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STRESS-STRAIN STATE OF REINFORCED CONCRETE PIPES UNDER THE INFLUENCE OF CLIMATIC TEMPERATURE CHANGES IN THE ENVIRONMENT

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Abstract. The research analysis on determining temperature fields, stresses and deformations of transport structures under the influence of variable climatic temperature changes in the environment is carried out. It is established that climatic temperature changes in the environment cause the occurrence of temperature stresses and deformations of transport structures.

The main damages and defects of reinforced concrete pipes in operation are given. It is established that one of the causes of defects and damages to reinforced concrete pipes is the level of temperature stresses and deformations that occur in the contact of a metal structure with a reinforced concrete pipe due to the action of variable temperatures caused by climatic temperature changes in the environment.

A finite element model is developed for estimating the temperature fields and stresses of reinforced concrete pipes reinforced with metal corrugated structures, taking into account the action of variable climatic temperatures of the environment.

The distribution of temperature fields in the transverse and longitudinal directions of reinforced concrete pipe under the action of positive ambient temperatures is calculated. It is established that the temperature field will be unevenly distributed over the pipe surface. In the transverse direction of the pipe, a temperature difference of +10° C was recorded between the reinforced concrete and metal shells.

The calculation of temperature stresses and deformations of the pipe under the action of positive ambient temperatures is performed. It is established that the maximum value of normal stresses occurs at the contact of a metal pipe with a reinforced concrete one. At the same time, the value of temperature stresses in the transverse direction of the pipe is 321.61 kPa, in the longitudinal direction it is 321.61 kPa and in the vertical direction, it is 253.84 kPa.

It is established that improving the theory and practice of determining the impact of climatic temperature changes on reinforced concrete pipes in the future will allow using appropriate materials and methods to strengthen these structures that meet the real conditions of pipe in operation, which will cause an increase in the service life of these structures in operation.

Key words: temperature fields, temperature stresses and deformations, climatic temperature changes, reinforced concrete pipe, metal corrugated structure, reinforcement.

Introduction. During the entire period of operation, reinforced concrete pipes are exposed to environmental influences, resulting in damages and defects that significantly affect the durability and load-bearing capacity of these structures.

The most common defects and damages of reinforced concrete pipes include damage to the heads, roll for links subsidence, chipping, crack development, leaching and waterproofing violation.

Defects in reinforced concrete pipes that occur under operating conditions are shown in Fig. 1.

a)

b)

c)

d)

Fig. 1. Defects in reinforced concrete pipes in operation:
a – longitudinal pipe cracks; b – transverse pipe cracks;
c – chipping of pipe concrete; d – the destruction of the pipe tray

To ensure the reliable operation of reinforced concrete pipes, it is necessary to analyze operational damage and take into account real operating conditions to determine the causes that contribute to the occurrence of defects and damage.

One of the causes of defects and damage is climatic temperature changes in the environment, which lead to the formation of temperature stresses and deformations in a reinforced concrete pipe. This requires an assessment of the stress-strain state of reinforced concrete pipes under the influence of variable ambient temperatures.

The problem and its relevance. Reinforced concrete pipes are an integral part of urban and transport infrastructure, however, there is a negative trend of deterring the technical condition of pipes, which causes defects and various types of damage.

During the entire period of operation, reinforced concrete pipes are exposed to temperature and climate influences, which significantly affect the technical condition and service life of these structures, which in turn can cause a decrease in durability and load-bearing capacity and affect the safety of vehicles.

In addition, when defective reinforced concrete pipes are reinforced with metal structures, it leads to forming a multi-layered structure, each of the layers of which has its own physical and mechanical parameters. And under the influence of variable climatic temperature changes, each layer of the structure will react differently to the temperature outflow. As a result, temperature stresses occur over the thickness of the pipe, which can lead to forming defects and damage to such structures.

Analysis of recent research and publications. Nowadays, many works on studying temperature fields and stresses in transport structures under the influence of climatic temperature changes in the environment are known. However, studies on determining the thermally stressed state of a multilayer structure have not been conducted. Although the norms [1] indicate that maximum and minimum ambient temperatures should be taken into account to assess the stress state of transport structures. Also in works [2, 3], the authors noted that it is important to conduct theoretical and experimental studies of the temperature distribution by the surfaces of bridge structures to assess temperature stresses and deformations of bridges.

In works [4-6], the authors note that daily and seasonal temperature differences affect the stress state of bridges and can cause deformations and stresses that contribute to the premature decommissioning of structures.

In work [7], the authors considered a reinforced concrete pipe reinforced with a metal corrugated structure and evaluated the stress-strain state. It is established that the effect of climatic temperature influences should be taken into account when designing the reinforcement of defective structures in addition to taking into account the effect of transport load. Since the value of temperature stresses from their action is up to 30% of the total stresses and this can lead to premature decommissioning of such structures.

From the research analysis, it is established that climatic temperature changes in the environment play a significant role in forming a thermally stressed state in transport structures. Therefore, the task of assessing the thermal stress state of reinforced multilayer pipes under the influence of climatic temperature influences is relevant and timely.

In addition, it should be noted that there are no clear recommendations for assessing the impact of climatic temperature changes on the condition of transport structures so far [8, 9]. However, in work [10] it is indicated that the value of ambient temperatures in operation constantly changes, which leads to changing the stress state of structures.

The research objectives are to assess the thermal stress state of a reinforced concrete metal pipe under the influence of positive ambient temperatures.

Materials and methods of research. To study the thermal stress state of a reinforced concrete pipe reinforced with a metal corrugated structure under the action of a positive ambient temperature, a geometric model of the pipe is shown in Fig. 2.

Reinforced concrete pipe has the following parameters: the length of reinforced concrete pipe l=1000 mm; the thickness of the reinforced concrete pipe is 150 mm; the thickness of the concrete between the reinforced concrete pipe and the metal pipe is 150 mm, and the thickness of the corrugated metal pipe is 6 mm.

Numerical studies of temperature stresses are carried out by the values of parameters a = 1000 mm; r_1 = 1006 mm; r_2 = 1156 mm; b = 1306 mm; κ_1 = 45 W/(m·°C) (corresponds to Steel St 3); κ_2=1.51 W/(m·°C) (corresponds to new concrete); κ_3=1.69 W/(m·°C) (corresponds to old concrete); $E_1 = 2{,}1 \cdot 10^5$ MPa; $\nu_1 = 0{,}3$; $\alpha_1 = 1{,}25 \cdot 10^{-5}$ 1/°C; $E_2 = 3{,}6 \cdot 10^4$ MPa; $\nu_2 = 0{,}25$; $\alpha_2 = 1{,}0 \cdot 10^{-5}$ 1/°C; $E_3 = 3{,}9 \cdot 10^4$ MPa; $\nu_3 = 0{,}25$; $\alpha_3 = 1{,}0 \cdot 10^{-5}$ 1/°C and at positive ambient temperatures t_1 and t_2 .

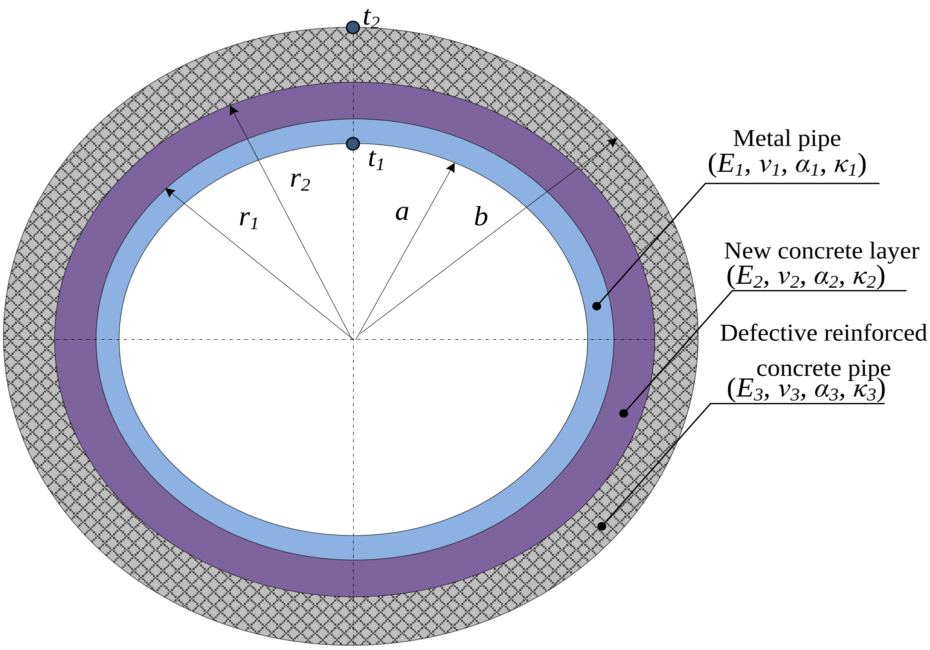

Fig. 2. Model for calculating the temperature field and stresses reinforced concrete pipe

The assessment of the thermal stress state of the reinforced concrete pipe was performed using the finite element method in software package NX NASTRAN.

The finite element model of a reinforced pipe consists of 99547 elements forming 124012 nodes of a finite element grid.

Studies results of the thermally stressed state of reinforced concrete pipe. The results of calculating the temperature field of a reinforced concrete pipe under the action of positive ambient temperatures are shown in Fig. 3.

As a result of calculating the temperature field, it was found that the temperature is distributed unevenly in the transverse direction of the pipe. The temperature difference between the metal and reinforced concrete shells was +10 ° C.

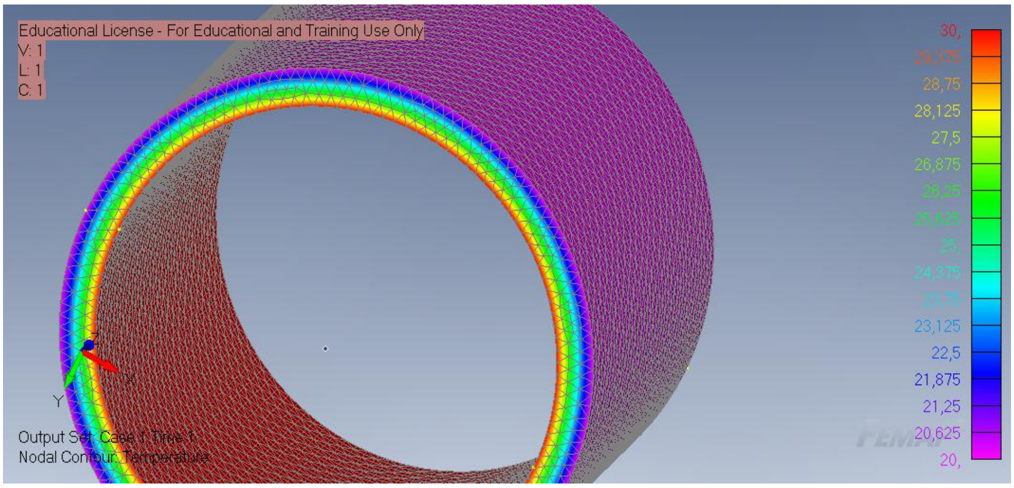

Fig. 3. Temperature field distribution in reinforced concrete pipe

The temperature stresses distribution in a reinforced concrete pipe under the action of positive ambient temperatures is shown in Fig. 4.

The results of calculating temperature stresses showed that a jump in temperature stresses occurs at the point of contact between a metal pipe and a reinforced concrete one. The maximum stress values were 302.44 kPa.

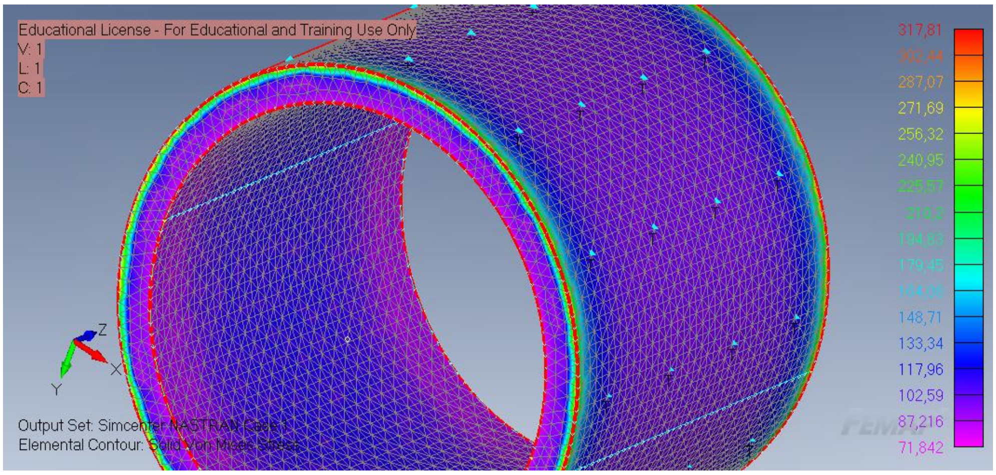

Fig. 4. The temperature stresses distribution in the reinforced concrete pipe when exposed to positive ambient temperature changes

The results of calculating normal stresses in the reinforced pipe showed that the highest temperature stresses in the transverse and longitudinal directions are 321.61 kPa, and in the vertical direction – 253.84 kPa. The maximum tangential stresses at the contact boundaries of the pipe shells in the longitudinal direction are 73.22 kPa, in the transverse, it is 173.3 kPa and in the vertical, it is 172.44 kPa. It is established that the maximum tangential stresses occur at the contact limit of reinforced concrete pipe and metal and are 173.3 kPa.

The temperature deformations distribution in a reinforced concrete pipe under the action of positive ambient temperatures is shown in Fig. 5.

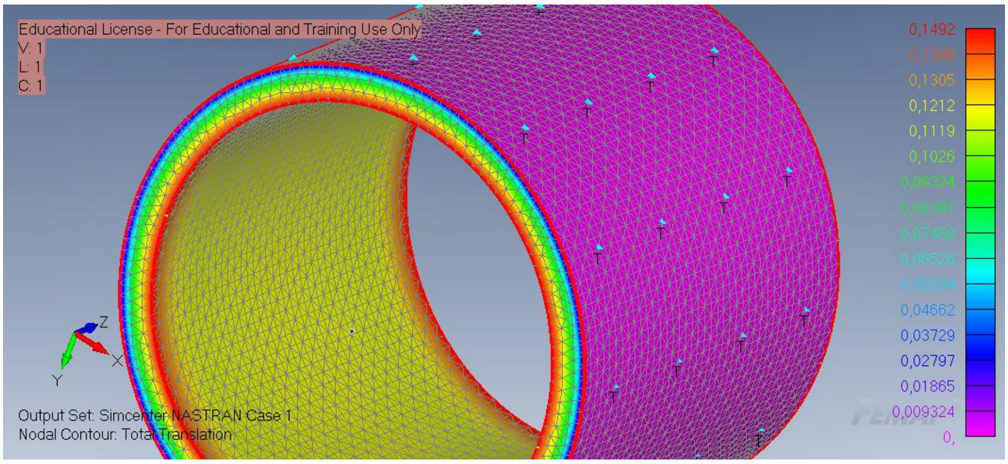

Fig. 5. The temperature deformations distribution in a reinforced concrete pipe under the influence of positive ambient temperature changes

The results of calculating the total deformations of reinforced concrete pipe showed that their maximum value is 0.1492 mm. In the longitudinal direction, the deformation pipes are 0.1184 mm, in the transverse direction they are 0.1182 mm and in the vertical direction they are 0.1377 mm.

It should be noted that to calculate the total stress state of reinforced concrete pipes must be added to the found temperature stresses, more stresses from the action of mobile transport units. Since their combination can lead to stresses in the reinforced pipe exceeding the allowable and as a result leads to damage to the pipe in operation.

Conclusions. As a result of calculating temperature stresses and deformations the following conclusions can be drawn:

1. It is established that the temperature is distributed unevenly in the transverse direction of the reinforced concrete pipe. There is a temperature jump at the contact of metal and reinforced concrete shells. The maximum temperature difference between the shells over the thickness of the reinforced pipe is recorded at +10° C.

2. The results of calculating temperature stresses showed that a jump in temperature stresses occurs at the point of contact of a metal pipe with a reinforced concrete one. The maximum values of stresses were 302.44 kPa, and deformations were 0.1492 mm.

3. When designing the repair of defective reinforced concrete pipes, in addition to determining the stress from the action of vehicles should take into account the stress and climatic temperature effects. Since their combination can lead to stresses in the reinforced pipe exceeding the allowable and as a result leads to damage to the pipe in operation.

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НАПРУЖЕНО-ДЕФОРМОВАНИЙ СТАН ПІДСИЛЕНИХ ЗАЛІЗОБЕТОННИХ ТРУБ ПРИ ДІЇ КЛІМАТИЧНИХ ТЕМПЕРАТУРНИХ ПЕРЕПАДІВ НАВКОЛИШНЬОГО СЕРЕДОВИЩА

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Анотація. Виконано аналіз науково-дослідних робіт із визначення температурних полів, напружень та деформацій транспортних споруд при дії змінних кліматичних температурних перепадів навколишнього середовище. Встановлено, що кліматичні температурні перепади навколишнього середовища призводять до виникнення температурних напружень та деформацій конструкцій транспортних споруд.

Наведено основні пошкодження та дефекти залізобетонних труб в умовах експлуатації. Встановлено, що однією з причин виникнення дефектів та пошкоджень залізобетонних труб є рівень температурних напружень та деформацій, що виникає у контакті металевої конструкції із залізобетонною трубою внаслідок дії змінних температур, зумовлених кліматичними температурними перепадами навколишнього середовища.

Розроблено скінченно-елементу модель для оцінки температурних полів та напружень залізобетонних труб підсилених металевими гофрованими конструкціями із врахуванням дії змінних кліматичних температур навколишнього середовища.

Виконано розрахунок розподілу температурних полів у поперечному та повздовжньому напрямах підсиленої залізобетонної труби при дії додатних температур навколишнього середовища. Встановлено, що температурне поле розподілиться нерівномірно поверхнею труби. У поперечному напрямі труби зафіксовано перепад температури величиною +10ºC між залізобетонною та металевою оболонками.

Виконано розрахунок температурних напружень та деформацій труби при дії додатних температур навколишнього середовища. Встановлено, що максимальна величина нормальних напружень виникає на контакті металевої труби із залізобетонною. При цьому величина температурних напружень у поперечному напрямку труби складає 321,61 кПа, у повздовжньому напрямку – 321,61 кПа та у вертикальному складає 253,84 кПа.

Встановлено, що удосконалення теорії та практики визначення впливу дії кліматичних температурних перепадів на підсилені залізобетонні труби в майбутньому дозволить використовувати відповідні матеріали та методи для підсилення даних споруд, що відповідають реальним умовам експлуатації труб, що призведе до підвищить терміну служби цих конструкцій в експлуатації.

Ключові слова: температурні поля, температурні напруження та деформації, кліматичні температурні перепади, залізобетонна труба, металева гофрована конструкція, підсилення.

НАПРЯЖЕНО-ДЕФОРМИРОВАННОЕ СОСТОЯНИЕ УСИЛЕННЫХ ЖЕЛЕЗОБЕТОННЫХ ТРУБ ПРИ ДЕЙСТВИИ КЛИМАТИЧЕСКИХ ТЕМПЕРАТУРНЫХ ПЕРЕПАДОВ ОКРУЖАЮЩЕЙ СРЕДЫ

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Аннотация. Проведен анализ научно-исследовательских работ по определению температурных полей, напряжений и деформаций транспортных сооружений при действии сменных климатических температурных перепадов окружающей среды. Установлено, что климатические перепады окружающей среды приводят к возникновению температурных напряжений и деформаций транспортных сооружений.

Представлены основные повреждения и дефекты железобетонных труб в условиях эксплуатации. Установлено, что одной из причин возникновения дефектов и повреждений железобетонных труб является уровень температурных напряжений и деформаций, возникающих в контакте металлической конструкции с железобетонной трубой в результате воздействия изменяющихся температурных воздействий, обусловленных климатическими температурными перепадами окружающей среды.

Разработана конечно-элемент модель для оценки температурных полей и напряжений железобетонных труб усиленных металлическими гофрированными конструкциями с учетом действия переменных климатических температур окружающей среды.

Выполнен расчет распределения температурных полей в поперечном и продольном направлениях усиленной железобетонной трубы при воздействии положительных температур окружающей среды. Установлено, что температурное поле распределится неравномерно по поверхности трубы. В поперечном направлении трубы зафиксирован перепад температуры величиной +10 С между железобетонной и металлической оболочками.

Произведен расчет температурных напряжений и деформаций трубы при воздействии положительных температур окружающей среды. Установлено, что максимальный размер нормальных напряжений возникает на контакте металлической трубы с железобетонной. При этом величина температурных напряжений в поперечном направлении трубы составляет 321,61 кПа, в продольном направлении – 321,61 кПа и вертикальном составляет 253,84 кПа.

Установлено, что усовершенствование теории и практики определения влияния воздействия климатических температурных перепадов на усиленные железобетонные трубы в будущем позволит использовать соответствующие материалы и методы для усиления данных сооружений, отвечающих реальным условиям эксплуатации труб, что приведет к повышению срока службы этих конструкций в эксплуатации.

Ключевые слова: температурные поля, температурные напряжения и деформации, климатические перепады, железобетонная труба, металлическая гофрированная конструкция, усиление.

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