Experimental Analysis of the Demountable System with Embedded Diaphragms

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Abstract: Demountable precast structures allow repeated use of reinforced concrete elements, and thus they significantly reduce the negative impact of concrete structures on the environment. The characteristic parts of the demountable column system are the "girder – column" joint and the "stiffening diaphragm – girder" joint. The dynamic characteristics of the whole structure can be significantly affected by mounting of the diaphragm on elastomeric bearings with required hardness. 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. This article deals with the experimental analysis of the section of frame structure with flexible embedded diaphragm by elastomeric bearings of different hardness or steel screw fasteners. The experimental research was carried out within TA02010837 "Multipurpose dismantleable prefabricated reinforced concrete building system with controlled joint properties and possibility of repeated use".

Keywords: Demountable; Experimental Analysis; Diaphragm; Bearings; Dynamic Characteristics.

1 Introduction

Current dynamically developing human society has got increasing requirements on flexibility in buildings. However traditional precast systems do not correspond to this dynamics and they are characterized by limited adaptability and relatively high labor intensity when changing use. Almost all reconfigurations of the current structures due to the change in use or transfer of the building caused by production, transportation or demographic requirements are associated with full or partial demolition, as the reuse of precast elements joined by wet processes is very limited. The solution is to use structures whose rigidity is ensured by joints, which can be if necessary removed easily, without reducing the possibility of further use of precast elements.

2 Column System with Demountable Joints

Demountable joint 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 [1].

Column – girder joint (Fig. 1 and Fig. 2) used at test assembly consists of a welded special steel element which allows quick installation based on the principle of a special locking joint. The girder is then mounted on this console using similarly shaped base plate. The disadvantage of this joint is higher intensity of labor, when the special steel element is produced, but no need to use bolts. This solution enables the connection of the required number of girders on the column. 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 flor panels in the outer fields or during assembly (asymmetric loads) [2].

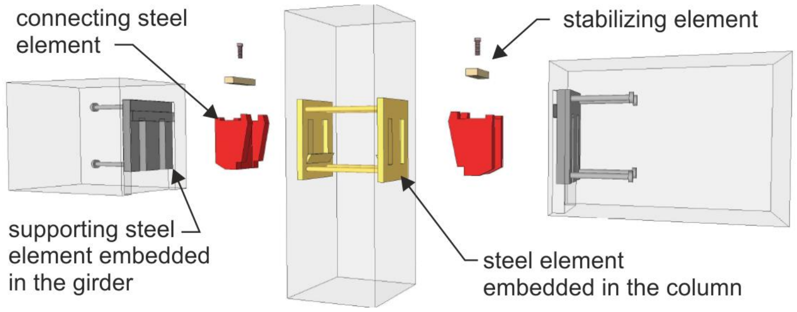

Fig. 1: Visualization of the column – girder joint.

Fig. 2: Embedded steel elements.

The connection of the diaphragm and the girder can be ensured in two basic ways. The first variant is a rigid connection using steel screw fasteners (Fig. 3). The second variant is a soft connection using elastomeric bearings of different hardness (Fig. 4) [3].

Fig. 3: Rigid connection with steel screw fasteners.

Fig. 4: Soft connection with elastomeric bearings.

3 Experimental Analysis

The aim of experimental analysis was to determine and compare the stiffness characteristic for each type of the connection between diaphragm and girders.

3.1 The Test Assembly

The test assembly of the section of frame structure consisted of two prefabricated columns (180 × 180 mm in cross-section and 2500 mm in height), two girders (180 × 240 mm in cross-section and 2860 mm in length) and embedded stiffening diaphragm (2800 mm in length, 1650 mm in height and 50 mm of thickness), which was connected with girders by elastic bearings of two different hardness (45 ShA and 85 ShA) or with steel screw fasteners. Elastic bearings are made of steel plates with welded screw fasteners, which are vulcanized in the elastomer.

The arrangement and dimensions of the test assembly are shown in Fig. 5. The materials of reinforced concrete elements are C50 / 60 and steel B500B. The steel connecting elements are made of steel S355J0.

3.2 The loading

The test assembly was loaded using a hydraulic press by forced deformations of 0.5 – 5 mm, and different frequencies in the range of 0.1 – 20 Hz. 14 linear deformation sensors (LVDT) were mounted on the test assembly. These sensors recorded total deformations of the frame (sensors 1, 2) and relative displacements between columns and girders (sensors 8, 12, 13, 14), columns and diaphragm (sensors 9, 10, 11) and girders and diaphragm (sensors 3, 4, 5, 6, 7). The test was controlled by deformation (amplitude) of hydraulic press and the force which caused the required amplitude was recorded.

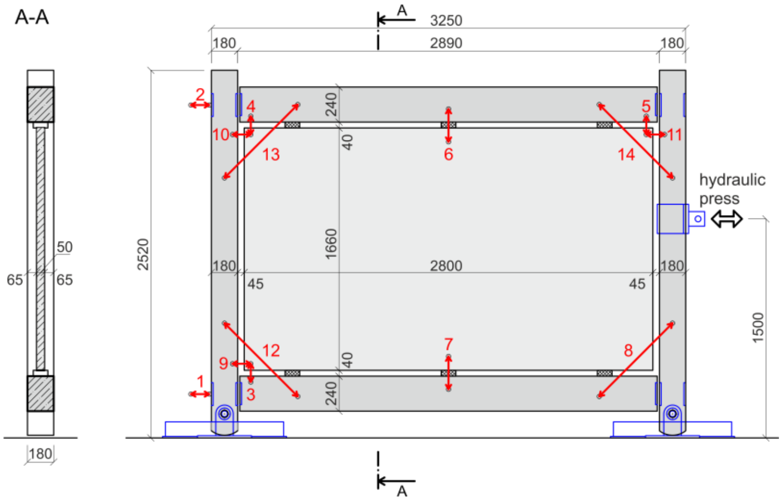

Fig. 5: The test assembly.

Fig. 6: LVDT sensors.

3.3 The Measured Values

The maximum value of the force in the hydraulic press (corresponding required amplitude and frequency) was recorded for each load case. The identified values are shown in Fig. 7.

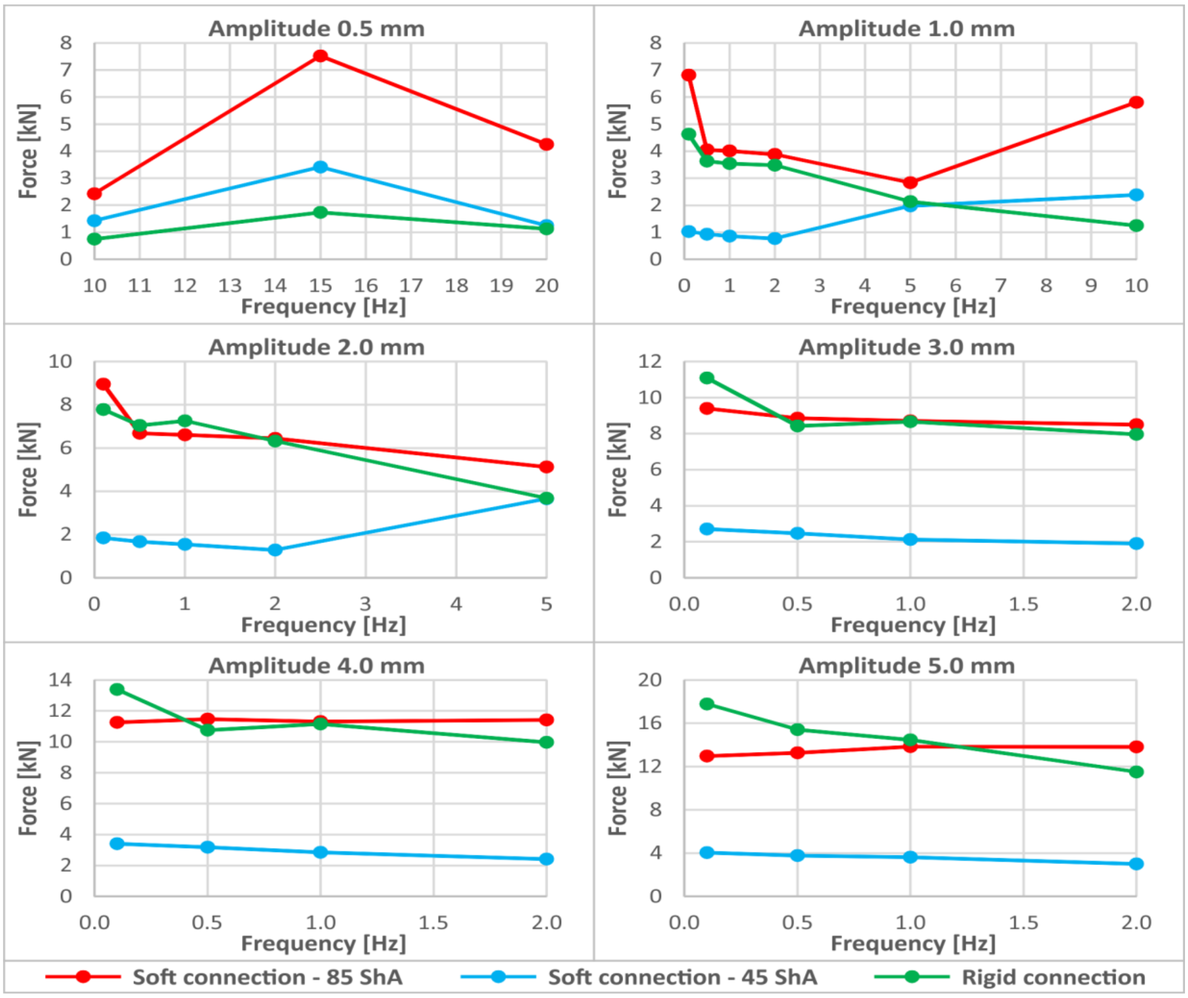

Fig. 7: Dependence of force in hydraulic press on frequency for required amplitudes

When comparing the individual types of the connection it is apparent that the values of the forces required for individual amplitudes are 3 times lower in the case of soft connection (bearings 45 ShA) than for the other two types. For small frequencies, downward strength is apparent depending on the frequency increas. This relationship is nearly linear to the value of the frequency 2.0 Hz, if the elastomeric bearings 45 ShA hardness are applied. When increasing the frequency to 5 Hz, which is a value close to the first natural frequency of this assembly, there is a significant increase in the required force. The highest values of forces are achieved with the rigid connection, wherein these forces are at low frequencies and amplitudes 4 and 5 mm in the range of 11 to 18 kN. The lowest forces were achieved with small amplitude (0.5 mm and 1.0 mm) for rigid connection and at amplitudes of 2.0 to 5.0 mm for bearings 45 ShA. The force values at different amplitudes and frequency of 5 Hz for all connections are roughly comparable.

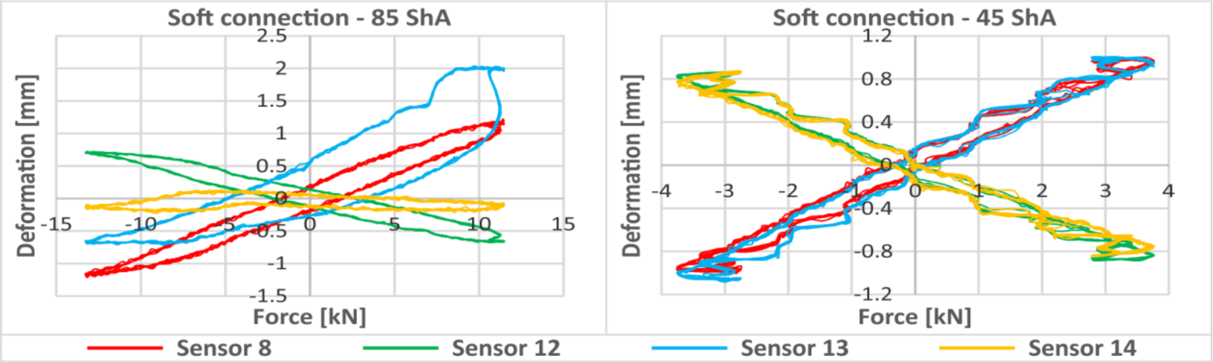

Fig. 8: The comparison of the shapes of the hysteresis curves (frequency 0.5 Hz, amplitude 5 mm)

The comparison of the shapes of the hysteresis curves for soft connection is shown on the graphs in the Fig. 8. The shapes of hysteresis loops recorded from opposite sensors are almost identical for connecting bearings with a hardness of 45 ShA. In the case of bearings with a hardness of 85 ShA, the shapes of hysteresis loops are different. This was caused by the lifting of girders due to a large stiffness of the bearing.

4 Conclusion

Selection of the hardness of the elastomeric bearing significantly affects the stiffness of the whole system. Use of bearings with high hardness can be much closer to the rigid connection of the diaphragm and girders. This can be used for damping vibrations caused by natural or technical seismicity.

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References

[1] J. Witzany, T. Čejka, R. Zigler, Dismantleable Joints of Load-bearing Reinforced Concrete Units of Prefabricated Concrete Building System with Controlled Stiffness, in proc.: Research and Applications in Structural Engineering, Mechanics and Computation (2013), ed. CRC Press/Balkema, University of Cape Town, Cape Town, 1503–1506.

[2] A. Polák, Experimental Verification of Demountable Precast Column System, in proc.: Applied Methods of Static and Dynamic Loads of Structures and Machines II (2016), ed. P. Padevět, Trans Tech Publications Ltd, Český Krumlov, 259–262.

[3] J. Witzany et al., Demountable Precast Reinforced Concrete Building System of Multi-Story Buildings, in proc.: Implementing Innovative Ideas in Structural Engineering and Project Management (2015), ed. Fargo: ISEC Press, Sydney, 219–224.