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Eccentricity Influence on Bearing Capacity of Subtle Column Using Numerical Analysis and Experimental Verification

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Abstract: Paper presents influence of eccentricity on bearing capacity of subtle column based on high performance composites. Columns from high performance concrete (HPC) were loaded using numerical simulations with different eccentricity of load. Atena Engineering finite element software for nonlinear analysis of structures were used for numerical simulations. Paper presents results from numerical modeling together with results from experimental verification. This tested column is part of new optimized subtle precast construction system, which is designed for construction of buildings in passive or zero-energy standard. Advantages of this system are material and also energy savings during production, transport, manipulation and construction on building site.

Keywords: Subtle Column; Eccentricity; High Performance Concrete; Numerical Analysis; Experimental Verification.

1 Introduction

Subtle precast columns, beams and floor panels as a complete building system were developed above all for energy efficient building constructions [1]. It takes advantages of HPC as a popular and modern solution in modern architecture [2]. Resulting cross section of column has a C shape and it has been designed wit respect to mechanical, technological, thermal and environmental properties. This shape can be more easily integrated into the building envelope with minimization of thermal bridges because of its small dimensions. Second group of three prototypes of column was realized in cooperation with ZPSV a.s. company [3]. Asymmetric crossectional area around one axis in combination with small dimensions and used material have a significant influence on the stability of element in compression. In this study was created numerical model for compression test of column and eccentricity of load in both axis has been changed. The required data for numerical simulations were used from previous sub-experiments. Datas from numerical model were finally experimentally verificated on bearing capacity of the column.

2 Materials and Dimensions of Column

First group of prototypes of columns were produced from high performance fiber reinforced concrete class FC 70/85 with cross section of 180/250 mm. This mixture was optimized at ZPSV a.s. company. Concrete cover were designed only around 10 mm. Elements were reinforced by 4 ØR25 longitudinal reinforcement and ØR10 ā 150 mm stirrups at the ends of elements. The shape of column is exactly presented in Fig. 1.

Basic parameters of concrete used in numerical model are: compressive strength 80.9 MPa on cubes with edge length 150 mm and 57.8 MPa on cubes with edge length 100 mm according to CSN EN 12390-3 standard, tensile strength in bending 7.7 MPa on prisms 100 × 100 × 400 mm according to CSN 731318 standard, static modulus of elasticity 44.8 GPa on prisms 100 × 100 × 400 mm according to CSN ISO 6784 standard. Direct tensile test of concrete was not performed. Numerical model with using of these measured values was calibrated according to test of fracture energy. This measurement was performed on prisms 100 × 100 × 400 mm according to CSN EN 14651 + A1 standard.

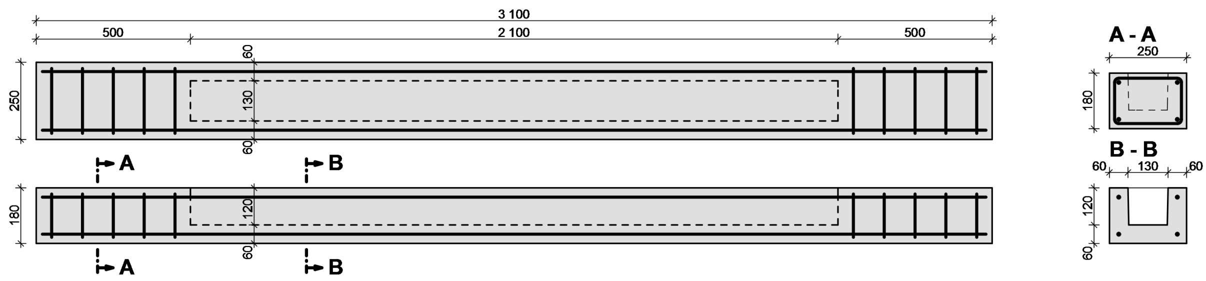

Fig. 1: Picture of the shape of three column prototypes.

3 Numerical Modeling and Experimental Verification

In Fig. 2 and 3 are presented views at the both ends of elements. Small eccentricity of load for experimental verification was applied always only in the top part of column. Eccentricity of load was smaller than 20 mm in both directions because of subsequent initiation of higher side forces. Steel frame around of column with other testing equipment could be damaged from these forces. Fig. 2 also shown, that all parts were fixed on the steel frame because of safety of experiment.

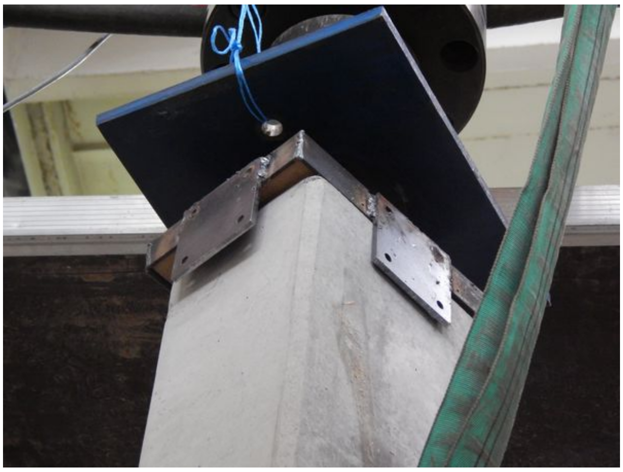

Fig. 2: Top part of column where the eccentricity of load were applied.

Fig. 3: Bottom part of column without the eccentricity of load.

One numerical model with different values of eccentricity of load for both directions and their combination was developed using finite element software for nonlinear analysis Atena Engineerig 3D [4]. The problem was modeled without using of symmetry. Concrete part was modeled using instrument Macro-elements and reinforcement using instrument Bar reinforcement. As a material for concrete was used 3D non-linear cementitious with automatically generated parameters, but these parameters were subsequently modified according to measured and calculated values. As mentioned in chapter about materials, test of fracture energy was used for calibration of model. In Fig. 4 and 5 are presented results from measurement of three prototypes. As seen in the graphs below maximum possible force exerted by the hydraulic press was 1000 kN.

In Fig. 6 and 7 are presented results of numerical modeling. The influence of eccentricity on load bearing capacity is shown for both directions separately. Eccentricity of applied force was changed from the middle of column to the edges. Results logically show more dangerous the y axis in the direction of smaller dimension without symmetry. Decrement of maximum force before damage and also first cracks initiation is very fast.

Results of numerical model comparing to experimental verification are presented in Fig. 8 for the column number 1. They are very interesting. Imperfections of load applied in the top part of column were measured before testing, but because of results also just after measurement. From the middle of column before measurement it was 10 mm in the x direction and 5 mm in the y direction, after measurement it was 60 mm in the x direction and again 5 mm in the y direction. For numerical model were used imperfections 60 and 5 mm. Results from modeling and experimental verification in the y direction are almost same. Results in the x direction are different, because imperfection of load was changed during measurement in the x direction. It is the

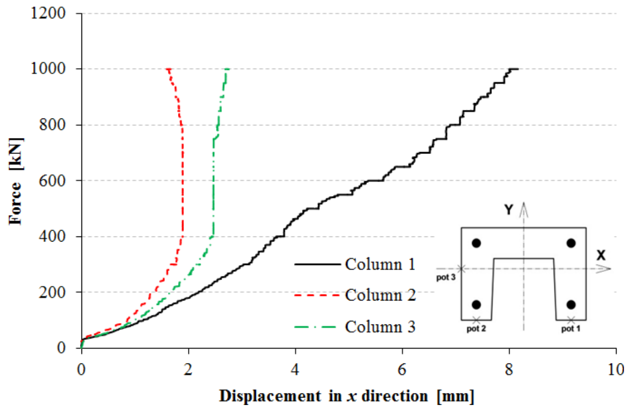

Fig. 4: Force-displacement curve from measurement in the middle of columns, the x direction.

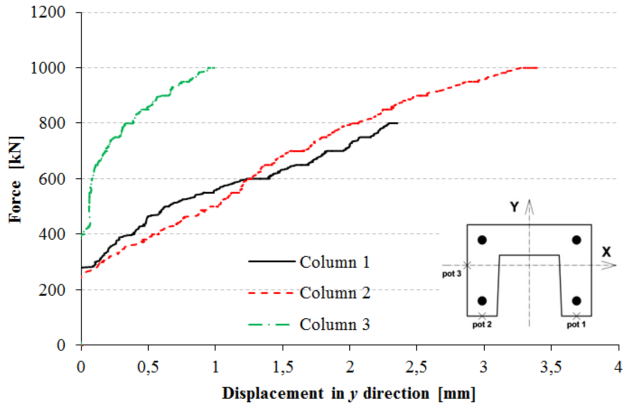

Fig. 5: Force-displacement curve from measurement in the middle of columns, the y direction.

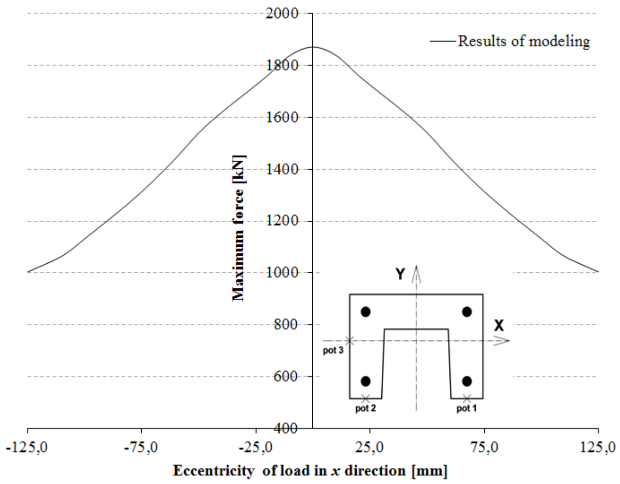

Fig. 6: Force-displacement curve of maximum force before damage from modeling in the middle of columns, the x direction.

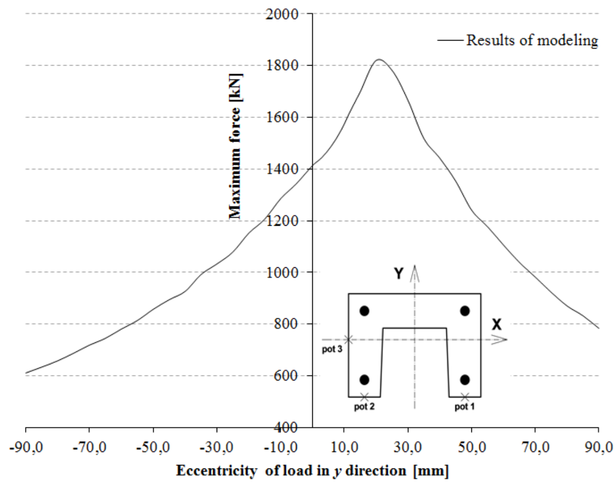

Fig. 7: Force-displacement curve of maximum force before damage from modeling in the middle of columns, the y direction.

reason of suddenly jumps on the curve in Fig. 8. In the last Fig. 9 is presented picture with view on all three potentiometers used for experimental verification.

4 Conclusion

Results of the measurement show a significant influence of eccentricity on deformations in the middle of columns and also on bearing capacity. Load eccentricity was measured just before each testing. It is seen the negative influence of higher load eccentricity in Fig. 2, column 1, and conversely the positive influence of lower load eccentricity in Fig. 3, column 3. Results from numerical modeling shows maximum load bearing capacities with different eccentricities of load and lower bearing capacity in the y direction. Experimental verification shows rightness of numerical modeling and also complication with moving of one tested column. But in summary, tested prototypes are sure useful for new optimized subtle precast construction system.

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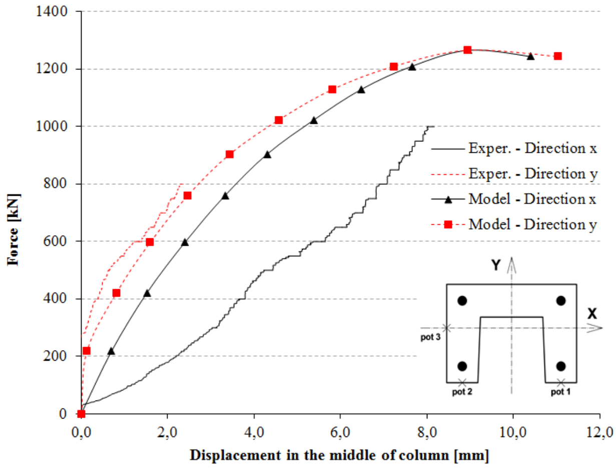

Fig. 8: Force-displacement curve from modeling and experimental verification of column 2 for both directions.

Fig. 9: Three potentiometers installed in the middle of tested columns.

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