Zukunft Bau

Short Report

Title

„Durable and thermally insulating wall elements made of prefabricated hybrids of ultra-high performance concrete (UHPC) and chemically foamed and air-hardening mineral foam concrete (CLM-foam)“

Occasion/ Starting Position

Conventional wall elements nowadays usually consist of a variety of materials in order to meet the requirements for load transfer and thermal insulation according to national guidelines like the EnEV. Mainly, these materials are connected that way it is not possible to separate them by type during reintatement. This problem is to be solved by the purely mineral wall system consisting of two UHPC shells which protect the heat-insulating and load-bearing foam concrete core.

Purpose of the research project

Sandwich wall elements made of mineral foam as core and ultra-high performance concrete (UHPC) as shells were developed and investigated in this project. A mineral, chemically expanded, air-hardening foam (CLM-foam) based on a UHPC fine-grain mixture was used, which, unlike autoclaved aerated concrete, is air-hardening and does not require energy-intensive autoclaving. As a multifunctional building material, the CLM-foam core is intended to perform both load-bearing and heat-insulating functions. The first focus of this work - and its differentiation from the existing hybrid UHPC components - was optimising the microstructure of the CLM-foam in order to achieve the highest possible strength and at the same time high thermal insulation properties. These properties were optimized by adding fine grained lightweight aggregates, basalt fibres and redispersible polymer powder. After optimization, a density of 0.55 t/m³ with a strength of 2.7 MPa after seven days and a thermal conductivity of 0.10 W/(mK) was determined in the developed CLM-foam.

In order to achieve a sustainable bond between CLM-foam and UHPC without additional adhesives and separating layers, different concreting orders were studied. In order to achieve good adhesion between UHPC and CLM-foam, the best results were achieved by concreting UHPC to a saw-rough CLM-foam surface. With this procedure it was possible to produce consistently good fracture patterns during the tensile adhesion test. A good interlocking of the materials resulting from this could also be proven in the microstructural investigations using high-resolution computed tomography images.

In component tests on small-format as well as on wall-high test specimens, their properties were investigated with regard to the bond between concrete shells and CLM foam core, their load-bearing and deformation behaviour and the thermal conductivity of the exterior wall system. Initial estimations of the load-bearing behaviour of the hybrid wall element components investigated here, showed that they are very well suited for building construction due to their mechanical properties and their fracture behaviour. The result of this is currently the preliminary recommendation to design the ultimate limit state for an experimentally determined maximum load and to remain well below this maximum load in the serviceability limit state, because it indicated a detachment of the wall shell and thus an irreversible condition.

In order to demonstrate the principle applicability a small building made of 6 hybrid wall elements was build. On this wall elements a long-term monitoring documents the behaviour of the UHPC shells and CLM-foam concerning daily and seasonally temperature and humidity variations. The project was accompanied by a life cycle cost calculation and life cycle assessment. This showed that the sandwich wall elements are characterised by relatively high initial investment costs, but very low repair costs and long service lives compared to wall constructions with comparable physical and mechanical properties.

Conclusion

In this project, a CLM foam mixture was optimized in strength and density using lightweight aggregates (perlite), basalt fibres and redispersible polymer powder. As a result, the bulk density could be reduced to 0.55 t/m³, on laboratory scale to 0.45 t/m³. The microstructure is optimized to ensure a low thermal conductivity. It is also lower than comparable autoclaved aerated concrete. Without thermal post-treatment, a material has been developed that is also very suitable for building construction due to its mechanical properties and its fracture behaviour. In the course of the project, the wall elements were produced as composite elements without additional adhesives in the precast factory and a demonstrator was built on the area of the University of Kassel.

Key Data

Short title: Wall elements made of UHPC/foamed concrete hybrid precast elements

Researcher/ Project Management: Prof. Dr. rer. nat. Bernhard Middendorf und Prof. Dr.-Ing. Ekkehard Fehling

Total cost: 367.538,00 € €

Share of federal grant: 235.238,00 €

Project term: 30 months

IMAGES/ ILLUSTATIONS:

Image 1: Bild 1
Section of a wall element (left) and possible construction (right).

Image 2: Bild 2
Foamed CLM-foam in factory test at Hentschke Bau

Image 3: Bild 3
3D-pore model (left) developed from a computer tomographic image of a CLM foam sample with subsequently concreted UHPC, 2D-section shows the cross-section of both layers (right).

Image 4: Bild 4
Test specimens for tests with the GOM measuring system, specimen before the test (left) and after loading (right).

Image 5: Bild 5
Deformation and relative displacement between HPC shell and CLM-foam (left) and deformation of CLM-foam (right).

Image 6: Bild 6
Demonstrator. Lateral view (left) and frontal view (middle) and ground plan (right).

Image 7: Bild 7
Demonstrator after its completion.