Large-sized energy-efficient sandwich facades made of textile reinforced concrete – production process, design and joining concepts

Reason / starting position

Sandwich panels with facings made of steel reinforced concrete usually have thicknesses of at least 8 to 9 cm. The ecological as well as the energy requirements for the building envelope will continue to intensify in the coming years resulting in a further increase of exterior walls due to thicker insulation. In order to counteract this effect, thin textile reinforced concrete layers can be used to replace the steel reinforced concrete layers.

Subject of the research project

The aim of this research project was to develop the technical basics for producing and designing large-sized, lightweight and energy-efficient sandwich panels with facings made of textile reinforced concrete for exterior walls with internal insulation (Fig. 1). It was planned to achieve a load-carrying sandwich panel in which the thermal insulation is involved in the load transfer. The bond behaviour between the built-in insulation and both concrete layers decisively influence the load bearing capacity of a sandwich panel. Nevertheless, it was decided not to consider the thermal insulation for the load transfer to be flexible in the selection of the insulation. With this approach, only the connection devices transfer the forces between both concrete layers so that the thermal insulation can be selected independently. Due to the thin layers made of textile reinforced concrete, neither the construction principles and connection devices nor the design models of conventional sandwich panels made of steel reinforced concrete can be transferred to the construction of the panels and the description of the load bearing behaviour.

Six work packages (WP) were defined to achieve the research objective. In WP1, static-constructive, building-physical and manufacturing-technical requirements were set up. Based on these requirements, sandwich panels were designed to subsequently determine the minimum requirements for the building materials. In the following WP suitable concrete configurations for thin facings made of textile reinforced concrete were developed. Both facings should be connected with connection devices with low thermal conductivity. Punctual connection devices made of glass fibre reinforced plastic (GFK) and shear connectors made of alkali-resistant (AR) glass textiles impregnated with epoxy-resin, which can be arranged in line, were considered. The decisive factor for the selection of the connection devices was the anchoring depth into the thin concrete facings as well as the suitability for the production process. Regarding these requirements, the shear connector was preferred and applied within the further course of the project. The manufacturing technology for sandwich panels was developed in WP3 (Fig. 2). The positioning of the textiles and the shear connectors was a technical challenge, as the textiles tend to float (Fig. 3). The load-bearing capacity of several specimen, which were produced in a precast factory, were tested at the same time in WP4. On the one hand, the load bearing capacity of the textile reinforced concrete was tested on slab strips. On the other hand, small specimen were tested to investigate the shear, tensile and compression behaviour of the connection devices as well as the load bearing capacity of the transport anchors. The total load bearing capacity of an entire sandwich panel was tested on seven small sandwich strips (Fig. 3-5). The sandwich strips differed in the number of shear connectors, the width and the height. Five sandwich strips were produced with a flexible mineral wool insulation and two specimen were produced as reference value with a load bearing extruded polystyrene (XPS) insulation. In the last two work packages the test results were analysed more precisely by simulations using the finite elements program ABAQUS. Two design models based on the experimental and numerical investigations were developed to describe the bearing behaviour of the thin sandwich panels: The simplified model for square/ rectangular plates and the model for geometrically demanding plates. In the second model, the internal force variables of the shear connectors are initially calculated using a finite elements program. Afterwards, these results are compared with the experimentally determined resistances. The new sandwich panels cannot be attached to buildings using conventional fastening elements so that new fastening and joining details have been developed. Finally, the construction of a demonstrator on a 1:1 scale (Fig. 6) completed the project.

Conclusion

The aim of the research project to prove the functional capability of sandwich panels with thin facings made of textile reinforced concrete has been achieved successfully. The load bearing capacity was analysed by experimental and numerical investigations resulting in a satisfactory outcome. In the proposed system, the variable distances between the shear connectors allow an individual and economic design regarding all expected influences. In addition, the production process of the large-sized sandwich panels was considered to ensure a feasible and efficient implementation in a precast factory.

Basic data

Short title: large-sized energy-efficient sandwich facades made of textile reinforced concrete

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Overall cost: 345.116,00€

Contribution of the government: 169.818,00€

Project duration: 30 month

Figures

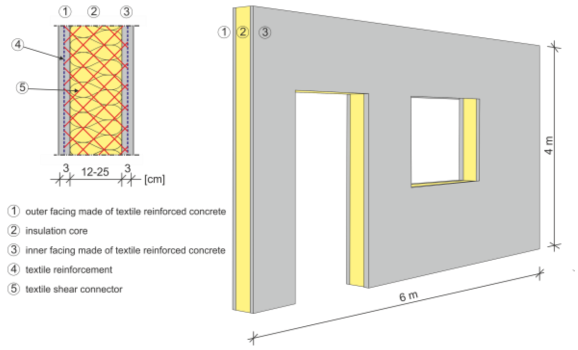

Fig. 1: aim of the research project – two thin facings made of textile reinforced concrete with a non-metallic connection device

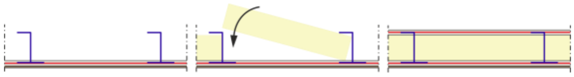

Fig. 2: schematic representation of the production

Fig. 3: reinforcement of the first facing with shear connectors secured against floating

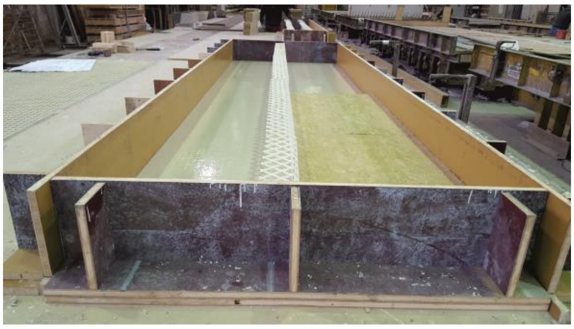

Fig. 4: installation of the flexible mineral wool insulation

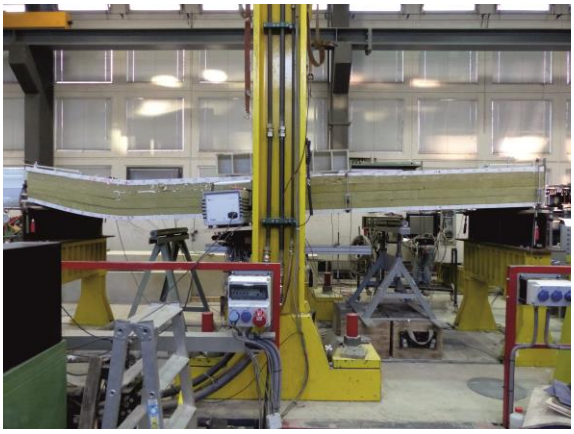

Fig. 5: deformation of a large-sized specimen with mineral wool insulation

Fig. 6: sandwich panel with gate opening