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Durability of FRP Sheets and Wrapped Specimens with them in Tidal Zone of Persian Gulf

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ABSTRACT: In this paper in order to the evaluation of Fiber Reinforced Polymer (FRP) sheets' durability in less time, marine simulator was designed and built similar to the tidal zone of Persian gulf. In addition of tidal modeling, cyclic radiation of UV, high temperature and humidity were other parameters that were controlled in this environment. The changes in the mechanical properties of Carbon Fiber Reinforced Polymer (CFRP) and Glass Fiber Reinforced Polymer (GFRP) sheets, bonding strength of sheets to concrete and the effect of wrapping were investigated by putting the specimens in the marine environment. Ultimate strength and elastic modulus of CFRP sheets decreased by 2% and 18%, respectively. These values were 28.8% and 17% for GFRP sheets, respectively. Bonding strength reduction of FRP sheets to concrete was 13.9% and 15.9%, respectively for CFRP and GFRP sheets. Also ultimate strength of confined specimens was decreased by 11.6%, 41% and 34%, respectively by wrapping with one layer of CFRP, one and two layers of GFRP after exposure. The reduction value of modulus of plastic region was 17%, 18% and 12% for these specimens respectively.

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1- Introduction

Despite the all positive properties of Fiber Reinforced Polymer (FRP) sheets, it is necessary to notify that the durability of them in the outdoor environments is still under investigation as well, and the necessity for more researches, especially in the harsh environments which there are a lot of destructive factors, is being felt [1]. Micelli et al. placed the wrapped columns by Glass Fiber Reinforced Polymer (GFRP) sheets in 15% salt solution for 120 days and observed that the ultimate strength reduction by 27% which this value was almost three times more than the reduction by wrapping with Carbon Fiber Reinforced Polymer (CFRP) [2]. Bae and Belarbi proceeded to investigate the effects of environmental conditions on long-term properties of Reinforced Concrete (RC) columns strengthened with CFRP and GFRP sheets .In this study significant reduction of the ultimate load and the ductility of the samples which were strengthened by GFRP after exposure of saltwater was observed [3]. In the research conducted by Gharachorlu and Ramezanianpour on confined specimens by CFRP and GFRP, the most reduction of strength was related to the wrapping by GFRP sheets in a high temperature environment combined with wet-dry cycles of saltwater [4].

These researches indicated the reduction in durability of FRP sheets in exposure to the aggressive environments, such as high humidity, saltwater and high temperature. The main objective of this paper is to investigate the performance of GFRP and CFRP sheets in the marginal region of the southern sea of Iran (tidal zone of Persian Gulf). This area had extraordinarily harsh conditions that might be due to the presence of chloride ions in seawater, high temperature and humidity, the tidal phenomenon and also solar UV radiation.

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2- Methodology

Durability evaluation of FRP sheets was carried out by preparing three types of specimens. First type was CFRP and GFRP sheets. In these specimens, tensile properties of sheets were investigated. Second type was concrete prisms, which FRP sheets were applied on the surface of them. Pull-Off test was carried out on these samples to evaluate bonding strength between FRP sheet and concrete. Third type was concrete cylinders which wrapped by FRP sheet. Mechanical properties of these samples under compressive loading were studied. These three types of specimens were put in two different environmental conditions and results were compared with each other. First environment was normal condition in laboratory and second one was marine condition similar to tidal zone of Persian Gulf. The temperature and humidity of the interior simulator were set as 40 °C and 68%, respectively. Salt concentration was set as 36.6 grams per liter too. The samples were placed in the simulator environment for 3,000 hours and they experienced 125 cycles of saltwater and UV radiation.

3- Results and Discussion

The results of tensile and bonding tests after exposure were summarized in Tables 1 and 2, respectively. The marine condition had negative effect on tensile behavior of FRP sheets. Tensile strength was reduced by 2% and 28.8%, respectively, for CFRP and GFRP sheets. Also reduction in bonding strength was observed by 13.9% and 15.9% for CFRP and GFRP sheets.

Table 1. Result of tensile test for FRP sheets after exposure

FRP type	Tensile strength (MPa)	Tensile modulus (GPa)
CFRP	335.1 (-2%)*	36.7 (-18%)*
GFRP	135.3 (-28.8%)*	12.9 (-17%)*

*The values in the parenthesis are the percentile ratio of increase/ decrease of the FRP properties when compared to the results of the laboratory specimens.

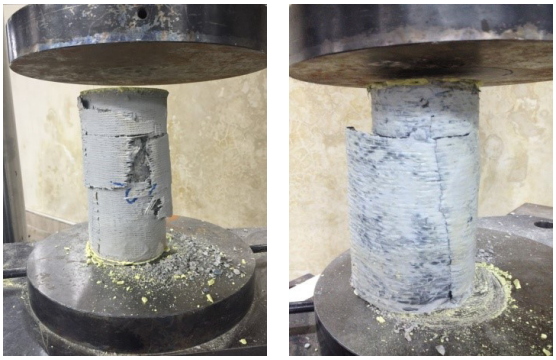
Table 2. Results of Pull-Off test after exposure

FRP type	Bonding strength (MPa)
CFRP	2.27 (-13.9%)*
GFRP	2.5 (-15.9%)*

*The values in the parenthesis are the percentile ratio of decrease of the bonding strength when compared to the results of the laboratory specimens.

Ultimate strength and ultimate axial strain were increased by 60% and 167%, respectively, after wrapping by one layer of CFRP in laboratory condition. These values were 64% and 219% for wrapping by two layers of GFRP and 28% and 155% for wrapping by one layer of GFRP, respectively. After exposure, these values changed to the 53% and 121% for wrapping by on layer of CFRP, 42% and 154% after wrapping with two layers of GFRP, 16.5% and 126% by confining by one layer of GFRP, respectively.

Mode of failure revealed that CFRP sheet, was failed parallel to fiber (matrix rupture), but in confine cylinder by GFRP, mostly, the rupture was happened perpendicular to fiber (fiber rupture). So it was concluded the exposure could not any significant effect on carbon fiber, but had a negative effect on glass fiber (Figure 1).



a b

Figure 1. a) Fiber rupture in GFRP-wrapped specimen b) Matrix rupture in CFRP-wrapped specimen

4- Conclusions

1. After marine exposure, ultimate strength and modulus of CFRP sheets decreased by 2% 18%, respectively. These values were 28.8% and 17% for GFRP sheets. So the durability of CFRP sheet was more than GFRP in marine condition.
2. Marine environment caused reduction in bonding strength. 13.9% and 15.9% for CFRP and GFRP to the surface of concrete. All of failure modes were concrete failure.
3. The compressive behavior of specimens showed 11.6%, 41% and 34.3% reduction in ultimate strength of wrapped samples by one layer of CFRP, one and two layers of GFRP, respectively. So confined specimens with one layer of CFRP was more durable, and also applying two layers of GFRP sheets caused improving in durability.
4. The comparison between modes of failure revealed GFRP failure was fiber rupture but mode of failure in CFRP was matrix rapture. So it was conclude that marine had more negative effect on glass fibers.

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