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Research into glue materials for repairing the cross-section of RC beams

Zinoviy Blikharskyy[1] (*orcid id: 0000-0002-4823-6405*)
[1] Czestochowa University of Technology

Abstract: In this article, the results of glue material regarding concrete connections between existent and new concrete bonds are presented. The basic experimental studies into selecting the optimal bonding layer involved testing 100 × 100 × 100 mm concrete cubes. These cubes modeled so-called "old" concrete constructions. Because most of the currently used reinforced concrete structures that require reinforcement or restoration were made decades ago, most of them do not contain chemical additives and multi-fractional concrete, so the concrete composition was adopted in the proper way, namely ordinary heavy concrete in 1970-1980. As a result of the experimental testing of concrete specimen restoration by means of a clamp arrangement, it is established that the maximum compatible work of "old" and "new" concretes is ensured by the use of bonding layers of specially modified mineral materials and the use of concretes using superplasticizers and a selection of their fractional composition.

Keywords: concrete bond, reinforced concrete, fractional composition

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Introduction

Due to the long operational lifespan of buildings and structures, often in difficult conditions, there is often a need for their reconstruction. It is usually associated with the need for reinforced concrete structures. The peculiarity of such work is that when reinforcing, it is necessary to perform the extension of the concrete section or reinforcement of the structure. Ensuring high-quality adhesion of existing concrete to concrete reinforcement is an important technical task that needs to be addressed. Coupling also affects the physical and mechanical characteristics of the reinforcement elements. Therefore, studies into ensuring the compatibility of elements of reinforcement ("new" concrete) and reinforced construction ("old" concrete) are relevant and of practical importance.

Many scientists have been engaged in research in the field of reinforcement of concrete structures (Byung-Wan et al., 2008; Erki & Rizkalla, 1993; Grace et al., 1999; Jung et al., 2002). The most common methods of building cross-sections of reinforced concrete structures are the arrangement of reinforced concrete clips, shirts, etc. An analysis of the performed research shows that a small number of them relate to the study of providing adhesion of concrete with the help of modern materials: organic, inorganic, mineral, synthetic, etc. (Golestaneh et al., 2010). The need for reinforcement or restoration of building structures also often arises as a result of premature corrosion of materials.

1. Aim of the work

The purpose of this work is to model the reinforcement of reinforced concrete beams by arranging the clamp with the use of specially prepared, available, bonding mixtures. For this purpose, experimental and analytical studies of connecting mixtures are envisaged, the results of which will formulate the basic principles of the development method of reinforcement in reinforced concrete beams. Such studies are necessary because the cross-section of the "old" concrete structure with the "new" concrete of the reinforcement sleeve is very important when reinforcing the section.

2. Experiment results

It should be noted that the improvement of the joint work of "old" and "new" concrete is influenced by the composition of the "new" concrete, namely its property as minimal shrinkage deformation during curing (Lin & Fangtian, 1997; Rai et al., 2012). It is clear that the greater the shrinkage deformation occurring in the reinforcement concrete, the greater the internal stresses occurring at the contact zone of the two concretes, which must be additionally perceived at the connecting layer. That is why, in the beginning, the composition of the concrete composition was made and should be used in experimental studies of the bonding layer. For this purpose, several formulations of concrete were prepared with the obligatory use of different types of superplasticizers and the selection of the fractional composition of large and small aggregates in the concrete mixture. For the study of concrete for shrinkage during hardening, concrete prisms with dimensions 100 × 100 × 400 mm with metal balls concreted at the ends were used. For a reliable connection with the concrete, the balls were made with anchors in the form of soft wire. This design made it possible to measure the longitudinal deformations of the prisms by means of a special installation, taking into account the distance between the outer faces of the beads (Fig. 1).

To determine the most effective composition of concrete after 28 days after the formation of the samples, the following two main indicators of concrete quality were determined:
– maximum concrete compression strength;
– minimum shrinkage deformation during curing.

Fig. 1. General view of samples of the experimental concrete prisms (*own study*)

According to the results of the research, the following reinforcement concrete composition (composition # 2) was selected: C: P: W = 1: 1.14: 2.62 at the water-cement ratio B/C = 0.35. M400 cement from the Mykolaiv cement plant, quartz sand from the Yasniy Quarry without impurities with modulus of size Ms = 1.4, crushed stone - granite from the Selischan Quarry of Rivne region of different fractions 0-2 mm - 15%, 2-5 mm - 35%, 5-10 mm - 50%. In concrete is a Sika ViskoCrete - 3 superplasticizer (150 mm cone sediment). The average cubic strength at the time of testing was 49.5 MPa.

This composition showed the highest cubic strength of all and, with the other concretes using super-plasticizers (ADDIMENT FM 34, Woermann FM 21), the insignificant amount of deformation of concrete shrinkage. Therefore, it was decided to use this composition in further studies as a model of concrete reinforcement of reinforced concrete structure through the arrangement of the clamp.

The basic experimental studies to select the optimal bonding layer involved testing 100 × 100 × 100 mm concrete cubes. These cubes modeled the so-called “old” concrete construction. Because most of the currently used reinforced concrete structures that require reinforcement or restoration were manufactured decades ago, most of them were without the use of chemical additives and multi-fractional concrete, and therefore the concrete composition was adopted as appropriate, namely ordinary heavy concrete in 1970-1980 (composition # 1): C: P: N = 1: 1.51: 2.97 at the water-cement ratio B/C = 0.46. M400 cement from the Nikolaev cement plant. Sand used: quartz from the Yasenetsky quarry of the Lviv region without impurities with modulus of size Mc = 1.4, crushed stone granite fractions 5-10 mm. The cubic strength of concrete was 34 MPa.

In order to create a damaged surface, the concrete cubes were first immersed in an aggressive environment (a 10% sulfuric acid solution was used). When the edge of the cubes was reduced from the size of 100 to 62-67 mm, access to the aggressive environment was stopped, the surface of the cubes was cleaned with a sandblasting device (Fig. 2).

a) b)

Fig. 2. General view of the experimental cubes damaged by the aggressive environment: a) immediately after exposure to an aggressive environment; b) after cleaning with a sandblasting device (*own study*)

Concrete # 2 was used to restore the cubes to their previous sizes (see above). The following materials are most commonly used as a bonding layer in construction:
– epoxy resins (one-component or multi-component);
– mineral compounds (cement);
– synthetic chemical compounds (rubber, latex, etc.).

Therefore, in these experimental studies, the following four different materials were used as a bonding layer:
– epoxy resin;
– silol - latex;

also on the basis of mineral compounds, according to which in our opinion the future (due to their closeness in their mineral nature to the chemical composition of concrete) the following two materials:
– Dietermann Cerinol ZH;
– Sika Monotop 610.

The damaged cubes were covered with a bonding layer and restored by cross-sectioning of the "new" concrete in metallic forms. Three concurrent cubes of the same type of restoration were concreted.

On day 28, the recovered cubes were tested on a hydraulic press for compression to fracture. The highest cubic strength of the recovered specimens and, accordingly, the highest strength of the bonding contact layer during the tests were shown by the samples with the Sika Monotop 610 bonding layer - 45.4 MPa (see Table 1).

Table 1. The strength of recovered concrete cubes (*own study*)

No	The connecting layer	The average value of cube strength $f_{cm,cube}$	
		[MPa]	R/R_{max} [%]
1	Epoxy resin	37.0	81.5
2	Silol - latex	39.1	86.2
3	Dietermann Cerinol ZH	43.8	96.5
4	Sika Monotop 610	45.4	100

The analysis of the destruction of the compressed cubes showed reliable joint work between the “old” (composition # 1) and “new” (composition # 2) concretes and only with the destruction of the cube did the contact layer break down. Experimental specimens using binders of epoxy resin and silo latex during the compression test showed stratification of existing “old” concrete and “new” concrete reinforcement (Fig. 3) and as a consequence of their lower compressive strength compared to the mineral ones, connecting layers, namely with epoxy resin by a maximum of 18.5%, silo latex - by 13.8% less, respectively.

a) b)

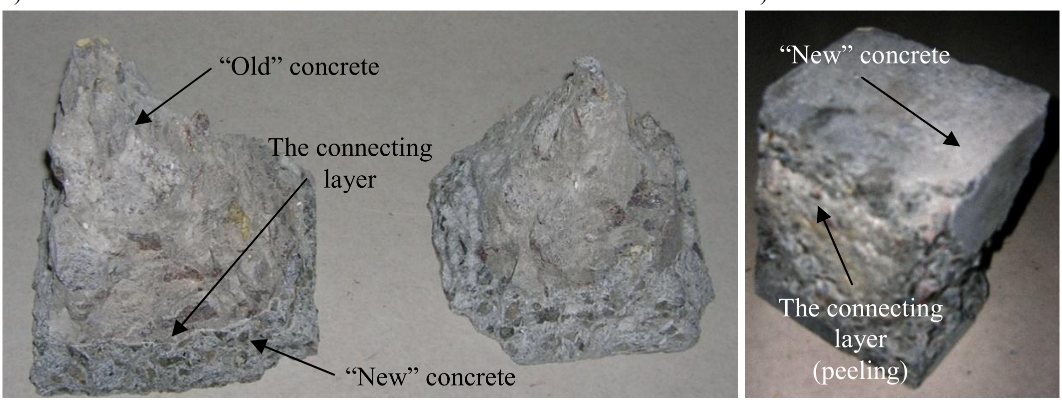

Fig. 3. General view of the sample cubes after the compression test: a) without detachment of the “old” and “new” concretes (Sika Monotop 610), b) with detachment of the “old” and “new” concretes (epoxy resin) (*own study*)

On the basis of the described experimental tests, the basic principles for the method of reinforcement of reinforced concrete beams have been developed, which are planned in further studies. The principles are intended to be used to reinforce reinforced concrete beams with a modern concrete composition with Sika ViskoCrete-3 superplasticizer to reduce shrinkage and a mineral-based Sika Monotop 610 bonding layer for the “old” and “new” concrete to work together.

Conclusions

As a result of the experimental testing of concrete specimen restoration by means of a clamp arrangement, it is established that the maximum compatible work of “old” and “new” concretes is ensured by the use of bonding layers of specially modified mineral materials and the use of concretes using superplasticizers and the selection of their fractional composition. On the basis of the conducted research the basics of the method of reinforcement of reinforced concrete beams by increasing their cross-section were developed.

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Badania mieszanek łączących w celu wzmocnienia przekroju belek żelbetowych

Streszczenie: Przedstawiono wyniki badań dotyczące połączeń kleju betonowego między istniejącym a nowym spoiwem betonowym. Podstawowe badania eksperymentalne mające na celu wybranie optymalnej warstwy wiążącej obejmowały testowanie kostek betonowych 100 × 100 × 100 mm. Na kostkach tych zamodelowana została tak zwana „stara” konstrukcja betonowa. Ponieważ większość obecnie stosowanych konstrukcji żelbetowych, które wymagają zbrojenia lub renowacji, została wykonana kilkadziesiąt lat temu, większość z nich nie zawierała dodatków chemicznych i wielofrakcyjnego betonu, a więc skład betonu został przyjęty w odpowiedni sposób, a mianowicie jako zwykły ciężki beton z lat 1970-1980. W wyniku przeprowadzonych badań odtworzonych próbek betonu za pomocą układu zaciskowego ustalono, że maksymalne kompatybilne działanie „starych” i „nowych” betonów jest zapewnione przez zastosowanie warstw wiążących ze specjalnych modyfikowanych materiałów mineralnych oraz wykorzystanie betonów z superplastyfikatorami i dobór ich odpowiedniego składu frakcyjnego.

Słowa kluczowe: wiązanie betonu, żelbet, skład frakcyjny