Glass plus X - Development of Innovative Hybrid Structures

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Summary

The systematic development of innovative hybrid structures and the associated methodical procedure for a variety of load-bearing elements is described in detail within this paper. Results of the structural performance and the post-breakage behaviour of polycarbonate-glass composite elements are presented, as well. Innovative hybrid composite beams combining glass and steel are introduced with resulting specimen studies to clarify and substantiate the methods presented and utilized.

Keywords: Hybrid structures, composite material, glass, polycarbonate, steel.

1. Introduction

The appearance of modern architecture is shaped by dematerialisation and transparency as evidenced by the presence of lighter load-bearing structures coupled with the increased use of light penetrating façade treatments. In this context, glass, due to its transparency and subsequent ability to transmit light, has become one of the most important materials in building design and modern architecture. The continuous improvement to the production and processing of glass has established a constructive vision of an increasingly wide range of glass applications in building construction.

In spite of its positive attributes, the brittleness of glass requires particular attention and substantial experience in its handling. Local stress concentrations due to contact with hard materials should be avoided. The post-breakage behaviour of glass, as well as its general structural strength in functional situations, must be taken into account, in particular, for those applications in which glass is used as a supporting component of a structure. Currently, laminated safety glass with polymer interlayers that normally consist of polyvinyl butyral (PVB) films is used in these situations. Laminated safety glass, once broken, generally looses a vast proportion of its bending capacity. The structural design of laminated glass panes is therefore usually carried out using necessarily high safety factors, which may, in some cases, result in over-conservative glass build-ups.

2. Glass-Polycarbonate Composite

The European standards for security glazing classify safety glazing according to their exposure to attacks. Security glass may be designed to provide resistance against manual attack, bullet attack and explosive pressure. The use of laminated glass in conventional security glazing situations can result in relatively thick cross-sections with high dead weight. This, in turn, results in the need for complex framework and supporting elements. A composite material was developed from the two basic materials glass and polycarbonate to benefit from each materials functional properties. Glass has a high material stiffness and an unsusceptible surface. Polycarbonate is characterised by its high impact strength and low weight. The build-up of glass-polycarbonate sandwiches comprises at least two outer glass panes and a sheet of polycarbonate in between. The individual sheets are bonded together with interlayers of polyurethane.

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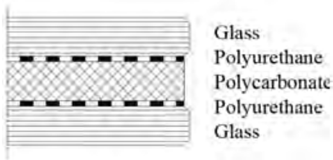

Fig. 1: Example of cross-section of glass-polycarbonate sandwich elements.

The crucial determinant of the composite structural behaviour is, consequently, the material glass. The post-breakage performance of glass-polycarbonate sandwiches is mainly determined by polycarbonate sheets in combination with bonded glass fragments. Innovative hybrid structures of glass and polycarbonate are lighter and thinner than conventional laminated security glass at a similar or improved level of performance. The build-up of glass polycarbonate composites for use as security glazing, which meets the highest class of resistance against manual attack according to European standards, has a thickness of 24 mm. The thickness of an adequate laminated security glass is 36 mm - more than thirty per cent thicker than the glass-polycarbonate composite.

3. Glass-Steel Composite

Typical glass beams are principally made up of laminated glass panes with rectangular cross-sections. The load at which fracture occurred during laboratory testing demonstrated a significant dependence between the existing edge strength of the panes and the slenderness ratio of the beams. The glass beams lost their entire load bearing capacity after breakage of each of the glass panes independent of the type of glass. An innovative hybrid beam combining glass and steel elements was developed as a typical composite material to address the aforementioned issue.

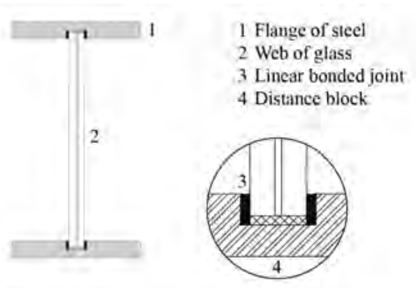

Fig. 2: Example of cross-section of glass-steel beam.

The cross-section of the glass-steel beam was principally designed as a flange beam featuring two steel flanges and a glass web. The joint detail was optimised with regard to the application of a linear bond between the two materials. The steel flange contains a slot for the linearly bonded joint, thereby, the glass acts as a structural element within the hybrid beam. The cross-section of steel-glass beams has an optimised geometrical stiffness resulting in an increased structural capacity compared to conventional laminated glass beams.

Diverse pilot surveys on four-point bending tests were executed as part of a joint research project. The experimental results demonstrated the potential of glass-steel beams for a transparent architecture. The study indicated a considerable increase of post-breakage performance of glass-steel beams compared to conventional glass beams. As a result of the development to this composite of brittle glass and ductile steel, the required redundancy of structural transparent elements in building construction can be improved. The flanges of steel enable the application of standard joining techniques for connection to other structural elements.

4. Conclusion and Summary

Innovative hybrid structures play a significant role in the development of new technologies for building construction. The creation of new functional properties is possible with the systematic composition of a variety of materials into a single composite component, which cannot otherwise be achieved by the individual materials alone. The addition of brittle glass coupled with ductile materials like plastics or steel expands the scope of applications beyond the limits of the original material. The trend to use glass not only as an enclosing element but also as a structural element is given an advantage by further developing hybrid structures.