Introduction

Brackets form the link between the curtain wall and the structure. They are of critical importance to the safety and serviceability 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 the design costs, or the same proportion as the framing members themselves.

This Technical Note highlights the performance issues relevant to the design of brackets supporting curtain walling. The principles discussed in this Technical Note are applicable to brackets for all types of curtain walling but the examples discussed relate to stick curtain walling where the primary load bearing elements that must be supported are mullions.

SCI publication 101 describes curtain wall connections in more detail with greater emphasis on panellised systems.

Performance criteria

Brackets for fixing curtain walling are required to fulfil some or all of the following functions:

- Transfer loads from the curtain wall to the structure;
- Accommodate induced deviations (tolerances);
- Accommodate inherent deviations (movements);
- Resist corrosion;
- Resist fire;
- Be quick and simple to fix, adjust, inspect and maintain (buildable).

Loads

Vertical forces due to dead loads and horizontal forces due to live loads are transferred to the structure by the brackets.

- Dead load

The precise weight of the cladding will be determined as the design is developed, but early estimates need to be realistic to prevent lengthy re-design of the support members. This requires a knowledge of the type of cladding system, materials, wind load and grid dimensions.

The curtain wall is normally supported in front of the supporting structure with a buffer zone to accommodate tolerances. The line of action of the load will therefore be in front of that of the support and bending and/or torsional stresses will be induced in the connecting bracket.

- Live load

Wind loads in the form of negative (suction) or positive pressures are usually the dominant load case, with negative pressures at, for example, corners twice the magnitude of positive pressure at the centre of the windward face. Wind loads are determined by the site location and surrounding terrain, the shape of the building, local effects (e.g. sharp corners) and the size and location of openings.

Live loads resulting from building occupancy and maintenance are usually less significant than wind loads but still need to be considered.

To transfer these loads two types of fixings are required:

- Support fixings are required to carry dead loads and these fixings will prevent vertical
movement of the mullion relative to the supporting structure. Only one support fixing is necessary for each length of mullion and provision of additional support fixings is undesirable as movement will be restricted (see discussion of inherent deviations below).

For panellised systems two support brackets at the same level are normally required to provide stability.

- Restraint fixings are required at both top and bottom of mullions to resist wind loads.

For panellised systems it will normally be necessary to provide restraint near each corner of the panel.

Two possible arrangements of these fixings for a single storey height mullion are shown in Figure 1. The top hung arrangement is more common but the bottom supported arrangement may be used, particularly for low rise construction. Where mullions span more than one storey restraint fixings are usually provided at the intermediate floors.

Figure 1 Loading requirements for brackets

Induced deviations

Deviations are differences between specified nominal dimensions and the actual measured dimensions. Induced deviations are permanent deviations, which arise due to variations and errors in the manufacturing and construction process. Tolerances are agreed limits to these deviations, which the design should be able to accommodate.

Deviations are considered in greater detail in Technical Note 21 *Tolerance, fit and appearance of cladding*.

BS 5606 provides guidance on the accuracy that can be achieved in masonry, concrete, steel and timber members and structures based on measured and estimated survey data. This reflects the standards of construction/erection and manufacture achieved by industry in 1979 and 1990 respectively. BS5606 indicates that the edge of a suspended concrete floor slab may vary from its intended position by +/-15 mm in plan and +/-25mm in level. These values have a probability of 1 in 22 of being exceeded and to reduce this probability to 1 in 80 the deviation would be increased to +/-19mm and +/-31mm respectively. For a probability of 1 in 370 the tolerances would be 22.5mm and 37.5mm.

All brackets should provide adjustment in three directions to overcome the induced deviations. Means of adjustment include:

- Slotted holes for fixings - These may need to be combined with serrated surfaces to prevent further movement after adjustment or low friction surfaces to allow for inherent deviations after installation;
- Site-drilling or welding after positioning of components - This may be used for final fixing to mullions after initial fixing with slotted holes. It is likely to be less successful for fixings into concrete as the required hole positions may coincide with reinforcement;
- Shims, packing pieces or washers - If excessive thicknesses are used nuts may not engage fully with bolt threads and bending stresses may be induced in bolts. Packing pieces may also reduce the contact area between components increasing stresses and inducing additional bending;
- Sliding connections;
Threaded rods which pass through brackets and can be secured by nuts on both sides of the bracket;

Channel fixings - Comments for slotted holes apply.

**Inherent deviations**

Inherent deviations are changes in dimensions arising as a result of inherent material properties. They may be permanent or reversible and include:

- Deflections due to applied loads;
- Thermal movements;
- Shrinkage;
- Moisture movement;
- Creep;
- Settlement.

Design of brackets needs to take account of differences in the inherent deviations of the curtain wall and structure to avoid:

- Imposing loads on the curtain wall for which it has not been designed;
- Breakdown of seals due to large movements being transferred from the frame to the curtain wall.

Movement and dimensional changes described above can be accommodated at fixings by:

- Slotted holes in brackets and low friction washers;
- Interlocking joints which allow sliding in one direction but allow load transfer in the other two directions;
- Design to minimise movement, for example by avoiding connections at mid-span where deflections are greater.

Wind restraint brackets that incorporate vertically slotted holes and low friction washers allow the curtain wall and frame to move independently of one another in the vertical direction. Thermal movement of the curtain wall is accommodated in the splices between mullions.

Sufficient clearance should be provided within the rest of the curtain wall framework to allow the other components to move freely and still remain secure, and the system as a whole weathertight.

Although vertical movements will normally be greater than horizontal movements, horizontal movements must also be considered.

**Resistance to corrosion**

Two forms of corrosion warrant consideration - general corrosion of individual components including brackets, fixing bolts and curtain walling and bi-metallic corrosion resulting from contact between components made from different metals. Corrosion mechanisms are described in greater detail in Technical Note 24 *Corrosion*.

CWCT Guide to good practice for facades requires steel components to be protected by hot dip galvanising or coated with an approved treatment in accordance with BS 5493. BS 5493 has been superseded by BS EN ISO 12944. Not all coatings provide the same degree of protection and an appropriate level of protection must be provided.

If different metals come into contact in the presence of moisture a corrosion cell can be set up. PD 6484 gives guidance on the risk of corrosion with different combinations of metal. Bimetallic corrosion can be prevented by using gaskets, bushes or coatings of PTFE, neoprene or nylon to electrically isolate different components.

**Resistance to fire**

The performance of brackets will be affected by fire. Brackets fixed to soffits will be more vulnerable than those on the top surfaces of floors as they will generally be subject to higher temperatures during a fire. The bracket material will also affect performance, as steel will retain its integrity at higher temperatures than aluminium.
Aluminium and glass curtain walls do not have significant resistance to fire hence providing fire protection to the brackets will give limited benefit unless the whole wall construction is modified. With cladding materials with greater inherent fire resistance such as precast concrete, more extensive fire protection of the brackets may be required. The consequences of failure of the brackets may also be more significant if large elements can fall.

Requirements for fire safety are given in Part B of the Building Regulations however these are open to interpretation and the guidance of the local authority should be sought. The need for fire protection of brackets will depend on the required fire performance of the wall. In many cases curtain walls are not required to provide fire protection. However, where they are adjacent to escape routes or near adjacent buildings they may need to be fire rated.

In large buildings, fire/smoke barriers may be required in façade cavities and between the façade and internal walls and floors. Spread of fire may be restricted by firestops incorporated at intervals defined by Approved Document B of the Building Regulations.

Fire protection to the cladding supports or firestops must not interfere with other aspects of the performance of the cladding fixings.

**Buildability**

Cladding is often erected at height in inclement conditions, Fixing details should therefore be simple to construct, to improve safety and reduce the risk of poor workmanship. Design of the interface between the frame and cladding must be appreciated and discussed between the structural engineer, architect and cladding contractor at an early stage for it to be effective. Too often fixing details are decided upon late in the design process and as a result are poorly resolved. Building elements are poorly co-ordinated, and possibly costly and difficult to construct.

When panellised curtain walling is used it will be important to ensure that the cladding can be fixed quickly to minimise the time that a crane is required. This will not be so important when stick systems, which can be manhandled, are used.

Fixings to concrete present problems and there are differing views as to the best solution. Cast in channel fixings appear to provide a simple means of providing a connection which allows for adjustment however if they are misplaced they can be unusable and difficult to replace by drilled fixings due to the area taken up by the channel. Drilled fixings are more time consuming to install and may be difficult to get in the right place due to the presence of reinforcement. It is probably best to use channel fixings where they can be fixed to the formwork reducing the risk of displacement and to use drilled fixings in the top surfaces of slabs where there is generally less risk of hitting reinforcement.

Brackets which are capable of being lined and levelled in advance of the cladding operation can produce overall cost benefits.

Bolts should be tightened to a specific torque (advised by the bolt manufacturer) and checked before being concealed. To ensure that all bolts are checked it is good practice to clearly mark bolts after checking (for example by spraying with paint). If bolts are subsequently undone for any reason they should then be re-marked (for example by spraying with a different colour paint) to indicate the need for rechecking. Torquemeters used for tightening and checking bolts should be calibrated. When bolted connections are made to hollow aluminium sections care is necessary to ensure that the section in not distorted by over-tightening bolts.

Connections should ideally be accessible for inspection after fixing and tightening; this is not always possible but can be achieved by the use of removable internal linings.

The flexibility designed into the cladding connection system must not be abused to overcome fixing problems arising from, say, an out-of-tolerance frame. For example, the final position of a bolt in a slotted hole may need to be specified so as not to restrict post-installation
movement Ill-conceived remedial measures, to overcome problems of fit can compromise safety.

Where excessive induced deviations are found, the participants should discuss whether to modify the structure, drill some additional fixing positions or supply one-off bespoke brackets. The latter course of action would involve the cladding engineer, structural engineer (the solution alters the loads on the structure), and the architect if the solution generates a different aesthetic effect.

**Fixing arrangement**

A typical support arrangement for stick curtain walling is shown in Figure 2. In this case the brackets are fixed to the steel edge beam but they could also be connected to the floor slab.

Note that the splice joints between mullions can accommodate live load movement of the structure and thermal expansion of the mullions. Structurally, the splice is designed to transfer horizontal shear.

Splice joints should be located above the points of connection in a suspended curtain wall and below them in bottom-supported walls. For a continuous curtain wall, the most efficient structural use of the mullion occurs when the joint is at about one fifth of the span from the support.

**Types of brackets**

This section shows a number of examples of brackets for curtain walls.

a) A pair of angle brackets used to fix top of mullion to face of floor slab: adjustment is provided by positioning of drilled fixing holes in the slab and shims between brackets and concrete. The spigot in top of mullion provides restraint to foot of next section.

![Image](image.png)

b) A composite bracket formed from three pieces of aluminium angle bolted together. The slotted holes provide adjustment.

![Image](image.png)

c) Close-up of part of bracket for panellised curtain wall showing slotted fixing holes to allow adjustment and serrated surfaces to prevent slip after fixing.

**Figure 2** Fixings for single span hung curtain wall
Bearing stresses can be reduced by increasing hole size and using bushes.

- Shear failure or pull-out of connections to concrete;
- Bending, axial force and shear in brackets.

**Summary**

Brackets for fixing curtain walling are required to fulfil some or all of the following functions:

- Transfer loads from the curtain wall to the structure;
- Accommodate tolerances during construction;
- Accommodate differential movements of curtain wall and structure during service life;
- Resist corrosion;
- Resist fire;
- Be quick and simple to fix, adjust, inspect and maintain.

Structural design of brackets is considered in greater detail in Technical Note 29 *Design of curtain wall brackets*.

**References**


PD 6484, 1979, *Commentary on corrosion at bimetallic contacts and its alleviation*, British Standards Institution.