used in calculations to adjust the capacity of a wall to account for the possibility of buckling causing a premature mode of failure.

6.1 Slenderness ratio for Pronto Block walls

AS 3600 Clause 11.2 outlines the design procedures for walls and the limiting slenderness ratio depends on the design method being used (refer Section 7):

a) For braced walls designed using the simplified method the maximum slenderness ratio is 30.

b) For braced walls designed as a slab the maximum slenderness ratio is 50 (refer Clause 11.1(b)).

c) For walls designed as columns see below.

AS 3600 Clause 11.5 contains provisions for the design of walls for vertical compression forces using a simplified design method where the slenderness ratio does not exceed 30. The values in the design tables in the subsequent parts of this manual have been calculated using the simplified method.

Clause 11.4 gives the method of calculating effective height ($H_{we}$) depending on whether one-way or two-way buckling applies to the design. In all cases $H_{we} = kH_w$ where:

- $H_w$ is the unsupported height of a wall, and
- $L_1$ is the length of a wall between centres of lateral restraint or from a lateral restraint to a free edge.

There are three different circumstances for braced walls in which the value of $k$ varies:

1. **one-way buckling**
   - $k = 0.75$ for braced walls where rotational restraint is provided at both ends, and
   - $k = 1.0$ where rotational restraint is not provided at one or both ends.

2. **two-way buckling with lateral support provided on three sides by floors and intersecting walls**
   - $k = 1/(1+(H_w^2/9L_1^2))$ but not less than 0.3 and not greater than $k$ for one-way buckling

3. **two-way buckling with lateral support provided on four sides by floors and intersecting walls**
   - $k = 1/(1+(H_w^2/2L_1^2))$ where $H_w \leq L_1$
   - $k = L_1/2H_w$ where $H_w > L_1$

Note that if a wall is designed for two way buckling then both the vertical and the horizontal reinforcement must be positioned in both faces – refer Section 3 of this design manual.

For walls with openings there two circumstances to be considered (Clause 11.4):

a) If the total area of the openings is less than 10% of the area of the wall and the height of any opening (not vertically one above the other) is less than $1/3$rd of the height of the wall, then the effect of the openings can be ignored.

b) In other cases the area of the wall between the support and the opening shall be designed as supported on three sides, and the area between openings shall be designed as supported on two sides.

In Clause 11.4 it is stated that an intersecting wall with a minimum length of $0.2H_w$ can be considered a lateral restraint.

6.2 Slenderness ratio for columns

For walls designed as columns the maximum slenderness ratio as defined in Clause 10.3.1 must not exceed 120 unless a rigorous analysis has been carried out (Clause 10.5.1).

The method of calculating the effective length of a column is given in Clause 10.5.3, and the means of calculating the slenderness ratio is given in the other parts of Clause 10.5. Note that the slenderness ratio of a column is the effective length divided by the radius of gyration.
When designing Pronto Block walls and piers for compression loads the vertical reinforcement is not considered to make any contribution to the compressive strength simply because it cannot be restrained in two directions with ties at close centres.

It is normal practice when designing reinforced concrete walls to neglect any contribution the reinforcement might make to the compression load capacity, however AS 3600 Clause 11.7.4 permits the contribution of unrestrained vertical reinforcement if the area of reinforcement in certain circumstances – refer 3.1 above. In all of the design aids in this manual any contribution of the reinforcement to the vertical load capacity has been ignored.

**Design of Proto Block walls in axial compression**

The design strength of a wall in compression is dependent on the following:

- Slenderness
- Effective eccentricity at the top
- Characteristic compressive strength of the masonry and the grout
- Cross sectional area of the masonry

In Pronto Block wall construction the Pronto Block masonry units are permanent shutters or formwork that contribute just a little to the compressive strength of the wall. The design thickness is less than the total thickness; it is just the overall thickness of the grout (concrete core fill). The portion of the masonry face shells that have no provision for concrete penetration are ignored. In unchamfered Pronto Block that generally means that 26mm of the wall thickness is ignored and in chamfered Pronto Block it means that 36mm of the thickness is ignored.

AS 3600 Clause 11.2 outlines the design procedures for walls and there are various options:

For braced walls where there are in-plane horizontal forces acting in conjunction with axial forces and where these are such that a horizontal cross section of the wall is subject to compression over the entire section then the in-plane bending can be neglected and the wall designed for the horizontal shear forces as per Section 5 in Parts 2 and 3 of this design manual. In this circumstance the wall can be designed for vertical compression forces either

a) as a wall in accordance with the simplified procedure provided the slenderness ratio does not exceed 30, or

b) as a column in accordance with AS 3600 Section 10 with vertical reinforcement provided in both faces (but with no requirement to consider the contribution of the vertical reinforcement to the compression load capacity).

For braced walls that are subject to simultaneous in-plane and out-of-plane load effects, and for unbraced walls, AS 3600 Clause 11.1(b) requires that they be designed as slabs in accordance with Section 9 or columns in accordance with Section 10 as appropriate.

If further states that where the stress at the mid-height section due to factored in-plane bending and axial forces does not exceed the lesser of 0.03$f'_c$ and 2MPa, then the wall may be designed as a slab in accordance with Section 9 provided:

i) the second-order deflections due to in-plane loads and long-term effects are considered in the calculation of bending moments, and

ii) the ratio of effective height to thickness does not exceed 50.

All of the axial compression load values in the design tables in the subsequent Parts of this manual have been calculated using the simplified method.
The values used in the interaction diagrams however have been calculated using column design formulae. When using the interaction diagrams it is essential that a proper analysis be completed.

**Simplified design method for walls in axial compression**

Note that this method of design is permitted for walls in which the slenderness ratio does not exceed 30.

Clause 11.5.1 states that the design axial strength per unit length of a braced wall in compression can be taken as \( \Phi N_u \)

Where \( \Phi = 0.6 \) and

\[ N_u = 0.6f'_c(t_w - 1.2e - 2e_a) \]

In the above \( e \) is the eccentricity of the load measured at right angles to the plane of the wall, and \( e_a \) is the additional eccentricity taken as \((H_w)^2/250t_w\).

The method of calculating the eccentricity \( e \) at the top of a wall when using the simplified method is given in Clause 11.5.2 and this is also shown in detail in the subsequent parts of this manual.

The minimum eccentricity on any wall designed using this method is 5% of the wall thickness, i.e. 0.05\( t_w \).

**Design for compression in mortarless shear walls**

When a load-bearing wall is also acting as a shear wall, in plane bending should be checked. When a horizontal force is resisted by more than one shear wall, the load may be distributed between the walls in proportion to their flexural stiffness about an axis perpendicular to the plane of the wall.

The in-plane bending moment will result in non-uniform compression in the wall and the wall should be designed for the maximum resulting compression force.

AS 3600 Clause 11.2.1 states that in-plane bending may be neglected in the case where the horizontal cross section is always under compression due to the combined effect of horizontal and vertical loads, and the wall be simply designed for axial load and for shear. It is recommended by the author however that the maximum compression in any wall due to the combined loading always be considered.

Clause 11.2.1 further states that if any part of a wall is subject to tension due to in-plane bending then the wall shall be designed for in-plane bending in accordance with Section 8 and for horizontal shear in accordance with Clause 11.6, or for in-plane bending and shear in accordance with Section 12 if appropriate.

**Bearing Stress**

AS 3600 Clause 12.6 should be used for checking the bearing stress at load concentrations.
section 8.
design of pronto block walls for bending

All Pronto Block walls are fully grouted and they are readily reinforced with certainty of the reinforcement positioning within. As such they can readily be designed for flexure as members spanning vertically, horizontally or both.

8.1 Reinforced Pronto Block walls subject to out-of-plane bending:
The provisions of AS 3600 Section 9 (Design of Slabs for Strength and Serviceability) are used for the design of Pronto Block walls for out-of-plane bending.
Clause 9.1.1 refers back to Clauses 8.1.1 through 8.1.8 for determining the strength of a one-way slab in bending. Clause 8.1.2 outlines the assumptions used when calculating the strength in bending which incorporates equilibrium and strain-compatibility considerations, and Clause 8.1.3 provides the deemed-to-satisfy provisions using a rectangular compression stress block. These can be summarized as follows:

a) Plane sections normal to the axis remain plane after bending;
b) The concrete has no tensile strength;
c) Compressive stress distribution is represented by an equivalent rectangle where the stress is $a_s f'_c$ and the depth of the compression block is $\gamma k d$ where

$$a_s = 1.0 - 0.003 f'_c \text{ (within the limits } 0.67 \leq a_s \leq 0.85)$$

$$\gamma = 1.05 - 0.007 f'_c \text{ (within the limits } 0.67 \leq \gamma \leq 0.85)$$
d) The maximum strain in the outermost compression fibre is taken as 0.003;

AS 3600 Clause 11.1(b) permits the design of walls simply as slabs in accordance with the appropriate provisions of Section 9 provided the stress at the mid-height section of the wall due to factored in-plane bending and axial forces does not exceed the lesser of 0.03$f'_c$ and 2MPa, provided the second-order deflections due to in-plane loads and long-term effects are considered in the calculation of bending moments, and provided the slenderness ratio (using effective height) does not exceed 50.

8.2 Reinforced Pronto Block beams, i.e. Pronto Block walls subject to in-plane bending:
The recommended limiting span to effective depth ratios for beams are as follows:

- 20 for simply supported beams,
- 26 for continuous beams, and
- 7 for cantilever beams.

The cross section should be designed in accordance with the provisions of AS 3600 Section 8. Special consideration needs to be given to the detailing of any required shear reinforcement.
Section 9.

Design for Combined Compression and Bending

Section 7 of this design manual deals with the design of Pronto Block walls for compression which are always designed for bending moments due to eccentricity of the applied load and for additional bending moments due to the eccentricity caused by slenderness effects. In addition to these two bending moments however, walls can also be subjected to out-of-plane lateral loads and therefore additional bending moments. A typical example of such a wall is a perimeter load-bearing wall in a building that is also a retaining wall.

In walls subjected to both compression and bending, compressive stress in the concrete can govern the design in situations where the compression stress due to axial load is high and the applied bending moment is sufficient to increase the compressive stress in the concrete (at the extreme fibre) to the point where it fails. In such circumstances the entire section can still be in compression and tensile reinforcement plays no direct role in the strength of the wall.

The other extreme is where the axial compression load is low and the wall fails in flexure through excessive tension in the reinforcement. The wall is essentially a vertical slab and can be designed as a slab.

9.1 Axial Compression and In-Plane Bending

AS 3600 Clause 11.2 covers the situation in which the bending results from in-plane lateral loads e.g. load-bearing shear walls in buildings. It states that where the entire horizontal cross section of the wall remains in compression then the in-plane bending in the wall can be ignored and the wall simply designed for axial compression as outlined in Section 7 of this manual and for in-plane shear as outlined in Section 11 of this manual.

If the in-plane bending is such that parts of the walls horizontal cross section are in tension then reinforcement must be provided to accommodate the tensile forces. The masonry and the grout cannot be designed for such tensile forces.

9.2 Axial Compression and Out-of-Plane Bending

AS 3600 Clause 11.1(b) states that when walls are subject to axial compression plus out-of-plane bending they can be designed as slabs – refer 8.1 above.

When the axial compression load is larger than that which produces the limiting compressive stress for the application of 11.1(b) then it is necessary to consider the combined effect to ensure that neither the concrete in compression nor the steel reinforcement in tension is overstressed. This is referred to in Clause 10.6.1 for columns in which it is stated that the compression member shall be designed on the basis of Clauses 10.6.1 and 10.6.2.

Clause 10.6.1 outlines the basic assumptions for limit state design of a section, viz that plane sections remain plane, that the concrete has no tensile strength, that the distribution of stress in the concrete and the steel is determined using the stress-strain relationship determined from Clauses 3.1.4 and 3.2.3 respectively, and that when the neutral axis lies outside the cross section consideration should be given to the effect on strength of spalling of the concrete cover.

The maximum strain in the concrete in the extreme compression fibre is given in Clause 8.1.2 as 0.003. Interaction diagrams are provided in the subsequent Parts of this design manual for the purpose of checking combined axial compression and out-of-plane bending.

Note that when using the interaction diagrams a proper analysis should be carried out to determine the bending moments at the critical sections and these must include the bending moments due to secondary effects.
section 10.
design for tension

Any Pronto Block member designed to resist axial tension must be reinforced as it is only the reinforcement that carries the tensile load.

There are no provisions in AS 3600 for the design of members in direct tension. There is however a section (AS 3600, section 7) on strut and tie modeling of structures, and Clause 7.3.2 provides guidance on the design of ties.

Refer also to Section 3 of Part 1 of this design manual for information on splicing reinforcement in tension members.

It is recommended by the author that walls should not generally be used in situations where they will be subjected to direct tension.
section 11. design for shear

All Pronto Block walls are reinforced and fully grouted and can readily be designed to satisfy the provisions of AS 3600:2009 for shear.

11.1 Shear resistance of reinforced Pronto Block members in bending

This covers Pronto Block beams and possibly short Pronto Block walls subjected to intermediate or uniformly distributed in-plane lateral loads. AS 3600 Clause 8.2.2 states that the design strength of a beam in shear shall be taken as:

\[ \bar{V}_u = V_{uc} + V_{us} \]

\[ V_{uc} = \beta_1 \beta_2 \beta_3 b_v d_o (A_{sf} b_v d_o)^{1/3} \]

- **\( \beta_1 \)** = 1.1 \((1.6 – d_o/1000) \geq 1.1 \) if shear reinforcement equal to or greater than minimum area is provided
- **\( \beta_2 \)** = 1 for members subject to pure bending
- **\( \beta_3 \)** = 1 – \( (N^*/14A_d) \geq 0 \) for members subject to axial tension
- **\( d_o \)** = the distance from the extreme compression fibre to the centroid of the outermost layer of tensile reinforcement
- **\( f_{sv} \)** = \( f_k^{1/3} \leq 4 \text{ MPa} \)
- **\( A_{sf} \)** = cross-sectional area of tensile reinforcement provided in the tensile zone and fully anchored in accordance with the principles of Clause 8.1.10., in the direction of reducing moment, at the cross section under consideration
- **\( b_v \)** = the effective width of the beam web for shear

Clause 8.2.5 contains the following rules regarding the provision of shear reinforcement:

a) Where \( V^* \leq 0.5 \bar{V}_u \), then no shear reinforcement is required unless the overall depth of the beam is greater than 750mm in which case minimum shear reinforcement \( (A_{sv.min}) \) shall be provided in accordance with Clause 8.2.8.

b) Where \( 0.5 \bar{V}_u < V^* \leq \bar{V}_u.min \), then minimum shear reinforcement shall be provided in accordance with Clause 8.2.8.

c) Where \( V^* > \bar{V}_u.min \), then shear reinforcement shall be provided in accordance with Clause 8.2.10

The minimum area of shear reinforcement \( (A_{sv.min}) \) is given in Clause 8.2.8 as follows:

\[ A_{sv.min} = 0.06 \sqrt{f'_c} b_v s / f_{ys.f} \geq 0.35 b_v s / f_{ys.f} \]

Where:
- **\( s \)** = centre to centre spacing of shear reinforcement measured parallel to the longitudinal axis of the beam
- **\( f_{ys.f} \)** = yield strength of the fitment reinforcement

The shear strength of a beam with minimum shear reinforcement \( (A_{sv.min}) \) is given in Clause 8.2.9:

\[ V_{u.min} = V_{uc} + 0.10 \sqrt{f'_c} b_v d_o \geq V_{uc} + 0.6 b_v d_o \]

The contribution to shear strength of vertical shear reinforcement is given in Clause 8.2.10:

\[ V_{us} = A_{sv} f_{sv.d} / s \text{ (when } \theta_s = 45^\circ) \]
11.2 Shear resistance of reinforced Pronto Block walls subject to in-plane horizontal load

AS 3600 Clause 11.6 is devoted to the design of walls for in-plane shear.

Clause 11.6.1 states that the critical section for maximum shear shall be taken at a distance from the base of 0.5Lw or 0.5Hw whichever is less.

AS 3600 Clause 11.6.2 states that the design strength of a wall subject to in-plane shear shall be taken as:

\[ \phi V_u \]

Where:

\( \phi \) is the capacity reduction factor – refer 1.3.1 in this Part of the manual

\[ V_u = V_{uc} + V_{us} \leq 0.2f'_c (0.8L_w t_w) \]

The shear strength of a wall excluding the wall reinforcement is given in Clause 11.6.3 as follows:

a) For walls where \( H_w/L_w \leq 1 \)

\[ V_{uc} = (0.66f'_c - 0.21(H_w/L_w)f'_c) 0.8L_w t_w \]

b) For walls where \( H_w/L_w \leq 1 \)

\[ V_{uc} = (0.05f'_c + 0.1f'_c / ((H_w/L_w)-1)) 0.8L_w t_w \]

But not greater than \( V_{uc} \) calculated as given in a) above

The contribution to the shear strength of the wall reinforcement \( (V_{us}) \) is given Clause 11.6.4 as follows:

\[ V_{us} = p_w f_{sy} (0.8L_w t_w) \]

Where \( p_w \) is determined as follows:

For walls where \( H_w/L_w > 1 \), \( p_w \) is the ratio of the horizontal wall reinforcement area to the cross-sectional area of the wall per vertical metre.

11.3 Shear resistance of reinforced Pronto Block walls subject to out-of-plane horizontal load

Shear stress in a Pronto Block wall might need to be checked if the wall is subjected to significant out-of-plane lateral loads. In such circumstances the wall should be designed in the same way as a slab but consideration should be given to any permanent axial compression loads as these will increase the shear capacity of the concrete. It is most important however to only consider permanent axial compression loads when checking shear capacity.

The shear strength provisions for slabs apply to walls in these circumstances and Clause 9.2.2 states that where the shear failure can occur across the width of the slab, the design shear strength is to be calculated in accordance with Clause 8.2 (refer 11.1 above). In this case the value of \( \beta_2 \) will be increased due to the axial compression.
pronto block walls design manual

Part 2
AS 3600:2009

Warwick Colefax
BE(Hons) DipTechEng(Struct) MIEAust CEng RPEQ
Pronto Block Design Manual Part 2 provides design tables and diagrams for combinations of block grades (unconfined compressive strengths) and core fill grout strengths (28 day cylinder strengths) as follows:

**Block Grades**
15 & 20 MPa

**Core Fill Concrete (Grout)**
20MPa

**Availability of supply**
The 200 Pronto Block masonry units to which these design tables apply are available in the following regions: Australia (NSW, QLD & VIC)

Prior to specifying 200 Pronto Block check the proximity of the nearest supplier with local Licensee.

**DISCLAIMER:**
This Pronto Block Design Manual has been compiled to assist structural engineers quickly and efficiently prepare designs and details of load-bearing Pronto Block structures and elements. Numerous design tables and diagrams have been provided and these cover a broad range of typical design applications. While every care has been taken to ensure the information provided is accurate and complete for the design situations and actions covered, the information should only be used by experienced practising structural engineers, and all engineers should familiarise themselves with the full contents of the applicable Standards to ensure no requirement is overlooked. Mortarless Pty Ltd, its licensees and the author accept no liability whatsoever arising out of the use or misuse of the information provided in this design manual.
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Section 2. Design of walls for axial compression
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section 1.
200 Pronto Block masonry units

Cross section dimensions & properties

<table>
<thead>
<tr>
<th>Mortarless Block</th>
<th>O/A width (mm)</th>
<th>Chamfer Width (ext) (mm)</th>
<th>Chamfer Width (int) (mm)</th>
<th>( t_d ) (mm)</th>
<th>Core Width (mm)</th>
<th>( A_e ) (sq.mm./m)</th>
<th>( A_s ) (sq.mm./m)</th>
<th>( A_c ) (sq.mm./m)</th>
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<td>136000</td>
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Note: \( t_d \) is the design thickness of the wall

Cross Section Through Block

Properties of 200 Pronto Block masonry units
section 2.
Design of walls for axial compression

Design of pronto block walls for axial compression using simplified design method

Many walls are designed using the simplified design method of AS 3600 Clause 11.5 and this Section 2 of the design manual is dedicated to that approach. When using this method a simplified approach is taken to the calculation of the eccentricity of the applied axial compression load on any wall panel. When using this method however a conservative approach is also taken to calculate the compression load capacity of a wall panel.

The tables in this section can be used to directly confirm the compression load capacity of 200 Pronto Block walls of a wide range of heights constructed with masonry units of Grade 15 or 20, and grouted with 20MPa concrete.

Pronto Block masonry units are essentially permanent formwork for concrete walls however the masonry units do contribute to the strength of the wall. Only the portion that is filled with concrete is considered in the design thickness of the wall and this means that only 61% of the face shell thickness is considered in the calculation of compressive strength. The other 39% is ignored.

Walls are designed assuming thickness $t = 174$mm which ignores any contribution that the outer 39% of the face shell thickness might have to the stiffness of the wall.

Pronto Block masonry units are manufactured with compressive strengths of 15MPa and 20MPa and it is recommended that the minimum grout strength be 20MPa. This is despite the fact that when calculating the load capacity of a wall a 28 day compressive strength equal to the unconfined compressive strength of the masonry units is assumed and this is considered to be somewhat conservative.

When designing walls for compression it is necessary to first calculate the eccentricity of the design compression load ($N^\prime$) applied to the top of the particular storey height of wall. It is permissible to use simplified methods to calculate the effective eccentricity as outlined in AS 3600 Clause 11.5 provided the slenderness ratio $(H_{ew}/t_w)$ does not exceed 30.

The simplified method of calculating the effective eccentricity is outlined on the following page. When using this method to calculate the effective eccentricity, it is permissible to assume that the effective eccentricity at the base of any storey height of the wall is zero as indicated in the diagrams on pages 33 and 34. (refer AS 3600 Clause 11.5.2)

After calculating the effective eccentricity for a particular wall panel it is then necessary to determine the effective height of the wall. Clause 11.4 contains the provisions for calculating effective height and these take into account the possibility of either one-way or two-way buckling.

The simple approach is to assume one-way buckling in which case the effective height factor is either 0.75 or 1.0 depending on the end restraint conditions. If the wall panel is restrained against rotation at both ends then the effective height factor $k = 0.75$. If there is no restraint against rotation at one or both ends then the effective height factor $k = 1$. Note that this is for walls in structures that are laterally braced in both directions meaning that all wall panels are laterally restrained at both ends.

Clause 11.4 also provides a means of calculating the effective height factor for wall panels in which two-way buckling can govern the design and this can be significantly less than 0.75. Diagram 2.1 in this Section can be used to determine the effective height.
Design Procedure: Axial Compression

**Step 1:** Calculate ultimate limit state design load on the wall.

**Step 2:** Select a Pronto Block size and strength (grade) based on local availability, and any other requirements (fire rating, sound rating, thermal rating etc).

**Step 3:** Calculate the design eccentricity at the top of the wall panel (refer pages 33 and 34).

**Step 4:** If the wall is subject to one-way buckling determine the design axial strength of the wall from the applicable table of Tables W1-200U to W4-200U and check that it is greater than or equal to the design axial load. Note that the tables include allowance for all partial safety factors. Ensure that all cross walls are adequately tied when using this approach – refer AS 3600 Clauses 11.3 and 11.4. Refer to Section 1 of this manual for the value of \( t_d \).

If the wall is subject to two-way buckling rather than one-way buckling, determine the effective height factor (\( k \)) from Diagram 2.1 and use this to calculate the design slenderness ratio (SR) for the wall panel (\( SR = k \frac{H_w}{t_d} \)). Then use either Table W5-200U or Table W6-200U to determine the design ultimate strength of the wall and check that it is greater than or equal to the design axial load. Note that the tables include allowance for all partial safety factors. Ensure that all cross walls are adequately tied when using this approach – refer AS 3600 Clauses 11.3 and 11.4. Refer to Section 1 of this manual for the value of \( t_d \).

**Step 5:** If the load capacity is not adequate, make the necessary adjustments to block strength, grout strength and/or wall thickness etc and check again.

**Step 6:** If the wall is also subject to out-of-plane lateral loads check the adequacy of the selected wall for combined action – refer to Section 4.

**Step 7:** If the wall is subject to in-plane lateral load check the adequacy of the wall for shear – refer to Section 5.

**Step 8:** If the wall is subjected to substantial out-of-plane lateral load check the out-of-plane shear stress – refer to Section 5.

**Fire, sound attenuation etc:**

**Step 9:** Check that the wall satisfies all other requirements in terms of durability, slenderness, thickness etc.
Calculation of effective eccentricity when designing for compression using simplified method:

AS 3600 Clause 11.5.2 permits the calculation of eccentricity of applied vertical loads at the top of walls as follows:

- The minimum eccentricity shall be $0.05l_d$
- The vertical load transmitted to a wall by a discontinuous concrete floor or roof shall be assumed to act at one third of the bearing depth measured from the span face of the wall.
- Where there is an insitu concrete floor or roof continuous over the wall, the load shall be assumed to act at the center of the wall.
- It is recommended by the author that if the continuous slab has different spans on each side of the wall then each side of the floor or roof shall be taken as being individually supported on half the total bearing area.

It also permits the assumption that the eccentricity of aggregated load from all floors above the floor at the top of the wall being designed is zero.

Examples of how to calculate the effective eccentricity using the above:
Examples of how to calculate the effective eccentricity using the above:

Effective eccentricity
\[ e = 0.167 t_d = 29 \text{mm} \]

\[ t_d / 3 = 58 \text{mm} \]

Effective eccentricity
\[ e = 0 \]

Effective eccentricity
\[ e = \frac{(P_3 - P_2) \times 58}{P_2 + P_3 + P_4} \]

Load = \[ P_2 + P_3 + P_4 \]

\[ t_d / 6 = 29 \text{mm} \]

\[ t_d / 6 = 29 \text{mm} \]
TABLE W1-200U
Effective height factor $k = 0.75$

15MPa Blocks
20MPa Core fill ($f'_{c} = 20$MPa)
Rotational restraint both ends of wall panel

<table>
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<th>$H_e$</th>
<th>$H_{ew}$</th>
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Notes
Use this table to determine the design axial strength ($\varnothing N_u$) for a wall of any clear height that does not exceed the slenderness ratio limit set in AS 3600:2009. Note that the slenderness ratio limit for walls is 30 (refer AS 3600 Clause 11.5) and this table is curtailed at that slenderness ratio.

8.7mm is the minimum design eccentricity for any unchamfered 200 Pronto Block wall.

Linear interpolation may be used for any intermediate values of design eccentricity.

When using this table ensure that the ends of the wall panel (the top and bottom end) are restrained rotationally. Insitu slabs at top and bottom are considered to provide rotational restraint.

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A capacity reduction factor ($\varnothing$) of 0.6 has been used when calculating the tabulated strengths.
### TABLE W2-200U
**Effective height factor** \( k = 0.75 \)

**20MPa Blocks**

**20MPa Core fill** \( f'_c = 20\text{MPa} \)

**Rotational restraint both ends of wall panel**

<table>
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<th>( H_w )</th>
<th>( H_{wx} )</th>
<th>SR</th>
<th>( e_a )</th>
<th>Design ultimate strength ( \bar{N}_u ) (kN/m)</th>
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</table>

**Notes**

Use this table to determine the design axial strength \( (\bar{N}_u) \) for a wall of any clear height that does not exceed the slenderness ratio limit set in AS 3600:2009. Note that the slenderness ratio limit for walls is 30 (refer AS 3600 Clause 11.5) and this table is curtailed at that slenderness ratio.

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The tabulated values of \( \bar{N}_u \) account for the reduction in axial load resulting from the additional eccentricity \( e_a \) due to slenderness effects. The value of \( e_a \) for each wall height is tabulated.

A capacity reduction factor \( (\Phi) \) of 0.6 has been used when calculating the tabulated strengths.
**TABLE W3-200U**

**Effective height factor \( k = 1.0 \)**

15MPa Blocks  
20MPa Core fill \( (f'_c = 20\text{MPa}) \)  
No rotational restraint both ends of wall panel (just lateral restraint)

<table>
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<tr>
<th>( H_w )</th>
<th>( H_{tot} )</th>
<th>SR</th>
<th>( e_a )</th>
<th>Design ultimate strength ( \Phi N_u ) (kN/m)</th>
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**Notes:**

Use this table to determine the design axial strength \( (\Phi N_u) \) for a wall of any clear height that does not exceed the slenderness ratio limit set in AS 3600:2009. Note that the slenderness ratio limit for walls is 30 (refer AS 3600 Clause 11.5) and this table is curtailed at that slenderness ratio.

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Linear interpolation may be used for any intermediate values of design eccentricity.

This table is for walls in which the ends are only restrained laterally and not rotationally. Ensure always that there is adequate connection between the walls and the roof or floor slabs to provide such restraint (refer AS 3600 Clause 11.3)

The tabulated values of \( \Phi N_u \) account for the reduction in axial load resulting from the additional eccentricity \( (e_a) \) due to slenderness effects. The value of \( e_a \) for each wall height is tabulated.

A capacity reduction factor \( (\Phi) \) of 0.6 has been used when calculating the tabulated strengths.
### TABLE W4-200U

**Effective height factor** $k = 1.0$

20MPa Blocks  
20MPa Core fill ($f'_c = 20$MPa)  
No rotational restraint both ends of wall panel (just lateral restraint)

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<th>$e = 10\text{mm}$</th>
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</table>

**Notes**

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This table is for walls in which the ends are only restrained laterally and not rotationally. Ensure always that there is adequate connection between the walls and the roof or floor slabs to provide such restraint (refer AS 3600 Clause 11.3).

The tabulated values of $\bar{N}$ account for the reduction in axial load resulting from the additional eccentricity ($e_a$) due to slenderness effects. The value of $e_a$ for each wall height is tabulated.

A capacity reduction factor ($\Phi$) of 0.6 has been used when calculating the tabulated strengths.
DIAGRAM 2.1:

Refer AS 3600 Clauses 11.4b) and 11.4c)
TABLE W5-200U
15MPa Blocks
20MPa Core fill \(f'_c = 20\text{MPa}\)

<table>
<thead>
<tr>
<th>SR</th>
<th>(e_a)</th>
<th>Design ultimate strength (\Delta N_u) (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(e = 8.7\text{mm})</td>
</tr>
<tr>
<td>12</td>
<td>10.0</td>
<td>775</td>
</tr>
<tr>
<td>13</td>
<td>11.8</td>
<td>756</td>
</tr>
<tr>
<td>14</td>
<td>13.6</td>
<td>736</td>
</tr>
<tr>
<td>15</td>
<td>15.7</td>
<td>714</td>
</tr>
<tr>
<td>16</td>
<td>17.8</td>
<td>691</td>
</tr>
<tr>
<td>17</td>
<td>20.1</td>
<td>666</td>
</tr>
<tr>
<td>18</td>
<td>22.6</td>
<td>640</td>
</tr>
<tr>
<td>19</td>
<td>25.1</td>
<td>612</td>
</tr>
<tr>
<td>20</td>
<td>27.8</td>
<td>583</td>
</tr>
<tr>
<td>21</td>
<td>30.7</td>
<td>552</td>
</tr>
<tr>
<td>22</td>
<td>33.7</td>
<td>519</td>
</tr>
<tr>
<td>23</td>
<td>36.8</td>
<td>486</td>
</tr>
<tr>
<td>24</td>
<td>40.1</td>
<td>450</td>
</tr>
<tr>
<td>25</td>
<td>43.5</td>
<td>413</td>
</tr>
<tr>
<td>26</td>
<td>47.0</td>
<td>375</td>
</tr>
<tr>
<td>27</td>
<td>50.7</td>
<td>335</td>
</tr>
<tr>
<td>28</td>
<td>54.6</td>
<td>294</td>
</tr>
<tr>
<td>29</td>
<td>58.5</td>
<td>251</td>
</tr>
<tr>
<td>30</td>
<td>62.6</td>
<td>207</td>
</tr>
</tbody>
</table>

Notes

Use this table to determine the design axial strength \(\Delta N_u\) for a wall of any clear height that does not exceed the slenderness ratio limit set in AS 3600:2009. Note that the slenderness ratio limit for walls is 30 (refer AS 3600 Clause 11.5) and this table is curtailed at that slenderness ratio.

8.7mm is the minimum design eccentricity for any unchamfered 200 Pronto Block wall. Linear interpolation may be used for any intermediate values of design eccentricity.

This table is provided design engineers that are checking walls subjected to two-way buckling. It is valid also for walls subjected to one-way buckling but Tables W1 – W4 are more convenient for checking such walls.

The tabulated values of \(\Delta N_u\) account for the reduction in axial load resulting from the additional eccentricity \(e_a\) due to slenderness effects. The value of \(e_a\) for each wall height is tabulated.

A capacity reduction factor \(\Phi\) of 0.6 has been used when calculating the tabulated strengths.
### TABLE W6-200U

20MPa Blocks  
20MPa Core fill ($f'_c = 20$MPa)

<table>
<thead>
<tr>
<th>SR</th>
<th>$e_a$</th>
<th>Design ultimate strength $\bar{\Omega}N_u$ (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$e = 8.7$mm</td>
</tr>
<tr>
<td>12</td>
<td>10.0</td>
<td>1033</td>
</tr>
<tr>
<td>13</td>
<td>11.8</td>
<td>1008</td>
</tr>
<tr>
<td>14</td>
<td>13.6</td>
<td>981</td>
</tr>
<tr>
<td>15</td>
<td>15.7</td>
<td>952</td>
</tr>
<tr>
<td>16</td>
<td>17.8</td>
<td>921</td>
</tr>
<tr>
<td>17</td>
<td>20.1</td>
<td>888</td>
</tr>
<tr>
<td>18</td>
<td>22.6</td>
<td>853</td>
</tr>
<tr>
<td>19</td>
<td>25.1</td>
<td>816</td>
</tr>
<tr>
<td>20</td>
<td>27.8</td>
<td>777</td>
</tr>
<tr>
<td>21</td>
<td>30.7</td>
<td>736</td>
</tr>
<tr>
<td>22</td>
<td>33.7</td>
<td>693</td>
</tr>
<tr>
<td>23</td>
<td>36.8</td>
<td>647</td>
</tr>
<tr>
<td>24</td>
<td>40.1</td>
<td>600</td>
</tr>
<tr>
<td>25</td>
<td>43.5</td>
<td>551</td>
</tr>
<tr>
<td>26</td>
<td>47.0</td>
<td>501</td>
</tr>
<tr>
<td>27</td>
<td>50.7</td>
<td>447</td>
</tr>
<tr>
<td>28</td>
<td>54.6</td>
<td>392</td>
</tr>
<tr>
<td>29</td>
<td>58.5</td>
<td>335</td>
</tr>
<tr>
<td>30</td>
<td>62.6</td>
<td>276</td>
</tr>
</tbody>
</table>

**Notes**

Use this table to determine the design axial strength ($\bar{\Omega}N_u$) for a wall of any clear height that does not exceed the slenderness ratio limit set in AS 3600:2009. Note that the slenderness ratio limit for walls is 30 (refer as 3600 Clause 11.5) and this table is curtailed at that slenderness ratio.

8.7mm is the minimum design eccentricity for any un chamfered 200 Pronto Block wall.

Linear interpolation may be used for any intermediate values of design eccentricity.

This table is provided design engineers that are checking walls subjected to two-way buckling. It is valid also for walls subjected to one-way buckling but Tables W1 – W4 are more convenient for checking such walls.

The tabulated values of $\bar{\Omega}N_u$ account for the reduction in axial load resulting from the additional eccentricity ($e_a$) due to slenderness effects. The value of $e_a$ for each wall height is tabulated.

A capacity reduction factor ($\bar{\Omega}$) of 0.6 has been used when calculating the tabulated strengths.
This section is for the design of walls subjected to out-of-plane lateral loads only, however it can also be used for the design of walls subjected to only small axial compression loads where the stress at mid-height due to bending and compression does not exceed the lesser of $0.03f'_c$ and 2MPa (Refer AS 3600 Clause 11.1b).

**Reinforcing bar positions**

The location of all reinforcement in Pronto Block walls is controlled by the notches in the connectors that support the horizontal bars. The 200 mortarless connectors have four notches, and the bar positions are described as V1, V2, H1 and H2 as shown in the following diagrams. Positions V1 and H1 are located furthest from the neutral axis, while positions V2 and H2 are located closest to the neutral axis. These positions are referred to in the moment capacity tables 3.1, 3.2 and 3.3.
Bar position H1 for load on side B

Bar position H1 for load on side A

Reinforcing bar positions H1 for 200 unchamfered Pronto Block
Alternate position of horizontal bars to provide support for vertical bars

Bar position V2 for load on side B
Bar position V2 for load on side A

Reinforcing bar positions H1 for 200 unchamfered Pronto Block
**Design Procedure: Bending**

**Out-of-plane bending (walls):**

**Step 1:** Calculate ultimate limit state design bending moment.

**Step 2:** Select a Pronto Block size and strength (grade) based on local availability and any other requirements (fire rating, sound rating, thermal rating etc).

**Step 3:** Using Table 3.1 determine the reinforcement size, spacing and location that will give a bending moment capacity equal to or greater than the design bending moment.

Ensure the bar positions (vertical and/or horizontal) are specified on the drawings. Note that when the vertical bars are required to be in any of the four possible locations it is necessary to specify the appropriate horizontal bar positions. The horizontal bars are used to guide the vertical bars into their correct location and to support them in that location throughout the height of the wall – refer to the sections on pages 42 - 44.

**In-plane bending (beams):**

**Step 1:** Calculate ultimate limit state design bending moment.

**Step 2:** Using Table 3.2 or 3.3 determine the reinforcement requirement noting that these tables can be used for checking both the positive and the negative bending moment reinforcement requirements.
Bending moment capacities for Pronto Block walls subject to out-of-plane loads

**TABLE 3.1:**

<table>
<thead>
<tr>
<th>Block Grade &amp; Reinforcement (f_y = 500MPa)</th>
<th>200 Pronto Block (unchamfered)</th>
<th>Bending moment capacity $\theta M_u$ (kNm/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$A_s$ mm$^2$/m</td>
<td>Vertical bending</td>
</tr>
<tr>
<td></td>
<td>$A_{sd}$ mm$^2$/m bars in position V1 $d = 112$</td>
<td>$A_{sd}$ mm$^2$/m bars in position V2 $d = 93$</td>
</tr>
<tr>
<td><strong>Grade 15 blocks 20MPa Grout</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-200</td>
<td>550</td>
<td>17.0</td>
</tr>
<tr>
<td>N12-400</td>
<td>275</td>
<td>8.9</td>
</tr>
<tr>
<td>N12-600</td>
<td>183</td>
<td>6.0</td>
</tr>
<tr>
<td>N16-200</td>
<td>1000</td>
<td>28.6</td>
</tr>
<tr>
<td>N16-400</td>
<td>500</td>
<td>15.6</td>
</tr>
<tr>
<td>N16-600</td>
<td>333</td>
<td>10.6</td>
</tr>
<tr>
<td><strong>Grade 20 blocks 20MPa Grout</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-200</td>
<td>550</td>
<td>17.3</td>
</tr>
<tr>
<td>N12-400</td>
<td>275</td>
<td>9.0</td>
</tr>
<tr>
<td>N12-600</td>
<td>183</td>
<td>6.0</td>
</tr>
<tr>
<td>N16-200</td>
<td>1000</td>
<td>29.9</td>
</tr>
<tr>
<td>N16-400</td>
<td>500</td>
<td>15.9</td>
</tr>
<tr>
<td>N16-600</td>
<td>333</td>
<td>10.8</td>
</tr>
</tbody>
</table>

**Notes**

All reinforcement to be Grade 500 deformed bars.

The tabulated values have been calculated in accordance with AS 3600 Clause 8.1.

$A_s$ is the area of tensile reinforcement installed in the wall.

$A_{sd}$ is the area of tensile reinforcement used for design of the section.

The tabulated bending moment capacities include all of the capacity reduction factor $\Theta=0.6$. 


Bending moment capacities for mortarless beams

**TABLE 3.2: Beams with one bar in the bottom course**

<table>
<thead>
<tr>
<th>15 MPa</th>
<th>D x B</th>
<th>d</th>
<th>Bending moment capacity (kNm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1N12 bottom</td>
</tr>
<tr>
<td>2 course beam</td>
<td>400 x 200</td>
<td>230</td>
<td>7.5</td>
</tr>
<tr>
<td>3 course beam</td>
<td>600 x 200</td>
<td>430</td>
<td>25.6</td>
</tr>
<tr>
<td>4 course beam</td>
<td>800 x 200</td>
<td>630</td>
<td>37.6</td>
</tr>
</tbody>
</table>

**TABLE 3.3: Beams with one bar in the bottom course**

<table>
<thead>
<tr>
<th>20 MPa</th>
<th>D x B</th>
<th>d</th>
<th>Bending moment capacity (kNm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1N12 bottom</td>
</tr>
<tr>
<td>2 course beam</td>
<td>400 x 200</td>
<td>230</td>
<td>7.5**</td>
</tr>
<tr>
<td>3 course beam</td>
<td>600 x 200</td>
<td>430</td>
<td>25.6</td>
</tr>
<tr>
<td>4 course beam</td>
<td>800 x 200</td>
<td>630</td>
<td>37.6</td>
</tr>
</tbody>
</table>

**WARNING – 1N12 in a 400x174 beam does not quite satisfy the minimum reinforcement requirements of AS 3600 Clause 8.1.6**
section 4.
design of pronto block walls for axial compression combined with out-of-plane bending

Section 2 deals with the design of walls for axial compression loads where the axial load capacity is determined in accordance with the simplified design method outlined in AS 3600 Clause 11.5. The tabulated values in Section 2 take into account both the design eccentricity of the axial load and the additional eccentricity resulting from slenderness.

Walls can also be subjected to out of plane lateral loads however that may increase the design bending moments. While axial compression loads can increase the moment capacity of a wall it is important to check that the increased design compressive stress in the extreme fibre of the concrete section does not exceed the permissible stress when the wall is subjected to the combined action.

In this Section of the design manual interaction diagrams are provided for the purpose of checking combined bending and compression. These diagrams can be used to determine whether or not a critical section is over stressed due to the combined action.

There is no provision in AS 3600 for checking combined bending and compression using the simplified design method. The simplified design method takes into account the design bending moment due to eccentricity of the applied load at the top of the wall panel and it also takes into account the additional design bending moment due to slenderness effects but there is no provision for adding in any additional bending moment resulting from out-of-plane lateral loads.

When using the interaction diagrams it is very important to remember that the minimum design bending moment at any cross section is $N^* \times 0.05t_d$, i.e. the bending moment that corresponds to a minimum 5% design eccentricity.

The reinforcement requirements for the wall panel can be determined using the interaction diagrams.
**Design Procedure: Combined axial compression and bending (one-way buckling)**

This design procedure is for walls spanning vertically.

**Step 1:** Select a Pronto Block size and strength (grade) based on local availability and any other requirements (fire rating, sound rating, thermal rating etc).

**Step 2:** Carry out a structural analysis for all applicable load combinations to determine the ultimate limit state design compression load on the wall and the ultimate limit state design bending moments at the critical sections including the bending moments from slenderness effects and the bending moments from out-of-plane lateral loads.

**Step 3:** Use the interaction diagrams (Diagrams 4.1 and 4.2 on the following pages) to check that the selected reinforcement is adequate. Enter the interaction diagram with the design axial load ($N^*$) on the Y axis and read off the maximum design bending moment ($M^*$) on the X axis. Check that the actual design bending moment is less than or equal to the maximum design bending moment.

**Step 4:** If the wall is subject to in-plane lateral loads check the adequacy of the wall for shear – refer to Section 5. It might also be necessary to check the wall panel for in-plane bending – Refer 9.1 in Part 1.

**Step 5:** If the wall is subjected to substantial out-of-plane lateral loads check the out-of-plane shear stress – refer to Section 5.

**Fire, sound attenuation etc:**

**Step 6:** Check that the wall satisfies all other requirements in terms of durability, slenderness, thickness etc.
Notes
This interaction diagram is to be used for checking the adequacy of any critical cross section for the combined action of compression and out-of-plane bending.

A compressive stress of $0.85f'_c$ was used for the rectangular stress block when calculating the values in the above diagram. This is not compatible with the values in Tables W1-200U – W4-200U that were prepared using the simplified design method for walls in vertical compression and in which the compressive stress in the rectangular stress block was just $0.6f'_c$.

When using this diagram use bending moments derived from a structural analysis which include the additional bending moments due to slenderness effects. Do not use the bending moments calculated using the simplified approach.

Always ensure that the axial compression load used when checking for reinforcement requirements is the minimum sustained design axial compression load.

When using the chart enter with the design axial compression load $N^*$ and read off the maximum design bending moment $M^* = \phi M_u$.

Ensure that the vertical reinforcement is placed in the tension face of the wall in all cases.
Notes

This interaction diagram is to be used for checking the adequacy of any critical cross section for the combined action of compression and out-of-plane bending.

A compressive stress of 0.85$f_c'$ was used for the rectangular stress block when calculating the values in the above diagram. This is not compatible with the values in Tables W1-200U – W4-200U that were prepared using the simplified design method for walls in vertical compression and in which the compressive stress in the rectangular stress block was just 0.6$f_c'$.

When using this diagram use bending moments derived from a structural analysis which include the additional bending moments due to slenderness effects. Do not use the bending moments calculated using the simplified approach.

Always ensure that the axial load used when checking for reinforcement requirements is the minimum sustained design axial compression load.

When using the chart enter with the design axial compression load $N^*$ and read off the maximum design bending moment $M^* = \varnothing M_v$.

Ensure that the vertical reinforcement is placed in the tension face of the wall in all cases.
section 5.
Design of Pronto Block Walls for shear

Load-bearing walls are mostly designed to carry axial compression loads, however in many load bearing wall structures they are also designed to carry the lateral loads arising from wind, earthquake etc, i.e. they are designed as shear walls. Diagrams 5.1 and 5.2 in this Section provide a means of readily checking the capacity of a wall to take in-plane shear. The design strength of the wall is the sum of the values obtained from the two Diagrams. It is necessary to use the correct reinforcement area when using Diagram 5.2 and this is explained in the notes below the Diagram.

Load-bearing walls can also be subjected to out of plane lateral loads, a typical example being a retaining wall designed to carry earth pressure loads. These walls may need to be checked for transverse shear loads at critical sections and Diagrams 5.3 and 5.4 in this Section is provided to make this task very easy. It can readily be seen in the Diagram that the transverse shear capacity increases as the axial load \(N^e\) increases.

Reinforced Pronto Block is also often used as lintel beams and the like to span across openings. These members need to be designed for shear the same as any reinforced concrete beam and Tables 5.1 and 5.2 in this Section make it very easy to check the shear capacity of Pronto Block beams.

### Design Procedure: Shear

#### In-Plane Shear (Shear Walls):

**Step 1:** Calculate ultimate limit state design shear force on the wall panel.

**Step 2:** Determine the shear strength of the wall panel (excluding the contribution from reinforcement) using Diagram 5.1. Note that the value obtained from Diagram 5.1 is the shear capacity per linear metre of the wall panel length, so simply multiply the value obtained from the Diagram by the length in metres to obtain the total shear capacity.

**Step 3:** Determine the contribution to shear strength of the wall reinforcement using Diagram 5.2.

Again note that this gives the shear strength per linear metre and note that all reinforcement used when determining a value from this Diagram must be anchored beyond the critical section.

#### In-Plane Shear (Beams):

**Step 1:** Calculate ultimate limit state design shear force on the beam at the critical section.

**Step 2:** Use Table 5.2 to determine whether the beam has adequate shear strength without the need for shear reinforcement. If not then proceed to Step 3.

**Step 3:** Use Table 5.2 to determine whether the beam has adequate shear strength with single leg R10 shear reinforcement. If not then select a deeper beam or use an alternative beam.

#### Out-Of-Plane Shear:

**Step 1:** Calculate ultimate limit state design shear force on the wall.

**Step 2:** Use Diagram 5.3 or 5.4 to determine the shear capacity of the wall and check that this is equal to or greater than the design shear force.
DIAGRAM 5.1 - In-plane shear strength of Pronto Block shear walls excluding contribution of reinforcement

Notes
The shear strengths given in the above Diagram are kN per linear metre of wall length.
Critical section for shear is the lesser of 0.5Lw and 0.5Hw from the base of the wall (AS 3600 Clause 11.6.1).
This diagram takes no account of the contribution of the reinforcement to the shear strength.

For the contribution of reinforcement to shear strength refer Diagram 5.2.
A value of $\varphi = 0.7$ has been used in the calculations.
DIAGRAM 5.2: Contribution of reinforcement to in-plane shear strength of Pronto Block shear walls

Notes

The shear strengths given in the above Diagram are kN per linear metre of wall length.

As is the cross sectional area of reinforcement per metre of wall length or wall height:

- If $H_w / L_w \leq 1$ use the lesser $A_v$ of the vertical and the horizontal reinforcement.
- If $H_w / L_w > 1$ use the $A_h$ of the horizontal reinforcement.

Critical section for shear is the lesser of $0.5L_w$ and $0.5H_w$ from the base of the wall (AS 3600 Clause 11.6.1).

This diagram takes no account of the contribution of the concrete to the shear strength.

For the contribution of concrete to shear strength refer Diagram 5.1.

A value of $\varnothing = 0.7$ has been used in the calculations.
Notes

The shear strengths given in the above Diagram are kN per linear metre of wall length.

Vertical reinforcement must be fully anchored in the direction of diminishing bending moment.

A value of $\varnothing = 0.7$ has been used in the calculations.
DIAGRAM 5.4: Shear capacity of Pronto Block walls subject to out-of-plane lateral loads – 20MPa blocks

Notes
The shear strengths given in the above Diagram are kN per linear metre of wall length.
Vertical reinforcement must be fully anchored in the direction of diminishing bending moment.
A value of $\varnothing = 0.7$ has been used in the calculations.
### TABLE 5.1: Shear capacity of 200 Pronto Block beams without shear reinforcement

Shear reinforcement: nil

<table>
<thead>
<tr>
<th>Dimensions $D \times B$</th>
<th>Effective Depth $d'$</th>
<th>Maximum $V_u$ without shear reinforcement (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1N12 bottom</td>
</tr>
<tr>
<td>2 course beam 15MPa blocks</td>
<td>400 x 200</td>
<td>235</td>
</tr>
<tr>
<td>2 course beam 20MPa blocks</td>
<td>400 x 200</td>
<td>235</td>
</tr>
<tr>
<td>3 course beam 15 MPa blocks</td>
<td>600 x 200</td>
<td>435</td>
</tr>
<tr>
<td>3 course beam 20 MPa blocks</td>
<td>600 x 200</td>
<td>435</td>
</tr>
<tr>
<td>4 course beam 15 MPa blocks</td>
<td>800 x 200</td>
<td>635</td>
</tr>
<tr>
<td>4 course beam 20 MPa blocks</td>
<td>800 x 200</td>
<td>635</td>
</tr>
</tbody>
</table>

### TABLE 5.2: Shear capacity of 200 Pronto Block beams with shear reinforcement

Shear reinforcement: R10-200 single leg

<table>
<thead>
<tr>
<th>Dimensions $D \times B$</th>
<th>Effective Depth $d'$</th>
<th>Maximum $V_u$ with R10-200 shear reinforcement (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1N12 bottom</td>
</tr>
<tr>
<td>2 course beam 15MPa blocks</td>
<td>400 x 200</td>
<td>235</td>
</tr>
<tr>
<td>2 course beam 20MPa blocks</td>
<td>400 x 200</td>
<td>235</td>
</tr>
<tr>
<td>3 course beam 15 MPa blocks</td>
<td>600 x 200</td>
<td>435</td>
</tr>
<tr>
<td>3 course beam 20 MPa blocks</td>
<td>600 x 200</td>
<td>435</td>
</tr>
<tr>
<td>4 course beam 15 MPa blocks</td>
<td>800 x 200</td>
<td>635</td>
</tr>
<tr>
<td>4 course beam 20 MPa blocks</td>
<td>800 x 200</td>
<td>635</td>
</tr>
</tbody>
</table>
pronto block walls
140 pronto block (design tables) unchamfered

In this Pronto Block Design Manual Part 3 design tables and diagrams are provided for combinations of block grades (unconfined compressive strengths) and core fill grout strengths (28 day cylinder strengths) as follows:

**BLOCK GRADES:**
15 & 20 MPa

**CORE FILL CONCRETE (GROUT):**
20MPa

**AVAILABILITY of SUPPLY:**
The 140 Pronto Block masonry units to which these design tables apply are available in the following regions: Australia (NSW, QLD & VIC)

Prior to specifying 140 Pronto Block check the proximity of the nearest supplier with local Licensee.

**DISCLAIMER:**
This Pronto Block Design Manual has been compiled to assist structural engineers quickly and efficiently prepare designs and details of load-bearing Pronto Block structures and elements. Numerous design tables and diagrams have been provided and these cover a broad range of typical design applications. While every care has been taken to ensure the information provided is accurate and complete for the design situations and actions covered, the information should only be used by experienced practising structural engineers, and all engineers should familiarise themselves with the full contents of the applicable Standards to ensure no requirement is overlooked. Mortarless Pty Ltd, its licensees and the author accept no liability whatsoever arising out of the use or misuse of the information provided in this design manual.
Section 1. 140 Pronto Block masonry units
Cross section dimensions and properties

Section 2. Design of walls for axial compression
Design Procedure – Axial compression
Calculation of effective eccentricity – simplified design method – one-way buckling
Table W1-140U: 15MPa blocks, 20MPa grout, k=0.75
Table W2-140U: 20MPa blocks, 20MPa grout, k=0.75
Table W3-140U: 15MPa blocks, 20MPa grout, k=1.0
Table W4-140U: 20MPa blocks, 20MPa grout, k=1.0
Diagram 2.1: Effective height factor k for walls with two-way buckling
Table W5-140U: 15MPa blocks, 20MPa grout, two way buckling
Table W6-140U: 20MPa blocks, 20MPa grout, two way buckling

Section 3. Design of walls for bending
Reinforcing bar positions
Design Procedure – Out-of-plane bending
Table 3.1: Bending moment capacities (vertical and horizontal)
Table 3.2: Design bending moment capacity of Pronto Block beams – 15MPa
Table 3.3: Design bending moment capacity of Pronto Block beams – 20MPa

Section 4. Design of walls for combined bending and compression
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Diagram 4.1: Interaction Diagram – f’c = 15MPa
Diagram 4.2: Interaction Diagram – f’c = 20MPa

Section 5. Design of walls for shear
Design Procedure – Shear
Diagram 5.1: In-plane shear strength of shear walls – excluding contribution of reinforcement
Diagram 5.2: Contribution of reinforcement to in-plane shear strength of shear walls
Diagram 5.3: Out-of-plane shear capacity – walls with 15MPa blocks
Diagram 5.4: Out-of-plane shear capacity – walls with 20MPa blocks
Table 5.1: Shear capacities Pronto Block beams without shear reinforcement
Table 5.2: Shear capacities Pronto Block beams with shear reinforcement
section 1.
140 Pronto Block – Unchamfered

Cross section dimensions & properties

Properties of 200 Pronto Block masonry units

<table>
<thead>
<tr>
<th>Mortarless Block</th>
<th>Q/A width</th>
<th>Chamfer Width (ext)</th>
<th>Chamfer Width (int)</th>
<th>t_d</th>
<th>Core Width</th>
<th>A_s</th>
<th>A_t</th>
<th>A_c</th>
<th>f'_cu</th>
</tr>
</thead>
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<tr>
<td></td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>sq.mm./m</td>
<td>sq.mm./m</td>
<td>sq.mm./m</td>
<td>MPa</td>
</tr>
<tr>
<td>140</td>
<td>140</td>
<td>0</td>
<td>14</td>
<td>114</td>
<td>86</td>
<td>28000</td>
<td>86000</td>
<td>114000</td>
<td>15</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20</td>
</tr>
</tbody>
</table>

Note: t_d is the design thickness of the wall
Design of Pronto block walls for axial compression using simplified design method

Many walls are designed using the simplified design method of AS 3600 Clause 11.5 and Section 2 of this design manual is dedicated to that approach. When using this method a simplified approach is taken to the calculation of the eccentricity of the applied axial compression load on any wall panel. When using this method however a conservative approach is also taken to calculate the compression load capacity of a wall panel.

The tables in this section can be used to directly confirm the compression load capacity of 140 Pronto Block walls of a wide range of heights and lengths constructed with masonry units of Grade 15 or 20, and grouted with 20MPa concrete.

Pronto Block masonry units are essentially permanent formwork for concrete walls however the masonry units do contribute to the strength of the wall. Only the portion that is filled with concrete is considered in the design thickness of the wall and this means that only 54% of the face shell thickness is considered in the calculation of compressive strength. The other 46% is ignored. Walls are designed assuming thickness $t = 114$mm which ignores any contribution that the outer 46% of the face shell thickness might have to the stiffness of the wall.

Pronto Block masonry units are manufactured with compressive strengths of 15MPa and 20MPa and it is recommended that the minimum grout strength be 20MPa. This is despite the fact that when calculating the load capacity of a wall a 28 day compressive strength equal to the unconfined compressive strength of the masonry units is assumed and this is considered to be somewhat conservative.

When designing walls for compression it is necessary to first calculate the eccentricity of the design compression load ($N^*$) applied to the top of the particular storey height of wall. It is permissible to use simplified methods to calculate the effective eccentricity given in AS 3600 Clause 11.5 provided the slenderness ratio $$(H_{we}/t_{we})$$ does not exceed 30.

The simplified method of calculating the effective eccentricity is outlined on the following page. When using this method to calculate the effective eccentricity, it is permissible to assume that the effective eccentricity at the base of any storey height of the wall is zero as indicated in the diagrams on pages 65 and 66. (Refer AS 3600 Clause 11.5.2).

After calculating the effective eccentricity for a particular wall panel it is then necessary to determine the effective height of the wall. Clause 11.4 contains the provisions for calculating effective height and these take into account the possibility of either one-way or two-way buckling.

The simple approach is to assume one-way buckling in which case the effective height factor is either 0.75 or 1.0 depending on the end restraint conditions. If the wall panel is restrained against rotation at both ends then the effective height factor $k = 0.75$. If there is no restraint against rotation at one or both ends then the effective height factor $k = 1$. Note that this is for walls in structures that are laterally braced in both directions meaning that all wall panels are laterally restrained at both ends.

Clause 11.4 also provides a means of calculating the effective height factor for wall panels in which two-way buckling can govern the design and this can be significantly less than 0.75. Diagram 2.1 in this Section can be used to determine the effective height factor for a wall panel laterally restrained on three or four sides and subject to two-way buckling. Table W5-140U and Table W6-140U are provided for use with Diagram 2.1.

If walls are designed for two-way buckling then it is necessary to install the reinforcement in both faces.
Note: An alternative approach is to carry out a structural analysis to determine more accurately the design bending moments and to then use the interaction diagrams in Section 4 to check the adequacy of any wall panel. Wall panels with a slenderness ratio greater than 30 can be designed if a proper analysis is carried out.

Design Procedure: Axial Compression

**Step 1:** Calculate ultimate limit state design load on the wall.

**Step 2:** Select a Pronto Block size and strength (grade) based on local availability and any other requirements (fire rating, sound rating, thermal rating etc).

**Step 3:** Calculate the design eccentricity at the top of the wall panel (refer pages 65 and 66).

**Step 4:** If the wall is subject to one-way buckling determine the design axial strength of the wall from the applicable table (W1-140U to W4-140U) and check that it is greater than or equal to the design axial load. Note that the tables include allowance for all partial safety factors.

If the wall is subject to two-way buckling rather than one-way buckling, determine the effective height factor \( k \) from Diagram 2.1 and use this to calculate the design slenderness ratio \( (SR) \) for the wall panel \( (SR=kH_w/t_d) \). Then use either Table W5-140U or Table W6-140U to determine the design ultimate strength of the wall and check that it is greater than or equal to the design axial load. Note that the tables include allowance for all partial safety factors. Ensure that all cross walls are adequately tied when using this approach – refer to AS 3600 Clauses 11.3 and 11.4. Refer to Section 1 of this manual for the value of \( t_d \).

**Step 5:** If the load capacity is not adequate, make the necessary adjustments to block strength, grout strength and/or wall thickness etc and check again.

**Step 6:** If the wall is also subject to out-of-plane lateral loads check the adequacy of the selected wall for combined action – refer to Section 4

**Step 7:** If the wall is subject to in-plane lateral load check the adequacy of the wall for shear – refer to Section 5

**Step 8:** If the wall is subjected to substantial out-of-plane lateral load check the out-of-plane shear stress – refer to Section 5

**Fire, sound attenuation etc:**

**Step 9:** Check that the wall satisfies all other requirements in terms of durability, slenderness, thickness etc.
Calculation of effective eccentricity when designing for compression:

AS 3600 Clause 11.5.2 permits the calculation of eccentricity of applied vertical loads at the top of walls as follows:

- The minimum eccentricity shall be 0.05\( t \)
- The vertical load transmitted to a wall by a discontinuous concrete floor or roof shall be assumed to act at one third of the bearing depth measured from the span face of the wall.
- Where there is an insitu concrete floor or roof continuous over the wall, the load shall be assumed to act at the center of the wall.
- It is recommended by the author that if the continuous slab has different spans on each side of the wall then each side of the floor or roof shall be taken as being individually supported on half the total bearing area.

It also permits the assumption that the eccentricity of aggregated load from all floors above the floor at the top of the wall being designed is zero.

Examples of how to calculate the effective eccentricity using the above:
Examples of how to calculate the effective eccentricity using the above:

\[ e = \frac{(P_4 - P_2) \times 67}{P_3 + P_2 + P_4} \]

\[ e = \frac{(P_1 + \text{self wt of wall}) - \text{Load}}{P_3 + P_2 + P_4} \]

\[ e = \frac{t_a}{3} = 58 \text{mm} \]

\[ e = \frac{t_a}{6} = 19 \text{mm} \]
### TABLE W1-140U
Effective height factor $k = 0.75$

15MPa Blocks
20MPa Core fill ($f'_c = 20$MPa)
Rotational restraint both ends of wall panel

<table>
<thead>
<tr>
<th>$H_0$ or $L_0$</th>
<th>$H_{mn}$</th>
<th>SR</th>
<th>$e_a$</th>
<th>Design ultimate strength $\phi N_u$ (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$e = 5.7$mm</td>
</tr>
<tr>
<td>2000</td>
<td>1500</td>
<td>13.2</td>
<td>7.9</td>
<td>493</td>
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</tr>
<tr>
<td>2800</td>
<td>2100</td>
<td>18.4</td>
<td>15.5</td>
<td>412</td>
</tr>
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<td>2250</td>
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<td>3150</td>
<td>27.6</td>
<td>34.8</td>
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<tr>
<td>4400</td>
<td>3300</td>
<td>28.9</td>
<td>38.2</td>
<td>166</td>
</tr>
</tbody>
</table>

**Notes**

Use this table to determine the design axial strength ($\phi N_u$) for a wall of any clear height that does not exceed the slenderness ratio limit set in AS 3600:2009. Note that the slenderness ratio limit for walls is 30 (refer AS 3600 Clause 11.5) and this table is curtailed at that slenderness ratio.

5.7mm is the minimum design eccentricity for any un chamfered 140 Pronto Block wall. Linear interpolation may be used for any intermediate values of design eccentricity.

When using this table ensure that the ends of the wall panel (the top and bottom end) are restrained rotationally. Insitu slabs at top and bottom are considered to provide rotational restraint.

The tabulated values of $\phi N_u$ account for the reduction in axial load resulting from the additional eccentricity ($e_a$) due to slenderness effects. The value of $e_a$ for each wall height is tabulated.

A capacity reduction factor ($\phi$) of 0.6 has been used when calculating the tabulated strengths.
TABLE W2-140U
Effective height factor $k = 0.75$

20MPa Blocks
20MPa Core fill ($f'_c = 20$MPa)
Rotational restraint both ends of wall panel

<table>
<thead>
<tr>
<th>$H_w$ or $L_w$</th>
<th>$H_{mn}$</th>
<th>SR</th>
<th>$e_a$</th>
<th>Design ultimate strength $\bar{N}$ (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$e = 5.7mm$</td>
</tr>
<tr>
<td>2000</td>
<td>1500</td>
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<td>11.4</td>
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<tr>
<td>4200</td>
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<td>4400</td>
<td>3300</td>
<td>28.9</td>
<td>38.2</td>
<td>221</td>
</tr>
</tbody>
</table>

Notes

Use this table to determine the design axial strength ($\bar{N}$) for a wall of any clear height that does not exceed the slenderness ratio limit set in AS 3600:2009. Note that the slenderness ratio limit for walls is 30 (refer AS 3600 Clause 11.5) and this table is curtailed at that slenderness ratio.

5.7mm is the minimum design eccentricity for any unchamfered 140 Pronto Block wall. Linear interpolation may be used for any intermediate values of design eccentricity.

When using this table ensure that the ends of the wall panel (the top and bottom end) are restrained rotationally. Insitu slabs at top and bottom are considered to provide rotational restraint.

The tabulated values of $\bar{N}$ account for the reduction in axial load resulting from the additional eccentricity ($e_a$) due to slenderness effects. The value of $e_a$ for each wall height is tabulated.

A capacity reduction factor ($\varnothing$) of 0.6 has been used when calculating the tabulated strengths.
**TABLE W3-140U**

Effective height factor \( k = 1.0 \)

15MPa Blocks
20MPa Core fill \( (f'_c = 20 \text{MPa}) \)
No rotational restraint both ends of wall panel (just lateral restraint)

<table>
<thead>
<tr>
<th>( H_o ) or ( L_o )</th>
<th>( H_e )</th>
<th>SR</th>
<th>( e_a )</th>
<th>Design ultimate strength ( \varnothing N_u ) (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( e = 5.7 \text{mm} )</td>
</tr>
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<td>2000</td>
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<td>17.0</td>
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<td>40.6</td>
<td>141</td>
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**Notes**

Use this table to determine the design axial strength \( (\varnothing N_u) \) for a wall of any clear height that does not exceed the slenderness ratio limit set in AS 3600:2009. Note that the slenderness ratio limit for walls is 30 (refer AS 3600 Clause 11.5) and this table is curtailed at that slenderness ratio.

5.7mm is the minimum design eccentricity for any un chamfered 140 Pronto Block wall. Linear interpolation may be used for any intermediate values of design eccentricity.

This table is for walls in which the ends are only restrained laterally and not rotationally. Ensure always that there is adequate connection between the walls and the roof or floor slabs to provide such restraint (refer AS 3600 Clause 11.3)

The tabulated values of \( \varnothing N_u \) account for the reduction in axial load resulting from the additional eccentricity \( (e_a) \) due to slenderness effects. The value of \( e_a \) for each wall height is tabulated.

A capacity reduction factor \( (\varnothing) \) of 0.6 has been used when calculating the tabulated strengths.
TABLE W4-140U

Effective height factor $k = 1.0$

20MPa Blocks
20MPa Core fill ($f'_{c} = 20$MPa)
No rotational restraint both ends of wall panel (just lateral restraint)

<table>
<thead>
<tr>
<th>$H_e$ or $L_e$</th>
<th>$H_m$</th>
<th>SR</th>
<th>$e_a$</th>
<th>$\phi N_u$ (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$e = 5.7\text{mm}$</td>
</tr>
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<td>2000</td>
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</tr>
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<td>29.8</td>
<td>40.6</td>
<td>187</td>
</tr>
</tbody>
</table>

Notes

Use this table to determine the design axial strength ($\phi N_u$) for a wall of any clear height that does not exceed the slenderness ratio limit set in AS 3600:2009. Note that the slenderness ratio limit for walls is 30 (refer AS 3600 Clause 11.5) and this table is curtailed at that slenderness ratio.

5.7mm is the minimum design eccentricity for any unchamfered 140 Pronto Block wall. Linear interpolation may be used for any intermediate values of design eccentricity.

This table is for walls in which the ends are only restrained laterally and not rotationally. Ensure always that there is adequate connection between the walls and the roof or floor slabs to provide such restraint (refer AS 3600 Clause 11.3).

The tabulated values of $\phi N_u$ account for the reduction in axial load resulting from the additional eccentricity ($e_a$) due to slenderness effects. The value of $e_a$ for each wall height is tabulated.

A capacity reduction factor ($\phi$) of 0.6 has been used when calculating the tabulated strengths.
**DIAGRAM 2.1:**

Refer AS 3600 Clauses 11.4b) and 11.4c)
## TABLE W5-140U

15MPa Blocks
20MPa Core fill ($f' = 20$MPa)

<table>
<thead>
<tr>
<th>SR</th>
<th>$e_a$</th>
<th>Design ultimate strength $\Omega N_u$ (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$e = 5.7$mm</td>
</tr>
<tr>
<td>12</td>
<td>10.0</td>
<td>508</td>
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<td>13</td>
<td>11.8</td>
<td>495</td>
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<td>62.6</td>
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</tbody>
</table>

**Notes**

- Use this table to determine the design axial strength ($\Omega N_u$) for a wall of any clear height that does not exceed the slenderness ratio limit set in AS 3600:2009. Note that the slenderness ratio limit for walls is 30 (refer AS 3600 Clause 11.5) and this table is curtailed at that slenderness ratio.

- 5.7mm is the minimum design eccentricity for any unchamfered 140 Pronto Block wall. Linear interpolation may be used for any intermediate values of design eccentricity.

- This table is provided design engineers that are checking walls subjected to two-way buckling. It is valid also for walls subjected to one-way buckling but Tables W1 – W4 are more convenient for checking such walls. The tabulated values of $\Omega N_u$ account for the reduction in axial load resulting from the additional eccentricity ($e_a$) due to slenderness effects. The value of $e_a$ for each wall height is tabulated.
### TABLE W6-140U

20MPa Blocks  
20MPa Core fill ($f'_c = 20$MPa)

<table>
<thead>
<tr>
<th>SR</th>
<th>$e_a$</th>
<th>140 Pronto Block (unchamfered)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Design ultimate strength $\varnothing N_u$ (kN/m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$e = 5.7$mm</td>
</tr>
<tr>
<td>12</td>
<td>6.6</td>
<td>677</td>
</tr>
<tr>
<td>13</td>
<td>7.7</td>
<td>661</td>
</tr>
<tr>
<td>14</td>
<td>8.9</td>
<td>643</td>
</tr>
<tr>
<td>15</td>
<td>10.3</td>
<td>624</td>
</tr>
<tr>
<td>16</td>
<td>11.7</td>
<td>603</td>
</tr>
<tr>
<td>17</td>
<td>13.2</td>
<td>582</td>
</tr>
<tr>
<td>18</td>
<td>14.8</td>
<td>559</td>
</tr>
<tr>
<td>19</td>
<td>16.5</td>
<td>535</td>
</tr>
<tr>
<td>20</td>
<td>18.2</td>
<td>509</td>
</tr>
<tr>
<td>21</td>
<td>20.1</td>
<td>482</td>
</tr>
<tr>
<td>22</td>
<td>22.1</td>
<td>454</td>
</tr>
<tr>
<td>23</td>
<td>24.1</td>
<td>424</td>
</tr>
<tr>
<td>24</td>
<td>26.3</td>
<td>393</td>
</tr>
<tr>
<td>25</td>
<td>28.5</td>
<td>361</td>
</tr>
<tr>
<td>26</td>
<td>30.8</td>
<td>328</td>
</tr>
<tr>
<td>27</td>
<td>33.2</td>
<td>293</td>
</tr>
<tr>
<td>28</td>
<td>35.8</td>
<td>257</td>
</tr>
<tr>
<td>29</td>
<td>38.3</td>
<td>219</td>
</tr>
<tr>
<td>30</td>
<td>41.0</td>
<td>181</td>
</tr>
</tbody>
</table>

**Notes**

Use this table to determine the design axial strength ($\varnothing N_u$) for a wall of any clear height that does not exceed the slenderness ratio limit set in AS 3600:2009. Note that the slenderness ratio limit for walls is 30 (refer AS 3600 Clause 11.5) and this table is curtailed at that slenderness ratio.

5.7mm is the minimum design eccentricity for any unchamfered 140 Pronto Block wall. Linear interpolation may be used for any intermediate values of design eccentricity.

This table is provided design engineers that are checking walls subjected to two-way buckling. It is valid also for walls subjected to one-way buckling but Tables W1 – W4 are more convenient for checking such walls.

The tabulated values of $\varnothing N_u$ account for the reduction in axial load resulting from the additional eccentricity ($e_a$) due to slenderness effects. The value of $e_a$ for each wall height is tabulated.
section 3. Design of walls in bending

This section is for the design of walls subjected to out-of-plane lateral loads only however it can also be used for the design of walls subjected to only small axial compression loads where the stress at mid-height due to bending and compression does not exceed the lesser of 0.03$f_c'$ and 2MPa (Refer AS 3600 Clause 11.1b)

Reinforcing bar positions

The location of all reinforcement in Pronto Block walls is controlled by the notches in the connectors that support the horizontal bars. The 140 mortarless connectors have three notches, and the bar positions are described as V1, V2, H1 and H2 as shown in the following sketches. Positions V1 and H1 are located furthest from the neutral axis, while positions V2 and H2 are located closest to the neutral axis. These positions are referred to in the moment capacity tables below.

[Diagram of wall with bar positions H1, V1, H2, V2]
Bar position H1 for load on side B

Bar position H1 for load on side A
Design Procedure: Bending

Out-of-plane bending (walls):

Step 1: Calculate ultimate limit state design bending moment.

Step 2: Select a Pronto Block size and strength (grade) based on local availability and any other requirements (fire rating, sound rating, thermal rating etc).

Step 3: Using Table 3.1 determine the reinforcement size, spacing and location that will give a bending moment capacity equal to or greater than the design bending moment.

Ensure the bar positions (vertical and/or horizontal) are specified on the drawings. Note that when the vertical bars are required to be in any of the four possible locations it is necessary to specify the appropriate horizontal bar positions. The horizontal bars are used to guide the vertical bars into their correct location and to support them in that location throughout the height of the wall – refer to the sections on pages 74-75.

In-plane bending (beams):

Step 1: Calculate ultimate limit state design bending moment.

Step 2: Using Table 3.2 or 3.3 determine the reinforcement requirement noting that these tables can be used for checking both the positive and the negative bending moment reinforcement requirements.
Bending moment capacities for Pronto Block walls subject to out-of-plane loads

**TABLE 3.1:**

| Block Grade & Reinforcement ($f_y = 500\text{MPa}$) | 140 Pronto Block (unchamfered) |  |  |  |  |  |  |  |
|-----------------------------------------------|--------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                                               |                                | Vertical bending | Horizontal bending |
|                                               | $A_s$ mm$^2$/m | $A_{sd}$ mm$^2$/m | bars in position V1 $d = 71$ | $A_{sd}$ mm$^2$/m | bars in position V2 $d = 57$ | $A_{sd}$ mm$^2$/m | bars in position H1 $d = 74$ | $A_{sd}$ mm$^2$/m | bars in position H2 $d = 57$ |
| Grade 15 blocks 20MPa Grout                    |                                 |                |               |               |               |                |                |
| N12-300 avg.                                  | 367                            | 367            | 10.8          | 350           | 8.0            | 367            | 11.4           | 350            | 8.0            |
| N12-400                                       | 275                            | 275            | 8.5           | 275           | 6.6            | 275            | 8.9            | 275            | 6.6            |
| N12-600                                       | 183                            | 183            | 6.0           | 183           | 4.7            | 183            | 6.2            | 183            | 4.7            |
|                                               |                                 |                |               |               |               |                |                |                |                |
| N16-200                                       | 1000                           | 440            | 12.5          | 350           | 8.0            |                |                |
| N16-400                                       | 500                            | 440            | 12.5          | 350           | 8.0            |                |                |
| N16-600                                       | 333                            | 333            | 10.0          | 333           | 7.7            |                |                |
| Grade 20 blocks 20MPa Grout                    |                                 |                |               |               |               |                |                |
| N12-200                                       | 550                            | 550            | 15.8          | 470           | 10.7           | 550            | 16.7           | 470            | 10.7           |
| N12-400                                       | 275                            | 275            | 8.8           | 275           | 6.9            | 275            | 9.3            | 275            | 6.9            |
| N12-600                                       | 183                            | 183            | 6.1           | 183           | 4.8            | 183            | 6.4            | 183            | 4.8            |
|                                               |                                 |                |               |               |               |                |                |                |                |
| N16-200                                       | 1000                           | 580            | 16.5          | 470           | 10.7           |                |                |
| N16-400                                       | 500                            | 500            | 14.7          | 470           | 10.7           |                |                |
| N16-600                                       | 333                            | 333            | 10.5          | 333           | 8.1            |                |                |

**Notes**

All reinforcement to be Grade 500 deformed bars.

The tabulated values have been calculated in accordance with AS 3600 Clause 8.1.

$A_s$ is the area of tensile reinforcement installed in the wall.

$A_{sd}$ is the area of tensile reinforcement used for design of the section.

The tabulated bending moment capacities include all of the applicable capacity reduction factors.

It is recommended that N16-200 be specified with caution as the sections are over reinforced. This applies also to all other capacities where the $A_{sd}$ box is dark shaded.
Bending moment capacities for Pronto Block beams

**TABLE 3.2: Beams with one bar in the bottom course**

<table>
<thead>
<tr>
<th>15 MPa</th>
<th>$D \times B$</th>
<th>$d$</th>
<th>Bending moment capacity (kNm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1N12 bottom</td>
</tr>
<tr>
<td>2 course beam</td>
<td>400 x 140</td>
<td>230</td>
<td>12.5</td>
</tr>
<tr>
<td>3 course beam</td>
<td>600 x 140</td>
<td>430</td>
<td>23.5</td>
</tr>
<tr>
<td>4 course beam</td>
<td>800 x 140</td>
<td>630</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 3.3: Beams with one bar in the bottom course**

<table>
<thead>
<tr>
<th>20 MPa</th>
<th>$D \times B$</th>
<th>$d$</th>
<th>Bending moment capacity (kNm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1N12 bottom</td>
</tr>
<tr>
<td>2 course beam</td>
<td>400 x 140</td>
<td>230</td>
<td>12.5</td>
</tr>
<tr>
<td>3 course beam</td>
<td>600 x 140</td>
<td>430</td>
<td>23.5</td>
</tr>
<tr>
<td>4 course beam</td>
<td>800 x 140</td>
<td>630</td>
<td></td>
</tr>
</tbody>
</table>
Section 4.

Design of Pronto Block Walls for Axial Compression Combined with Out-of-Plane Bending

Section 2 of this manual deals with the design of walls for axial compression loads where the axial load capacity is determined in accordance with the simplified design method outlined in AS 3600 Clause 11.5. The tabulated values in Section 2 take into account both the design eccentricity of the axial load and the additional eccentricity resulting from slenderness.

Walls can also be subjected to out-of-plane lateral loads however that may increase the design bending moments. While axial compression loads can increase the moment capacity of a wall it is important to check that the increased design compressive stress in the extreme fibre of the concrete section does not exceed the permissible stress when the wall is subjected to the combined action.

In this section of the design manual, interaction diagrams are provided for the purpose of checking combined bending and compression. These diagrams can be used to determine whether or not a critical section is overstressed due to the combined action.

There is no provision in AS 3600 for checking combined bending and compression using the simplified design method. The simplified design method takes into account the design bending moment due to eccentricity of the applied load at the top of the wall panel and it also takes into account the additional design bending moment due to slenderness effects but there is no provision for adding in any additional bending moment resulting from out-of-plane lateral load.

When using the interaction diagrams it is very important to remember that the minimum design bending moment at any cross section is $N^* \times 0.05t_d$, i.e. the bending moment that corresponds to a minimum 5% design eccentricity.

The reinforcement requirements for the wall panel can be determined using the interaction diagrams.

### Design Procedure: Combined Axial Compression and Bending (One-Way Buckling)

This design procedure is for walls spanning vertically.

**Step 1:** Select a Pronto Block size and strength (grade) based on local availability and any other requirements (fire rating, sound rating, thermal rating etc).

**Step 2:** Carry out a structural analysis for all applicable load combinations to determine the ultimate limit state design compression load on the wall and the ultimate limit state design bending moments at the critical sections including the bending moments from slenderness effects and the bending moments from out-of-plane lateral loads.

**Step 3:** Use the interaction diagrams (Diagrams 4.1 and 4.2 on the following pages) to check that the selected reinforcement is adequate. Enter the interaction diagram with the design axial load ($N^*$) on the Y axis and read off the maximum design bending moment ($M^*$) on the X axis. Check that the actual design bending moment is less than or equal to the maximum design bending moment.

**Step 4:** If the wall is subject to in-plane lateral load check the adequacy of the wall for shear – refer to Section 5. It might also be necessary to check the wall panel for in-plane bending - Refer 9.1 in Part 1.

**Step 5:** If the wall is subjected to substantial out-of-plane lateral load check the out-of-plane shear stress – refer to Section 5

**Fire, Sound Attenuation etc:**

**Step 6:** Check that the wall satisfies all other requirements in terms of durability, slenderness, thickness etc.
**Notes**

This interaction diagram is to be used for checking the adequacy of any critical cross section for the combined action of compression and out-of-plane bending.

A compressive stress of $0.85f'_c$ was used for the rectangular stress block when calculating the values in the above diagram. This is not compatible with the values in Tables W1-200U – W4-200U that were prepared using the simplified design method for walls in vertical compression and in which the compressive stress in the rectangular stress block was just $0.6f'_c$.

When using this diagram use bending moments derived from a structural analysis which include the additional bending moments due to slenderness effects. Do not use the bending moments calculated using the simplified approach.

Always ensure that the axial compression load used when checking for reinforcement requirements is the minimum sustained design axial compression load.

When using the chart enter with the design axial compression load $N^*$ and read off the maximum design bending moment $M^* = \varnothing M_u$.

Ensure that the vertical reinforcement is placed in the tension face of the wall in all cases.
Notes

This interaction diagram is to be used for checking the adequacy of any critical cross section for the combined action of compression and out-of-plane bending.

A compressive stress of $0.85 f'_c$ was used for the rectangular stress block when calculating the values in the above diagram. This is not compatible with the values in Tables W1-200U – W4-200U that were prepared using the simplified design method for walls in vertical compression and in which the compressive stress in the rectangular stress block was just $0.6 f'_c$.

When using this diagram use bending moments derived from a structural analysis which include the additional bending moments due to slenderness effects. Do not use the bending moments calculated using the simplified approach.

Always ensure that the axial compression load used when checking for reinforcement requirements is the minimum sustained design axial compression load.

When using the chart enter with the design axial compression load $N^*$ and read off the maximum design bending moment $M^* = \phi M_u$.

Ensure that the vertical reinforcement is placed in the tension face of the wall in all cases.
section 5.
Design of Pronto Block Walls for shear

Load-bearing walls are mostly designed to carry axial compression loads, however in many load bearing wall structures they are also designed to carry the lateral loads arising from wind, earthquake etc, i.e. they are designed as shear walls. Diagrams 5.1 and 5.2 in this Section provide a means of readily checking the capacity of a wall to take in-plane shear. The design strength of the wall is the sum of the values obtained from the two diagrams. It is necessary to use the correct reinforcement area when using Diagram 5.2 and this is explained in the notes below the diagram.

Load-bearing walls can also be subjected to out of plane lateral loads, a typical example being a retaining wall designed to carry earth pressure loads. These walls may need to be checked for transverse shear loads at critical sections and Diagrams 5.3 and 5.4 in this Section are provided to make this task very easy. It can readily be seen in the diagram that the transverse shear capacity increases as the axial load N increases.

Reinforced Pronto Block is also often used as lintel beams and the like to span across openings. These members need to be designed for shear the same as any reinforced concrete beam and Tables 5.1 and 5.2 in this Section make it very easy to check the shear capacity of Pronto Block beams.

---

**Design Procedure: Shear**

**In-Plane Shear (Shear Walls):**

**Step 1:** Calculate ultimate limit state design shear force on the wall panel.

**Step 2:** Determine the shear strength of the wall panel (excluding the contribution from reinforcement) using Diagram 5.1. Note that the value obtained from Diagram 5.1 is the shear capacity per linear metre of the wall panel length, so simply multiply the value obtained from the Diagram by the length in metres to obtain the total shear capacity.

**Step 3:** Determine the contribution to shear strength of the wall reinforcement using Diagram 5.2. Again note that this gives the shear strength per linear metre and note that all reinforcement used when determining a value from this diagram must be anchored beyond the critical section.

**In-Plane Shear (Beams):**

**Step 1:** Calculate ultimate limit state design shear force on the beam at the critical section.

**Step 2:** Use Table 5.2 to determine whether the beam has adequate shear strength without the need for shear reinforcement. If not then proceed to Step 3.

**Step 3:** Use Table 5.2 to determine whether the beam has adequate shear strength with single leg R10 shear reinforcement. If not then select a deeper beam or use an alternative beam.

**Out-Of-Plane Shear:**

**Step 1:** Calculate ultimate limit state design shear force on the wall.

**Step 2:** Use Diagram 5.3 or 5.4 to determine the shear capacity of the wall and check that this is equal to or greater than the design shear force.
**DIAGRAM 5.1 – In-plane shear strength of Pronto Block**

shear walls excluding contribution of reinforcement

---

**Notes**

The shear strengths given in the above Diagram are kN per linear metre of wall length.

Critical section for shear is the lesser of 0.5Lw and 0.5Hw from the base of the wall (AS 3600 Clause 11.6.1).

This diagram takes no account of the contribution of the reinforcement to the shear strength.

For the contribution of reinforcement to shear strength refer Diagram 5.2.

A value of Ø=0.7 has been used in the calculations.
Notes

The shear strengths given in the above Diagram are kN per linear metre of wall length.

$A_s$ is the cross sectional area of reinforcement per metre of wall length or wall height:

- If $H_w / L_w \leq 1$ use the lesser $A_s$ of the vertical and the horizontal reinforcement.
- If $H_w / L_w > 1$ use the $A_s$ of the horizontal reinforcement.

Critical section for shear is the lesser of 0.5$L_w$ and 0.5$H_w$ from the base of the wall (Clause AS 3600 11.6.1).

This diagram takes no account of the contribution of the concrete to the shear strength.

For the contribution of concrete to shear strength refer Diagram 5.1.

A value of $\varnothing=0.7$ has been used in the calculations.
**Notes**

The shear strengths given in the above Diagram are kN per linear metre of wall length.

Vertical reinforcement must be fully anchored in the direction of diminishing bending moment.

A value of $\varnothing = 0.7$ has been used in the calculations.
DIAGRAM 5.4: Shear capacity of Pronto Block walls subject to out-of-plane lateral loads – 20MPa blocks

Notes
The shear strengths given in the above Diagram are kN per linear metre of wall length.

Vertical reinforcement must be fully anchored in the direction of diminishing bending moment.

A value of $\varnothing=0.7$ has been used in the calculations.
**TABLE 5.1: Shear capacity of 140 Pronto Block beams without shear reinforcement**

Shear reinforcement: nil

<table>
<thead>
<tr>
<th></th>
<th>Dimensions $D \times B$</th>
<th>Effective Depth $d'$</th>
<th>Maximum $V_u$ without shear reinforcement (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1N12 bottom</td>
</tr>
<tr>
<td>2 course beam</td>
<td>15MPa blocks</td>
<td>400 x 140</td>
<td>235</td>
</tr>
<tr>
<td>2 course beam</td>
<td>20MPa blocks</td>
<td>400 x 140</td>
<td>235</td>
</tr>
<tr>
<td>3 course beam</td>
<td>15 MPa blocks</td>
<td>600 x 140</td>
<td>435</td>
</tr>
<tr>
<td>3 course beam</td>
<td>20 MPa blocks</td>
<td>600 x 140</td>
<td>435</td>
</tr>
<tr>
<td>4 course beam</td>
<td>15 MPa blocks</td>
<td>800 x 140</td>
<td>635</td>
</tr>
<tr>
<td>4 course beam</td>
<td>20 MPa blocks</td>
<td>800 x 140</td>
<td>635</td>
</tr>
</tbody>
</table>

**TABLE 5.2: Shear capacity of 140 Pronto Block beams with shear reinforcement**

Shear reinforcement: R10-200

<table>
<thead>
<tr>
<th></th>
<th>Dimensions $D \times B$</th>
<th>Effective Depth $d'$</th>
<th>Maximum $V_u$ with R10-200 shear reinforcement (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1N12 bottom</td>
</tr>
<tr>
<td>2 course beam</td>
<td>15MPa blocks</td>
<td>400 x 140</td>
<td>235</td>
</tr>
<tr>
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</tr>
<tr>
<td>3 course beam</td>
<td>15 MPa blocks</td>
<td>600 x 140</td>
<td>435</td>
</tr>
<tr>
<td>3 course beam</td>
<td>20 MPa blocks</td>
<td>600 x 140</td>
<td>435</td>
</tr>
<tr>
<td>4 course beam</td>
<td>15 MPa blocks</td>
<td>800 x 140</td>
<td>635</td>
</tr>
<tr>
<td>4 course beam</td>
<td>20 MPa blocks</td>
<td>800 x 140</td>
<td>635</td>
</tr>
</tbody>
</table>
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