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Experimental Verification of the Demountable Structure Prototype

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Abstract. Demountable steel joints allow easy assembly and disassembly of precast reinforced concrete elements. Traditional prefabricated joints use grout mortar and steel reinforcement to achieve the required rigidity of the structure. Demountable structures are characterized by discrete joining of individual elements through contact, usually articulated, joints. This type of joints brings different demands for ensuring of the structures rigidity. This paper is focused on experimental verification of the demountable structure's prototype and its demountable steel joints. Both static and dynamic load tests were carried out on this prototype.

Introduction

The negative impact of reinforced concrete structures on the environment, a high amount of energy associated with their production and carbon dioxide released into the atmosphere can significantly eliminated by frequent use of demountable structures. Demountable structures consume only a fraction of energy during disassembly compared to the energy required for demolition. In addition, the individual elements of demountable structures can be reused. This method of construction is compared with conventional concrete structures very environmentally friendly and saves natural resources [1].

The goal of the project TA02010837 was research and development of a new multipurpose demountable prefabricated reinforced concrete building system with controlled joints' properties and possibility of repeated use. The demountable structure prototype was developed under this project.

Prototype of the Demountable Structure

The prototype was designed for experimental testing the feasibility of the system and verifying the functional properties of individual demountable joints.

The proposed arrangement of the load-bearing structure included characteristic parts of the column system, column system with embedded flexible diaphragms, pillar system and combination systems within the so-called integrated systems, the system of spatial units, basic types of precast reinforced concrete elements and characteristics bearing joints.

The prototype was designed as a two-storey building with a usable area 160 m^2. The realization itself was divided into two phases. The structure of ~~a~~ rectangular shape with plan dimension 12.75 x 6.25 m with the same structural height of both floors 3.3 m was conducted in the first phase. The experimental verification was carried out on this structure, after that the second realization phase followed.

The ceiling structure was formed hollow core prestressed ceiling panels Partek thickness of 200 mm. Ceiling panels were placed on the girders and walls via steel pins. These pins were screwed into the embedded steel anchor elements in the hollows of the panels during assembly. Anchor elements were inserted into the freshly cut ceiling panels and concreted by self-compacting concrete through the preformed hole in the upper face of the panel [2].

Experimental Verification

The aim of the experiment was to verify properties of the ceiling plate composed of prestressed ceiling panels. The structure was loaded with a horizontal force to verify critical issues related to spatial rigidity of the system with demountable joints.

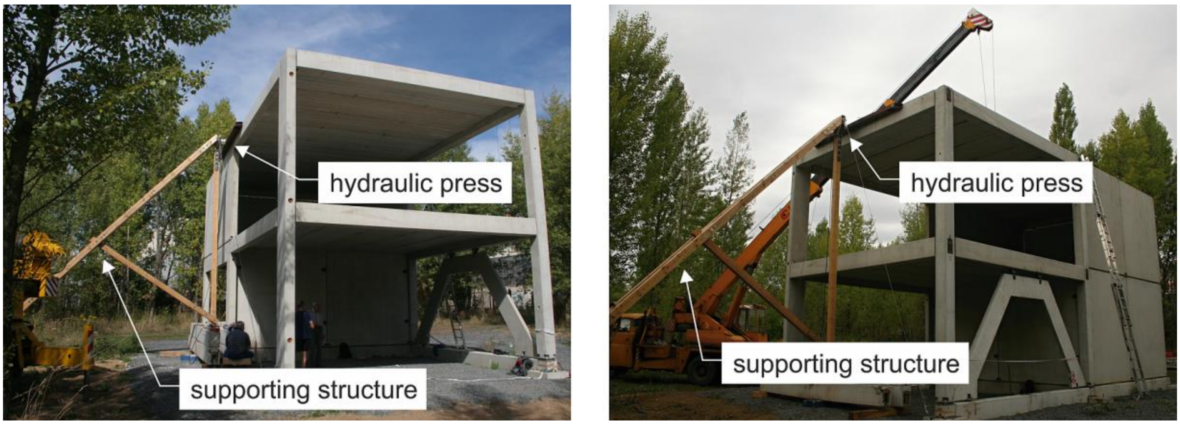

Fig. 1 Horizontal static loading in transverse (left) and longitudinal direction (right)

The static test examined the response of the experimental prototype (superstructure) on the horizontal load acting in the longitudinal and transverse directions. The loading was applied via hydraulic press at the level of second storey ceiling. Supporting wooden structure allowed imposing the hydraulic press at the required height. The static loading was applied by means hydraulic press, a hand pump with manometer and a valve. The loading with a horizontal force was applied into the structure by the hydraulic press in 9 kN steps. The maximum force reached the value of 54 kN.

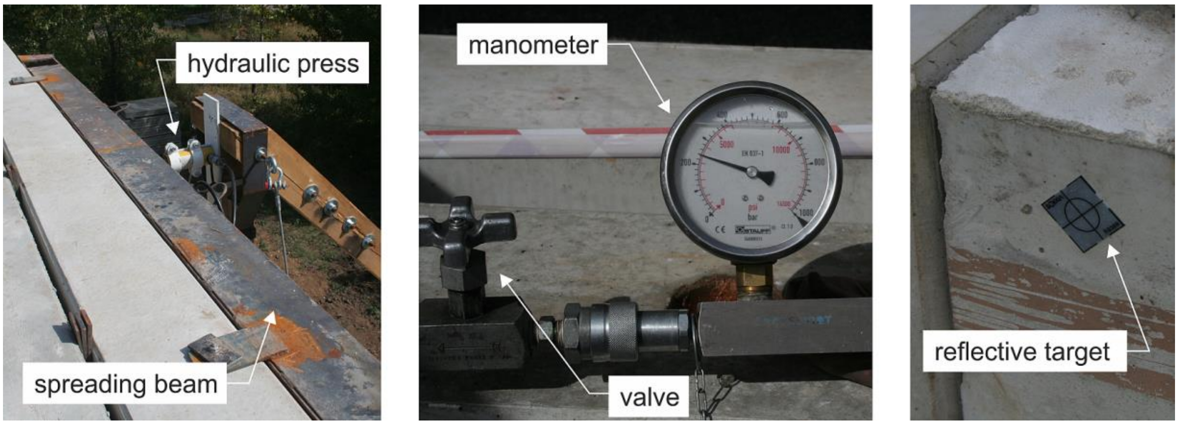

Fig. 2 Details of the test assembly

Geodetic measurements method was chosen for measuring deformations. This method (in contrast to the other methods of measuring deformation and strain) did not require complicated auxiliary structure for the installation and monitoring of measuring sensors. Deformation measurement were carried out by geodetic total station Nikon DTM 430. The mean error of changing position of the monitored point was less than 0.25 mm. Four points at the top edge of the object were chosen and fitted with reflective targets for monitoring horizontal displacement of the load-bearing structure.

Verification of the prototype structure to the effects of dynamic loading was carried out between individual loading cycles. This loading was induced by dynamic vibration generator positioned at the top center of the ceiling slab. Six accelerometers with high sensitivity was used to measure the response of the structure. Accelerometers Wilcoxon Research Model 731A with high sensitivity of 10 V / g were placed according to the scheme in Fig. 3.

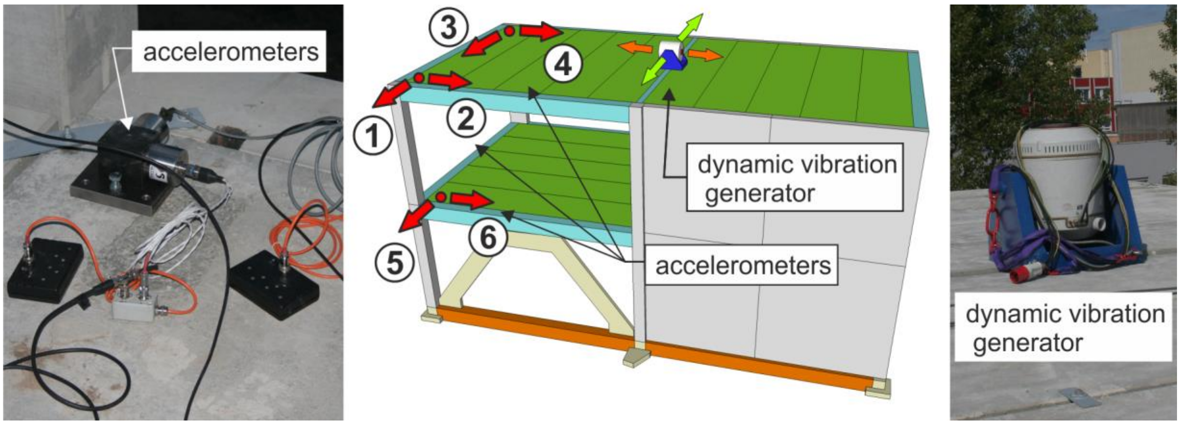

Fig. 3 Placement of accelerometers and dynamic vibration generator

Accelerometers measure the vibrations reliably from -10 ° C to + 65 ° C, and have an integrated low-pass filter, which can eliminate the high frequencies resulting from changes in acoustic pressure in the area. Accelerometers are connected to the sixteen-channel analog computer Dewetron DEWE 43 with a 24-bit AD converter and simultaneous sampling of 200 kS/s. Input voltage can be set for four ranges of ± 10V, ± 1V, ± 100 mV and ± 10mV. One accelerometer was placed on the movable part of the dynamic vibration generator and measured movement of the mass. The obtained data were evaluated by own procedures in MATLAB.

Measured Values

Resonant frequencies can be read from the spectral densities (Fig. 4) taken from the Fourier transform of the autocorrelation functions obtained from the structure excited by pulsed load –rubber hammer blow on the structure in the direction of the sensors. The hammer blow was conducted for the transverse and longitudinal direction.

The identification test was followed by the horizontal cyclic load (in longitudinal and transverse direction), that was applied between individual static load cases. The resonant frequencies of the concrete structure and the loading parameters are shown in Table 1, together with the number of counted oscillations during 1 oscillation hour.

Loading cycle	Direction of loading	Mobile mass [kg]	Oscillation frequency [Hz]	Number of oscillation	Dynamic force [kN]
1	Longitudinal	13.2	29.14	105 000	4.926
2	Longitudinal	13.2	29.14	110 000	4.873
3	Transverse	13.2	30.21	108 800	5.079
4	Transverse	13.2	30.21	109 100	5.143

Table 1 Resonant frequencies with the appropriate parameters for the structure excitation

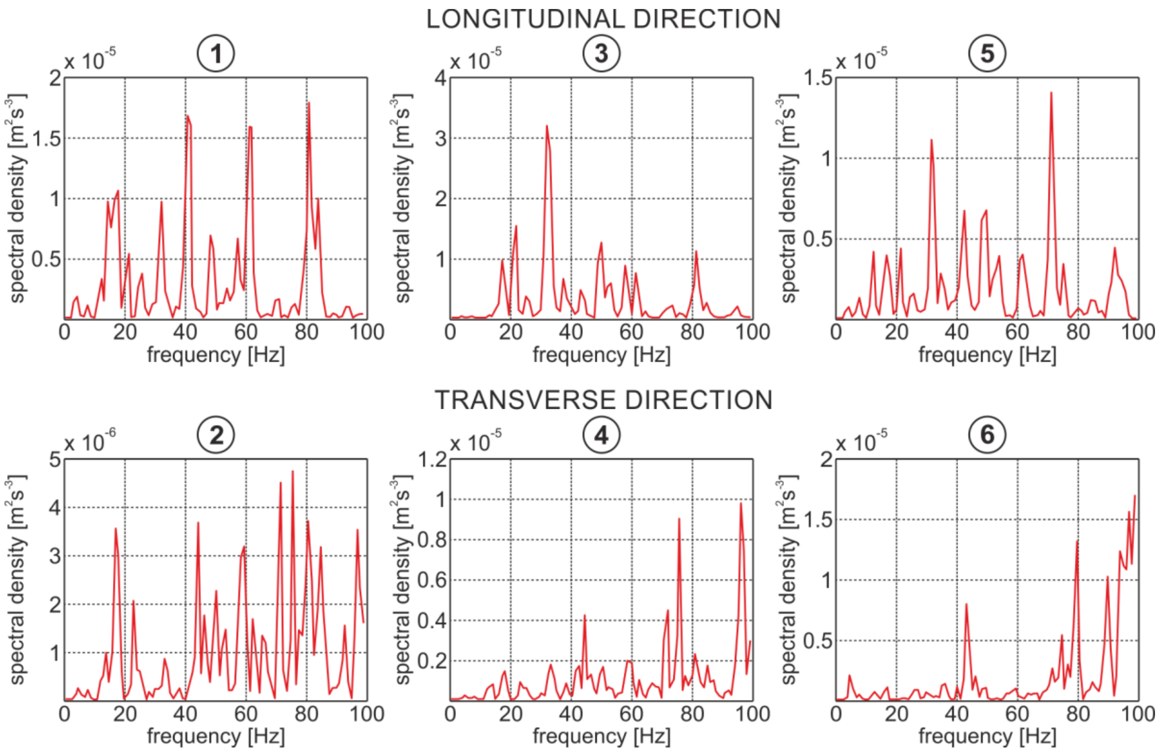

Fig. 4 Response spectrum identification of natural frequencies before the dynamic loads

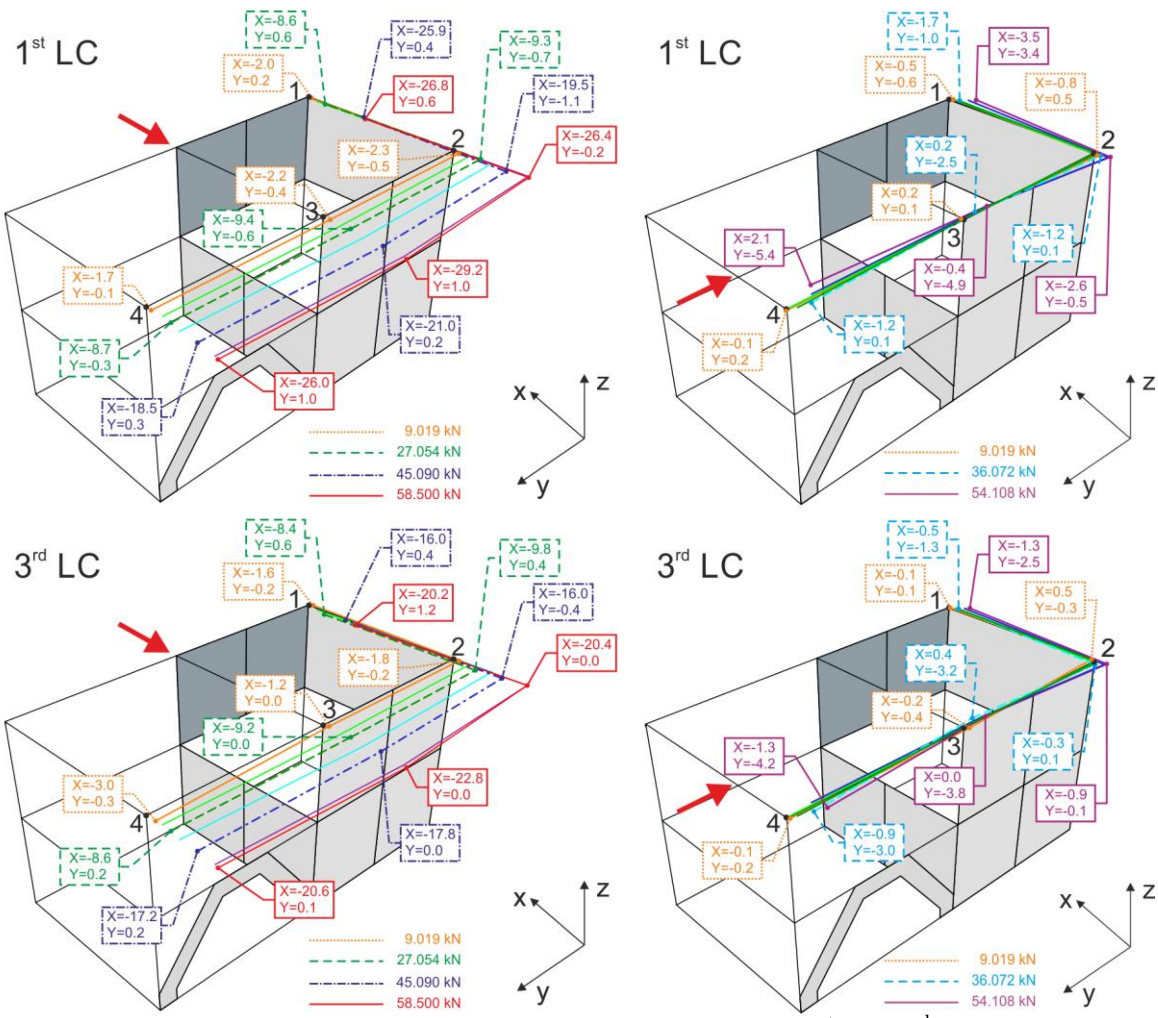

Fig. 5 Measured deformations for individual load steps (1st and 3rd load cycle)

Different values of deformation between the static load cases were caused by abutment of individual steel joints, dynamic load and tolerances of individual joints and prefabricated elements. Table 2 shows the resulting experimentally determined deformations' values of the ceiling slab. Percentage values are relative to the dimensions of the ceiling board in the second direction.

Direction of loading	Loading cycle	Deformation of flatness	
		[mm]	[%]
Transverse	1	2.7	0.020
Transverse	2	1.0	0.012
Transverse	3	1.3	0.011
Longitudinal	1	2.0	0.030
Longitudinal	2	1.5	0.025
Longitudinal	3	1.65	0.027

Table 2 Experimentally determined deformations of the ceiling slab

Conclusion

The analysis shows that experimentally determined deformations' values of the ceiling slab when the maximum horizontal force (acting in the longitudinal or transverse direction) reached 54 kN are in the range from 0.011 to 0.030%. Based on these percentage expressed deformations' values of ceiling slab can be stated that the prefabricated concrete slab with a discrete steel joints meets the requirements of a rigid horizontal beam and ensures spreading of the effects of the horizontal load on the individual vertical support elements in proportion to their stiffness.

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