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The influence of the damaged reinforcing bars on the stress-strain state of the rein-forced concrete beams

Zenoviy Blikharskyy[1], Taras Shnal[1], Roman Khmil[1]

[1]Place Civil Engineering, Department of Roads and Bridges, Lviv Polytechnic National University; Ukraine,
79013, Lviv, S. Bandera Street 12.
e-mail: zergxs@ukr.net

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Abstract
The article is devoted to the overall view of experimental research of reinforced concrete beams with the simultaneous influence of the corrosion environment and loading. The tests have been carried out upon the reinforced concrete specimens considering the corrosion in the acid environment, namely 10 % H2SO4 that have been taken as a model of the aggressive environment. The beams are with span equalling to 1,9m with different series of tensile armature, concrete compressive strength and different length of impact of corrosion (continuous and local). The influence of simultaneous action of the aggressive environment and loading on strength of reinforced-concrete beams has been described. For a detailed study of the effect of individual components there was suggested additional experimental modelling of the only tensile armature damage without concrete damage. It will investigate the influence of this factor irrespective of the concrete.

1. Introduction

During exploitation, especially in conditions of the aggressive environment, reinforced concrete constructions tend to receive defects and damages which influence their stress-strain state and worsen considerably their technical characteristics. This concerns both the damages of concrete and the damages of armature. Mainly damages lessen the cross section of constructions. Though, apart from that, the physical-mechanical characteristics of the material can change (FAGERLUND G. 1997, BRÓZDA K., SELEJDAK J. 2016). Particularly this refers to concretes with the large water-cement ratio w/c > 0,5….0,6 (MOSKVIN V.M., 1980). The pores in such concretes tend to join together and transform into capillaries. Through the capillaries created in such a way the aggressive environment damages not only the outer surface of the concrete construction, but also penetrates inside the cuts, changing the physical-mechanical characteristics of concrete. Besides, the aggressive environment, through the capillaries created in the concrete, reaches the armature surface causing its corrosion. It is worth mentioning, that the additional factor of the armature corrosion is the penetration of the aggressive environment to the armature through cracks (VERBETSKYY G.P. 1990, SUCHAN M.1998, GAWRON M. et al. 2015). Moreover, the cracks in concrete can be of technological character as well as caused by the loading action. The mentioned factors witness about the topicality of the research of the damages' influence upon the stress-strain state of reinforced concrete constructions (KLIMENKO Y.V. 2010, PODOLSKI B. et al. 2000). It is also important to mention that reinforced concrete constructions receive damages and defects being in exploitation under the influence of loading and the least of all under their own weight. This demands to carry out additional research of the loading action simultaneously with the obtained defects and damages in the stress-strain state of reinforced concrete constructions.

2. Experimental research of the corrosion damages upon the reinforced concrete beams

Corrosion damages are the most widely spread defects of reinforced concrete constructions that are exploited in the aggressive environment. Nevertheless their influence upon the stress-strain state of reinforced concrete constructions, especially taking into account the loading influence, has not been studied sufficiently. In connection with the mentioned facts, experimental researches was carried out within the laboratory work with the general amount of 22 reinforced concrete beams which were under the simultaneous influence of loading and aggressive environment (KHMIL R.Y. 2003, VASHKEVYCH R.V. 2005). Reinforced concrete beams were under the loading 0,3; 0,5; 0,7 from the limit load which corresponded to the maximal bearing capacity of beams. 10% sulfuric acid solution (H_2SO_4) has been used as an aggressive environment which has been placed in special containers of attached above beams. The loading has been applied in the third part of the beams' span in the form of two focused forces (Fig. 1, 2).

Fig. 1. The overall view of the beam during testing
Sources: (KHMIL R.Y. 2003)

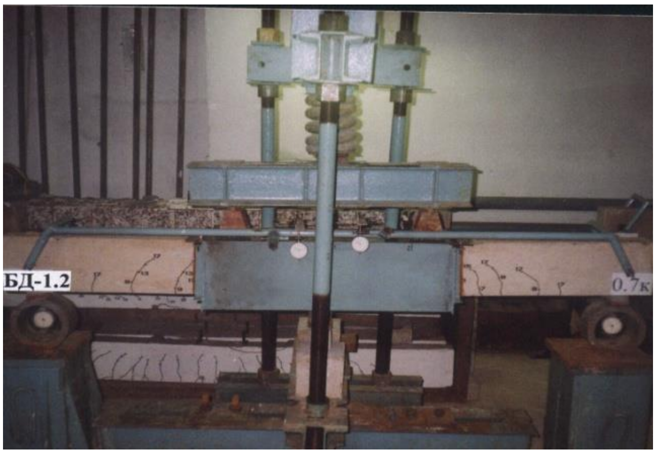

Fig. 2. The overall view of the beam during testing (VASHKEVYCH R.V. 2005).

The reinforced concrete beams were of 2100x200x100 mm size with 3 series of reinforcement in the tensile area (2∅12, 14, 16 A-III (A400)) accordingly, and in compressed area 2∅5 Bp-1, and with transverse reinforcement ∅5 Bp-1 placed with step of 75...100 mm. The concrete prism strength was made 44…53.6 MPa.

The deformations of concrete, armature and beams' deflections have been measured by gauges (Fig. 3).

Fig. 3. Gauges position on of the beam during testing.

The overall view same specimens after testing are presented on Fig. 4, 5.

Fig. 4. The overall view of the beam after testing
(KHMIL R.Y. 2003)

Fig. 5. The overall view of the beam after testing
(VASHKEVYCH R.V. 2005)

The analysis of the results of the experimental research shows that owing to the influence of the aggressive environment the concrete and armature received significant corrosion damages. As a result of obtained damages of concrete a reduction of the cross section occurred. Moreover, the increase of the concrete, armature and bends' deformations was witnessed. It is worth noticing that in beams, where the concrete damage did not cause a full destruction of the armature protective layer, its corrosion was not been observed. In beams where the protective concrete layer was destroyed the corrosion of the tensile armature as well as the reduction of its cross section was observed. This was accompanied by a significant increase of the beams' concrete and armature deformation and finally led to the exhaustion of their bearing capacity. Additionally, it is worth mentioning that the armature corrosion took place unequally (not simultaneously) along the perimeter – only from the side of the destroyed protective layer. From the inner side owing to the dense attachment of concrete the corrosion of armature did not take place (Fig. 6).

a)

b)

Fig. 6. The overall view of the armature corrosion:
a) a small corrosion intensity; b) a bigger corrosion intensity

Though in such conditions it was impossible to observe which factor – the concrete corrosion or the corrosion of armature – caused a more significant influence upon the change of the stress-strain state of reinforced concrete beams. In connection with this there arises the question of the research of the influence of armature damage (without the concrete damage) upon the stress-strain state of reinforced concrete constructions.

3. The experimental modelling of the influence of armature damage upon the reinforced concrete beams

The experimental modeling of the influence armature damage influence upon the reinforced concrete beams.

For the experimental research of the influence of armature damage upon the strained-deformed state of reinforced concrete constructions there has been produced a series of beams by 2100 x 200 x 100 mm size containing 16 items. Out of them 12 reinforced concrete beams were with the tensile armature ∅ 20 A400, 2 beams with ∅ 16 A400, and 2 beams with ∅ 22 A400. In the middle part of reinforced concrete beams span there has been arranged an open part of the tensile armature 300 mm in size It was foreseen that devices for measuring armature deformations and applying mechanical damages of armature will be attached to this part with the aim to reduce its cross section. It was foreseen to measure the mechanical damages of tensile armature by the way of drilling holes inside the cross section. Moreover, it was foreseen to drill holes in the reinforced concrete beams with the tensile armature ∅ 20 A400 ($As=31{,}4mm^2$), ∅ 3mm, 4mm and 5 mm, which will model the reduction of the cross section of the tensile armature by 6 mm^2, 8 mm^2 and 10 mm^2 consequently the damage of the tensile armature will be by 19%, 25% and 32% correspondingly. The damage of the tensile armature ∅ 20 A400 by 32% will correspond to the area of the tensile armature ∅16 A400I ($As=20{,}1\ mm^2$) of the produced reinforced concrete beams. Testing of reinforced concrete beams, where the armature will be damaged, is foreseen to be carried out under the influence of loading on beams on the level 0,3; 0,5; 0,7 and 0,9 from the limit load which corresponds to the bearing capacity of reinforced concrete beams with the tensile armature ∅20 A400.

The suggested experimental modeling of the tensile armature damage will allow researching the influence of its factor upon the change of parameters of the stress-strain state of reinforced concrete beams. The results of the carried out testing will give the possibility to suggest the methods of calculating of reinforced concrete beams taking into account the influence of armature damage in order to secure their safety and durability.

4. Summary and conclusion

The experimental research carried out in laboratory conditions has allowed establishing the influence of the concrete and armature corrosion upon the parameters of the strained-deformed state of reinforced concrete beams under loading. It has been established that corrosion damages lead consequently to the reduction of the cross section of both concrete and armature of beams which under loading influences upon the increase of deformations of concrete, armature and bends of beams and finally leads to the exhaustion of bearing capacity of reinforced concrete beams. To study the peculiarities of influence of armature damage upon the strained-deformed state of reinforced concrete beams it has been suggested carrying out research with the experimental modelling of the damaged working armature of reinforced concrete beams under loading.

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受損鋼筋的影響 對鋼筋混凝土梁的應力應變狀態的影響

關鍵詞
腐蝕
損傷，電樞，
應力應變狀態
鋼筋混凝土
光束

摘要
本文致力於鋼筋混凝土梁的實驗研究的總體視圖，同時影響腐蝕環境和負荷。考慮到酸性環境中的腐蝕，即已經作為侵蝕性環境的模型的10%H 2 SO 4，對鋼筋混凝土試樣進行了試驗。梁的跨度等於1,9米，具有不同系列的拉伸電樞，混凝土抗壓強度和不同長度的腐蝕衝擊（連續和局部）。 已經描述了侵蝕性環境和負載對鋼筋混凝土梁的強度的同時作用的影響。對於各個部件的影響的詳細研究，建議僅有的沒有混凝土損壞的拉伸電樞損傷的附加實驗模型。 它將調查這個因素的影響，而不考慮混凝土。