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# Experimental Analysis of Demountable Precast Structure

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**Abstract:** Repetitive use of prefabricated reinforced concrete units with a long life cycle within a new design solution in construction allow reaching considerable material and energy savings. The dry assembly and disassembly option creates conditions for reaching a harmony between the service life and the serviceability of a building, reducing material and energy needs and reducing the negative effects of building operations on the environment. A characteristic component of precast reinforced concrete construction system for multi-storey buildings are demountable joints of load-bearing precast reinforced concrete elements. This paper is focused on experimental analysis of demountable precast column structure and its demountable steel joints. The experimental research carried out within TA02010837 "Multipurpose dismantleable prefabricated reinforced concrete building system with controlled joint properties and possibility of repeated use".

**Keywords:** Precast Column System; Demountable Joints; Experimental Analysis.

## 1 Introduction

Solution of load-bearing precast column system consisting of beam elements, wall elements or spatial units creates prerequisite for achieving high variability of composition and design solution of structure and therefore fulfills the demanding requirements for residential houses, civil houses and manufacturing houses.

System design requires an entirely new structural, analytical and static solutions-based theoretical analysis and experimental verification, within which the actual conditions, external influences and effects are simulated [1].

Demountable joint, as such is a characteristic part of demountable structure. These joints should allow simple and precise assembly of components, while using the structure to fulfill its structural function and subsequently enable seamless disassembly of the structure [2].

## 2 Structural and Static Design of Demountable Joints

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 [3].

Currently two variants of these joint were designed and compared. The first variant ("column – girder" joint type 1) characterizes the console with round base portion which is attached by bolts to the base plate embedded in the column. The girder is then mounted on this console using similarly shaped base plate. The advantage of this solution is relatively simple production, but the need to use high strength bolts. The second variant ("column – girder" joint type 2) consists of a welded special steel element which allows quick installation based on the principle of a special locking joint. The disadvantage of this variant is higher intensity of labor, when the special steel element is produced, but no need to use bolts. This and the previous solution enables the connection of the required number of girders on the column.

Both of these joints are attached to anchor plates embedded in columns. These are short consoles on which allow the girders to be mounted using similarly shaped base plate. From the static point of view, this joint is designed as articulated pin joint. It is designed to transfer both vertical and horizontal shear forces and torque that can be caused by depositing on-side panels in the outer fields or during assembly.

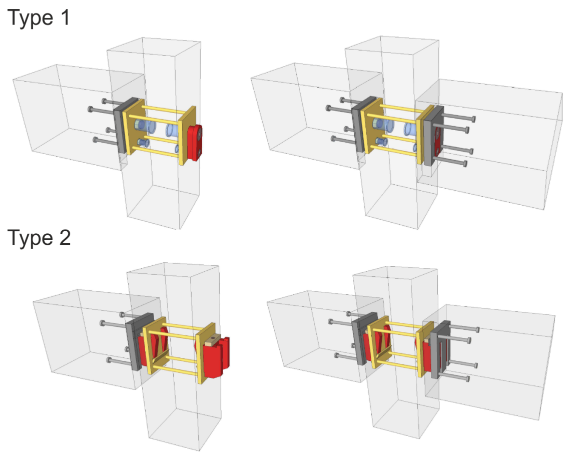


Fig. 1: Structural design and composition of a “column – girder” demountable joint of precast load-bearing units.

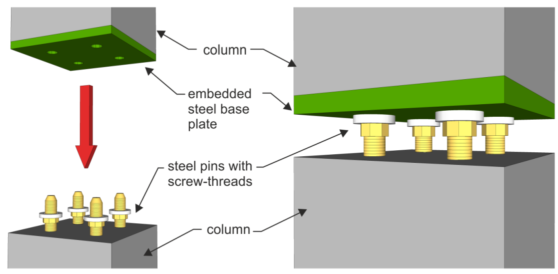


Fig. 2: Structural design and composition of a “column – column” demountable joint of precast load-bearing units.

The joint of columns (“column – column” joint) is designed on principle of leveling screws provided with mounting and also rectification nuts. These nuts are used for levelling of the upper level column to the desired horizontal and vertical position. There are four mounting pins with threads in the head of column. Nuts are screwed on these pins and washers are placed on them. Upper level column is fitted with a steel plate in the heel, which transmits the load through the set screws into the column of the lower floor.

“Column – column” joint is situated with respect to the technical and static requirements above “column – girder” joint. The upper face of the girder is the same height level as the upper face of the column.

# 3 Experimental Analysis

Experimental verification of demountable joints was done on a test assembly consisting of two split columns and connected girder. The columns were 300 × 300 mm in cross-section and 1500 mm in length, the girder cross-section was 300 × 400 mm and length 4800 mm. The arrangement and dimensions of the test assembly is shown in Fig. 3. The materials of reinforced concrete elements are C50 / 60 and steel B500B. The steel connecting elements are made of steel S355J0.

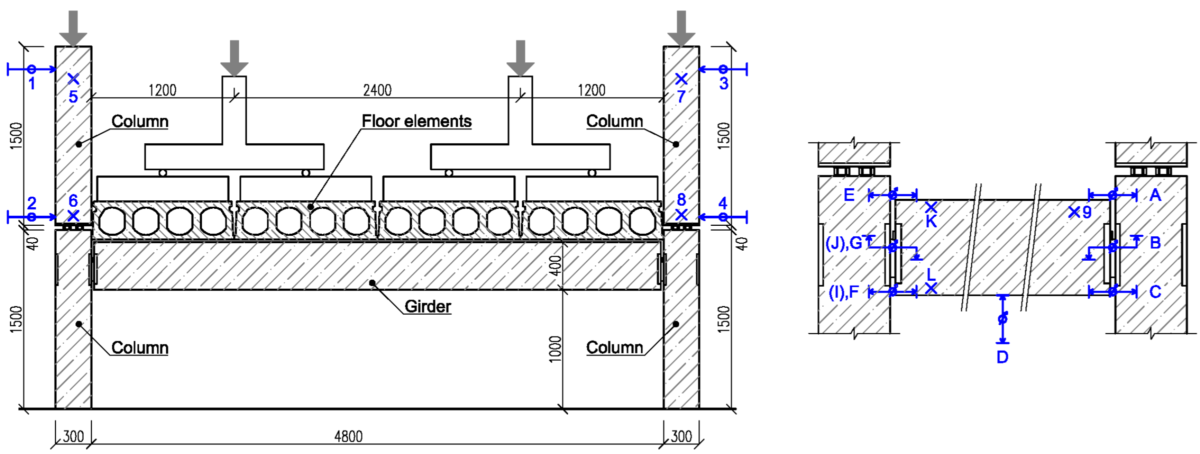


Fig. 3: Test configuration scheme and placement of LVDT sensors.

The load was applied in the individual load steps directly to the columns and through the floor panels to girder. The load cases were chosen so as to cause maximum values of bending moment to girder, vertical shear forces on the girder and column connection and torque to girder, in order to verify the load-bearing capacity of the girder and the steel joints. Another part of the static test was to verify the column – column joint. For this test four load cases with different axial force acting on the columns were chosen. These forces had values of

50 kN, 100 kN, 50 kN (unloading) of 200 kN for each column. The load on girder which produced the torque was applied in individual 15 kN steps in a range from 15 to 120 kN. The aim of the test was to determine the influence of the loading of columns by axial force to stabilize the frame while loading girder with torque. The test assembly was equipped with LVDT sensors to record the relative and total deformations of the frame and strain gauges to determine the strain in the joint area. LVDT Placement of sensors is shown in Fig. 3.

Fig. 4: Photos the test assembly.

The "column - girder" joint type 1 failure occurred at a total load of 450 kN applied on the girder. Shear force had value of 225 kN. The area load corresponding to the considered size of frame field 6.0 × 6.0 mm reached a value of 12.5 kN/m$^2$ (including dead-load). "Column – girder" joint type 2 failed at the load on the girder of 595 kN, which corresponds to the shear force of 298 kN and the area load of 16.5 kN/m$^2$. Real load of the structure (including dead-load) has a value of 7.3 kN/m$^2$. Both joint variants failed in the upper part of the reinforced concrete girder while loaded by maximal shear force (Fig. 5). The course of deformation depending on the time obtained from the strain gauge measurement with a vertical gauges for contact type 1 is drawn on Fig. 6.

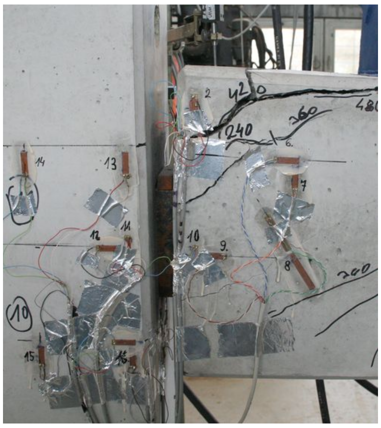

Fig. 5: Placement of strain gauges and the crack in the upper part of the girder.

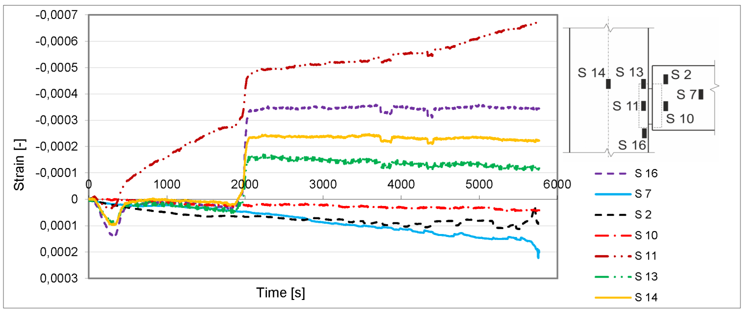


Fig. 6: Dependence of strain on time – vertical strain gauges.

Experimental verification of "column – column" joint has been conducted only in combination with "column – girder" joint type 2. The graphs in Fig. 7 show that the loading of the columns has a positive effect on reducing the in-plane deformation of the frame (LVDT sensor 1 and 2). The difference between the deformations is in the order of tenths of a millimeter. Conversely, the beneficial effects of axial load of split columns to deformation out-of-plane of the frame (LVDT sensor 7 and 8) cannot be unequivocally confirmed. It is obvious that when girder is loaded by torque, rotation occurs, as well as a parallel rotation of columns at their place of joint. But even with loading of columns there is no significant reduction in rotation of columns.

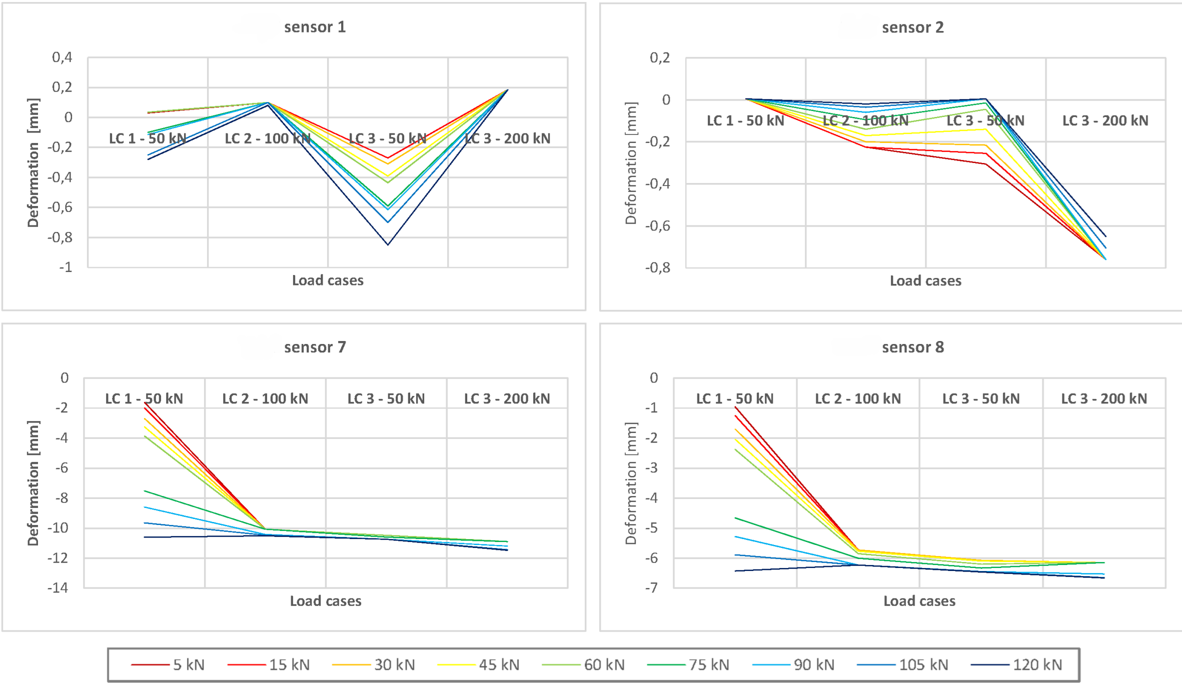


Fig. 7: Deformation curve for individual load cases and load steps.

# 4 Conclusion

Experimental analysis verified the load-bearing capacity of “column – girder” joints. The above mentioned values indicate that the joints are capable of transmitting the load which is approximately 2 times higher than the intended real load. Loading of columns with axial force has a positive effect on the in-plane deformations of the frame. Out-of-plane deformations of the frame due to the torque on the girder are not reduced with increased load of the columns.

# Acknowledgement

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