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SERVICEABILITY OF REINFORCED CONCRETE COLUMNS STRENGTHENED BY REINFORCED CONCRETE JACKETING

Introduction

Jacketing is a traditional method of reinforced concrete (RC) structures strengthening. This method is universal, since it is appropriate for enhancing various structural elements. There are various design solutions for jacketing considering different materials and techniques. Traditional options include reinforced concrete jacketing [1-3] and steel jacketing [4]. New methods include high performance fiber reinforced concrete (HPFRC) jacketing [5] and fiber reinforced polymer (FRP) jacketing [6, 7].

Each strengthening method can enhance structures` performance, however, it is important to keep in mind all advantages and disadvantages of every particular method and material. For example, an important advantage of steel jacketing is that the size of the strengthened structure increases insignificantly while its strength increases considerably [4]. However, exposed steel elements of steel jacketing have low fire resistance and require corrosion protection (especially in case of possible chemical corrosion).

HPFRC jacketing has no problems regarding fire or corrosion protection. The strengthening effect of HPFRC jacketing can be equal to RC jacketing but with considerably less jacketing thickness [5]. However, the cost of HPFRC is very high. Also the effectiveness of HPFRC jacketing is greatly reduced by the action of high bending moments.

FRP composites are very effective for bending members strengthening and not so much with the compressed ones [6, 7]. They also have very low fire resistance and are very expensive.

RC jacketing works equally well for compressive and flexure and does not require additional fire or corrosion protection. Also there is much experimental and theoretical research in RC jacketing, but there is very little that considers strengthening after initial loading. Therefore, the subject still needs some research.

1. Experimental program

For this study twelve RC columns were designed and tested. Column's length equaled 2200 mm including cantilever sections on both ends. Cross-section between the cantilevers had dimensions of 180 mm by 140 mm. The cantilevers were made to apply eccentric load to columns. Four 12 mm rebars were used as longitudinal reinforcement and 6 mm wire was used for ties with 50÷200 mm spacing. Columns were cast from C25/30 concrete according to [8]. Overall view of a column is presented in Figure 1.

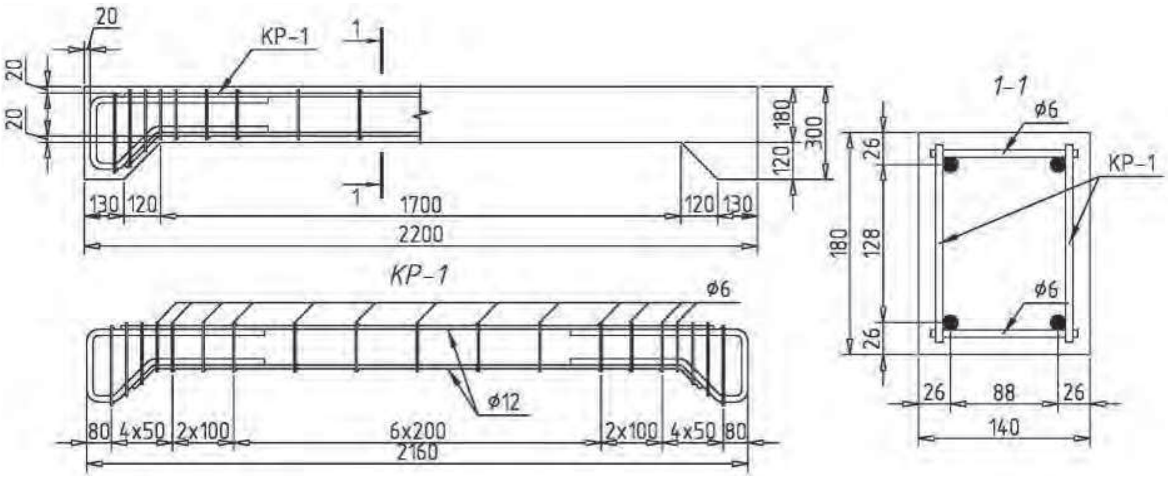

Fig. 1. Column dimensions and reinforcement drawings

The columns were tested according to the following program:

- 2 columns (C-01 and C-02) tested to failure without strengthening to experimentally determine their ultimate strength N_u;
- 2 columns (CS-03-0.0 and CS-04-0.0) strengthened without previous loading then tested to failure;
- 8 columns (CS-05-0.3 and CS-06-0.3; CS-07-0.5 and CS-08-0.5; CS-09-0.7 and CS-10-0.7; CS-11-0.9 and CS-12-0.9) loaded to $0.3N_u$, $0.5N_u$, $0.7N_u$, $0.9N_u$, then strengthened and tested to failure;

Strengthening process began after the columns were loaded to a planned level according to the test program. The columns were kept under loading during strengthening process. New reinforcement was placed around the column and C25/30 concrete was cast. No interface preparation methods were used to increase bonding between the jacketing concrete and the columns. Cross-section dimensions of a column after jacketing became 260 mm by 200 mm. The length of RC jacketing equaled 1700 mm. Four 10 mm rebars were used as longitudinal reinforcement and 6 mm wire was used for ties with 200 mm spacing. Drawings of test specimens after strengthening are presented in Figure 2.

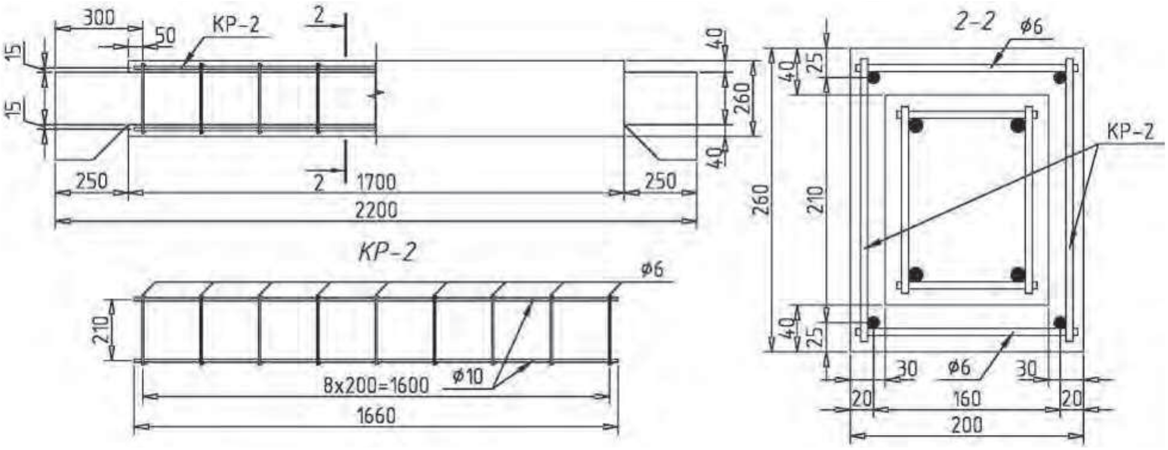

Fig. 2. Strengthened column dimensions and reinforcement drawings

All specimens of columns were tested by compressed loading. Loading was applied with eccentricity that equaled 150 mm and incrementally. Fixation of the column's deflection along its length was taken from the gauges after each increment. In total, there were 5 gauges installed on the column during the test.

2. Results of the research

Based on data acquired during the tests "load vs midspan's deflection" graphs for all tested columns were plotted (Fig. 3). Figure 3 shows that all columns except CS-03-0.0 and CS-04-0.0 display identical behavior in terms of deflection increase until strengthening. Stiffness increase of all strengthened columns is observed in comparison with C-01 and C-02.

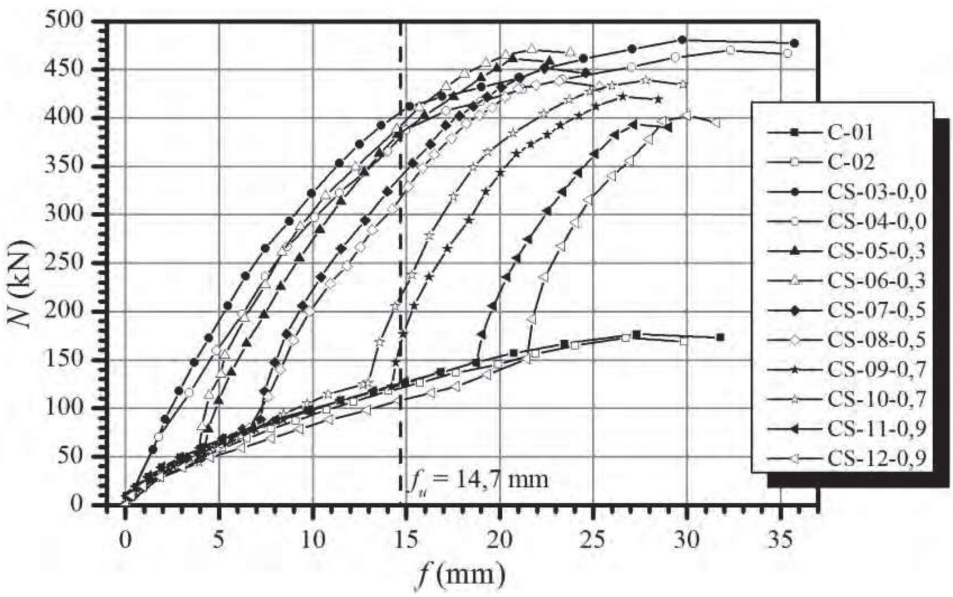

Fig. 3. Load vs midheight deflection graphs for tested columns

Experimental deflections of tested columns were compared with ultimate value according to Ukrainian codes [9]. Ultimate deflection f_u that determines serviceability failure equals $l/150 = 2200/150 = 14.7$ mm, where l is the span of the specimen. Since our columns were compressed on both ends, their span equals their actual length. Knowing the ultimate deflection f_u, serviceability failure load N_f was determined for every column (Tab. 1).

TABLE 1

Columns serviceability test results

Column	Serviceability failure loading N_f [kN]		Strengthening effect
	specimen	average value	
C-01	124.23	122.68	–
C-02	121.12		
CS-03-0.0	405.47	393.13	220.5%
CS-04-0.0	380.78		
CS-05-0.3	384.53	388.22	216.5%
CS-06-0.3	391.91		
CS-07-0.5	339.19	328.57	167.8%
CS-08-0.5	317.95		
CS-09-0.7	166.71	191.24	55.9%
CS-10-0.7	215.76		
CS-11-0.9	126.04	117.16	–
CS-12-0.9	108.27		

Maximum strengthening effect was achieved by columns CS-03-0.0 and CS-04-0.0. Their average serviceability failure load increased by 220.5% in comparison with C-01 and C-02. With the increase of initial loading before strengthening the effect was decreasing.

Columns CS-11-0.9 and CS-12-0.9 showed no strengthening effect since the serviceability failure load was already exceeded at the moment of strengthening. Nevertheless, strengthening at $0.9N_u$ level was successful in terms of stiffness and bearing capacity increase.

Columns CS-09-0.7 and CS-10-0.7 were on the verge of serviceability failure at the moment of strengthening. Nevertheless, they obtained 55.9% increase of N_f after strengthening.

Columns CS-05-0.3 and CS-06-0.3 showed similar results to CS-03-0.0 and CS-04-0.0. Their average serviceability failure load increased by 216.5%, which shows us that strengthening of completely unloaded or majorly unloaded columns has the best effect.

Conclusions

RC jacketing proved to be very effective in terms of column serviceability improvement and allowed us to obtain up to 220% increase of serviceability failure load. Strengthening effect decreased with the increasing of an existing loading level during strengthening. This should be taken into account in the design of strengthened structures.

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Abstract

In this article serviceability of reinforced concrete columns, strengthened by reinforced concrete jacketing was investigated. Performance of reinforced concrete columns strengthened after initial loading was studied. Different loading levels before strengthening were considered.

Keywords: jacketing, reinforced concrete columns, serviceability

Odkształcalność słupów żelbetowych, wzmocnionych przez obetonowanie

Streszczenie

W artykule zaprezentowano wyniki badań doświadczalnych dotyczących trwałości słupów żelbetowych przed i po wzmocnieniu z zastosowaniem obejm żelbetowych. Badano wzmocnienia słupów, wstępnie obciążonych do różnych poziomów wyczerpania nośności.

Słowa kluczowe: wzmacnianie, słupy żelbetowe, trwałość