Evaluation Experimental of the Dynamic Wharf Structure: A Study Case at Nabire Port, Indonesia

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ABSTRACT
Indonesia is an archipelagic country where one of the supporting transportations is ship. Based on the government's program to relaunch the sea highway, the wharf is considered very important as the supporter of activities in transportation. Therefore, it is necessary to carry out the assessment activities to determine the existing condition of the wharf structure. Since the wharf that will be used as the location of the status is located at Nabire Regency which is a location that is crossed by the earthquake line, it is necessary to carry out the dynamic analysis. The dynamic analysis that is carried out is in the form of non-linear analysis by using the response spectra method and time history analysis. The results of the assessment of the visual condition and wharf structure indicate that the structure is still in good condition and is functioning properly. Based on the results of the analysis carried out on the wharf with existing conditions using SAP2000 V14.2.2 software, it is known that the natural frequency magnitude of the analysis results is different from the results of field testing. It is due to the natural frequency which is affected by stiffness and mass, and the stiffness is affected by the cross-sectional inertia of a structure and the modulus of elasticity.

Keywords: *Wharf, Assessment, Non-linear Analysis.*

1. INTRODUCTION

Indonesia is an archipelagic country where one of the transportation that supports its activities is ships. One of the supporting factors for this shipping activity is the port, where the facilities for the port are in the form of a dock. Wharf has several types, such as type wharf, pier, and jetty. In this case, the wharf that will be the research location is at Nabire Harbor located in Teluk Kimi District. It is on the east of the city center of Nabire Regency with an access road and a part of the Manokwari - Jayapura national road. The wharf at Nabire Harbor uses an open wharf type with the bottom structure in the form of piles.

Wharves are made in parallel to the coast and can be made to coincide with the shoreline or protrude slightly into the sea. Wharf can also function as a retainer of the soil behind it. Wharf is usually used for the port of cargo pieces or containers where it takes an open yard that is wide enough to ensure the smooth transportation of goods. Wharf planning must take into account moorings, loading and unloading equipment, and land transportation facilities. Characteristics of the ship that will be docked affect the wharf length and depth required to close the ship [1]. In Nabire's wharf, there are several problems such as the concrete structure, the damage of the concrete structure either in the form of cracks, corrosion of reinforcing steel, chipping, porous and loss. In steel structures, corrosion of piles is often caused by the chlorides attack.

Figure 1 Nabire Wharf

In addition to discuss the assessment to determine the type of damage to each element of the wharf, it is also to obtain the wharf structure data to perform dynamic modelling and analysis by using SAP2000. The dynamic analysis used is 2 non-linear methods. There are response spectrum and time history analysis to get the natural frequency results from the analysis to be compared with the actual natural frequency based on field testing use an accelerometer.

1.1. Related Research

Studies related to research on the dynamic analysis of the wharf structure have several times been carried out before, both in Indonesia and outside Indonesia. Wharves are one of the most important structures in the coastal area, which can be used for transporting large quantities of goods and raw materials from one place to another. Their functionality is very much essential because they are the lifeline structures of the country. It is observed during the past earthquakes that wharves have been damaged even under mild shaking [2]. Concrete harbour infrastructures are designed to perform their functions for a long period of service (100 years for the studied structure) while they are exposed to severe conditions (environment and loading) and they are often very sensitive to deterioration. Their design and maintenance strategy must be optimal in a highly competitive market and the sense of a life-cycle management approach [3]. A seismic design of wharves is commonly performed utilizing simplified dynamic analyses, such as multi-mode spectral analyses. Simplified analyses can be useful for evaluating the limited state of structures. However, several pile-supported wharves, that have been damaged during past earthquakes, have shown that soil deformation and soil-pile dynamic interaction significantly affect the entire behaviour of structures [4]. There are influencing factors such as damping value, calibration, and natural frequency of the wharf structure [5]. In addition, each structure has a dynamic behaviour in the form of a natural frequency that can be searched by empirical field vibration tests and numerical analysis [6].

1.2. Objective

This study aims to perform dynamic analysis of the wharf structure and determine the natural frequency of the wharf structure in the existing conditions based on the modelling results with the natural frequency of the test results. So, the research that has been done can be used as reference material in dynamic analysis in further research. The wharf used as study material is the Nabire wharf located in Jayapura, Indonesia. This wharf structure is divided into the main wharf, trestle 1, and trestle 2 with an open type wharf.

2. BACKGROUND

Dynamic analysis performed on wharves has not been done much. So, in this study, a dynamic analysis of the wharf structure was carried out using the non-linear time history analysis method. The results of this analysis will know the magnitude of the natural frequency obtained based on the modeling that has been carried out with the help of the response spectrum actual as standard for scaling the 11-ground motion accelerogram. Response spectrum is taken from the earthquake records of PUSJATAN Indonesia. It is the earthquake records for the bridge structure since the wharf characteristics are like the bridge. Meanwhile, 11 earthquake records (ground motion accelerogram) are based on other countries taken from the PEER site. The scaling is done by using the help of seismomatch software.

This analysis was conducted to determine the effect of dynamic loads on wharf structures because there have been many studies that discuss dynamic analysis in buildings but rarely found on the wharf.

2.2. Assessment

This assessment activity is carried out to obtain data information from the field testing process to determine the existing state of the wharf structure that will be the research location. Dynamic testing in the field is carried out non-destructively with a vibration test method using an accelerometer sensor to measure the structure's response to the dynamic load given in the experiment.

2.2.1. Hammer Test

A Hammer test is usually used to check the quality of concrete and get an estimate of the compressive strength of concrete [7]. The results of tests carried out on wharf segments 1 to 6, as well as trestle 1 and trestle 2, are presented in the following table.

Table 1. Hammer Test Result

Location	Element Structure	Concrete Grade	
		MPa	K (kg/cm^2)
Trestle 1-2	Pile Cap	33,31	402
	Beam	22,02	266
	Slab	25,12	303
Wharf 1-6	Pile Cap	27,63	333
	Beam	27,72	334
	Slab	26,03	313

2.2.2. Compressive Strength of Concrete

Testing the compressive strength of concrete from the core drill aims to estimate the value of the compressive strength of concrete [8]. The core concrete compression test (concrete core drill) carried out at the Test Laboratory for Engineering and Materials can be seen in Table 2.

Table 2. Compressive Strength Result

No	Segment	Max Loads (kg)	Compressive Strength (kg/cm²)	Mpa	K
1	JT 1#	5000	121,4	12,38	149,1
2	JT 2	11250	254,5	20,76	250,2
3	JT 2#	13500	291,2	29,63	356,9
4	JT 3	11250	213,1	21,72	261,7
5	JT 4	9500	190,2	19,39	233,6
6	JT 5	2500	69,3	6,98	84,1
7	T1#	11500	217,4	22,16	267,0
8	T1 slab	12500	240,6	24,53	295,5
9	T1 Pilecap	5000	121,4	12,38	149,1
10	T2	11250	254,5	20,76	250,2
11	T1 Pilecap#	13500	291,2	29,63	356,9
12	T2#	11250	213,1	21,72	261,7

2.2.3. Carbonation Test

Carbonation testing aims to obtain the level of carbonation depth of the concrete that has been installed [9]. The results of carbonation testing of concrete samples can be seen in Table 3.

Table 3. Carbonation Test Result

No	Segment	Carbonation Depth
1	JT 1	0 (Uncorbonated)
2	JT 2	0 (Uncorbonated)
3	JT 4	0 (Uncorbonated)
4	JT 5	0 (Uncorbonated)
5	T1#	0 (Uncorbonated)
6	T1 Slab	0 (Uncorbonated)
7	T2	0 (Uncorbonated)

2.2.4. Rebar Scan Test

The rebar scan test was carried out to determine the conditions in the concrete, measure the concrete cover, and observe the interaction of reinforcement in the concrete. The results of the rebar scan test can be seen in the table below.

Table 4. Rebar Scan Test Result

No	Segment	Reinforcement Distance (mm)				Concrete Ducking (mm)	
		X		y		Min	maks
		-	+	-	+		
1	Wharf 1 (Slab)	60	140	20	200	53	66
	Wharf 1 (Beam)	80	160	60	140	37	59
	Wharf 1(Pier)	100	280	100	520	58	67
2	wharf 2 (Slab)	80	180	100	400	47	68
	Wharf 2 (Beam)	180	460	120	200	48	65
	Wharf 2 (Pier)	120	160	100	160	50	64
3	Wharf 3 (Slab)	80	180	80	140	56	61
4	Wharf 4 (Slab)	80	120	80	180	54	65
5	Wharf 5 (Slab)	80	180	80	200	52	67
6	Wharf 6 (Slab)	100	160	140	280	60	68
7	Trestle 1 (Beam1)	60	140	60	200	24	67
	Trestle 1 (Beam2)	60	140	200	220	48	63
	Trestle 1 (Beam3)	100	200	80	80	58	67
	Trestle 1 (Slab)	80	140	80	160	42	66
	Trestle 1 (Pier)	160	260	60	180	50	69
8	Trestle 2 (Beam1)	80	120	80	260	47	59
	Trestle 2 (Beam2)	120	220	80	100	58	69
	Trestle 2 (Slab 1)	80	180	120	200	43	67
	Trestle 2 (Slab 2)	80	180	80	160	31	60

2.2.5. Vibration Test

Dynamic testing in the field is carried out non-destructively with a vibration test method using an accelerometer sensor to measure the response of the structure to the dynamic load given in the experiment [10]. The vibration test was carried out on main wharf segments 1, 2, and 3. The dominant frequencies extracted from the vibration data are summarized in the following table.

Table 5. Vibration Test Result

Structure Module	Natural Frequency (HZ – Rounds Per Second)
Jetty 1	0,30
Jetty 2	0,25
Jetty 3	0,36

3. MODELS AND ANALYSIS

3.1. Models

This modelling is done by using the SAP2000 software, where the dimensions and loadings used are based on the results of field tests that have been carried out and the results of calculations.

Geometric modeling on this wharf includes pile, beam, and pier floor structures based on actual geometric on the field and input all the damages based on the field test using SAP2000 software. As for the pile cap, it is not modeled but only input as a dead load. As for modeling pile, it uses spring.

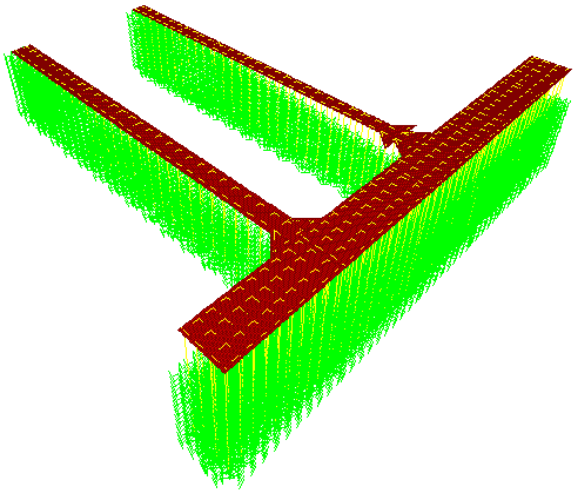

Figure 2 Actual Structure Before Analysis

3.1.1. Geometric Detail

Geometric detail only displays existing building facilities, namely trestles 1 and 2, and wharfs 1,2,3,4,5, and 6. Dimensions related to existing facilities are presented in Table 6 below.

Table 6. Rebar Scan Test Result

Segment	Depth (m)	Pile Dia (m)	Beam (mm)	Slab (mm)	Pilecap (cm)
Wharf 1 - 6	42,171 42,290 42,587	0,55	500/700	300	110 x 110 x 80 200 x 110 x 80 115 x 110 x 80
Trestle 1	28 & 30	0,55	500/750	300	100 x 100 x 80
Trestle 2	28 & 30	0,55	500/75	300	100 x 100 x 75

3.1.2. Response Spectrum

SNI 1726-2012 from the results of this platform point plot includes the earthquake area with peak acceleration based on soft soil conditions

PGA (g)	0.579
SS (g)	1.468
S1 (g)	0.515
CRS	1.092
CR1	1.041
FPGA	0.9
FA	0.9
FV	2.4
PSA (g)	0.521
SMS (g)	1.321
SM1 (g)	1.235
SDS (g)	0.881
SD1 (g)	0.824
T0 (detik)	0.187
TS (detik)	0.935

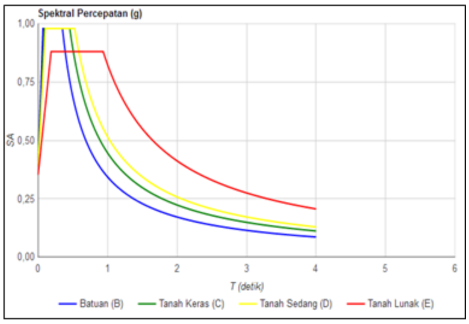

Figure 3 Response Spektrum at Nabire

In planning the earthquake, the design uses the rules of SNI 1726-2012. So, the response spectrum is used according to the applicable regulations. The earthquake load is applied to the structure by using an earthquake priority factor (I) of 1.5. While the use of the earthquake response modification factor (R) for wharf analysis is taken R=2. To simulate the direction of the influence of an arbitrary design earthquake on the building structure, the effect of earthquake loading in the main direction must be considered 100% effective and must be considered to occur simultaneously with the effect of earthquake loading in a direction perpendicular to the main direction of loading but with the effectiveness of only 30%[11].

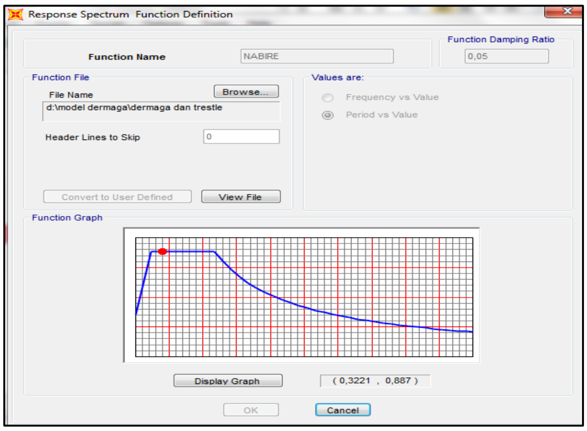

Figure 3 Definition Function of Spectrum in SAP 2000

3.1.2. Time History Analysis

The ground motion accelerogram used in the time history analysis must have at least 11 pairs [12] from the PEER site. The location and value of the magnitude can be seen in Table 7:

Table 7. Ground Acceleration Used

No	Quake Name	Statio	Year	Magnitude
1	Northern Calif-03	Ferndale City Hall	1954	M 6,5
2	Imperial Valley-06	El Centro Array #7	1979	M 6,53
3	El Alamo	El Centro Array #9	1956	M 6,8
4	Kobe, Japan	Port Island	1995	M 6,9
5	Loma Prieta	LGPC	1989	M 6,93
6	Imperial Valley-02	El Centro Array #9	1940	M 6,95
7	Duzce, Turkey	Duzce	1999	M 7,14
8	Tabas, Iran	Tabas	1978	M 7,35
9	Kern County	Taft Lincoln	1952	M 7,36

The following is a scale carried out on 11 earthquake records with the Nabire response spectra as the reference use seismomatch program then can be used for analysis and used as earthquake load data in modeling using SAP2000.

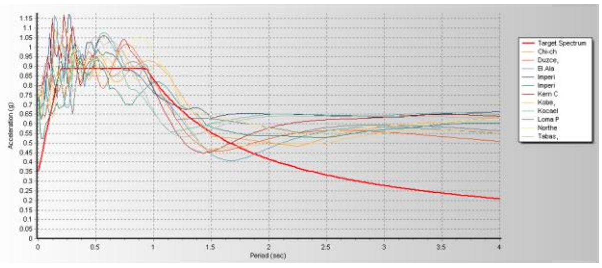

Figure 4 Scaled using Seismomatch Program

3.2. Analysis

Wharf construction consists of slab structure, beam, pile cap, and pile as the foundation. In the case of the dynamics of the construction structure, it has a vibration system with many degrees of freedom (MDOF) so that the measured frequency content in the wharf structure is not limited to the natural frequency of the beam but is a combination of the above systems.

The measured natural frequency value of the wharf is then compared with the theoretical natural frequency (overall natural frequency) where the wharf structure is in good condition. f_{teo} calculation can be done by using SAP2000 structural model analysis.

The measure of the relative degree of damage to the ratio (k) is the difference between the natural frequency measured in the field and the theoretical natural frequency (whole natural frequency) to the intact natural frequency.

$$k = \frac{\Delta f}{f_{teoritis}} = \frac{\Delta f_{field\ test} - \Delta f_{teoritis}}{f_{teoritis}} \quad (1)$$

The following is the measurement of the damage level based on the value of the ratio (k), where this measure is used to provide damage status to the wharf structure. Table 8 presents the condition value:

Table 8. Rating Condition Value

Condition Value	Damage Type	Relative Damage Value (k)	Capacity Lost Value (D_{cap})
Good	Undamaged	0%- 5%	0%- 10%
Fair	Lightly damage (non-structural)	6%- 10%	11 - 20%
Medium	Lightly dagame (structural)	11%- 17%	21% - 34%
Poor	Heavily damage (structural)	18% - 20%	35% - 40%

3.2.1. *Wharf Segment 1 and 2*

The measured natural frequency value from the accelerometer is 0.3 Hz while the theoretical natural frequency value from SAP2000 is 0.852 Hz as shown in the following figure.

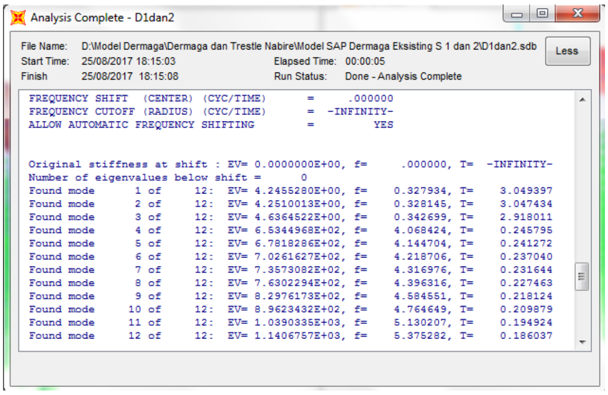

Figure 5 Natural Frequency Output SAP2000 Segmen 1 & 2

Then the value of k that can be obtained is as follows:

$$k = \left[\frac{0.3 - 0.328}{0.328}\right] = 8.53\ \% \qquad (1)$$

Based on the above calculation, the relative damage value obtained at wharfs 1 and 2 is 8.53%. The k value of 8.53% shows the value of the condition is fair with the type of light damage (non-structural).

3.2.1. *Wharf Segment 1 and 2*

The measured natural frequency value from the accelerometer is 0.25 Hz while the theoretical natural frequency value from SAP2000 is 0.855 Hz as shown in the following figure.

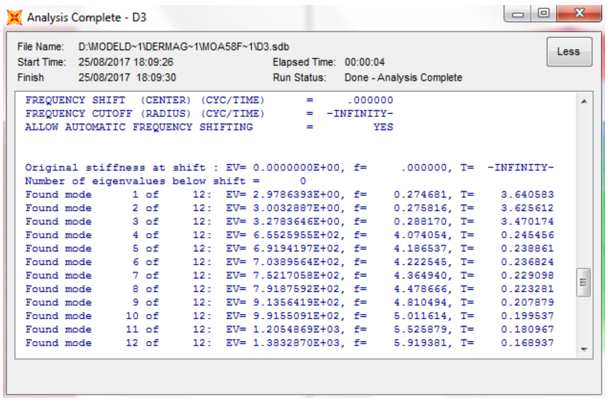

Figure 6 Natural Frequency Output SAP2000 Segmen 3

Then the value of k that can be obtained is as follows:

$$k = \left[\frac{0.25 - 0.315}{0.315}\right] = 9.09\ \% \qquad (1)$$

Based on the above calculation, the relative damage value obtained at wharf 3 is 9,09%. The k value of 9,09% shows the value of the condition is fair with the type of light damage (non-structural).

4. CONCLUSION

Based on the results of the assessment that has been carried out, it is known that some parts of the wharf and trestle structures are damaged but do not interfere with the function of these structures.

The results of visual observations that have been carried out in the field indicate that the port facilities for trestles 1 and 2 are in the poor category. This is due to severe settlement, damage or overstress which can be seen in most structures but will not reduce the bearing capacity of the structure.

Damage to port facilities in the form of trestles 1 and 2 are in the poor category. This is due to the severe settlement, damage or overstress that can be seen in most structures but does not reduce the bearing capacity of the structure.

Trestle 3 is a trestle that is no longer functioning and is heavily damaged by the earthquake. The trestle can no longer be repaired because the damage is very heavy.

The visual condition of the structure is still relatively good and only a few elements on the beams and floors that are damaged. The corrosion of the reinforcement can be repaired by repairing the beams and plates.

Based on the structural analysis, both trestle and wharf conditions are still quite safe by using earthquake reduction 3 and building priority factor 1.5.

The results of the dynamic analysis carried out to determine the magnitude of the natural frequency on the wharf structure showed different results of the vibration test that had been carried out in the field. This is because the natural frequency is affected by stiffness and mass, where stiffness is affected by the cross-sectional inertia of a structure and the modulus of elasticity. In addition, in modeling the dimensions of the wharf element, the dimensions on the DED image are not based on actual conditions in the field.

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