TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

BAUINGENIEURWESEN
Fachgebiet Massivbau und Baukonstruktion
Prof. Dr.-Ing. Jürgen Schnell
Jun.-Prof. Dr.-Ing. Matthias Pahn

Paul-Ehrlich-Straße
67663 Kaiserslautern
Gebäude 14, Zimmer 515
Telefon (0631) 2 05 - 21 57
Telefax (0631) 2 05 - 35 55
e-mail: juergen.schnell@bauing.uni-kl.de

FORSCHUNGSINITIATIVE Zukunft BAU

Outline Report

High heat-insulating sandwich wall panels with connectors made of GFRP

(SF - 10.08.18.7-11.9/ II 3-F20-10-1-077)

This research report was funded by the Research Initiative "Future Building" of the Federal Institute for Research on Building, Urban Affairs and Spatial Development. The author takes responsibility for the content of the report.

Bundesministerium für Verkehr, Bau und Stadtentwicklung

Bundesamt für Bauwesen und Raumordnung

Schöck

FEHR Technologies

Project Manager: Prof. Dr.-Ing. Jürgen Schnell
Jun.-Prof. Dr.-Ing. Matthias Pahn

Project Engineer: Dipl.-Ing. Andreas Schmitt

Date: January 31th, 2014

Prof. Dr.-Ing. Jürgen Schnell	Jun.-Prof. Dr.-Ing. Matthias Pahn	Dipl.-Ing. Andreas Schmitt

This report covers 9 pages.

Contents

1 Initial situation and objectives

Exterior walls are produced more and more as precast elements with internal insulation. Reason for this is a number of advantages in comparison to in-situ concrete construction. Between precast elements and in-situ concrete there is the semi-precast construction. Such wall elements are casted at the construction site with in-situ concrete. This saves the time-consuming and cost-intensive formwork procedure.

The wall layers are coupled with connectors, which must carry the fresh concrete pressure during casting with sufficient safety. Presently, the fresh concrete pressure is calculated in accordance to DIN 18218 “Fresh concrete pressure to vertical formwork”. The influence due to an internal insulation on the pressure is not considered, yet. Depending upon the thickness of the in-situ concrete layer and the type of internal insulation, the fresh concrete pressure can be considerably overestimated, which can lead to an uneconomic design result.

The aim of the research project is the examination of basic principles for an economic and practice-oriented design of the number of connectors for sandwich panels with a subsequent layer of in-situ concrete.

2 Execution of the research project

In the frame of the research project practical test series as well as theoretical studies have been performed.

2.1. Practical investigations

The water absorbency of thermal insulation varies greatly depending upon the structure and composition. Water absorbing insulation used in sandwich walls with a subsequent layer of in-situ concrete extracts water from the fresh concrete. This has a direct effect on the concrete consistency and possibly also affects the fresh concrete pressure. Accordingly the water absorbency of expanded (EPS) and extruded (XPS) polystyrene has been analyzed and reviewed. For this purpose, fresh concrete was exposed to insulation materials and compacted. The dark coloring of EPS in figure 1 shows the absorbency of the water-cement mixture. When using XPS no water absorption could be observed.

In the following large-scale test series sandwich panels with a height of 160 cm with a subsequent layer of in-situ concrete were produced and tested. In the frame of eight tests the surface-roughness of the pre-fabricated load carrying layer, the roughness of the internal insulation as well as the stiffness and thickness of the insulation material was varied (figure 2). In the tests, the solidification of the concrete as an influencing factor was excluded, because the concrete casting duration was only 30 minutes. The compaction always proceeded till the foot of the walls. All test bodies were equally filled with concrete and compacted. The fresh concrete pressure was determined using strain gauges on the connectors.

For the further small-sized test series a reusable test stand has been designed, which allows the measurement of the fresh concrete pressure under variation of different influencing factors. This saves the time-consuming and cost-intensive manufacture of sandwich walls for each test. The focus of the investigations was placed to the influencing factors "thickness of the in-situ concrete layer" and "concrete consistency", which weren’t considered so far in the large-scale tests (Figure 3).

In the last test series, the fresh concrete pressure was examined at high sandwich walls under practical conditions, considering the solidification and the compacting mode of the concrete. In total three sandwich walls with a subsequent layer of in-situ concrete and a height of 400 cm (Figure 4) were tested. For direct comparison, there were two identical walls, which differ only in the type of insulation. On the one hand, a soft EPS (PV01), and on the other hand a stiff XPS (PV02) was used as insulating. As a reference, a third wall PV03 with double-sided internal, smooth formwork was produced. This test represents the limit value to PV01 and PV02 as well as to DIN 18218. Each wall was casted in eight batches of 40 l. For each batch, a concrete consistency class F4 was used and the same compacting depth was ensured.

2.2. Theoretical investigations

After the practical tests, the development of a calculation model was targeted. The aim was to bring the obtained expertise of the research project into a mathematical relationship and to find a reason for the different pressure distribution in dependence on an internal insulation. Based on the experimental results, the model of DIN 18218 has been modified. This allows a meaningful explanation and consideration of the influence of an internal insulation for the investigated boundary conditions (Figure 5).

- The lateral pressure factor λ_0 of fresh concrete is corrected for a stiffer formwork system (sandwich wall with a subsequent layer of in-situ concrete) and is not assumed according to DIN 18218.
- By using of an internal, water absorbing material, the lateral pressure factor for the calculation has to be reduced to an effective value $\lambda_{0,eff}$ after the compaction of the fresh concrete, because water is removed from the concrete.
- The range of the concrete vibrator h_W must be adjusted to the concrete consistency.

3 Summary and recommendations for practice

Expanded (EPS) polystyrene features a water absorbing property. When using such type of insulation in sandwich wall panels with subsequent in-situ concrete, water is removed from the fresh concrete during the compacting procedure. Here the fresh concrete consistency changes, which has influences on the maximum concrete pressure. The amount of water removal depends on the pore size and density of the insulation material. Extruded polystyrene (XPS) doesn't absorb water.

During execution of the tests with low casting height up to 160 cm numerous influencing factors on the horizontal concrete pressure were analyzed (see section 2.1). The experimental results have shown, that under variation of the parameters and a compaction of the fresh concrete to the foot of the walls, there are no significant differences between the maximum pressure and the pressure distribution over the component height. Then the fresh concrete pressure can be calculated under the assumption of hydrostatic pressure according to DIN 18218 "Fresh concrete pressure to vertical formwork".

In the frame of the test series under practical conditions, care was taken to a standardized compacting method (compaction and connection of the upper two batches). Here a significant dependence of the maximum concrete pressure by an internal insulation has been observed. As justification, the water absorbing property of EPS has been pointed out. Due to the removal of water from the fresh concrete, results a stiffer concrete consistency. Accordingly lower fresh concrete pressures occur at higher casting heights. In addition the

influence area of the dynamic depth effect of the concrete vibrator reduces and the friction between fresh concrete and the formwork surfaces increases (silo effect). Both also lead to a pressure reduction. In sandwich walls with an internal insulation made of EPS the connectors are loaded much less during casting of the in-situ concrete layer.

The test results show, that under the tested boundary conditions:

- Casting velocity 1,6 m/h
- Concrete consistency F4
- Thickness of in-situ concrete layer 100 mm
- Surface of pre-fabricated load carrying layer rough
- Thermal insulation EPS (ρ = 15 kg/m³)

a more economic design of the grid of the connectors is possible. The experimentally obtained maximum fresh concrete pressure of sandwich walls with internal insulation made of EPS amounts in comparison to the characteristic fresh concrete pressure according to DIN 18218 only about 50 %. This pressure reduction results starting at a casting height of approximately 200 cm. At lower casting heights an influence of the insulation to the maximum fresh concrete pressure can be excluded.

A lower fresh concrete pressure enables a more economic design of the grid of the connectors. In addition the durability of such walls is increased by using EPS, because the permanent tensile loading of the connectors is reduced. A disadvantage is the absorption of the water-cement mixture during compaction of the fresh concrete. This leads to a reduction of the heat insulation of the wall elements.

4 Basic information

Short title: High heat-insulating sandwich wall panels with GFRP-connectors

Researcher / Project management: F20-10-1-077
Project manager: F20-10-1-077

Total costs: 166.794,20 €
Amount of federal grand: 96.194,00 €

Project duration: 01.2012 to 01.2014

Reference list

DAfStb Heft 567 Frischbetondruck fließfähiger Betone [Bericht]. - Berlin : Beuth, 2006.

DIBt Zulassung Z-21.8-1878, TM-Verbundsystem für dreischichtige Stahlbetonwandtafeln. - Berlin : Deutsches Institut für Bautechnik, Juni 2011.

DIBt Zulassung Z-21.8-1894, Schöck ComBAR Thermoanker. - Berlin : Deutsches Institut für Bautechnik, Dezember 2011.

DIN 18218 Frischbetondruck auf lotrechte Schalungen. - Berlin : Deutsches Institut für Normung, Januar 2010.

DIN EN 12350-5 Prüfung von Frischbeton - Teil 5: Ausbreitmaß. - Berlin : Deutsches Institut für Normung, August 2009.

DIN EN 12350-6 Prüfung von Frischbeton. - Berlin : Deutsches Institut für Normung, März 2011.

DIN EN 12878 Pigmente zum Einfärben von zement- und/oder kalkgebundenen Baustoffen - Anforderungen und Prüfverfahren. - Berlin : Deutsches Institut für Normung, Februar 2012.

Gastmeyer Ralf Tragverhalten von teilweise vorgefertigten Stahlbetonwänden mit Ortbetonergänzung und integrierter Wärmedämmung [Artikel] // Bautechnik. - Berlin : Ernst & Sohn, 2004. - Heft 11, S.869-873 : Bd. 81.

Pahn Matthias Beitrag zur Ermittlung von Schnitt- und Verformungsgrößen bei mehrschichtigen Stahlbetonwandtafeln mit Verbindungsmitteln aus glasfaserverstärktem Kunststoff. - Kaiserslautern : [s.n.], 2011.

Proske Tilo Frischbetondruck bei Verwendung von Selbstverdichtendem Beton. - Darmstadt : [s.n.], 2007.

Specht Manfred Der Frischbetondruck nach DIN 18218 - die Grundlagen und wichtigsten Festlegungen [Artikel] // Bautechnik. - Berlin : [s.n.], 1981. - Bd. Heft 8.

Specht Manfred Die Belastung von Schalung und Rüstung durch Frischbeton [Buch]. - Düsseldorf : Werner-Verlag, 1973.

Specht Manfred Theorie des Frischbetondrucks - gegenwärtiger Stand und ungeklärte Probleme [Artikel] // Bautechnik. - Berlin : [s.n.], 1987. - Bd. Heft 3.

Figures

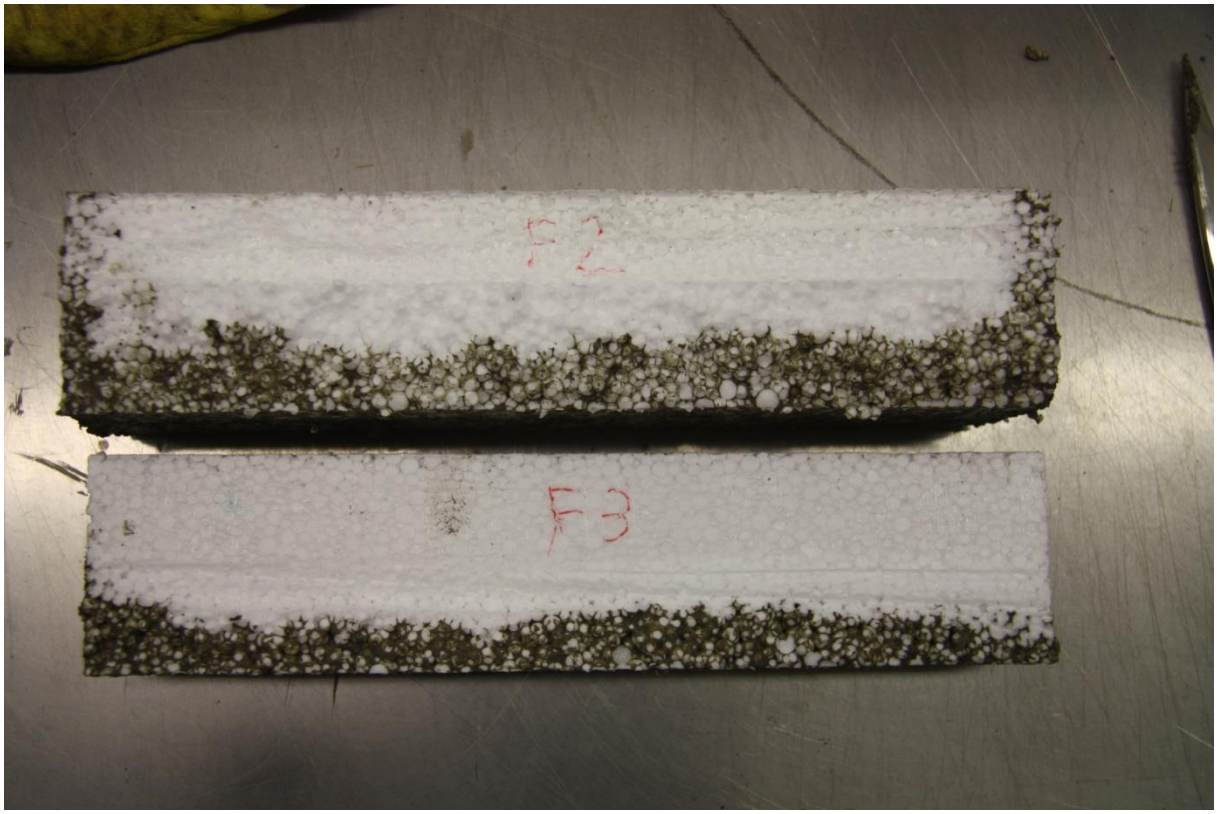

Figure 1: Dark coloring of EPS due to absorbency of the water-cement mixture.jpg

Caption: Dark coloring of EPS due to absorbency of the water-cement mixture

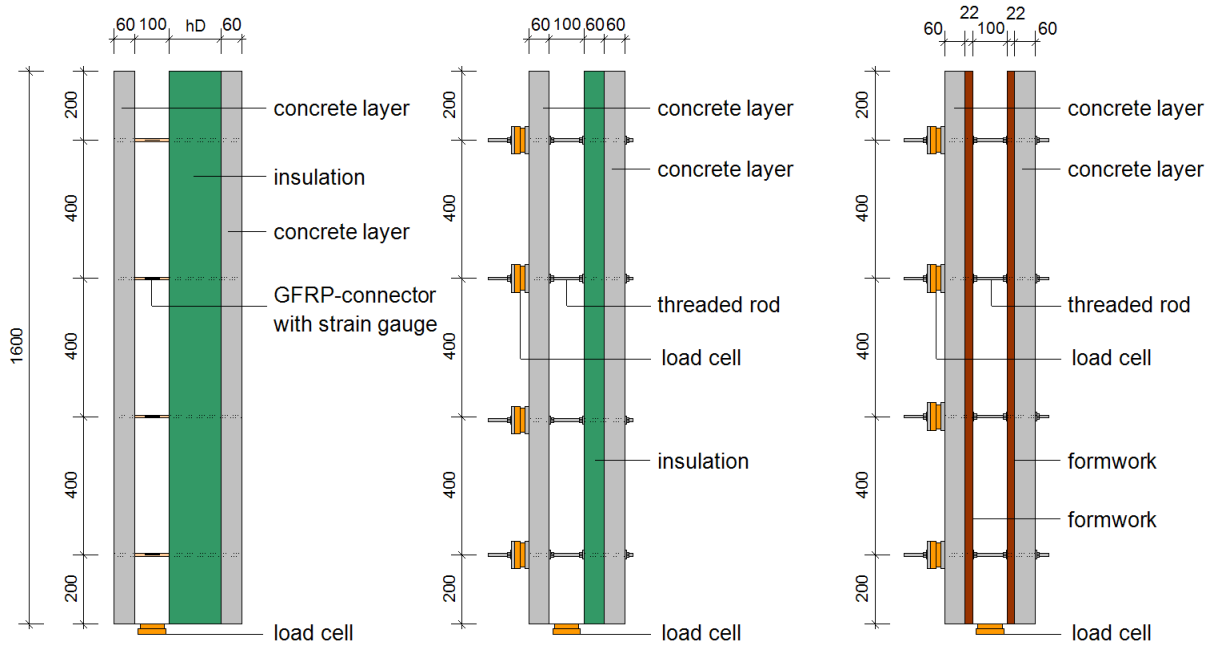

Figure 2: Geometry and composition of large-scale test series.png

Caption: Geometry and composition of large-scale test series

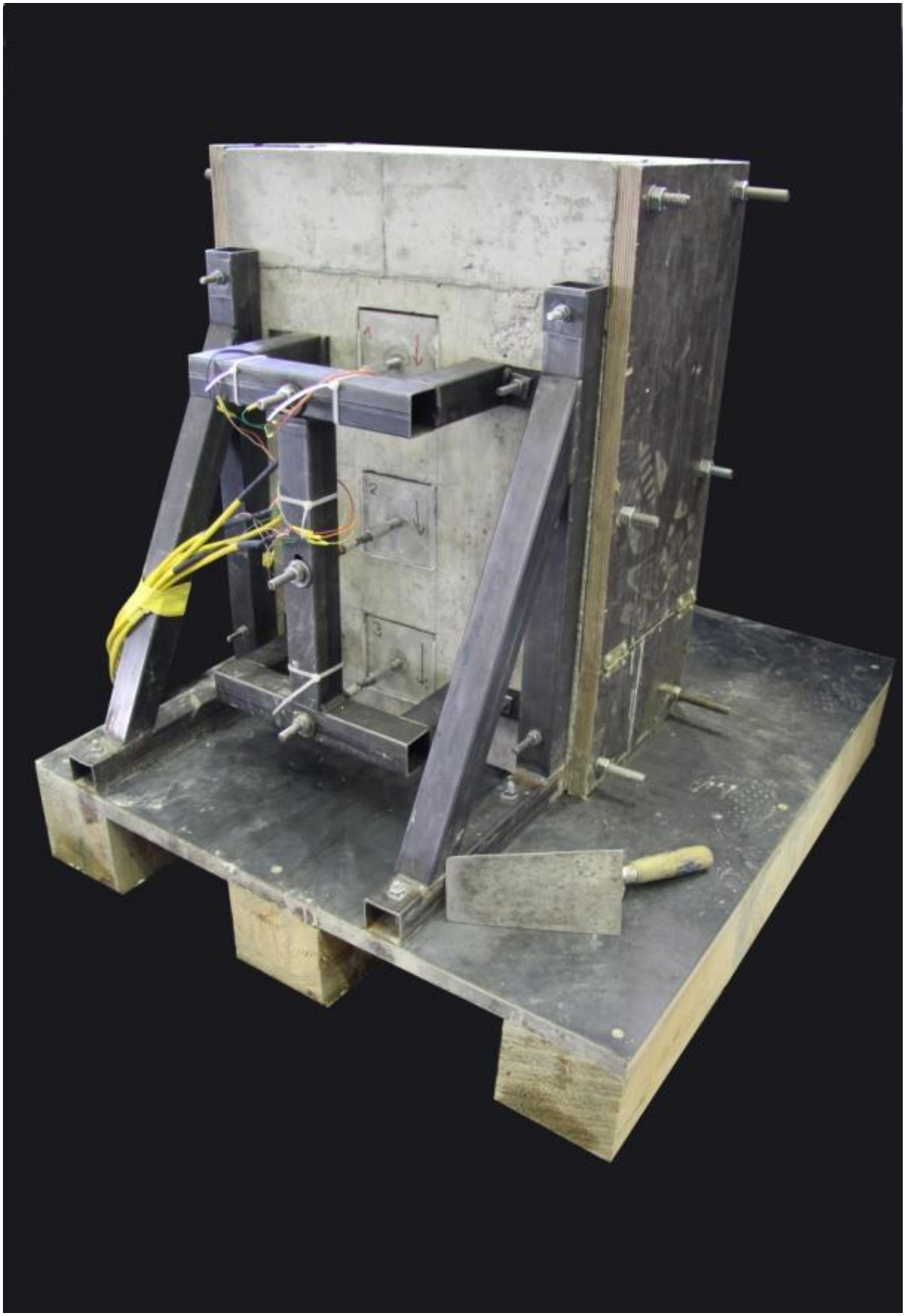

Figure 3: Test stand of small-sized test series.jpg

Caption: Test stand of small-sized test series

Figure 4: Vertical aligned sandwich wall and top view of test bodies.jpg

Caption: Vertical aligned sandwich wall (left); Top view of test bodies (right above PV01, right center PV02, right below PV03)

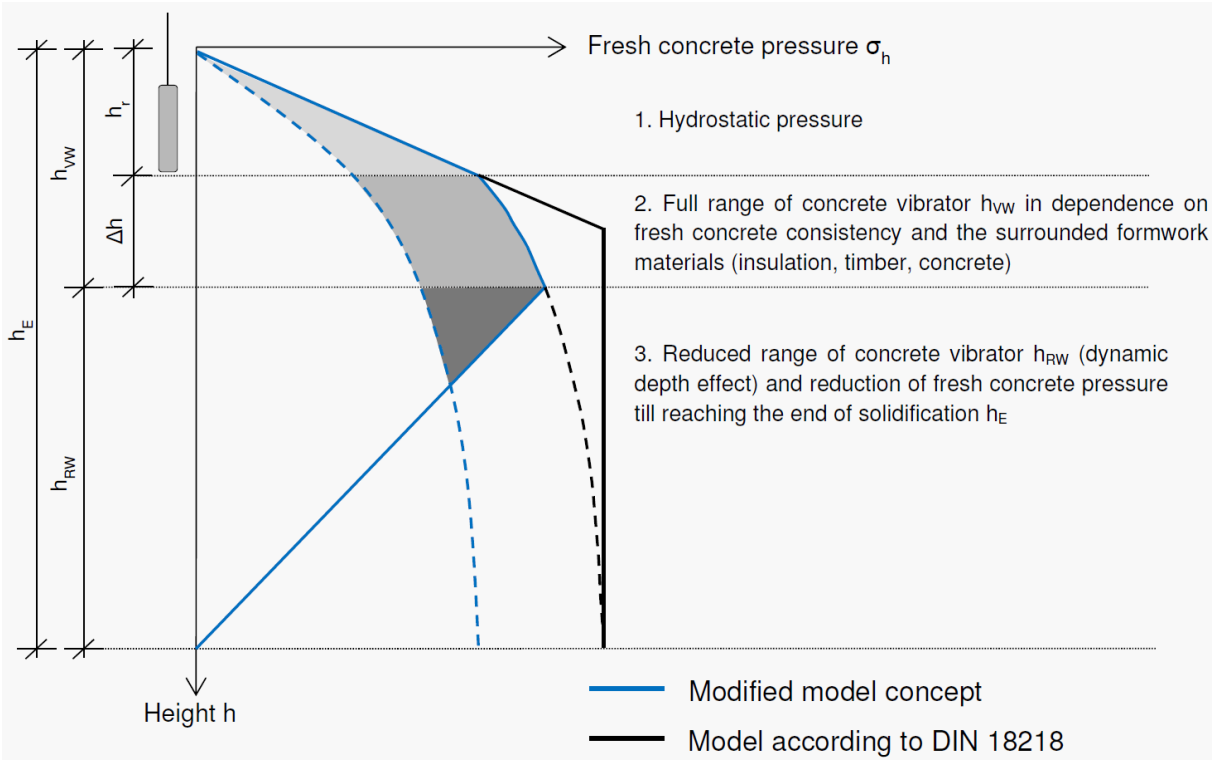

Figure 5: Modified model for sandwich walls with a subsequent layer of in situ-concrete.png

Caption: Modified model for sandwich walls with a subsequent layer of in situ-concrete