Shadow Boxes

Shadow boxes have been used in curtain wall construction for a number of decades. Their use is becoming more widespread, not just in commercial buildings as before, but also in residential construction. This has prompted insurers such as the NHBC to take a keener interest, and this Technical Note is in response.

This Technical Note discusses the principles of shadow box construction and the key design considerations. When discussing factors such as condensation, it is done in the context of a UK-type climate.

Introduction

A shadow box generally consists of:

- Clear glazing,
- A cavity behind the glazing,
- An insulated panel/tray.

A shadow box should not be confused with a glazed spandrel panel. One of the key features of a shadow box is the cavity behind the external glazing, Figure 1 below. Glazed spandrels may also contain a cavity in this position or alternatively the insulation will be tight up against the external glazing.

A further difference is with the type of glazing used; shadow boxes generally use transparent glass, whereas glazed spandrels use opaque glass (painted, fritted, etc).

Glazed spandrel panels are beyond the scope of this Technical Note.

Shadow boxes are used for the particular appearance they give. The cavity behind the glazing adds depth to the appearance, creating greater visual interest than can be achieved with a more typical glazed spandrel. In addition they allow the use of the same glass as that used in the vision areas, thus giving visual continuity between the different zones of the façade.

The external appearance of a shadow box will depend on:

- The glass used;
- The depth of cavity;
- The colour and material used to form the back of the cavity.

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Figure 1 – Shadow box (left), glazed spandrel (right)

Figure 2 – Shadow boxes at floor slab level
The only reliable way of demonstrating the appearance of a shadow box is via a mock-up. This may form part of a weathertightness test specimen or may be a separate visual mock-up in which case the additional cost should be budgeted for.

When using a glass with a printed pattern it should be noted that it may be subject to visual effects, such as moiré patterns shown in Figure 3. These are formed due to inference between the pattern on the glass and its shadow on the back panel of the cavity. These may be undesirable for the building owner and distracting for people passing the building.

**Figure 3 – Moiré interference patterns**

**Concerns**

There are several concerns regarding the use of shadow boxes;

- Condensation,
- Dust etc within the cavity,
- Thermal bridging at the perimeter caused by the cavity behind the glass.

Both condensation and dust will give rise to visual issues and in the case of condensation potential damage to materials and surfaces within the cavity.

Condensation is generally considered to be more of a concern in residential buildings due to the 'client'/building owner being generally less well informed than those in the commercial sector, and therefore viewing condensation as a significant fault rather than an accepted risk.

The cavity behind the external glazing may result in additional thermal bridging at the perimeter between the shadow box and the curtain wall frame. Depending on the level of ventilation, the cavity may be cold which will allow heat to ‘bypass’ the thermal break in the profile resulting in cooler frame temperatures. The effect of thermal bridges should be assessed during the design process in order that the façade meets the overall thermal specification.

**Configuration/layout**

There are various ways of constructing a shadow box.

**Glazing**

The glazing used may be:

- Single glass,
- Insulating glass unit (IGU).

Generally the glass will be clear. Although opaque glass may also be used, this negates the visual benefits of a shadow box and a glazed spandrel may be a better option in such cases.

The glass may not need to be coated for reasons of performance, however it may be coated in order to better resemble the glazing in the vision areas.

Appropriate glass selection is vital in terms of aesthetics, durability, safety and thermal performance. However there are advantages and disadvantages of all glazing options.

- Glass and cavity temperatures are likely to be very high and therefore annealed glass is not suitable due to the risk of thermal fracture. It should be noted that thermally treated glass is not as flat as basic annealed glass. Allowable roller wave amplitude and direction should be agreed upon and visual mocks-ups may be required to demonstrate acceptable performance. Thicker glass may be required to limit roller wave.

- Laminated glass is unlikely to fall if broken and hence it is usually the safest option. However it is more expensive than monolithic glass the risk of delamination needs to be assessed by determining the temperatures that will be attained and confirming the suitability of the interlayer.
• Monolithic heat strengthened and toughened glass are normally acceptable for the inner pane of a glazing unit and heat strengthened glass would normally be preferred due to the lower risk of nickel sulphide failure. However a design check may need to be undertaken to confirm the strength of the heat strengthened glass to resist the thermal stresses. The same applies to the outer pane.

• Monolithic heat strengthened or toughened glass may be acceptable for the outer pane of a glazing unit or for single glazing however there is a risk of glass falling if the pane breaks. The risk is greater for single glazing and for larger panes. If toughened glass falls, it may fall in large plates due to the failure of the dice to separate.

• Where toughened glass is used it should be heat soaked to reduce the risk of nickel sulphide failure.

The glass should be selected on the basis of a risk assessment as described in TN68. This will take into the account the consequences of broken glass falling. Thermal fracture is discussed in detail in TN 65.

Cavity
There is no recognised standard cavity dimension. It appears that this is principally an aesthetic decision, and will depend on factors such as;

• Glass type,
• Cavity back panel colour and material.

Typically cavities are in the range 50 – 100mm.

The cavity is usually formed by a painted metal tray behind the glazing. This gives a uniform appearance which is particularly important if a very clear glass is used.

Other materials such as metal meshes or timber may also be used to give a particular appearance.

Alternatively rigid insulation alone may be used to form the back of the cavity. This is more likely to be appropriate when a tinted or highly reflective glass is used as back of the cavity will not be seen as clearly and therefore its appearance is not so critical.

Behind the cavity there will generally be insulation, a vapour control layer (see later section) and the internal finish. Rigid or mineral wool insulation may be used. If mineral wool is used it is important to ensure it does not slump leaving a gap at the top.

Depending on the configuration of the shadow box, the insulation may be fixed to either the front or back panel of the cavity, or else it may be sandwiched between two suitable rigid layers of the build-up.

Figure 4 – components of a shadow box

Specification
The specification for a shadow box will tend to centre on the visual appearance, and therefore should include;

• Glass configuration;
  ▪ Single or double glazed;
  ▪ Coatings/frits/tints etc;

• Back panel configuration;
  ▪ Material;
  ▪ Colour and finish (for example gloss or matt).

The performance elements of the design are left to the specialist contractor.

Condensation
Condensation forms when warm moisture-laden air comes into contact with a cold surface. At this reduced temperature less water can be held by the air and the excess is deposited on the surface. In UK-type climates internal air contains more moisture than external air and therefore a vapour pressure gradient exists and water vapour will tend to diffuse from inside to out.

Condensation should not form anywhere within the build-up of the shadow box under
the design conditions, typically -5°C with a relative humidity of 90/95% externally and 20°C with a relative humidity of 40% (commercial) or 55% (residential) internally. The risk of condensation forming will be increased if the temperatures are reduced (through lack of heating for example) or if the relative humidity is exceeded (due to insufficient ventilation for example).

It is not possible to say that condensation will never occur and therefore it has to be accepted that condensation may occur on the inner face of the glazing or on the cavity face of the back panel of a shadow box when the design conditions are exceeded. This may happen for example due to clear night sky radiation cooling the glass significantly below the ambient air temperature. Under such conditions the temperature of the glass may fall as low as -20°C and therefore condensation is highly likely.

Consideration should be given to the materials used within the cavity of the shadow box and it should be ensured that they will not be damaged by occasional formation of condensation.

Frequent condensation on the glazing may lead to staining, and should therefore be avoided. Any staining that occurs is likely to be more obvious on single glazing than with an IGU.

The risk of condensation is greater if single glazing is used. Due to its low thermal resistance, the glass and the cavity will be at a similar temperature to the external environment. Due to the higher thermal resistance provided by an IGU, the cavity temperatures will be slightly higher, however this benefit will be reduced if there is significant ventilation in the cavity (see below).

Whist condensation may occur more frequently in a single glazed shadow box it should be more short-lived than for double glazing. The single glass and cavity will heat up more quickly and therefore the condensation will quickly evaporate.

There is no current guidance on how to calculate the frequency and amount of condensation which may form. 1D simulation software is available, however there no guidance on taking into account the effects of factors such as:

- Night sky radiation losses,
- Dynamic effects such as the amount of incident solar radiation,
- 2D/3D effects.

Condensation on the external surface of the glass may also occur. Again this is due to clear night sky radiation losses cooling the glass below the dew point of the ambient air. External condensation has become more widespread as a result of increased levels of insulation in buildings. This is not a fault. External surfaces have become colder and therefore are more likely to drop below the external dew point temperature. The risk will be increased by ventilating the cavity as this will further isolate the glazing from the internal environment resulting in even colder temperatures.

**Ventilation**

Various strategies have been used to ventilate the cavity of a shadow box. In UK-type climates it is recommended that shadow box cavities are ventilated/open to the outside.

Openings are required for a number of reasons including:

- Control of condensation;
- Accommodation of pressure changes in the cavity due to temperature variations.

Air exchange between the cavity and external environment will be determined by a number of factors including:

- Size of openings,
- Position of openings,
- Pressure difference.

The aim is to remove water vapour from the cavity, thus lowering the vapour pressure and therefore reducing the risk of condensation. It will also encourage evaporation of any condensate which has formed. This is discussed further in CWCT TN70.

Depending on the area of openings between a cavity and the external environment, it can be defined as being:

- Unventilated;
- Slightly ventilated;
- Ventilated.

An unventilated air cavity is one in which there is no express provision for air flow through it. Some small openings are permitted.
A slightly ventilated cavity is one in which there is provision for limited air flow through it.

A well ventilated cavity is one where they are significant openings between the cavity and the external environment.

A conflict exists between the amount of air exchange/ventilation, the thermal performance and dust etc entering the cavity.

A large area of openings will result in higher levels of air exchange between the cavity and the external environment which will be best in terms of controlling condensation, however high levels of ventilation may allow significant amounts of dust into the cavity.

The area of openings will not only affect the ventilation capacity but also the thermal performance. This is particularly important when an IGU is used as if the ventilation openings are too large, the thermal performance advantage over single glazing is negated.

The thermal performance of each type of cavity is calculated differently. This is described in further detail in CWCT TN70 and BS EN ISO 6946.

Also important is the position of the openings to the external environment. Warm air is less dense than cold air and therefore rises. Openings need to be positioned so that this warm air can leave the cavity and cooler external air can replace it, Figure 4. This is known as the stack effect. This air exchange will not only remove water vapour from the cavity but also help to control the temperature. If openings are provided at the top of the cavity it must be ensured that any water draining through the curtain wall system does not enter the cavity.

There is some confusion regarding the definition of the air cavity in a shadow box, with the term ‘pressure equalised’ often being used. The cavity is not pressure equalised in the same way as a window/curtain wall frame, or a rainscreen cavity where the object is for the cavity pressure to follow the differences in external wind pressure. This requires large openings to allow the cavity pressure to closely match that of the rapidly fluctuating external pressure. In a shadow box the object is to relieve the pressure induced in the cavity by temperature variations. This is a much slower process and therefore the openings to the external environment can be much smaller.

Temperatures in the cavity will fluctuate depending on the external environmental conditions. A variation between the minimum and maximum temperature of as much as 100°C may be possible which will result in significant changes in cavity air pressure/volume. If the cavity was not ventilated this pressure variation would cause either the glass or the panel at the back of the cavity to bow, which may result in unacceptable changes in appearance.

Taking these factors into account a common approach is to provide the minimum area of openings to the external environment, in the form of drainage openings at the base and several additional small openings at the top of the cavity. This configuration would provide:

- An unventilated cavity which is best for thermal performance,
- Pressure relief of the cavity to account for variations in temperature,
- Limited air exchange to aid in the removal of water vapour from the cavity,
- Limited air exchange to minimise dust entering the cavity.

There is no current guidance on how to calculate the area of ventilation openings required for the shadow box cavity.

**Dust**

Ventilation openings to the external environment may allow dust etc into the cavity.
This can be reduced by incorporating a fine mesh or open cell foam into the opening, however this will not completely eliminate the issue. It will also reduce the air flow through the opening, and this reduced performance should be taken into account. It may also become blocked requiring access for cleaning and maintenance which is usually impractical.

Vapour control layer (VCL)

A VCL is a key component in the reduction of condensation risk in the shadow box cavity. This needs to be of robust construction and in the correct position within the build-up of the shadow box.

In UK-type climates the VCL should be placed to the warm-side (internal) of the main insulation layer of the wall.

The most robust option is to have a metal sheet behind the insulation which is then fixed and sealed to the curtain wall framing. This should provide an effective and durable VCL, Figure 6.

If such an approach is taken consideration must be given to any movement that will occur between the panel and framing. This is of greater concern with stick curtain walling where the horizontal movement between floors is accommodated by the edge clearance between the glass and the frame. If the back panel is rigidly fixed to the curtain wall frame this movement will be restrained, resulting in additional stresses at the seal which may fail. Any movement joints in the mullions will also be restrained. With a unitised system movement is accommodated by the gaskets between the units so that a panel fixed to the framing will not hinder this movement.

An alternative approach is to use an EPDM (or similar) membrane in place of the metal sheet. This may also form an effective VCL, however it is heavily reliant on good workmanship and therefore may be considered less robust than using a metal panel.

Alternative methods include the use of foil-backed rigid insulation which is taped to the curtain wall frame. This method of construction is less robust. This method is also heavily reliant on proper workmanship as the foil is prone to rips and tears and there are questions over the durability of tape seals, which will both severely limit the performance of the VCL. This form of VCL is therefore not recommended.

Temperature

Cavity air temperatures may reach 80°C or higher. Material temperatures will primarily depend on their colour and exposure, but may well be of the same order.

The materials used in the construction of the shadow box need to be able to withstand these high temperatures without degrading (in terms of performance and possible appearance if they are visible through the glass). This may be especially important for materials such as sealants and gaskets which may release volatile compounds which may subsequently condense and stain the glazing. Manufacturers should be able to provide data demonstrating the suitability of their products.

Such temperatures will cause materials to expand, particularly dark painted metal panels. This movement must be accommodated. If the movement is restrained the panel will tend to bow which may affect the visual performance of the shadow box (this will depend on the light transmission of the glass). An alternative solution would be to hang the panel from the frame above and let move/expand freely so that it remains flat.
Due to these elevated temperatures a thermal fracture risk assessment must be carried out for the glass.

References


Bibliography