

Upper Structure Repairing and Strengthening to Increase Capacity and Performance of Jetty: Case Study of Indonesia Sea Highway Program in West Nusa Tenggara

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ARTICLE INFO

Keywords: CFRP (Carbon Fiber Reinforced Polymer), Jetty, Repairing, Sea Highway Program, Strengthening

Received : 4 April

Revised : 19 April

Accepted: 19 May

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ABSTRACT

The Indonesia Government has launched the sea highway to speed up transportation and economic deployment in Indonesia. So, each jetty shall be upgraded to use for sea highways. The small jetty should be upgraded to support Ship berthing from 3000 to 5000 DWT, that in this case studied is in West Nusa Tenggara. Improvement ability and performance of the jetty, this research will be looking for upgrading methods to get the target of repairing and strengthening that is cheaper than new re-constructing. Based on the research result, the repairing is patching and strengthening, which will be done by a CFRP as additional existing steel reinforcing. Those methods can increase jetty capacity, performance, and reduce cost

INTRODUCTION

The Sea Highway program is a regular and scheduled shipping in all Indonesian zones to strengthen shipping and logistic lines to reduce time transportation and logistics costs. Indonesia Government initiates this program to speed up economic growth and economic equity, facilitating local produce transportation, shorten inter-island connectivity, simplify material supply & distribution, improve regional population prosperity, and decrease the index value of a goods commodity (Andilas, D. D, Yanggana L.A., 2017; Krisdiyanti, F & et. al., 2023; Dirjen Perla, 2021; Nur, H.I, et.al., 2020). So, all materials can be reduced to one price in all Indonesian areas.

The Indonesian Government aims to make a practical shipping services program, including facilities and infrastructure (Andilas, D. D., and Yanngana, L., A., 2017). The facility is the availability of shipping transportation that is adequate and capable of all required materials (Krisdiyanti, F & et. al., 2023). In contrast, the infrastructure is a jetty that should be berthing for large ships to meet local criterion requirements and can load a lot of material (Haidir, S., Pribadi, S. R.W. & Baihaqi, I., 2015; Nur, H.I, et.al., 2020). In remote Indonesian zones, there are still many jetties that cannot berth for minimum ship criterion requirement for local sea highway, so those jetties should improve their capacity and performance (Ratnawati, E., 2019). One of the Jetty for this research is West Nusa Tenggara Jetties as the case study and research focus; where the jetty belongs to the Indonesia Transportation Ministry; the name of the jetty is Pelabuhan Calabai – Dompu that is constructed in two steps in 1993 for jetty 1 & trestle 1 and 1998 for jetty & trestle 2. One of the methods is repairing and strengthening the existing jetty to the cheapest cost construction when compared to rebuilding a new jetty that needs a dismantling and revamp cost (ACI 546-14, 2014; ACI 562M-13, 2013; Pardhesi S, & Deshpande, U.L., 2017; Paul, J H., 2002; Riyanto, R. et. al., 2021; and Syahroni, et. al., 2021). Strength Analysis and Repair Strategy of Aged Steel Jetty Pile. Kapal: Jurnal Ilmu Pengetahuan dan Teknologi Kelautan. 18. 28-40. 10.14710/kapal. v18i1.34899.).

Research has been conducted by field data collecting of existing structural element dimensional measurements, Non-Destructive Test (NDT) and Semi-Destructive Test (SDT) to existing structural elements, and where all of the data are obtained from PT. Rayasurverindo Tirta Sarana is a consultant company for jetty and other civil structure design. Existing structural element dimensional measurements have been done by meter measurements equipment to know the dimension for all structural elements, NDT has worked by hammer test, rebar detector, Ultrasonic Pulse Velocity (UPV), and Half Cell Potential, and SDT has been run by small chipping and core drill on some part of a structural element that considered representative to the whole of a structural component. All data will be analyzed for material strength, condition, and performance, then re-calculated to the existing jetty by all data obtained as input. Re-calculation will be done several times to get an optimal capacity and implementation of the jetty to accommodate increasing Ship DWT from 3000 DWT to 5000 DWT. Re-calculation will be simulated case by case, such as repairing and strengthening

processes, and then conclusions are drawn to get recommendations and design drawings.

LITERATURE REVIEW

1. Sea Highway Program Regulation

The Sea Highway program is a national program from the President of the Republic of Indonesia that is caused high price disparity between the West-East Indonesia zones and uneven economic growth for all Indonesia Zones. So, Indonesia Government should be looking for alternative solutions to solve the problem; there is a sea highway that can sort cut the time delivery and bureaucracy (. It can reduce the price because the material can arrive sooner so that it can be direct shipping, with no mooring fees at the port, and reduce the operating cost of Ship overnight (Andilas, D. D, Yanggana L.A., 2017; Dirjen Perla, 2021; Krisdiyanti, F & et. al., 2023; Ratnawati, E., 2019; and Nur, H.I, et.al., 2020). However, the sea highway program needs regulation for setting government policies. The Indonesian Government has made a few rules, and there are a) Law Number (UU No.) 7 of 2014; b) President Regulation No.27 of 2021; President Regulation No.59 of 2020 Junto President Regulation No.71 of 2015; c) President Regulation No.70 of 2020, d) Transportation Ministry Regulation No. 29 of 2018 Junto Transportation Ministry Regulation No.113 of 2018; e) Transportation Ministry Regulation No.4 of 2018; f) Transportation Ministry Regulation No.22 of 2018; g) Trading Ministry Regulation No.53 of 2020; h) Trading Ministry Regulation No.38 of 2020; i) Transportation Ministerial Decree No 44 of 2020; j) Sea Transportation Director General No. KP.912/DJPL/2019; k) Sea Transportation Directory General No. KP.272 TAHUN 2019; l) Sea Transportation Director General Decree No. KP.631/109/2/DJLP-18; m) Sea Transportation Director General Decree No. UM.002/72/14/DJPL-18; n) Trading Director General Decree No. 41 of 2018; o) Sea Transportation Director Circular Letter No. PR.101/160/7/DA-2017.

All the regulations are made for sea highway implementation to become legal and basic laws for operators and government officials. Therefore, if someone abuses their authority and violates it, they can be punished according to regulation.

2. Jetty Design Code and Guide

A jetty is a bridge structure on the beach used for ship berthing and Ship loading-unloading, so the jetty system should be designed to meet design codes and standards in good condition, sturdy, and strong for shipping activity. Therefore, the design jetty should comply with code or standard and design guide that have been government setting and foreign regulations recognized by the designer and owner (Da Costa, T. G. S., Arawan P., and Ariana, K. A. 2020). A few codes that have been by Indonesia Government, there are: a) SNI 2847: 2019; b) SNI 1726:2019, c) SNI 1725:2016, d) BMS 1992, and other SNI, whereas foreign regulations are: a) BS 6349-1; b) BS 6349-2.; c) BS 6349-4; d) Trelleborg Fender Application Design Manual (2015); e) OCDI, 2002, and other regulation that relevant with structural jetty design. The design guide for structural jetty designs is a) Design Guide of Bridge, Wharf, Jetty, Culvert, and Crossing

Structures (Fiji Road Authority); b) Perencanaan Pelabuhan. (Triatmodjo, B. 2009); c) PIANC report WG121, (2014) Harbor approach changes design guidelines from 2014, including the latest design information on vessels and another procedure for jetty or wharf design (MarCom Working Group 121).

3. Review Similarly Research

A little research about structural jetties evaluation has been done to know the strength, sturdy, capacity, and other requirements. It aims to accommodate owner requests or upgrade capacity. The research is:

- a. Da Costa, T. G. S., Arawan P., and Ariana, K. A (2020) have done to evaluate the Dilli-Timor Leste Jetty, and the research result is obtained where the existing structural jetty is still in good condition, but it only needs maintenance to keep in good condition.
- b. Haidir, S., Pribadi, S. R.W. and Baihaqi, I., (2015), have done to analyze the capability of shipyards in all Indonesia Zones that obtain 65% shipyard for Ship 1200 to 2000 DWT (type C); 35% of the shipyard for Ship more than 5000 DWT (type D); and 29% shipyard does not meet to a minimum production facility, and the other is 71% complete to the minimum requirement.
- c. Husni (2022), has analyzed a stopover port in line T-4 of Makasar port that obtained 54,5% meet-to-port location for the sea highway 21.3% meet to hinterland potential aspect.

Similar research on upgrading jetty has been done, but this article cannot display due to limitations in time and the number of article pages.

METHODOLOGY

In this research, the methodology is an experimental study in that data is directly taken in the field by conducting a visual survey, NDT, and SDT on the physical jetty. A visual survey is worked by looking in detail and zooming in on all material and structural elements; then, the result will be drawn in the map or jetty layout drawing. A lot of equipment uses NDT; there is Meter equipment (Figure 1.a & b), Hammer Test (Figure 1.c), UPV (Figure 1.d), Rebar Detector (Figure 1.e), Half Cell Potential (Figure 1.f), and carbonation. Meter equipment is used for structural element dimensional measurement to slab thickness and dimension of a beam, pile cap, pilling, and another structural element; the data will be displayed in tabular form for each structural element. Hammer Test is used for concrete strength estimation for all structural elements done to the concrete surface. The test value is a rebound of the Hammer Test that can be predicted to the concrete strength. UPV is used for concrete density, quality, and crack depth.

The value of UPV is ultrasonic wave velocity that propagates in the concrete material. It compares with the standard to predict the concrete density and quality, while crack width is obtained from time lag wave propagation in the concrete material. A rebar detector is used for the distance and number of rebar or reinforcement in the concrete; there are longitudinal and transversal or stirrup reinforcement detectors. It needs to know the reinforcement condition in the concrete. The last NDT is Half Cell Potential which is used to predict the corrosion rate of reinforcement or rebar in the concrete. Half Cell Potential's value is the current voltage, which will be compared to the standard voltage to get the

corrosion rate. Concrete carbonation is the chemical reaction between carbon dioxide in the air and calcium hydroxide and hydrated calcium silicate in the concrete. It causes concrete material to become frail and delamination between the concrete core and cover. Concrete carbonation will be checked by phenolphthalein liquid that was sprayed onto a concrete surface. If the colour does not change, it means that the concrete has been exposed to carbonation then the carbonation contamination in the concrete material should be replaced by new concrete material. So, the depth of carbonation contamination in the concrete material should be tested to know how deep carbonation contamination. The combination test can apply to the concrete core drill sample to know the depth of carbonation contamination.

SDT will be done by small chipping (Figure 1.g) to structural element and core drill (Figure 1.h) to get concrete core sample. Small chipping is used to ensure the diameter of reinforcement, and a core drill is used to know the actual concrete strength that the concrete core sample will be crushing tested in a laboratory to get a maximum load to crush the concrete.

The other research methodology is building re-calculation design that the building integrated will be calculated in the computer analysis program to get the service load, strength, and stress ratio. All the field survey data will be analyzed and used for input data of building re-calculation design. The final research results from building performance and service load capacity can be used for building capacity and performance information to the owner or another user.

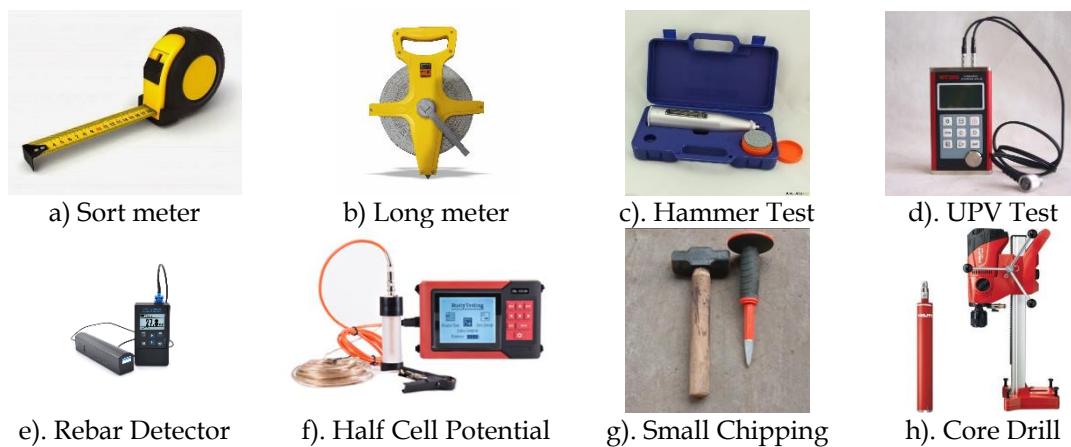


Figure 1. Field Survey Equipment

RESEARCH RESULT

1) Data Collection

All filed survey data will be collected and recap in the table.

a) Visual Survey

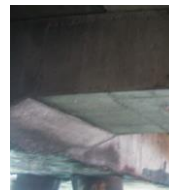
Visual survey results for structural element dimensional are obtained that all structural elements dimensions have complied with the as-built drawing, such as concrete slab thickness is 250 mm, beam dimension is 500 mm wide & 750 mm height, pile cap is 1000 mm in length, 1000 mm wide and 800 mm height for type 1; and 2000 mm length, 1000 mm wide and 800 mm height for type 2. Visual survey results of the physical conditions obtained a little damage on the bottom slab and a part of the beam and pile cap surface, but the steel pilling does not damage, the thickness is still in good condition, and much marine growth on the splash zone. A photo physical survey can be seen in Figure 2.a to d.



a). Bottom surface Slab condition



b). Beam surface condition



c). Pile cap surface condition



d). Steel pile condition

Figure 2. Documentation Test Results

The other visual field survey checks the existing fender, which is the type of vender and existing condition. The current type of Fender is ANP-500, and it is still in good condition.

b) Hammer Test

Hammer test results can be seen in Table 1 and 2 (strength result).

Table 1. Rebound Hammer Test Results

Sampel/Lokasi Titik	DERMAGA 1									
	Elemen Pelat									
	Rebound Value [R]									
	21	22	23	24	25	26	27	28	29	30
Arah Hammer	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
1	43	36	22	15	24	30	28	37	35	30
2	34	26	18	21	18	18	29	34	34	31
3	40	16	17	24	25	32	26	32	34	32
4	43	35	15	14	22	19	37	36	34	27
5	39	30	14	27	16	30	23	39	36	28
6	38	22	17	20	15	24	32	36	29	28
7	34	23	15	25	14	16	29	37	34	22
8	40	18	18	22	27	18	24	39	23	27
9	29	23	20	26	16	21	26	34	30	32
10	31	17	19	23	13	23	20	32	30	25
Nilai R Minimum	29	16	14	14	13	16	20	32	23	22
Nilai R Maksimum	43	36	22	27	27	32	37	39	36	32
Nilai R Rata-Rata	37	25	18	22	19	23	27	36	32	28
Deviasi	4.9	7.1	2.5	4.4	5.1	5.8	4.8	2.5	3.9	3.2
Nilai R Karakteristik	30.6	15.1	14.2	15.8	12.2	15.4	21.0	32.2	26.6	23.9
Kualitas permukaan	Baik	Kurang Baik	Baik	Kurang Baik	Baik	Baik	Kurang Baik	Baik	Baik	Kurang Baik
Prediksi Kuat Tekan Kubus 15x15x15 (kg/cm ²)	306.0	131.0	124.0	137.7	108.8	133.7	186.8	329.3	253.0	219.9
Dispersi Alat [±] (kg/cm ²)	20.1	10.4	8.2	12.3	2.6	11.2	21.5	17.1	24.0	23.9
Prediksi Kuat Tekan Karakteristik Kubus 15x15x15 (kg/cm ²) rata-rata prediksi kuat tekan (kg/cm ²)	279.1	117.0	113.0	121.2	105.3	118.7	158.1	306.4	220.9	187.9
	172.7									

Table 2. Strength Evaluation Results from Rebound Test Value

Beam Structural Element	Jetty 1 (kg/cm ²)	Jetty 2 (kg/cm ²)	Jetty 1 (kg/cm ²)	Jetty 2 (kg/cm ²)
Beam	276.2	265.9	304.9	244.9
Slab	276.2	261.9	259.6	303.3
Pile cap	253.9	188.9	336.5	289.0

c) UPV

UPV test results can be seen in Table 3.

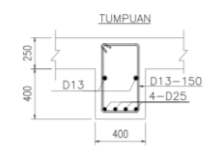
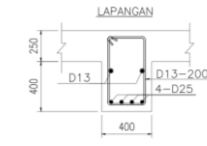
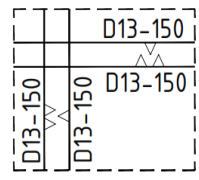
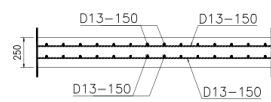
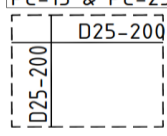
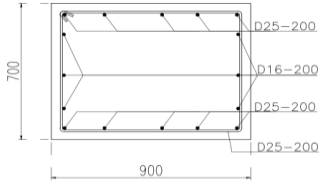
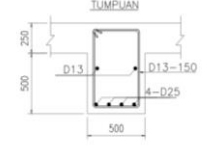
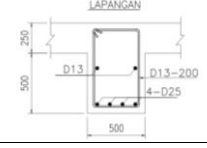
Table 3. Ultrasonic Wave Velocity from UPV Test Value

Beam Structural Element	Jetty 1 (km/second)	Jetty 2 (km/second)	Trestle 1 (km/second)	Trestle 2 (km/second)
Beam	4.524	4.487	4.398	4.427
Slab	4.608	4.454	4.542	4.511
Pile cap	4.336	4.566	4.622	4.357

d) Rebar Detector

Rebar detector test results can be seen in Table 4.

Table 4. Dimensional Measurement, Rebar Detector Test, and Small Chipping Results

Beam	Jetty 1 (400x650)		<p>D1-B1, D1-B2, D1-B3, & D1-B4</p>  
	Edge	Middle	
Top Bars	-	-	
Middle Bars	2 D13	2 D13	
Bottom Bars	4 D25	4 D25	
Stirrup	D13-150	D13-200	
Slab	Jetty 1 (Thickness: 250mm)		<p>T1-PL1, & T1-PL2</p>  
Top Bars X	D13-150		
Bottom Bars X	D13-150		
Bottom Bars Y	D13-150		
Bottom Bars Y	D13-150		
Pile Cap	Jetty1 (1000 x 1000 x 800)		<p>PC-13 & PC-23</p>  
Top Bars X	D25-200		
Bottom Bars X	D25-200		
Top Bars Y	D25-200		
Bottom Bars Y	D25-200		
Beam	Jetty 2 (400x650)		<p>D2-B1, D2-B2, D2-B3, & D2-B4</p>  
	Edge	Middle	
Top Bars	-	-	
Middle Bars	2 D13	2 D13	
Bottom Bars	4 D25	4 D25	
Stirrup	D13-150	D13-200	
Slab	Jetty 21 (Thickness: 250mm)		
Top Bars X	D13-150		
Bottom Bars X	D13-150		
Bottom Bars Y	D13-150		

Bottom Bars Y	D13-150		<p>T2-PL1, & T2-PL2</p>
Pile Cap	Jetty2-Pile Cap Type 1	Jetty2-Pile Cap Type 1	<p>PC-16 & PC-25</p>
	(1000 x 1000 x 800)	(1000 x 1000 x 800)	
Top Bars X	D25-200		
Bottom Bars X	D25-200		
Top Bars Y	D25-200		
Bottom Bars Y	D25-200		
Beam	Trestle 1 (400x650)		<p>T1-B1, & T1-B2</p>
	Edge	Middle	
Top Bars	-	-	
Middle Bars	2 D13	2 D13	
Bottom Bars	4 D25	4 D25	
Stirrup	D13-150	D13-200	
Slab	Trestle 1 (Thickness: 250mm)		<p>D1-PL1, D1-PL2, D1-PL3, & D1-PL4</p>
Top Bars X	D13-100		
Bottom Bars X	D13-100		
Bottom Bars Y	D13-100		
Bottom Bars Y	D13-100		
Pile Cap	Trestle 1 (700 x 700 x 600)		
Top Bars X	D25-200		
Bottom Bars X	D25-200		

Top Bars Y	D25-200		
Bottom Bars Y	D25-200		
Beam	Trestle 2 (400x650)		
	Edge	Middle	
Top Bars	-	-	
Middle Bars	2 D13	2 D13	
Bottom Bars	4 D25	4 D25	
Stirrup	D13-150	D13-200	
Slab	Trestle 21 (Thickness: 250mm)		
Top Bars X	D13-100		
Bottom Bars X	D13-100		
Bottom Bars Y	D13-100		
Bottom Bars Y	D13-100		
Pile Cap	Trestle 2 (700 x 700 x 600)		
Top Bars X	D25-200		
Bottom Bars X	D25-200		
Top Bars Y	D25-200		
Bottom Bars Y	D25-200		

e) Half Cell Potential

Half Cell Potential test results can be seen in Table 5.

Table 5. Half Cell Potential Test Results

Beam Structural Element	Jetty 1 (% Corrosion Potential)	Jetty 2 (% Corrosion Potential)	Trestle 1 (% Corrosion Potential)	Trestle 2 (% Corrosion Potential)
Beam	95	95	95	95
Slab	95	95	95	95
Pile cap	95	95	95	95

f) Carbonation Contamination Test

Carbonation Contamination Test results can be seen in Table 6.

Table 6. Carbonation Contamination Test Results

Beam Structural Element	Jetty 1	Jetty 2	Trestle 1	Trestle 2
Beam	Negative	Negative	Negative	Negative
Slab	Negative	Negative	Negative	Negative
Pile cap	Negative	Negative	Negative	Negative

g) Small Chipping

Small Chipping Test results can be seen in Table 4 that the rebar diameter is same with as-built drawing.

h) Crushing/compressive test of core drill

Crushing Test results can be seen in Table 7.

Table 7. Concrete Crushing Test Results

No.	Sampel Code	W (Gr)	L (cm)	D (cm)	Ratio L/D	P (kg)	C1	C2	f _c (MPa)	f _{cc} (MPa)	K-Cube (kg/cm ²)
Jetty 1											
1	D1-PL1	1135	13.6	6.8	2.0	12995.0		1.00	35.1	35.1	422.9
2	D1-PL2	1125	13.6	6.8	2.0	18786.0		1.00	50.7	50.7	611.4
3	D1-PL3	1034	12.2	6.8	1.8	12685.0		1.01	34.3	34.1	410.6
Jetty 2											
13	D2-PL1	895	10.0	6.8	1.5	19352.0		1.04	52.3	50.4	606.9
14	D2-PL2	716	9.4	6.8	1.4	10729.0		1.05	29.0	27.5	331.9
15	D2-PL3	1125	13.6	6.8	2.0	10673.0		1.00	28.8	28.8	347.4
16	D2-PL4	1129	13.2	6.8	1.9	12237.0		1.00	33.1	33.0	398.1
17	D2-B1	1067	12.1	6.8	1.8	13790.0		1.00	37.2	37.0	446.0
18	D2-B2	759	8.9	6.8	1.3	16229.0		1.06	43.8	41.1	495.4
19	D2-B3	1105	13.3	6.8	2.0	13936.0		1.00	37.6	37.6	453.4
20	D2-B4	1120	13.5	6.8	2.0	10941.0		1.00	29.6	29.6	356.1
21	D2-PC1	1120	13.5	6.8	2.0	10941.0		1.00	29.6	29.6	356.1
Trestle 1											
25	T1-PL1	895	10.0	6.8	1.5	19352.0		1.04	52.3	50.4	606.9
26	T1-PL2	716	9.4	6.8	1.4	10729.0		1.05	29.0	27.5	331.9
27	T1-B1	1125	13.6	6.8	2.0	10673.0		1.00	28.8	28.8	347.4
Trestle 2											
31	T2-PL1	895	10.0	6.8	1.5	19352.0		1.04	52.3	50.4	606.9
32	T2-PL2	716	9.4	6.8	1.4	10729.0		1.05	29.0	27.5	331.9

Note: D1 = Jetty 1; T = Trestle; PL : Concrete slab, B : Beam; PC : Pile Cap

2) *Data Analysis*

a) Visual Survey

Based on the visual survey results, the structural element is small damage in the concrete slab, that it has to spall concrete on the concrete cover. It should be repaired by patching the material of concrete. The patching material should be of good quality, and the concrete strength must be higher than the existing. The concrete shall be chipped until good existing concrete condition, brush the surface concrete, spayed by concrete bonding agent on the concrete surface, and then patch the new concrete material. The other surface of concrete structural element will be battered to coat the concrete surface to stop hazardous chemical intrusion in the concrete material.

Based on the fender type analysis (strength and deflection value), the existing fender type (ANP-500) cannot support additional Ship DWT (for ship 5000 DWT), so it shall be changed to the fender type, which is stronger and sturdier. The new type of fender is ANP-800; the dimension is 2 m in length and 0.8 m in height. The distance of the fender space will follow the existing location because the fender must be installed on the transversal beam position, and it still can support the new Ship DWT.

b) Hammer Test

Based on the Hammer Test result, the concrete strength value is still in good condition, but only in the pile cap that is lower than 200 kg/cm². It shall be re-calculated to ensure the pile cap strength and support the service load. All structural element strength overall does not need repair or special treatment.

c) UPV

Based on the UPV test results, the concrete density is still in good condition, and the ultrasonic wave velocity value is more than 4 km/second, so the range value is still in good condition, as shown in the standard requirement (Table 7).

Table 8. General Criterion of UPV Test Value

Kecepatan Gelombang (km/det)	Kualitas Beton
>4	Baik
2 - 4	Cukup
<2	Kurang

d) Rebar Detector

Based on the Rebar detector test results written in Table 4, the rebar or reinforcement diameter is the same as-built drawing and installed in the field. So, the rebar installation is not a problem.

e) Half Cell Potential

Based on the Half Cell Potential test results written in Table 5, the rebar condition is in good condition; the corrosion rate is only 95%, indicating very small corrosion.

f) Carbonation Contamination Test

The Carbonation Contamination Test results written in Table 5 indicate negative value, so all structural elements are not contaminated by carbon dioxide and are still in good condition.

g) Small Chipping

Based on the Small Chipping Test results written in Table 4 and described on the rebar detector result, the rebar diameter is the same as existing installation and as-built drawing.

h) Crushing/Compressive Test of the Core Drill

Based on the crushing test result of the concrete material, the strength of the concrete is still above 300 kg/cm², so it are still in good strength and condition.

RESEARCH DISCUSSION

After the field survey, data recorded and analyzed, the next activities of integrated jetty structure evaluation and re-calculation to re-design the jetty to meet requirements and service load. It is important to discuss further to ensure the jetty structure can support the additional Ship DWT capacity.

The structure analyzer program will calculate the structural jetty as structural analysis software. Input data will use field survey data results and data analysis; layout & structural elements are dimensional, number & diameter of rebar, and concrete & rebar strength. The other input data are loading there are dead load or self-load, live load, line load as bridge line load, truckload, seawater wave load, wind load, water flow rate, berthing load, earthquake load CFRP characteristic, ship DWT, and other data of jetty that will be used for structural calculation. Furthermore, structural modelling in the analyzer software uses the 3 Dimension model to get a model like actual conditions. The software will input all jetty structure length, width, and height values to draw the jetty structure model (Figure 3 and 4).

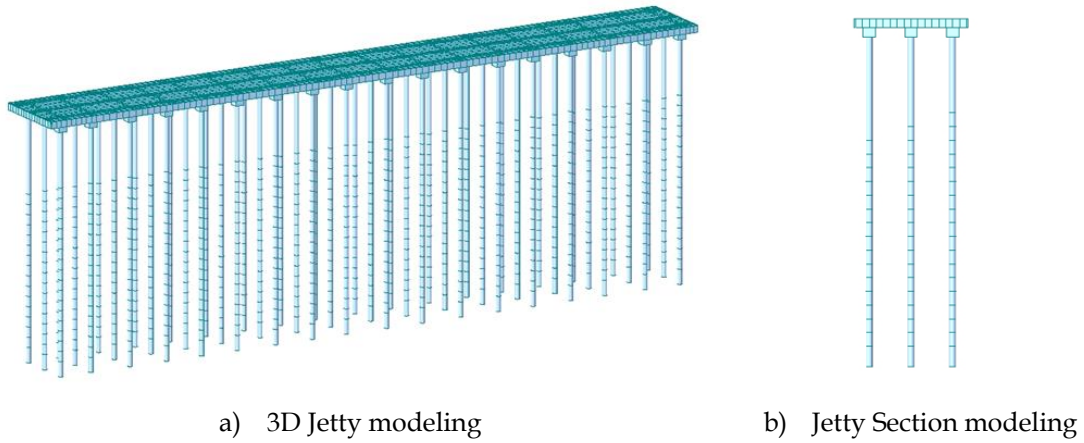


Figure 3. Structural Model of Jetty

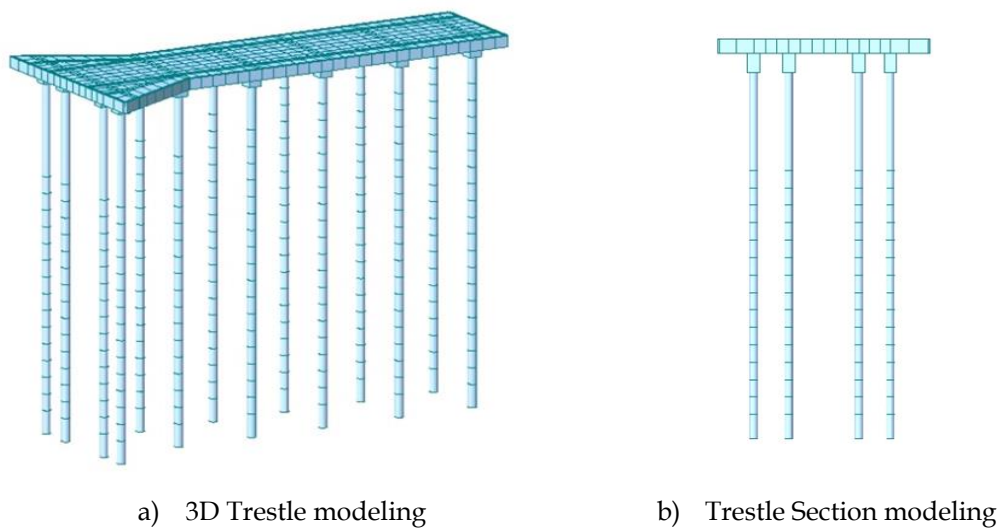
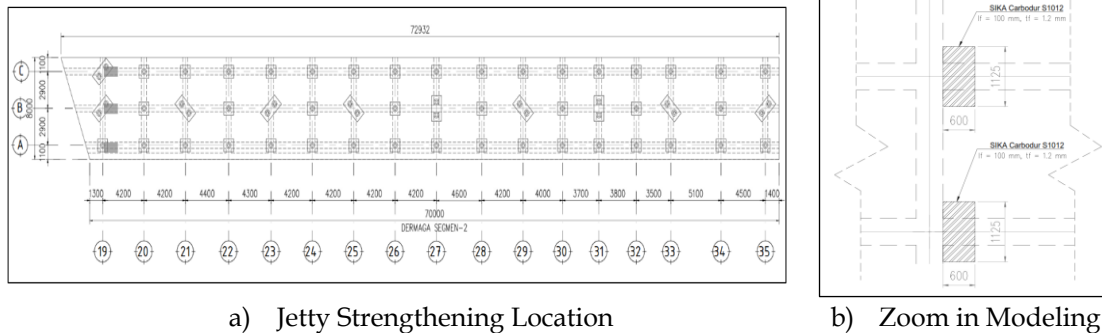


Figure 4. Structural Model of Trestle

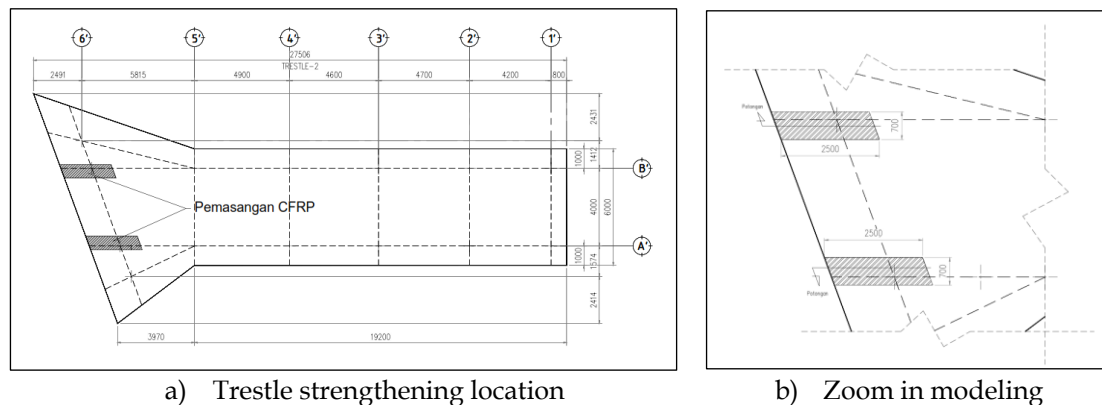
The next step is that structural analyzer software will run to get the output value; displacement for each edge and middle structural element, strength ratio for each structural element, and internal loads such as moment, shear, and axial force. Based on the structural re-calculation, all structural elements can support service load, except only a few jetties 2 and trestle 1 & 2 beams should be added by CFRP strengthening material (Figure 5 & 6). It will be installed on the concrete surface that needs strengthening. After CFRP position installation, the integrated structural jetty shall be re-calculated to know the condition. Based on the integrated structural re-calculation after strengthening, the jetty and Trestle can support the service load that new service load is ship 5000 DWT.

The repairing and strengthening method for existing structures is very simple and cheapest because the structure is only repaired to damage structural elements and strengthen to a few beam elements when they do not meet requirements. The strengthening installation is also easy to apply because it has only adhered to the concrete surface with polymer glue material, and they can recover or restore the integrated structure system to support service load. The

structural modification system is very simple to do if compared with dismantling the existing structure and rebuilding the new structure.



a) Jetty Strengthening Location
 b) Zoom in Modeling
 Figure 5. CFRP Strengthening Location on the Jetty 2 Beam Concrete Surface



a) Trestle strengthening location
 b) Zoom in modeling
 Figure 6. CFRP Strengthening Location on the Trestle 1 & 2 Beams Concrete Surface

CONCLUSION AND RECOMMENDATION

A few test fields have been conducted, from visual surveys to integrated structure re-calculation. The existing jetty is still in good condition, but a small repair on the bottom slab needs concrete patching to repair concrete spalling. The other field survey results are fender condition and type to check capacity and damage. Based on the survey recording, the existing type of Fender is ANP-500, and it is still in good condition. However, the current type of fender cannot support the new Ship DWT (Ship 5000 DWT), so it should be changed to the new type that is ANP-800, which can support the new Ship DWT. The existing fender distance can still support the new Ship DWT, so the fender distance does not change and still follow to existing space. The fender position also shall be installed on the beam position to accommodate the berthing load.

Based on the integrated structure re-calculation, the jetty and Trestle structure need additional reinforcement that uses CFRP on a few beams. It aims to increase the structure element capacity to accommodate the increasing Ship DWT from 3000 DWT to 5000 DWT. The structure can re-cover or restore strength and support the service load.

The repairing and strengthening method for the existing structure is one method that is a simple system and cheapest if it compares with dismantling the existing structure and rebuilding the new structure. Engineers and owners chose this method because it is practical, inexpensive, and easy to implement on the

existing structure. This method also applies to other structures, such as buildings, bridges, monuments, and civil structures.

Furthermore, all of Jetty and Trestle element structure (slab, beam, and pile cap) will be recommended to maintain to keep it and coat on the concrete surface to stop hazardous chemical intrusion in the concrete material.

ADVANCED RESEARCH

This research still has a loading test for integrated jetty and trestle structure, so the next research needs to be tested loading as actual loading. It aims to know the actual strength and capacity of the jetty and trestle structure. The loading test can be conducted by truck loading to simulate live load, sandbag to simulate additional dead load, and tug boat load to simulate berthing load.

ACKNOWLEDGEMENTS

The authors would like to thank the following company there are PT. Rayasurverindo Tirta Sarana, who has given field data to Indonesia Transportation Ministry, has a research location and activity permit.

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