GL&SS

THE CANNING TOWN BUS STATION

Glazing Feasibility Study

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Document verification

Project name
The Canning Town Bus Station

Document title
The Canning Town Bus Station -

Glazing Feasibility Study

Project number
1365
Report number
01

Revision	Date	Description	
	29/09/22	Draft 1	
	Prepared by	Checked by	Approved by
Name	[redacted]	[redacted]	[redacted]
Signature			

Revision	Date	Description	
	30/09/22	Client Issue	
	Prepared by	Checked by	Approved by
Name	[redacted]	[redacted]	[redacted]
Signature			

Revision	Date	Description	
	03/10/22	Added further comments	
	Prepared by	Checked by	Approved by
Name	[redacted]	[redacted]	[redacted]
Signature			

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GLOSS

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INTRODUCTION - OVERVIEW

1 INTRODUCTION - OVERVIEW

Glass Light & Special Structures (GL&SS) was appointed by CBS Ltd to perform a feasibility study of the overhead glazing in the Canning Town Bus Station - London E16 1ED, UK.

This report is an initial assessment of the remediation design.

Canning Town Bus Station roofing comprises a central canopy section made of a series of glazing panels surrounded by cement panels on the front and sides. Basedon O&M manual, build date is believed to be 1998.

Following a breakage of a section of overhead glazing at Canning Town Bus Station, GL&SS was requested to conduct an investigation to establish the cause of the problem and present possible new design solutions to improve safety measures in the commuting complex.

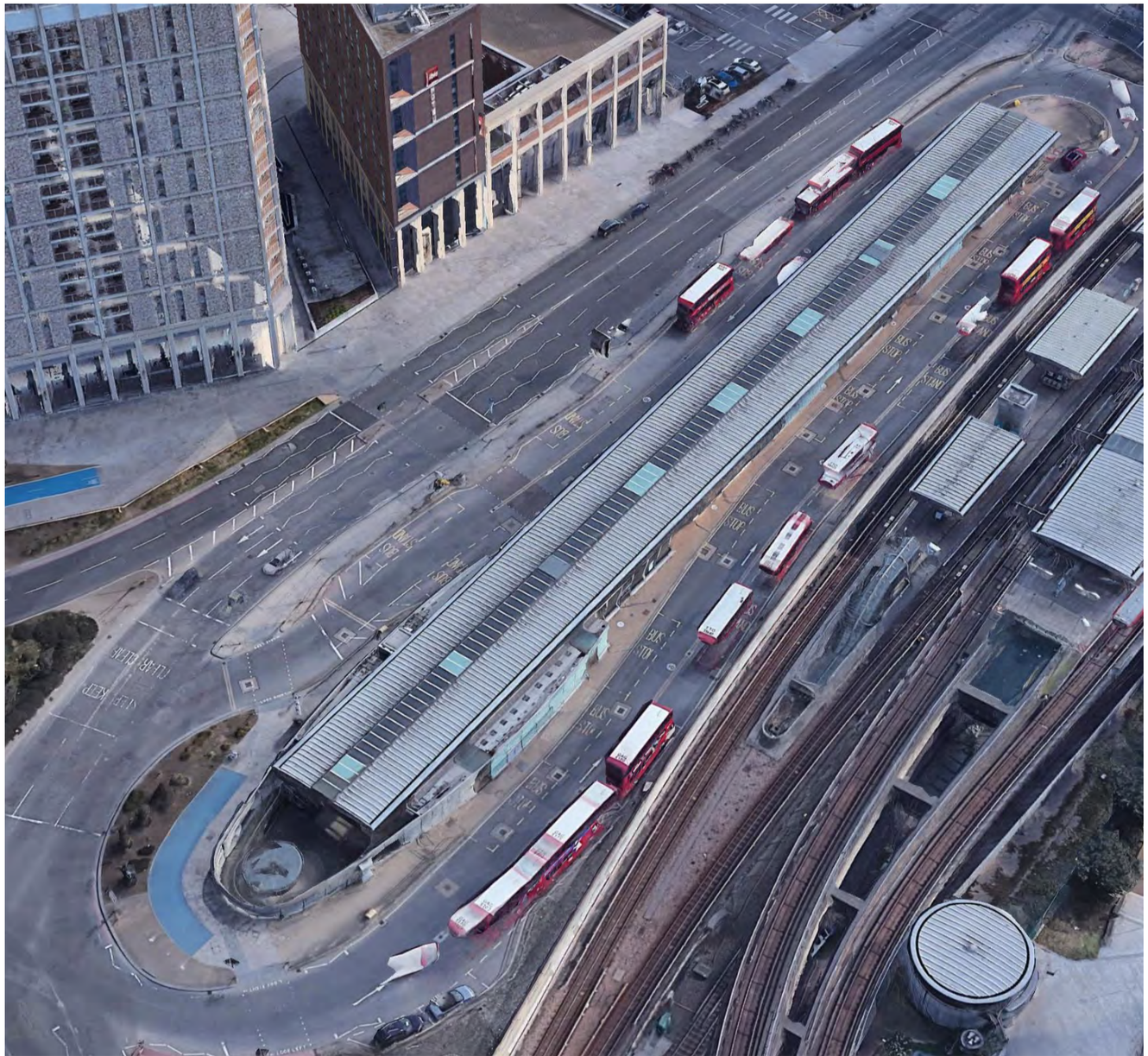


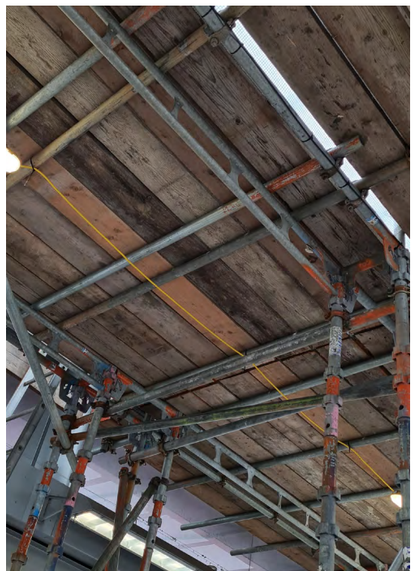
Figure 1: Aerial view of the Canning Town Bus Station and surrounding area (photo by Google).

1 INTRODUCTION - OVERVIEW

Current Photographs

Figure 2: External view of Canning Town Bus Station entrance showing scaffolding in place under the glazed cannopy.

Figure 3: The broken glass panel has been replaced with plywood board.



Figures 4-5: Left: Scaffolding structure viewed from inside the station. **Right:** Station interior prior to breakage.

1 INTRODUCTION - OVERVIEW

Based on observed and reported evidence gathered and previous case studies, the most likely cause of the recent failure of the toughened glass pane in the canopy glazing of the Canning Bus Station was due to the presence of nickel sulphide inclusions (NSI).

Nickel sulphide is an impurity which may be found in soda lime silicate float glass. It can form due to two possible reasons:
- manufacturing creation
- as a Millerite contamination of the ingredients (the millerite is a natural form of nickel sulphide).

Another potential cause for the toughened glass failure could be the spider fitting ball-joint seizing and not allowing for glass movement under load, which would then cause the glass to fail at its weakest point (which could be at NSI, if present on the glass).

As observed on site, toughened glass with a thickness of more than 6 mm breaks into unacceptably large fragments.
3m² area of 6 mm thick glass weighs 45 kg - this is a significant weight of falling glass fragments.

This report contains recommendations for the remedial works to prevent the failure of the rooflight glazing in the future.

Figure 6: Glass fragments from broken glazing panel strewn over the floor following the panel failure. Large chunk fragments can be seen mixed with smaller fragments.

2

LEGISLATION

2.1. Legislation and Other Recommendations Review

2 LEGISLATION

2.1. Legislation and other recommendations review

Among all others, the glazing applications in England are deemed to be compilant with Building Regulations Approved Document K (K2 - Protection from falling and K4 - protection againts impact with glazing).

Monolithic toughened glass is commontly used by designers due to meeting the requirements of the Approved Document K as Class A safety glass when tested in accordance with BS6206 *Specification for impact performance requirement for flat safety glass and safety plastics for use in buildings* or Class 1 when tested in accordance with BS EN 12600 *Glass in building. Pendulum test. Impact test method and classification for flat glass.*
In spite of the regulatory requirements, it is well known that the monolithic glass with thickness grater than 6mm is more likely to exibit clumping behaviour when it fells. The regulated safety factors do not consider the risk of spontaneous failure, like nickel sulfide.

The Fenestration And Cladding Engineering Technology Scheme was originally published in 2002 in order to facilitate technology transfer, information sharing and best practise within the façade sector. FACETS was developed by the Centre for Window and Cladding Technology with funding from the Department of Trade and Industry, Focus Technical programme. The project provides design recommendations for the facade works, among other things, glazing placing.

Section 8 clause 0.8 OVERHEAD GLAZING states the glazing risk assesment should be the design priority. The most difficult aspect of glazing safety to assess is not the actual risk of being hurt by falling glazing, which is small, but the perception of the risk of being hurt.
The overhead glazing for buildings between 5 and 13 m above lowest floor level should me made of:
a) laminated glass, or
b) heat soaked toughened glass, of not more than 6 mm thickness and with a maximum pane size of 3 m2 , or
c) wired glass, or
d) plastics glazing material.

Mesh positioned immediately below the glazing can be considered to ensure that falling clumps of glass are either separated into individual fragments or prevented from falling.

Figure 7: Overhead glazing panel in place. Also visible are the fixing system, glazing bar, and tensioning wire.

Figure 8: Glazed roof canopy with access restrictors to prevent persons stepping on the glass panels.

3

REMEDIAL DESIGN STRATEGIES

3 REMEDIAL DESIGN STRATEGIES

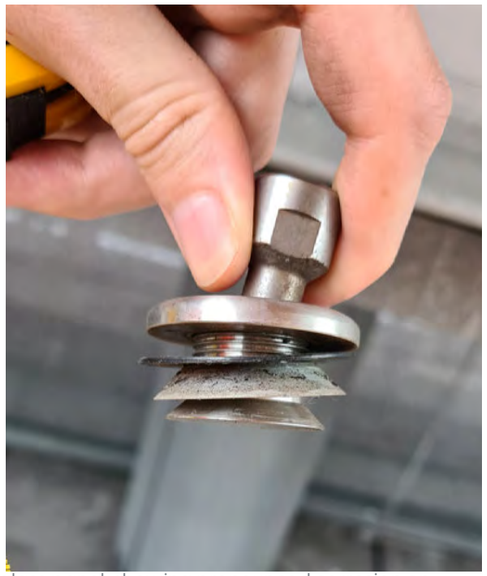
3.1. Steelwork and Spider Fittings

During a visit to site on the 21st September, it was observed that the spider fittings holding the glass panels could potentially have their ball-joints seized, which in turn could introduce a source of stress to the glass in the event it failed to allow for glass movement under load (e.g., wind or thermal load).

It was also observed that the spacers on the taller fittings were corroded, likely due to the wrong grade of steel being used for these. The bused used to separate the spider fitting from the steelwork had failed severely, showing extensive cracking and weathering.

Dirt accumulation was evident not only on the glass panels but also along the steelwork structure. The steelwork structure itself presented signs of flaking coating.

Based on these site observations, we therefore recommend:
- the replacement of all spider fittings, including the spacers and bushes. The spacers should be sourced in a suitable grade of steel.
- the regular cleaning of the steelwork and the top-side of the glass panels.
- thee assessment of the structural integrity of the steelwork structure and its repair and maintenance where required. At least, new coating should be applied on the steelwork.



Figures 9-10: Left: Spider fitting viewed from underside of glass panel, showing pronounced corrosion on spacers, severely degraded bush between fitting and steelwork, and dirt accumulation. **Right:** Spider fitting from failed glass panel. Ball-joint appeared seized as it couldn't be moved by hand.

Figures 11-12: Left: Steelwork structure showing flaky coating. **Right:** Spider fitting on lower edge of glass panel, also showing a severely failed bush, and general dirt accumulation.

3 REMEDIAL DESIGN STRATEGIES

3.2. Replacement Options Summary

The following has been identified as suitable options for the replacement of the panels composing the glazed canopy roof at Canning Town Bus Station.

- Laminated Glass
- Plastic Glazing
- Architectural Mesh

Laminated Glass

Laminated glass comprises (at least) two layers of glass which are permanently bonded together with an interlayer material. The interlayer material can be PVB or Ionoplast - PVB is more readily available than Ionoplast however it softens with increasing temperature and at 40°C it is much softer than at lower temperatures; Ionoplast is stiffer than PVB and does not soften to the same extent at the temperatures likely to be experience in roof glazing. The laminated glass life span is generally 50 years.

Plastic Glazing

Plastic glazing materials like Polycarbonate (PC), Poly(methyl methacrylate) (PMMA, acrylic), or Ethylene tetrafluoroethylene (ETFE) can be used as glass alternatives but have a shorter life span than glass at 5 to 10 years.

Architectural Mesh

A type of mesh could be considered to strengthen the glass panels in the event of failure, preventing them from falling from their supports. Several types of mesh exist, such as metal or laminated (usually glass fibre core covered with PTFE film) mesh. The mesh life span is similar to the laminated glass, at 5 to 10 years.

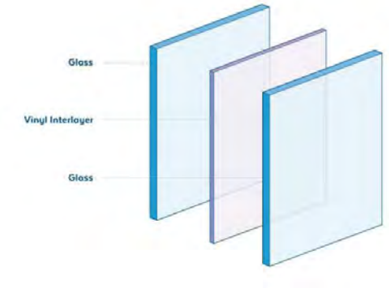


Figure 13: Example materials to replace the existing glazing on the roof canopy at Canning Town Bus Station.

3 REMEDIAL DESIGN STRATEGIES

3.3. Laminated Glass

We recommend the most feasible and optimum option is to replace the glass panes with laminated glass composed of an ionoplast interlayer insert and with glass panes of 6/6mm or 6/8mm thickness.
This can overcome further debonding, peeling and cracking.

When the laminated glass break, the glass fragments should be held in position by the adhesive bond between the interlayer(s) and the glass. The glass still breaks into shards, exposing sharp edges, but these are held by the interlayer.
Laminated glass is generally recommended for the inner pane of overhead glazing with the agreement of the local building control officer.

Usage of laminated glass provides:

- Safety: maintains integrity in the event a pane of glass breaks,
- Secutity: reduces likelihood of penetration,
- Acoustic: improves sound properties,
- Aesthetics : many design possibilities.

The costs are higher than monolythic glass, but the aesthetics of the construction are not affected and it will not become subject to planning permissions.

Considering that these panels are point supported and are supposed to last for their design life of 50 years, we recommend to use SentryGlas Plus as interlayer. With this interlayer material, the vertical deflection due to gravity loads should not exceed 20mm. However, the deflections due to maintenance actions will be higher than 20mm. In our opinion, similar higher deflections for maintenance should not be a problem.
The SGP is stronger than conventional laminating materials and is much less vulnerable to moisture exposure or yellowing over time.

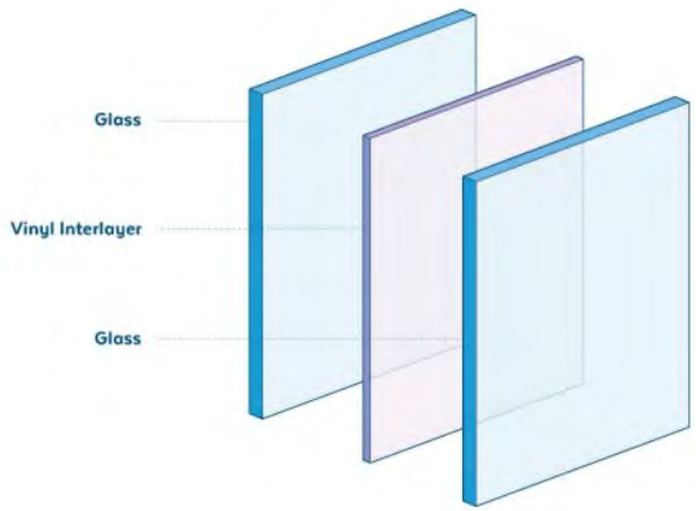


Figure 14: Top: Example of breakage pattern on glass. **Bottom:** Example composition of generic laminated glass

3 REMEDIAL DESIGN STRATEGIES

3.3. Laminated Glass (continued)

Assuming generic maintenance loads (0.6kPa uniform and 0.9kN point load):

Option 1:

- 6mm top pane + 6mm bottom pane - toughened laminated with a generic interlayer

In post breakage conditions, similar panels are not able to support maintenance loads. Walking on the panels would not be possible in this situation.

Option 2:

- 8mm top pane + 6mm bottom pane - toughened laminated using an interlayer of 1.52mm.

Option 3:

- three 5mm thick glass layers.

This solution will be the most effective, but the cost will be much higher with SentryGlas usage as interlayer (2 interlayers 0.76mm thick).

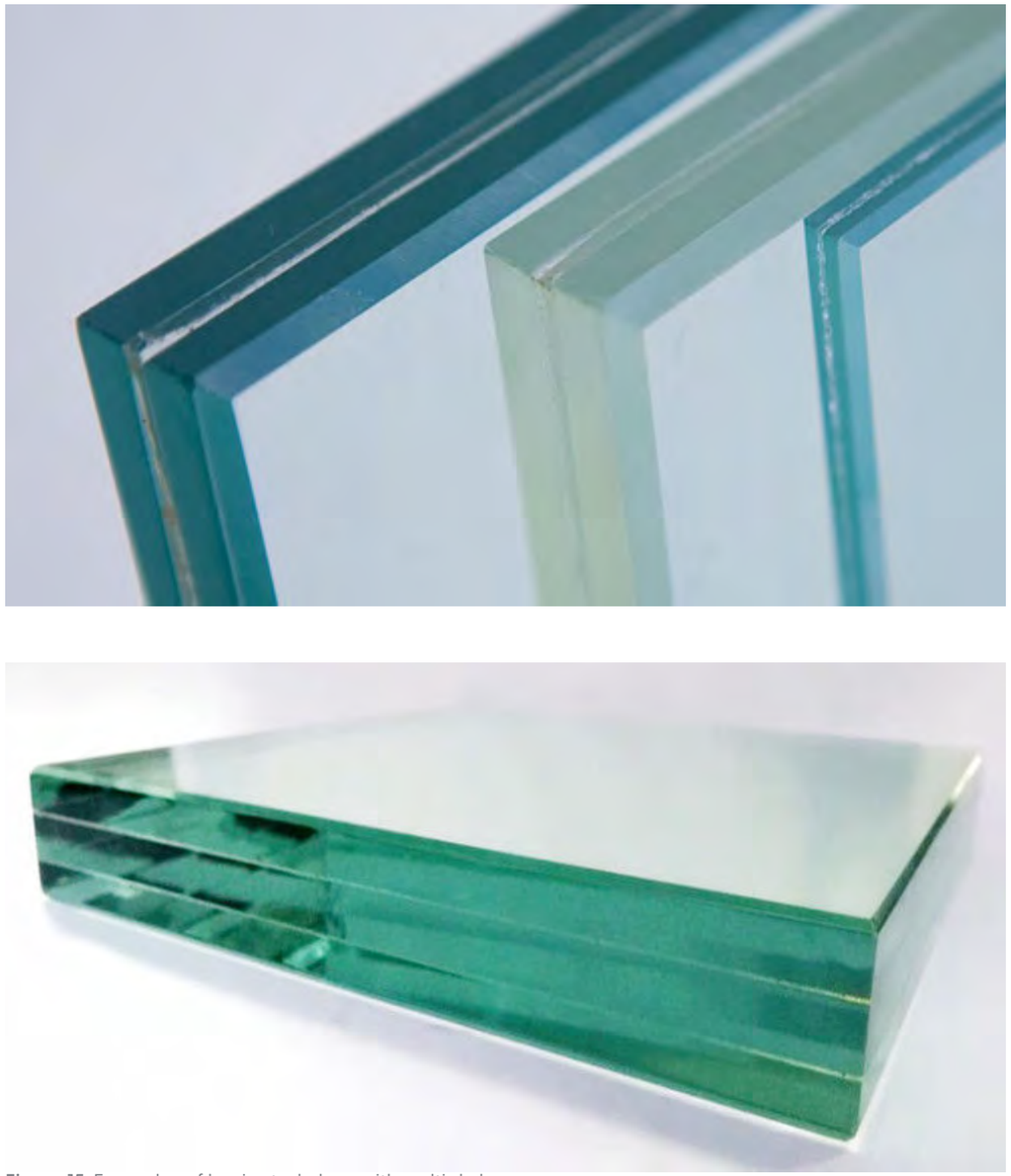


Figure 15: Examples of laminated glass with multiple layers

3 REMEDIAL DESIGN STRATEGIES

3.4. Alternative Solutions - Plastic Glazing and Architectural Mesh

Alternative options could be used to improve the canopy roof safety.

1. Replacement with plastic glazing materials.

Plastic glazing materials like Polycarbonate (PC), Poly(methyl methacrylate) (PMMA, acrylic), or Ethylene tetrafluoroethylene (ETFE) could replace the existing glazing.

The advantage of these materials is its better impact resistance - when broken they tend to remain in place. The construction is much lighter than traditional glazing.
If not properly designed, plastic glazing can be more affected by load deflection. The substrate is easily scratched and discolours over time. The lifespan of the products are between 5 to 10 years - depends on the used product.
During a fire situation some plastics can burn and release particulate contaminants or toxic gases. The materials are combustible and flammable. These conditions should be considered when planning use in public spaces.

The costs are lower than traditional glazing options. The aesthetics of the building could be affected. This solution could require planning permission.

This solution was used in Business Directory Kampala Uganda.

2. Architectural mesh installation.

Another possible remedial solution is to install architectural mesh close to the glass surface. Different types of mesh could be considered - metal mesh or laminated mesh (usually glass fibre core covered with PTFE laminated film).

As long as the material is properly designed and installed, it should offer good protection from vandalism and falling broken glass fragments. Sun and glare-protection could be an asset of the installation.
The lifespan of the mesh varies from 5 to 10 years. It needs proper regular maintance - especially debris cleaning.

The costs are lower than traditional glazing options. The aesthetics of the building could be affected. This solution could require planning permission.

This solution was used in Waterloo Train Station in London.

Figure 16: Alternative overhead glazing solution examples

3 REMEDIAL DESIGN STRATEGIES

3.5. Glazed Wall Remediation and Replacement

From the site observations, we believe the vertical glazing along the Station constitutes a low risk. Considering the glazing is not placed straight on the ground but on a plinth 30 to 50 cm high and the glazing panels are installed recessed in relation to the plinth face, there is a low probability that the glass panels will be impacted by a falling piece of luggage or similar.

It is, however, possible for bystanders to lean against the glass panels. In the event of a vertical panel breakage, we would expect the glass fragments to mostly remain in place. Were the fragments to fall, the initial height is deemed to not be enough to cause significant accelaration of the falling pieces to a degree that would cause severe injury to any members of the public standing in the vicinity of the failed glass pane.

Nevertheless, we have identified 3 options for your consideration that could be used to improve the glazing walls safety:

1. Safety film application

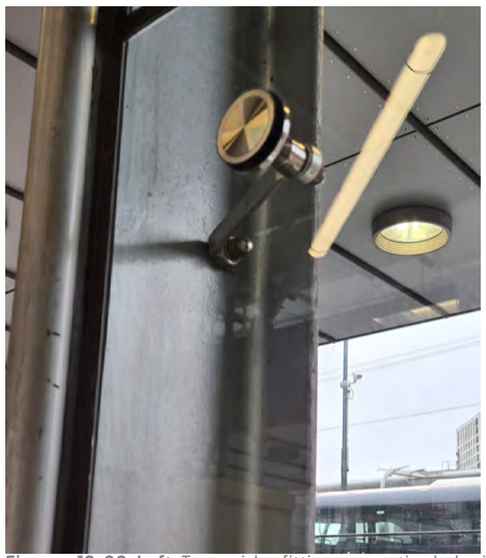
The simplest way to improve the glass wall panes safety is by applying a safety glass film to one side of each panel.

Glass safety film may improve the strength of a glass pane while reducing the risk of breakage. The film holds the glass fragments together when broken to diminish the possibility of injury.

This solution would require the removal of the existing glass panels to apply the film, and then their installation into the existing frame.

It is the most cost-effective solution with no need for planning permission.

Figures 17-18: Left: Vertical glazing corner to waiting area of Station. **Right**: Spider fitting on vertical glazing. Both photographs show the plinth offsetting the glass panels from the ground floor.



Figures 19-20: Left: Top spider fitting on vertical glazing panel. **Right:** Vertical glazing walls are composed of two glass panels on top of each other.

3 REMEDIAL DESIGN STRATEGIES

3.5. Glazed Wall Remediation and Replacement (continued)

2. Replacement with laminated glazing

Another option is to replace the existing glazing with laminated glass panels, most likely laminated heat soaked toughened glass.
The use of laminated glass panels may sagnificantly improve the building safety by reducing the risk of failure (from NIS, vandalism, ...).

This is the most costly solution, but with no aesthetics changes hence no need for planning permission.

3. Architectural mesh

The third option is to introduce a mesh to the glazed walls. It is a low cost solution, but will most likely affect the aesthetics of the building and require planning permission.

Figure 21: Alternative wall glazing solution examples: (top) architectural mesh. (bottom) safety film being applied to glazing

GLASS

4

ASSESSMENT AND COMMENTS

4.1. Glazing Testing and Assessment

4.2. Service Life

4.3. Primary and Secondary Structures

4.4. Cold Bridging, Condensation Risk and Thermal Modelling

4.5. Accoustic Attenuation and Flanking Noise Transfer

4.6. Day Lighting Transmittance

4 REMEDIAL DESIGN STRATEGIES

4.1.Glazing Testing and Assessment

We recommend carrying out assessment and testing on the canopy roof glass The tests should conform to CWCT TN66 to TN68.

The testing will require at least one glass panel to be removed, including the spider fitting supports. This will enable the site conditions to be replicated at the off-site testing centre.

4.2. Service Life

Generally, the service life of a building as a whole is 60 years, with the requirement for the whole building and its components to perform for a required service life of not less than 35 years (as per BS 7543). Materials and components that cannot meet the specified service life under normal conditions are classified as *replaceable elements* and those that require servicing and maintenance to meet the specified service like are classified as *maintainable elements*.

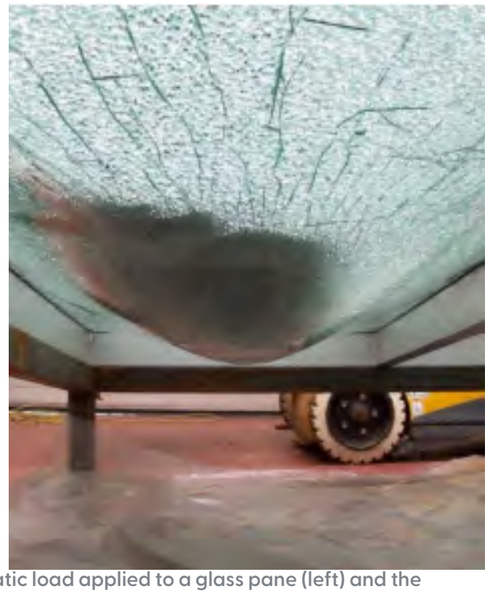
Table 1 illustrates the anticipated service life for each of these replaceable and maintainable elements, as relevant to the Canning Town Bus Station.

The glazing on the canopy roof was around 24 years-old by the time the panel failed. This is lower than the anticipated service life for glazing however it already falls out of the anticipated warranty provided by manufacturers.

It was observed on site that the glass fixings gaskets are severely weathered, even though the service life is also lower than anticipated. The reduced service life is most likely due to exposure to the sun and UV radiation as well as night-day thermal cycles. Refer to section 4.1 on this report for recommendations on the fittings and gaskets.

Table 1: Anticipated service life for the replaceable and maintainable (repairable) elements of a building.

Item	Anticipated Manufacturer's guarantee (years)	Anticipated Service Life (mininum years)	Maintenance Level (per BS 7543 Table 1)
Glazing	12	35	replaceable
Aluminium Frames	12	60	repairable
Steelwork	12	35	repairable
Gaskets (all)	12	35	replaceable
Brackets	12	60	repairable
Structural Silicone	12	35	replaceable



Figures 22-23: Glazing testing - photos show the 90 kg static load applied to a glass pane (left) and the underside of the sample under the static load (right).

3 REMEDIAL DESIGN STRATEGIES

4.3. Primary and Secondary Structures

We believe the steelwork structure is adequate and have seen no evidence of any problems with it. As long as maintenance if performed frequently (refer to Section 3.1), the structure should be fit for purpose.

4.4. Cold Bridging, Condensation Risk and Thermal Modelling

The Canning Town Bus Station building has several entrances and the canopy glazed roof is also open to the elements, as such there is no risk of cold bridging or condensation causing issues to the glazing or its supporting structure. Were the existing glass panels to be replaced by an alternative panel in glass (for example, laminated glass as per section 3.3), the resulting conditions would remain the same and no further risk increase would occur.

Replacing the glass panels with a plastic alternative could however result in a slight increase in the shading caused by the panels, especially if the plastic material is susceptible to discolouring.

4.5. Accoustic Attenuation and Flanking Noise Transfer

Whichever type of plastic is used as replacement of the existing glass panels will result in a pronounced "drumming" effect due to the rain and wind. This effect is generally much louder with plastic roofing than with glass - the noise on plastic could be 10dB (or more) louder than on glass panels.

With the exception of the extra rain/wind noise on the plastic panels, the flanking noise will be no different to the current levels at the station. With glass panels there would be no difference in the flanking noise.

4.6 Day Lighting Transmittance

Glass and plastic materials generally have different light absorption/ transmittance properties. Some types of plastic (especially Policarbonate but some types of acrylic as well) are extremely susceptible to discoulouring when exposed to direct sunlight, which would reduce their light transmittance properties. Table 2 summarises the differences between the two panels types. The addition of the architectural mesh (refer to section 3.4) could also significantly impair the amount of light that enters the station.

Table 2: Comparision between glass and plastic light transmittance properties

	Glass	Plastic
External Visible Light Reflectance	target of 14%	target of 10%
Internal Visible Light Reflectance	target of 15%	target of 20%
Total Solar Energy Transmission (Solar factor) (EN410)	0.35	0.60
Colour Rendering Index (Ra)	95 minimum	

Figure 24: The cannopy roof glazing is open, allowing unrestricted air circulation within the Bus Station.