Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(10) (2022) 963-966
DOI: 10.22060/ceej.2020.18324.6836

Assessing the compressive strength and permeability of protective coating layers applied to CFRP sheets, under harsh environmental conditions

R. Rahbari , M. Naderi*

Department of Civil Engineering, Faculty of Engineering, International University of Imam Khomeini, Qazvin, Iran

ABSTRACT: In this paper, the results of the effect of exposure of CFRP strengthened and coated 150mm concrete cubes to harsh environments are presented. The harsh environment included: wet-dry, freeze-thaw and different temperature change cycles. It is anticipated that the intended environmental conditions harm the performance of the CFRP sheet by reducing the compressive strength of concrete and, at the same time, increase its permeability. The test specimens used in this investigation included 150mm CFRP strengthened concrete cubes with and without protective coating layers. The methods employed were "Cylindrical Chamber" permeability, mortar capillary water absorption and mortar compressive strength tests. The results obtained tend to indicate that the proper selection of protective coating has a significant impact on the performance of the CFRP-coated concrete cubes that were under harsh environmental conditions. Application of suitable coatings onto the CFRP layer caused respective reductions of about 28%, 34%, and 36%, on the permeability of specimens after being exposed to specified wet-dry, freeze-thaw and temperature change cycles.

Review History:

Received: Apr. 26, 2020
Revised: Jul. 16, 2020
Accepted: Jul. 17, 2020
Available Online: Aug. 22, 2020

Keywords:

Protective coating layer
CFRP
Permeability
Capillary absorption
Cylindrical chamber
Harsh environment

1. INTRODUCTION

Nowadays, fiber-reinforced polymer sheets have been known to be one of the most effective composite materials that can be used to increase the strength and durability of concrete structures. Owing to the lightweight, corrosion resistance, high tensile strength and ease of application without any interruption of the services, the use of these sheets has become very widespread [1]. Despite the desirable properties of these materials, it should be noted that their durability and performance exposed to extreme environmental conditions appears to be a critical issue because of water penetration; in recent years, some organizations in Iran have opted for the use of FRP sheets for the strengthening and protection of their concrete structures that are located in the areas exposed to extreme environmental conditions. Most of the research performed on the performance of FRP sheets is limited to the evaluation of the bond strength of these sheets under acute environmental conditions. Therefore, the study of their permeability as the most important indicator of structural durability has been ignored. In this study, the permeability of CFRP sheets covering concrete cubes, under harsh environmental conditions has been investigated. In order to increase the long-term durability of these sheets under harsh environmental conditions, protective coating layers were applied to the CFRP sheets exposed surfaces. The purpose of this paper is to evaluate the performance of these protective coating layers as a low-cost solution to increase the durability, performance and service life of these sheets. Therefore, the CFRP-covered concrete specimens, with and without protective coating layers, were exposed to acute environmental conditions, including freeze-thaw, wet-dry and temperature changes cycles. Noting the permeability as the most important determining factor for the long-term behavior of concrete structures [2], the permeability of these specimens was evaluated using the "Cylindrical chamber" method. Capillary water absorption and compressive strength of each protective coating layer were also measured at the end of the cyclic conditions mentioned above.

*Corresponding author's email: Profmahmoodnaderi@eng.ikiu.ac.ir

2. METHODOLOGY

As mentioned earlier, the permeability of the prepared specimens was measured using the "Cylindrical Chamber" method [3]. Before evaluating the capillary water absorption of the coating layers, they were cured for 7 days, and then they were subjected to freeze-thaw, wet-dry and temperature changes cycles. According to EN480-5 [4], capillary water absorption is obtained from Equation (1):

$$C = \frac{M_j - M_0}{1600} \tag{1}$$

In Equation (1), M_j is the specimen mass after the time required for absorption (gr), M_0 is the specimen mass after seven days of curing (gr), C is the capillary adsorption at any

Figure 1. Changes in total penetrated volume of water in 5 hours compared with those belonging to specimens without protective coating.

Mortar type	Combination	Mixing ratio
Cement-based with fiber mortar	Cement-based adhesive	6
	Fiber	0.01 (0.3%) volume fraction)
	Water	1
Epoxy-based waterproof mortar	Epoxy-based adhesive	4.5
	Resin	1
Cement-sand with adhesive mortar	Cement	1
	Sand	3
	Epoxy based adhesive	0.5
	Water	0.5
Air entrained cement-based fiber mortar	Cement-based adhesive	6
	Fiber	0.01 (0.3% volume fraction)
	Water	1
	Air content	0.012

time (gr/mm^2). To determine the compressive strength of the mortars employed, their 50 mm cubic specimens were tested after 28 days of standard curing.

In order to establish suitable protective coating layers, various materials were tested to combine them to create a mortar with the desired properties. After performing different experiments on mortars, four types of mortars with mixtures shown in Table 1 were selected. The first type of protective coating layer was a cement-based mortar with a polypropylene fiber that was used under temperature change conditions. For the wet-dry conditions, two types of mortar were employed which were a waterproof epoxy mortar and a cement-sand mortar with epoxy adhesive. For the freeze-thaw conditions, cement-based air-entrained mortar with fibers was used as one of the protective coating layers.

3. RESULTS AND DISCUSSIONS

3.1. Capillary water absorption

According to the results obtained, the amount of capillary water absorbed by different mortars under laboratory conditions are as follows: fiber mortar = 3900 (gr/m^2), epoxy-based waterproof mortar=3200 (gr/m^2), cement sand with adhesive=3600 (gr/m^2) and fiber mortar with entrained air=4300 (gr/m^2). When the mortar specimens were exposed to 150 cycles of harsh environmental conditions, the increase in the amount of capillary absorbed water for the waterproof epoxy mortar increased by 46%, and the same respective value for the fiber mortar was seen to be 3%. Although the epoxy-based waterproof mortar had the lowest capillary absorption under laboratory conditions, but under the influence of wet-dry cycles, its water absorption increased dramatically.

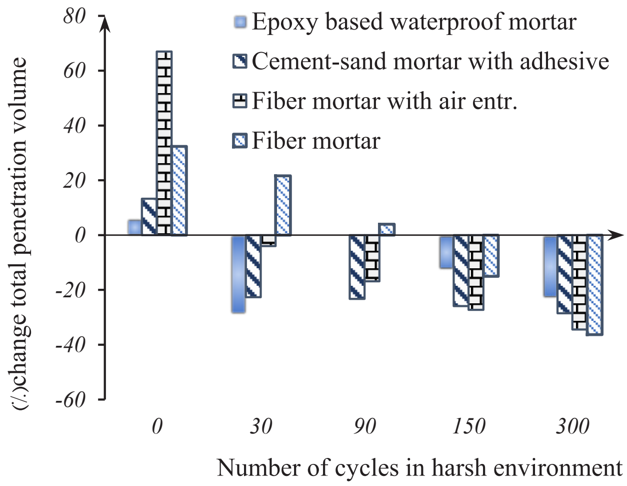

Table 1. Mix properties of coating layers

3.2. Compressive strength tests

The compressive strength of fiber mortar after exposure to 150 and 300 temperature change cycles decreased by about 6.4% and 14.4%, respectively. The results also showed that, the compressive strength of fiber mortar with entrained air after undergoing 150 and 300 cycles of…. decreased by 5.5% and 8%, respectively. After 150 and 300 cycles of wet-dry conditions, the compressive strength of epoxy-based waterproof mortar dropped by 19.8% and 53.5%, compared to the respective values obtained under laboratory conditions.

3.3. Results of “Cylindrical Chamber” tests

In order to evaluate the performance and efficiency of the proposed protective coating layers, the percentage changes in the total penetrated water volume into the specimens are compared with the respective values belonging to the specimens without protective coating layer, in Figure 1.

As shown in Figure 1, the total volume of permeated water into the specimens with epoxy base waterproof coating in the laboratory (cycle 0) is 6% higher than the respective value belonging to the specimen without protective coating. The results have shown that exposure to the wet-dry, freeze-thaw and temperature changes cycles has negative effects on the performance of the CFRP sheet by increasing its permeability. Two types of protective coatings were applied to the surface of CFRP sheets in order to increase their durability under wet-dry cycles. The first one was an epoxy-based waterproof mortar. Figure 1 shows the changes in the total penetrated volume of water into the specimens after different cycles of exposure to the harsh environment, with and without coatings. It can be seen from Figure 1 that the penetrated volume of water into the specimen with the protective coating of epoxy base waterproof, after 300 cycles, has been reduced by 22%. The cement-sand with adhesive mortar coating applied to the surface of CFRP sheets was found effective in the wet-dry cycles, as it improved the permeability with respect to the uncoated ones. After 300 cycles, the penetrated volume of water into the specimen with this protective coating has been reduced by 28%, compared with uncoated ones. CFRP sheets specimens with fiber mortar coating under temperature change showed a decrease of 36% in the total penetrated volume of water after 300 cycles. The air-entrained cement-based fiber mortar increased durability in comparison with the specimens without any coating when exposed to freeze-thaw cycles. The reduction in the penetrated volume into the specimen with this protective coating was approximately 34% after 300 cycles.

4. CONCLUSIONS

In this paper, permeability, water absorption and compressive strength of protective coating layers of CFRP sheets under harsh environments are presented. Compared with the control specimen kept at normal laboratory conditions, the exposure of unprotected CFRP sheets to the wet-dry, freeze-thaw and temperature changes cycles recorded an increase in their penetrated volume of water. Freeze-thaw cycles had the most adverse effect on the performance of CFRP sheets. Using fiber mortar coating with an overall total thickness of 10 mm was demonstrated to give better protection under different temperature changes. Protecting CFRP sheets by a 10 mm-thick layer of cement-sand mortar with adhesive reduced the penetration of water into the CFRP sheets under wet-dry cycles. Protection of the CFRP sheets with air-entrained cement-based fiber mortar may be recommended for use under the freeze-thaw situation because this coating reduces the penetration of water and thus increases the durability.

REFERENCES

[1] Sharp, B.N., 1996. “Reinforced and prestressed concrete in maritime structures”. Proceedings of the Institution of Civil Engineers-Structures and Buildings, 116(3), pp.449-469.

[2] Banthia, N., Biparva, A. and Mindess, S., 2005. “Permeability of concrete under stress”. Cement and Concrete Research, 35(9), pp.1651-1655.

[3] Naderi, M., 2010. “Determination of concrete, stone, mortar, brick and other construction materials permeability with cylindrical chamber method.”. Iran Registration of Patent in Companies and industrial property Office, Reg. N. 67726.

[4] BSI, 2005. *BS EN 480-11*: Admixtures for concrete, mortar and grout–test methods–determination of air void characteristics in hardened concrete.

HOW TO CITE THIS ARTICLE

R. Rahbari , M. Naderi, Assessing the compressive strength and permeability of protective coating layers applied to CFRP sheets, under harsh environmental conditions, Amirkabir J. Civil Eng., 53(10) (2022) 963-966.

DOI: 10.22060/ceej.2020.18324.6836