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Gulf of Lampung Bamboo Fixed Net Cages Structural Design Identification

Shila Atika Sari[a], Mochammad Fathurridho Hermanto[a], Elsa Rizkiya Kencana[a], Nafisa Nandalianadhira[a]

[a)] Ocean Engineering Department, Institut Teknologi Sumatera, South Lampung, Indonesia
*Corresponding author: mochammad.hermanto@kl.itera.ac.id

ABSTRACT
Renewable materials are being discussed and researched more recently. One renewable source of material is plants, either with a long life like wood or a short life like bamboo. In Indonesia, bamboo is widely used also for the structures of fixed net cages. This research aims to analyze the structure of the fixed bamboo net cage installed in the waters of Gulf Lampung. The analysis used in this paper is in place. The in-place analysis will give the unity check and deflection result due to load combined by the standard BKI Guidelines for Aquaculture. Based on the results, the structure has met the standard in operation conditions with the maximum unity check value of 0.52 on the group pile. Nevertheless, the largest unity check value of 1.20 on group piles in storm conditions is due to increased lateral loading. The result of deflection already has good serviceability, with a maximum horizontal deflection value occurring in storm conditions of 0.58 cm and a maximum vertical deflection in operation conditions of 0.89 cm. The structure of the fixed net cages has yet to meet the requirements during storm conditions by unity check.

Keywords: *Cages, Fixed, Gulf Lampung, Renewable Materials*

1. INTRODUCTION

The marine and fishing potential of the Province of Lampung dominates both catch fishing and fishery cultivation [1]. Unwise fishing or harvesting seafood or overfishing can reduce the population and sustainability of such resources [2]. However, some marine biological resources have renewable properties. Thus, efforts to increase production using marine resources must be made through cultivation efforts and capture efforts. One is catching fish using various catch tools such as caterpillars called cage-building [3].

Fishermen in the Gulf of Lampung usually use cages to catch fish, squirrels, shrimp, and so on in shallow and inland waters. A cage is a fishing facility comprising essential components such as bamboo material, wooden rods, cage houses, lamps, generators, rods, and square-shaped lamps given a mesh [4]. According to Wijayanti, Bamboo is a renewable building material made from plants [5]. Plants of different kinds are divided into two categories: plants with a lifecycle of 25 years, like wood, and plants with a short life cycle of 4-5 years, like bamboo.

Fishing gear using bamboo fixed net cages can be used as an alternative to a barbed structure that can be easily renewed by seeing the advantages of the bamboo plant. The designs of fixed net cages are often found in square coastal areas and are placed in shallow sea waters. Fixed net cages can affect environmental load conditions or parameters such as winds, sea depths, current speeds, and sea waves. Many rods discovered on the coast are destroyed due to less robust designs caused by high surfs and strong winds. The research was carried out to identify the design of the bamboo fixed net cages in the waters of the gulf, considering the structural stability aspects and the hydro-oceanography factors in the region.

2. METHODOLOGY

The methodology used in this study is shown in Figure 1. This research has been conducted from January to July 2024. This research is carried out starting with a literature study and data collection. Data in this research, which the source needs to be described, is primarily collected from the Gulf of Lampung.

The net cages data collected from the survey in the Gulf of Lampung are 42 points of floating cages and 7 points of fixed cages. This spread map of the surveyed floating cages and fixed cages in the Gulf of Lampung is shown in Figure 2. This research is focused on BT2 structure.

The environmental data used in this study are secondary data derived from Hermanto et al., as shown in Table 1 [6]. The environmental data used in this research are wave height and period, wind speed, and current speed. The environmental data are applied the same value in every direction, omnidirectional.

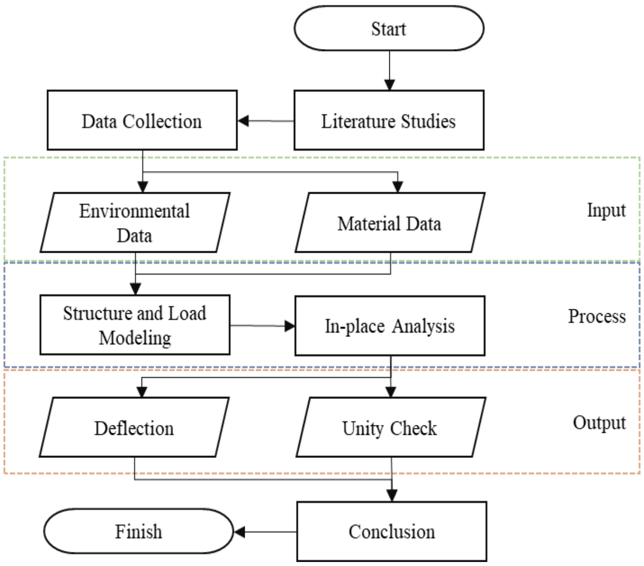


Figure 1. Research Methodology

The bamboo material data used are from other research. Those Betung bamboo parameters are shown in Table 2, consisting of thickness, tensile strength, density, elastic modulus, and shear strength from references [5], [7], [8], [9], and [10].

The data obtained is processed and modelled using finite element structural analysis software. All the load, equipment, operational, and environmental aspects are modelled for that structure. The in-place analysis is taken to analyze the structural strength and stability. Structural strength is in the form of unity checks. Structural stability is in the form of deflection [11].

This unity check is a comparison between the acting stress and the stress capacity of the member. General equations are shown in equations (1) and (2) [12]. According to the standard, the total number of members on the structural unity check must be fewer than 1.00. In order to account for the danger, a factor of 1.33 is given to stress in the unity check computation during storm conditions.

$$UC = \frac{P_u}{\phi_c P_n} + \frac{8}{9}\left(\frac{M_{ux}}{\phi_b M_{nx}} + \frac{M_{uy}}{\phi_b M_{ny}}\right) \text{ for } \frac{P_u}{\phi_c P_n} \geq 0.2 \quad (1)$$

$$UC = \frac{P_u}{2\phi_c P_n} + \left(\frac{M_{ux}}{\phi_b M_{nx}} + \frac{M_{uy}}{\phi_b M_{ny}}\right) \text{ for } \frac{P_u}{\phi_c P_n} < 0.2 \quad (2)$$

The value of deflection must be less than the allowable deflection. The deflections are checked in two directions, horizontal and vertical. The distance between acting and reference or relative joint determines allowable deflection. The allowable deflection formulas based on SNI 03-1729-2002 are shown in equations (3) and (4) [13].

$$\Delta_{\text{all-hor}} = \frac{h}{200} \quad (3)$$

$$\Delta_{\text{all-ver}} = \frac{l}{240} \quad (4)$$

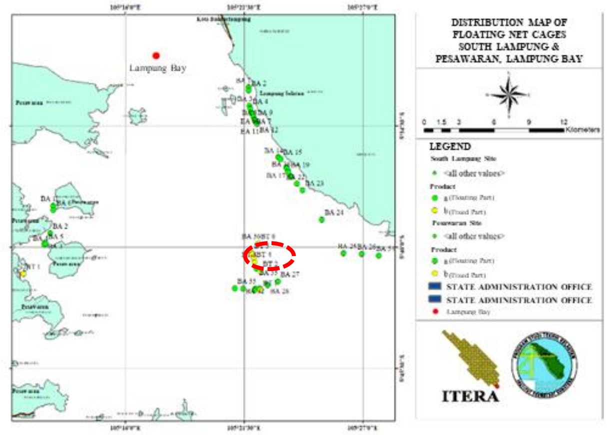


Figure 2. Spread Map of the Fixed and Floating Net Cages

Table 1. Environmental Data

No	Data	Operating	Storm	Unit
1	Wave Height (H)	1.07	2.37	m
2	Wave Period (T)	3.76	4.95	S
3	Wind Speed (U)	8.5	13.36	m/s
4	Current Speed at Seabed	0	0.170	m
5	Current Speed at Surface	0.047	0.510	m

Source: Hermanto et al. [6]

Table 2. Bamboo Material Data

No	Parameter	Value	Unit	Reference
1	Tensile Strength (F_y)	118 - 275	Mpa	[9]
2	Density (ρ)	0.5 – 0.8	g/cm^3	[9]
3	Elasticity Modulus (E)	178,758	kg/cm^2	[5]
4	Shear Strength (G)	9.505	Mpa	[10]

3. RESULTS AND ANALYSIS

3.1 Field Identification

The structure was designed for a depth of 27 m from MSL. The structure is an offshore structure made of bamboo used to catch fish [4]. The structure has a level deck with different brace levels and distinct numbers of legs, as shown in (b) Figure 3. There are three main configurations on the part of the shell structure in Table 3.

Table 3. Structure Elevation

Description	Elevation from MSL (m)
Main Deck	3
Brace	0
Seabed	-27

(a)

(b)

Figure 3. Fixed Net Cages Structure from Field Survey (a) and (b)

3.1.1 Structure of a Fixed Net Cage

Measurement of structure in the field includes dimensions of the main structure and all member diameters and lengths. All those measurements, including layout shape, area, and secondary structural sizes, such as on deck house and pillar, will be used for structure modelling. The results of the measurement can be seen in Table 4.

Table 4. Fixed Net Cage Dimension Data

Property	Data	Unit
Configuration shape	Rectangle	-
Deck area	15 × 15	m^2
House on cage area	2 × 3	m^2
Pillar height	5	m
Brace to deck	3	m

3.1.2 Equipment and Operational Data

Based on the field survey, the equipment on the deck is a roller, generator, and cage houses used for seafood capture. The fixed cage tool usually starts operating when the sun begins to go down. Fishing begins with lowering the net to the desired depth. This step is called “the setting stage," where the net is usually slowly lowered by rotating the roller. After that, the lights are turned on to get the fish to congregate under or around the cages. When the fish gather, the net is lifted, commonly called “hauling." The nets can be lifted to the surface when the fish have accumulated enough, and the condition of the fish is calm. The net is then lifted to be above the surface of the water. The final stage is brailing or transferring the capture from the net to the deck using a rake.

3.2 Modelling

The cage's structure modelling in this study uses finite element structural analysis software [14]. The structural parts modelled are pile, brace, and deck. The pile batter ratio is 1:10, and it is commonly used in waters with wave heights that are not too high and current speeds that are not too strong. This modelling step also applies the bamboo material property in each member.

3.2.1 Structure Modeling

Structure modelling includes pile, brace, and deck. The side view of the structural model is shown in Figure 4. The members' size data for the structure are shown in Figure 4. In this case, the waters in the Gulf of Lampung are 27 meters. The pile modelling has a double batter slope, with a vertical distance (rise) to horizontal distance (run) ratio of 10:1 for all slope directions. This slope is used in waters with wave heights and current speeds that could be stronger. In this model, the pile-soil interaction is modelled as a dummy pile. The structure is supported with a fixed support in every pile.

In the joint modelling, the structure used a spring joint model. The spring joint connection will accommodate semi-rigid behaviour in the joint, allowing for limited movement and interaction between structural elements. This connection corresponds to the behaviour of the connection in the actual structure, where the connection allows rotational deflection to occur with a small value.

Table 5. Member Dimension

Member Group	Structure 1		Structure 2	
	Diameter (cm)	Thickness (cm)	Diameter (cm)	Thickness (cm)
On Deck Pillar	12.55	2.12	12.55	2.12
Brace	24.5 - 26.1	2.35 - 2.50	24.5 - 26.1	2.35 - 2.46
Deck	25.6 - 27.7	2.35 - 2.46	25.6 - 27.7	2.35 - 2.50
Pile	28.5 - 30	2.48 - 3.10	28.5 – 30	2.48 - 3.10

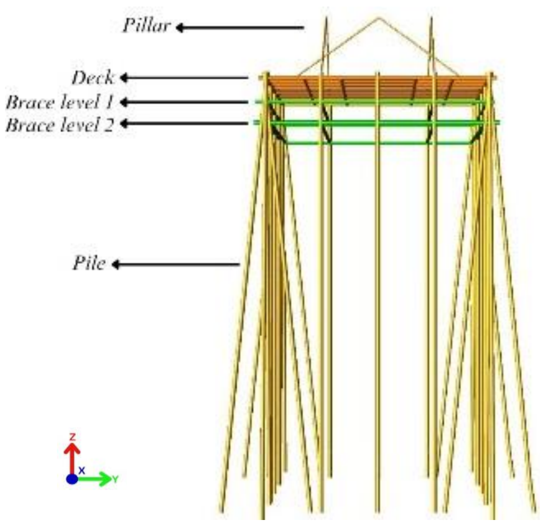
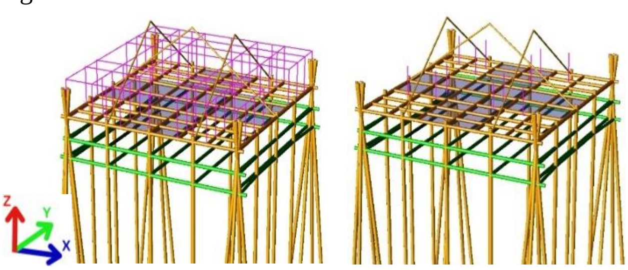


Figure 4. Structure Model

3.2.2 Load Modeling

The structures of the fixed net cages need to consider all these types of loads to ensure the safety and optimal performance of the structure. Structural loading refers to the operational process in a structural element that can cause tension, deformation, and displacement. The loads that work on such structures are commonly dead, live, environmental, and equipment loads. The following are structural and equipment load data, which are presented in Table 6 and Table 7. Loading applied in the structure model is shown in Figure 5.



(a) (b)

Figure 5. Live Load (a) and Equipment Load (b) of Structure Model

Table 6. Structure Load Data

Load ID	Location	Load Type	Weight	Units
BH	On Deck	Member	100	kg/m
BL	Above & Below Deck	Member	2.2	kg/m
BT	Above & Below Deck	Member	100	kg/m

Table 7. Equipment Load Data

Load ID	Location	Load Type	Weight	Units
GEN	On Deck	Point	26.35	kg
ROLL	On Deck	Point	14.5	kg
RUMAH	On Deck	Point	250	kg

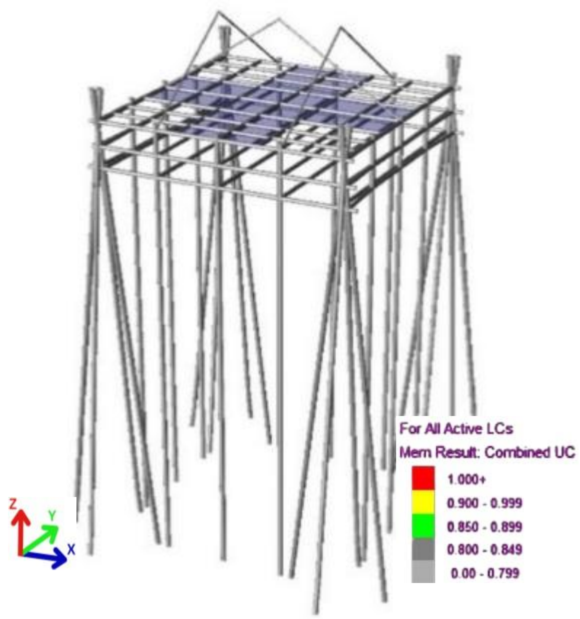
3.3 In-Place Analysis

In-place analysis is a static analysis of offshore structures to analyze the strength and stability of structures. The in-place analysis is carried out under two conditions: operating conditions, which are performed with a 1-year environmental load, and storm conditions, which are performed with a 100-year environmental load. Storm conditions mean the entire activity ceased working, including the people and tools used [15]. The previously defined load will be combined to obtain the value of the load condition [14].

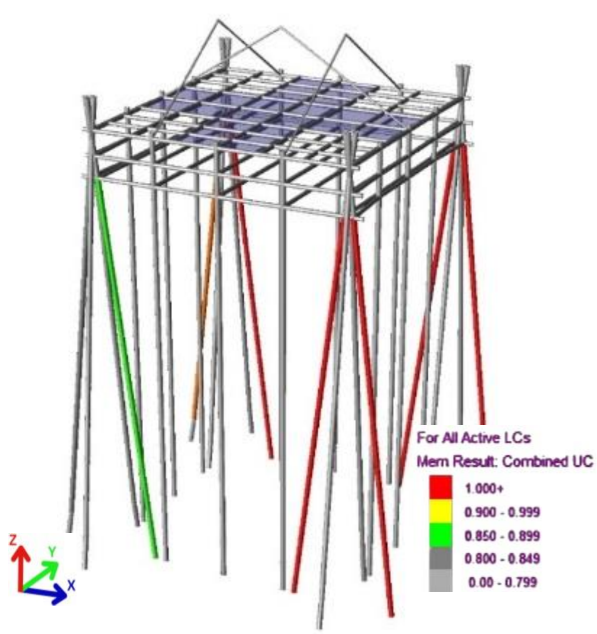
3.3.1 Unity Check

The output obtained from the in-place analysis is the value of the member's unity check. This unity check is a comparison between the acting stress and the stress capacity of the member. Otherwise, the unity check represents the strength of a member to withstand the load that occurs. The unity check values of the structure are presented in Table 8. The results of the in-place analysis of both designs during operating conditions and storms can be visualized in Figure 6.

Based on the operating and storm conditions in-place analysis results, the two conditions significantly differ in unity check values. Table 8 shows that the highest unity check value in the pile is 0.52 in operating conditions and 1.20 in storm conditions. The structure model in operating conditions already meets the requirement (<1.00). Nevertheless, the structure model needs to meet the requirements in storm conditions. That storm condition unity check value is bigger than 1.00, marked with red in Figure 6. That means the pile is still unable to withstand the load in case of a storm.



(a)



(b)

Figure 6. Unity Check Visualization Structure 1 of Operating (left) and Storm (right)

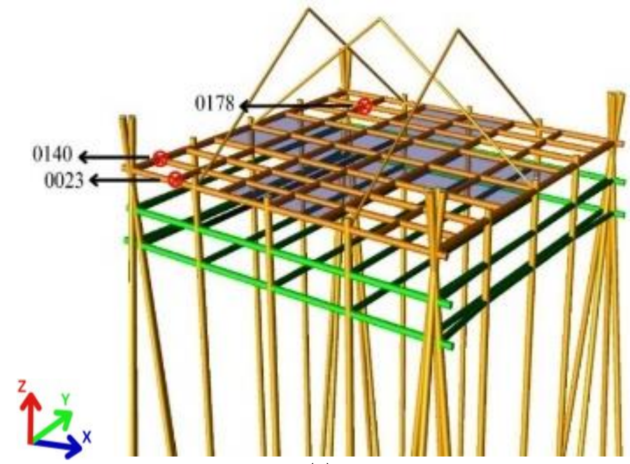
Due to that inability to meet the UC under storm conditions, a structure redesign is necessary to achieve sufficient strength. The redesign is carried out by increasing the dimensions of the cross-section member and enhancing the material properties of the bamboo [16]. That redesign must be done until the structure has sufficient strength to withstand the loads acting on the structure during storm conditions.

Table 8. Structure Unity Check Result

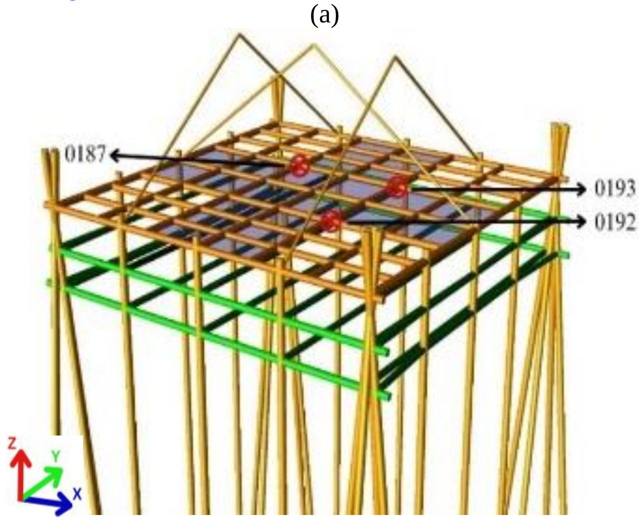
Group	Description	UC Value	
		Operating	Storm
AT	On Deck Pillar	0.01	0.01
B1 – B10	Y Braces	0.01 – 0.04	0.05 – 0.17
BR1 – BR4	X Braces	0.01 – 0.02	0.06 – 0.07
D1 – D16	Deck	0.01 – 0.02	0.06 – 0.26
P1 – P28	Pile	0.04 – 0.52	0.10 – 1.20

3.3.2 Deflection

All the acting joints with the maximum deflection are shown in Figure 7.



(a)



(b)

Figure 7. Maximum Deflected Joint in Horizontal (a) and Vertical (b)

The horizontal distance from acting joints 0023, 0140, and 0178 to relative joints 0079 are 2.65 m. Using equation (3), the allowable horizontal deflection is 1.32 cm. The vertical distance from acting joints 0187, 0192, and 0193 to relative joints 0043 and 0051 is about 2.93 m. Using equation (4), the allowable vertical deflection is 1.22 cm.

Based on the maximum deflection value above, the total horizontal deflection in any condition is smaller than the allowable deflection. This indicates that deflection on the deck already meets the serviceability requirement. The horizontal deflection values on structures during storm conditions tend to be greater than those during operating conditions. This happens because in storm conditions, the operating load, such as from above deck, will decrease, and the environmental load, dominantly lateral, is higher during storms.

4. CONCLUSIONS

From all the calculations and analyses done in this research, the fixed net cage structure already meets the standard in operating conditions with a maximum unity check value of 0.52 on the pile. However, the maximum unit check value in storm conditions is 1.20 on the pile due to increased lateral load. The structure deflection result already meets the serviceability requirement. The maximum horizontal deflection value occurring in storm conditions is 0.58 cm, and the maximum vertical deflection value in operating conditions is 0.89 cm. The structure must be redesigned to achieve sufficient strength to withstand the storm conditions in the Gulf of Lampung.

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REFERENCES

1. K. Hidayat, B. H. Iskandar, M. Riyanto, and D. P. Yuwandana. “Komoditas dan Alat Penangkapan Ikan Unggulan Berbasis Pelabuhan Perikanan Pantai Kuala Stabas Kabupaten Pesisir Barat, Lampung,” Jurnal Penelitian Perikanan Laut, Volume 5, No. 3, Oktober 2021, pp. 265-275, 2022, doi: 10.29244/core.5.3.265-275.
2. D. C. Israel and C. P. Banzon, “Overfishing in the Philippine Commercial Marine Fisheries Sector,” Philippine Institute for Development Studies (PIDS) Discussion Paper Series, No. 1997-01, pp. 1-25, 1997.
3. S. Heltria, R. Rimbi, Mulyadi, and M. E. O. Sirait. “Laporan Praktikum Eksplorasi Sumber Daya Laut "Bagan Tancap dan Analisis Finansial",” Program Studi Ilmu Kelautan, Universitas Sriwijaya, Palembang, Sumatera Selatan, 2015.

A. Afriani, L. Sitinjak, and H. A. Waruwu. “Komposisi Hasil Tangkapan Bagan Tancap Pada Kedalaman 16 Meter di Perairan Poncan Gadang Teluk Tapian Nauli,” Jurnal Penelitian Terapan Perikanan dan Kelautan 3 (2), pp. 121-127, 2021.

4. D. A. Wijayanti, “Konstruksi Bambu Pada Struktur Bangunan Bentang Lebar,” Fakultas Teknik, Universitas Indonesia, Depok, 2008.
5. M. F. Hermanto, N. Nandalianadhira, E. R. Kencana, M. H. I. Khaldun, I. D. Hutajulu, D. Epipanus and J. D. Samosir. “Pesisir Barat Lampung Offshore Wind Characteristic in Local Renewable Energy Development Studies,” IOP Conference Series: Earth and Environmental Science, pp. 1-12, 2024, doi: 10.1088/1755-1315/1298/1/012024.
6. T. B. L. Sony, Sekilas Keunggulan Bambu (Aksi Menanam Bambu Balikpapan 2014-2017), Balikpapan: Kementerian Lingkungan Hidup dan Kehutanan, 2017. [Online]. Available: https://p3ekalimantan.menlhk.go.id/wp-content/uploads/2021/11/Sekilas-Keunggulan-Bambu.pdf.
7. F. T. Wulandari, D. S. Rini, E. Wahyuningsih, and A. T. Lestari. “Pemanfaatan Papan Laminasi Bambu Petung (Dendrocalamus asper (Schult. f.) Backer ex Heyne) Sebagai Pengganti Kayu,” Jurnal Bina Wakya, ISSN No. 1978-3787, Vol.15 No.8 Maret 2021, pp. 4897-4907, 2021.
8. G. L. B. Eratodi, Struktur dan Rekayasa Bambu, Denpasar, Bali: Universitas Pendidikan Nasional, 2017. [Online]. Available: https://www.academia.edu/34108840/Buku_Struktur_dan_Rekayasa_Bambu.
9. Irawati and A. Saputra, “Analisis Statistik Sifat Mekanika Bambu Petung (Dendrocalamus Asper),” Simposium Nasional Rekayasa dan Budidaya Bambu I, Rekayasa Bambu Sebagai Solusi Pelestarian Lingkungan, pp. ISBN:978-602-95687-6-9, JTSL FT UGM, Yogyakarta, 2012.
10. S. E. A. Raheem, E. M. A. Aal, A. G. A. A. Shafy, M. F. M. Fahmy, and M. Omar, “In-Place Analysis for Structural Integrity Assessment of Fixed Steel Offshore Platform,” Arabian Journal for Science and Engineering, vol. 46, pp. 5031–5045, 2021, doi: 10.1007/s13369-020-05200-3.
11. API RP 2A-LRFD, Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms - Load and Resistance Factor Design, Northwest Washington: American Petroleum Institute, 1993.
12. SNI03-1729-2002, Tata Cara Perencanaan Struktur Baja Untuk Bangunan Gedung, Bandung: Badan Standarisasi Nasional, 2000.
13. Paramashanti, Rildova, M. F. Hermanto, and N. Nandalianadhira, "Determination of LRFD Environmental Load Factors of Offshore Platform in

the North of Java Sea and Makassar Strait," International Journal of GEOMATE, vol. 25, no. 111, pp. 91–103, 2023, doi:10.21660/2023.111.4010.
14. R. F. Hamendra, “Analisis Struktur Lepas Pantai Tipe Jacket 4 Kaki,” Institut Teknologi Bandung, Bandung, Jawa Barat. [Online]. Available: https://tekniklepaspantai.itb.ac.id/wp-content/uploads/sites/441/2022/03/15512052-Roby-Febrya-Hamendra.pdf.
15. F. A. Ramadhan, M. A. H. Habib, J. H. B. Mustofa, “Perancangan Struktur Jacket Tiga Kaki Pada Leigen z-10 Wellhead Platform,” Teknik Kelautan, Institut Teknologi Sepuluh Nopember, Surabaya, 2016. [Online].