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THE IMPACT OF THE AGRESSIVE ACID ENVIRONMENT ON RC CONSTRUCTIONS

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Abstract: The main issue of the article is the corrosion of the reinforced concrete elements by the co-influence of the aggressive and power factors. The problem of corrosion is ex-tremely actual one. Therefore the tests were carried out upon the specimens considering the corrosion in the acid environment, namely 10 % H2SO4. The acid environment H_2SO_4 was taken as a model of the aggressive environment. Conclusions concerning the corrosion model of the cross section and investigation of stress-strain state have been made. That material concerns the problem of the reinforced concrete corrosion as a whole construction. Reinforced concrete beams were tested with and without the co-action of the aggressive environment and power factor.
Keywords: aggressive environment, reinforce concrete, beams, corrosion, damaged constructions.

1. INTRODUCTION

Due to numerous advantages concrete and reinforced concrete constructions are successfully applied practically in the majority of buildings and constructions (Bobalo et al., 2018; Bobalo et al., 2020; Blikharskyy et al., 2020; Krainskyi et al., 2018; Krainskyi et al., 2020; Vegera et al., 2018). Researches of many authors (Al. Sherrawi et al., 2018; Lobodanov et al., 2020; Lipinski et al., 2017) have proved, that enough frequently these constructions are maintained in different aggressive environments. Aggressive components can be in a firm, liquid or gaseous condition (Blikhars'kyi and Obukh, 2018; Blikharskyy et al., 2019). Depending on it the character of influence of an aggressive environment on a construction changes. In all cases of the influence of an aggressive environment consequences, which are shown as the corrosion of concrete and reinforced concrete constructions, are general. According to the research data (Selejdak et al., 2018) the corrosion by the influence of various acids take place faster. The influence of acids on constructions most often takes place in buildings connected to chemical manufacturing, galvanic shops, there can be acids in chimneys as well. Owing to combustion of fuel (black oil, coal) in which sulfur takes place sulfuric and sulphurous anhydride (SO_2, SO_3) come out. At temperature 40 ÷ 60 °C sulphurous anhydride together with evaporations of water forms the sulfuric acid. Concentration of sulfuric acid on an internal surface of the concrete of chimneys can reach 5...7 %. For the avoidance of the direct influence of the acid the protection by acid-fast flue lining is carried out. However, in case of damage of the protection system favorable conditions for corrosion processes are created (Abu-Tair et al., 1996; Fadhil et al., 2018; Teyeh et al., 2013). Thus it is necessary to notice, that constructions simultaneously with the influence of the aggressive environment are under the action of operational loadings. So important to strength and repair this constructions by different modern methods (Blikharskyy et al., 2018; Brozda et al., 2017; Khmil et al., 2018; Selejdak et al., 2020).

For the given time the significant amount of researches of corrosion processes in the concrete have been carried out by the action of the acid aggressive environment. It has been established, that destruction of the cement stone and concrete passes owing to the chemical reaction of acids with components of the cement stone. Owing to these reactions the infringement of the concrete structure and its destruction take place. Thus the influence of different acids in view of change of their concentration, temperatures, term of their action was investigated. Almost in all carried out researches the corrosion of concrete without taking into account the influence of external loading was studied.

This article presents the corrosion of concrete and reinforced concrete constructions by the simultaneous influence of the aggressive environment and power loading.

With the purpose of studying of stress-strain state of constructions by the simultaneous influence of the aggressive environment and external power loading experimental researches have been carried out. These researches included two stages: testing the central loaded prisms; testing of reinforced concrete beams.

2. DESIGN OF EXPERIMENTS SAMPLES

For experimental researches a series of concrete cubes in the size 100×100×100 mm, prisms 400×100×100 mm and reinforced concrete beams 2100×200×100 mm have been made. The concrete composition was cement:sand:crushed aggregate = 1:1.01:2 28 with W/C = 0.33 with the application of supersoftener and air involving additives. The concrete compressive strength for 28 day was 47 MPa. Reinforced concrete beams were reinforced in tensile zone of the concrete 2Ø14 A–III, in compressed – 2Ø5 Bp-I. The transverse reinforcement was ØBp-I with step of 75÷100 mm. Two metal finger were casted in the middle of the span in the top zone of a beam on distance of 200 mm one from another with the adaptation for fastening devices and measurement of deformations of concrete.

3. RESULTS OF EXPERIMENTAL STUDY

Special stands (Fig. 1) have been made for prism testing. Prisms were under the simultaneous influence of the central enclosed compressing force and an aggressive environment - 10 % of the solution of the sulfuric acid. The solution of the acid was in the special way fixed on prisms. For the comparison, simultaneously similar prisms were in the environment of water and without environment.

The destruction of prisms in the environment of the sulfuric acid occurred in 89 days from the moment of their immersing in the aggressive environment. On this time the sizes of cross section have decreased up to 58×58 mm. It is necessary to notice, that the sizes of cross section decreased during time of tests almost behind the linear dependence.

Fig. 1. Arrangement testing equipment with presence of an aggressive environment

Thus the area of cross section decreased according to square-law dependence. For measured deformations of concrete prisms there were constructed diagrams of their change in time (Fig. 2). Thus for the conditional zero deformations of prisms after their loading in a level 0.3 Rb are taken.

That is on the diagram increments of deformations. Apparently from the diagram of deformations of concrete prisms in the environment of the sulfuric acid about 55 days grew not quickly (up to 6Ø10-5) With the sharp increase from 55 up to 89 day (up to 165 Ø10-5). According to size of effort of axial compression and the sizes of concrete cross section of prisms the stress of prism concrete are determined. In prisms without environment and submerged the stress did not change. In the concrete of prisms with the environment of the sulfuric acid before the destruction of a stress have increased up to 39.5 MPa, thus the level of stress has increased to σ_b/R_b=0.91 (Fig. 3).

After destruction of concrete prisms in the environment of the sulfuric acid with the help of a diamond saw the cut of concrete, nearby the place of destruction was executed. Researches of concrete have shown, that traces of destruction are revealed on the surface of concrete, which directly had contact with the acid liquid environment. Internal layers of concrete had the untouched structure, corrosion processes of concrete are not revealed.

Experimental tests of beams were carried out on specially made equipment (Fig. 4 and 5). Loading was put as two concentrated forces in thirds of span, in the middle of a beam the zone of a pure bend was created. For research of influence of corrosion environments at simultaneous influence of power loading on beams specially projected baths with an internal corrosion-resistant coating were fixed. In quality of the corrosion environment the 10% solution of a sulfuric acid was also used. At change of concentration greater than the 1 % full replacement of a solution of an acid was carried out. During the change of an acid from a bath, products of corrosion of materials of a beam were removed. For measurement of deformations of the top compressed side of a beam, the concreted metal cores, which indicators with base of measurement of 200 mm were fastened, were used. Microindicators were fixed also on the stretched working armature with the help of welded to it during manufacturing special fixing agents. For measurement of deformations of armature in beams with fixed baths with the help of special metal cores indicator-comparators were fixed beyond limits of a bath. Similarly with the help of metal cores microindicators were fixed on beams - twins without corrosions environments as well. Besides it, deflections of beams with the help of the indicators fixed on special frameworks were measured.

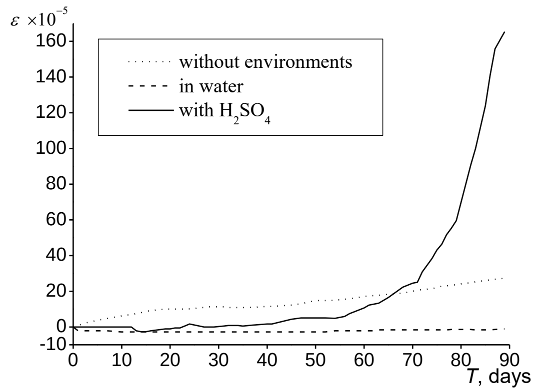

Fig. 2. Changes of deformations of concrete in time

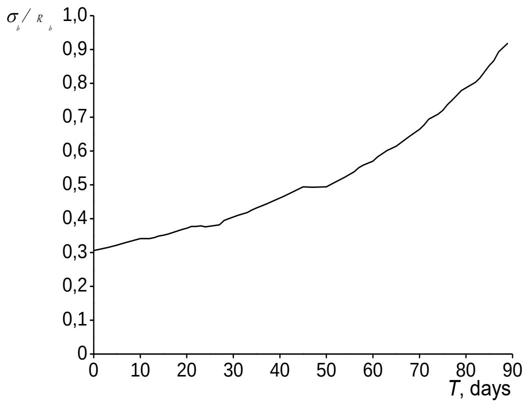

Fig. 3. Change of the relation σ_b/R_b in time

At long-term tests two beams - twins were loaded to a level 0.37 and 0.75 from destroying that is in borders of operational loadings. The invariance of long-term loading was provided with presence on the stand of test of the special spring device. Special baths for creation corrosion environments were fixed on beams, in parallel to their twins, which were under loading without environment. For the control of deformations of shrinkage in parallel with beams with base of 200 mm microindicators-comparators were established on concrete prisms.

Fig. 4. The testing equipment of beams on long-term loading

Fig. 5. A reinforced concrete beam after test for simultaneous action of power loading and corrosion environments

Experimental researches have established, that about up to 10 days the change in stress-strain state of the loaded beams both with the corrosion environment, and without it occurred approximately equally. For all beams the accelerated increase of deformations of compression in concrete and deflections is typical. In 10 days of the deformation of compression in concrete and deflections in the beams, loaded by only power factor, grew a little with the linear dependence (Fig. 6 and 7). In beams with simultaneous action of power loading and corrosion environments the nonlinear increase of deformations of the compression in concrete eventually was observed. Also deflections of this beam accrued curvilinearly. In particular intensively deflections have started to grow the in 50 days. In the same period the sharp increase of deformations of the working stretched armature has been fixed. It testifies to yielding of the armature. It was not possible to fix the exact size of deformations of armature, as measurements were carried out with the special cores removed beyond borders of the top side of a bath with the corrosion environment. Such a system of data fixing from devices gives only the qualitative picture of the change of deformations.

Physical destruction of a beam with a level of loading 0.75 M_{max} at simultaneous influence of corrosion environments and power loading has passed on 59 day. Thus deflections made f = 12.5 mm, in comparison with the initial after loading f = 6.9 mm, increment has made 5.6 mm. The beam with a level of loading 0.37 M_{max} has collapsed simultaneously with the yielding of armature on the sloping section on 79 days the deflection made f = 12.4 mm, in comparison with the initial after loading f = 2.5 mm, the increment has made 9.9 mm.

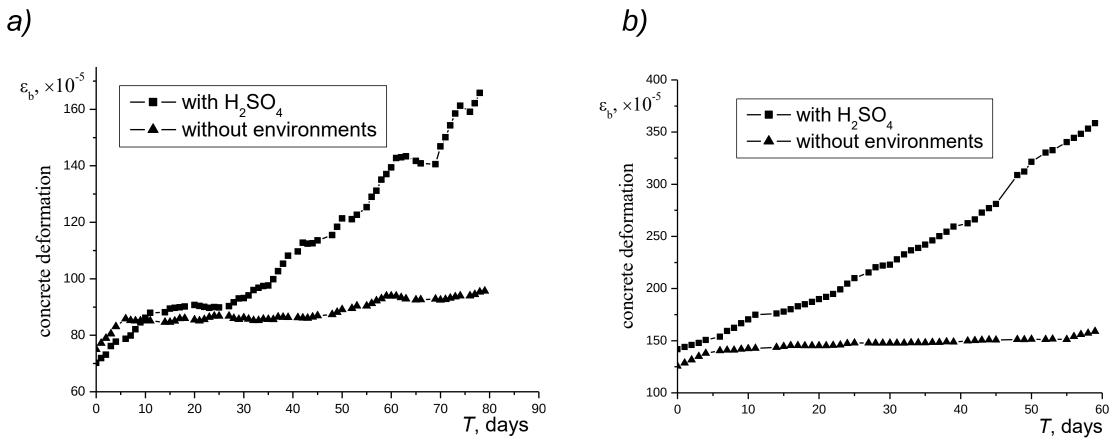

Fig. 6. Changes in time of deformations of the compressed zone of concrete of beams: a) - a level of loading – 0.37 M_{max}; b) a level of loading – 0.75 M_{max}

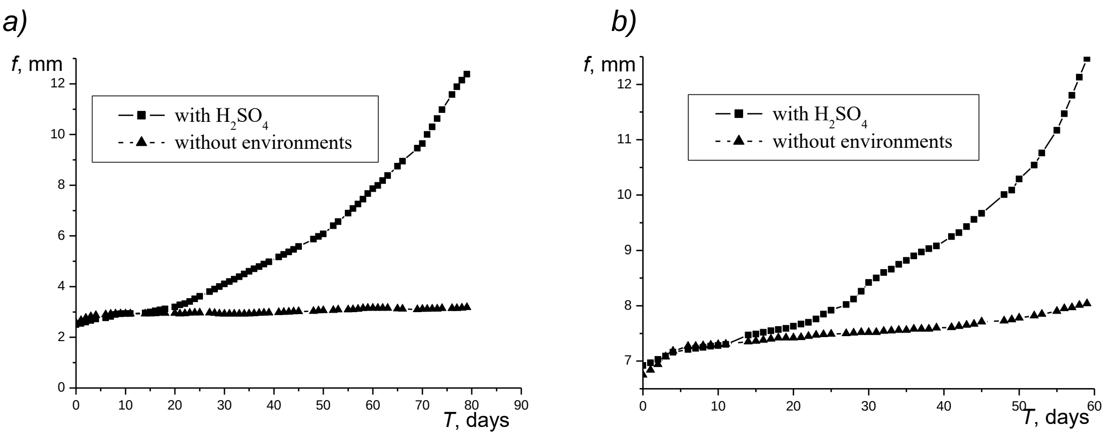

Fig. 7. Change in time of deflections of beams: a) - a level of loading – 0.37 M_{max}; b) a level of loading – 0.75 M_{max}

Deformations of shrinkage during tests have increased insignificantly and essentially could not affect the change of intense – deformed conditions of beams. During tests geometrical sizes of the cross section of a beam were constantly measured. The width and height changed according to the linear dependence. The width of the section of a beam with a level of loading 0.75 M_{max} has decreased from 100 mm up to 62 mm, and the height from 202 mm up to 172 mm, for a beam with a level of loading 0.37 M_{max} the width of the section has decreased up to 52 mm, the height-up to 167 mm.

Reduction of the sizes of section was held owing to the corrosion of concrete of a beam. The corrosion of concrete has been observed practically since the first day of the influence of aggressive environment. On the surface of concrete a white deposit - a product of chemical reaction of components of a cement stone with solutions of an acid constantly appeared. During the time of corrosion penetration in depth of section the loss of sand and road metal of concrete was observed. After the corrosion of concrete of a protective layer the corrosion of the cross-section of armature began. The intensive corrosion of the reinforcing bar has not been observed.

It is necessary to notice, that the survey of a site of the destroyed concrete of the compressed zone has shown, that corrosion of concrete occurred gradually from superficial layers in to the depth of section owing to the destruction of a surface of contact of concrete with the corrosion environment. In a place of the destruction of concrete of the compressed zone the corrosion of an internal part of concrete of a beam is not revealed. The analysis of the received results of experimental researches and verifying calculations show, that destruction of a beam has passed owing to reduction of sizes of the cross section of a beam which was in its turn caused by the corrosion of concrete. Thus fluidity of armature, and after then smashing of concrete of the compressed zone in beams with a level of loading 0.75 $M_{\max}$ and simultaneous destruction on the advanced section in beams with a level of loading 0.37 $M_{\max}$ all over again was held.

4. CONCLUSIONS

As a result of the carried out experimental researches parameters of the stress-strain state of concrete prisms and reinforced concrete beams have been received at simultaneous influence of corrosion environments and external power loading. The analysis of the received results and calculations have shown, that destruction of concrete prisms and reinforced concrete beams was held owing to reduction of the sizes of the cross sec-tion, caused in turn its by the corrosion of concrete. Absence or presence of the dam-aged anticorrosive protection of constructions at influence of operational loadings can result in destruction or emergencies. The received results of the carried out researches can be used at the analysis of a condition of reinforced concrete constructions with corrosion damages.

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