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Flexural capacity of concrete beams strengthened using GFRP sheet after seawater immersion

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Abstract

Structures built in the marine environment need to be carefully designed, due to the possibility of chloride ion penetration into the concrete. Among these attempts, FRP was evaluated as one of the best methods to deal with the problem because FRP does not corrode even in marine environment. This study presents the results of the application of GFRP sheet for strengthening of the concrete beams. A series of specimen of reinforced concrete beams with dimension 15×20×330 cm were cast. The samples were tested under different duration of the immersion of sea water. Beams were immersed in sea water for 1 month (BF_1), 3 months (BF_3) and 6 months (BF_6). Three specimens were prepared control beam without immersion to sea water (BF_0). The results indicated that the flexural capacity of BF_1, BF_3, and BF_6 when compared to that of BF_0 decreased by 2.65%, 2.73% and 3.78% respectively. The decreasing was caused by the weakening of the bonding capacity GFRP due to the influence of sea water immersion.

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Keywords: sea water; GFRP; concrete beams; flexural capacity

1. Introduction

Concrete structures that are not protected or close to the sea may be affected by corrosion, than if maintenance or preventive repairs is not done on the structure, it may cause the collapse [1]. FRP was evaluated as one the best method to deal with the problem because FRP does not corrode even in marine environment [2]. The repair of damaged

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reinforced concrete members by externally bonding of fibre reinforced polymer (FRP) was becoming increasingly popular in the construction industry. Flexural strengthening of concrete beams accomplished by epoxy bonding the FRP material were bonded to the beam on the tension area. Several studies conducted on concrete structures with FRP have been done intensively, Z. G. Guo reported that using FRP composites were successfully used for strengthening of existing reinforced concrete structures because of their superior properties [3], Banthia reported that using GFRP composite materials in the area interested in the beams and plates, the increase of the moment capacity [4]. Rose demonstrated that the strengthening of the corroded steel reinforced concrete increased ductility and ultimate strength [5]. Alam conducted research using GFRP as reinforcement flexural in reinforced concrete beams. The result indicated is an increasing in load up to 75.13 % [6]. Sultan et al, conducted research the effect marine environment to the concrete beams Strengthened Using GFRP Sheet**.** The result of this study also showed that for areas closer to the sea has a greater effect in terms decreasing flexural capacity of the beam [7]. However further study needed to clarify the behavior of beams with GFRP sheet reinforcement influenced by the sea water immersion.

2. Specimen and test set up

2.1. Specimen

A series of concrete beams that to be strengthened with dimension 150 x 200 x 3300 mm were prepared with the parameters of the bonding area of GFRP-S. Glass fibre used in this study was type G of Fibre-wrap system. Material properties of the glass fibre and the epoxy resin is shown in table 1. Glass fiber sheet as showed in Fig. 1 is most commonly used due to its relatively lower cost compared to the other FRP materials.

Fig. 1. Glass fibre sheet.

Table 1. Material properties of GFRP and epoxy resin

Test Specimen	GFRP (type SHE-51A)	Epoxy resin (tyfo S)
Tensile strength (MPa)	575	72.4
Modulus Young (GPa)	26.1	3.18
Laminate Thickness (mm)	1.3	--

Figure 2 shows the reinforcement details of the beam specimens. It is consisted of two 6 mm diameter bars at the top and two 14 mm diameter bars at the bottom. Shear reinforcement consisted of 10 mm diameter stirrups at 200 mm spacing. The concrete beams were cured 28 days before the application of the GFRP sheet.

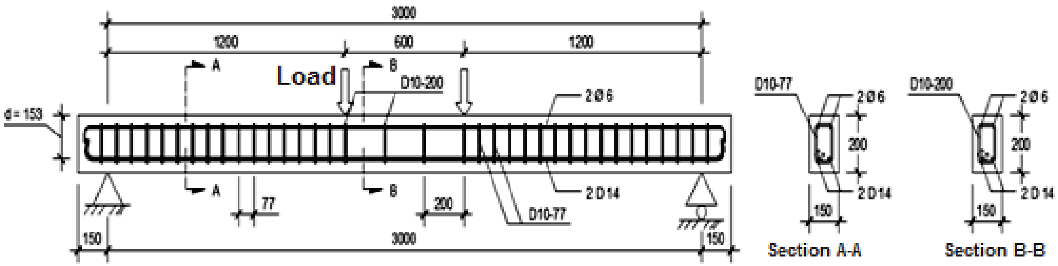


Fig. 2. Detailing of specimen (beam with strengthened use GFRP Sheets).

2.2. Immersion tank

All specimens were immersed in a tank containing seawater for one month (BF1), three months (BF3) and six months (BF6). Three specimens were prepared control beam without immersion to sea water (BF0). Fig. 3 shows a tank containing seawater the immersion of the specimens.

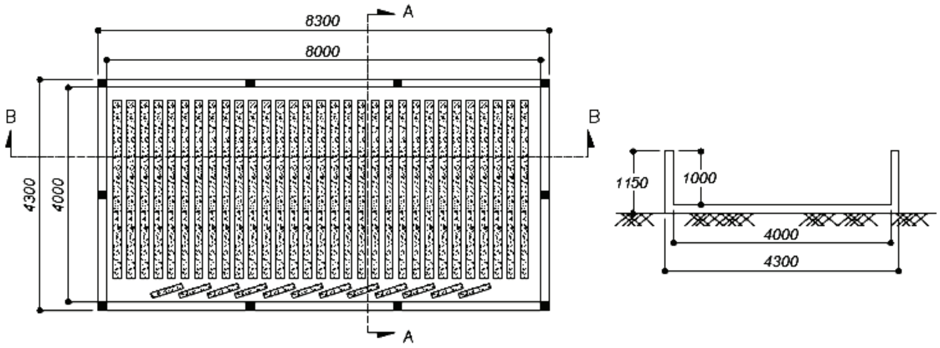
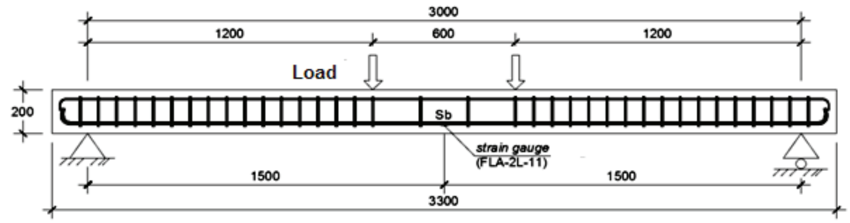


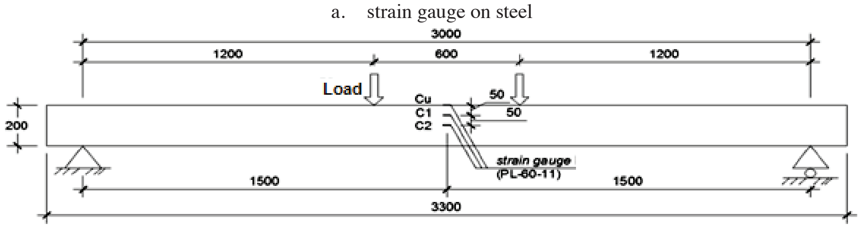
Fig. 3. Immersion tank.

2.3. Test set up

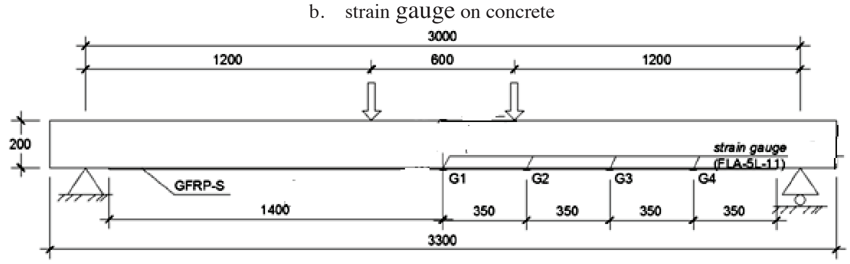
Installation of strain gauge on the steel reinforcement in the pull as much as 2 pieces, the concrete strain gauge mounted 3 pieces are in press area of the test specimen, the test specimen area high ½ and ¼ area high on the middle span of the test specimen, the GFRP-S mounted strain gauge the installation of 4 pieces from the middle position of the test specimen and spread on each 35 cm distance to the tip of the test specimen is shown in Fig. 4.



a. strain gauge on steel



b. strain gauge on concrete



c. strain gauge on GFRP-S

Fig. 4. Position of strain gauge on reinforcing steel, concrete and GFRP-S.

The beam specimens were tested under two point loads in a loading frame of 1000 kN capacity, as shown Fig 4. Each specimen was instrumented by strain gauges on concrete at extreme compression , on steel bar and on the GFRP sheet. The deflection and loading were measured using LVDT and a load cell. The load was applied gradually with constant 0.05 mm per second up to failure. All instrumentation was connected a computer based data logger for data recording.

Flexural capacity in this study can be obtained using Equation 1:

$$Mu = 0.8019 + 0.6P \quad (1)$$

Equation 1 is used in this study, obtained from the equation flexure. This equation applies to the beam dimensions 15×20×300 m.

3. Result and Discussion

3.1. Maximum load capacity

From the table 2 it can be seen that the average maximum load beams BF0, BF1, BF3 and BF6 is 43.10 kN, 41.93 kN, 41.89 kN and 41.42 kN respectively. A Decrease in strength of the beams after immersion in sea water to the beams without immersion is 2.74% the immersion 1 month, 2.81% the immersion 3 month and 3.90% the immersion 6 month.

Table 2. Maximum load capacity of the beams

Test Specimen	Averages maximum load *(kN)*	Decrease in the strength of beam without immersion (%)
BF0	43.10	
BF1	41.93	2.74
BF3	41.89	2.81
BF6	41.42	3.90

3.2. Load and deflection relationship

Fig. 5 show the load-deflection relationship of the specimens BF0, BF1, BF3 and BF6, respectively. It can be observed that that the four types of charts have the same flexural behavior up to failure where the deflection BF0 have tended to be larger than the BF1, BF3 and BF6.

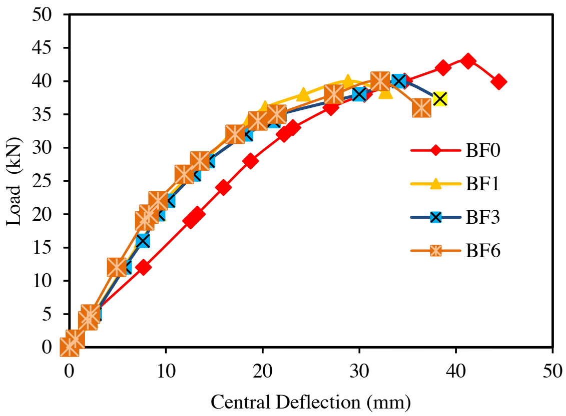


Fig. 5. Measured load versus mid span deflection for all beams.

3.3. Load and GFRP-S strain relationship

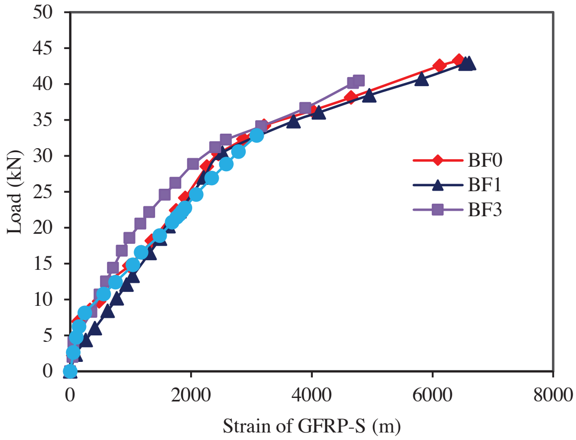


Fig. 6. Load strain relationship of GFRP-S.

Fig. 6 shows the GFRP-S strain on each beam. Decrease strain of GFRP-S on the beam BF1, BF3 and BF6 compared BF0, 22.37%, 22.83% and 23.27%, respectively. This indicates that after sea water immersion, capacity of the beam decreases..

3.4. Flexural capacity

In Fig. 7 it can be seen that the flexural capacity of the beams will decrease with the time immersion. This show that the immersion time will affect flexural capacity of the beams. Flexural capacity of the beams BF0, BF1, BF3 and BF6 each is 26.66 kNm, 25.96 kNm, 25.94 kNm and 25.66 kNm. The decrease flexural capacity on the beams BF1, BF3 and BF6 compared BF0, 2.65%, 2.73% and 3.78% respectively.

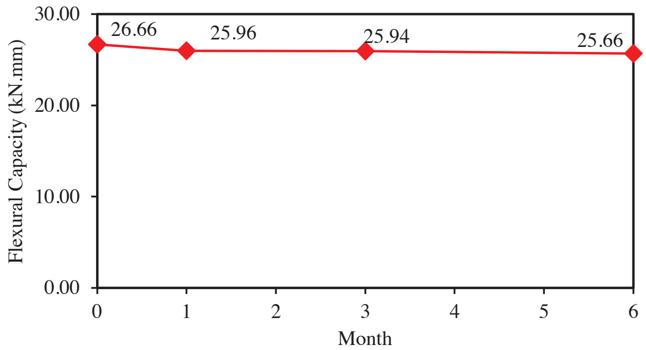


Fig. 7. Flexural capacity of the beams after immersion time.

3.5. Failure mode

Fig. 8 shows the beams pattern of failure B0, BL3, Bl6 and BL12. It can be seen that failure of beams patterns show tendencies similar pattern is debonding failure. Debonding failure that occurs causes the propagation of cracks from the bottom propagate rapidly to the top up and knocked out of the beam. Failure occurs suddenly after GFRP-S apart, so that the beam failed. GFRP-S apart starting at the crack tip propagate to the end of the GFRP-S.

BF0

BF1

BF3

BF6

Fig. 8. Failure mode of the beams

4. Conclusion

The ultimate load capacity of beam strenghtened GFRP-S without immersion, immersion one month, three months and six months respectively is 43.10 kN, kN 41.93, 41.89 and 41.42 kN kN, here seen a decrease in strength after the beams immersion with sea water to the test beam without Immersion. The decrease flexural capacity on the beams BF1, BF3 and BF6 compared BF0, 2.65%, 2.73% and 3.78% respectively.

Acknowledgements

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