МОСТИ ТА ТУНЕЛІ: ТЕОРІЯ, ДОСЛІДЖЕННЯ, ПРАКТИКА

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LABORATORY STUDIES OF PRESTRESS LOSS WHEN REINFORCING REINFORCED CONCRETE BEAMS WITH COMPOSITE MATERIALS

Purpose. The article analyzes a scientific experiment to study the loss of prestressing when reinforcing reinforced concrete bending elements with composite materials. **Methodology**. To achieve this goal, the authors carried out experimental work in the scientific laboratory “Bridges” SibNII of STU, using the developed amplification technology. The object of study is three reinforced concrete twin beams with a prestressing degree of the composite material of 12 kN. Losses were measured over a period of 180 hours, from the beginning of the prestressing moment for each beam separately. **Findings.** After analyzing the laboratory experiment, three characteristic zones were identified with a decrease in the prestress value: “Primary zone”, “Moderate zone” and “Relaxation zone”, in which the magnitude of the prestress of the composite material changes within different limits. **Originality.** The average value of the loss of prestress of bending reinforced concrete elements during the strengthening of laboratory samples is found. **Practical significance.** Analysis of the loss of the prestress value is an important factor in the further study of the calculation methodology and improvement of the technology for reinforcing reinforced concrete structures with composite materials.

Keywords: prestressed polymer composite materials; bridges; strengthening; reinforced concrete beam; hydraulic jack; improving and restoring the bearing capacity; span structures

Introduction

The use of polymer composite materials (FRP) when reinforcing bridges makes it possible to carry out repair work with a material that actually has a low weight, which means that it reduces the labor intensity and cost of work, while increasing the convenience of work. Due to the structure of polymer composites (fabric), it is possible to carry out reinforcement and repair work without interrupting the operation of the bridge.

The high impact-resistant characteristics of polymer composites make it possible to compensate for the absence of a protective layer, which reduces the cost of maintaining the bridge. There is a possibility of using FRP in contact with water or with high humidity, since, for example, FRP based on carbon fibers have high corrosion resistance. This makes this material one of the best for bridge maintenance and repair (Michels, 2013; Harmanci, 2016; Harmanci, 2018a; Harmanci, 2018b).

A FRP casing impregnated with a special adhesive has a high chemical resistance, which prevents the removal of the joints responsible for strength from concrete, and also prevents the accumulation of salts in concrete, leading to degradation and a rapid decrease in the strength of concrete.

At the same time, an increasing time load, concrete degradation, corrosion of reinforcement and damage to structural elements often lead to the need to strengthen reinforced concrete bridge spans. Over the past years in Russia, polymer composite materials are increasingly used to strengthen bridge structures, deep scientific developments have been carried out, and technologies for strengthening polymer composite materials are being introduced into practice. To increase the efficiency of FRP reinforcement, the technology of restoring the bearing capacity of spans with preliminary stressing of composite materials can be used (Sena-Crus, 2015; Бокарев, 2016; Казарян, 2018; Марочка, & Бобошко, 2018; Плевков, 2017).

Purpose

Analysis, taking into account the losses in time of the prestressing force when reinforcing bendable reinforced concrete elements with an external reinforcement system based on polymer composite materials, based on the laboratory testing of reinforced concrete specimens with a rectangular cross section, for subsequent use in the practice of strengthening the beams of the span structure of bridges made not of prestressed reinforced concrete.

Methodology

To solve the set tasks of experimental laboratory Research, reinforced concrete beams of rectangular section were chosen as samples to be tested. Figure 1 shows a reinforcement drawing of reinforced concrete specimens made of concrete of class B30, frost resistance grade F200, water resistance grade W6.

For the reinforcement of reinforced concrete samples, the materials of the COMPOSIT company were chosen – FibArm Lamel HS 12/50; epoxy adhesive composition FibArm Resin Laminate +.

Below are the technical characteristics of composite reinforcement material:

1. Width 50 mm;
2. Thickness 1.2 mm;
3. Strength at break 3500 MPa;
4. The modulus of elasticity is 170 GPa.

Also presented are the technical characteristics of the adhesive for strengthening beams:

1. The shear strength of the glue samples is not less than 15 MPa;
2. Time of complete hardening 5 days;
3. Adhesion strength not less than 2.5 MPa.

The amplification technology with pre-voltage FRP provides for the following types of work:

a) leveling the surface of the reinforced concrete beam on which the FRP is glued. The permissible deviations from the flatness of the surface should not exceed 1 mm on the basis of 0.3 m.

b) drilling holes for anchoring the hydraulic jack frame and fixing the fixed end of the FRP plate;

c) cleaning, dedusting and degreasing the surface of the beam.

d) installation in the anchoring of the frame of the hydraulic jack.

e) applying epoxy glue to the surface of the beam with a layer of 1…2 mm.

f) the sticker of the plate begins with preparatory work, it is laid out on the working table (workbench) and carefully wiped with a cloth moistened with acetone. After that, on an absolutely dry surface of the plate, a triangular profile is formed from the adhesive using a specially made dispenser (conductor) or trowel, while the thickness of the adhesive layer in the middle should be 2 mm, narrowing towards the edges to 1 mm. After applying the adhesive, the lamella is placed on the base and rolled with a rigid roller to remove air from the adhesive layer. Remove excess adhesive with a spatula.

g) fixing the fixed end of the FRP plate.

h) tension of the FRP strip with a jack to the design level;

i) warming up the adhesive composition to accelerate its polymerization (no longer than three hours);

j) dismantling the prestressing system (24 hours after the end of the warm-up).

On the basis of the calculations and analysis of the work of the structures, the samples were divided into four groups (designated by the letters A, B, C, D), three twin beams in each group. The first group of samples A is represented by unreinforced reinforced concrete beams. The second group B – with reinforced concrete beams, reinforced with unstressed plates, fixed with vertical FRP clamps. In the third group, samples C were reinforced with the first level of FRP prestress up to 6 kN. In the fourth group D – the second prestressing level up to 12 kN.

This study analyzes the data on prestressing losses in a group of samples with a prestressing level of 12 kN. The beam reinforcement scheme with geometric dimensions is shown in Figure 2.

The control over the force in the plate of the polymer composite material directly during the amplification of laboratory samples and during the next 180 hours was carried out mainly using the multichannel measuring complex TDS-150 with primary transducers – strain gauges. A beam with a FRP prestressing system and glued strain gauges connected to the TDS-150 multichannel complex are shown in Figure 3.

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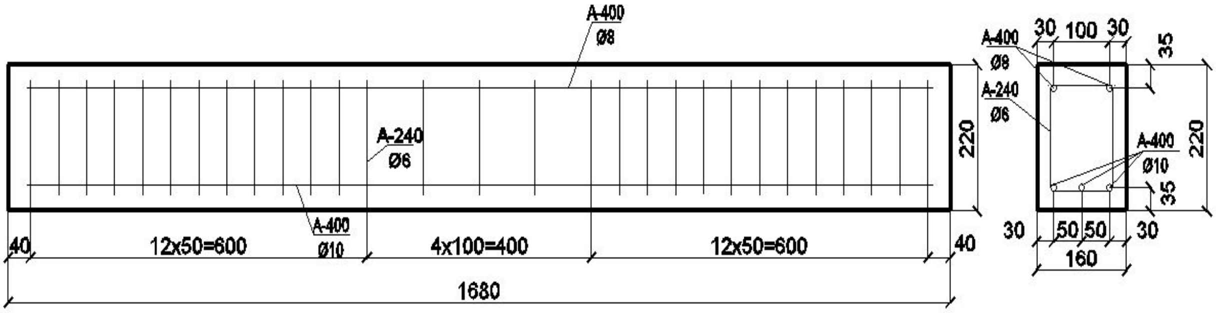

Fig. 1. Reinforcement scheme for a reinforced concrete laboratory sample (Ящук, 2017a; Ящук, 2017b)

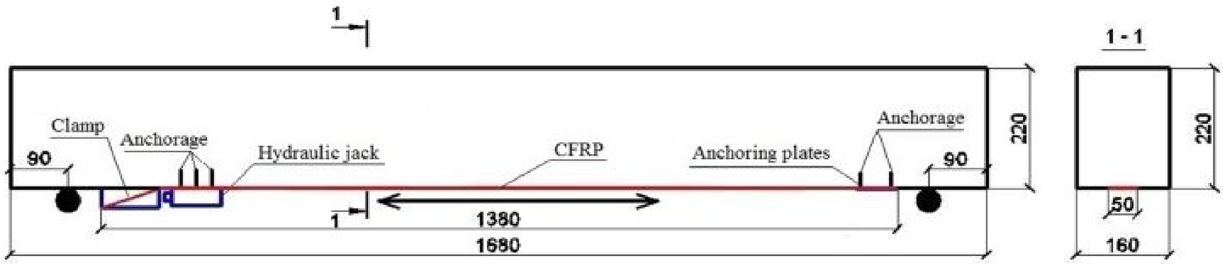

Fig. 2. Beam reinforcement

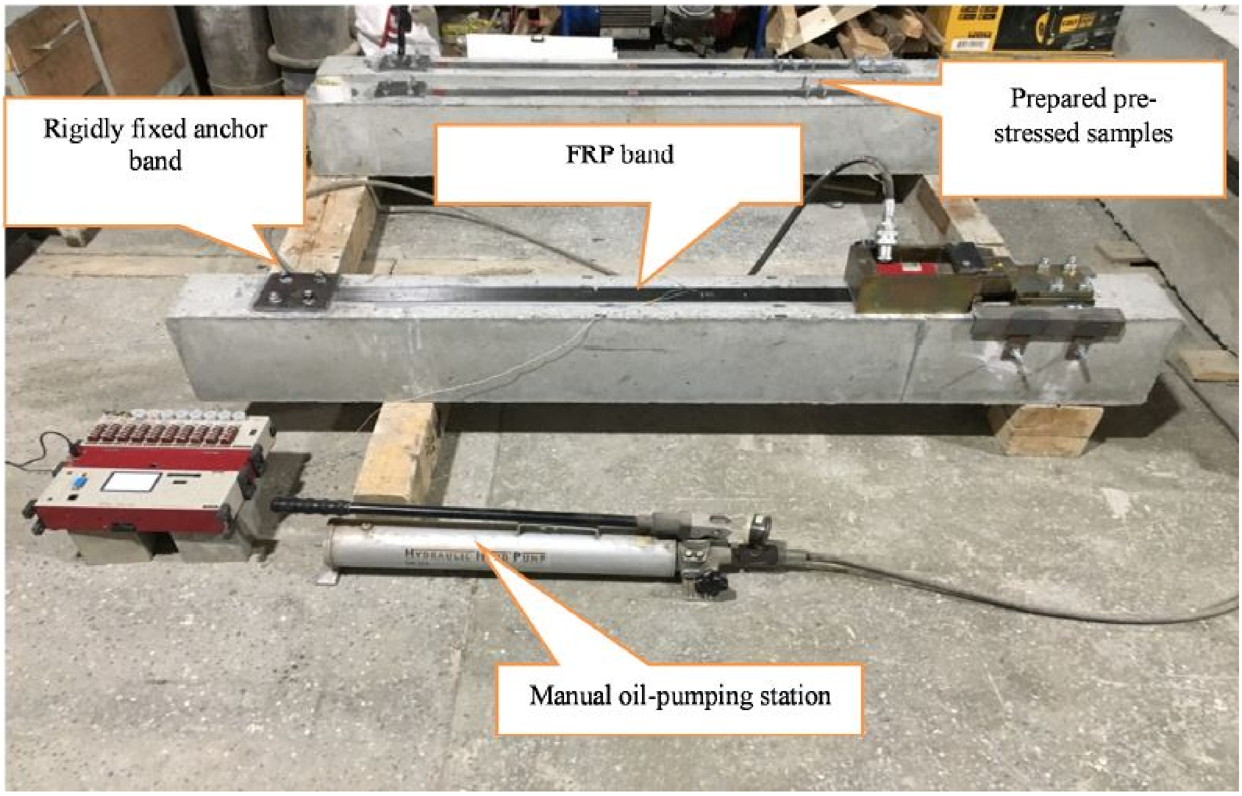

Fig. 3. Scheme of work of the TDS-150 to control the loss of prestressing, when reinforcing the FRP of a reinforced concrete beam

Measurement of the voltage level is carried out by the "Interval measurement" function – with the help of which the measurement data is automatically recorded during the set time intervals. From the moment the prestressing of the FRP plate began and until the expiration of 24 hours, in the first 5 hours of time, the voltage level was measured every 1 second. In the period from 5 hours to 24 hours, the voltage was measured every 10 minutes. After dismantling the prestressing system of polymer composite materials (after 24 hours), the measurement in the following days up to 180 hours occurred at intervals of once every 60 minutes. In the study of the drop in prestressing level, three programmed intervals of time measurements were applied, which were performed sequentially. To compensate for additional measurement errors, a built-in method of full deformation compensation is used, which prevents jumps and additional errors in the event that the measured value is unstable, for example, from temperature influences.

Results

The results of the experiment show that a sharp decrease in the prestressing level of the FRP plate occurs in the interval of the first 24 hours and amounts to about 16 MPa for sample No. 2, in the region of 10.5 MPa, a decrease in stress according to sample No. 2 and a drop in the prestress level in sample No. 3 was equal to 13.5 MPa. (Смердов, 2019).

The first zone of the prestress drop in the FRP plate can be called conditionally “Primary zone”. The time interval between 24 hours and 70 hours will be called the "Temperate zone" in which there is a smooth drop in the prestressing level of the glued composite, in which sample No. 1 loses 8 MPa compared to the boundary value in the “Primary zone”. Based on the data, the same boundary data in the previous zone, sample No. 2 showed a greater decrease in prestress equal to 13.5 MPa. Average indicators of prestress reduction for sample No. 3, which amounted to 11.5 MPa.

The conventionally introduced name "Relaxation zone" is the zone in which the prestress indicators in the FRP plate are stable for a long time, regardless of the temperature effect. The above values are shown in the diagram in Figure 4.

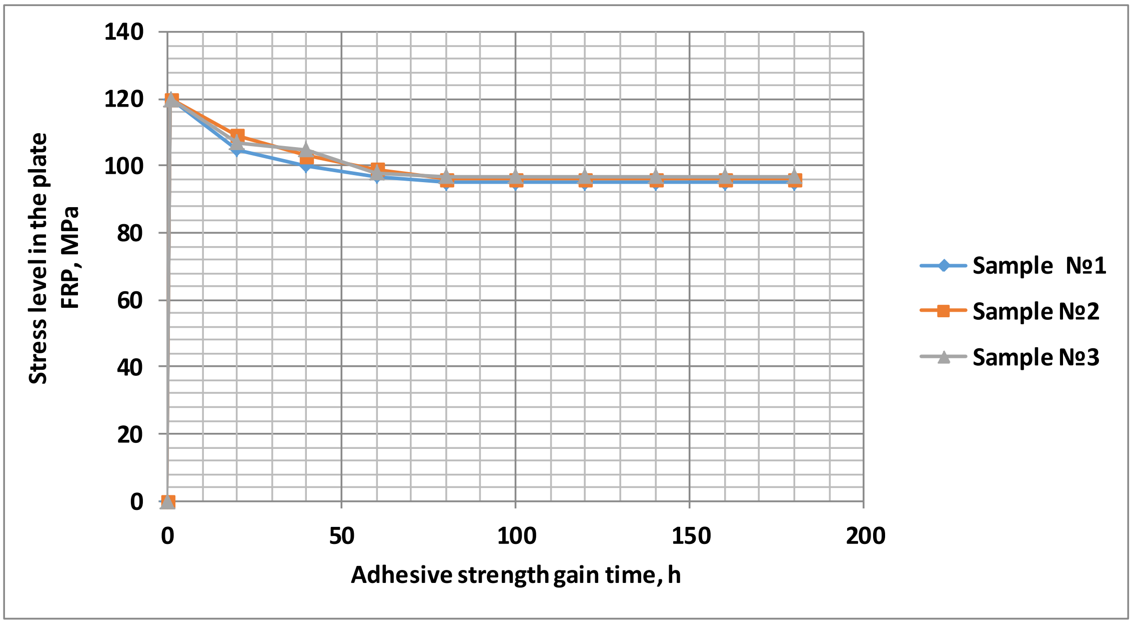

Fig. 4. Diagram of the loss of prestress in time in a FRP plate, with reinforcement of laboratory reinforced concrete specimens

Originality and practical value

The problem of the loss of magnitude, from the initial level of prestressing of the composite material when reinforcing reinforced concrete bending elements, is important in relation to the further improvement of the calculation methodology and design of the reinforcement system. With the help of the applied prestressing system, it was possible to achieve minimum losses based on a given tension level, while a sample consisting of three samples with a force of 12 kN allows us to speak of the practical significance of this laboratory study.

Conclusions

The article analyzes the study of the loss of prestress in time. The average losses for the three beams in the samples before the start of the "Relaxation Zone" were about 22.5 MPa, which is 18.7%. These indicators allow us to conclude that the developed and applied prestressing system is quite efficient.

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ЛАБОРАТОРНІ ДОСЛІДЖЕННЯ ВТРАТИ ПОПЕРЕДНЬОГО НАПРУЖЕННЯ ПРИ ПІДСИЛЕННІ ЗАЛІЗОБЕТОННИХ БАЛОК КОМПОЗИЦІЙНИМИ МАТЕРІАЛАМИ

Мета. У статті виконаний аналіз наукового експерименту з вивчення втрат попереднього напруження при підсиленні композиційними матеріалами залізобетонних елементів, що згинаються. **Методика.** Для досягнення поставленої мети авторами була проведена експериментальна робота в науковій лабораторії «Мости» СГУПС, із застосуванням розробленої технології посилення. Об'єктом вивчення були три залізобетонних балки-близнючки зі ступенем попереднього напруження композиційного матеріалу 12 кН. Вимірювання втрат проводилося протягом 180 годин з початку моменту попереднього напруження для кожної балки окремо. **Результати.** Після аналізу проведеного лабораторного експерименту було виділено три характерні зони при зменшенні величини попереднього напруження: «Первинна зона», «Помірна зона» і «Зона релаксації», в яких в різних межах змінюється величина попереднього напруження композиційного матеріалу. **Наукова новизна.** Знайдена середня величина втрати попереднього напруження залізобетонних елементів, що згинаються, при підсиленні лабораторних зразків. **Практична значимість.** Аналіз втрати величини попереднього напруження є важливим фактором у подальшому вивченні методики розрахунку і вдосконалення технології підсилення залізобетонних конструкцій композиційними матеріалами.

Ключові слова: попередньо напружені полімерні композиційні матеріали; мости; підсилення; балка залізобетонна; домкрат гідравлічний; поліпшення і відновлення несучої здатності; прогонові будови

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ЛАБОРАТОРНЫЕ ИССЛЕДОВАНИЯ ПОТЕРИ ПРЕДНАПРЯЖЕНИЯ ПРИ УСИЛЕНИИ ЖЕЛЕЗОБЕТОННЫХ БАЛОК КОМПОЗИЦИОННЫМИ МАТЕРИАЛАМИ

Цель. В статье сделан анализ научного эксперимента по изучению потерь предварительного напряжения при усилении железобетонных изгибаемых элементов композиционными материалами. **Методика.** Для достижения поставленной цели авторами была проведена экспериментальная работа в научной лаборатории «Мосты» СГУПСа, с применением разработанной технологии усиления. Объектом изучения являются три железобетонных балки-близнеца со степенью преднапряжения композиционного материала 12 кН. Измерение потерь проводилось в течение 180 часов с начала момента преднапряжения для каждой балки по отдельности. **Результаты.** После анализа проведенного лабораторного эксперимента было выделено три характерные зоны при уменьшении величины преднапряжения: «Первичная зона», «Умеренная зона» и «Зона релаксации», в которых в разных пределах изменяется величина преднапряжения композиционного материала. **Научная новизна.** Найдена средняя величина потери преднапряжения изгибаемых железобетонных элементов при усилении лабораторных образцов. **Практическая значимость**. Анализ потери величины преднапряжения является важным фактором в дальнейшем изучении методики расчета и совершенствования технологии усиления железобетонных конструкций композиционными материалами.

Ключевые слова: предварительно напряженные полимерные композиционные материалы; мосты; усиление; балка железобетонная; домкрат гидравлический; улучшение и восстановление несущей способности; пролетные строения

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