Technical Note No 90

Structural performance of systemised walls – Bracket requirements and principles – supersedes TN 28

This Technical Note is one of a series describing the structural design and assessment of wall framing systems and brackets. The series comprises:

- TN 84 Structural performance of systemised walls – Introduction
- TN 85 Structural performance of systemised walls – Design charts and profile data
- TN 86 Structural performance of systemised walls – Connections
- TN 87 Structural performance of systemised walls – Closed profiles
- TN 88 Structural performance of systemised walls – Buckling and torsion
- TN 89 Structural performance of systemised walls – Open profiles
- TN 90 Structural performance of systemised walls – Bracket requirements and principles
- TN 91 Structural performance of systemised walls – Bracket calculations

This Technical Note covers the requirements for brackets and associated fixings and bolts, and the principles that affect their design.

Introduction

This Technical Note gives advice on the design of brackets and fixings for the support of curtain walling, rainscreen and other forms of building envelope.

The appropriate design/selection of brackets and fixings will simplify the installation process and allow for more accurate construction.

Brackets and fixings are one of the more complex structural components in a building envelope. It is important that they are analysed or tested to ensure that they are safe in use.

This Technical Note describes the principles relevant to the structural checking of bracket and fixing capacity. Methods of calculation are given in TN 91.

Performance criteria

Brackets for systemised building envelopes are required to meet some, if not all, of the following requirements:

- Transfer loads from the building envelope to the structure
- Limit movement of the building envelope relative to the structure
- Accommodate movement
- Accommodate tolerances
- Resist corrosion
- Resist fire
- Be simple to fix, adjust, inspect and maintain

Load transfer

Two types of bracket are used:

Fixed brackets transfer loads acting in the plane of the wall and normal to it. In the case of a vertical wall:

- The in-plane loads are the self-weight of the wall and any attachments or fixtures,
- The out-of-plane loads are windload, barrier load and secondary loads caused by the off-set between the bracket and the line of action of the self-weight.

Note: ‘Fixed brackets’ are sometimes referred to a ‘support brackets’. ‘Support’ has been used in this series of Technical Notes to refer to any type of bracket and to avoid confusion the term ‘fixed bracket’ has been adopted.

Fixed brackets are required to prevent in-plane movement. Out-of-plane movement should be limited to 2 mm between extremes of positive and negative windload (CWCT 2006).

Restraint brackets transfer only loads acting normal to the plane of the wall. In the case of a vertical wall the out-of-plane loads are those described above for fixed brackets.
Restraint brackets should allow in-plane movement. They should limit out of plane movement as described above for fixed brackets.

**Partial load factors**  
Brackets should be designed to carry the load combinations described in TN 84.

When considering brackets the dead load may in some cases counteract the windload leading to lower forces and stresses; in this case the dead load is said to be a favourable load. The load factors applied to individual loads are:

<table>
<thead>
<tr>
<th>Load type</th>
<th>$\gamma_m$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable load</td>
<td>1.50</td>
</tr>
<tr>
<td>Dead load (unfavourable)</td>
<td>1.35</td>
</tr>
<tr>
<td>Dead load (favourable)</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Redundancy**  
The Approved Document to Part A of the Building regulations requires cladding fixings to be able to transmit loads on the cladding to the primary structure. In considering the safety of fixings account should be taken of whether the fixings are redundant or non redundant but non-redundant fixings are not prohibited.

The CWCT Standard (2006) requires that fixings shall be designed such that failure of any one connection does not lead to progressive failure of adjacent fixings. Fixings are defined as components providing the attachment of the structural frame (of the cladding) or brackets to the primary structure or backing wall.

This may be achieved by:

- Ensuring that any group of fixings is capable of carrying the load with one fixing failed.
- Ensuring that the wall can transmit loads to brackets adjacent to a bracket that fails.

The second possibility is not easily achieved with stick curtain walling and is more relevant to rainscreen rails, unitised walls and cladding panels.

Post-installed anchors are more reliant on workmanship than cast in anchors.

- When using post installed anchors the possibility of any one anchor not working should be considered.

- When using cast in anchors assumptions about redundancy will depend on:
  - Embedment depth of studs/bars
  - Number of studs/bars
  - Interaction with reinforcement

**Bracket location**  

**Stick curtain walling**  
Each mullion is supported independently in one of the following configurations:

- A fixed bracket at the head of each mullion and a restraint bracket at the bottom (hung). For multi storey applications restraint brackets are required at intermediate floors and mullion lengths are joined with spigots that transfer both axial and transverse load.
- A fixed bracket at the foot of each mullion and a restraint bracket at the top (stood). For multi storey applications restraint brackets are required at intermediate floors and mullion lengths are joined with spigots that transfer both axial and transverse load.
- Fixed brackets at every storey and storey height mullion lengths joined with spigots that transfer transverse load and permit axial movement. Walls constructed in this way are normally hung and the bottom of the lowest section of mullion is provided with a restraint bracket.

More detail is given in TN 84.

![Figure 1 Support location](image-url)
Structural performance of systemised walls – Brackets and fixings

Unitised curtain walling

Unitised curtain walling is normally hung from fixed brackets at each floor level. Units are connected by a stack joint that transfers horizontal load and permits vertical movement.

Although there are normally two fixed brackets for each unit, each bracket has to be capable of supporting the whole weight of the unit and the unit has to be capable of lifting-off each bracket so that upwards forces are not transmitted to the primary structure. This is necessary to accommodate structural movement as described in TN 56.

Rainscreen

Rainscreens may be supported by rails spanning between floor slabs in which case the brackets will be similar to those for a stick curtain wall. Many rainscreens are supported by lighter rails which require more frequent brackets with spans in the range 700 – 1500 mm depending on load. In this case the brackets are fixed to the back wall. Where multiple brackets support a single section of rail, one of the brackets is a fixed bracket and all other brackets are restraint brackets. It is normal for the fixed bracket to be at the centre of the rail which reduces the maximum movement to be accommodated by the bracket furthest from the fixed point.

Position on supporting structure

Brackets may be connected to:
- The vertical face of the floor slab edge
- The top surface of the floor slab
- The soffit of the floor slab
- Steelwork
- Back wall

Connecting to the slab soffit is less common as it is less convenient for the site operatives and structurally less efficient for fixed brackets. It is used where the wall is inset from the face of the floor or roof slab.

Connecting to steelwork allows many configurations of bracket. It will invariably give rise to secondary forces and localised stresses in the steelwork of the supporting structure. In particular it may give rise to torsion in edge beams.

Connecting to a back wall is appropriate for a rainscreen.

Movement accommodation

Movement of the wall relative to the structure may arise as a result of:
- Movement of the structure
- Movement of the cladding

Movement may be accommodated by:
- Movement joints, such as mullion spigots, within the wall
- Allowance for movement at the brackets

At a bracket, movement may be accommodated by:
- Slotted holes and low friction interface materials
- Interlocking components that slide in one direction but transfer loads in the orthogonal direction
- Components that flex or rotate but are still able to act as a strut/tie

Figure 2 Restraint bracket allowing vertical movement
Accommodation of tolerances

Differences between nominal dimensions and actual dimensions of both the supporting structure and the façade components have to be accommodated at the brackets. Information on tolerances is given in CWCT TN 21.

All brackets should provide adjustment in all three directions to allow for fit and accurate positioning of the wall. Adjustment may be achieved by movement:

- Of the wall relative to the bracket
- Of the bracket relative to the structure
- Between the components of the bracket

Means of adjustment include:

- Slotted holes – These will not transfer load in their long direction unless there is a mechanical interlock such as a serrated surface. Frictional interfaces are not recommended for reversible loads.

- Site drilled holes – It may not be possible to accurately position holes in concrete because of the reinforcement

- Shims, washers and packers – The acceptable depth of these will be limited by:
  - Bolt lengths
  - Bolt embedment
  - Bending stresses in bolts
  - Other secondary forces

Shims and packers should be non-compressible and should not creep.

- Threaded rods –

- Channel fixings – The comments for slotted holes apply

A bracket may be required to be adjusted before it supports the weight of the wall or once it is supporting the weight of the wall. In the second case it is necessary to consider how the adjustment may be made if the bracket is to be raised or lowered. Brackets comprising threaded elements may be used as jacks whereas other designs may require an external jack or hoist.

Resistance to fire

Where a curtain wall is fire resisting, the brackets will need to be fire resisting with a fire resistance period at least as great as that for the wall they support.

Most curtain walls are not fire resisting and for these walls the brackets should be designed to:

- Prevent the curtain wall moving away from a compartment floor and rendering the firestopping ineffective
- Prevent premature falling of large components of the curtain wall. Most curtain walls will loose their integrity and fall from the building if exposed to a prolonged fire.

In most cases curtain wall brackets will be exposed to fire from below and placing the brackets above the fire stopping may provide sufficient protection. Where greater levels of fire resistance are required brackets should be either:

- Steel brackets
- Fire protected aluminium brackets

Fire resistance is not generally required for brackets supporting a rainscreen.

Resistance to corrosion

Corrosion of brackets may occur as a result of:

- Use of a metal with inadequate durability for the environment
- Bi-metallic corrosion
- Alkali corrosion from contact with concrete or calcareous stone

The risk of corrosion will depend on the whether the brackets are in the wet zone or the dry zone of the wall.

Rainscreen brackets are invariably in the cavity which is in the wet zone of the wall. Curtain walling brackets are more likely to be in the dry zone of the wall.

Mill finish aluminium will normally give adequate durability in both locations. Mild steel brackets, even if they are in the dry zone of the wall, should be hot dip galvanized or coated with a suitable protective coat in accordance with BS EN ISO 12944.

The durability of galvanized steel brackets may be inadequate in a rainscreen cavity where a very long design life is required and for materials such as stone that may be adversely
affected by rust staining if local corrosion occurs.

Aluminium is susceptible to alkali corrosion and brackets, even if they are in the dry zone of the wall, should be separated from new concrete by bitumen paint or a membrane such as EPDM.

Fixings and connectors should be of the same materials as the materials they are used to fix or of more durable material. For this reason stainless steel is normally used.

Bimetallic corrosion from use of stainless steel fixings for aluminium and galvanized steel components is unlikely to be significant. The combination of galvanized steel and aluminium for curtain wall brackets and mullions is also unlikely to lead to significant bimetallic corrosion in a dry environment. Rainscreen brackets are normally supplied as part of a system with the support rails and the issue of bimetallic corrosion does not arise.

**Buildability**

It is implicit that it must be possible to install a building envelope. It is also preferable that it can be installed and adjusted with relative ease so that a better installation is achieved.

When designing brackets attention should be given to:

- Handling
- Ease of installing anchors
- Access to bolts and anchors
- Ease of adjustment
- Fineness of adjustment
- Temporary support of framing components

**Bracket configurations**

There are many ways to configure a bracket. Some of the basic configurations are shown below for various bracket locations.

The brackets are shown schematically with round holes. Some holes will be slotted to allow for adjustment and movement.

The forces acting on brackets may vary from 2 kN to 20 kN depending on the wind load, spacing of brackets, weight of wall and any secondary dead loads. Some bracket configurations shown below are only suitable for smaller loads.

**Edge of slab brackets**

Connecting to the edge of the floor slab may be difficult for higher loads. Post installed anchors have limited tension capacity when used in the edge of a thin slab and cast in anchors may be necessary.

The simplest form of connection is to place an angle at either side of a mullion as shown in Figure 3; these may be of aluminium or steel. They are easy to make and install and a hole is normally drilled in the mullion at site to avoid the use of shims. At higher loads it may be difficult to achieve redundancy.

![Figure 3 Two angles](image)

An advance over using two separate angles is to use a compound shape as shown in Figure 4. This is most easily constructed from an aluminium profile. It is easier to achieve redundancy with this configuration. It is also easier to use serrated washers. Otherwise many of the comments above apply. A disadvantage of this type of bracket is that the mullion must be installed from the front and this may conflict with connections for transoms. Some proprietary brackets overcome this by making one of the projecting arms hinged.
A single angle may be used where the loads are small as shown in Figure 5. This normally only applies to rainscreen brackets where the brackets are more closely spaced and the connection is often to the leg of a tee section rail. Note that the bracket will provide limited torsional restraint to the framing member. It is difficult to achieve redundancy with a single angle.

At a vertical interface with a different form of construction it may not be possible to use a symmetrical bracket. An off-set arrangement as shown in Figure 6 may be possible. This can provide torsional restraint to the framing member and achieve redundancy.

Connecting to the surface of the floor slab allows the anchors to be set back from the edge of the slab to achieve maximum resistance. Furthermore the anchors are predominantly loaded in shear.

The simplest form of construction is to use two projecting angles as shown in Figure 7. These are easy to make and install and a hole is normally drilled in the mullion at site, otherwise slotted holes and serrated washers are required at the anchors to provide adjustment.

Fabricating a bracket as shown in Figure 8 has the advantage that it is easier to achieve redundancy.
Structural performance of systemised walls – Brackets and fixings

Figure 8  Compound cantilever

A multi-part bracket as shown in Figure 9 is easiest to use as it may be adjusted within the bracket as well as at the slab and mullion connections. With the use of slotted holes and serrated washers it is possible to avoid the need for both site drilling and shimming.

Figure 9  Multi-part

At the foot of a wall the framing members may be fixed to the ground slab. A simple stub of the form shown in Figure 10 may be used. A similar bracket may be used at the top of the wall.

Figure 10  Stub

Brackets to steelwork

When connecting to steelwork, bolts rather than anchors are used and redundancy is not an issue although a partial material factor is applied.

Bolts are more easily positioned as it is possible to have slotted holes in the steelwork.

A multi-part bracket may be used as shown in Figure 11. Note that the inner portion may be provided by the steelwork contractor. If this is welded to the supporting structure as part of the steel fabrication, scope for adjustment will be limited and shims may be required.

Figure 11  Multi-part

As an alternative to the angles shown in Figure 11 a cup cleat may be used; this may be useful if it is desirable to minimize the visual impact of the bracket.

Figure 12  Cup cleat

An alternative to the cup cleat is a stirrup as shown in Figure 13; this may be easier to attach and adjust. Depending on the configuration of the steel work; using a horizontal leg rather than a vertical one may allow easier adjustment.
Brackets for unitised curtain walling

These brackets have to:

- Allow for adjustment under self-weight load
- Carry greater loads
- Be installed by working on the floor slab

A typical unitised wall bracket is shown in Figure 14. A hanger on threaded bars is incorporated to facilitate vertical adjustment under load.

Anchors

Anchors into concrete may be cast in place or post installed. Both have advantages and disadvantages.

Cast in place anchors

Cast in place anchors may be:

- Single sockets
- Plates with studs or sockets
- Channels

These are installed and positioned by the concrete contractor. As a result, accuracy of installation is outwith the direct control of the envelope contractor. Even if the envelope contractor checks the location prior to concreting, the anchors may be affected by the concreting operation.

Cast in place anchors may be integrated with the reinforcement of the concrete and may often be designed to offer greater resistance than post installed anchors.

Post installed anchors

Post installed anchors include:

- Undercut anchors
- Expansion anchors
- Resin anchors
- Concrete screws

These are placed in holes normally drilled by the envelope contractor. The choice of anchor will depend on:

- The loads to be transferred
- Type of load
- Location of anchor
- Substrate

Anchor performance

The load capacity of a given anchor type depends on:

- Concrete strength
- Embedment length
- Anchor diameter
- Edge distance
- Spacing from other anchors

The load capacity of a group of anchors will depend on:

- Disposition of the anchors
- Stiffness of plate or bracket
- Clearances and tolerances

All reputable anchor manufacturers are able to supply design tables and/or software for the simpler configurations of anchor.

Structural performance

Structural design of brackets and fixings is discussed in greater detail in TN 91. This section describes the underlying approach to structural performance.

Design approach

When designing brackets, the loads should be calculated in accordance with BS EN 1990 as described in TN 84.
Structural design of brackets should comply with the relevant Eurocode; BS EN 1999-1-1 or BS EN 1993-1-1.

When designing anchors the requirements of BS EN 1992-4-1 and BS EN 1992-4-3 should be followed. This is a partial safety factor method that is consistent with the Eurocodes. The partial safety factor method applies factors to the material strength and factors to the applied loads.

Previous practice has been to use the global safety factor method where a single factor of safety was taken. Typically this was a value of 3.

Fixings manufacturers sometimes produce data relating to each method of analysis. Care is needed to ensure that the appropriate material characteristics and factors are taken which ever method of assessment is used.

Secondary forces
Secondary forces should be taken into account. Secondary forces may occur as a result of:

- Off-set loads – Where a load and reaction are not co-linear secondary moments or couples may occur. This may be exaggerated by excessive shimming and packing.

- Prying action – This occurs when a bracket or cleat acts as a lever with the effect that forces in a bolt or anchor are increased.

Failure mechanisms
The following failure mechanisms should be considered:

- Shear, bearing and tension failure of bolts
- Bearing failure at bolt to bracket interfaces
- Bending, axial force and shear in the brackets
- Tensile failure of anchors
  - Bolt failure
  - Bolt pull out
  - Concrete Cone pull out
- Shear failure of anchors

Plastic behaviour
The dominant load on a wall is the wind load which is a reversible load. For this reason structural design is based on elastic behaviour. However, when considering redundancy of an anchor it may be acceptable to allow for plastic behaviour of a bracket. The risk of a fixing failing is low but this will result in gross deformation of the cladding and will require remedial work.

Effect on supporting structure
The structural engineer responsible for the design of the supporting structure should be involved in the design of the brackets and fixings.

Brackets will transfer load to the structure which should not exceed those anticipated in the design of the structure.

Cast-in anchors will have to be constructed as part of the supporting structure and should be designed to take account of the reinforcement in the concrete.

Brackets connected to steel framing members may:

- Cause torsion within a beam
- Cause high stresses local to the bracket

The structural steelwork design and fabrication may have to incorporate plates, tees, lugs and so on to accept the brackets.
Over cladding and refurbishment
When attaching brackets to an existing structure the supporting structure should be checked for strength. The loads and load distribution may be different from that caused by the original building envelope as:

- The area of wall may be greater
- Spacing between fixings may be greater
- Fixings may connect to different parts of the structure; for instance infill blockwork

When over cladding, it may be necessary to install anchors into an existing concrete structure. For anchors into existing concrete it is recommended that 5 percent of all anchors installed should be tested and a minimum of ten anchors should be tested.

References
BS EN 1990, Eurocode 0. Basis of structural design
NA to BS EN 1990, National Annex to Eurocode 0, Basis of structural design.
DD CEN/TS 1992-4-3, Design of fastenings for use in concrete – Part 4-3 Anchor channels
BS EN 1999-1-1, Eurocode 9: Design of aluminium structures - Part 1-1: General structural rules
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