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Design of Overhead Sloped Glazing in Places of Public Assembly

Étude de lanternaux inclinés dans les lieux de rassemblement

Entwurf geneigter Oberlichter in öffentlichen Versammlungsstätten

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SUMMARY

This paper discusses the factors which need to be considered when designing and specifying overhead sloped glazing in places of public assembly. The paper reviews the technical information and standards available to designers and proposes a minimum level of information to be provided in the specification and drawings. It also reviews criteria to be considered in the selection of the glass.

RÉSUMÉ

L'article traite des critères pour la conception et l'appel d'offres de fenêtres disposées en lanterneaux inclinés dans les lieux publics. Il passe en revue les données techniques et directives qui sont à la disposition du projecteur, ainsi que les normes minimales proposées pour établir le devis descriptif et les plans. Il indique en outre les critères servant au choix des vitrages.

ZUSAMMENFASSUNG

Der Beitrag diskutiert die Faktoren, die beim Entwurf und der Aussschreibung von geneigten Verglasungen in öffentlichen Versammlungsbauten beachtet werden müssen. Es werden die technischen Angaben und Richtlinien durchgesehen, die dem Entwerfenden zur Verfügung stehen, und Minimalstandards für die Leistungsbeschreibung und Plandokumentation vorgeschlagen. Ferner werden die Kriterien für die Auswahl des Glases besprochen.

INTRODUCTION

This symposium, entitled "Places of assembly and long span building structures", is focused on structural engineering matters; large structures, elegant structures, which provide a framework to support the covering to the public assembly space below. Whereas the consequence of failure of one of the elements of the covering is not normally as catastrophic as that of the supporting structure, the effects on serviceability, durability, usefulness and ultimately cost of maintenance and falling rental values is all to often overlooked during the initial design.

This paper considers the roof covering, and in particular the use of glass in that situation, and outlines the issues to be considered with respect to the design and specification of the elements concerned.

The total building envelope plays a vital role, not only in the architectural aesthetic but also in the technical or engineering performance of the building. On many projects, the requirements of the building envelope are becoming increasingly demanding as designs become increasingly sophisticated. The envelope is required to contribute actively to the building's performance in terms of energy control, whilst at the same time to let in as much natural daylight as possible. Supporting structures are required to span further and the roof covering needs to respond to this. Glass is being called upon to do more and more in terms of thermal performance and strength. Do designers actually have enough information or guidance on how to achieve these aims?

For a steel or concrete structure it is standard practice to specify grades of material to perform in accordance with particular requirements, to design the elements of the structure, in accordance with permissible stresses and deflections and to specify connection details, tolerance and standards of construction. Structural engineers are able to do this because there is a vast amount of information available in the form of standards, design guides and research papers.

Why is cladding, and glazing in particular, not procured in this way? One of the reasons is because there have not been until recently standards to cover the design, manufacture and installation of curtain walls or overhead glazing. The standard for curtain walls published last year by the Centre for Window and Cladding Technology has filled a very real need here, but specifically excludes internal vertical enclosures, overhead glazing systems with a slope of less than 75° to the horizontal and structural glass assemblies. Another reason is the fact that, in the case of the cladding, the contractor is normally responsible for the detailed design based on a performance specification produced by the original designer.

It is my view that, in the absence of any comprehensive standard, the original designer should be responsible for specifying not only the performance requirements, but also the materials to be used and all the design constraints relating to the cladding and in particular the interfaces with other elements to allow the contractor to carry out his duty. When one considers that the cost of the cladding of a building can be up to 20-25% of the total construction cost, as well as the consequences of failure, then surely the designer should specify in more detail.

However, in order to do this, a lot more information needs to be made available by the manufacturers of the various components. By way of contrast, structural engineers are continually being presented with new information, resulting from research and development programmes carried out by the steel and concrete industries. This research is going on in the glass industry, but it is difficult for design engineers to get the information they need. There is a fair amount of information available on U-values, shading coefficients, solar heat transmittance, and light transmittance, but very little is available on the structural performance and safety aspects of glass. More needs to be known about glass as a material in its different forms and strengths, its behaviour under imposed loads and the effects of weathering, aging, support conditions and edge conditions.

That said, what should the specification contain? How detailed should the design be without removing the opportunity for competitive tendering or undermining the manufacturers design responsibility?

Overhead glazing is more susceptible to falling objects and windblown debris, more likely to fall from its supporting framework when it breaks, exposed to greater levels of solar energy, frequently supported on adjacent structures which are subject to complex movements and required to support long duration snow loading, as well as wind loading. The design and specification needs to recognise these requirements which should be clearly set out on a set of tender drawings, including sections and details describing the preferred arrangements and constraints of the critical components. The contractor should use these as a basis for the detailed design.

Whilst each building needs to be considered on its own merits, the following may serve as a useful check list in the production of a specification and the development of design and tender drawings.

The PRELIMINARIES should include details of:

The Building

The role and function of the building, its appearance, form and size and its relationship to its neighbours should be described.

The Glazing System

The extent of the glazing, the geometry, the method of attachment to the building, the intended solidity, lightness, texture, contrast and colour should be defined. Expectations on weathertightness, drainage and staining, durability, life expectancy, maintenance and replacement should also be made clear. It is most important that the way in which the glazing is required to interact with other parts of the building is fully described, since it is at these interfaces that most problems occur. Finally, the issue of public safety needs to be addressed including principles to be adopted to minimise the risk of injury due to cladding failures.

Technical Procedures

The regulations, standards, codes and guides which define the procedures for design and analysis should be listed. The CWCT Standard and Guide to Good Practice contains a full list of relevant standards. In addition, there are a number of documents produced by the American Architectural Manufacturers Association (AAMA) covering, the structural performance of glass, sloped glazing guidelines and glass design for sloped glazing.

Technical Criteria

A detailed definition of internal and external climatic conditions, including temperature, humidity and acoustic levels should be included as well as an indication of the anticipated variation of external surface temperatures. Wind loading, snow loading, access loading, and other loads imposed on the cladding should be specified, with estimates of anticipated movements of the building structure under its dead loads, live loads, wind loads, settlement, shrinkage and creep.

The PERFORMANCE REQUIREMENTS should be clearly specified and, the tender documents should include adequate guidance in the form of drawings to illustrate the preferred method of achieving compliance with these.

Thermal Performance

Solar radiation on sloped glazing applications is normally substantially higher than on vertical glazing, due to the angle of inclination. This will affect thermal stresses within the glass and the performance of the glazing materials. Allowance for thermal expansion and contraction etc. are vital. Thermal performance criteria (U-value, shading coefficient, light transmittance etc.) need to be considered for the particular application.

Weathertightness

It is imperative in all glazing systems that water infiltration and condensation should be drained from the system, and in particular from the edge of the glazing unit. Drainage of the water in sloped glazing requires special design to the framing, since systems that work well in vertical situations are often unsatisfactory in sloped situations.

Design Loads

The strength of glass is a function of load duration, and long term loads, such as snow, must be treated differently to short term loads, such as wind. In addition to dead, wind and snow loads, consideration should also be given to the possibility of impact loading on sloped glazing installations, either due to airborne debris, missiles, building components or human accident.

Movement and Compatibility

All structures move and sloped glazing systems are no exception. In addition to deflections within the system itself, the relative movements between the overhead glazing system and its supporting structure under the various combinations of load needs to be thoroughly understood and the framing, supports and any joints must be designed to accommodate these movements. Inadequate provision for movement is a likely cause of failure of cladding components, particularly glazing.

Acoustic Performance

Any requirement for sound reduction through the glazing, and, consequently the level of acoustic insulation should be specified.

Fire Rating

Any requirements for fire rating of the glazing should be specified.

Safety

Safety of the public is of primary concern since the consequences of failure of glazing in overhead situations could be catastrophic. There is no single issue governing this, but a host of issues - specifying and design for the appropriate loads, movements, tolerances and thermal conditions, and ensuring that all parties are aware of these requirements at all stages.

Another, and equally important issue factor relating to performance in use, and safety concerns MATERIALS AND WORKMANSHIP. Critical materials should be prescribed in the specification, whether this is by specifying a particular type, or grade, or specific properties. Materials for use in the framework and their corrosion protection, fixings to the building, gaskets and sealants should all be specified, with respect to performance, compatibility and durability.

Glass Selection

The building regulations do not give any guidance as to what type of glass should be used in overhead situations. It is left to the designer to consider the particular application, the imposed loads, the thermal loads, the risk of impact from airborne missiles and the exposure of the public to injury from falling debris. Glass when procured in the U.K., would normally be supplied in accordance with BS 952 "Glass for Glazing". But there is a considerable difference between the performance of the types of glass included in the standard, particularly when it comes to strength and safety.

Any evaluation of the strength of glass must take into account its inherent structural characteristics. It is classified as a brittle material. It has no yield point, and fractures suddenly. The stress level required to break a pane of glass is related to surface compression, fabrication, surface quality, support conditions, type and duration of loading, size, thickness, geometry, edge quality, age and service history. Glass strength can only be expressed on a statistical basis, and fracture risk, while never entirely eliminated, can usually be reduced to an acceptable, practical level by appropriate selection. In determining the appropriate strength, a view must be taken on an acceptable statistical probability of breakage under design load.

In addition to strength requirements, the selection of glass, type is a fundamental issue when dealing with the safety of overhead glazed systems. Major building codes, both in this country and in the United States, are not in agreement on this matter. Both fully toughened as well as laminated glass are currently considered to be suitable for this type of use. Laminated glass, due to the influence of the PVB interlayer will tend to remain in one piece when fractured. Provided the interlayer is adequately retained in the frame, there should be little risk of the pane falling from its frame. However, if it is not adequately retained, the pane could fall as one complete piece causing significant damage. On the other hand, fully toughened glass breaks into small pieces when fractured and should fall to the ground in a shower of relatively harmless pieces of glass. However, it could fall to the ground before fragmenting.

In addition, in the case of toughened glass, the possibility of spontaneous breakage due to nickel sulphide inclusions should not be ignored. If toughened glass is specified, it is important to specify an additional heat soaking process in order to reduce the potential for spontaneous breakage due to this defect. Heat strengthened glass could be considered as an alternative to fully toughened, as this does not appear to suffer from the same phenomenon.

Overall, the final selection of glass must consider the type and duration of loading, the requirements for tolerance and movement, the thermal effects, support conditions, the degree of exposure, and the consequence of failure. A design and specification which thoroughly addresses these issues and their consequences, and the incorporation of these requirements into the design of the glazing and its support system, is essential if we are to instill the level of confidence into building owners and architects to allow them to incorporate overhead glazed structures into their projects in the future.

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