Technical Note 95

Weathertightness of windows, doors, window assemblies and curtain walls

Windows may be installed in buildings as individual windows but may also be coupled together to form assemblies. Extensive window assemblies are considered a form of curtain walling which should be designed accordingly however disputes arise over:

- when a window assembly becomes a curtain wall,
- and
- requirements for the joining details of other window assemblies.

These issues are heightened by the higher weathertightness requirements that are often applied to curtain walls.

This Technical Note gives guidance on the requirements for window assemblies and suggests a consistent approach to design and performance assessment.

The satisfactory performance of windows depends on appropriate detailing of interfaces both within a glazing/panel system and connecting it to the surrounding construction. This Technical Note deals with the performance of interfaces between windows and panels of an assembly, and between windows and curtain walling. Other interfaces are outside the scope of this document.

This Technical Note also highlights the requirements of the National House Building Council (NHBC).

Introduction

A window is defined in EN 12519 as a ‘building component for closing an opening in a wall or pitched roof that will admit light and may provide ventilation’. This definition does not set any limit on the size of a window but windows are normally produced in a factory and size is limited by practical constraints of transport and handling. A window may contain a number of glazed openings within an enclosing frame.

Windows may be installed in buildings as individual windows within a wall. Windows may also be installed as assemblies of various forms including:

- A horizontal ribbon of windows one window high
- A storey height assembly of windows and opaque panels more than one window high and wide set between the floor slabs
- A vertical ribbon of windows one window wide that may extend across the floor slabs and may be connected by panels that form part of the system assembly
- An assembly of windows more than one storey high and more than one window wide that is continuous across the front of the floor slab and may include spandrel panels that form part of the system assembly.

The use of windows in assemblies places additional demands on the windows and requires jointing details to be developed. Extensive window assemblies are considered a form of curtain walling which should be designed accordingly. An assembly of windows more than one storey high and more than one window wide that is continuous across the front of the floor slab is considered to be a form of curtain walling.

The specification of weathertightness of windows in the UK is usually based on the recommendations given in BS 6375-1 which refer to the classification system given in EN 14351-1 whereas curtain walls are generally specified following the guidance in the CWCT Standard for systemised building envelopes which refers to the classification system in EN 13830. The requirements of the CWCT Standard are higher than those in BS 6375-1. This can lead to different components of the same building having different levels of performance.

This Technical Note gives guidance on the requirements for window assemblies and appropriate weathertightness requirements for
windows, window assemblies, curtain walls and windows within curtain walls.

The satisfactory performance of windows depends on appropriate detailing of interfaces with surrounding construction. The design of interfaces between windows of a window assembly and between windows and curtain walls is part of the system design and hence the performance of these interfaces is covered by this Technical Note. Interfaces with the surrounding construction such as between a window and a rainscreen wall are generally designed on a project basis and are outside the control of the window system manufacturer. They are not included within the scope of this Technical Note.

Doors

This Technical Note refers to windows but the requirements for windows also apply to doors providing direct access to habitable spaces. This includes all external doors of individual apartments or dwellings. Entrance doors intended for frequent operation are unlikely to meet the same level of performance for weathertightness. This is acceptable for doors opening into an entrance lobby, porch etc.

Low threshold doors should meet the same requirements however this may not be achievable unless the design of the floors allows the incorporation of appropriate drainage and detailing of the door interface needs to be considered before the design of the floor is finalised.

Performance of individual windows

Windows are tested and classified in accordance with EN 14351-1. Since July 2013 they are required to be CE marked. This allows manufacturers to declare the performance of their products however EN 14351-1 does not provide guidance on the appropriate performance class for particular applications. Guidance on appropriate classes of performance for weathertightness is given in the section on specification at the end of this Technical Note.

Testing and classification of windows to EN 14351-1 relates to the window alone and does not include consideration of the interfaces with the surrounding construction including the interface between the window and the cill. The EN test methods for windows specifically exclude joints between the window and the surrounding construction as these are outside the control of the window system manufacturer.

Where individual windows are incorporated into traditional forms of construction such as masonry, standard details including dpcs and flashings are used to ensure weathertightness of the interface. The window is normally fixed to the supporting construction at close centres which replicates the support provided by the test box used for weathertightness tests.

When windows are incorporated into systemised building envelopes such as curtain walling, it is good practice to test the window interface as part of the evaluation of the weathertightness of the wall system. Standard test layouts for curtain wall tests include an opening light within the curtain wall test specimen for this purpose. The window may also be tested as part of the wall test as the behaviour of the window may be affected by the support conditions however this is rarely done and the opening joints in the window are normally taped up to exclude them from the test.

The NHBC requires windows to be tested as part of the curtain wall. This may require a project test to be carried out. Alternatively specifiers could select products that have been tested in this way and system companies are encouraged to test in this way for at least some of their products.

Performance of window assemblies

Principles of design

Where windows are installed as an assembly, the components used to join the windows must be evaluated to ensure that the properties of the entire assembly are satisfactory. The windows may also require additional testing which is most likely to be in respect of wind resistance as described below.

The scope of EN 14351-1 includes ‘screens’. A ‘screen’ is defined in the standard as ‘an assembly of two or more windows and/or external pedestrian doorsets in one plane with or without separate frames’. Hence window assemblies described in this Technical Note are within the scope of EN 14351-1. They should therefore be CE marked and the assessment of performance for CE marking should include the effect of the joining details.

The test methods referred to in EN 14351-1 have been written assuming tests are to be carried out on individual windows and additional guidance is required where they are to be used for window assemblies. Window system manufacturers produce joining details for their
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windows and are therefore able to carry out the necessary testing. Alternative joining details should not be used unless they have been fully evaluated and tested.

Aspects of performance that are likely to be affected by the design of the joint between the windows of an assembly include:

- **Weathertightness**
  For weathertightness, a dual sealed approach to joint design is recommended with an outer seal as the primary water barrier and the inner seal providing the air barrier and a secondary barrier to water ingress. This is a requirement of the NHBC. The air barrier must be continuous around the full perimeter of the window. All seals should be permanently flexible, resistant to weathering and easy to replace. The space between the seals should be drained to remove any water that passes the outer seal. The cavity between the seals must also be detailed to prevent water escaping into parts of the structure which are not intended to become wet, for example by draining out of the unsealed ends of framing members.

- **Structural integrity**
  Windows tested and classified in accordance with EN 14351-1 will have been subjected to wind load tests but during those tests the perimeter of the window is supported by the test box hence the response of the perimeter frame to wind load will not have been fully assessed. When used in an assembly, the perimeter frame of the window either needs to be able to resist the wind load in bending or the joining component needs to provide support and contribute to the overall stiffness of the system in resisting deflection arising from wind pressure and other loadings including accidental impact.

  Where the window assembly extends to more than one window in both directions, the joining component in one direction must span the full width or height of the assembly and will have to carry all the load at the junction(s) between the window frames. It will also have to support the ends of the joining components running in the transverse direction.

  The test criteria for windload resistance in EN 14351-1 allow three classes of deflection. For window assemblies, it is recommended that the main structural members of the assembly satisfy class B for which the allowable deflection is span/200 under the design wind load in both positive and negative directions. This is the limit which applies for curtain wall Mullions in EN 13830.

- **Movement accommodation**
  Windows fixed into openings in the wall need to accommodate differences in movement of the window and of the surrounding wall construction. For individual windows these movements will normally be small. Window assemblies are larger so that the movements to be accommodated are also likely to be greater.

  Where the building is of framed construction with a non loadbearing façade, there is often a movement joint in the façade at floor level. Where a window assembly extends across a movement joint in the façade, the design should allow for suitable jointing of the window assembly that will accommodate predicted structural movement whilst remaining weathertight and transferring loads to the building structure.

- **Thermal performance**
  Joining details that introduce additional metal components may create additional heat flow paths that increase the U value of the assembly. These effects should be assessed by calculation.

  If the assembly is continuous in front of the floor slab it may be necessary to consider fire stopping and acoustic performance of the interface with the floor.

  Specific guidance on the treatment of different types of window assembly is given in Appendix A.

**Curtain walls**

Curtain walls include any window assemblies that are more than one window wide and extend across the floor slabs.

Curtain walls are tested and CE marked in accordance with EN 13830. EN 13830 defines classes of performance for different characteristics of curtain walls. The classification for weathertightness includes air permeability, watertightness and wind resistance. In the basic test sequence, watertightness is assessed by a static test and this is often referred to as a CWCT test.
sequence A. There is an option to include a dynamic watertightness test and this would be referred to as a CWCT test sequence B. The test procedures are similar to those used for windows but differ in the following respects:

- A repeat watertightness test is required after application of the serviceability wind load
- A larger specimen incorporating a joint at floor level is required
- There is an option to carry out a dynamic watertightness test
- Wind load is limited to a single application in each direction at both serviceability and safety level; for windows there is also a requirement for 50 cycles of load at half the serviceability wind load.

The features that affect a curtain wall and may require a different test regime are as follows:

- Curtain walls are exposed on the face of the building rather than being protected in reveals. This may require a more severe watertightness test.
- Curtain walls form more extensive areas of impermeable wall surface increasing the amount of water rundown. This may require a more severe watertightness test.
- Curtain walls run past the edge of the floor slab and the inner face is often concealed by internal finishes. Any leakage may not be immediately detected and greater reliability may therefore be required.
- Curtain walls often include movement joints which may form a weak point for water ingress.

### Specification of performance for weathertightness

EN 14351-1 defines classes of performance for different characteristics of windows. This allows manufacturers to declare the performance of their products however EN 14351-1 does not provide guidance on the appropriate performance class for particular applications. BS 6375-1 is the UK national application document for EN 14351-1. It gives guidance on the selection of appropriate performance classes for windows and doorsets intended for the UK market. The recommended class of performance for air permeability and watertightness in BS 6375-1 depends on the design wind load as shown in Table 1.

Some specifiers require higher performance and many windows have been tested to much higher pressures, commonly 600Pa for both air permeability and watertightness.

<table>
<thead>
<tr>
<th>Design Wind Load</th>
<th>Air permeability Test Pressure</th>
<th>Watertightness Test Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>800Pa</td>
<td>300/450/600 Pa</td>
<td>300 Pa</td>
</tr>
<tr>
<td>1200</td>
<td>300/450/600 Pa</td>
<td>300 Pa</td>
</tr>
<tr>
<td>1600</td>
<td>300/450/600 Pa</td>
<td>450 Pa</td>
</tr>
<tr>
<td>2000</td>
<td>300/450/600 Pa</td>
<td>600 Pa</td>
</tr>
<tr>
<td>2000+</td>
<td>0.25p</td>
<td>0.25p</td>
</tr>
</tbody>
</table>

Table 1 Recommended weathertightness performance of windows in BS 6375-1

An international comparison by Van Den Bossche shows that the requirements of BS 6375-1 for watertightness are lower than those used in many other countries.

The CWCT Standard gives guidance on the appropriate performance classes for curtain walls as shown in Table 2. The recommended class of performance for air permeability is chosen from the options given based on the environmental conditions required in the building - a higher test pressure would be specified for more airtight buildings which are commonly specified by services engineers to improve the energy model of the building.

The required watertightness performance depends on the exposure as given by the design wind load and is based on the rule that the watertightness test pressure should be at least 25% of the design wind load. Water penetration occurs under positive wind load hence the test pressure may be related to the positive design wind load which is often lower than the negative wind load.

<table>
<thead>
<tr>
<th>Design Wind Load</th>
<th>Air permeability Test Pressure</th>
<th>Watertightness Test Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 800</td>
<td>300/450/600 Pa</td>
<td>300 Pa</td>
</tr>
<tr>
<td>801 to 1200</td>
<td>300/450/600 Pa</td>
<td>300 Pa</td>
</tr>
<tr>
<td>1201 to 1600</td>
<td>300/450/600 Pa</td>
<td>450 Pa</td>
</tr>
<tr>
<td>1601 to 2000</td>
<td>300/450/600 Pa</td>
<td>600 Pa</td>
</tr>
<tr>
<td>2001 to 2400</td>
<td>300/450/600 Pa</td>
<td>600 Pa</td>
</tr>
<tr>
<td>Over 2400</td>
<td>0.25p</td>
<td>0.25p</td>
</tr>
</tbody>
</table>

Table 2 Recommended weathertightness performance of curtain walls in CWCT Standard for systemised building envelopes

The CWCT Standard as amended by CWCT Technical Update 21 requires that a dynamic watertightness test is carried out in addition to the static test where the design wind load greater than 1800 Pa.

The CWCT Standard recommends that opening lights within a curtain wall comply with the
requirements in Table 2 but permits opening lights to be specified in accordance with BS 6375-1. The different requirements for windows and curtain walls lead to the following issues:

- It is inconsistent to have different parts of the façade giving different levels of performance. There may be situations where this is acceptable on the basis that the opening lights are in visible areas of the façade where any leakage can be dealt with before it causes serious damage but most building owners would regard this as unacceptable. It is particularly likely to be unacceptable in domestic owner occupied property and consequently is not acceptable to the NHBC.

- When using standard systems, reliance is often made on the manufacturer’s test data; in this case windows and doors are not generally tested within curtain walls or to the curtain wall standards. The test procedures for windows and doors differ slightly from those used for curtain walls, as described above, and there is no provision for carrying out dynamic watertightness testing of windows unless this is carried out as part of a curtain wall test.

The following approach is recommended by CWCT:

**Windows, doors and window assemblies in low rise buildings**

Weathertightness may be specified in accordance with BS 6375-1 but the use of windows and doors with higher levels of performance will reduce the risk of leakage and should be considered for locations exposed to high levels of driving rain.

**Windows, doors and window assemblies in medium and high rise buildings**

In medium and high rise buildings remedial action in the event of water leakage is likely to be more difficult and hence more costly. Windows in high rise buildings may also be exposed to higher levels of water for the same wind pressure than low rise buildings. This may be due to reduced shelter from adjacent buildings or runoff from large areas of wall. It is therefore recommended that higher levels of performance are specified. Experience suggests that testing for watertightness at 25% of the design wind load gives satisfactory performance provided that the installation is carried out proficiently.

Testing at these higher pressures may preclude the use of some styles of opening window and door. In such cases lower test pressures could be accepted provided the associated risk of water leakage is recognised and acceptable to the client. This would not be acceptable on NHBC projects. Alternatively, specifiers should limit their choice of window and door styles to those that can provide the required performance. There may be a conflict between this level of weathertightness performance and requirements for low threshold doors unless provision for drainage is made in the design of the floors.

**Windows within Curtain walls**

Windows within curtain walls should be tested for watertightness to the same test pressures as the curtain walls within which they are used.

Where a project test is carried out, the windows can be subjected to the same test regime as the curtain wall which can include a dynamic watertightness test if considered appropriate. It should be recognised that some styles of opening light may not be able to achieve this level of performance particularly where the curtain wall is subject to a dynamic watertightness test.

When relying on manufacturer’s test data for standard systems, the curtain wall will be tested and classified in accordance with EN 13830 and the window will normally be tested and classified in accordance with EN 14351-1 although there are a few systems available where windows have been tested within a curtain wall system. The testing of the curtain wall should as a minimum include the interface detail between the window and the curtain wall.

Although it is recommended that the window be tested to the same test pressures as the curtain wall, it will not be subject to a dynamic watertightness test if it has not been tested as part of a curtain wall. The window may also give lower performance when mounted in a curtain wall rather than a window test box due to more flexible support conditions. If this is unacceptable a project test would have to be carried out. The NHBC require the windows to be tested within the curtain wall but do not require the window to be subject to a dynamic watertightness test. They also require a minimum watertightness test pressure of 600Pa.

**Curtain walls**

Curtain walls should be tested to the pressures given in Table 2. Where the positive design wind load is greater than 1800Pa, a dynamic watertightness test is required.
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The NHBC Standard requires curtain walls to be tested for air permeability and watertightness at 600Pa but it is not clear when a dynamic watertightness test is required. When curtain walling is being provided on buildings to be covered by an NHBC warranty, the need for a dynamic test should be agreed with NHBC as should requirements for windows within the curtain wall.

**Site testing**

Laboratory testing, classification and CE marking in accordance with EN 14351-1 or EN 13830 demonstrate that the glazing system can provide a specified level of performance. That performance will only be achieved in practice if site installation is carried out correctly. Site testing may be required to demonstrate that this is the case.

The CWCT Standard recommends site watertightness testing for curtain walls. Site testing may be carried out using the hose test or the spray bar method and the testing may include opening joints or may be restricted to fixed joints. It is a requirement of the CWCT Standard for the specifier to state the method and extent of site testing. Where opening lights are to be site tested, it is recommended that a calibration of the test is carried out on a laboratory specimen.

The NHBC standard requires site watertightness testing of the fixed joints of curtain walls including interfaces with adjacent construction. This would include window assemblies that are classed as curtain walls. There is no requirement for testing windows or window assemblies which are not classed as curtain walls. For rainscreen walls, interfaces which are designed to be permanently watertight should be tested. This may include interfaces between the rainscreen and windows but would not include the opening joints of the windows.

The CWCT Standard allows the building envelope contractor to carry out the site testing but it should be witnessed by an independent person with appropriate experience.

Site testing should be carried out before internal finishes are installed so that any water leakage can be identified. On a large contract, site testing should be carried out in stages as the work progresses. This allows systematic errors to be identified early in the programme and minimises the need for remedial work.

**References**

- EN 12519 Windows and pedestrian doors. Terminology.
- EN 14351-1 Windows and doors. Product standard, performance characteristics. Windows and external pedestrian doorsets without resistance to fire and/or smoke leakage characteristics.
- BS 6375 Performance of windows and doors. Part 1 Classification for weathertightness and guidance on selection and specification
- Part 2 Classification for operation and strength characteristics and guidance on selection and specification
- Part 3 Classification for additional performance characteristics and guidance on selection and specification
- EN 13830 Curtain walling. Product standard
- CWCT Standard for systemised building envelopes
  - Part 1 Scope, terminology, testing and classification
  - Part 3 Air, water and wind resistance
  - Part 4 Operable components, additional elements and means of escape
- NHBC Standard
  - Chapter 6.7 Doors, windows and glazing
  - Chapter 6.9 Curtain walling and cladding.
Guidance relating to different types of window assembly

Horizontal ribbon glazing

Figure 1 shows a horizontal ribbon of windows which requires a joining detail that will provide a seal against water and air leakage. The vertical edges of the window will not be supported by fixings to the wall hence either the window frame will have to be sufficiently robust to span the height of the window without additional support or the joining detail will have to provide additional support. Depending on the length of the ribbon of windows, it may be necessary to allow horizontal movement at the joint between the windows. A number of possible joint types are illustrated below:

Figure 2 shows a coupling detail that has inner and outer seals. The cavity between the seals should be drained to the outside at sill level. The joint detail does not provide structural support and the window frames must therefore be able to span the height of the assembly. The screw connection through the joint prevents movement hence any thermal expansion/contraction of the windows must be accommodated at the other ends of the windows. The absence of any metal strengthening members means there will be little effect on the thermal performance.
Figure 3 Vertical joint with a structural coupling bar but no provision for movement

Figure 3 shows a joint detail which incorporates a structural mullion. It relies on clamping the window frames to the mullion to provide the outer seal but has a sealant at the inner seal. Due to the fixing s between the windows and the mullion there is no provision for movement. The structural section is thermally broken but will have a significant effect on the U value as the thermal breaks are shorter and not fully aligned with those in the window frames.

Figure 4 Vertical joint with a structural coupling bar and provision for movement

Figure 4 shows a joint detail that incorporates a coupling component that is screwed to one window but has a sliding connection to the other window which permits movement to take place. The coupling section will provide some addition stiffening of the joint and is thermally broken to reduce the effect on thermal performance.

Weathertightness of these joining details can be assessed from tests on a window assembly comprising two windows and the joining detail. It would also be necessary to include a cill as this is required to drain water from the cavities between the front and back seals at the joining detail.

To satisfy requirements on test specimens given in Annex E of EN 14351, the height of the test specimen and hence the span of the vertical framing members must be greater than or equal to the maximum span of framing members in a window assembly to which the test relates. The windows should also be the same width as those in the assemblies to which they relate as this dimension will affect the amount of load taken by the joint. Whilst this requirement for the size of the specimen only applies to the assessment of wind load, the wind load assessment includes a repeat air permeability test to check that seals have not been impaired and the test cannot be replaced by calculation alone.
Where a range of framing members with the same sealing details but different I values is available it would be appropriate to test one framing member. The results could then be applied to other framing members provided that:

- The overall span of the framing member is not greater than for the tested framing member
- The design wind load is no greater than for the tested framing member
- The strength and stiffness of the member are shown by calculation to be adequate. The stiffness requirement will be satisfied if the calculated curvature of the proposed framing member under its design wind load is no greater than the calculated curvature of the tested framing member under the test wind load

Window assembly more than one window wide, more than one window in height but not more than a single storey height

![Figure 5 Storey height window assembly](image)

Figure 5 shows a storey height window assembly two windows high. An assembly of this form will require joining framing members which span the full height or width of the assembly. This will normally be a mullion in the vertical joint. An example of a jointing system is shown in Figures 6 to 8.

![Figure 6 Horizontal joint between windows](image)

Figure 6 shows a horizontal joint with the upper window supported on the lower window. There are outer and inner seals but no direct means of drainage of the cavity which relies on draining along the framing members to the vertical joints. The joint does not have any bending strength in the vertical direction and there is no additional framing member to provide additional bending strength in the horizontal direction. The horizontal framing members of the windows must be able to span between the vertical coupling mullions and the mullions will then have to carry all the load to the supporting structure. Weather tightness of the joint may be adversely affected by rotation caused by bending of the coupling mullion and this must be proved by test. The joint does not allow for any vertical movement so movement must be accommodated at the top of the assembly. The absence of any additional framing members means that there will be little effect on the thermal performance.
Figure 7 shows the vertical joint with front and back seals and a range of coupling mullion depths that can be used depending on the load to be carried. The cill detail needs to provide drainage for any water passing the outer seal and is shown in Figure 8. The joint permits movement in the horizontal direction to accommodate expansion/contraction of the window frames. The coupling mullion is thermally broken in a similar manner to the window frames minimising the effect on thermal performance.

Figure 8 Cill detail

Weathertightness of an assembly may be assessed by testing an assembly consisting of four windows in a window test box. The most critical arrangement will depend on the relative stiffness of the window frames and mullions, and the location of the horizontal joint however it is not practical to consider all possibilities and a single test may be carried out on a storey height assembly with the horizontal joint at mid height.

The strength and deflection of the mullion would need to be calculated if there is any variation from the tested arrangement. It is fairly simple to calculate strength and deflection of the mullion if this is considered to carry all the load directly. In practice the window frames will provide a stiffening effect and may contribute to the strength of the section if the horizontal joint between the windows is not located at the point of maximum bending moment. The structural performance of the composite section depends on how the windows and mullions are connected and the location of joints between the windows.

Where a range of framing members with the same sealing details but different I values is available it would be appropriate to test one framing member. The results could then be applied to other framing members provided that:

- The overall span of the framing member is not greater than for the tested framing member
- The design wind load is no greater than for the tested framing member
- The calculated curvature of the proposed framing member under its design wind load is no greater than the calculated curvature of the tested framing member under the test wind load
A vertical ribbon of windows requires a horizontal joining detail that will provide a seal against water and air leakage. The horizontal framing members at the head and cill of the window will not be supported by fixings to the wall hence either the window frame will have to be sufficiently robust to span the width of the window without additional support or the joining detail will have to provide additional support. Depending on the height of the ribbon of windows, it may be necessary to allow vertical movement at the joint between the windows. Each window module that makes up this assembly will require connections with sufficient capacity to provide secure anchorage to the structural opening whilst allowing for predicted movement. A possible joint is illustrated in Figure 10:
Figure 10 Horizontal joint between windows

The joint in Figure 10 has inner and outer seals with a drained cavity. The ends of the coupling detail need to be sealed to prevent water draining out the end of the framing members rather than through the drainage opening in the front face of the window frame. An end plate should be available as part of the window system for this purpose. The joint permits vertical movement and hence requires the jambs of windows to be fixed to the surrounding wall to support both wind load and self weight but allow for differential vertical movement between the window and the wall. As there is no additional framing member, the window frames must be designed to span between the jambs.

Vertical ribbon windows in stairways do not generally require firestops or acoustic seals where they pass in front of floor slabs however if vertical ribbon windows are used in habitable areas, fire stops and acoustic seals may be required.

Weather tightness of these joining details can be assessed from tests on a window assembly comprising two windows and the joining detail.