Introduction

Brackets form the link between the curtain wall and the frame. They are of critical importance to the safety of the wall and also have a profound effect on its buildability. Bracket design is normally undertaken by the system fabricator; bespoke connections can account for around 20 per cent of the cost of a curtain walling system when full account is taken of design costs, or the same proportion as the framing members themselves.

Little or no specific guidance exists on the design of curtain walling connections. Technical Note 28 Performance requirements for curtain wall brackets describes the overall requirements for brackets. This Technical Note gives guidance on load bearing aspects of brackets.

Structural systems

The general requirements for brackets are described in Technical Note 28. Figure 1 shows a typical two-storey height mullion section, where the bracket at the head of the section carries both dead load and wind load. The bracket at the intermediate floor carries wind load only. The foot of the mullion is connected to the mullion section below by a splice joint which transmits horizontal (wind) load but does not resist bending and permits vertical movement of one mullion section relative to the other due to thermal expansion.

Figure 2 shows a typical bracket detail at the head of the mullion. The head of the mullion is fixed to a shoe bracket, which is connected to an angle cleat, which itself is bolted to a channel cast into the top of the concrete floor slab. Alternative arrangements include fixing the shoe bracket to a channel cast into the outside face of the slab and using drilled fixings rather than cast in channels for the connection to the concrete slab.

DL = dead load connection
WL = wind load restraint

Figure 1 Fixings of a continuous, hung curtain wall

A single slotted hole and two circular holes have been provided in the shoe-bracket. The single slotted hole will serve to carry a bolt to be used for initial fixing and adjustment of the mullion. However this type of connection is likely to slip in service as the hollow section of the mullion will prevent the bolt being tightened sufficiently to mobilise sufficient friction between the surfaces of the bracket and mullion. The two circular holes in the bracket will therefore be used as a template to site-drill holes in the mullion to carry the fixing bolts and complete the connection. These two bolts will share the loads transmitted from the mullion to the bracket and prevent movement taking place.
after fixing. This fixing arrangement restrains the connected mullion against horizontal and vertical movement but can be assumed to allow rotation due to bending under live load if the bolts are in clearance holes.

The base of each mullion is restrained by being sleeved over a spigot inserted into the mullion below or, at the ground floor slab, the base bracket. This sliding spigot joint restrains the mullion against lateral movement but allows movement in the vertical direction. The mullion must be secured on one side of the joint only, leaving the mullion on the other side free to move and expand. The sleeve joint maintains alignment and visual continuity of the mullions and its integrity must be maintained to prevent water leakage.

Brackets are normally made of aluminium, galvanised steel or stainless steel. Bolts and screws into the aluminium should be stainless steel, whereas bolts into the structure may be galvanised, sherardised and dichromate passivated or zinc plated and passivated.

### Load paths

Design of brackets and fixings requires an understanding of how the loads are transferred from the wall to the structure and in particular the mechanisms involved in load transfer between components.

The load transfer in a normal bolted connection is achieved by shear in the bolt and bearing of the bolt against the sides of the hole. The holes require some clearance to allow the bolts to be inserted but if this is excessive the capacity of the connection will be reduced. The normal permitted clearance in BS 8118 for bolts up to 13mm in diameter is 0.4mm. When the bolt is tightened and subject to low loads the load may be transferred by friction between the contact surfaces of the joined components however as the load is increased the joint will slip to allow the bolt to bear against the sides of the hole. The design procedures for normal bolted connections are shown in the example at the end of this Technical Note.

High strength friction grip bolts are made from high strength steel and are tightened to produce a controlled clamping force across the joint that allows transfer of load by friction. They cannot be used to join hollow sections, as it would not be possible to develop the required clamping force. They may be used to join components with slotted holes provided suitable load spreading washers are used. They are not
Design of curtain wall brackets

commonly used in conjunction with stick curtain walling and guidance on their use is given in BS 8118 and BS 5950 according to the material being joined.

When joining components with slotted holes to allow adjustment, it is necessary to incorporate a mechanism to prevent subsequent movement. The development of friction by the clamping force of the fixing, as in friction grip bolts, only gives reliable results when the clamping force is accurately controlled and the contact surfaces are carefully prepared. This is rarely possible and the normal method adopted is the use of serrated surfaces. In the example shown in Figure 2, a slotted hole would normally be provided in the angle bracket where it is connected to the cast in channel in the slab to allow adjustment of the gap between the face of the slab and the curtain wall. To prevent movement after fixing, the top surface of the angle would have a serrated surface and a plate with a similar surface would be used under the nut on the fixing bolt. If aluminium components are used serrated surfaces can readily be formed by extrusion.

Design

The design of connections may be considered in three stages:

- Transfer of load from the mullion to the bracket,
- Transfer of load through the bracket,
- Transfer of load from the bracket to the structure.

This is illustrated in the following sections, which relate to the design of the brackets for the mullion shown in Figures 1 and 2. The loads on the connections are those for the mullion given in Technical Note 27 Structural design of stick curtain walling-sample calculations which are as follows:

- dead load – 2380N, which will be entirely taken by the bracket at the head of the mullion (calculated as the maximum tensile load on the mullion on page 7 of Technical Note 27).
- wind load – 6144N per span (calculated on page 6 of Technical Note 27). For the arrangement shown in Figure 1, 5/8 of the wind load on each span will be taken on the intermediate support giving a total load of

\[ 6144 \times \frac{5}{8} \times 2 = 7680N \]

The load on the bracket at the head of the mullion will be

\[ 6144 \times \frac{3}{8} \times 2 = 4608N \]

assuming that there is another, similar section of mullion above that being considered. If there is no further curtain walling above the mullion under consideration, the horizontal load on the upper bracket will be half that calculated above.

The design formulae in the following sections are taken from BS8118, which is the Code of Practice for the design of aluminium structures. Similar formulae are given in BS5950 for the design of steel structures but the values adopted for safety factors are different. In BS5950 the safety factors applied to the loads are higher whereas the safety factors applied to material strengths are lower. Calculating the load effect in accordance with one code and the strength of the section in accordance with another can therefore give unsafe results.

Mullion to shoe connection

The transfer of load from the mullion to the shoe is achieved by shear in the connecting bolt. The bracket at the head of the mullion will be subject to both horizontal and vertical shear due to wind and dead loads respectively. The bracket at the intermediate floor will only be subject to horizontal shear but the horizontal load will be greater than for the bracket at the head of the mullion. It can be seen from the loads above that
the load on the intermediate bracket will be more severe and the following calculations will be carried out for this case.

In accordance with BS 8118 the shear capacity of a bolt (\(V_{RS}\)) is given by:

\[
V_{RS} = \alpha_s \times p_f \times A_{es} \times K_1 / \gamma_m
\]

where:
- \(\alpha_s\) is 0.7 for steel
- \(p_f\) is the limiting stress which is the yield stress in the case of mild steel. For stainless steel it is the lesser of 0.5\(f_{0.2} + f_u\) and 1.2\(f_{0.2}\) where \(f_{0.2}\) is the 0.2% proof stress and \(f_u\) is the ultimate stress
- \(K_1\) is 1.0 for rivets, 0.95 for close tolerance bolts and 0.85 for normal clearance bolts
- \(A_{es}\) is the effective area of shear, which may be the area of the shank or threaded part of the bolt depending on the location of the shear plane.

Rearranging the above equation, the required area of the bolt is given by

\[
A_{es} = \frac{V \times \gamma_f}{\alpha_s \times (p_f / \gamma_m) \times K_1}
\]

where \(V\) is the applied shear force and \(\gamma_f\) is the partial safety factor for loads.

Assuming bolts of stainless steel with \(f_{0.2} = 210\text{N/mm}^2\) and \(f_u = 500\text{N/mm}^2\) hence \(p_f\) is 252N/mm². Substituting the known values in the equation:

\[
A_{es} = \frac{7680 \times 1.2}{0.7 \times (252 / 1.2) \times 0.85} = 73.75 \text{ mm}^2
\]

As the bolt is in double shear the required cross-sectional area of the bolt is half this value and an 8mm bolt with an area of 50mm² would be satisfactory. It is however necessary to check that the bearing surfaces of both the bolt and mullion have adequate strength.

The bearing strength (\(B_{RF}\)) of a steel bolt is given by:

\[
B_{RF} = d_f \times t \times 2 \times p_f / \gamma_m
\]

where:
- \(d_f\) is the nominal bolt diameter, mm
- \(t\) is the thickness of the connected ply, mm

The minimum thickness of bolt bearing in this case is bearing against the mullion wall with a thickness of 2mm. Substituting the known values in the above equation gives:

\[
B_{RF} = 8 \times (2+2) \times 2 \times 252 / 1.2 = 13440\text{N}
\]

These values should be compared with the applied load of 7680N multiplied by the partial factor of safety (\(\gamma_f\)) of 1.2 (i.e. 9216N). Clearly the capacity of the bolt is greater than that required and the bolt is satisfactory.

The load capacity of the connected aluminium ply is given by the lesser of the following

- the bearing capacity of the ply which is given by:

\[
B_{RP} = c \times d_f \times t \times p_a / \gamma_m,
\]

- the tear out resistance of a fixing close to the edge of the material given by

\[
B_{RP} = e \times t \times p_a / \gamma_m.
\]

where:
- \(c\) is dependent upon \(d_f / t\) {where \(d_f / t < 10, c = 2\)},
- \(d_f\) is the nominal diameter of the fastener, mm,
- \(t\) is the thickness of the connected ply, mm,
- \( p_a \) for the material of the connected ply is the lesser of 0.5(\( f_{0.2} + f_u \)) and 1.2(\( f_{0.2} \)). For 6063 aluminium alloy in temper T6,
  \[ f_{0.2} = 160 \text{N/mm}^2 \]
  and \( f_u = 185 \)
  hence \( p_a = 172 \text{N/mm}^2 \),
- \( e \) is the distance from centre of the hole to the adjacent edge in the direction the fastener bears,
- \( \gamma_m \) is the factor of safety for material strength.

Substituting the known values in the above equations gives:

\[
B_{RP} = 2 \times 8 \times (2+2) \times 172 / 1.2 = 9173 \text{N}
\]
and

\[
B_{RP} = 40 \times (2+2) \times 172 / 1.2 = 22933 \text{N}
\]

As above, the required capacity is 9216N and the tear out resistance is clearly satisfactory. The shortfall in the bearing capacity is less than 0.5% and hence within the accuracy of the design formulae. It may, therefore, also be considered acceptable. If a greater shortfall in bearing capacity were found it would be necessary to use a larger bolt. Alternatively, the bearing area in the aluminium could be increased by drilling a larger hole and using a steel bush between the aluminium and the bolt.

Provided that the wall thickness, edge distance to the hole and material strength of the bracket are at least as great as for the mullion, the bearing of the bracket will also be adequate. If these conditions are not met additional calculations will be required.

The calculations above show that the single 8mm diameter bolt is adequate to carry the loads on the intermediate bracket. The same size bolt would be suitable for the bracket at the head of the mullion, however Figure 2 shows two bolts for the final fixing. Two 6mm diameter bolts would give slightly higher load capacity than the single 8mm diameter bolt and would therefore be sufficient.

### Bracket

The bracket will be subject to a combination of direct and bending stresses. For the bracket arrangement shown in Figure 2 the critical points that need to be checked are the connecting bolts between the shoe and the angle bracket and the bending stress in the angle bracket. It may be necessary for the bracket to incorporate a fillet to sustain the bending moment.

The design of the bolts will follow the same procedures as given above except that the bolts will also be subject to tension resulting from both negative wind loads and bending of the bracket due to the dead load.

The tensile capacity of the bolt is given by:

\[
P_{RT} = a \times p_f \cdot A_{th} / \gamma_m.
\]

Where:

- \( a \) is 1.0 for steel and 0.6 for aluminium
- \( p_f \) is the limiting stress which is the yield stress in the case of mild steel. For stainless steel it is the lesser of 0.5(\( f_{0.2} + f_u \)) and 1.2\( f_{0.2} \) where \( f_{0.2} \) is the 0.2% proof stress and \( f_u \) is the ultimate stress
- \( A_{th} \) is the stress area of the threaded part of the bolt.

Where bolts are subject to shear and tension simultaneously the following condition should be satisfied:

\[
\left( \frac{P}{P_{RT}} \right)^2 + \left( \frac{V}{V_{RS}} \right)^2 \leq 1
\]

### Bracket to structure connection

The fixing connecting the bracket to the structure will be subject to a combination of shear and tension.

Fixings should comply with Section 2 of Approved Document A of the Building.
Regulations, which requires a factor of safety of 3 to be applied to the strength of fixings determined from tests. The basic strength to which the factor of safety is applied is the mean test result less three times the standard deviation. This is a global factor of safety and in this case it would not be necessary to apply a partial factor of safety to the loads.

The connection between the bracket and the structure will usually make use of proprietary fixings and the design will be based on the manufacturer’s recommended safe loads.

**Summary**

Brackets form the link between the curtain wall and the frame. They are of critical importance to the safety of the wall and also have a profound effect on its buildability.

Technical Note 28 *Performance requirements for curtain wall brackets* describes the overall requirements for brackets. This Technical Note gives guidance on load bearing aspects of brackets.

The design of connections may be considered in three stages:

- Transfer of load from the mullion to the bracket,
- Transfer of load through the bracket,
- Transfer of load from the bracket to the structure.

**References**


BS 5950, *Structural use of steelwork in building*, British Standards Institution.