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STRENGTH OF PREVIOUSLY DESTROYED REINFORCED CONCRETE BEAMS RESTORED BY IMPREGNATION METHODS

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Abstract. This paper presents the design of prototypes, methods of testing and analysis of the strength of concrete beams reinforced with rebar connections. To determine the characteristics of strength, deformation and fracture of experimental beams were tested to complete re-fracture. It is shown that it is possible to restore the strength of reinforced concrete beam by 77–90% by treatment with modern injection materials and technologies.

Key words: injection technologies, damaged reinforced concrete beams, bearing capacity restore

PROBLEM ANALYSIS AND PROBLEM STATEMENT

Loss of operational characteristics of the reinforced concrete structures caused by their ageing, faults in operation, technologic errors in the producing and so on, state problem to engineers of partial and full restoration of these structures during their operation [Report on the subject... 2006, Luchko and Parneta 2006, Luchko et al. 2006, Nazarevych et al. 2010].

In the papers Czarnecki [2002], Luchko et al. [2010, 2012], Gajda and Pentsak [2012] the possibility of solving the above mentioned problem is examined, i.e. restoration bearing capacity of previously stressed and usual reinforced concrete structures with the help of impregnation technology of injection materials based on polyurethane.

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For this purpose methodology and program of experimental research of reinforced concrete beams, reinforced rebar connections using crimp bushings for small cyclic fatigue were planned. The design and technology of the samples, the application of experimental studies of beams' elements were described Luchko et al. [2010]. The results of studies of the beams operation on the small cyclic fatigue are shown in Luchko et al. [2012].

At later stage completely and partially damaged reinforced concrete beams of rectangular section were restored with modern injection technologies. Design and technology of industrial prototype restoration are described in Gajda and Pentsak [2012].

The test beams were mounted on temporary supports. In the upper beam zone metallic casing was fixed, using sealing epoxy glue SP RESIN 220 and fixing vertical and horizontal clamps (Fig. 1). To the packer on the top of the casing it is attached the hose of mechanical pump brand Desoi type HP 30-LD (Fig. 1). In the neck of the pump poured the prepared injectable material polyurethane resin KÖSTER KB-PUR IN III. Submission of injecting material into the casing was fulfilled gradually, pump pressure jumps to 0.2 MPa. Injection continues until the injectable material does not appear in the control top hole and then the hole was screwed by special screw. Pump injection material continues on the need for an hour to maintain the pressure at the level of 0.2–0.4 MPa. Then the pump hose was disconnected and the beam was leaved during two days. In two days metallic casing was demounted and beam became ready for further testing.

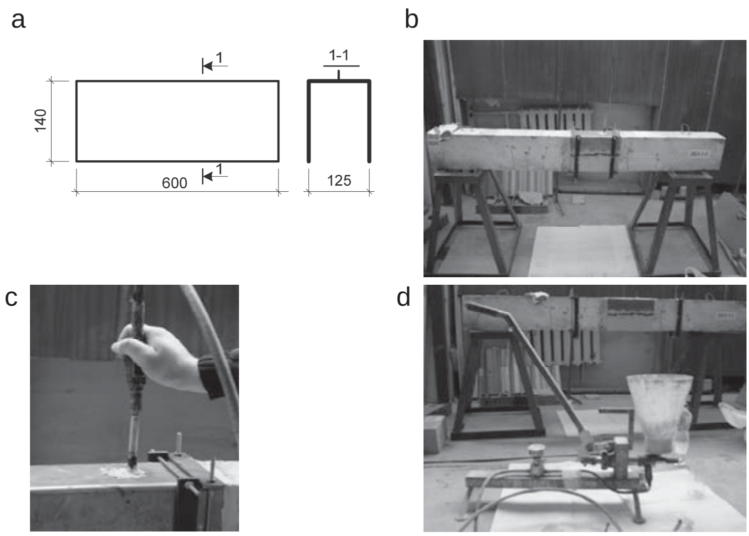

Fig. 1. The beam with fixed metallic casing: a – metallic casing, b – general view of the beam with casing in the upper area of the beam , c – packer on the top of the casing, d – general view of the mechanical pump brand Desoi type HP 30-LD

The purpose of this study is to investigate the degree of restoration of destroyed and partially destroyed beams, set the possibility of increasing bearing capacity of new constructions, and use of injection technologies and techniques to restore the strength of existing full-scale objects.

RESEARCH METHODOLOGY OF EXPERIMENTAL BEAMS

To determine the characteristics of strength, deformation and fracture of experimental beams they were tested for bending to complete re-fracture.

Loading of beams was going on by two concentrated forces applied to the upper edge in the third span. Application of concentrated forces took place by using a hydraulic jack of 200 kN and distributive cross-arms. Beam deflection was measured by three indicators clock type with a scale division 0.01 mm.

This method of measuring deflections simplifies information processing, since the deformation of bearings do not affect indicators and studies have shown that the error made in measuring is no more than 1%.

Stand for testing prototypes of the beams on bending by static load is shown in Figure 2.

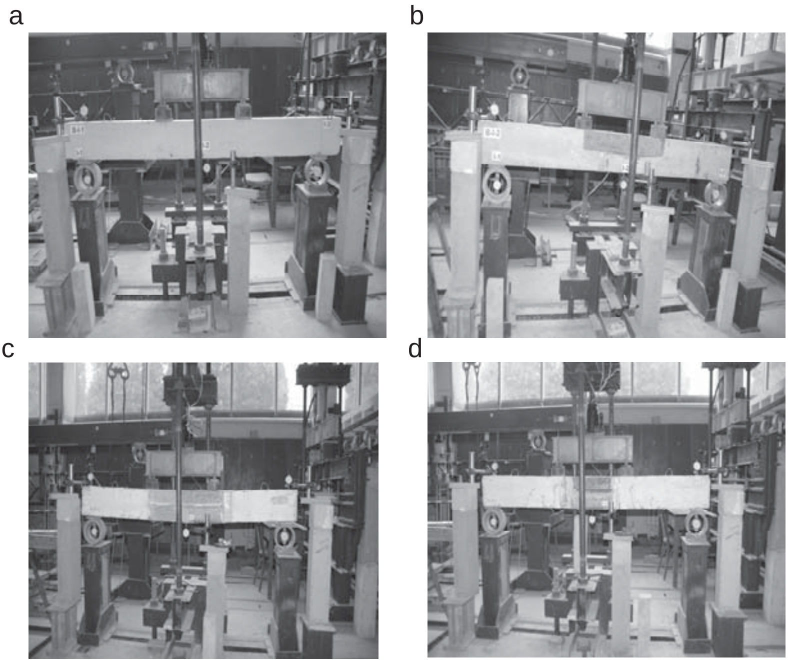

Fig. 2. General view of the stand with the test specimens beams: a – without pretreatment, b – impregnated only the upper zone beam, c – impregnated and gluing the upper and lower zones of beams, d – impregnated and gluing the upper and lower zones of the beams is not the entire length of the zone of pure bending beam

RESEARCH OF THE REINFORCED CONCRETE BEAMS ON THE STRENGTH IN BENDING

For the determination of the deflected mode of structures the test of beams bending to fracture was carried out. Comparing the strength of cross-sections of beams in destroying experimental and theoretical point is given in Table 1 ($M_1^{\exp}$ – tested destructive moment restored (impregnated) beams; $M_2^{\exp}$– tested destructive point of reference samples beams [Luchko et al. 2012]; M_3^{theor} – theoretical destroying beam moment calculated by DBN B.2.6-98:2009, Ukraine).

Following a series of beams were investigated: not impregnated – 0БЗ-1-0, 0БЗ-1-1;impregnated – 0БЗ-1-2, 0БЗ-1-3-1-1БЗ 1 1БЗ-13-2-1-1БЗ 3 1БН-13-1 1БН-13-2 1БН-13-3 1БН-13-4-13-1БН 5 1БН-13-6-1-2БЗ 1 2БЗ-13-2-1-2БЗ 3 2БН-13-1-13-2БН 2-2БН 13-3, 2БН-13-4-13-2БН 5 2БН-13-6.

Table 1. Destructive moments tested beams

No	Beam code	M_1^{exp} [kN·m]	M_2^{exp} [kN·m]	M_3^{theor} [kN·m]	$\frac{M_2^{exp}}{M_3^{theor}}$	$\frac{M_1^{exp}}{M_2^{theor}}$
Concrete C12/15. New beams without pre-stressing						
1	0БЗ-1-0		10,73	9,4566		0,94
2	0БЗ-1-1		11,23	9,4566		0,99
Concrete C12/15. New beams without pre-stressing with impregnation of upper zone						
3	0БЗ-1-2	10,10		9,3100		1,06
4	0БЗ-1-3	11,10		9,6254		1,01
Concrete C12/15. Previously destroyed beams without pre-stressing						
5	1БЗ-1-1	10,11	11,52	11,05	1,04	0,88
6	1БЗ-1_3-2	9,62	11,47	11,56	0,99	0,84
7	1БЗ-1-3	10,12	11,67	11,81	0,99	0,87
Concrete C12/15. Pre-stressed beams, previously destroyed						
8	1БН-1_3-1	9,42	11,28	11,28	1,00	0,84
9	1БН-1_3-2	9,32	11,53	11,77	0,98	0,81
10	1БН-1_3-3	9,97	11,43	11,88	0,96	0,87
11	1БН-1_3-4	9,94	11,37	11,72	0,97	0,87
12	1БН-1_3-5	8,77	11,32	11,45	0,99	0,77
13	1БН-1_3-6	9,42	11,11	11,37	0,98	0,85
Concrete C20/25. Previously destroyed beams without pre-stressing						
14	2БЗ-1-1	10,87	12,87	13,01	0,99	0,84
15	2БЗ-1_3-2	11,23	13,01	13,06	1,00	0,86
16	2БЗ-1-3	10,23	12,35	12,77	0,97	0,83
Concrete C20/25. Pre-stressed beams, previously destroyed						
17	2БН-1_3-1	10,21	12,72	12,67	1,00	0,80
18	2БН-1_3-2	11,11	12,91	12,73	1,01	0,86
19	2БН-1_3-3	11,00	12,73	12,97	0,98	0,86
Concrete C20/25. Pre-stressed beams, previously destroyed with partial impregnation zone of pure bending						
20	2БН-1_3-4	11,21	12,52	13,01	0,96	0,90
21	2БН-1_3-5	10,97	12,68	13,29	0,95	0,87
22	2БН-1_3-6	11,21	12,62	13,14	0,96	0,89

Explanations: M_1^{exp} – researched destroying moment restored (impregnated) beams; M_2^{exp} – researched destroying moment of reference samples beams in Luchko et al. [2012]; M_3^{theor} – theoretical destroying beam moment calculated by DBN B.2.6-98:2009 (Ukraine).

The first series of beams is shown in Table 1 (pp. 1–4) – not destroyed, with concrete class C12/15 without pre-stressing with impregnated upper zone. Normal strength sections of impregnated beams (0БЗ-1-0, 0БЗ-1-2) and not impregnated (0ВЗ-1-3 0ВЗ-1-4) in this experiment was close. Depth of impregnation of the concrete body in the upper zone of concrete beams was within 1–5 mm. Significant increase in bearing capacity impregnated beams has occurred, the deviation between the values of normal strength sections kept in the range of 1–2%, which is likely due to inaccuracies of the experiment – heterogeneity of concrete in different beams, the error in indices of devices during the experiment, etc. (Fig. 2a).

The second series of beams is shown in Table 1 (pp. 5–7) – pre-destroyed concrete class C12/15 without tension with impregnated upper zone beam. Depth treatment of the body concrete in the upper zone of concrete beams is within 1–5 mm. Partly cracks were filled in the middle zone of the beams. The strength of normal cross section of the beam (1БЗ-1-1, 1БЗ-13-2, 1БЗ-1-3) after treatment was 89–94% of their initial strength of normal cross section defined in Luchko et al. [2012] (Fig. 2b).

The third series of beams is shown in Table 1 (pp. 8–13) – pre-destroyed concrete class C12/15 of pre-stressing with impregnated upper and lower zone of the beam (Fig. 2c). Depth treatment of the body concrete in the upper zone of concrete beams is within 1–5 mm. The lower and upper zones of the beams occurred filling and bonding existing cracks and defects. As a result of treatment there was a significant restoration of carrying capacity impregnated beams. The strength of normal cross section of the beam (1БН-13-1-1БН-13-6) after treatment was 86-90% of their initial strength of normal cross section defined in Luchko et al. [2012].

The fourth series of beams is shown in Table 1 (pp. 14–16) – pre-destroyed concrete class C20/25 without pre-stressing with impregnated upper and lower zones of the beam (Fig. 2c). Depth treatment of the body concrete in the upper zone of concrete beams is within 1–4 mm. The lower and upper zones of the beams occurred filling and bonding existing cracks and defects. As a result of treatment there was a significant restoration of carrying capacity of impregnated samples. The strength of normal cross section of the beam (2БЗ-1-1-1БЗ-1-3) after treatment was 85–86% of their initial strength of normal cross section defined in Luchko et al. [2012].

The fifth series of beams is shown in Table 1 (pp. 17–19) – pre-destroyed concrete class C20/25 of pre-stressing with impregnated upper and lower zones of the beam (Fig. 2c). Depth treatment of the body concrete in the upper zone of concrete beams is within 1–4 mm. The lower and upper zones of the beams occurred filling and bonding existing cracks and defects. As a result of treatment there was a significant restoration of carrying capacity of impregnated samples. The strength of normal cross section of the beam (2БН-1з-1-1БН-1з-3) after treatment was 82–85% of their initial strength of normal cross section defined in Luchko et al. [2012].

The sixth series of beams is shown in Table 1 (pp. 20–22) – pre-destroyed concrete class C20/25 of pre-stressing with impregnated upper and lower zones of the beam between the applied forces on half plot of pure bending beams in places of destruction concrete upper zone (Fig. 2d). Depth treatment of the body concrete in the upper zone of concrete beams is within 1–5 mm. The lower and upper zones of the beams occurred filling and bonding existing cracks and defects. As a result of treatment there was a significant restoration of carrying capacity of impregnated samples. The strength of normal cross section of the beam (2БН-1з-4-1БН-1з-6) after treatment was 85–88% of their initial strength of normal cross section defined in Luchko et al. [2012]. And the destruction of the upper zone beam held in places where there was no treatment (Fig. 3). The nature of re-fracture zone of the upper beams of the sixth series shown in Figure 3.

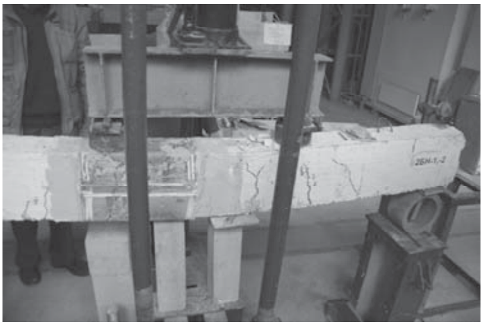

Fig. 3. The nature of re-fracture zone of the upper beams of the sixth series

Thus, on the basis of the tests and analysis of research results can be noted that it is possible to restore the strength of reinforced concrete beam constructions to 80–90% by impregnating with modern injection materials and technologies. Depth treatment of the body of concrete beams ranged 2–5 mm. The lower and upper zones of the beams occurred filling and bonding existing cracks and defects. Fracture pattern beams samples is similar to previous episodes of destructions described in Luchko et al. [2012]. Existing cracks in the load re-disclosed at load levels for fatigue-free beams is at 0.3–0.35 $M_1^{\exp}$, and for pre-stressed beams is 0.5–0.6 $M_1^{\exp}$.

Analysis of the opening of main cracks in the zone of pure bending beams showed that tops of cracks not filled with an injection solution are at 2–10 mm. This is obviously connected with the presence of the top of crack compressed air and water that can't go out and resist the promotion of injection solution. This related to general theory of impregnating and filtration concrete and reinforced concrete structures [Luchko et al. 1999].

Normal strength sections impregnated experimental beams in these experiments was higher than the theoretical, calculated at the current SBN on 10–20% due to higher actual concrete strength.

In the experiments for testing impregnated and non-impregnated beams not exposed preload, was shown no significant increase in the strength of beams by impregnating the upper zone beam with given injection material was observed.

CONCLUSIONS

On the basis of the tests and analysis of research results can be noted that it is possible to restore the strength of reinforced concrete beam constructions to 80–90% by impregnating with modern injection materials and technologies. It is shown that new beams without cracks and demerits, impregnated in upper zone show no significant increase in the strength comparing to non-impregnated beams

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WYTRZYMAŁOŚĆ WCZEŚNIEJ ZNISZCZONYCH BELEK ŻELBETOWYCH WZMOCNIONYCH METODĄ IMPREGNACJI

Streszczenie. W artykule omówiono konstrukcje oraz metody badań żelbetowych belek wzmocnionych metodą iniekcji żywic epoksydowych. Belki badano na zginanie do wtórnego całkowitego zniszczenia. Udowodniono, że głębokość wnikania (penetracji) w beton żywicy epoksydowej wynosiła około 2–5 mm. Na podstawie przeprowadzonych badań stwierdzono wzrost wytrzymałości o 77–90% poprzednio zniszczonych i ponownie naprawionych medodą iniekcji żywic epoksydowych żelbetowych belek.

Słowa kluczowe: technologia wtrysku, uszkodzone żelbetowe belki, zdolność do restauracji

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