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A DEMOUNTABLE PRECAST REINFORCED CONCRETE BUILDING SYSTEM OF MULTI-STORY BUILDINGS

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The demountable precast reinforced concrete building system consists of bar and thin-walled units allowing designing hybrid integrated systems of multi-storey buildings. The system's characteristic property are demountable, self-rectifiable and dry joints enabling assembly without wet processes and, in case of need, the disassembly and relocation of the structure. The system applies special mounting, the joint of prestressed hollow core floor units and the load-bearing structure by steel pins additionally embedded in the hollow cores. The article presents the results of experimental research into the major parts and joints of the load-bearing system and the verification of the load-bearing system's prototype exposed to static load tests with an example of the load-bearing system's assembly and disassembly.

Keywords: Frame, Dynamic characteristics, Bearings, Natural oscillation, Forced oscillation.

1 INTRODUCTION

A characteristic element of the demountable precast building system for multi-storey buildings are demountable joints of load-bearing precast reinforced concrete units. Demountable joints allow dry assembly, disassembly and relocation of the building, or a change in the spatial and functional arrangement of the load-bearing structure in keeping with new requirements. Potential "recycling" of the reinforced concrete structure at the level of precast units, therefore, represents significant energy and material savings eliminating negative environmental impacts compared to the common recycling of building materials up to now. A prominent characteristic of these demountable joints is their ability to absorb the strain energy induced by dynamic effects to a required level (Makovicka 2011, 2012; Witzany *et al.* 2013, 2014).

2 EXPERIMENTAL RESEARCH

The on-going experimental research verified the major joints of load-bearing precast reinforced concrete units.

2.1 Verification of the Joint of Precast Cross Bars and Precast Columns ("Column – Girder" Joint)

A demountable joint of a girder and a column ("column – girder") consists of steel anchoring and mounting plates embedded in a precast column and a girder and of connecting steel elements additionally mounted during the assembly. The demountable “column – girder” joint is designed to allow simple assembly of a column structure using precast columns one, two or up to three storeys in height. The connecting steel elements, which are immovably fixed by means of a bolted connection or a special lock connection to anchoring plates embedded in the columns, form short brackets onto which girders are successively mounted by means of steel mounting plates. In structural terms, the demountable “column – girder” joint is designed as an articulated joint. It is dimensioned for a vertical and horizontal shear force and for the twisting moment exerted by the effect of one-sided mounting of units in edge bays. The designed solution was subjected to 3D numerical analysis in the ANSYS programme (Figure 1).

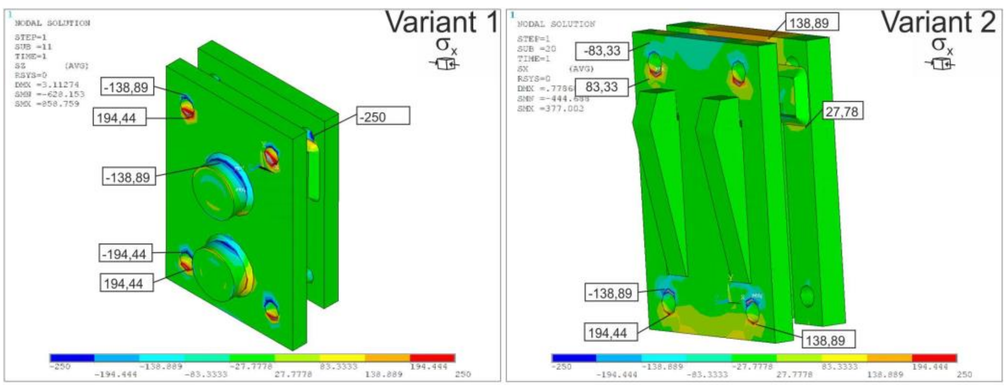

Figure 1. Results of numerical (FEM) analysis of steel connecting elements.

For verification purposes, a configuration was designed corresponding to the edge part of a load-bearing system composed of two divided columns and an inserted girder of a symmetrical cross section onto which segments of floor units were mounted. Apart from the static test, the designed layout of the load-bearing structure also allowed the verification of the assembly and disassembly of demountable joints, including the verification of the demands for precision.

The setup was loaded gradually; first, the columns were loaded with an axial force of 100 kN. The loading of the girder was applied onto the floor structure via a pair of presses. By means of steel load distribution beams, uniform linear loading of the floor structure and, through it, of the girder was achieved. The loading in the presses loading the floor structure grew step by step by 50 kN. The joint in the area of the embedded steel mounting plate failed under loading with 450 (Variant 1) and 595 (Variant 2) kN. This load corresponds to e.g., the loading of the floor structure with 12.5 (Variant 1) and 16.5 (Variant 2) kN/m^2 (including own weight) for frame bay dimensions of 6m x 6m.

The experimental verification of the “column – girder” joint manifested sufficient load-bearing capacity of the designed joint solution for the presumed utilisation of the precast structure for the purposes of administrative and civic infrastructure and light industry structures (Figure 2). The assessment of the results of experimental tests provided knowledge to be applied in the next research phase, during the optimisation of the dimensions of anchoring and mounting elements and partial modifications of the anchoring of mounting elements. Experimental tests manifested the agreement of the designed solution with assumptions, i.e., the feasibility of dry assembly and disassembly of the load-bearing structure, reaching the desired structural characteristics of mainly load-bearing joints and the verification of the structural action of the joint.

For a frame bay of 7.2m x 6.0m, the achieved joint limit load of 450 (variant 1) and 595 (Variant 2) kN represents loading with 10,5(Variant 1) and 13,8 (Variant 2) kN/m^2, i.e., a value 3 (Variant 1) or 3,9 (Variant 2) x higher compared to the load value corresponding to the presumed utilisation of the system.

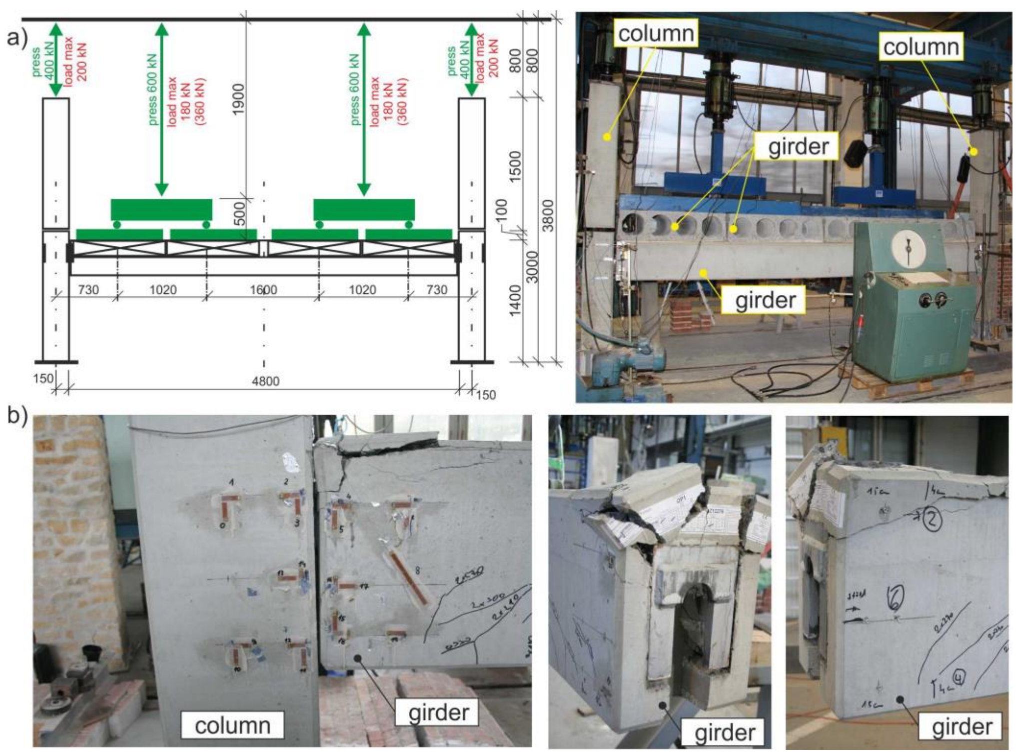

Figure 2. a) Test configuration scheme, b) Failure of the test configuration at reaching limit load.

2.2 Experimental Verification of a Joint of Floor Units and a Supporting Structure ("Floor – Wall, Girder" Joint)

The system applies special mounting, the joint of prestressed hollow core floor units and the load-bearing structure using steel pins additionally embedded in the hollow cores.

To verify the load-bearing capacity of a floor structure mounted onto a wall by means of steel pins, a segment of a load-bearing wall 900 mm in height, 1200 mm in width, 200 mm in thickness was designed and fitted with "pockets" for mounting steel pins projecting from the front of floor units and the hollow core precast concrete floor unit 1200 mm in width, 1500 mm in length and 200 mm in thickness with two embedded steel pins Ø 30 mm projecting from the floor unit front. Both the wall and the floor unit were of concrete C 45/55 (Figure 3).

The structure was loaded with a force growing in 10 kN steps, always in three loading levels with subsequent load removal to the basic value of 10 kN. Nine LARM LVDT strain gauges were installed to monitor the joint deformation. At reaching the limit load value of the joint formed by two steel pins Ø 30 mm, the destruction of a floor unit in the area of steel pins mounted in hollow core prestressed units occurred due to longitudinal cracks – partial pull out of embedded steel pins from the hollow core floor unit. The limit load at the joint failure was 200 kN, i.e., the ultimate shear force at the point of mounting was 123.5 kN.

The characteristic bearing capacity (V_{rd}) in shear of the used floor unit without modifications is 65.7 kN. The identified ultimate bearing capacity of modified floor units was minimally by 88 and 109% higher.

The experimental verification of the "floor – wall" joint manifested a sufficient reserve in the load-bearing capacity of the designed joint in terms of the presumed utilisation of the structure for the purposes of administrative and civic infrastructure and light industry structures.

The experimental programme further included the verification of the load-bearing capacity of a joint of columns and walls in compression, the load-bearing capacity of a longitudinal joint in compression and a vertical joint of wall units in shear.

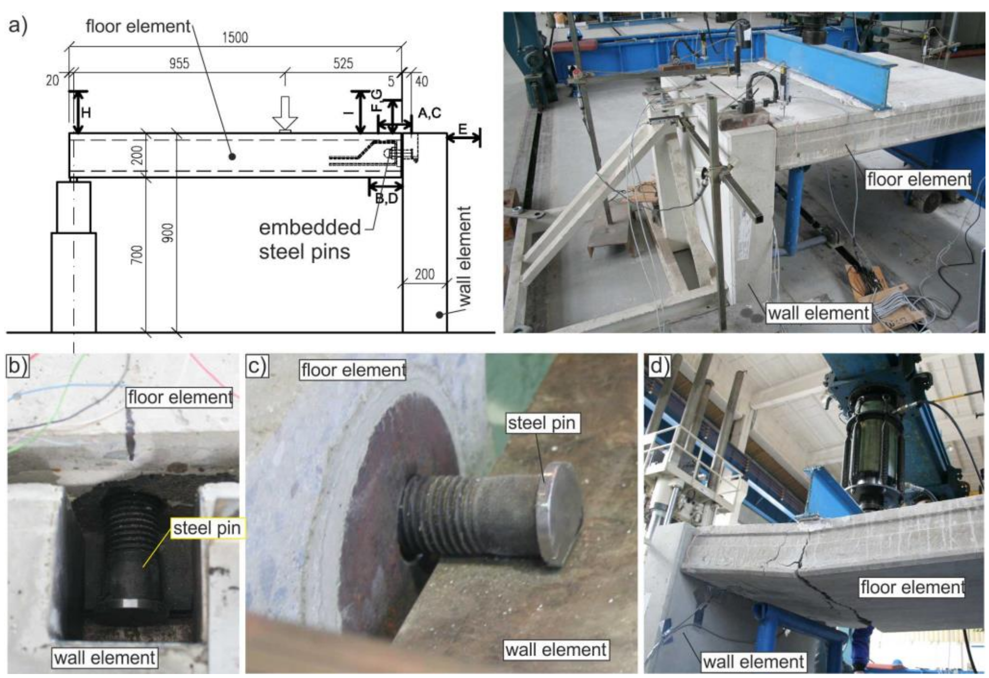

Figure 3. a) Test configuration scheme, mounting of strain gauges, detail of mounting, b) Steel pin befor test, c) Steel pin after test, d) Failure of the test configuration at reaching limit load.

3 EXPERIMENTAL IMPLEMENTATION OF A PROTOTYPE OF AN INTEGRATED PRECAST STRUCTURE

The load-bearing structure of an experimental prototype with dry demountable joints was designed to verify the assembly and disassembly of a precast structure with dry demountable joints applying bar, pillar and wall units, the requirements for production and assembly tolerances and the possibility of mutual combinations of individual types of precast units.

No serious problems in terms of the precision and tolerances of precast reinforced concrete units and embedded connecting or anchoring steel elements occurred during the assembly (Figure 4).

The assembly proved the feasibility of mutual combinations of individual designed systems, including the creation of so-called integrated systems.

Figure 4. a) Preparation of foundations, b) Assembly of foundation beam, c) Assembly of a stiffening diaghragm (bracing wall), d) Assembly of load bearing wall in second floor, e) Gradual disassembly of the structure.

The assembly was collision-free confirming the assumed feasibility of reaching significant shortening in the assembly time, improvement of working conditions of assembly workers, independence of climatic conditions (works were carried out at the time when the temperature ranged from -2°C to +5°C) and the possibility of non-degrading the quality of the units and connecting steel elements during the assembly and subsequent disassembly, i.e., verification of the assumptions of potential reuse of the units after dismantling.

The prototype of the setup was dismantled and relocated to another site where it will be implemented in an extended version and exposed to static and dynamic tests.

The designed composition, verified during the assembly, manifested a sufficient variability of the load-bearing system in terms of its application for housing, accommodation and hotel, administrative and civic buildings, or for buildings for the light industry.

4 CONCLUSIONS

The results of experimental verification of the major joints of load-bearing precast reinforced concrete units and the course of the assembly and disassembly of individual precast units verified the feasibility of the designed demountable system in its individual structural versions, including the so-called combined version – an integrated system. A significant part of this new demountable system is the contact joint of precast units. An essential characteristic of these joints is the ability to absorb energy, which allows limitation of the intensity of dynamic effects and elimination of outside noise (traffic, building and industrial activity) below the threshold of audibility thus enhancing the quality of internal environment, permitting construction in areas with increased noise levels, traffic etc. The system may analogically be applied in areas with substandard foundation conditions, with underground traffic, in undermined zones and in areas with high probability of the occurrence of natural seismicity.

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