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EXPERIMENTAL TESTING METHODOLOGY OF STRESS-STRAIN STATE OF THE REINFORCED CONCRETE PIPE WITH STRENGTHENING

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Reinforced concrete pipes are exposed to environmental influences during the entire period of their operation. As a result, defects and damage appear and reduce durability and bearing capacity. In this regard, there is a need to repair and strengthen them. In order to assess the effectiveness of strengthening of reinforced concrete pipes, it is necessary to get data about deformations appeared as a result of the loads on the reinforced concrete pipe.

The method for conducting experimental studies of the deformed state of reinforced concrete pipes has been developed, and the main devices and means necessary for conducting experimental research in laboratory conditions have been selected.

The obtained data of deformations appearance can be used to compare the effectiveness of various methods of strengthening reinforced concrete pipes and their improvement as well as to monitor technical condition and to predict the formation of defects.

Key words: reinforced concrete pipe, ring, deformed state, movement, deformations, experiment, strengthening, method.

Introduction

Transport structures are an important element of the road infrastructure. The proper technical condition of transport structures allows to use transport routes and ensures high throughput capacity of railways and roads what is extremely important for fast delivery of goods from one end of Ukraine to another in wartime conditions.

Reinforced concrete pipes are an integral part of urban economy and transport infrastructure both on the territory of Ukraine and abroad, however, today there is a negative trend of deterioration of their technical condition. Due to inefficient or improper operation of reinforced concrete pipes, most of them have reached an age close to the exhaustion of their physical or moral durability that leads to the restriction of traffic on the structures until the moment of their further replacement.

Ukrzaliznytsia operates 10940 culverts, of which 259 have various types of defects according to official data. Situation with operation of culverts in Ukravtodor is worse. The Highway Service of Ukraine operates 129053 culverts, of which 37425 are defective (Luchko & Kovalchuk, 2021; Kovalchuk, 2012; Koval, Babyak & Sitdykova, 2010).

Reinforced concrete culverts are exposed to environmental influences during the entire period of their operation. As a result, defects and damage appear and reduce durability and bearing capacity. (Rybak et al., 2022; Feng, Kong, Huo & Song, 2015; Du, Kong, Lai & Song, 2013; Laskar, Gu, Mo & Song, 2009; Moslehy, Gu, Belarbi, Mo & Song, 2010).

When defects and damage of reinforced concrete pipes are detected, it is necessary to repair these structures as soon as possible to restore traffic in the areas where they are operated. It is proposed to repair reinforced concrete pipes by the relining method, which involves installing a new metal pipe of a smaller diameter inside the defective pipe and filling the structural gap between pipes with cement mortar

(VBN V.2.3-218-198:2007, 2007; Osipov et al., 1996; SOU 45.120-00034045-015:2012, 2013; Borovik, 2006; Cherepov, Shylin, 2012; Mistewicz, 2019).

A schematic representation of the relining method is shown on Fig. 1.

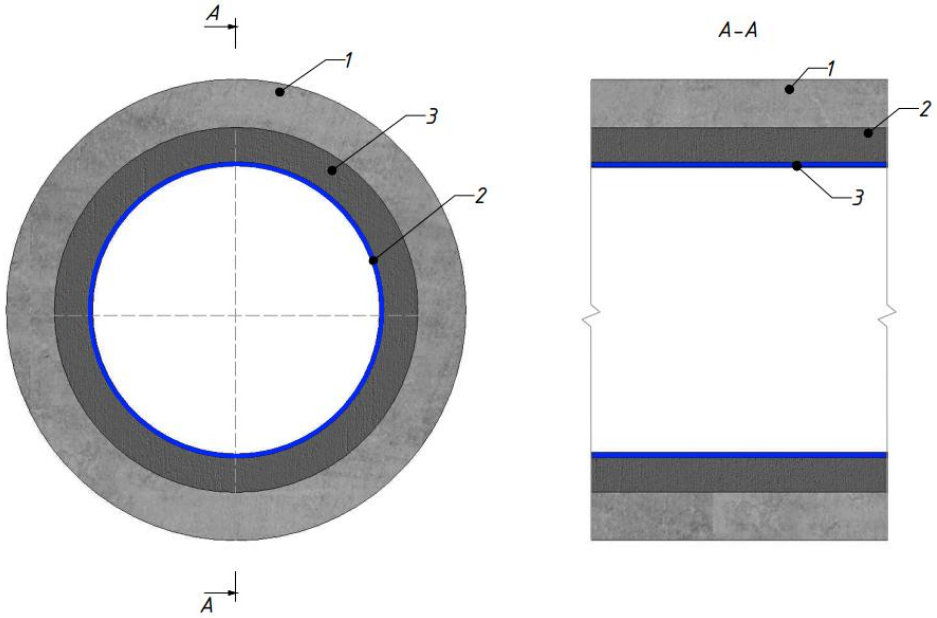

Fig. 1. A schematic representation of the relining method
1 – defective reinforced concrete pipe; 2 – metal pipe; 3 – cement mortar

In order to assess the effectiveness of strengthening of the reinforced concrete pipes by the relining method, it is necessary to obtain data about deformations appeared as a result of the load on the reinforced concrete pipe before strengthening and after it (Liu, Hoult & Moore, 2020; Gera & Kovalchuk, 2019; Onyshchenko, V.V. Kovalchuk, Fedorenko & Yu. Ye. Kovalchuk, 2021).

It is also necessary to develop an experimental method and conduct an experiment in laboratory conditions to obtain data about deformations appeared in reinforced concrete pipes before strengthening and after it.

Obtaining comprehensive results about formation of deformations in reinforced concrete pipes will make it possible to select the characteristics of the materials used for reinforcement by the relining method more properly. Also obtaining results about formation of deformations will improve the strengthening method in general.

The purpose of the work is to develop a method for conducting experimental research of the stress-strain state of a reinforced concrete pipe to determine the deformations and movements appear in reinforced concrete pipes before and after strengthening. This will make it possible to obtain comprehensive data about the deformed state in laboratory conditions that will allow to repair the defective transport structures more efficiently in the future.

To achieve the goal, the following tasks are set:

- selection of the necessary materials and means for testing;
- development of research method.

The work (Kovalchuk at al., 2017a) provides a methodology for researching of the horizontal and vertical pressure on a reinforced concrete pipe. The methodology is based on the determining of stress-strain state of the reinforced pipe by the relining method under the action of static and dynamic loads. The study was carried out by the finite element method in the software environment FEMAP with MSC NASTRAN. It is noted that the topic of scientific research aimed at choosing a rational and reliable structure of culverts with using corrugated metal is actual in Ukraine and its relevance is increasing over time.

In the work (Kovalchuk, Luchko, Bondarenko, Markul & Parneta, 2016) theoretical studies of the load-bearing capacity and stress-strain state of corrugated metal structures were carried out. It can be used

to strengthen reinforced concrete pipes by the relining method. However, no experimental research was conducted in the work.

Authors (Kovalchuk at al., 2017b) conducted experimental and theoretical research of the strength of metal corrugated structures of the railway track.

However, the works (Kovalchuk et al., 2017a; Kovalchuk et al., 2016; Kovalchuk et al., 2017b) do not describe the methods of conducting experimental research of stress-strain state of reinforced concrete pipes in laboratory conditions. Tests were carried out in the natural environment of the operation of structures that does not allow to evaluate deformed state under critical loads and to compare the effectiveness of different strengthening methods.

Therefore, the development of a method for conducting experimental research of deformed state of the reinforced concrete pipes is an actual task.

Materials and Methods

Geometric parameters of the research object

Experimental research of the deformed state was carried out with reinforced concrete rings.

Reinforced concrete rings were made for the experiment (Fig. 2).

Geometric parameters of the rings: outer diameter – 725 mm; internal diameter – 585 mm; thickness – 70 mm; ring height – 400 mm; weight – 130 kg; concrete class – C25/30; armature – wire Vr1.

Fig. 2. Reinforced concrete rings

Developed research method

Evaluation of the deformed state was based on the results of tests of reinforced concrete rings. The test was preceded by measurements of the rings.

A hydraulic testing press P-250 was chosen to apply the load on the reinforced concrete ring (Fig. 3).

A beam crane with electric winch was used to install the reinforced concrete rings on the testing press P-250.

One of the reinforced concrete rings was installed on the test press with the beam crane with an electric winch.

Installation of a reinforced concrete ring is shown on Fig. 4.

Fig. 3. Hydraulic testing press P-250

Fig. 4. Installation of a reinforced concrete ring on a test press

It was necessary to use devices that were able to recognize formation of the smallest deformations to determine the movements had been appeared as a result of applying a load on a reinforced concrete ring with a press.

Measurements were carried out by using electronic digital indicator with magnetic base (Fig. 5).

Two types of sensors were used in the measurement process:

1) measuring range 0–25.4 mm and resolution 0.01 mm;

2) measuring range 0–12.7 mm and resolution 0.001 mm.

Fig. 5. Electronic digital indicator with magnetic base

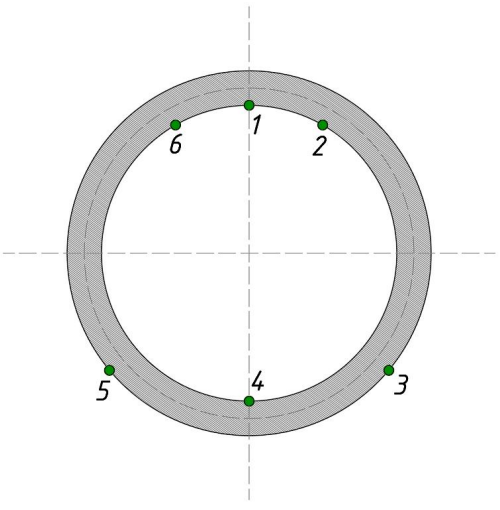

Fig. 6. Scheme of placement of measuring indicators on a reinforced concrete ring

Electronic digital indicators were placed and fixed symmetrically relative to the vertical axis of the reinforced concrete ring in places of maximum stress.

Placement of indicators on a reinforced concrete ring is shown on Fig. 6.

After placement and fixation, the electronic digital indicators were connected to an analog-to-digital converter which had been connected to the laptop.

Loads were applied to a reinforced concrete ring by the hydraulic press P-250. Formed deformations were red by electronic indicators and transmitted to the laptop software by using an analog-to-digital converter.

After the tests completing, the obtained results had to be processed and analyzed to determine the deformations according to the loads action on the reinforced concrete ring.

Load control was carried out by using a multi-turn dynamometer with a clock-type indicator had been installed on a reinforced concrete ring (Fig. 7).

Fig. 7. Dynamometer with a clock-type indicator

In order to ensure safe conditions for the experiment realization and to preserve the integrity of the equipment, loosened tension belts with a ratchet mechanism were used.

The MPB-2 microscope was used to monitor the formation of cracks in reinforced concrete pipes during the experiment (Fig. 8).

Fig. 8. MPB-2 microscope

The use of MPB-2 made it possible to monitor the appearance of cracks during the entire test on different load levels.

Results and discussion

To increase the effectiveness of strengthening of defective reinforced concrete pipes, it is necessary to obtain comprehensive data about the formation of deformations and the appearance of defects during operation.

The method of conducting experimental research of the deformed state of the reinforced concrete pipes is proposed, and the main devices and means necessary for conducting experimental research in laboratory conditions are selected.

The developed method makes it possible to carry out experimental research of the deformed state of the reinforced concrete pipes with and without strengthening that will allow obtaining comprehensive data about formation of the deformations and movements appeared as a result of the loads action.

The method also allows to carry out experimental research of both strengthened and non-strengthened reinforced concrete pipes that makes it possible to compare different methods of strengthening and evaluate their effectiveness.

The data obtained as a result of the application of the developed method can be used to improve the effectiveness of strengthening of the defective reinforced concrete pipes by the relining method and to improve it in general.

Conclusions

1. A method for conducting experimental research of the deformed state of a reinforced concrete pipe was developed as well as the main devices and means necessary for conducting the experiment in laboratory conditions were selected.

2. The proposed method make it possible to obtain comprehensive data about the formation of deformations during the operation of reinforced concrete culverts. It can be used to increase the effectiveness of strengthening structures like these.

3. The developed method helps to evaluate the deformed state of reinforced concrete pipes not only before reinforcement, but also after it. Therefore, the method can be used for practical application in order to establish the effectiveness of various strengthening methods as well as for their improvement in general.

4. The obtained parameters of deformations appeared in reinforced concrete pipes can be used to monitor their technical condition and to predict the defects formation in the future.

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МЕТОДИКА ПРОВЕДЕННЯ ЕКСПЕРИМЕНТАЛЬНИХ ДОСЛІДЖЕНЬ НАПРУЖЕНО-ДЕФОРМОВАНОГО СТАНУ ЗАЛІЗОБЕТОННОЇ ТРУБИ З УРАХУВАННЯМ ПІДСИЛЕННЯ

Встановлено, що технічний стан водопропускних залізобетонних труб, які експлуатуються в міському господарстві, на залізничних шляхах та автомобільних дорогах, погіршується та потребує відновлення.

Зазначено, що протягом всього періоду своєї експлуатації залізобетонні водопропускні труби постійно піддаються впливам навколишнього середовища, внаслідок чого з часом з'являються дефекти та пошкодження, що знижують довговічність і несучу здатність, і впливають на безпеку руху спорудою. У зв'язку з цим постійно виникає потреба у їхньому ремонті або підсиленні. Для проведення оцінки ефективності підсилення залізобетонних труб необхідно отримати дані про деформації, що виникають внаслідок дії навантаження на залізобетонну трубу до підсилення та після підсилення.

Наведено спосіб підсилення дефектних залізобетонних водопропускних труб за допомогою методу «гільзування».

Проведено аналіз перспектив використання методики для проведення експериментального дослідження деформованого стану залізобетонних труб.

Наведено спосіб визначення в лабораторних умовах деформацій, що виникають у залізобетонних трубах з підсиленням та без підсилення.

Розроблена методика проведення експериментальних досліджень деформованого стану залізобетонних труб та обрано основні пристрої й засоби, що необхідні для проведення експериментального дослідження в лабораторних умовах.

Практичне значення роботи полягає в тому, що запропонована методика дасть змогу проводити експериментальне дослідження деформованого стану залізобетонних труб із підсиленням та без нього в лабораторних умовах, що, своєю чергою, дозволить отримати вичерпні дані про утворення деформацій та переміщень, які виникають внаслідок дії навантажень.

Отримані дані з утворення деформацій можуть бути використані для порівняння ефективності різних методів підсилення залізобетонних труб та їх удосконалення, а також для моніторингу технічного стану та прогнозування утворення дефектів.

Ключові слова: залізобетонна труба, кільце, деформований стан, переміщення, деформації, експеримент, підсилення, методика.