The Effect of Sea Water on Effectiveness Of GFRP-S Bonding on The Reinforced Concrete Beam Submersion For 1 Year

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Abstract*— Several studies have shown that there is a debonding failure between GFRP-S and concrete. The research aimed at analyzing effectiveness of GFRP-S bonding capacity on the reinforced concrete beams submersed in the sea water within a period of one year. The testing method used a monotonic loading with two point loads at the constant ramp actuator speed 0.05 mm/sc until the beam underwent the failure. In which method the beams were flexural tested on two simple restraints until beams underwent the failure. The testing was carried out with the total of two specimens concrete beams with 15 cm x 20 cm x 330 cm dimensions which were submersed in the sea water of simulation pool for 1 year with the concrete quality f'c 25 MPa. Strengthening of GFRP-S coated on the tensile area of concrete beams with 15 cm x 280 cm dimensions to compare flexural concrete beams capacity. As for the observed data during testing include load crack, ultimate load, deflection, and failure modes. The research results indicates that as the ultimate loading beams and GFRP-S bonding capacity on the beams submersed in the sea is smaller than the beams submersed in the simulation pool. The decrease of the load capacity of the GFRP-S beams submersed in the sea water for 6 months and 12 months, the bonding effectiveness of GFRP-S beams submersed also decreases as much as 7.37%, and 7.64% on the bonding effectiveness of GFRP-S which are not submersed. Failure mode that occurs is a debonding failure between GFRP-S and concrete.

Key Words- Effectiveness of bonding, strengthening of GFRP-S, sea water, concrete beam.

I. Introduction

In the world of construction, concrete has an important role as the main material commonly used. Tihis is due to the advantages of the concrete it self, including the ease of processing, high compressive strength and economic value in its manufacture and maintenance.

The structure of the concrete in accordance with the age of the plan will experience a decrease in strength even a failure. In addition, environmental influences, changes in structural functions or changes in implementation loads that are inconsistent with the original design plan also result in structural failure. If that happens, there are two things that can be done, that is to dismantle the old structure or the failure structure and then replace it with a new structure, or to reinforce it with the technology that has developed in the construction field of Glass Fiber Reinforced Polymer (GFRP) [1].

GFRP (*Glass Fiber Reinforced Polymer*) is a structutal strengthening dan repairing material that has been used extensively, not only limited to building construction but can also be used in other types of construction [2]. Construction in the field of civil engineering is exposed on land such as building construction in general and some are exposed in marine environments such as jetty construction on docks and bridge construction.

Along with the development of technology in the field of construction, the construction of concrete structures also experienced very rapid development.The construction of structures in difficult regional areas and the marine environment has been very much done.

Construction of concrete structures in extreme environtmental areas such as coastal areas will result in a decrease in strength and even damage if no maintenance and repairs are carried out. This is due to the presence of chloride in sea water.

Structures that are generally located in coastal areas are very vulnerable to failure or degradation of strength because of the corrosion that occurs in reinforcement. With the advantage of GFRP as a non-metallic material that is corrosion resistant despite being in the marine environment in the long term, in this study used GFRP as an external strengthened and protection in overcoming the degradation of structural strength as well as increasing the strength of structures that have degraded the strength because of the corrosion in the reinforcement [3].

In general, GFRP is placed on the part of the structure that begins to show a decrease in performance, that is by attaching or wrapping GFRP on the weak part, so that GFRP is able to support the structure to stay in the expected position. However, there is a weakness in the application of this material where in some studies it has been obtained that the failure that occurs in concrete using GFRP reinforcement is the debonding failure where GFRP is detached from the concrete.

However, research related to the problem of GFRP bonding in structures that are in the marine environment in the long term is still lacking. Tihsi research discusses concrete by GFRP which are soaked with sea water for 1 year.

The research aimed at analyzing effectiveness of GFRP-S bonding capacity on the reinforced concrete beams submersed in the sea water within a period of one year.

II. BASIC THEORY

Based on previous research, there are several studies that serve as the basic of reference in preparing this research. Several studies have shown that there is a debonding failure between GFRP-S and concrete.

The key problem of retrofitting the structure with FRP is the problem of bonding between concrete and FRP [4]. The reinforced beam with FRP will increase the stiffness, the yield limit and the limit strength of the reinforced concrete beam. This suggests that the use of FRP sheets can strengthened reinforced concrete beams that have been corroded efficiently thus maintaining structural durability and beam behavior [5]. Flexural strengthened of reinforced concrete beams with GFRP increased load up to 75.13% [6].

GFRP-S has been used extensively, not only limited to new structures but also used as reinforcement materials in old structures [7]. The location placement of concrete beams with GFRP-S strengthened in extreme environments such as the marine environment also influences the value of load capacity produced. The addition of GFRP-S can increase the capacity of structures affected by the marine environment [8]. As for the column elements when exposed in the marine environment, there is also an increase in compressive strength along with increasing time of exposure of columns [9].

An increase in the mean flexural strength of 84.21% for concrete beams with GFRP strengthening when compared with no GFRP reinforcement for normal conditions without interaction with the marine environment. While the condition of concrete beams that interact with the marine environment also experienced a strong increase in the flexural strength value varies along with increased interaction time on the marine environment [10]. There was a decrease in the moment capacity of GFRP-S beams immersed for 1, 3 and 6 months of non-immersed GFRP-S beams by 2.65%, 2.73%, and 3.78%, respectively. This decrease in moment capacity is due to the weakening of GFRP-S bonding capacity that is influenced by sea water immersion [11].

III. RESEARCH METHOD

Tools

Steel reinforcement strain gauge
GFRP strain gauge
Concrete strain gauge
LVDT *(Linier Variable Displacement Tranducer)*
Static Loading Frame

Materials

Portland composite cement
The fine coarse agregat (sand and crushed stone) are from Bili-bili
Wire and reinforcement of PT. Barawaja
GFRP glass fiber type Tyfo SHE-51A Fyfe.Co.LLC
Tyfo S Epoxy Type adhesive material production Fyfe.Co.LLC
The water used for the mixture is clean water

Testing Method

Figure 1. Testing Method of Research

The testing method used a monotonic loading with two point loads at the constant ramp actuator speed 0.05 mm/sc until the beam underwent the failure. the observation of the test beam continues to be monitored visually, especially on the development of cracks that occur due to the increase of load, also to the behavior of the collapse that occurred. The loading is done until the press area on the beam is destroyed and has reached the ultimate load. Flexural testing is carried out when a block sample of GFRP-S 6 and 12 months old has been interacted with the marine environment. At the time of bending testing also held deflection measurements by installing LVDT at the bottom of the beam and examination of crack patterns that occur by using phi gauge. For strain on the diagonal and longitudinal bars, as well as the concrete surface, a few strain gauges are installed in certain positions.

This research is descriptive research using survey method. This research tries to find out the groundwater condition in the residential area around the mining area which is finally analyzed based on the safe result of groundwater utilization in order to avoid adverse environmental impact in the end. In this study, the survey conducted is a field survey that aims to take samples of residents' well water at some sample points.

Specimen Design

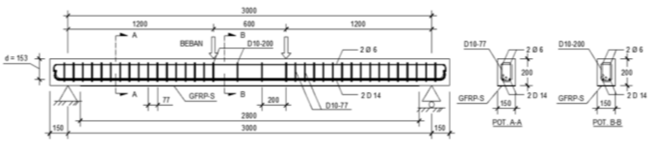


Figure 2. Specimen Design of Concrete

The testing was carried out with the total of two specimens concrete beams with 15 cm x 20 cm x 330 cm dimensions which were submersed in the sea water of simulation pool for 1 year with the concrete quality f'c 25 MPa.

Strengthening of GFRP-S coated on the tensile area of concrete beams with 15 cm x 280 cm dimensions to compare flexural concrete beams capacity. As for the observed data during testing include load crack, ultimate load, deflection, and failure modes.

For installation of GFRP-S used Wet Lay-up method. The adhesive material used in this study is also a product of Fyfe Co under the name Tyfo S component A and component B. The GFRP-S mounting process consists of five stages: the first stage is the surface finishing of the concrete. The second stage is cutting GFRP-S according to the size where in this case used GFRP-S as long as 3 meters as much as 1 layers. The third stage is mixing epoxy which in this case is used Tyfo S component A and component B. The fourth stage is mixing epoxy and GFRP-S. The fifth stage is the attachment of GFRP-S to the specimen using the wet-layup method.

IV. Results and Discussion

Distribution of GFRP-S Strain

From the table 1 it can be seen that the largest GFRP-S strain on a GFRP-S beam test object without immersion was 7127 μ. Along with the GFRP-S beam immersion time, there was a decrease in the GFRP-S beam strain value submersion against the non-immersed GFRP-S beams on the 6-month and 12-month GFRP-S beams with a strain value of 5469 μ and 5441 μ. This indicates that the capacity of the submersion beam strain will decrease due to the influence of sea water which causes the rapid debonding process to occur.

Table 1. Strain of GFRP-S and Beam Load on All Specimens BF

Variation	Testing Result			
	P_y (kN)	ε_y (μ)	P_u (kN)	ε_u (μ)
$BF_{0\text{-}1}$	32,31	2886	43,26	6442
$BF_{0\text{-}2}$	31,24	2976	42,33	6842
$BF_{0\text{-}3}$	33,65	4494	43,73	8098
BF_0	**32,40**	**3445**	**43,10**	**7127**
$BF_{6\text{-}1}$	39,12	5640	41,93	6947
$BF_{6\text{-}2}$	36,25	1939	40,92	3992
BF_6	**37,69**	**3789**	**41,42**	**5469**
$BF_{12\text{-}1}$	31,58	3023	40,62	5391
$BF_{12\text{-}2}$	36,58	2378	42,06	5492
BF_{12}	**34,08**	**2700**	**41,26**	**5441**

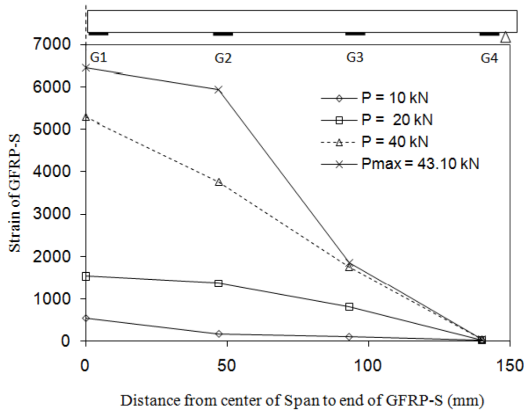


Figure 3. Distribution of GFRP-S Strain on the specimen BF_0

In Figure 3 for the non-submersion GFRP-S beam (BF-0) and submersion beam BF6 and BF12 , it can be seen that as the load increases, the strain capacity on GFRP-S increases, especially in the position of G1 and G2 located in the center of the beam, which receives the biggest load. This is because when the load yield GFRP-S has suffered a large enough strain until the beam failures.

In Figure 4 for the non-submersion GFRP-S beam (BF-0) and submersion beam BF6 and BF12 , it can be seen that as the load increases, the strain capacity on GFRP-S increases, especially in the position of G1 and G2 located in the center of the beam, which receives the biggest load. This is because when the load yield GFRP-S has suffered a large enough strain until the beam failures.

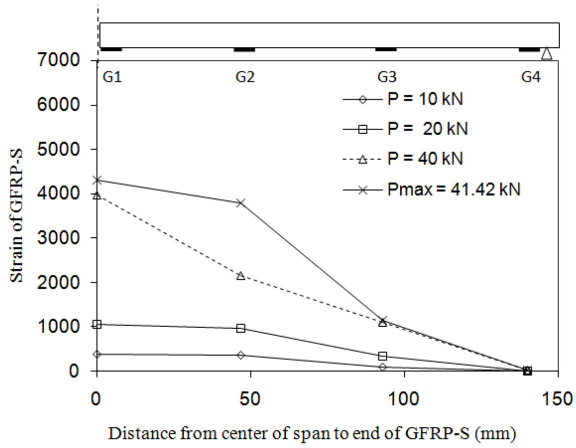


Figure 4. Distribution of GFRP-S Strain on the specimen BF_6

In Figure 5 for the non-submersion GFRP-S beam (BF-0) and submersion beam BF6 and BF12 , it can be seen that as the load increases, the strain capacity on GFRP-S increases, especially in the position of G1 and G2 located in the center of the beam, which receives the biggest load. This is because when the load yield GFRP-S has suffered a large enough strain until the beam failures.

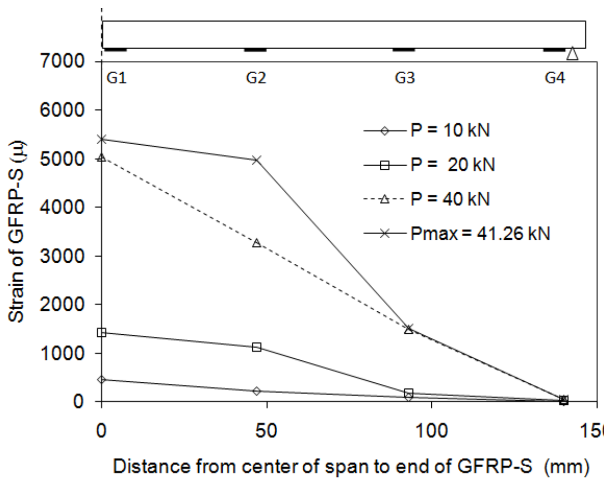
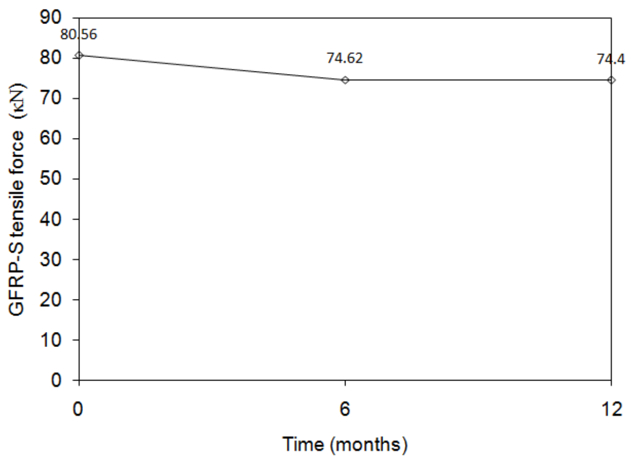


Figure 5. Distribution of GFRP-S Strain on the specimen BF_{12}

Debonding failure occurs at the stage indicated by the strain distribution of the strain curve to be gorizontal at the beginning of the failure of the bond which means that the reinforcement can not trabsfer the load so that the load is transferred to GFRP-S. A strain gauge that is far from the center of the span reads the strain along with increasing loading. This means the transfer of the load on the GFRPS shifts along the surface of the GFRP with the concrete until the debonding failure occurs.



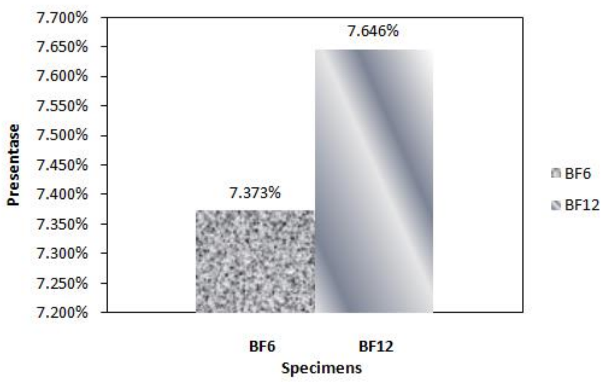


Figure 7. Histogram decrease bonding capacity of the specimens BF_6 and BF_{12} against

Figure 6 and 7 , show that there is a decrease in the bonding capacity of the BF_6 and BF_{12} specimens against BF_0 which is characterized by a decrease in tensile force on GFRP. The value of tensile force acting on GFRP resulting from BF_0, BF_6 and BF_{12} is 80.56 kN, 74.62 kN and 74.40 kN. From the tensile force, it can be concluded that there is a significant decrease in bonding capacity from BF_6 and BF_{12} specimens against BF_0. The percentage decrease in bonding capacity of the tensile force on GFRP from BF_6 and BF_{12} specimens against BF_0 were 7.37% and 7.64%. This decrease in GFRP tensile force caused a decrease in GFRP-S adhesion after being affected by sea water submersion.

V. CONCLUSION

Based on the results of the analysis and discussion of the effect of sea water submersed on the flexural capacity of reinforced concrete beams with the strengthening of GFRP-S can be concluded :

- There was a decrease in the bonding capacity of 6 months (BF6) and 12 months (BF12) immersion specimens against the specimen without immersion as much as 7.373% and 7.646%. This decrease in bonding capacity causes debonding of fast beams to occur. The failure model that occurs in all GFRP-S beams is the debonding failures between concrete and GFRP-S.
- The strain capacity of the submersion beams will decrease due to the influence of sea water which causes rapid debonding to occur.
- The ultimate loading beams and GFRP-S bonding capacity on the beams submersed in the sea is smaller than the beams submersed in the simulation pool.

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