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PhD thesis

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Experimental and numerical analysis of hybrid timber-glass beams

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Abstract

Current trends in modern architecture are focused on minimising the boundaries between the external environment and interior of the building. This requires a continuous increase of the amount of translucent surfaces allowing natural sunlight to enter the building, not only in facades but also as interior elements. The research project on hybrid timber-glass beams is based on an assumption that timber and glass work together to carry external loads. Glass no longer acts as a filling, as in traditional solutions, but actively participates in load transfer. The research project involves the most important mechanical properties of very different materials: the stiffness and strength of glass and ductile nature of timber to build a modern, safe and durable building components.

The research project involves a single pane web made of annealed float glass and timber block flanges bonded together with an adhesive. Even if the glass web fails, due to overloading or an act of vandalism, the glass shards are held in place by the timber flanges and the beam can still withstand loading. The bottom flange with the bond line adhesive connection acts as a bridge: the tensile forces that before failure were carried by the tensile zone of the web are now transferred by the timber flange. Therefore, the concept prevents brittle failure of the beam, provides ductility and offers a high post-breakage strength after possible glass failure. The post-breakage strength relates to an increased value of the load at final collapse of a beam in relation to the load at which an initial crack in the web occurs.

Experimental investigation on materials used in the research (glass, timber and adhesives) was conducted in order to better understand the behaviour of the materials and determine the basic material properties used in the numerical and analytical models. Tests on small- and life-size specimens were conducted in order to estimate the loadbearing capacity, bending stiffness and post-breakage strength. Also the influence of different adhesives covering the full range of stiffness from low (1-3 MPa) to high stiffness (1500 MPa) and types of glass (annealed float and heat-strengthened glass) on global glass beam behaviour was analysed.

Advanced 3D numerical models of beam specimens were implemented using Finite Element Code ABAQUS. Explicit solver and Brittle cracking material model for glass were used to simulate cracking of glass. The Influence of element geometry, element size and value of fracture energy on results were analysed. From these studies the most suitable model parameters were chosen for final models of small- and life- size hybrid timber-glass beams. The models were validated by comparing their results with experimental studies.

A simple analytical method for preliminary design of hybrid glass beams (determination of the load at first cracking of glass and the initial bending stiffness) was proposed by modification of the gamma-method included in PN-EN-1995-1-1. The method was validated by comparing its results with experimental studies.