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Glass Floor Plate Design for Sustainable Building Operation

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Large glass floor plates are usually designed as laminates of three or more glass leaves, bonded together with an interlayer. This means that, in the event of accidental breakage, the entire plate must be replaced, sometimes at considerable cost. In addition, where access is difficult, the costs and the disruption to the owner's operations are increased. Finally, it is difficult to recycle laminated glass. An alternative is outlined whereby a sacrificial layer is loose laid on top of the structural laminate. In the event of breakage, only this top layer is replaced, with the lower structural laminate remaining in place to provide safety throughout the operation. This design differs from the conventional construction where the top sheet is bonded to the rest. An in situ trial was carried out, and this proved the effectiveness of the loose laid approach.

Keywords: Glass, Floors, Sustainability, Film, Interlayers

1. Introduction

The first glass floors were formed of thick plates of glass of limited area, typically a single sheet of annealed glass. However, from about 1990, glass floor plates have usually comprised laminated glass, in order to achieve better post-breakage ductility. The glass itself can be of annealed, heat-strengthened or toughened glass, and the interlayers are usually of PVB or ionoplast.

The top surface of such floors can receive a great deal of wear, and can also be damaged by accidental impact, and for this reason it is often treated as 'sacrificial', in the sense that its strength is ignored when carrying out strength calculations for the panel. Minor cracking to the top sheet, if of annealed or heat strengthened glass, can sometimes be accepted. However, if the top sheet is of toughened glass, any damage leading to shattering makes it unusable, because, even if the substrate were structurally adequate, people would be unwilling to step on shattered glass. In this situation the glass has to be replaced.

2. Conventional glass floor construction

The design and construction of glass floors differs from country to country and from project to project. However, there are some common themes. There is usually a top wearing layer, a main structural layer as a substrate, and sometimes a soffit layer. The structural layer usually comprises two or three sheets of glass, laminated together.

The problem with conventional forms of panel construction is that the top sheet, which is the most likely to be damaged, is usually bonded to the substrate with an interlayer, so that the entire panel has to be replaced. This can be very expensive, not only because of the cost of supplying a new panel, but also because many locations require significant temporary access to be set up, to enable the replacement to be made safely. For example the glass panels to the lift landings at Heathrow Airport Terminal 5 are at about 15m above ground level. See Figure 1.

Figure 1: Heathrow Express Lift Landing, Terminal 5, Heathrow Airport
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3. Recycling of glass

An important issue is that the full laminated panel is usually discarded, even if just partly broken. This is because the panel is made of a mixture of glass and interlayer, and this combination is complicated and relatively expensive to recycle, as without special processing the plastic interlayer material (usually PVB) would contaminate the molten glass mixture. Also, the PVB itself has value, and can be recycled.

There exist specialist companies which take away broken glass (‘cullet’) from glass producers and building sites. This service is often offered free of charge, and the waste company then sells the ‘clean’ cullet back to glass producers, to be re-melted, while the ‘dirty’ cullet (laminated and coated glass) is sold to specialist glass recycling plants. However, there is no way to guarantee what happens to the cullet, and at least part of it will go to landfill.

4. Loose laid top sheet

One solution to minimize the amount of wastage is to use a loose laid top sheet which is truly ‘sacrificial’, and can be replaced independently of the substrate.

Figure 2 shows a typical build up of a glass floor panel with a loose laid top sheet.

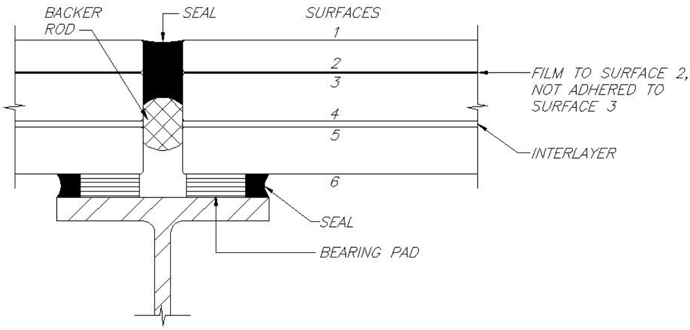

Figure 2: Typical composition of glass floor with loose laid top sheet

In the past there has been reluctance by the glass industry to use a loose laid top sheet, and various reasons have been given:

- Hard grit particles being trapped between the sheets and causing glass failure.
- Dirt being trapped between the sheets, and being unsightly.
- Water being trapped between the sheets and being unsightly, or freezing in external conditions.

There are, however, remedies for these issues.

Trapped dirt and grit can be avoided by careful cleaning prior to installation of the top sheet, and residue from cleaning fluids must be allowed to evaporate prior to laying the sheet.

In the event that there are residual grit particles, their effect can be minimized by using a 'soft' cushion between surfaces 2 and 3, in the form of a film applied to surface 2. This film, which needs to be at least 100 microns thick, also assists in holding a fractured panel together while it is being removed. Anti-shatter films are suitable for this purpose. It should be noted that these films tend to become electrostatically charged, so additional care is needed while cleaning, including the use of lint-free cloths. The curing time for these films tends to be long, and sufficient time needs to be allowed for this in the programme. In the absence of any manufacturer's advice to the contrary, a period of 4-6 weeks should be allowed.

Water between the sheets can arise from a number of causes:

- Residual moisture from cleaning not being allowed to dry thoroughly.
- Condensation when installed due to cold sheets being brought quickly from outside storage into a warmer, more humid environment. This can be avoided by acclimatization of the glass by storing in the internal environment for at least 24 hours prior to installation.

- Water vapour passing through the jointing between adjacent panels. Even silicone-sealed joints will permit the passage of water vapour, which can then form interstitial condensation. Again, acclimatization of the glass prior to installation should minimize this.

A loose laid top sheet has been used for a heavily-trafficked external entrance where the glass floor acts as a skylight to a basement below, so access for replacement is not straightforward and the cost of replacement units is high. See Figure 3.

Figure 3: Entrance to Sainsbury's Headquarters, 33 Holborn, London

5. Structural design

In the case of a glass floor build-up of three sheets of toughened glass, the top sheet is usually ignored for strength calculations, as the lower two sheets need to be able to carry all the loads safely, in the event of failure of the top sheet. Thus, if a loose laid top sheet is used, this should make no difference to the ultimate strength calculation. The same is true for deflection under long term loading, as the interlayers are assumed to provide no shear transfer in this case.

The use of a loose laid top sheet in toughened laminated glass construction should not therefore result in any increase of overall panel thickness.

Consideration needs to be given to the post-breakage behaviour in the extremely unlikely event that *all* the glass leaves were shattered. It may be necessary to specify one or more of the lower leaves to be of heat strengthened glass, which would not tend to sag when broken.

6. In situ trial

A trial of the approach described above was carried out on a panel at Heathrow Terminal 5. The panel of size 3090mm x 1155mm had been installed as a test in August 2009. The lower structural leaves comprised 2 x 12mm heat soaked toughened glass, with a 1.52mm PVB interlayer. The top sheet was of 12mm heat soaked toughened glass, with a 100 micron anti-shatter film on the underside. The top surface was fritted with a dot pattern, and also sand blasted and polymer coated. See Figure 4.

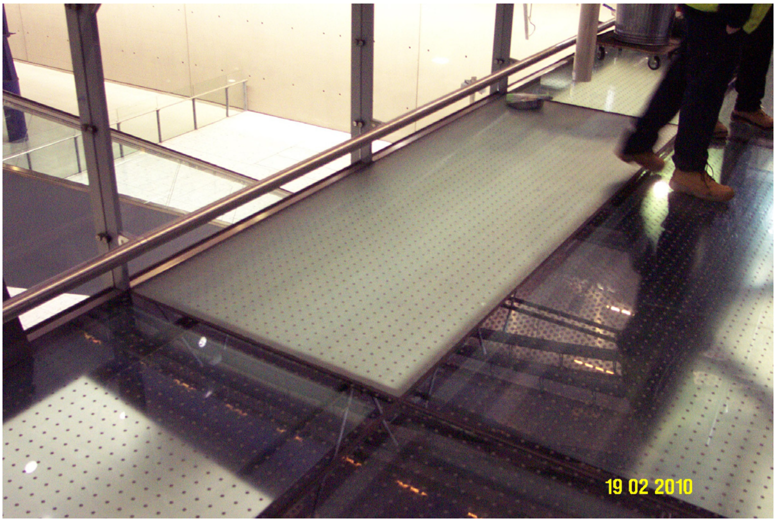

Figure 4: Trial panel

In February 2010 a trial was carried out, whereby the top leaf of the panel was deliberately shattered, using a steel punch. All the shattered fragments stayed adhered to the film. The silicone around the panel was then cut out and, by prising up one corner first it was possible to remove the entire sheet in one piece. See Figure 5.

Figure 5: Removing shattered top sheet

The remaining structural laminate was then thoroughly cleaned using a vacuum cleaner and methyl alcohol. See Figure 6.

Figure 6: Cleaning remaining structural laminate

The new top sheet was then carefully positioned, after which silicone sealant was placed around the edges.

Figure 7: Installing new top sheet

The entire operation of replacing the shattered panel took only 1.5 hours (not including sealing), and did not require any special access equipment nor lifting machinery. This trial proved the effectiveness of the loose laid top sheet approach.

7. Acknowledgements

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