Experimentální Analýza Napětí
2004

EXPERIMENTAL INVESTIGATION OF CONFINEMENT IN RC COLUMNS
EXPERIMENTÁLNÍ VYŠETŘOVÁNÍ VLIVU PŘÍČNÉ VÝZTUŽE V ŽELEZOBETONOVÝCH SLOUPECH

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This paper deals with an experimental investigation of the effect of transversal reinforcement in reinforced concrete columns on their ductility. Normal and high strength columns are studied with different stirrups density. Special attention is paid to the character of a failure, ductility and post-peak behavior of columns.

Tento článek pojednává o experimentálním vyšetřování vlivu příčné výztuže v železobetonových sloupech na jejich duktilitu. Jsou studovány sloupy z betonu normální a vysoké pevnosti s různou hustotou třmínků. Zvláštní pozornost je věnována charakteru porušení, duktilitě a povrcholovému chování sloupů.

Keywords *reinforced concrete columns, concrete, ductility, post-peak behavior.*

Klíčová slova *železobetonové sloupy, beton, duktilita, povrcholové chování.*

Introduction

The ductility is a crucial part of the design of reinforced concrete structure subjected to some exceptional loading like earthquake. At this type of loading the overloaded regions are usually supposed to be in plastic state. This is true for bended elements like beams and girders but different situation is in columns. Columns are typically compressed elements loaded by high axial force with small eccentricity. The ductility of these elements is reduced and the post-peak behavior exhibits softening. This concerns both high and normal strength concretes. Since columns are common structural elements it is necessary to pay an attention to the post-peak behavior of such columns, because reduction of ductility can lead to the significant reduction of the overall load bearing capacity of the structure. The problem of the ductility is further complicated by the dependence on the amount of confinement, i.e. the amount of transversal reinforcement. The better understanding of concrete behavior in reinforced concrete structures such columns is needed and precise and verified models are required.

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Methods

We decided to study the problem on eccentrically loaded reinforced concrete columns. It is a typical RC structure used multiple times in the structure. Combination of compression with small eccentricity produces relatively complicated triaxial stress state in the concrete that is longitudinally and transversally reinforced. Typical geometry with square cross section was chosen for all tested columns. The columns were reinforced with the same amount of longitudinal reinforcement and varied in the amount of lateral reinforcement (stirrups). Three different distances of stirrups were used. Two concrete grades (normal and high strength) were tested. Thus, the total number of studied cases was 6. The geometry of the column is shown in Fig. 1. The problem was studied also numerically. Details can be found in [4], [5].

Experiments

Two grades of concrete: normal 30 MPa (N series) and high strength 70 MPa (H series) were selected. Common geometry for all columns was used. The longitudinal distance between stirrups at the middle part of columns varied: 50, 100 and 150 mm. The dimension of specimens and their reinforcement is depicted in Fig. 1.

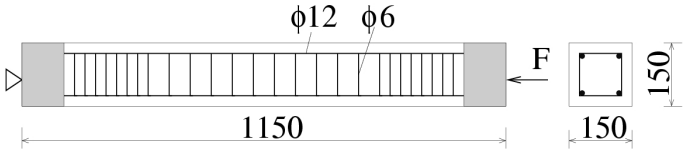

Fig. 1 Geometry of specimens in mm (drawn in horizontal position).

Each series consisted of five identical specimens. The columns were loaded in uniaxial eccentric compression. The eccentricity of compressive load was 15 mm in all cases. Measured and observed experimental parameters were: overall axial force, midheight lateral deflection, strains measured over the whole length of column, strains measured at the ends of column, type and character of a failure.

Behavior of all series was very similar. Almost all specimens failed around the midheight. As an example, all specimens of normal strength series after the collapse can be seen in Fig. 2. Their collapse was initiated by the concrete softening at the midheight, accompanied by the symmetric buckling of both reinforcing bars at the compressed side of the cross section. Bars always buckled between stirrups, as can be seen in Fig. 2. Failure localized at the middle part of the column where a wedge-shaped pattern developed. The yield plateau in the force-deflection was very small and the load-bearing capacity decreased from the peak value. Loading diagrams plotted for overall axial force versus midheight lateral deflection are shown in Fig. 3 for all series. Results show no significant influence of stirrups density on the peak values, i.e. strength and strain. However, in the post-peak region, this dependence occurs. The ductility characterized by the slope of force-deflection diagram increases as the distance between stirrups decreases.

Fig. 2 Experiments: Series N10 after collapse (left). Front view on the damaged zone at the midheight of the column (right).

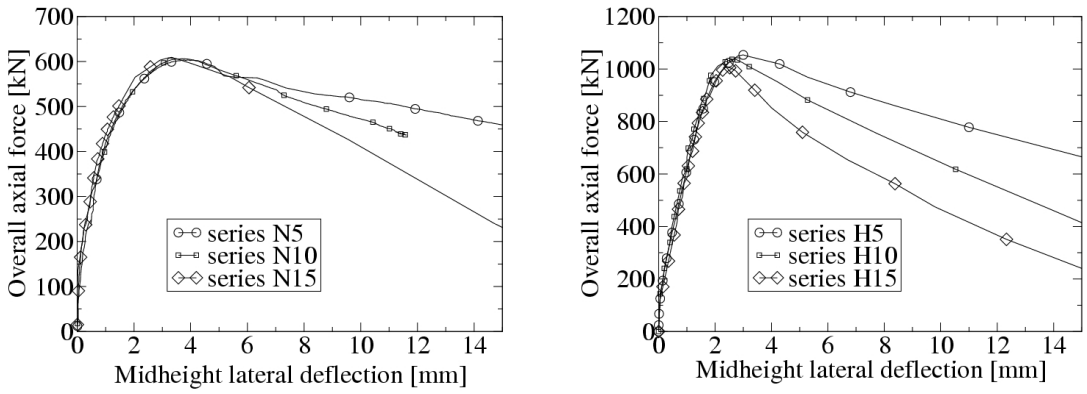

Fig. 3 Experiments: Force vs. midheight lateral deflection diagrams of N (left) and H (right) series. Numbers 5, 10 and 15 stand for distance of stirrups in cm.

Conclusions

Behavior of six series of reinforced concrete columns was investigated. Two different grades of concrete (normal and high strength) and three different stirrups density were studied. Columns were loaded in eccentric compression with small eccentricity. Major experimental results are as follows:

- Compression failure (crushing) accompanied by concrete softening and steel buckling developed in columns.
- Failure of columns localized into the middle part, where a wedge-shape failure pattern developed in concrete together with buckling of reinforcement between stirrups.
- The influence of stirrups density on the column strength was negligible in the investigated cases (i.e. square cross section, stirrups density 50-150 mm).
- Significant influence of stirrups density was observed in the post-peak region.

- Post-peak is characterized by the lack of yield plateau and the slope of the descending branch depends on the density of stirrups.
- Ductility of columns increases as the distance between stirrups is smaller. This was observed for both normal and high strength concrete.

Acknowledgements

Support of the Grant Agency of the Czech Republic (contract No. 103/02/1273) and Ministry of Education MSM 210000003 are gratefully acknowledged.

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