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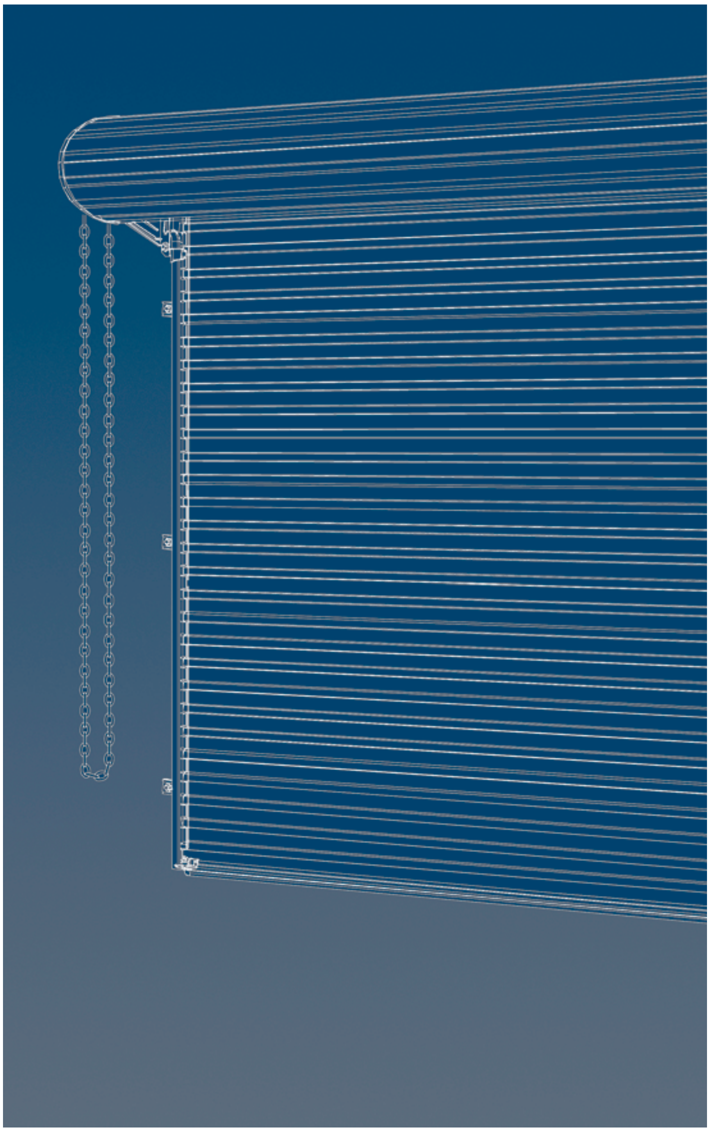

A method for estimating in-plane forces on roller shutter door guides

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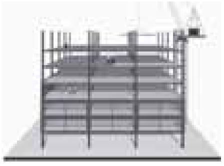
STEEL CONSTRUCTION—EDITORIAL



The behaviour and operation of roller shutter doors under significant wind load events is not well understood by industry. Whilst windlocks are commonly specified on roller shutter doors in high wind zones, their use introduces a close coupling in behaviour between the door and the building structure that supports the door frame. The form of the coupling, which includes both strength and stiffness considerations, may not be obvious, particularly to novice designers, who have no real understanding of what windlocks do, the substantial catenary loads that need to be resolved into the supporting structure or the effect of the stiffness of the building structure on the performance of the roller shutter.

This issue of Steel Construction presents a paper by George Haddad and Dr Scott Woolcock that is a significant and timely addition to the body of knowledge on this subject. It is relevant to industry in general and designers in particular.

Having spent many years in the design and construction of large industrial buildings including hangars in typhonic/cyclonic zones in Asia and Australia, I can first hand attest to the need for raising awareness and providing solutions for our steel community. A real bonus for designers is the inclusion of worked examples to illustrate the proposed methodologies.

George Haddad graduated from the Queensland University of Technology in 1997 and commenced working as a structural engineer for CMPS & F, before joining Bonacci Winward where he was responsible for the design of commercial and industrial buildings including Department of Defence workshops and hangars. In 2011, George became co-author of the fourth edition of the book "Design of Portal Frame Buildings" and is currently an Associate with Bonacci Group (Qld).

Dr Scott Woolcock is a consulting engineer with 42 years' experience in structural and civil design on a wide range of projects including defence, mining, aircraft hangars, heavy industrial, water treatment structures and busways. He is a former Director of Bonacci Group (Qld). Scott is the principal author of the ASI published book "*Design of Portal Frame Buildings*" and was a member of the Standards Australia Committee for the 2011 wind code AS/NZS 1170.2.

The authors wish to thank their colleague Chris Eden for preparing the diagrams.

Dr Peter Key
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AUSTRALIAN STEEL INSTITUTE

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Contributions of original papers or reports on steel design, research and allied technical matters are invited from readers for possible publication. The views expressed in these papers are those of the authors and do not necessarily reflect the views of the ASI. Submissions should be in Microsoft Word including all diagrams and equations in full page format, using Arial font (size 10 point). A clean printout should also be forwarded.

LIGHTWEIGHT STEEL STRUCTURES AND ROLLER DOORS—AN UPDATE

Lightweight steel structures utilising high strength cold–formed steel sections, while commonly used for domestic garages, are becoming increasing popular for use as light industrial, commercial and institutional buildings.

A high proportion of lightweight steel structures (sheds) have roller doors installed and a high level of roller door failures for both cyclonic and non-cyclonic wind events has been documented over recent years in reports by the James Cook University Cyclone Testing Station (refer: www.jcu.edu.au/cts/).

The recent revision of standard AS/NZS 4505 provides information that will greatly assist designers and suppliers in the specification and correct supply of roller doors of equal specification to the building for which it is intended to be installed.

Over recent years, the use of windlocks in higher wind areas has become more prevalent to minimise door failures. The use of windlocks on roller doors has the effect of transferring very considerable loads into the door mullions. Door frames that do not have these loads considered in the design are very likely to fail when subjected to them.

The Australian Building Codes Board will be regulating roller doors in Cyclonic Wind Regions C and D from May 2013 and all doors supplied in those regions will be required to meet AS/NZS 4505.

The following journal provides excellent detail on the correct design of door frames and should prove a valuable resource for designers and suppliers.

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A METHOD FOR ESTIMATING IN-PLANE FORCES ON ROLLER SHUTTER DOOR GUIDES

by

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SUMMARY This paper provides a detailed understanding of the performance requirements and design implications for roller shutter door guides, highlighting in particular the coupling of the behaviour of the roller shutter and that of the door guide support structure when windlocks are present. Two worked examples are presented.

1 INTRODUCTION

Roller shutter doors are widely used but their behaviour and strength under design wind loads appear to have been generally overlooked by engineers, architects and specifiers. By their nature, roller shutters have limited bending stiffness and they tend to deflect significantly under high wind loads. The consequence of this is that they often pull out of their guides in storms or cyclones. Windlocks are sometimes specified in the belief that this will prevent the doors pulling out of their guides, but the in-plane forces generated can be large and engineers or specifiers pay little or no attention to the strength of the guides, door jambs and fixings.

Whether windlocks are fitted or not, door guides are frequently just tack welded to steel jambs or they are fixed to masonry supports in a token manner. The fixings are rarely shown on design drawings and certification of design and installation by the manufacturer or engineer is virtually non-existent.

The issue for designers lies not only in the design of the door and the support structure, but also in the design of the building as a whole because internal pressures (or suctions) in the building can increase substantially once failure of the door occurs. Whilst a designer may acknowledge that roller shutter doors will be securely closed during a strong wind, if low internal pressures have been used in the design, verification is required to ensure that the doors do not blow open for the design to be valid.

A conservative method often used by engineers is to assume that the roller doors will blow in and design the structure for larger internal pressures and suctions. Whilst this is an acceptable approach, it leads to a less economical design. Designers must also realise that in using this design approach, there is a risk of damage to property or contents and a risk of injury from flying debris.

AS/NZS 4505:1998 [1] for domestic garage doors, is often thought to have addressed the issue of roller door design but unfortunately it stops short of specifically addressing the in-plane loading that occurs. Furthermore, Reference 2 has identified that the wind pressures derived from Reference 1 are lower than the wind pressures obtained from either AS 4055—2006 [3] or AS/NZS 1170.2:2002 [4] and consequently some roller doors under wind loading are reported to have been failing at wind pressures lower than the design wind pressure adopted for the building.

In the United States, the Door and Access Systems Manufacturers Association International (or *DASMA*) appears to have addressed the issue somewhat, by releasing a technical data sheet #*251* [5] that highlights the “catenary effect” that designers need to be aware of. Unfortunately, the data sheet does not provide a methodology for designers to use to determine in-plane loads and throws the responsibility to the manufacturer. *DASMA* however, does provide a product certification program as a means for manufacturers to certify the performance ratings of doors. By satisfying each criterion, the manufacturer’s door can then be endorsed by *DASMA* and thus be certified for a particular wind load and application. Figure 1, for example, shows a manufacturer’s roller shutter door being tested to failure under wind loading in a testing facility.

If a building owner is prepared to pay to protect his or her windows and to fit windlocks to roller shutter doors, then it is reasonable to expect that the door guides and their supporting structures will be structurally adequate. Recent reports prepared by the Cyclone Testing Station for Cyclones Larry [6], George [7] and Yasi [8] have shown that deficiencies do exist with much of the damage caused to buildings considered preventable had proper design, detailing and installation practices been carried out. Figures 2 and 3 for example, show the types of door damage that occurred under cyclonic wind pressures. Therefore, it is the purpose of this paper to address these issues and provide guidelines for the practicing engineer to apply appropriate design and detailing procedures.

Figure 1: Testing a roller shutter door to failure under wind.
Photo courtesy of Door and Access Systems Manufacturers Association International – *DASMA*

Figure 2: Roller door failure after Cyclone Larry.
Photo courtesy of the Cyclone Testing Station, School of Engineering, James Cook University

Figure 3: Roller shutter door failure after Cyclone Larry.
Photo courtesy of the Cyclone Testing Station, School of Engineering, James Cook University

2 TERMINOLOGY

In order to understand the behaviour of a roller shutter door under wind loading, it is important to be familiar with the basic components that make up a roller shutter door. Firstly, there is a difference between *roller doors* and *roller shutter doors*:

- Roller doors have a continuous pressed sheeting to form the curtain and tend to be used on residential and small commercial buildings. These types of doors are size-limited to approximately 5 m × 5 m and usually do not have windlocks fitted.
- *Roller shutters doors* have a series of interlocking slats to form the curtain and tend to be used on industrial buildings. Shutter type doors can be significantly larger than roller doors and unlike roller doors, should a slat or series of slats be damaged, they can usually be replaced without replacing the entire door.

In this paper, only *roller shutter doors* will be considered but the behaviour of *roller doors* can be treated similarly.

Roller shutter *slats* are available in a variety of cross-sections as shown in Figure 4 and range from 0.4 to 1.2 mm in thickness and from 75 to 130 mm in width. Steel is the most common material type for external doors, with the choice of slat cross-section and gauge thickness depending on such things as door opening size, wind pressure, environment and security. In environments where low level ventilation is required, perforated slats can be provided.

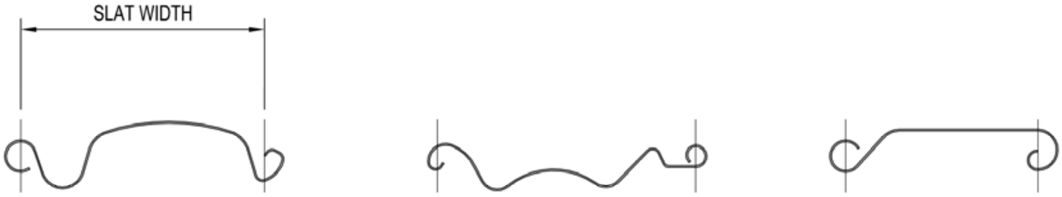

Figure 4: Typical slat profiles for roller shutter doors

At the sides of the curtain are the *guides* which hold the curtain in place by guiding it along the support structure. Guides are usually cold-formed Cee sections 3 to 4 mm thick. In some cases where the wind pressures are high, a backing angle is also provided to assist in transferring the imposed loads to the supports.

Windlocks are sometimes fitted to the ends of the slats to prevent the curtain from slipping out of the guide under wind loading and as will be explained later, windlocks change the behaviour of a door under pressure significantly. If windlocking is required, *anchor bars* located within the guide restrain the curtain by engaging the windlocks. The anchor bars are usually made of mild steel bars 20 to 65 mm wide and 8 to 10 mm thick. Depending on the manufacturer, windlocks can be fitted to every slat or intermittently up to every fourth slat.

The *roller curtain* is wound around the *roller drum* which is above the door opening. Depending on the client's requirement, roller shutter doors can be either *hand*, *chain* or *electrically* operated. There is a *drum wall bracket* at each end of the drum and the integrated components such as the gears and motor which are adjacent to one of the brackets.

At the base of the curtain is a *bottom rail* which is used to stiffen the free edge of the door. The bottom rail is usually a box or inverted Tee section with a compressible weather seal located on the underside.

Many manufacturers nominate the clearances necessary to make their doors operational and these depend on the size of the door opening. For example, should the door opening height be large, the depth and height clearances around the drum will need to be adequate for the curtain when fully wound up. Figure 5 illustrates the clearances required as well as the various components of the roller shutter door.

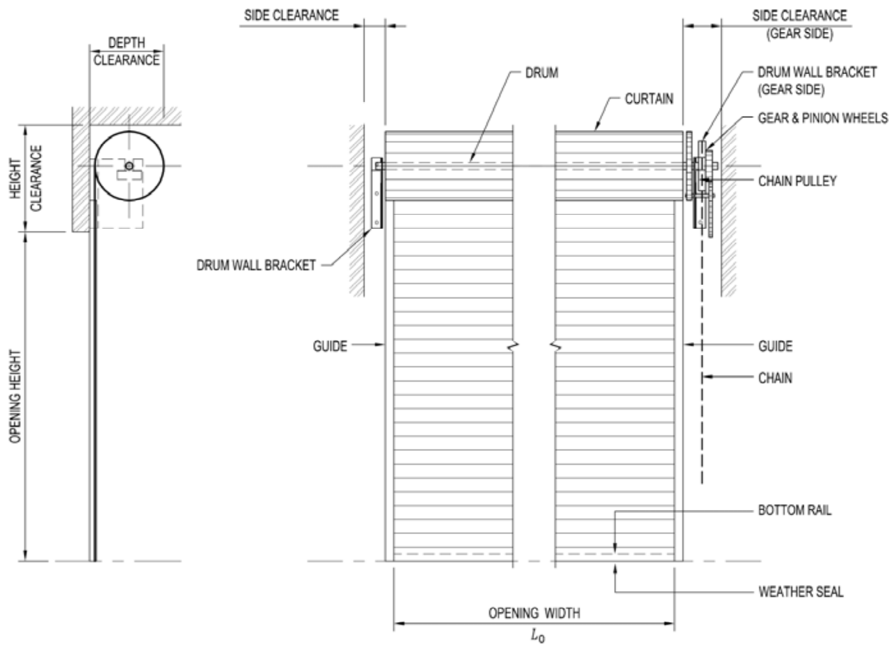

Figure 5: Typical roller shutter door cross-section and elevation

3 WINDLOCKS

The first step for a designer is to determine whether windlocks are required. Door manufacturers are able to provide some guidance on the requirement however the choice can be quite arbitrary. Some manufacturers believe that doors greater than 3 m wide should be fitted with windlocks whereas others have design charts to assist. However, what needs to be considered are the consequences of having a building secured by windlocks compared to a building without windlocks.

A building without windlocks carries the risk of the door blowing in (or out) during wind loading. This is not necessarily an adverse design condition as the designer could easily account for higher internal pressures (or suctions) in the building assuming one of many of the roller shutter doors fails. A designer needs to consider that a roller shutter "failure" may cause injury or may damage equipment or goods.

On the other hand, if windlocks are provided, the doors are secured during a wind event and lower internal pressures (or suctions) are possibly achieved. However, in providing windlocks, complexities in design and detailing the supports are introduced and whilst it is presumed the doors are secured by windlocks, it is the responsibility of the designer to ensure the supports are adequate. After careful consideration of the design and detailing aspects, there may or may not be benefit in providing windlocks. In any case, both options need to be presented to the client such that an informed decision can be made. Figure 6 shows a door guide with windlock arrangement compared to a door guide without.

It should be emphasised that a roller shutter door can be a large opening into a building and when assessed in accordance with AS/NZS 1170.2:2011 [9], it is very likely to be classed as a *dominant* opening. This means that in instances where windlocks are not provided, a designer would need to consider one or more roller shutter doors failing and determine the internal pressures (or suctions) accordingly. Most importantly, what must be realised is that wind loads do not need to be large for the curtain to pull out of the door guide. In fact, it may be thought curtain blowouts only occur in cyclonic zones whereas curtain blowouts can occur at relatively low wind pressures in non-cyclonic areas.

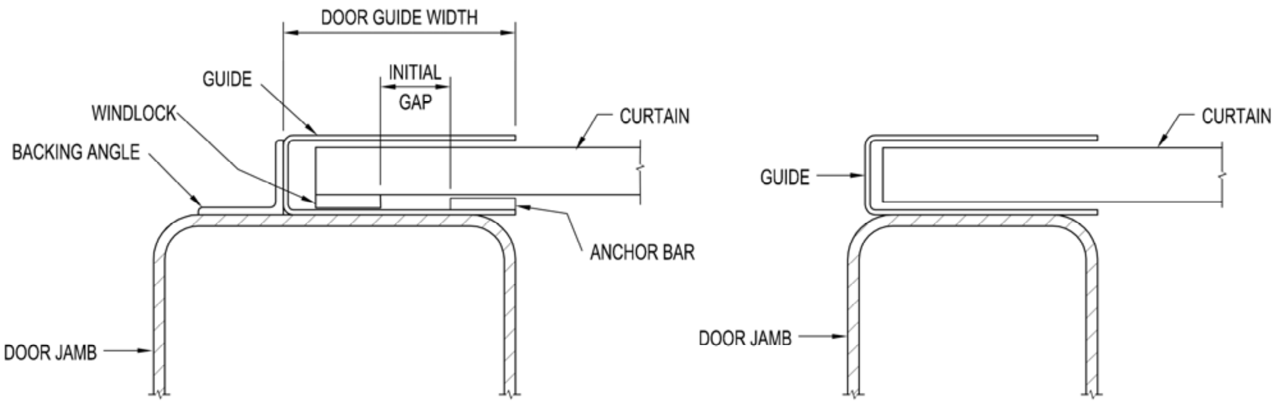

Figure 6: Roller shutter door jamb with and without windlocks

Blowout is predominantly a function of the slat bending stiffness, width of door guide and the wind pressure. Clearly, if the door guide is wide enough and strong enough, then blowout will not occur. In most circumstances however, the designer will not know what width of door guides is to be provided and as such, it is prudent to assume curtain blowout will occur if roller shutter doors are not fitted with windlocks. Figure 7 shows that even for a modest opening width of 4 metres, the pull-in within the guide can be significant.

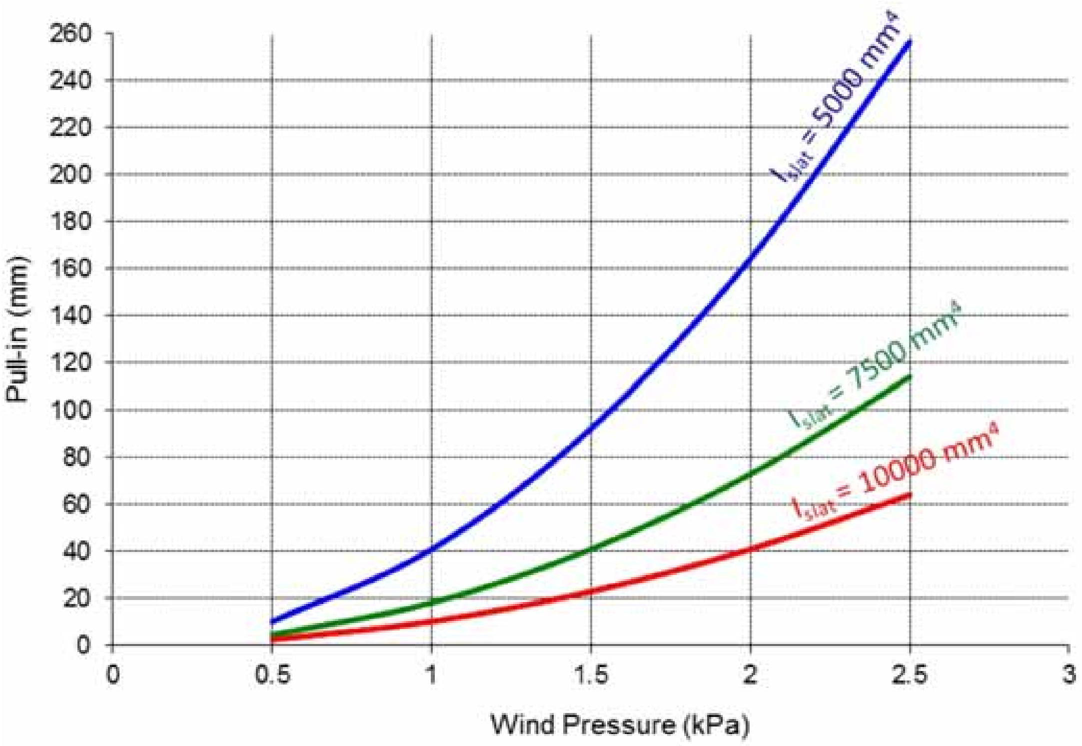

Figure 7: Pull-in within a door guide on each side, as a function of wind pressure for a 4 metre wide steel roller shutter door with three common slat stiffnesses

4 DESIGN PROCEDURE

By their very nature, roller shutter doors are flexible. The slats have limited bending stiffness and as such, curtain deflections tend to be large. With large deflections, "curvature shortening" or pull-in at the ends of the curtain occurs. When windlocks are provided, the pull-in is eventually restrained and tension within the curtain develops.

A conservative lower tier approach to determine the tension load is to treat the curtain as a "cable" by neglecting any stiffness in the slats. Whilst this may be an acceptable design method, the reality is that the stiffness of the slats can make a contribution. The draw back in using the "cable" method is that curtain tension will exist regardless of wind magnitude. In other words, at lower wind loads, the inherent stiffness of the slats is not taken advantage of with the cable method. This leads to higher curtain tension loads than would ordinarily be calculated, had the slat stiffness been accounted for.

However, in order to take advantage of the slat stiffness, it is important to ensure the manufacturer provide slats that have sufficient bending and axial capacity. The purpose of this is to ensure that the slats do not yield or locally buckle before the maximum capacity of the curtain is reached and as such, the designer will need to have this requirement specified on the drawings.

The real behaviour of a roller shutter door is a hybrid between beam flexure and cable tension. That is, as the wind pressure increases, the door flexes and the windlock slides until the *initial gap* x_i closes up and engages the anchor bar as shown in Figure 8. The pressure, for which the windlock just engages the anchor bar, is known as the c*ritical wind pressure,* p_{crit}. This is illustrated in Figure 8 which summarises the three stages of curtain deflection.

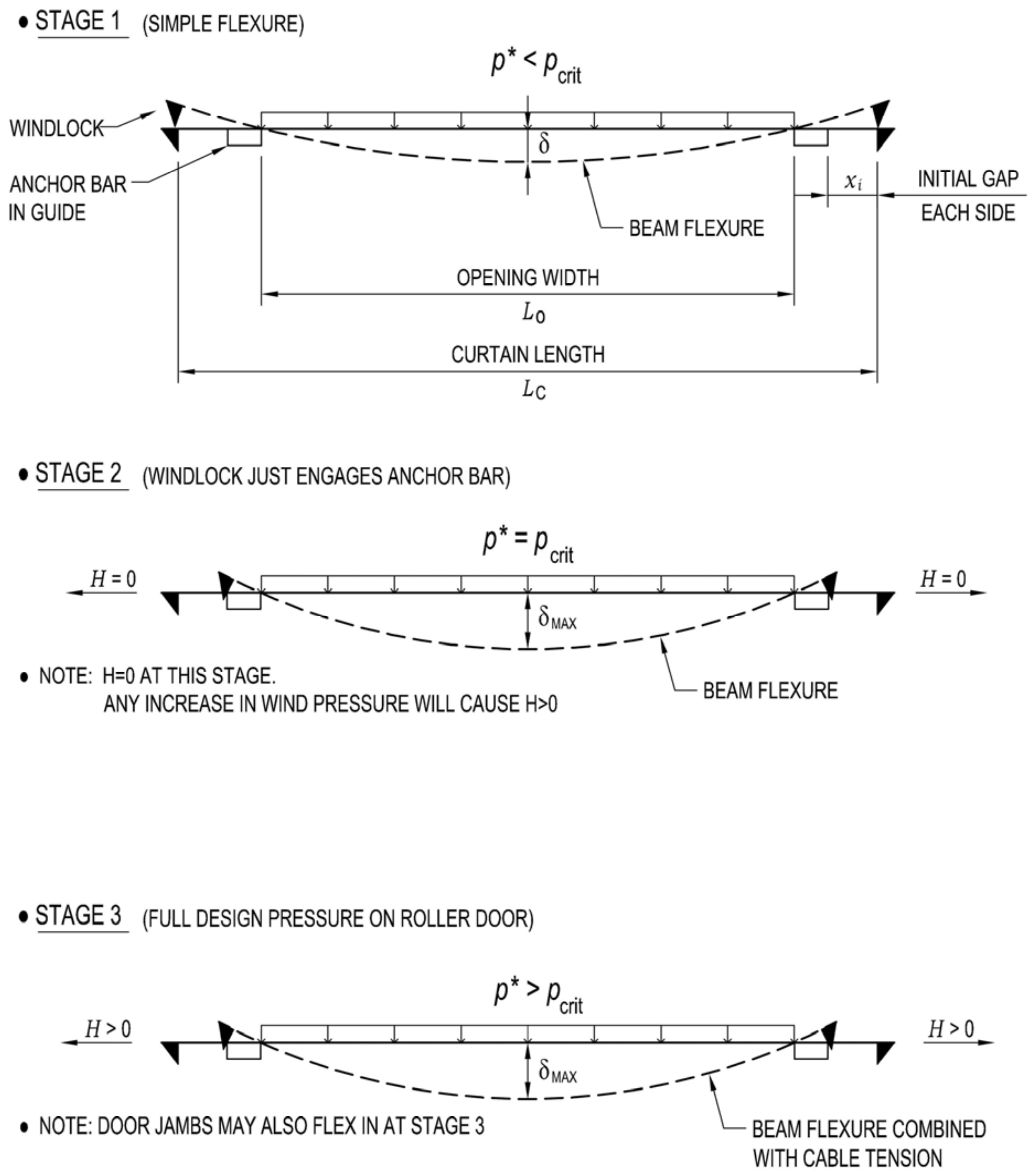

Figure 8: Stages of roller shutter curtain deflection and how in-plane loads develop

5 CALCULATIONS

Despite potentially large deflections, the calculations involved in determining the door guide forces are not difficult provided the basic variables such as design wind pressure p^*, door opening width L_o (commonly referred to as “daylight opening”) and the initial gap x_i are known. Note that an asterisk is used to indicate ultimate loads.

5.1 Doors without windlocks

In the case of doors without windlocks, the only force on the door guide will be an out-of-plane load w_y^* which is normal to the door opening. This load is simply calculated as:

$$w_y{*} = p{*}\left(\frac{L_o}{2}\right) \quad (1)$$

where $p*$ is the design wind pressure in kPa and L_o is in metres.

5.2 Doors with windlocks

If windlocks are required, both out-of-plane and in-plane forces are induced. The in-plane forces can be determined by analysing a simply supported beam shown in Figure 9 using large deflection geometry and the theory presented in Reference 10. This theory is as follows:

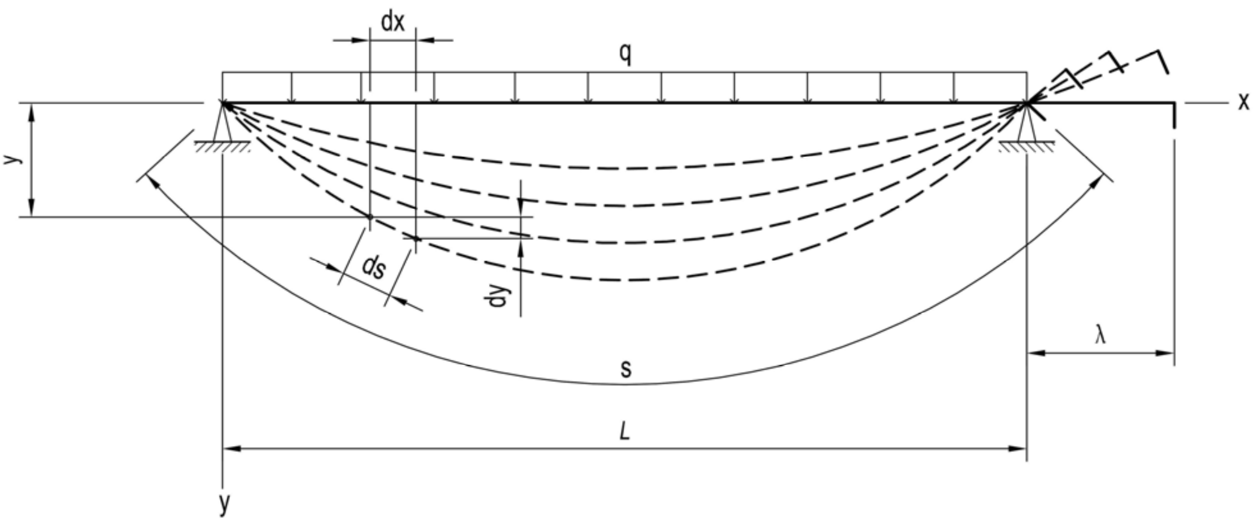

Figure 9: Increasing flexure of a simply supported beam

Consider the deflected beam curve of *length s* and the element *ds* which is measured along the curved axis of the beam. The length *ds* is the vector sum of the horizontal and vertical components *dx* and *dy* as follows:

$$ds = \sqrt{dx^2 + dy^2} = dx\sqrt{1 + \left(\frac{dy}{dx}\right)^2} \quad (2)$$

Substituting the variable *t* for $(dy/dx)^2$ and using the following binomial series for $\sqrt{1+t}$:

$$\sqrt{1+t} = 1 + \frac{t}{2} - \frac{t^2}{8} + \frac{t^3}{16} - \ldots.. \quad (3)$$

the series converges when *t* is less than 1 and if *t* is very small compared to unity, the terms in t^2 and t^3 etc… can be disregarded. Hence the term $\sqrt{1+t}$ can be approximated by:

$$\sqrt{1+t} \approx 1 + \frac{t}{2} \quad (4)$$

Re-writing Equation 2, *ds* can therefore be approximated by:

$$ds = dx\left[1 + \frac{1}{2}\left(\frac{dy}{dx}\right)^2\right] \quad (5)$$

The incremental shortening is then given by:

$$ds - dx = \frac{1}{2}\left(\frac{dy}{dx}\right)^2 dx \tag{6}$$

Integrating over the length of the beam, the expression for the curvature shortening λ can be found:

$$\lambda = \frac{1}{2}\int_0^L \left(\frac{dy}{dx}\right)^2 dx \tag{7}$$

For a simply supported beam of length L carrying a uniform distributed load *q,* the deflection *y* is given by:

$$y = \frac{qx}{24EI}\left(L^3 - 2Lx^2 + x^3\right) \tag{8}$$

and $\left(\frac{dy}{dx}\right)^2$ is given by:

$$\left(\frac{dy}{dx}\right)^2 = \frac{q^2(L^3 - 6Lx^2 + 4x^3)^2}{576E^2I^2} \tag{9}$$

Substituting into Equation 7 and integrating, the curvature shortening is given by:

$$\lambda = \frac{17L^7q^2}{40320E^2I^2} \tag{10}$$

This theory can be applied to roller shutter doors by first defining the initial gap x_i as the distance between the windlock and the anchor bar. As previously defined, L_o is the door opening width. The *effective curtain length* L_C is equal to the *curve length s* and L_B is the distance between the outer edges of the anchor bars. It should be noted that the effective curtain length is actually the distance between windlocks and this is slightly less than the overall length. Figure 10 below illustrates these terms.

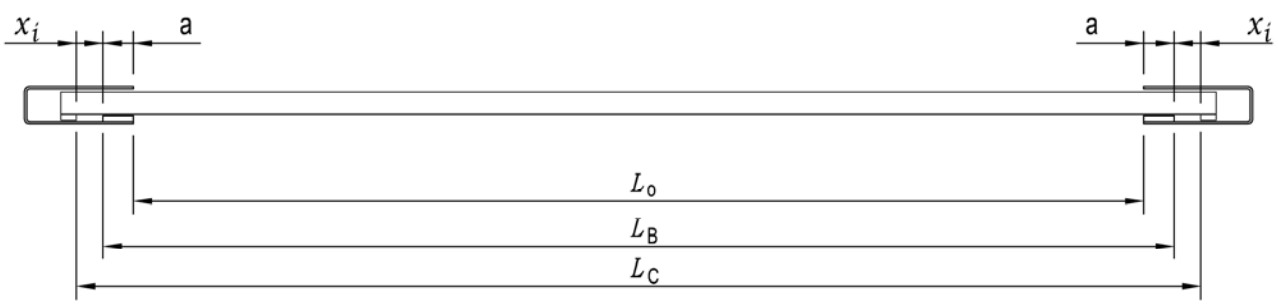

Figure 10: Curtain length definitions

Adopting the variable *a* for the anchor bar width, the effective curtain length can be calculated from $L_C = L_o + 2a + 2x_i$ and the distance between outer edges of the anchors calculated from $L_B = L_C - 2x_i$. As the beam in this case is a curtain, the applied pressure *p* can be used in lieu of the uniformly distributed load *q*. This then enables the stiffness per metre height to be used instead of the individual slat stiffness.

As $\lambda = L_C - L_B$, Equation 10 can be rearranged to determine the critical wind pressure p_{crit}. Again note that p_{crit} is the pressure that will just engage the windlock and any further pressure will start to induce tension in the curtain. Once p_{crit} has been established, the corresponding deflection of the curtain can be found.

$$p_{crit} = \sqrt{\frac{40320(EI)^2(L_C - L_B)}{17L_B{}^7}} \tag{11}$$

Since $L_C - L_B = 2x_i$, Equation 11 can be further simplified to:

$$p_{crit} = \sqrt{\frac{80640x_i(EI)^2}{17L_B{}^7}} \tag{12}$$

where

$$\delta_{max} = \frac{5p_{crit}L_B{}^4}{384EI} \tag{13}$$

Since the deflected shape of the curtain closely resembles a parabola, the cable equations in Reference 11 can be used to determine the in-plane force acting on the guide in terms of the maximum curtain deflection δ_{max}. Therefore, using the roller shutter terminology adopted, the maximum in-plane force w_x* in kN/m exerted on the door guide is given by:

$$w_x* = \frac{(p* - p_{crit})L_B{}^2}{8000\delta_{max}} \tag{14}$$

where

p* is the design wind pressure in kPa
p_{crit} is the critical wind pressure in kPa
L_B is the length between the outer edges of the anchor bars in mm
δ_{max} is the maximum deflection measured in mm

Strictly speaking, the foregoing beam deflection theory is valid for small deflections with its use reserved for beam displacements where the slopes of the curve at any point are small. The exact Euler-Bernoulli expression for curvature given in Reference 10 is as follows:

$$-\frac{M}{EI} = \frac{\frac{d^2y}{dx^2}}{\left[1 + \left(\frac{dy}{dx}\right)^2\right]^{3/2}} \tag{15}$$

When the term $(dy/dx)^2$ is very small, the denominator is close to unity. Although the deflections of roller shutter curtains can be substantial, it can be shown for typical values of slat stiffnesses, curtain length and initial gap, that the denominator is still close to unity. Hence small deflection theory is still a reasonable approximation even though the curtain deflections are larger than typical beam deflections.

The tension in the slat varies along its length with its value at midspan being equal to the in-plane component w_x* at each end. The magnitude of the slat tension increases slightly towards the ends of the slat as the “slope” increases due to the resolution of the forces. For practical purposes, the tension in the slat can be taken as w_x*.

6 SLAT STIFFNESS

Each manufacturer has its own slat profile and due to the competitive nature of the industry, there is reluctance to provide section properties of the slats. Ultimately, the manufacturer makes the selection of the slat size with the choice being dependent on such things as wind pressure, environment and security. However, as the slat stiffness greatly affects the deflection of the curtain and consequently the in-plane loads, the designer needs to understand and specify what minimum slat stiffnesses are acceptable.

Slats readily available in the industry have I_{slat} in the range from 4000 to 25000 mm^4. Obviously, the stiffer the profile, the less curtain deflection there is but the more costly the door becomes. Furthermore, as the stiffer profiles usually have a deeper cross-section, the drum diameter of the door usually increases. Thus, the designer should be mindful of these factors and not simply adopt a stiffer profile for the sake of being conservative. In most instances however, the building designer will be unable to obtain the slat stiffness and as such, should assume a low value of I_{slat} such as 4000 mm^4 until more information becomes available and then refine the design.

7 INITIAL GAP

The initial gap x_i, as shown previously in Figures 6 and 8, can be as low as 5 mm and as high as 50 mm with the most common range found in practice to be between 15 to 30 mm. Equations 12 to 14 of the preceding section show that the initial gap influences the amount of tension in the curtain. That is, for a given curtain length under wind load, the larger the initial gap, the larger the curtain deflection and the smaller the tension load. Conversely, if the initial gap is small, the curtain deflection is smaller but the tension load will be larger. Figure 11 illustrates the relationship between *initial gap* and the *tension load in a slat* for a 5 metre wide door under four different wind pressures. In these four cases, the anchor bar width is assumed to be 50 mm with I_{slat} = 5000 mm^4.

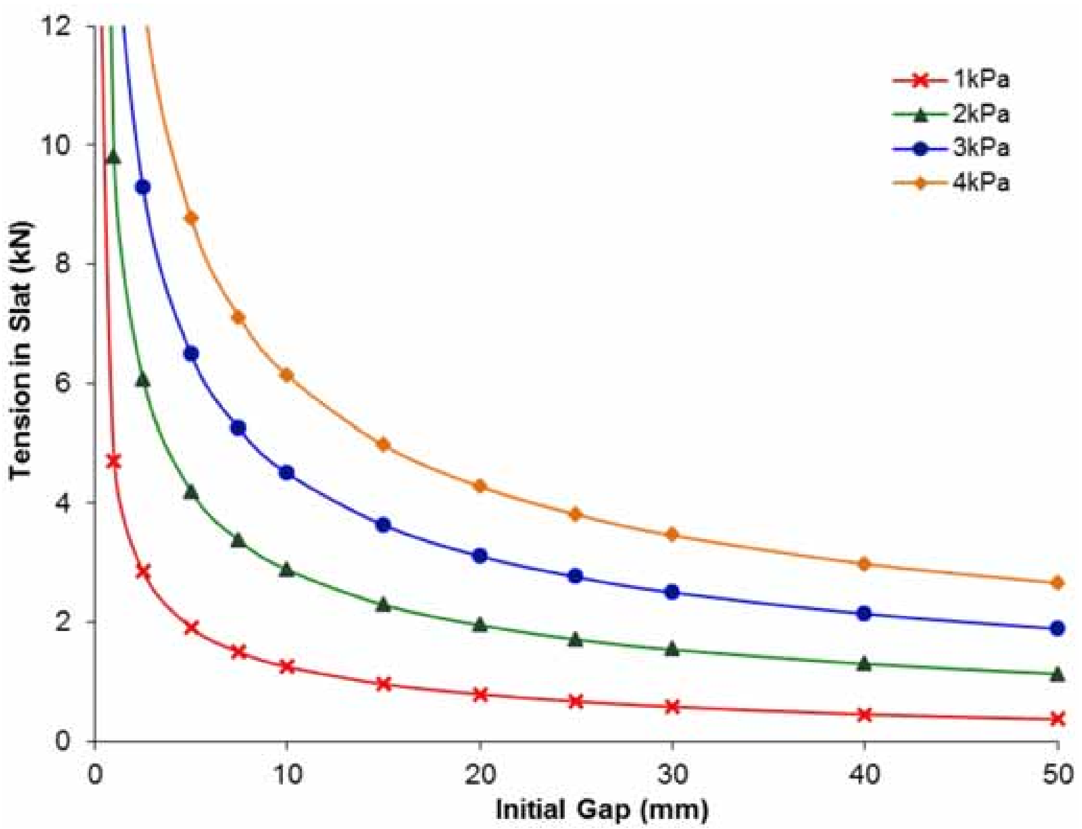

Figure 11: Relationship between initial gap and tension load in a slat of a 5 metre wide steel roller shutter door with I_{slat} = 5000 mm^4

As the initial gap x_i can vary one manufacturer to the other, it is recommended that the designer prescribe an initial gap within the guide together with a tolerance. Clearly, if too much initial gap is specified, the curtain will flex more and may result in an impractical design condition for the door manufacturer to meet. On the other hand, having a minimal gap generates large tension forces in the curtain as indicated in Figure 11. Thus, a compromise is needed whereby the designer is able to specify an initial gap that will result in a reasonably sized door jamb and a reasonable slat size.

The gap tolerance is needed more for construction than for manufacture and will be reduced if a roller shutter manufacturer measures the "as constructed" opening width on site. A tolerance on the initial gap should be included in the building designer's specification to cater for and control the ranges of initial gap mentioned previously (i.e. 15 to 30 mm). It is recommended that the specified tolerance be limited to ±5.0 mm and the designer should cater for this in his or her design. It should be noted that in special circumstances, the designer may approach one or more manufacturers to determine an appropriate initial gap which is considered reasonable for the application.

Summarising the previous points and referring to Equation 14, Figure 12 illustrates the relationship between *in-plane* loads and *door width* for four different wind pressures. In these cases, an initial gap of 15 mm has been assumed with an anchor bar width of 50 mm and an I_{slat} of 5000 mm^4. As expected, the larger the door width, the more "cable behaviour" becomes evident. This is illustrated in Figure 12 with the two curves for a given pressure approaching each other as the door width gets larger.

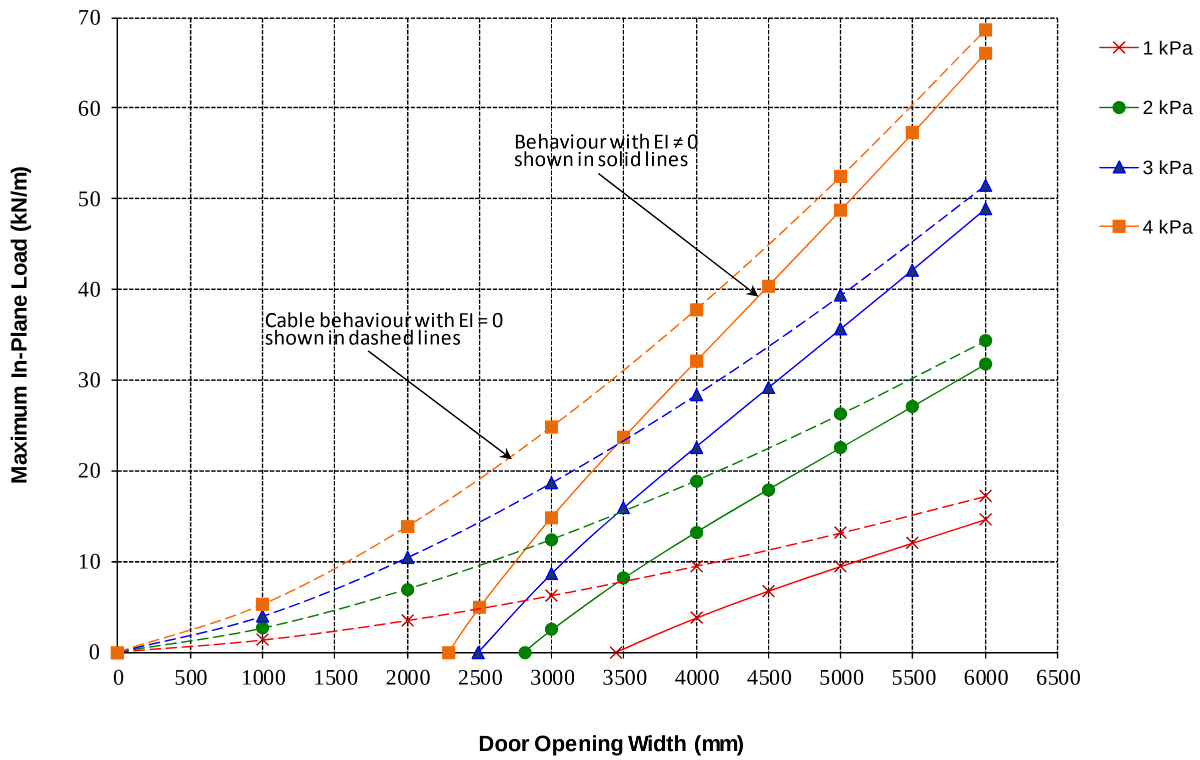

Figure 12: Relationship between door opening width and maximum in-plane load for I_{slat} = 5000 mm^4 (solid lines). Note, dashed lines indicate slats with assumed zero stiffness (i.e. cable behaviour) showing larger in-plane loads

8 DOOR AND WALL FRAMING

8.1 General

The stiffness of the door jambs and the wall structure also has an influence on the door deflection and the in-plane forces. Essentially there are two types: *Rigid* and *Non-Rigid* systems. Typical examples of each type are shown in Figure 13.

8.2 Rigid Wall System

A *rigid wall system* is one in which no movement of the door guide is possible in the plane of the door. Examples of this are door guides fixed directly to brick, block or concrete walls. Since there is no provision for flexure in the rigid support system, the in-plane loading on the door guide does not vary along the height of the door.

8.3 Non-Rigid Wall System

A *non-rigid wall system* is one in which movement of the door guide and jamb in the plane of the door is possible. An example is a steel-framed wall with girts or studs where the door jambs resist the in-plane loads in flexure with the adjacent girts and attached structure attracting some load.

It could be argued that steel clad walls on girts can be treated as a rigid wall system, but this should not be adopted for the following reasons:

- Girts are generally fabricated with elongated holes.
- There is limited diaphragm action if concealed fastener sheeting is used.
- In-plane loads acting on the girt centre-line are usually eccentric to the centroid of the main columns and could cause the columns to twist.
- The roller shutter door jamb may be in a different plane from that of the girts.
- Minor axis deflection of the main columns is possible.
- Discontinuities introduced by personnel access doors, windows or other roller doors may reduce the rigidity of the wall system.

Thus, for steel-framed buildings with girts, a conservative approach is recommended whereby the in-plane resistance offered by girts and other framing is ignored for the sizing of the jamb. However, for designing the girt to jamb connections and the door guide fixings to the jamb, it is recommended that the wall system be assumed rigid.

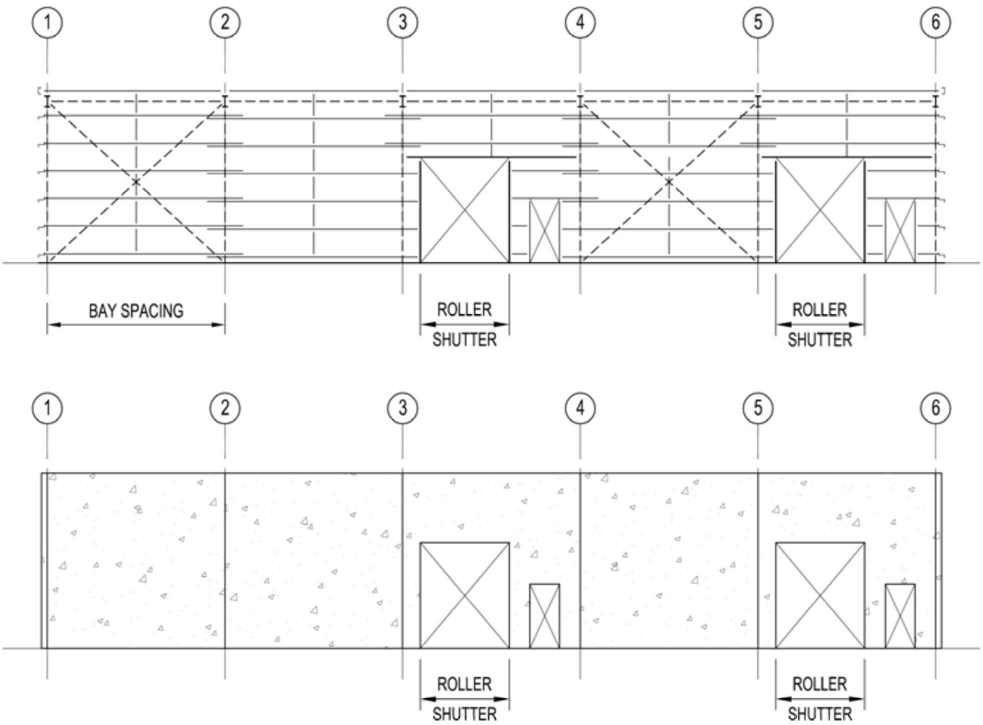

Figure 13: Typical non-rigid wall (above) and rigid wall (below)

The load distribution on a door jamb for a non-rigid system can be analysed by considering a vertical simply supported member with a varying load distribution along the height as shown in Figure 14. The load distribution is actually curved but a linear approximation is sufficient for analysis.

At the top and bottom, there is no in-plane movement of the jamb and the in-plane loads are at their highest values. At mid-height, where the jamb is most flexible, the in-plane load is at its lowest value.

An iterative numerical procedure is therefore needed to determine the loads on the jamb. The aim is to equate the force required to displace the jamb (at mid-height) a prescribed amount, to the force in the curtain for the same movement. This is illustrated more clearly with a worked example later where the deflection of the jamb at mid-height is determined from the following equation:

$$\delta_{\text{jamb}} = \frac{5 w_{\text{x}}{}^{*}{}_{\text{min}}\, h^4}{384(EI)_{\text{jamb}}} + \frac{3(w_{\text{x}}{}^{*}{}_{\text{max}} - w_{\text{x}}{}^{*}{}_{\text{min}})h^4}{640(EI)_{\text{jamb}}} \qquad (16)$$

where $w_x{}^*{}_{min}$ is the minimum in-plane load on the jamb at mid-height and $w_x{}^*{}_{max}$ is the maximum in-plane load at the top and bottom of the jamb as shown in Figure 14.

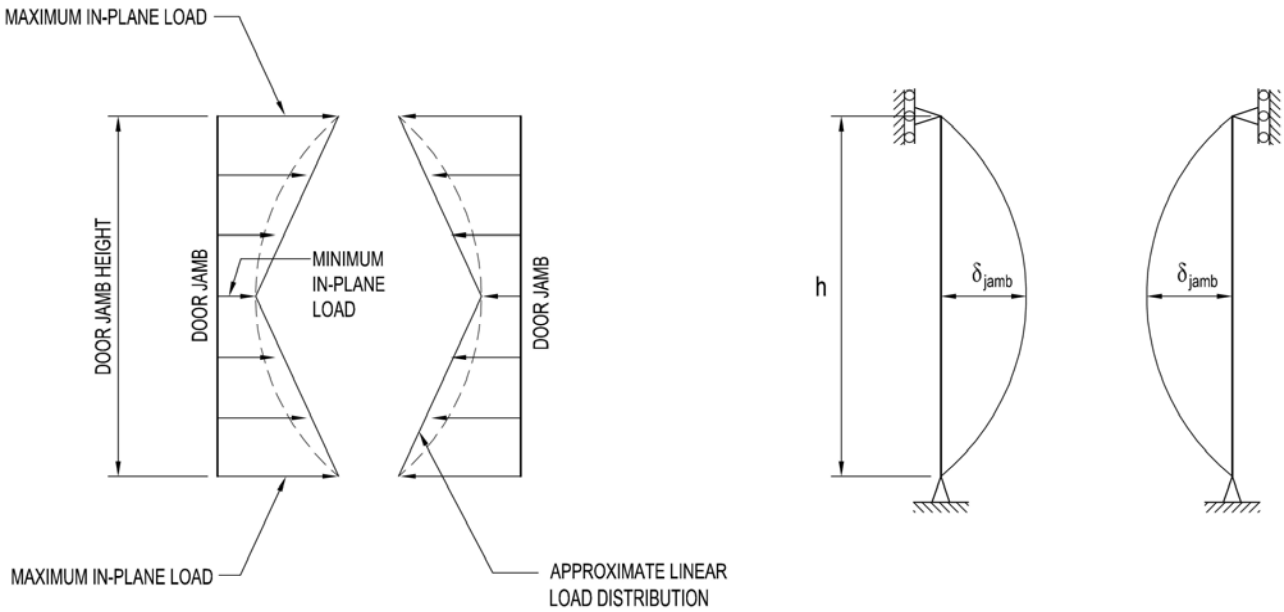

Figure 14: Varying load distribution along roller shutter door jamb for non-rigid system

8.4 Jambs

The choice of door jamb warrants careful consideration especially if windlocks are required. It has been common practice for designers to specify PFC members as jambs, as shown in Figure 15, for the convenience of having a flange to mount the guide and a one-sided web to provide a suitable finish. As a PFC is weak in torsion and in bending about its minor axis, it is recommended that PFC's be avoided if windlocks are fitted. Cold-formed Cee sections as jambs are even weaker and should not be used for windlocked doors.

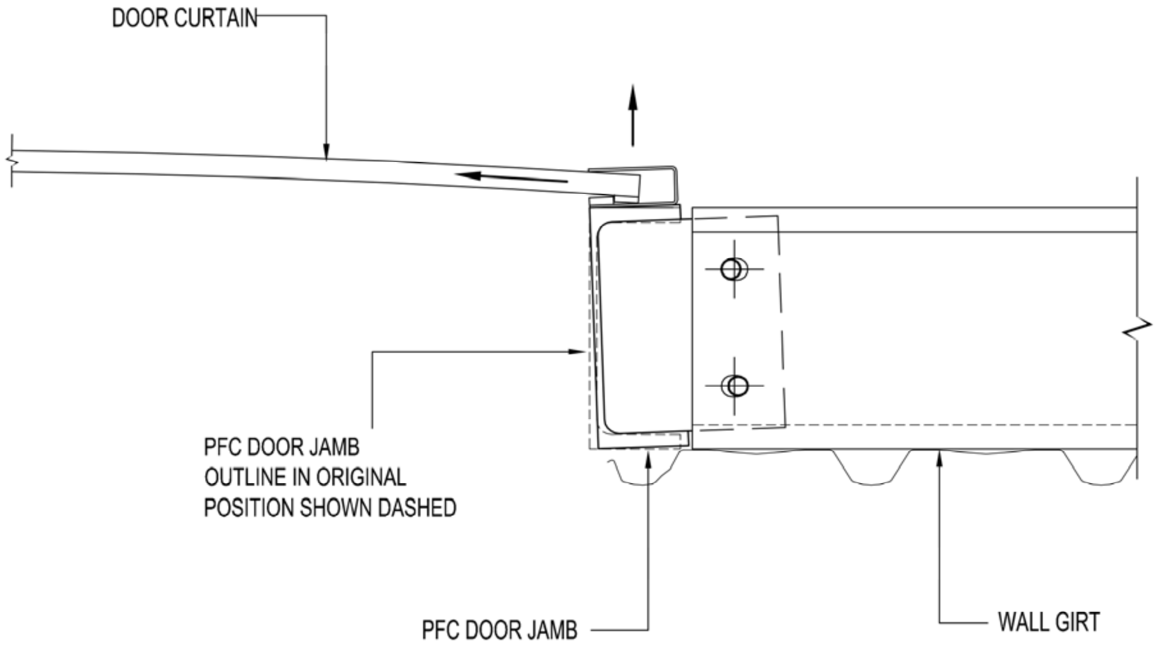

Figure 15: PFC rotation due to in-plane loading from the curtain

Even if torsion does not cause failure of the jamb, the large tension forces in the curtain coupled with the excessive rotation of the open section have in some cases caused the windlocks to become disengaged [5]. It is for this reason that RHS members should be considered as door jambs as these members not only have minor axis bending strengths that exceed those of PFC's with similar external dimensions, but also have much greater torsional strength and stiffness. There are instances of course, where windlocks are not fitted and as such, torsionally flexible members could justifiably be used.

9 CONNECTIONS

9.1 General

In designing the connections between the door guides and the jambs, the maximum in-plane load should be used regardless of rigidity type. This provides a conservative approach for designers should the rigidity of the wall system be underestimated.

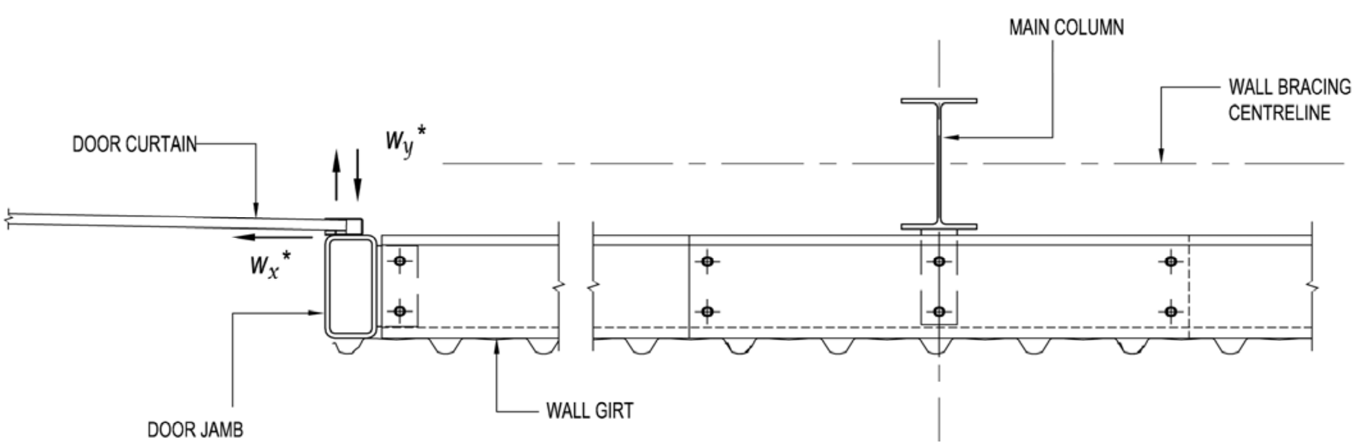

Figure 16: Forces on connections for a windlocked roller shutter door

Figure 16 illustrates typical detailing of a door jamb/girt connection with the following items that need to be designed or checked:

- Bolt tear-out capacity of the girt web.
- Bolt bearing capacity of the girt web.
- Girt bolt shear capacity.
- Bending strength of girt cleats fixed to the main columns.

This is not an exhaustive list as there may be other design issues that require consideration. One such check is the ability of the main columns to resist torsion resulting from the eccentric longitudinal load in the girts. It is also important to account for other loads that act simultaneously such as girts resisting out-of-plane wind loads as well as the in-plane loads. Girt bolts for example, would need to be checked for shear forces in both directions.

9.2 Guide Fixings

The fixing of door guides is normally done by the roller door supplier. However, as poor installation practices are widespread throughout the industry, designers need to be familiar with the fixing procedures available and specify performance criteria.

For steel-framed buildings, it is common practice to fix the door guides after the door has been hung by tack welding them in position, but these welds are unlikely to be strong enough to resist the imposed loads. As previously noted, the loads imposed on a door jamb can be large and a more robust welding procedure, such as continuous fillet welding or stitch welding, is required. Furthermore, the welding procedures need to be carried out in accordance with AS/NZS 4600:2005 [12] and AS/NZS 1554.1:2011 [13] and the weld sizes and details need to be certified by the door supplier as being capable of resisting the imposed loads.

Where on-site welding is not desirable, the door guide may need to be screwed to the door jamb. This can be done by drilling an oversize hole in the outer face of the guide to allow the fastener to secure the inner face of the guide in place. Alternatively, if the roller door supplier has been selected prior to fabrication of the steelwork, there is the option of having the guides welded to the door jamb and then painted or hot-dipped galvanized in one piece.

The door guide itself needs to be structurally sufficient to resist the combined in-plane and out-of-plane loads. In high winds, the guides can plastically deform [2] and even damage the slat and locking mechanism [6] as shown in Figure 17. This design aspect is beyond the building engineer’s responsibility, but nevertheless it highlights the importance of having properly designed door guides and windlocks.

Figure 17: Examples of failed windlocks torn from a door guide after Cyclone Larry.
Photos courtesy of the Cyclone Testing Station,
School of Engineering, James Cook University

For fixing to concrete or masonry, chemical and mechanical fasteners are most commonly used. However, care is needed particularly in the case of block walls even if core-filled and reinforced because in-plane loads can be large and it is critical that sufficient edge distance to the anchor is provided. Figure 18 illustrates typical fixing techniques.

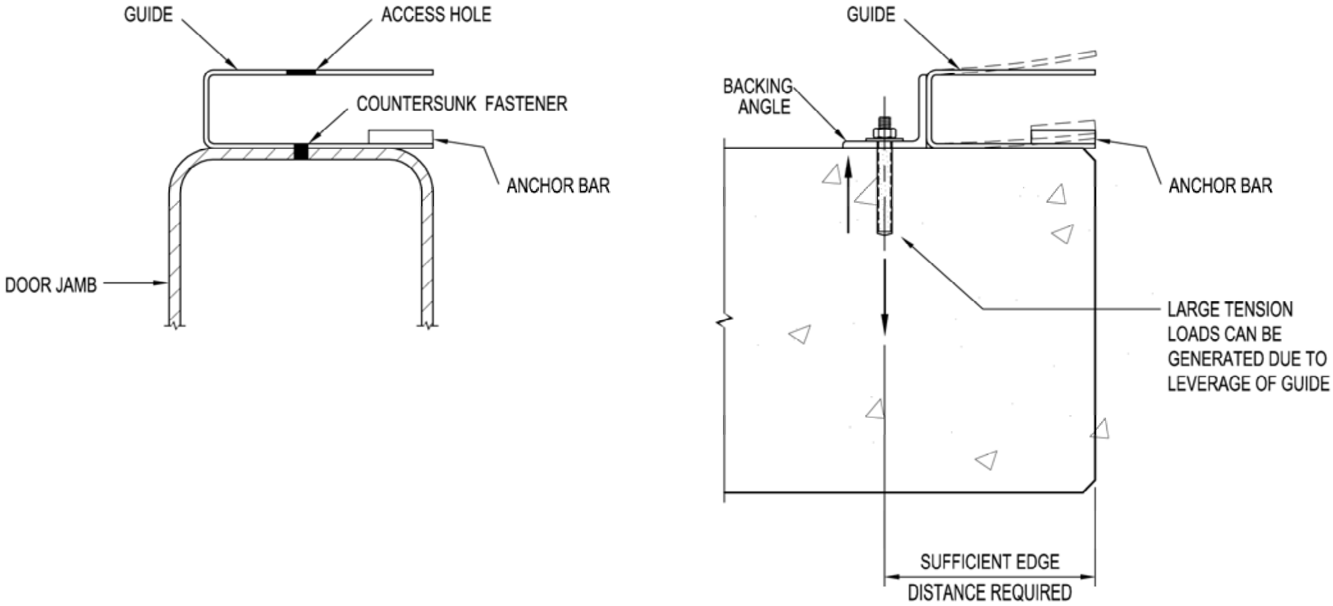

Figure 18: Examples of screw and masonry fastening of a door guide

10 CONCLUSION

Roller shutter doors are widely used for industrial, commercial and residential buildings, but their behaviour and strength under design wind loads appear to have been generally overlooked by engineers, architects and specifiers. Roller shutter doors have limited bending stiffness and deflect significantly under high wind loads. Technical papers presented by the Cyclone Testing Station have demonstrated that deficiencies in design and detailing of roller shutter doors and their fixings exist.

This paper demonstrates that when windlocks are provided, in-plane forces resulting from storms and cyclones can be very large and should not be ignored in the design of door guides, jambs and fixings. Unfortunately, there is limited international research on the topic and AS/NZS 4505:1998 [1] for domestic garage doors does not provide a method to determine in-plane loads.

A lower tier approach is to assume cable behaviour of the curtain but this can lead to an overly conservative design. This paper provides an alternative methodology that a practicing engineer can adopt by taking advantage of the slat stiffness. This method utilises classical beam bending theory and curvature shortening and can be used for rigid and non-rigid wall framing. Thus, by specifying a minimum slat stiffness and initial gap, the building designer is able to follow relatively simple steps to determine the in-plane loads.

WORKED EXAMPLE 1

A part elevation of a building to be built in Townsville is shown in Figure 19. The client has specified windlocks on every slat. The door opening is required to be 3.5 m wide and 3.5 m high. The facility is in Terrain Category 2 and the ultimate design wind pressure on the door is 2.75 kPa (inwards and outwards).

Determine the criteria that the supplier needs to meet including the imposed loads on the door guide.

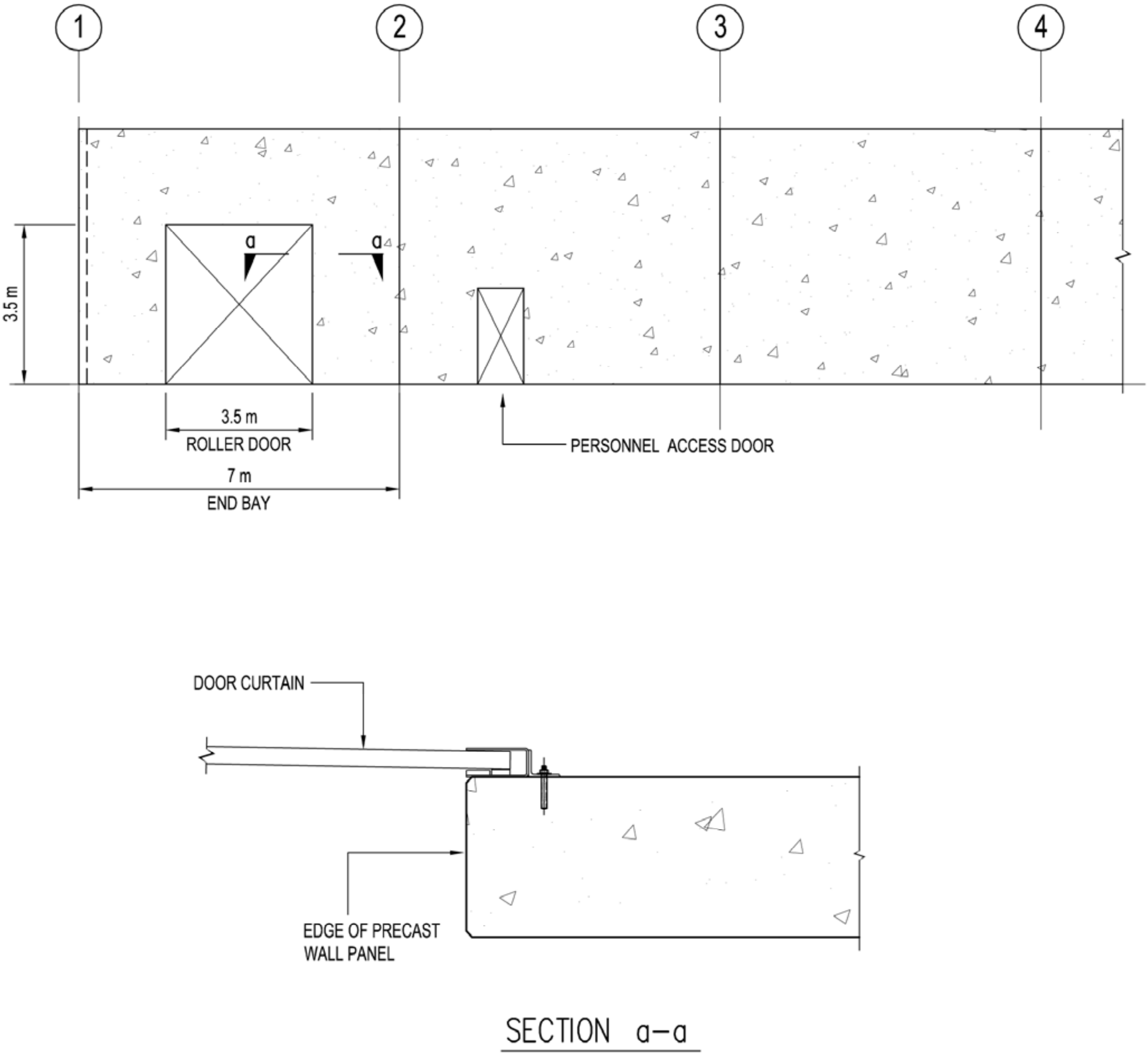

Figure 19: Part elevation of precast building (above) and plan detail (below)

As the client has specified windlocks, in-plane loads are likely. This is also a rigid system where the loading on the door guide will be resisted by the concrete with the in-plane load constant along the height of the door.

A conservative choice of I_{slat} = 4000 mm^4 could have been used but advice from several manufacturers indicate that a 100mm wide slat with I_{slat} = 10000 mm^4 is required. Therefore, adopt I_{slat} = 10000 mm^4 for this design with the stiffness per metre height equal to 100000 mm^4/m.

The initial gap x_i to be specified is 20 ± 5.0 mm. As this can vary within the range of 15 mm to 25 mm, adopt the conservative case of 15 mm to determine the in-plane loads.

Applied design wind pressure p^* = 2.75 kPa

Assume an anchor bar width a equal to 50 mm

Length of curtain $L_C = L_o + 2a + 2x_i +$ = 3500 + 2 × 50 + 2 × 15 = 3630 mm

Length between anchor bars $L_B = L_C - 2x_i$ = 3630 – 2 × 15 = 3600 mm

Calculate the out-of-plane load on the door guide w_y*:

$$w_y^* = p^*\left(\frac{L_o}{2}\right) = 2.75\left(\frac{3.5}{2}\right) = 4.8\,\text{kN/m}$$

Now calculate p_{crit} and the corresponding maximum deflection δ_{max}:

$$p_{crit} = \sqrt{\frac{80640 x_i \left(EI\right)^2}{17 L_B^{\;7}}} = \sqrt{\frac{80640\times15\times\left(200000\times100000\right)^2}{17\times3600^7}} = 1.91\,\text{kPa}$$

$$\delta_{max} = \frac{5 p_{crit} L_B^{\;4}}{384EI} = \frac{5\times1.91\times3600^4}{384\times200000\times100000} = 209\text{ mm}$$

Now calculate the in-plane load w_x*:

$$w_x^* = \frac{(p^* - p_{crit})L_B^{\;2}}{8000\delta_{max}} = \frac{(2.75-1.91)\times3600^2}{8000\times209} = 6.5\,\text{kN/m}$$ along the height of the door.

Note that the in-plane load of 6.5 kN/m is constant along the height and all connections need to be designed to resist this load.

As windlocks are fitted to every slat, the in-plane load will also be equal to the maximum tension in the curtain (i.e. 0.65 kN curtain tension in each slat). However, if for example windlocks were fitted on every second slat (i.e. 200 mm between windlocks), the maximum curtain tension would be 6.5 kN/m × (200/1000) = 1.3 kN at each windlocked slat.

Also note that had a conservative choice of I_{slat} = 4000 mm^4 been used, the in-plane load w_x* would be equal to 15.5 kN/m. Furthermore, if the slat stiffness was neglected altogether (i.e. cable behaviour), w_x* would be equal to 21.4 kN/m.

The designer has specified the following criteria on the drawings:

- Location: Region C, Terrain Category 2.
- Curtain to be certified as having sufficient bending and axial capacity to resist the nominated loads as well as impact loads specified in AS/NZS 1170.2:2011 Cl 2.5.7.
- Ultimate wind pressure on the door = 2.75 kPa (Inward and Outward).
- Minimum I_{slat} = 10000 mm^4 for 100 mm wide slats.
- Windlocks to be provided on every slat.
- Maximum in-plane loading on the guide and tension in the curtain = 6.5 kN/m (Ultimate).
- Maximum out-of-plane loading on the guide = 4.8 kN/m (Ultimate).
- Initial gap between anchor bar and windlock = 20±5.0 mm.
- All welds and screw fixings to comply with AS/NZS 1554.1:2011 and AS/NZS 4600:2005 for the nominated loads.

WORKED EXAMPLE 2

Consider the same building as in Worked Example 1, except this time the building is steel-framed as shown in Figure 20.

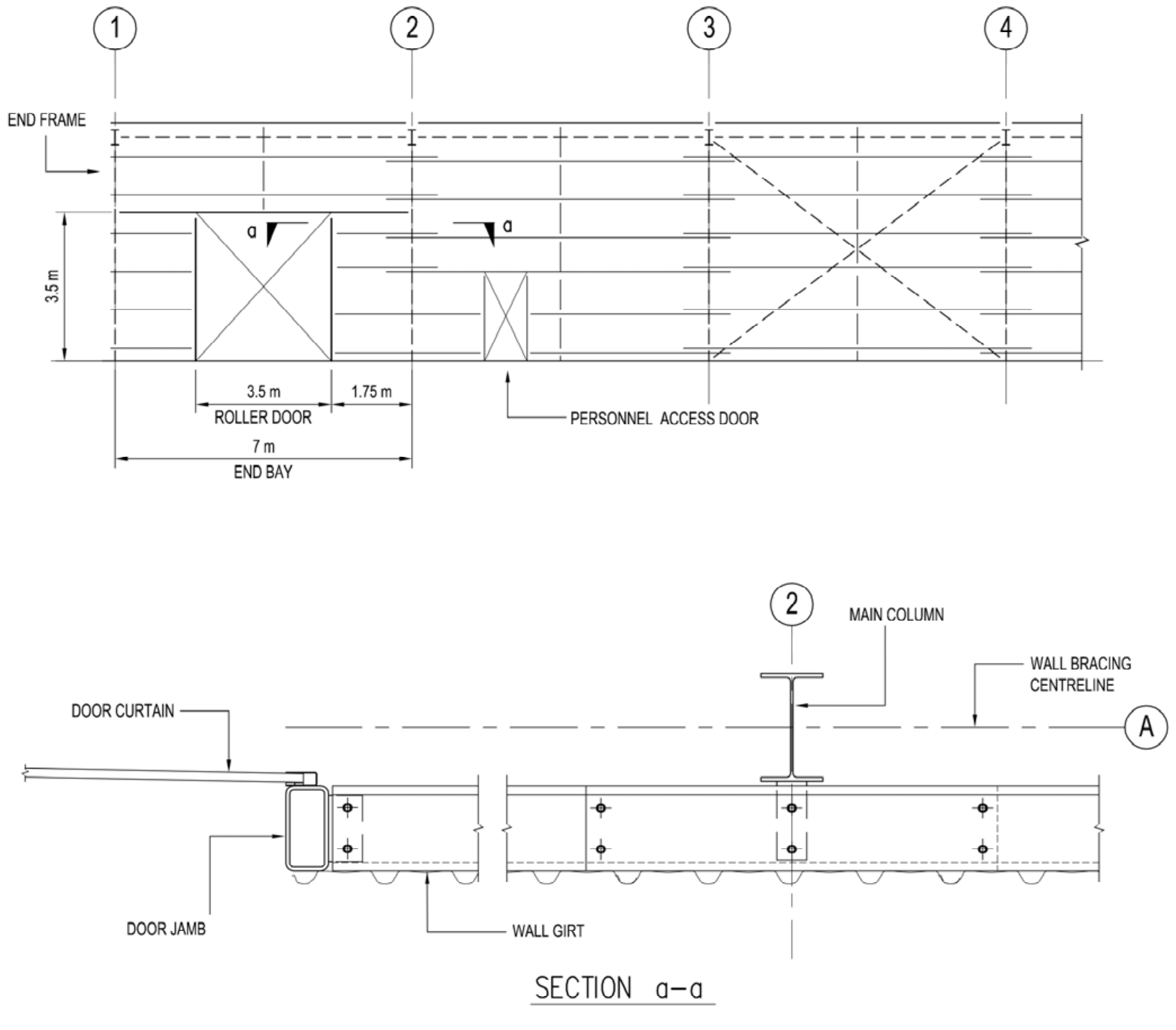

Figure 20: Part elevation of steel-framed building (above) and plan detail (below)

Solution

The same design procedure is carried out as per the previous example, however this time the wall is non-rigid. Again, noting that the client has specified windlocks on every slat, in-plane loads are possible. Being non-rigid, the door jambs will need to be designed to resist the in-plane loads as well as the out-of-plane loads.

As previously calculated, the in-plane load w_x* is equal to 6.5 kN/m. But for a non-rigid wall, the in-plane loads will vary from a maximum value of 6.5 kN/m at the top and bottom, to w_x*_{min} which occurs at mid-height.

Try a 200 × 100 × 4 RHS (Gr 350) as the jamb (I_{yy} = 4.07 × 10^6 mm^4).

Trial 1

Try a mid-height in-plane load equal to half of the maximum in-plane load in the guide. Thus, w_x*_{min} = 6.5/2 = 3.25 kN/m.

The deflection at mid-height is calculated as follows:

$$\delta_{\text{jamb}} = \frac{5 w_x*_{\text{min}}\, h^4}{384(EI)_{\text{jamb}}} + \frac{3(w_x*_{\text{max}} - w_x*_{\text{min}})h^4}{640(EI)_{\text{jamb}}}$$

$$\delta_{\text{jamb}} = \frac{5 \times 3.25 \times 3500^4}{384 \times 200000 \times 4.07 \times 10^6} + \frac{3(6.5 - 3.25)3500^4}{640 \times 200000 \times 4.07 \times 10^6} = 10.6 \text{ mm}$$

Thus, revised in-plane movement is calculated as 10.6 mm + 15 mm = 25.6 mm

The revised length between anchor bars L_B is calculated as: L_C – 2 × 25.6 = 3578.8 mm

p_{crit} is re-calculated as:

$$p_{\text{crit}} = \sqrt{\frac{80640 x_i (EI)^2}{17 L_B{}^7}} = \sqrt{\frac{80640 \times 25.6 \times (200000 \times 100000)^2}{17 \times 3578.8^7}} = 2.54 \text{ kPa}$$

$$\delta_{\max} = \frac{5 p_{\text{crit}} L_B{}^4}{384 EI} = \frac{5 \times 2.54 \times 3578.8^4}{384 \times 200000 \times 100000} = 271.3 \text{ mm}$$

$$w_x*_{\text{min}} = \frac{(2.75 - 2.54) \times 3578.8^2}{8000 \times 271.3} = 1.24 \text{ kN/m}$$

which does not equal the trial value of 3.25 kN/m and thus further iteration is required.

Trial 2

Now try a mid-height in-plane load equal to w_x*_{min} = 1.24 kN/m.

The deflection at mid-height is re-calculated as follows:

$$\delta_{\text{jamb}} = \frac{5 w_x*_{\text{min}}\, h^4}{384(EI)_{\text{jamb}}} + \frac{3(w_x*_{\text{max}} - w_x*_{\text{min}})h^4}{640(EI)_{\text{jamb}}}$$

$$\delta_{\text{jamb}} = \frac{5 \times 1.24 \times 3500^4}{384 \times 200000 \times 4.07 \times 10^6} + \frac{3(6.5 - 1.24)3500^4}{640 \times 200000 \times 4.07 \times 10^6} = 7.5 \text{ mm}$$

Thus, the revised in-plane movement is calculated as 7.5 mm + 15 mm = 22.5 mm

The revised length between anchor bars L_B is calculated as: L_C – 2 × 22.5 = 3585 mm

p_{crit} is re-calculated as:

$$p_{\text{crit}} = \sqrt{\frac{80640 x_i (EI)^2}{17 L_B{}^7}} = \sqrt{\frac{80640 \times 22.5 \times (200000 \times 100000)^2}{17 \times 3585^7}} = 2.37 \text{ kPa}$$

$$\delta_{\max} = \frac{5 p_{\text{crit}} L_B{}^4}{384 EI} = \frac{5 \times 2.37 \times 3585^4}{384 \times 200000 \times 100000} = 254.9 \text{ mm}$$

$$w_x*_{\text{min}} = \frac{(2.75 - 2.37) \times 3585^2}{8000 \times 254.9} = 2.40 \text{ kN/m}$$

which again does not equal the second trial value of w_x*_{min} = 1.24 kN/m. However, the difference diminishes with iteration and the values eventually converge at w_x*_{min} = 1.97 kN/m, which can be seen in the following table:

Table 1: Tabulated results for hand calculations

Trial w_x*_{min}	δ_{jamb}	Revised new movement (in-plane)	L_B	p_{crit}	Curtain δ_{max}	w_x*_{min}
kN/m	*mm*	*mm*	*mm*	*kPa*	*mm*	*kN/m*
3.25	10.6	25.6	3578.8	2.54	271.3	1.24
1.24	7.5	22.5	3585.0	2.37	254.9	2.40
2.40	9.3	24.3	3581.4	2.47	264.6	1.70
1.70	8.2	23.2	3583.6	2.41	258.8	2.11
2.11	8.9	23.9	3582.2	2.45	262.6	1.83
1.83	8.4	23.4	3583.2	2.42	259.7	2.04
2.04	8.7	23.7	3582.6	2.44	261.7	1.90
1.90	8.5	23.5	3583.0	2.43	260.7	1.97
1.97	8.6	23.6	3582.8	2.43	260.7	1.97

The capacity of the RHS jamb section can now be checked for strength in the following manner with the out-of-plane load on the door jamb calculated as:

$$w_y* = p*\left(\frac{L_o}{2} + girt\ \ tributary\ \ width\right) = 2.75\ \left(\frac{3.5}{2} + \frac{1.75}{2}\right) = 7.2\,\mathrm{kN/m}$$

with the in-plane loads w_x*_{max} = 6.5 kN/m at the extreme ends varying down to w_x*_{min} = 1.97 kN/m at mid-height.

Thus, $M*_x$ =7.2(3.5)^2/8 = 11.0 kNm with $M*_y$ = ½(6.5–1.97)3.5^2/12 + 1.97(3.5)^2/8 = 5.3 kNm.

Note, had a <u>uniform</u> in-plane loading of 6.5 kN/m been adopted, $M*_y$ would be 6.5(3.5)^2/8 = 10 kNm which is significantly larger than 5.3 kNm.

Checking the combined actions:

$$\frac{M*_x}{\varphi M_{sx}} + \frac{M*_y}{\varphi M_{sy}} = \frac{11.0}{46.2} + \frac{5.3}{19.9} = 0.5 < 1.0$$

Thus, a 200 × 100 × 4 Gr 350 RHS is adequate for strength but given the reserve capacity, a smaller section should be checked.

For the subsequent design of connections, the maximum in-plane loading (i.e. w_x*_{max} = 6.5 kN/m) needs to be adopted <u>along the entire height</u> as this conservatively assumes the restraint offered by the adjacent steelwork is more rigid than assumed.

For completeness and as a comparison, a finite element model was created using the wind pressure and member properties defined above. A *Strand 7* 3D model of the roller shutter door, as shown in Figure 21, was created using beam elements for the slats and jambs and “point contact” elements to simulate the initial gap. The spacing of the slats was modelled at 100 mm vertically. FEM can be time consuming and may not be practical in many instances but fortunately the proposed hand calculations give good correlation to the FEM model as shown in Figure 22. Note that they are slightly conservative due to the assumption of the linear varying load.

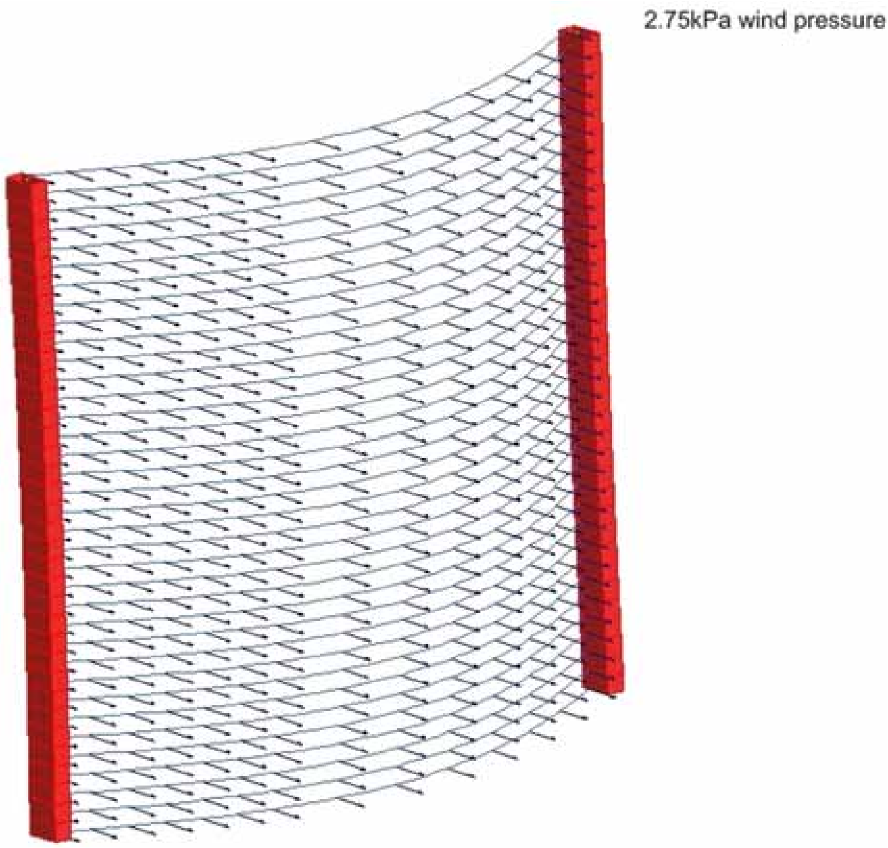

Figure 21: 3D model of roller shutter door for worked example 2

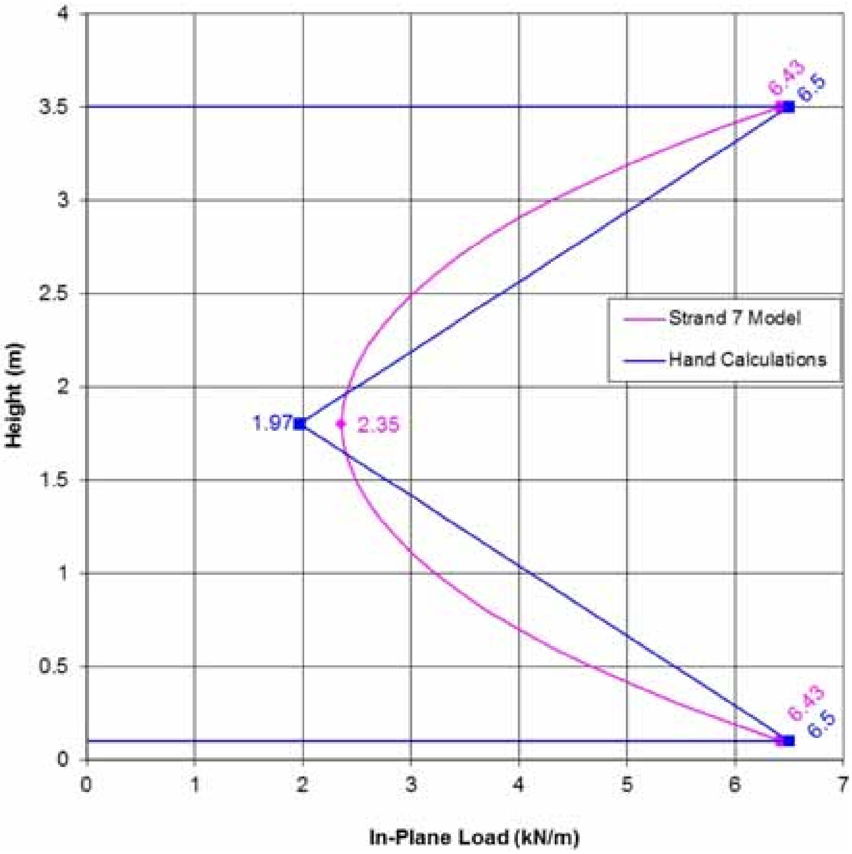

Figure 22: Comparison of results between hand calculations and FEM for the in-plane loading on a 200 × 100 × 4 RHS door jamb

The designer has specified the following criteria on the drawings:

- Location: Region C, Terrain Category 2.
- Curtain to be certified as having sufficient bending and axial capacity to resist the nominated loads as well as impact loads specified in AS/NZS 1170.2:2011 Cl 2.5.7.
- Ultimate wind pressure on the door = 2.75 kPa (Inward and Outward).
- Minimum I_{slat} = 10000 mm^4 for 100 mm wide slats.
- Windlocks to be provided on every slat.
- Maximum in-plane loading on the guide and tension in the curtain = 6.5 kN/m (Ultimate).
- Maximum out-of-plane loading on the guide = 4.8 kN/m (Ultimate).
- Initial gap between anchor bar and windlock = 20±5.0 mm.
- Jamb mid-height in-plane deflection = 8.6 mm.
- All welds and screw fixings to comply with the AS/NZS 1554.1:2011 and AS/NZS 4600:2005 for the nominated loads.

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NOTATION

a	anchor bar width
E	Young's modulus of elasticity
E_{slat}	Young's modulus of elasticity of slat
E_{jamb}	Young's modulus of elasticity of jamb
h	height of door jamb
H	horizontal load in door guide
I	second moment of area
I_{slat}	second moment of area of slat
I_{jamb}	second moment of area of jamb
L_o	door opening width or "daylight opening"
L_C	effective curtain length
L_B	length between outer edges of anchor bars
M^*_x	major axis bending moment due to strength limit state actions
M^*_y	minor axis bending moment due to strength limit state actions
ϕM_{sx}	major axis section capacity
ϕM_{sy}	minor axis section capacity
p	wind pressure
p^*	strength limit state wind pressure
p_{crit}	wind pressure that causes slats to just engage the windlock
q	uniformly distributed load acting on slat
s	length of deflected beam measured along the curve
T_{max}	maximum tension in the curtain
T^*_{max}	maximum tension in the curtain from strength limit state actions
w_y^*	out-of-plane load on door guide or jamb from strength limit state actions
w_x^*	in-plane load on door guide from strength limit state actions
$w_x^*{}_{min}$	minimum in-plane load on door guide from strength limit state actions
$w_x^*{}_{max}$	maximum in-plane load on door guide from strength limit state actions
x_i	initial gap within door guide
δ	deflection of curtain or door jamb
δ_{jamb}	in-plane deflection of door jamb at mid-height
δ_{max}	maximum deflection of slat or door jamb

ASI STEEL DETAILER MEMBERS

NEW SOUTH WALES

Cadraw Drafting Services
5a Killarney Drive
Killarney Heights NSW 2087 — 02 9452 1819

Draft Engine
35 Perisher Road
Beaumont Hills NSW 2155 — 0432 211 561

EDC
982 Hunter Street
Newcastle West NSW 2302 — 02 4927 6969

Multicad
Shop 14 Annett's Arcade
9-11 Orient St
Batemans Bay NSW 2536 — 02 4472 1611

QUEENSLAND

BDS Vircon
80 Tribune Street
South Brisbane QLD 4101 — 07 3503 5800

Brice Engineers
7-8 Brice Court
Mt Louisa QLD 4814 — 07 4774 8322

Cubic Steel
Building 1
747 Lytton Road
Murarrie QLD 4172 — 07 3399 5164

Draftology
Suite 11, Level 3
445 Upper Edward Street
Spring Hill QLD 4004 — 07 3831 3775

Hempsall Steel Detailing
Unit 7, 16-22 Bremner Rd
Rothwell QLD 4022 — 07 3204 1054

Innovative Steel Detailing
Suite 10, 68 Jessica Blvd
Minyama QLD 4575 — 07 5444 7600

Integrated Steel Detailing
Level 1, 32 Logan Road
Woolloongabba QLD 4101 — 0401 555 288

Steelcad Drafting
Level 1, 375 Montague Road
West End QLD 4101 — 07 3844 3955

Time Line Drafting
Suite 3, 231 Margaret Street
Toowoomba QLD 4350 — 07 4659 8633

SOUTH AUSTRALIA

Australian Steel Detailers
3/ 147 Goodwood Road
Goodwood SA 5034 — 08 8271 6555

SASTEEL Drafting Services
19 Berrett Road
Gawler East SA 5118 — 08 8284 1105

USDSA
16 Drury Terrace
Clovelly Park SA 5042 — 08 8374 4999

VICTORIA

Balpara
Unit 8, 104-106 Ferntree Gully Road
Oakleigh VIC 3166 — 03 9544 3877

Engineering Design Resource
68 Hotham St
Traralgon VIC 3844 — 03 5173 7600

Fabcad Drafting
Suite 3
59 Church Street
Morwell VIC 3840 — 03 5133 0733

G.A.M. Steel
557 Mount Derrimut Road
Derriumt VIC 3030 — 03 8368 1555

Hybrid Steel Engineering
48 Wilson Road
Melton VIC 3338 — 03 9746 9193

NV Drafting Services
4 Miners Court
Mulgrave VIC 3170 — 03 9790 5649

Planit Design Group
Unit 2a
14-16 Garden Boulevard
Dingley VIC 3172 — 08 9315 6600

WESTERN AUSTRALIA

3D Drafting
Suite 15, 73 Calley Drive
Leeming WA 6149 — 08 9312 2833

Bim Drafting Services
Unit A7, 435 Roberts Road
Subiaco WA 6008 — 08 9380 8380

Cad Lab
Suite 1, 5/18 Griffin Drive
Dunsborough WA 6281 — 08 9759 1024

Cadstruction Drafting
Suite 7
800 Albany Highway
East Victoria Park WA 6101 — 08 9472 7457

Multiplan Drafting
Unit 12, 4 Queen Street
Bentley WA 6102 — 08 9356 5993

PDC Global
48 Kishorn Road
Applecross WA 6153 — 08 9315 6600

Universal Drafting
Suite 2, 8 Hasler Road
Osborne Park WA 6017 — 08 9242 8944

Westplan Drafting
Unit 3/11 Robinson Road
Rockingham WA 6168 — 08 9592 2499

New Zealand
Steel Pencil
554 Main Street
Palmerston North 4410 — +64 6 356 8253

ASI STEEL MANUFACTURER, DISTRIBUTOR AND GALVANIZER MEMBERS

APC Group
www.apcgroup.com.au

Apex Building Products
www.apexsteel.com.au

Arrium Mining and Materials
www.arrium.com

Australian Reinforcing Company (ARC)
www.arcreo.com.au

Bisalloy Steels
www.bisalloy.com.au

Bluescope Steel
www.bluescopesteel.com

Bluescope Distribution
www.bluescopedistribution.com.au

Bluescope Lysaght
www.bluescopesteel.com

Brice Metals
www.brice.com.au

CMC Coil Steels
www.cmcaustralia.com.au

Commando
www.commando.com.au

Dematic
www.dematic.com/apac

Dexion Australia
www.dexion.com.au

Donhad
www.donhad.com.au

Ferrocut
www.ferrocut.com.au

Fielders Steel Roofing
www.fielders.com.au

Fletcher Building
www.fletcherbuilding.com

Fletcher Insulation Group
www.tasmaninsulation.com

Fletcher Challenge Steel - Bisalloy
+64 9 525 9414

GB Galvanizing Service
www.gbgalv.com.au

Hartway Galvanizers
www.hartway.com.au

Horan Steel
www.horan.com.au

Hunter Galvanizing
www.huntergal.com.au

Industrial Galvanizing Corporation
www.ingal.com.au

Ingal EPS
www.ingaleps.com.au

Independent Tube Mills
www.tubemills.com.au/

Intercast and Forge
www.intercast.com.au

Kingfield Galvanising
www.kingfieldgalvanizing.com.au

Kingspan Insulated Panels
www.kingspan.com.au

Korvest Galvanisers
www.korvest.com.au

Litesteel Technologies
www.onesteel.com/litesteel

Macrack
www.macrack.com.au

Mantamesh/ Delta Shelving
www.mantamesh.com.au

Menghello Galvanizing
www.meneghello.com

Metaland
www.metaland.com.au

Metalcorp Steel
www.metalcorpsteel.com.au

Midalia Steel
www.midaliasteel.com

National Galvanizing Industries
www.natgalv.com.au

Nepean Building & Infrastructure
www.nepean.com

Nepean Mining
www.nepean.com

New Zealand Steel
www.nzsteel.co.nz

Onesteel Limited
www.onesteel.com

Onesteel Australian Tube Mills
www.austubemills.com

Onesteel Market Mills
www.onesteel.com

Onesteel Reinforcing
www.onesteel.com

Orrcon
www.orrcon.com.au

Pacific Steel Group
www.pacificsteel.co.nz

Premier Steel
www.onesteel.com

RJE (Rigby Jones)
www.rigbyjones.com.au

Rondo Building Services
www.rondo.com.au

Southern Queensland Steel
www.sqsteel.com.au

Southern Sheet & Coil
www.southernsheetandcoil.com.au

Southern Steel Group
www.southernsteelgroup.com.au

Southern Steel W.A
www.southernsteelwa.com.au

Statewide Office
www.statewideoffice.com.au

Steel & Tube Holdings
www.steelandtube.co.nz

Steelpipe Australia
www.steelpipe.com.au

Stramit Building Products
www.stramit.com.au

Surdex Steel
www.surdexsteel.com.au

Vulcan Steel
03 8792 9600

Vulcan Steel (New Zealand)
+64 9 273 7214

Webforge Australia
www.webforge.com.au

ASI STEEL FABRICATOR MEMBERS

AUSTRALIAN CAPITAL TERRITORY

Baxter Engineering
177 Gladstone Street
Fyshwick ACT 2609 02 6280 5688

NEW SOUTH WALES

ACA-Ace Construction Australia
22 York Road
Ingleburn NSW 2565 02 9618 7874

Algon Steel
7 Pippita Close
Beresfield NSW 2322 02 4966 8224

Align H
Lot 102 Lackey Road
Moss Vale NSW 2577 02 4869 1594

Aljen Engineering
17 Deering Street
Ulladulla NSW 2539 02 4455 7299

Allthread Industries
15 Bellona Avenue
Regents Park NSW 2143 02 9645 1122

Amarcon Group
18-20 Lucca Road
North Wyong NSW 2259 02 4352 2468

AWI Steel
36 Day Street
North Silverwater NSW 2128 02 9748 6730

Belmore Engineering
47 Showground Road
Tamworth NSW 2340 02 6765 9311

Bosmac Pty Ltd
64-68 Station Street
Parkes NSW 2870 02 6862 3699

C & V Engineering Services
23 Church Avenue
Mascot NSW 2020 02 9667 3933

Charles Heath Industries
18 Britton Street
Smithfield NSW 2164 02 9609 6000

Colla Bros
100 Benerembah Street
Griffith NSW 2680 02 6962 2880

Combell Steelfab
51 Jedda Road
Prestons NSW 2170 02 9607 3822

Coolamon Steelworks
81 Wade Street
Coolamon NSW 2701 02 6927 4000

Cosme-Australia Stainless Steel Fab
19 Lasscock Road
Griffith NSW 2680 02 6964 1155

Cullen Steel Fabrications
26 Williamson Road
Ingleburn NSW 2565 02 9605 4888

D.A.M. Structural Steel
65 Hartley Road
Smeaton Grange NSW 2567 02 4647 7481

D.M.E. Kermac Welding & Engineering
8 Dupas Street
Smithfield NSW 2164 02 9725 5720

Davebilt Industries
116 Showground Road
North Gosford NSW 2250 02 4325 7381

Designed Building Systems
144 Sackville Street
Fairfield NSW 2165 02 9727 0566

Edcon Steel
Unit 3a, 9-13 Winbourne Road
Brookvale NSW 2100 02 9938 8505

Ficogi Engineering
33 Liverpool Street
Ingleburn NSW 2565 02 9829 2711

Flame-Cut
68 Elizabeth Street
Wetherill Park NSW 2164 02 9609 3677

Forgacs Engineering
50 Fitzroy Street
Carrington NSW 2294 02 4978 9100

Halley and Mellowes
10 Hereford Street
Berkeley Vale NSW 2261 02 4389 6191

HF Hand Constructors
26-32 Akubra Place
South Kempsey NSW 2440 1300 434 263

Hutchins Bros
25-27 Driscoll Road
Narrandera NSW 2700 02 6959 2699

ILB Steel Buildings
24-28 Lords Place
Orange NSW 2800 02 6362 3100

Industrial Building Systems
9 Old Punt Road
Tomago NSW 2322 02 4961 6822

Maximum Engineering
18 - 30 Mount Batten Drive
Dubbo NSW 2830 02 6884 9948

Mecha Design & Fabrication
Po Box 477
Wyong NSW 2259 02 4351 1877

Morson Engineering
4 Lucca Road
Wyong NSW 2259 02 4352 2188

Nepean Engineering & Innovation
23 Graham Hill Road
Narellan NSW 2567 02 4646 1511

Pacific Steel Constructions
Unit 1, 4 Maxim Place
St Marys NSW 2760 02 9623 5247

Piper & Harvey Steel Fabrications (Wagga)
51 Tasman Road
Wagga Wagga NSW 2650 02 6922 7527

Precision Oxycut
106 Long Street
Smithfield NSW 2164 02 9316 9933

Rambler Welding Industries
39 Lewington Street
Wagga Wagga NSW 2650 02 6921 3062

Redispan Conveyors
15 Old Punt Road
Tomago NSW 2322 1300 131 370

Riton Engineering
101 Gavenlock Road
Tuggerah NSW 2259 02 4353 1688

S & L Steel Fabrications
59 Glendenning Road
Rooty Hill NSW 2766 02 9832 3488

Saunders International
271 Edgar Street
Condell Park NSW 2200 02 9792 2444

Sydney Maintenance Services
2/16 Carnegie Place
Blacktown NSW 2148 02 9831 4085

TDA Snow Engineering
28 Jura Street
Heatherbrae NSW 2324 02 4987 1477

Tasman Tank Company
151 Glendenning Road
Glendenning NSW 2761 02 8887 5000

Tubular Steel Manufacturing
15 Johnson Street
Maitland NSW 2320 02 4932 8089

Universal Steel Construction (Australia)
52-54 Newton Road
Wetherill Park NSW 2164 02 9756 2555

W E Smith Engineering
Hamilton Drive
Boambee NSW 2450 02 6650 8888

Walpett Engineering
52 Hincksman Street
Queanbeyan NSW 2620 02 6297 1277

Weldcraft Engineering
79 Thuralilly Street
Queanbeyan NSW 2620 02 6297 1453

Weldmark
26-30 Hume Street
Tamworth NSW 2340 02 6765 8284

WGE
29 Glastonbury Ave
Unanderra NSW 2526 02 4272 2200

NORTHERN TERRITORY

M & J Welding and Engineering
1708 Mckinnon Road
Berrimah NT 801 08 8932 2641

QUEENSLAND

AG Rigging & Steel
207-217 McDougall Street
Toowoomba QLD 4350 07 4633 0244

Alltype Welding
55 Christensen Road
Stapylton QLD 4207 07 3807 1820

Austin Engineering
173 Cobalt Street
Carole Park QLD 4300 07 3271 2622

Beenleigh Steel Fabrications
41 Magnesium Drive
Crestmead QLD 4132 07 3803 6033

Bend-Worx
1 Viking Drive
Wacol QLD 4076 07 3271 1377

Bettabuilt Fabrication
685 Kingsthorpe-Haden Road
Kingsthorpe QLD 4400 07 4634 4355

Brown Steel
157 O'Mara Road
Charlton QLD 4350 07 4614 3901

Cairns Steel Fabricators
6 Walters Street
Portsmith QLD 4870 07 4035 1506

Casa Engineering (Brisbane)
1-7 Argon Street
Carole Park QLD 4300 07 3271 2300

Central Engineering
19 Traders Way
Currumbin QLD 4223 07 5534 3155

DWW Engineering
53 Station Avenue
Darra QLD 4076 07 3375 5841

Fritz Steel (Qld)
29 Enterprise Street
Richlands QLD 4077 07 3375 6366

Gay Constructions
225 Queensport Road
Murarrie QLD 4172 07 3890 9500

KG Fabrication
Unit 3/35 Sodium Street
Narangba QLD 4504 07 3888 4646

Morton Steel
78 Freight Street
Lytton QLD 4178 07 3396 5322

Noosa Engineering & Crane Hire
9 Leo Ally Road
Noosaville QLD 4566 07 5449 7477

Pierce Engineering
48 Quinn Street
North Rockhampton QLD 4701 07 4927 5422

Quality Assured Bolt & Steel Fabrication
44 Andrew Campbell Drive
Narangba QLD 4504 07 3888 3888

Ramscope Steel Fabrications
Unit 1, 4 Kimberley Road
Burleigh Heads QLD 4220 07 5593 8521

Rimco Building Systems
3 Supply Court
Arundel QLD 4214 07 5594 7322

Steel Fabrications Australia
Unit 12, 63 Burnside Road
Stapylton QLD 4207 07 3439 6126

Steel Structures Australia
18 Lochlarney Street
Beenleigh QLD 4207 07 3287 1433

Stewart & Sons Steel
11-17 Production Street
Bundaberg QLD 4670 07 4152 6311

Sun Engineering
113 Cobalt Street
Carole Park QLD 4300 07 3271 2988

Thomas Steel Fabrication
19 Hartley Street
Garbutt QLD 4812 07 4775 1266

Tobin Projects
2/15 Landy Street
Northgate QLD 4013 07 3260 5189

W D T Engineers
124 Ingram Road
Acacia Ridge QLD 4110 07 3345 4000

SOUTH AUSTRALIA

Advanced Steel Fabrications
61-63 Kapara Road
Gillman SA 5013 08 8447 7100

Ahrens Group
Wilhelm Road
Kingsford SA 5118 08 8521 0000

BGI Building Group
21-23 Tanunda Road
Nuriootopa SA 5355 08 8562 2799

Bowhill Engineering
Lot 100, Weber Road
Bowhill SA 5238 08 8570 4208

Gadaleta Steel Fabrication
12 Wattle Street
Port Pirie SA 5540 08 8633 0996

Manuele Engineers
240-280 Morphett Road
North Plympton SA 5037 08 8414 2000

RC & ML Johnson
671 Magill Road
Magill SA 5072 08 8333 0188

S A Structural
9-11 Playford Cresent
Salisbury North SA 5108 08 8285 5111

S J Cheesman
21 George Street
Port Pirie SA 5540 08 8632 1044

Samaras Structural Engineers
96-106 Grand Trunkway
Gillman SA 5013 08 8447 7088

Tali Engineering
119 Bedford Street
Gillman SA 5013 08 8240 4711

Williams Metal Fabrication
181 Philip Highway
Elizabeth South SA 5112 08 8287 6489

TASMANIA

Haywards Steel Fabrication & Construction
160 Hobart Road
Launceston TAS 7249 03 6391 8508

VICTORIA

A Bending Company
4 Monterey Road
Dandenong VIC 3175 03 9706 4440

Apex Welding & Steel Fabrication
15 Centofanti Place
Thomastown VIC 3074 03 9466 4125

Aus Iron Industries
15-17 Galli Court
Dandenong South VIC 3175 03 9799 9922

Australian Rollforming Manufacturers
17–23 Gaine Road
Dandenong South VIC 3175 03 8769 7444

Autodom
24 Monash Drive
Dandenong South VIC 3175 03 8795 3215

Bahcon Steel
549 Princes Drive
Morwell VIC 3840 03 5134 2877

Eliott Engineering
176 Colchester Road
Kilsyth VIC 3137 03 9728 5500

Geelong Fabrications
5-17 Madden Avenue
Geelong VIC 3214 03 5275 7255

GFC Industries
42 Glenbarry Road
Campbellfield VIC 3061 03 9357 9900

GVP Fabrications
25-35 Japaddy Street
Mordialloc VIC 3195 03 9587 2172

Keppel Prince Engineering
184 Darts Road
Portland VIC 3305 03 5523 8888

Kiewa Valley Engineering
34 Moloney Drive
Wodonga VIC 3690 02 6056 6271

Materials Fabrication/ Melbourne Facades
5/23 Bell Street
Preston VIC 3072 03 9480 0054

Metalform Structures
2 Zilla Court
Dandenong VIC 3175 03 9792 4666

Minos Structural Engineering
Building 3, 69 Dalton Road
Thomastown VIC 3074 03 9465 8665

Monks-Harper Fabrications
25 Tatterson Road
Dandenong South VIC 3175 03 9794 0888

Multicoat
7 Laser Drive
Rowville VIC 3178 03 9764 8188

Page Steel Fabrications
20 Fulton Drive
Derrimut VIC 3030 03 9931 1600

Riband Steel (Wangaratta)
69-81 Garden Road
Clayton VIC 3168 03 9547 9144

SGA Engineering (Aust)
1/67 High Street
Melton VIC 3337 03 9747 9600

Skrobar Engineering
34 Elliott Road
Dandenong South VIC 3175 03 9792 0655

Stilcon Holdings
37 Link Court
Brooklyn VIC 3012 03 9314 1611

Structural Challenge
63 Star Crescent
Hallam VIC 3803 03 8795 7111

Thornton Engineering Australia
370 Bacchus Marsh Road
Corio VIC 3214 03 5274 3180

Wolter Steel Co.
12 Elite Way
Carrum Downs VIC 3201 03 9775 1983

WESTERN AUSTRALIA

AGC
Level 2, 251 St Georges Terrace
Perth WA 6000 08 6210 4500

Allstruct Engineering
16 Ryelane Street
Maddington WA 6109 08 9459 3823

Alltype Engineering
52 Hope Valley Road
Naval Base WA 6165 08 9410 5333

Arch Engineering
9 Rivers Street
Bibra Lake WA 6163 08 9418 5088

Austline Fabrications
181 Welshpool Road
Welshpool WA 6106 08 9451 7300

Bossong Engineering
189 Planet Street
Welshpool WA 6106 08 9212 2345

Cays Engineering
17 Thornborough Road
Greenfields WA 6210 08 9582 6611

Civmec Construction and Engineering
16 Nautical Drive
Henderson WA 6166 08 9437 6288 S

Complete Steel Projects
31 Cooper Road
Jandakot WA 6164 08 9414 8579

EMICOL
First Floor, Ascot Place
Belmont WA 6104 08 9374 1142

Fitti Steel Fabrication
11 Erceg Road
Yangebup WA 6965 08 9434 1675

Fremantle Steel Fabrication Co.
Lot 600 Prinsep Road
Jandakot WA 6164 08 9417 9111

GF Engineering
39 Lionel Street
Naval Base WA 6165 08 9410 1615

Highline
8 Colin Jamieson Drive
Welshpool WA 6106 08 6454 4000

H’var Steel Services Pty Ltd
51 Jessie Lee Street
Henderson WA 6166 08 9236 2600

Inter-Steel
9 Ilda Road
Canning Vale WA 6155 08 9256 3311

Italsteel W.A.
1 Forge Street
Welshpool WA 6106 08 6254 9800

King Spring Contracting
19 Ilmenite Crescent
Capel WA 6271 08 9727 2861

Maicon Engineering
Marine Terrace (Cnr Connell Street)
Geraldton WA 6530 08 9964 0200

Metro Lintels
2 Kalmia Road
Bibra Lake WA 6163 08 9434 1160

Mintrex
Ground Floor, 1 Centro Avenue
Subiaco WA 6008 08 9442 3333

Pacific Industrial Company
42 Hope Valley Road
Naval Base WA 6165 08 9410 2566

Park Engineers
388 Welshpool Road
Welshpool WA 6106 08 9451 7255

Perna Engineering
32 Cocos Drive
Bibra Lake WA 6163 08 9418 6352

R&R Engineering (WA)
1021 Abernethy Road
Forestfield WA 6058 08 9454 6522

Scenna Constructions
43 Spencer Street
Jandakot WA 6164 08 9417 4447

TLF Constructions
Lot 108 Safari Place
Carabooda WA 6033 08 9561 8039

UGL Resources
Level 17, Westralian Square
141 St Georges Terrace
Perth WA 6000 08 9219 5500

United Industries WA
36 Stuart Drive
Henderson WA 6166 08 9410 5600

Uniweld Structural Co
10 Malcolm Road
Maddington WA 6109 08 9493 4411