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Bottom Structure Repair and FRP Carbon Installation to Increase The Capacity and Performance Of Jetty (Case Study: Jetty Structure Repair – Pax Ocean, Batam)

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ARTICLE INFO	***ABSTRACT***

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Non-Destructive Testing (NDT)

This study focuses on the repair of substructure and the installation of carbon FRP to enhance the capacity and performance of a pier, with a case study at Pax Ocean Batam. A pier, which is infrastructure extending into the sea and often exposed to chloride-containing seawater, is prone to concrete corrosion that can shorten the structure's lifespan. To ensure the safety and operational continuity of the pier, structural evaluation through field inspections, structural testing, analytical modeling, and repair recommendations is necessary. The study employs a quantitative research method, using primary data obtained from field surveys and secondary data from related documents. Non-Destructive Testing (NDT) using Ultrasonic Pulse Velocity (UPV) was conducted to assess the quality of the concrete and the extent of cracking. The findings indicate that the concrete quality is generally in the good to moderate range, though some areas require repair. Repairs were focused on areas with damage, such as delaminated concrete and cracking. To improve the structural capacity, reinforcement with Carbon Fiber Reinforced Polymer (CFRP) was applied. The repair recommendations include strengthening the damaged slabs, beams, and columns to ensure the safety and optimal performance of the pier.

1. Introduction

Jetty is one of the infrastructure buildings that juts into the sea uprightly. The use of a jetty forms a bridge to meet the needs of mooring ships in shallow water areas; the above is because applying a jetty is more economical with the depth required for boats to moor. Various parts comprise a concrete jetty, piles, headstocks, centre and edge beams, deck planks, and top deck. Their exposure circumstances vary based on their location within the structure (Osuji et al., 2020). Due to its location in the sea, the jetty structure is vulnerable to chloride-containing marine water, which is the primary cause of deterioration since the ions seep through piles, slabs, and beams. Regardless of whether a suitable cover is present, this chloride infiltration progressively permeates the concrete, causing corrosion in the reinforcements (Patil, 2019). This is the primary cause of the degradation, which shortens the structure's service life as it becomes weaker. To keep the owner informed about the state of the jetties, periodic structural assessments and monitoring of these structures are necessary.

Indonesian government aims to build an effective maritime service programme, which includes infrastructure and facilities. Facilities are equipped to accommodate all required materials and have sufficient delivery trucks in the (Krisdiyanti et al., 2023). On the contrary, infrastructure is a jet that needs to be positioned for big ships to fit the local requirements and be able to learn (Iqbal Nur, 2020). Many jetties in Indonesia's remote regions still need to meet the basic requirements for vessels operating on local sea highways. Therefore, these aircraft need to improve capacity and performance (Ratnawati, 2019). As a case study and research topic, one jetty used in this study is Batam Jetties, owned by PT. Pax Ocean. One way is to strengthen and repair the current jetty at the lowest possible construction cost rather than establishing a new one, which would need to be paid for demolition and repair.

The vast industrial area makes the Riau Islands one of the largest industrial cities in Indonesia. In addition to the manufacturing industry, the Riau Islands has many shipyard industries, manufacturing, piping, and oil and gas support industries. The shipyard industry in the free trade area and the free port of Batam is the largest in Indonesia (Azmi, Fadilatul Nurul, 2023). The Riau Islands, Especially Batam, has a shipyard for repairing and maintaining ships managed by a private entity. The strategic location of Batam City is an opportunity to expand this industry to various countries around the world. Pax Ocean, ASL, Batammec, KTU, etc., are Batam City Shipyards managed by private entities that repair and care for ships for specific purposes. These ports also have adequate and verified facilities (Leko, 2020).

The Pax Ocean Group's First Heritage Dock Jetty is a berth for ships that will be repaired or maintained periodically or for boats under construction. Due to the relatively old age of the building for 23 years, the structure of the First Heritage Dock Jetty needs to be tested for adequacy related to the adverse effects of deterioration, which causes a weakening of the structural components. Of course, the Jetty structure must be able to comply with building safety regulations by current regulations and standards to ensure the continuity of the Pax Ocean Group's business operations in general. So, checking the reliability of buildings, identifying risks, and simulating the capacity of the First Heritage Dock Jetty is very important to ensure security and avoid adverse risks that can threaten the safety of building users and the building itself. This final report contains data from inspections and field surveys, structural testing, structural modelling analysis, and recommendations related to the repair and strengthening of the Jetty structure that can be carried out.

This case study was done at Pax Ocean Batam, where the company has three yards, Dok Warisan Pertama, Graha Tri Saka, and Nanindah Mutiara. The Jetty area to be repaired is the Jetty that is in Dok Warisan Pertama. At the top of the Jetty, a crane is planned to be added to support Jetty activity that will help the work in the area. Seeing from the age of the jetty and the early design of the Jetty requires care and additional strengthening of the structure. It starts with improving the crack located on the sides and under the jetty area and performing protection and strengthening additions on pile pipe, beam, and slab using carbon fiber-reinforced polymer (CFRP). The purpose of writing this article is to evaluate and analyse the needs that need to be done on Jetty so that it can help the various activities required by this Jetty.

2. Literature Review

The Ultrasonic Pulse Velocity Test is conducted to determine the crack depth and describe the concrete quality of the structure. UPV tests are used to determine the current density of concrete and also measure the depth of cracks on the concrete surface (Oleh, 2023). The ultrasonic waves used are mechanical waves with a frequency above 20 Hz. Wave speed differences indicate a change in concrete strength in the UPV test, if concrete force drops, it is a signal that concrete power decreases on the contrary, an increase in speed indicates the strength of concrete increases (Rada & Aji, 2019). In general, this tool is referred to as Portable Ultrasonic Non-Destructive Indicating Tester. The working principle of the PUNDIT tool is to emit waves from the transducer (transmitter) through the concrete core layer and subsequent waves are received by the receiver. The PUNDIT device consists of a head unit, a transmitter probe, and a receiver probe. This tool records the speed of the ultrasonic pulse and the travel time between the transmitter and receiver probes according to the distance between the probes. The speed of the ultrasonic pulse will give an idea of the density of the concrete, the denser the concrete is, the higher the compressive strength of the concrete can be correlated, and vice versa. The process of wave propagation from the transmitter to the receiver will be faster if the concrete has a good density (small voids). In the implementation of the UPV Test on the Building Concrete Structure at the Graha Dok Warisan Jetty Structure, random sampling tests were carried out on concrete material. The number of UPV test points carried out is a total of 22 test points, 17 points on the Deck Slab and 5 points on the Jetty Head section.

Concrete Structure Reinforcements divided into 2 parts, Fiber-Reinforced Polymer and Grouting (injection). Structural review, structural analysis, and reinforcement and execution methods and materials are some of the methods that can be used to structural reinforcements, one of which is FRP. FRP is also considered as an inexpensive external reinforcing alternative that can improve structural performance (Harahap et al., 2024). Generally, FRP are mounted on the part of the structure by applying CFRP layers in the area affected to strengthen the structure and ensure it stays in the desired position (Nurul et al., 2020). It is not only used for building buildings but can also use for various other types of construction. As it is made of non-metallic materials that are non-corrosive, FRP can be used to strengthen old concrete that has lost its performance and to reinforce new concrete to lower crossings and reinforce them. At present, engineering structures often incorporate a variety of fiber-reinforced polymers (FRP) such as carbon fiber-reinforced polymer (CFRP), glass fiber-reinforced polymer (GFRP), basalt fiber-reinforced polymer (BFRP), and aramid fiber-reinforced polymer (AFRP). These materials offer diverse properties suited to specific applications in industries ranging from aerospace and automotive to construction and sports equipment (Hu et al., 2020), but in this study, carbon fiber-reinforced polymer (CFRP) was used as an external reinforcement on the slab, beam, and column on the jetty.

Grouting is a technique of injecting grout material into concrete plates to maintain stability and restore elevation of decreasing plates. Grouting work is done using a mixture of cement and water-based grouts, sometimes with or without aggregate addition (Junianto et al., 2019). Apart from that, grouting is also a method for filling voids in porous concrete structures and adding castings due to imperfect casting, Mortar fillets for machine foundations, as machine mounts, bridge foundation bearing holders, precast concrete manufacture, and covering large cracks. The grouting material used in grouting work can be in the form of suspended and/or chemical materials. The suspension material commonly used is cement and if necessary, bentonite or similar materials are used. Water as a liquid material used as a mixture of cement, must be free from silt, organic matter and other elements that can reduce the quality of the mixture. While the cement material used is Portland Cement, type I which does not contain other ingredients and meets the requirements specified in SII-3-1981.

3. Method

In this study, the authors use quantitative research methods where this method contains knowledge that uses data in the form of numbers as a reference in analyzing the description of what is to be known. In quantitative research methods there are two ways to obtain information or data. Primary data is data obtained and can be based on survey in the field directly by the researcher. Primary data must correspond to the conditions in the field which is the real proof of a data. Data from this study is to find out the general description of the existing condition of the Jetty structure through a series of field inspections and tests, obtain the results of evaluating the condition of the capacity of the existing structure of the building through structural analysis in accordance with applicable loading standard, and Recommend methods that can be carried out for maintenance. Secondary data on this study includes a map of the location of the research on this research carried out on the Dok Warisan Pertama.

The object of this work is the PaxOcean Jetty Structure Assessment, Tanjung Uncang – Batam, Riau Islands. This case study is located in Batam with the address Jl. Brigadier General Katamso, Tj. Uncang, Kec. Batu Aji, Batam City, Riau Islands.

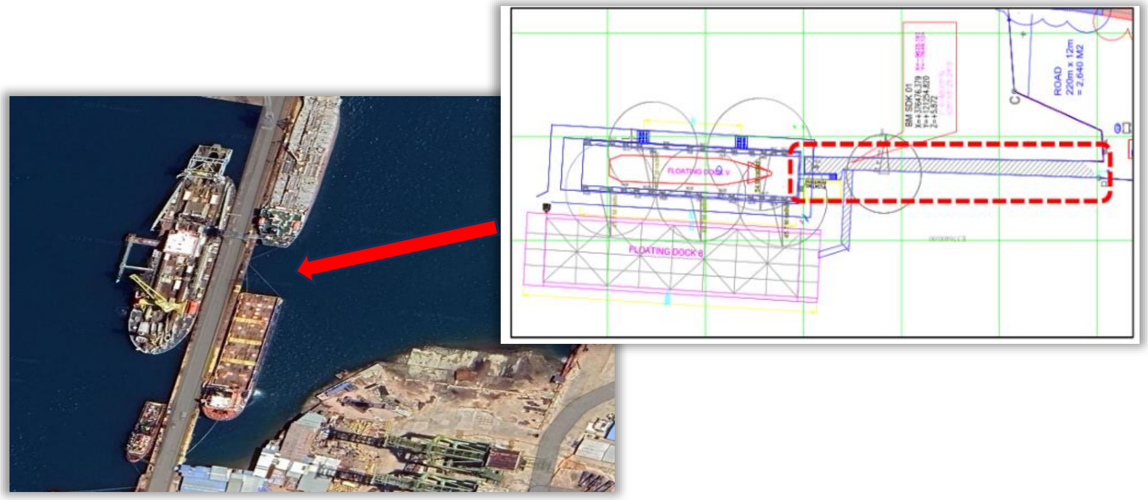

Figure 1. Layout of Jetty Dok Warisan Pertama

Field inspection and testing involve a comprehensive process to evaluate the condition and structural integrity of a building. Initially, the building's condition is assessed visually and documented with a digital camera. Structural design is verified using manual measuring tools, and reinforcement configurations are checked with a Covermeter. Non-destructive testing (NDT) is then conducted using an Ultrasonic Pulse Velocity tool to determine material density in column concrete structures, while the Half Cell Potential and Carbonation Tests, utilizing a 5% Phenolphthalein solution, assess the likelihood of corrosion and carbonation in concrete columns, beams, and floor slabs. Additionally, destructive testing involves sampling concrete slabs with the Coredrill method to obtain cylindrical test objects, which are then analyzed at Sucofindo's central laboratory to estimate compressive strength. Test points are determined by the Sucofindo inspector and agreed upon by both parties. The results from visual inspections, NDT, and destructive tests are recapitulated and processed to compare against applicable standard values. This data is used to model the building with structural analysis software, evaluating its reliability and operability under existing conditions, while considering load factors and combinations according to relevant loading regulations.

4. Result and Discussion

The following is a recapitulation of the concrete test results of the deck slab and jetty head structure using the Ultrasonic Pulse Velocity Test method on the Graha Dok Warisan Jetty structure. The results of the analysis are in the form of a classification of concrete quality (grade) based on the provisions of BS 13311-92 which is presented in the form of a percentage graph based on the test points and the estimated value of the compressive strength of the concrete according to the type of structural element.

Table 1. Recapitullation of Structural Concrete Classification of Buildings at Graha Dok Warisan Jetty Structure based on Ultrasonic Pulse Velocity Test

No	Object	Identification			Average Direct Velocity [m/s]	Concrete Classification*				Description
		Element	Position	STA		Excellent (>4500 m/s)	Good (3500-4500 m/s)	Medium (3000-3500 m/s)	<3000 m/s Doubtful	
1	JETTY PAXOCEAN	Deck Slab	Right Side	+010	3111	-	-	√	-	Medium Concrete
2			Left Side	+018	2682	-	-	-	√	Doubtful Concrete
3			Right Side	+040	3490	-	-	√	-	Medium Concrete
4			Center	+060	3280	-	-	√	-	Medium Concrete
5			Left Side	+080	3305	-	-	√	-	Medium Concrete
6			Right Side	+090	3872	-	√	-	-	Good Concrete
7			Center	+100	3125	-	-	√	-	Medium Concrete
8			Left Side	+110	3596	-	√	-	-	Good Concrete
9			Right Side	+125	3263	-	-	√	-	Medium Concrete
10			Left Side	+142	3519	-	√	-	-	Good Concrete
11			Right Side	+160	3393	-	-	√	-	Medium Concrete
12			Center	+180	2975	-	-	-	√	Doubtful Concrete
13			Right Side	+190	3254	-	-	√	-	Medium Concrete
14			Right Side	+210	3440	-	-	√	-	Medium Concrete
15			Center	+230	3110	-	-	√	-	Medium Concrete
16			Right Side	+270	3146	-	-	√	-	Medium Concrete
17			Left Side	+275	3333	-	-	√	-	Medium Concrete
18		Jetty Head	Left Side	+016	3394	-	-	√	-	Medium Concrete
19			Left Side	+010	4210	-	√	-	-	Good Concrete
20			Left Side	+115	4171	-	√	-	-	Good Concrete
21			Right Side	+250	3644	-	√	-	-	Good Concrete
22			Right Side	+175	3576	-	√	-	-	Good Concrete

With the following graph:

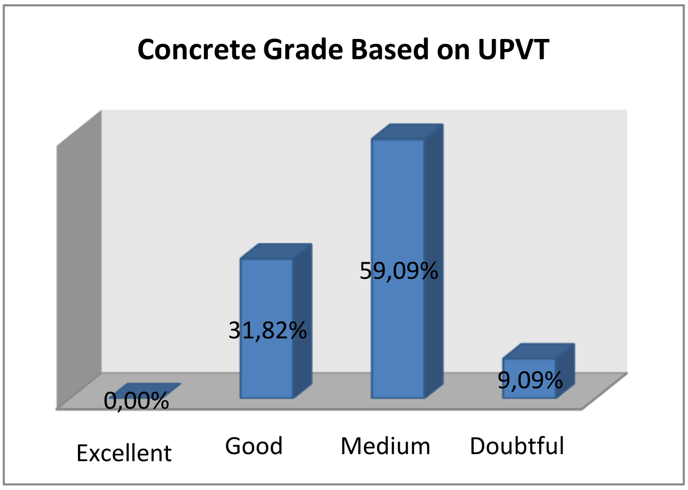

Figure 2. Classification of concrete based on ultrasonic wave propagation rate

From the 20 data points of Ultrasonic Pulse Velocity Test carried out in sampling on column, beam, and floor slab components, it can be seen in the graph of Concrete Classification in Building Structures at Graha Dok Warisan Jetty Structure in accordance with BS 13311-91: Concrete Quality Grading Based on Direct Velocity, by sampling it can be seen that the quality (grade) of structural concrete materials is generally in the Good and Medium criteria. The following is a recapitulation table of the estimated compressive strength of concrete based on the results of the UPV Test on the structural elements of the Airnav Building Jetty Structure Graha Dok Warisan.

Table 2. Recapitulation of Structural Concrete Quality Value at Graha Dok Warisan Jetty Structure based on Ultrasonic Pulse Velocity Test

No	Object	ID Number			Average Direct Velocity [m/s]	Poisson Ratio	Density (Kg/m³)*	Ec (Mpa)**	Compressive Strength***	
		Element	Position	STA					Mpa (N/mm²)	Kgf/cm²
1	JETTY PAXOCEAN	Deck Slab	Right Side	+010	3111	0,15	2320	21267,03	20,47	246,68
2			Left Side	+018	2682	0,15	2320	15803,50	11,31	136,22
3			Right Side	+040	3490	0,15	2320	26761,68	32,42	390,62
4			Center	+060	3280	0,15	2320	23644,01	25,31	304,91
5			Left Side	+080	3305	0,15	2320	23999,52	26,07	314,15
6			Right Side	+090	3872	0,15	2320	32947,72	49,14	592,08
7			Center	+100	3125	0,15	2320	21462,71	20,85	251,24
8			Left Side	+110	3596	0,15	2320	28419,43	36,56	440,51
9			Right Side	+125	3263	0,15	2320	23390,41	24,77	298,40
10			Left Side	+142	3519	0,15	2320	27204,72	33,50	403,66
11			Right Side	+160	3393	0,15	2320	25297,57	28,97	349,05
12			Center	+180	2975	0,15	2320	19444,55	17,12	206,22
13			Right Side	+190	3254	0,15	2320	23261,12	24,49	295,11
14			Right Side	+210	3440	0,15	2320	25997,48	30,60	368,63
15			Center	+230	3110	0,15	2320	21252,68	20,45	246,35
16			Right Side	+270	3146	0,15	2320	21743,38	21,40	257,86
17			Left Side	+275	3333	0,15	2320	24403,80	26,96	324,82
18		Jetty Head	Left Side	+016	3394	0,15	2320	25306,96	28,99	349,31
19			Left Side	+010	4210	0,15	2320	38939,02	68,64	826,98
20			Left Side	+115	4171	0,15	2320	38225,18	66,15	796,94
21			Right Side	+250	3644	0,15	2320	29171,08	38,52	464,12
22			Right Side	+175	3576	0,15	2320	28101,71	35,75	430,72

Note :
* Concrete Density based on actual data of Core Drill testing
** ASTM C597 – 09 Standard Test Method forPulse Velocity Through Concrete
*** ACI 318 Building Code Requirements for Structural Concrete

With the results of the recapitulation of concrete quality as follows

Table 3. Concrete Strength UPV Test

JETTY PAXOCEAN		Concrete Strength based on UPV Test (Estimation)		
		Criteria	Mpa	Kg/cm²
CONCRETE	Deck Slab	Minimum	11,31	136,22
		Maximum	49,14	592,08
		Average	**26,49**	**319,21**
	Jetty Head	Minimum	28,99	349,31
		Maximum	68,64	826,98
		Average	**47,61**	**573,61**

It can be seen in the recapitulation of the Ultrasonic Pulse Velocity test results data in the table above, the estimation for the concrete compressive strength value of the surface of the building structure at the Graha Dok Warisan Jetty Structure in a sampling of 22 test samples obtained all samples are above the minimum design criteria value in accordance with the specifications in the As Built Drawing document which is 45 Mpa. With the average value of concrete compressive strength according to the recapitulation data above, namely 30.74 MPa for the estimated quality of the Deck Slab and 57.30 MPa for the estimated quality of the Jetty Head.

The importance of conducting a carbonation test is to determine the extent to which the concrete blanket can withstand the carbonation process (depassivation). If the carbonation process has penetrated the entire thickness of the concrete blanket and reached the reinforcement layer, it can trigger a corrosion event in the reinforcing steel material. The expansion or widening of reinforcement dimensions due to corrosion reduces adhesion to concrete, and the weakening of steel material strength due to corrosion can have an impact on building safety risks. The reference standards used in this test are ASTM C 856-14: Standard Practice for Petrographic Examination of Hardened Concrete and standard ISO 1881-201: Testing Concrete, Guide to The Use of Non- Destructive Methods Of Test For Hardened Concrete.

Table 4. Recapitulation of Carbonation Test Results on the Graha Dok Warisan Jetty Structure

No.	Location			Depth of Carbonation [MCD]	Theoritical Depth Of Carbonation [TCD]	Minimum Cover [D]	Classification Table For Measured Carbonation Depth			Theoretical Depth Of Carbonation For The Purpose Of A Second Survey			Classification Of Degree Of Deterioration Due To Carbonation
	Location	Position	STA				A1 [MCD < 0.5D]	A2 [0.5D < MCD > D+20 mm]	A3 [D+20mm < MCD]	B1 [MCD<0.5TCD]	B2 [0.5TCD≤MCD<1.5TCD]	B3 [MCD>1.5TCD]	
1	DECK SLAB	Left Side	+018	8,3	51,7	100,1	√	-	-	√	-	-	I-MINOR
2		Right Side	+091	47,7		63,0	-	√	-	-	√	-	I-MINOR
3		Left Side	+142	19,8		41,0	√	-	-	√	-	-	I-MINOR
4		Right Side	+189	28,6		94,5	√	-	-	-	√	-	I-MINOR
5		Right Side	+264	45,2		141,8	√	-	-	-	√	-	I-MINOR

It can be seen in the table above, that carbon penetration in all test samples on the Deck Slab has not passed the depth of the concrete blanket and is I-Minor (minor damage category). If the carbonation process has penetrated the entire thickness of the concrete blanket and reached the reinforcement layer, it can trigger corrosion events in the reinforcing steel material, in this case the concrete has deteriorated along with the service life so that the concrete is no longer able to protect the reinforcing iron from the influence of the external environment.

5. Conclusion and Recommendation

In general, the structure of the Heritage Dock Graha Jetty can still be operated as it should be provided there is some damage to the structural elements that must be repaired and strengthened. The visual inspection of the building revealed several major findings related to the building's condition that require immediate repair. The list of necessary repairs and strengthening measures, along with the preliminary cost estimate, can be found in the attachment. Based on the test data, an Ultrasonic Pulse Velocity Test was conducted on the structural components of the Jetty Graha Dok Warisan in accordance with BS 13311-91. The samples taken showed that the quality of the structural concrete is generally within good and medium criteria. The estimated compressive strength of the concrete from 22 samples indicates that all samples exceed the minimum design criterion of 45 MPa, with an average compressive strength of 26.49 MPa for the Deck Slab and 47.61 MPa for the Jetty Head. The carbonation test results from 5 samples of the existing concrete structure show that carbon penetration in the Deck Slab area has not reached the depth of the concrete cover and is classified as minor damage (I-Minor).

Based on the results of field observations, we can convey the structure testing and analysis as follows, Repair of slabs, beams and columns. The principle of repair is to restore the damaged structure to its original condition which is still good. Repairs to floor slabs, beams and columns need to be carried out at locations where the concrete cover has peeled off, the reinforcement has been badly corroded in locations that have experienced cracks. Repairs to structural elements with peeling concrete covers are carried out by patching (coating the chipped concrete with epoxy resin). If the peel is thick or deep enough, this can be done by grouting. Repairs to structural elements that are cracked are carried out by injection method using expoxy resin and grouting materials. Closure of cracks is very necessary to prevent greater damage and to protect the reinforcement from direct contact with air which can cause rust or corrosion. We recommend using a grouting material with a compressive strength of $\pm$ 50 MPA (Estogrout MP 50) because this material has good adhesion with the existing concrete, so that it can be connected properly. The following is a map of the condition of Pax Ocean Pier, which is marked in blue below and is in good condition or not damaged.

The results of the Existing Jetty Structure Analysis show that the shear capacity of most of the columns is unable to withstand the lateral forces due to waves. So it is necessary to do reinforcement with Fiber Reinforced Polymer (FRP) Fibrap CIS System to inhibit corrosion. do is to use carbon fiber or Fiber Reinforced Polymer. With the following methods, after the concrete structure has been repaired, it will be coated with Fiber Reinforced Polymer type UC, after the concrete structure is coated with Fiber Reinforced Polymer, it is then finished with a special paint.

Even though the results of the analysis show that the beams are safe in accepting the loads that occur, however, based on observations in the field, several beams experience deflection exceeding the permit limit, so reinforcement is needed to increase capacity. For this reason, strengthening steps are needed to increase the beam capacity. An alternative to percutaneous sliding beams that can be done is to use carbon fiber or Fiber Reinforced Polymer. With the following methods, after the concrete structure has been repaired, it will be coated with Fiber Reinforced Polymer type UC, after the concrete structure is coated with Fiber Reinforced Polymer type UC, it is then plastered, filled, and finished with special paint.

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