Improving the reliability of metal structures of buildings and structures during reconstruction

A Mezentseva\textsuperscript{1*}, Z Gel'manova\textsuperscript{1} and A Konakbayeva\textsuperscript{1}

\textsuperscript{1}Karaganda state industrial university, 30 Republic Avenue, Temirtau, Republic of Kazakhstan

*avmez@mail.ru

Abstract. Recently, the direction of prestressing metal structures, the regulation of forces in which is made by various methods without the use of high-strength steel is one of the hot spots of research. In this paper, an unconventional method for creating pre-stress in tubular elements using an expanding substance is applied. As used by a non-explosive destructive mixture (NDM).

1. Introduction

Strengthening and repairing load-bearing structures with unconventionally stressed elements is one of the most pressing problems in construction. The Republic of Kazakhstan has a large number of buildings and structures that have a service life of more than 50 years. Aging, fatigue, and corrosion of building structures and structures are the most poorly studied. This work will help to reduce the gap to a certain extent and at the same time develop science and practice in improving the load-bearing capacity of bearing elements of buildings and structures.

2. An experiment

Compositions composed of a combination of different substances were tested as an expanding material. The best results are obtained for an expanding material consisting of calcium oxide (OST 21-27-78), a retarder of the hydration reaction of calcium oxide (OST 81-79-74), and also possible additives in certain conditions of nitrate and potash [1-5].

It was found that the aqueous solution of the expanding material increases in volume as a result of the reaction by about 23 times relative to the initial one. The working mixture is a powdered material, usually gray in color, non-flammable, non-explosive, with weak alkaline properties with a volume density of 1.251. 35 t / m\textsuperscript{3} and water absorption up to 30\%. The volume mass of the working mixture solution is 2.16 t / m\textsuperscript{3}. Developed pressure up to 30 MPa. According to the conclusion of the Republican sanitary and epidemiological station of the Ministry of health of the Republic of Kazakhstan, the components of the working mixture meet the hydrohygenic requirements for materials and products for industrial purposes.

When preparing a working mixture of powder, the amount of water for mixing should be from 28\% to 30\% of the powder weight. Mechanical stress in the working mixture occurs as a result of increasing its volume due to the hydration reaction in confined conditions. The hydration reaction is provided by the main component of the powder – calcium oxide. The content of calcium oxide reaches from 70\% to 90\% of the total weight of the powder. Additional components included in the powder are used to maintain certain modes of expansion of the working mixture.
Experiments were performed on a special stand to determine the values of stresses that occur in an expanding material (NDM solution). The General appearance of the stand included a frame with a DOSM-3-5 dynamometer and sliding cylinders of different diameters and heights [5-14, 19]. Sliding cylinders were filled with a solution of expanding material, closed from the bottom and top with a lid and tightly. With a preliminary voltage, they were installed to a dynamometer, according to the indications of which they judged the resulting stresses. To do this, it was necessary to divide the results recorded by the dynamometer by the area of the inner surface of the sliding cylinders containing the expanding material [15-18, 20-21]. A total of 60 preliminary experiments were conducted under the same conditions.

3. Results of experimental studies

Table 1 shows the results of experiments to determine the stresses in sliding cylinders of different diameters and heights. For 24 hours under the same conditions of the experiments, a voltage approximately equal to 17 MPa occurs, which is approximately 0.7 of the maximum voltage in the expanding material.

| Sketchslidingcylinders’ Parameterscylinders’ | Results |
|--------------------------------------------|---------|
| D(cm) | H(cm) | F(cm³) | n | σt=N/F(MPa) | T(hour) | σp/σmax |
| 2.5 | 2.5 | 19.6 | 7 | 17.0±1.5 | 24 | 0.68 |
| 3 | 6 | 28.4 | 7 | 16.8±1.1 | 24 | 0.67 |
| 3.6 | 4 | 45.2 | 7 | 18.7±0.9 | 12 | 0.35 |
| 4 | 3 | 37.7 | 7 | 18.1±0.8 | 12 | 0.34 |

The student’s distribution coefficient for seven repetitions of experiments (n) and the confidence probability Pₛ=0.95 is equal to tₛ=2.5.

The curve of the spread of the measured values of forces (stresses) from the expansion of the LDC is subject to the normal distribution law (Gauss curve). Processing of the measurement results showed that in order to obtain reliable data with a probability of P=0.95 and an accuracy of K=5%, it is necessary to conduct 7 repetitions of each experiment. This mixture works effectively at a positive temperature. Figure 1 shows the experimentally obtained dependence of the efficiency of increasing the voltage in the working mixture in a closed volume over time at a positive hardening temperature, which shows that the increase in the voltage in the working mixture occurs within two months, and for the first day the working voltage of the mixture reaches about 70% of the maximum. The remaining 30% increase in voltage occurs gradually.
The first two hours characterize the hardening of the working mixture placed in a closed volume. Then it begins to gradually expand and increase the stresses (figure 2). The maximum rate of expansion of the mixture falls on the first 610 hours of its hardening. In the future, the rate of expansion of the mixture gradually decreases.

When the working mixture solidifies in hot water (t=5060ºc), the intensity of stress increases faster (figure 2). Therefore, it is advisable to use hot water at a generally low positive temperature from +1ºC to +5ºC.

Inert additives can be used to change the stress in the expanding mixture. As an inert additive for the preparation of an expanding mixture, it is advisable to use dry fine sand. The addition of dry sand in an amount of 20% to 40% to the material slightly affects the amount of its expansion and stress reduction (figure 3).
Figure 3. Growth of stresses during the expansion of the working mixture on the first day: 1 – closing the mixture on water at room temperature; 2 – closing the mixture on water at t=50-60°C and hardening the mixture at 20°C; 3 – heating the mixture to intensify the hydration process.

4. Conclusions
In the present work, research has been carried out and the characteristics of the work of tubular elements that are strained using a non-explosive expanding mixture have been identified. The possibility of creating a pre-stress using non-traditional methods when strengthening the load-bearing capacity of building structures is proved. The advantages of the non-traditional method of creating pre-voltage under study are that it is less labor-intensive, the amplification effect is achieved quickly, and it does not require bulky equipment.

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