Zukunft Bau

Abstract of BBSR-research project

Title

Title: Thermal separation of reinforced concrete columns

Motiviation

A further improvement of the building envelope with regard to heat transfer is required in new buildings, because of the steadily tightening of the Energy-Saving Ordinance (EnEV). In order to achieve this, the heat-insulating properties of the individual components must be improved. This leads to an increasing influence of thermal bridges on the overall heat loss of the building. An avoidance or reduction of these heat bridges can significantly contribute to an increase in the quality of buildings and thus to the future requirements of energy-efficient construction. In addition, higher surface temperatures ensure a more comfortable room climate as well as the protection of the building structure and the occupants (free of mould fungus). In order to minimize heat bridges of reinforced concrete connections, which are predominantly subjected to bending and transverse forces e.g. cantilever plates there are already developed solutions from different companies. Technological pioneer was the company Schöck Bauteile GmbH, with which this research project is implemented. At present there is, however, no ready-made solution for a sufficient thermal separation of the pressure connection of steel support rests. The aim of this research project is to elaborate the scientific foundations for the development of thermally separated concrete column connections and to demonstrate the feasibility with first prototypes. The column connection should allow a sufficient thermal decoupling of reinforced concrete columns (in the area of cold outside air) from reinforced concrete ceilings (warm interior) and at the same time being capable to transfer high normal forces. Such connections can provide a significant contribution to energy saving and lowering life cycle costs without creating architectural constraints. The main application area of the support is for residential and office buildings with underground garages.

Scope of Research

The research approach is divided into three parts: the theoretical part, the experimental part and the computer-assisted modeling with the analytical part.

In the theoretical part (*work packages 1 to 4*) the basic principles for thermally decoupled pressure connections of reinforced concrete columns (short: column connections) are developed on the basis of extensive studies. In *work package 1*, the building physics influences fire, heat, moisture, light and sound are examined and the resulting requirements for the column connections are compiled. The resulting specifications are used to determine the materials, which can be used for the column connections. The static effects of the thermally decoupled column connections on different column-ceiling systems have been determined in *work package 2*. The column connections should have the same outer dimensions as the reinforced concrete columns, so only materials with a compressive strength higher than the concrete strength of these columns can be used. In the case of building construction, it is also frequently not possible to realize the same support widths for the ceiling over unheated areas (for example, park decks). From a numerical investigation, it can be seen that there must be restrictions with regard to the static systems. The load bearing capacity of the column connection is to be related to the cross-sectioning capacity of the reinforced concrete column. Thermally decoupled pressure connections are not yet dealt with in literature so a literature research (*work package 3*) is primarily used for material discovery. Subsequently, the materials were identified and excluded, which do not meet the requirements of *work packages 1* and *2*. Based on the remaining materials, a theoretical variant study is carried out in *work package 4*. Two versions are shown, which are suitable for the thermally decoupled pressure connection.

In the experimental section (*work packages 5, 6, 9 and 11*), the two variants of the column connections have been subjected to a comprehensive test program (*work package 6*). The building material parameters (*work package 5*) have been tested parallel to the tests. The static load tests were carried out on a small scale for partial areas of the column connections as well as on column connections on a 1: 1 scale. These load tests were primarily designed to find the load bearing capacity of the column connection. An optimization was carried out according to the numerical modeling of the tests in *work package 9*. Further load tests on the support connection were carried out to verify the assessment concept developed in the analytical part of the work (*work package 11*).

The computer-assisted models (*work packages 7, 8 and 10*) are used to investigate the static load-bearing behavior as well as to determine the structural-physical properties of the support connections. Finite element (FE) models are used to predict the failure modes (for example, pressure failure in the column connection, exceedance of the loadable material stresses), and to determine the load level in the component tests. Furthermore the FE models are used to optimize the shape of the column connections and to check the analytical design concept. The building physics models primarily serve to determine the thermal characteristics. The analytical part (*work package 10*) comprises the development of a design concept. This design concept must take into account all possible types of failure and enable a reliable prediction of the failure load.

Results and key findings

The requirements for the thermally decoupled column connection with regard to the individual structural influences of fire, heat, moisture, light and sound have been compiled. In particular, it was found that the structural element in the load-bearing parts must consist of "non-combustible" materials. At the same time, it is necessary for application in practice that the column connection generates not only less heat losses than a continuous reinforced concrete column connection but also generates less heat losses than the design solution with insulation on the upper part of the column. With regard to compliance with the structural requirements of moisture, light and sound, there are no further requirements for the column connection.

In this research project, only braced buildings are being treated, that are within the framework of the usual building construction, so a maximum surface load of 5.0 kN/m^2 is permitted. It is not possible to define a load-bearing capacity as a quantitative value, so the objective of achieving the load-bearing capacity of the reinforced concrete connection was given. For the dimensioning of the column connection in the case of bend-rigid columns connected to the ceilings, it is necessary to have a spanning ratio of $0.5 \leq l_1 / l_2 \leq 2.0$, a maximum span of 7.5 m and one of the outer dimensions of the support corresponding ceiling thickness. For other static systems with substructures and/or consoles, the loads are resulting from the statics. Furthermore, the column connection is to be designed for the load case impact of a car.

The identified materials were assessed using static, physical and ecological criteria. As suitable materials for the column connections, light concrete and ultra-high-strength concrete were found. On the basis of this, theoretical variants were developed for the formation of the column connection, and the two most suitable variants were identified by means of a rating scheme. In the one variant, the transfer of the compressive force takes place by means of a full-area lightweight concrete element and in the other variant the support element is formed from a square UHPC hollow profile. Both variants of the column connections (full-surface lightweight concrete as well as square UHPC hollow profile) were analyzed in a wide-ranging experimental program with regard to the bearing behavior. In summary, the mean of the normal force, the critical range below the light-touch element and various concrete pressures were investigated. The tests with a UHPC hollow profile were not successful and thus this variant was not pursued any further.

Using an FE model for thermal modeling, the heat transfer coefficient λ for the column connection could be determined and compared with that of the design solution with insulation on the upper part of the column. It was found that, in some cases, considerable saving potentials exist and the heat loss at the thermal bridge can be significantly reduced compared to the design solution. In this case, potential savings of up to 50 % are possible compared to the heat losses of the design solution.
The calculation of the experiments showed that the FE modeling is in good agreement with the tests with regard to the load bearing capacity, the deformation, the cracking pattern and the elongation of the reinforcement. Using this FE model for load calculation, which allows a reliable prediction of the failure load, a design approach has been developed which is as simple as possible to use. Parameter studies showed that only the degree of reinforcement, the concrete pressure strength and the external dimension of the column under the examined parameters have a significant influence on the degree of utilization of the cross-sectional column resistance. The reduction factor η determined by the design recommendation is multiplied by the cross sectional capacity of the reinforced concrete column and results in the bearing capacity of the column connection. The resulting load-bearing capacities can be determined quickly and easily. It was demonstrated that using the reduction factor η is always on the safe side.
In summary, it can be said that the novel support connection, consisting of a lightweight concrete element with a circular opening (75 mm) for compacting the concrete and a horizontal stirrup at half height, is of high load-bearing capacity, is cost-effective and at the same time significantly reduces the point of thermal bridging. For these reasons, a timely implementation of the research results into an approved construction product is taken into account.

Basic information

Short title: Thermally decoupled column connections

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Overall costs: 183.130,16€

Federal Government subsidy: 118.130,16€

Project duration: 24 months

Figures:

Figure 1: flowchart.jpg / Caption: Flowchart of the research project

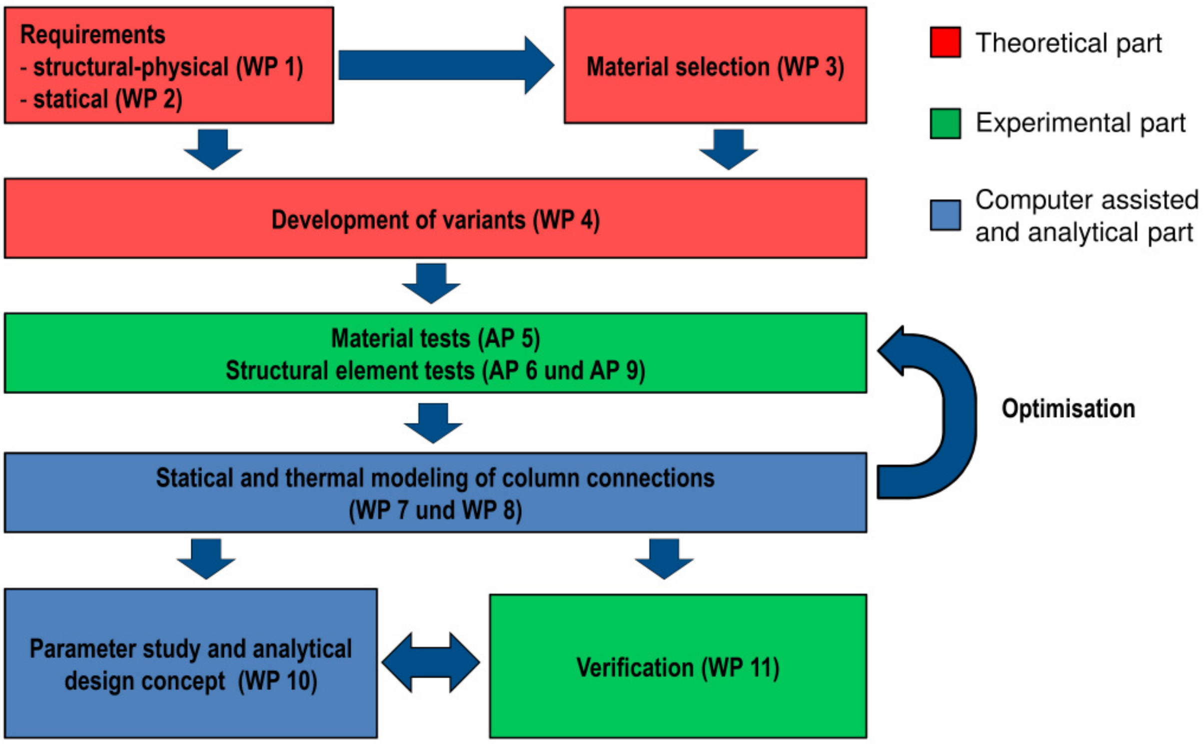

Figure 2: Overview.jpg / Caption: Overview