Study on the Failure Performance of Reinforced Concrete and Composite Concrete Structures due to Non-Linear Time History Earthquake Loads

Bimo B. Adhitya, Anthony Costa, Kencana Verawati, and Wadirin

***Abstract*— The water intake structure is a clean water storage building—a concrete building reinforced with composite steel piles. The structure form was a pier-type reinforced concrete structure, which is usually located on riverbanks. It supplied and distributed clean water through channels of pure water pipes. Several previous studies have stated that the type of jetty structure is appropriate if applied to riverside areas with high water wave pressure. This study analyzes the jetty structure's seismic performance at a specific earthquake scale modeled by finite 3-dimensional elements to assess its capacity. A design modeling intake structure using a finite element-based program, namely extended three-dimensional analysis of building system (ETABS), comprised the process of assessing the failure performance of the structure. Then, the nonlinear time-history load matched the response spectra region of Palembang. Based on the results, after being subjected to periodic earthquakes with El Centro-style nonlinear time-history loads, the pump intake structure failed structural deflection; the failure occurred in the pile cap. For the intake pier structure, composite-type piles are extremely effective because they reduce deformation in soft soil and produce smaller structural deviation values.**

***Index Terms*—Damage control, Finite element analysis, Intake structure, Non-linear time history**

I. INTRODUCTION

THE intake structure is designed to accommodate and process river water into clean water for community distribution. Intake structure selection is influenced by water level and pressure [1]. The jetty intake structure usually consists of several piles. The advantage of the jetty intake design is that it is economical and effective in areas with strong river currents, because it is generally stronger against waves and pressure. However, this type of jetty structure requires specific analysis. The design's performance will worsen if implemented in a loose, granular soil type [2]. The intake structure is reinforced concrete, providing clean water, sand, pollution-free from industrial waste and household waste, and other floating materials. There are two types of intake structures: wet and dry. The dock intake structure is a dry type because there is no water in the reservoir. Water is extracted from a river or lake source and then flows into the surrounding environment [3].

The water intake structure consists of inlet and outlet water channels, usually made of reinforced concrete. This intake structure helps regulate water flow from vertical to horizontal directions [4]. In planning the pump intake structure, pump loads, constituent materials, and soil conditions are considered using structural modeling that truly represents field conditions [5]. The building's intake structure receives loads in the form of hydrostatic pressure and pressure from changes in momentum from water velocity. Therefore, the design requires a 3D numerical program analysis to predict failures [6].

The intake structure's planning and construction are based on a review of geometry, concrete material (compressive strength), and steel material (tensile strength). Based on the previous study [7], it is necessary to analyze structure performance using finite element modeling with nonlinear time-history (NLTHA) loads. In the last few decades, nonlinear analysis has been performed to evaluate structural damage levels and predict the value of the susceptibility of reinforced concrete to earthquake loads [7]. The assessment is an analytical approach to the structure's behavior. A comprehensive approach that considers dynamic and nonlinear phenomena is most suitable for describing structures' reactions to ground motion or earthquakes. NLTHA analysis is a reliable tool that considers the dynamic movement of the system during seismic and nonlinear events. Previous research has analyzed the intake building as an 88-m reinforced concrete tower. This intake building was modeled using 3D finite element software with 30 types of typical near-fault impulsive and nonpulse records. The scaled earthquake load is a boundary condition in the model. Damage above the intake tower area signifies declining performance levels. The performance level

Manuscript received September 6, 2022; revised February 21, 2023. This research/publication of this article was funded by DIPA of Public Service Agency of Universitas Sriwijaya 2022. SP DIPA-023.17.2.677515/2022, on December 13, 2021. In accordance with the Rector's Decree Number: 0110/UN9.3.1/SK/2022, on April 28, 2022.

Bimo B. Adhitya is as a lecturer in the Department of Civil Engineering, Faculty of Engineering, Universitas Sriwijaya, Indralaya 30662, South Sumatera, Indonesia. (e-mail: bimo@unsri.ac.id).

Anthony Costa is a lecturer in the Department of Civil Engineering, Faculty of Engineering, Universitas Sriwijaya, Indralaya 30662, South Sumatera, Indonesia. (corresponding author to provide phone: +62-711-580-062; e-mail: anthonycosta@ft.unsri.ac.id).

Kencana Verawati is a lecturer in the Department of Transportation, Faculty of Engineering, Universitas Negeri Jakarta, Jakarta - Indonesia. (e-mail: kencanaverawati@unj.ac.id).

Wadirin is a lecturer for the Study Program of Mechanical Engineering Education, Faculty of Teacher Training and Education, Universitas Sriwijaya, Indralaya 30662, South Sumatera, Indonesia (e-mail: wadirin@fkip.unsri.ac.id).

category is based on the magnitude of the displacement and curvature of the structure capacity due to the original earthquake scale, which is greater than the earthquake because the coefficient has been scaled up to 1.77 g [8].

Civil engineering infrastructure must be strong enough to withstand earthquake loads and have high structural attenuation. Building-level performance is a building criterion applied after an earthquake. Building-level performance be explained by descriptions of the steel ratio level, structural displacement value, plastic hinge, deflection, and drift that occur in the building [9], [10]. Other studies have stated that dock-type buildings can be used as a strong building solution in coastal or riverside areas. Dock-type building is reviewed based on a small percentage of waves the pier pole receives, but the overall rate of these waves can change based on differences in structure height and water elevation [11]. Based on this and considering the existing conditions of the construction of the intake pier in an area with significant river flow, this study aimed to identify and analyze the effectiveness and capacity of the intake pier using 3D numerical program modeling with additional loads in the form of time-history earthquake loads

II. CASE STUDY DESCRIPTION

Composite structures are extremely suitable for dock-type buildings. Composite piles can minimize external load influence and water wave reflections while also helping to withstand current, wind, impact, wave, and other extreme loads. This composite structure has a high bearing capacity, is more plastic and sturdy, and has more economic efficiency than concrete structure [12]. In addition, foundation structures with precast piles for buildings located on coasts and rivers are difficult to implement because piles sink faster, so selecting a composite structure foundation for piers is recommended [13]

Modeling the liquefied natural gas (LNG) jetty structure with time-history loads shows a structural displacement and stress response 10–20% greater than that of ordinary waves [13]. Then, 3D numerical modeling provides a dynamic response of waves on the pier structure. The dynamic load of water waves affects the pier structure and produces a relatively large internal force [13]

III. STRUCTURAL FEATURE

A wharf-type raw water intake structure located in Karanganyar, South Sumatra, Indonesia, was completed in 2021. This structure's total height is ± 24 m, and it consists of 20 m high composite piles, 4 m high steel beams, and columns, pile cap beams, and floor slabs made of reinforced concrete.

The structure's dimensions include 35-cm-thick floor slabs, 60 cm × 80 cm pile cap beams, and 60-cm-diameter composite steel piles with a pipe thickness of 1.5 cm and 20.75 MPa strength concrete filler material. In addition, the pump housing area consists of 10 × 12 W steel beams and 6-m high steel columns with dimensions of 12 × 26 W.

The structural materials were reinforced concrete, steel, and composites. The concrete material specifications had a compressive design strength of 20.75 MPa, and the steel material specifications had a tensile strength of 400 MPa. The data used to calculate the intake structure included the results of existing measurements and soil mechanics tests. The soil mechanics test aimed to determine the parameters and properties of the soil at the location using the design sketches shown in Figures 1–3. Structural modeling, especially in the reinforcement section of the lower structure (foundation), also affects increasingly plastic hinges [14].

After data are obtained, a mathematical modeling method is conducted using a 3D modeling capacity analysis with the help of finite element-based software (ETABS) by checking the stress–strain, drift, ratio, displacement, and period modes so that the design represents the field conditions.

IV. METHOD

A. Finite Element Modelling

Design modeling on ETABS used finite element model analysis with the previously described detailed dimensions and materials. Inertial mass, self-weight, and type of loading were applied to the model in the form of distributed loads on beams, columns, and floor slabs. The loads the structure received included a dead load of 7.42 kN from a hoist crane, a 400 kg/m^2 live load, an 8.278 kg point load of 7 points, a 329 kN hydrostatic pressure water load received by the composite pile section, and an active earth pressure soil load with a shear angle value of 0^0, cohesion of 110.12 kN/m^2 to 662.4 kN/m^2 [15]. Finally, it received an earthquake load in the form of El Centro's NLTHA. The earthquake that occurred in El Centro, California, was one of the most powerful earthquakes on record, with a magnitude of 7.1, which is scaled to the response spectra of the Palembang region with hard rock types [16]. A time-history model analysis assigns the earthquake loads of particular earthquake records to the building structure base [17]. The shape of the El Centro NLTHA earthquake load matched the time domain of the response spectra of the Palembang region, as seen in Figure 3.

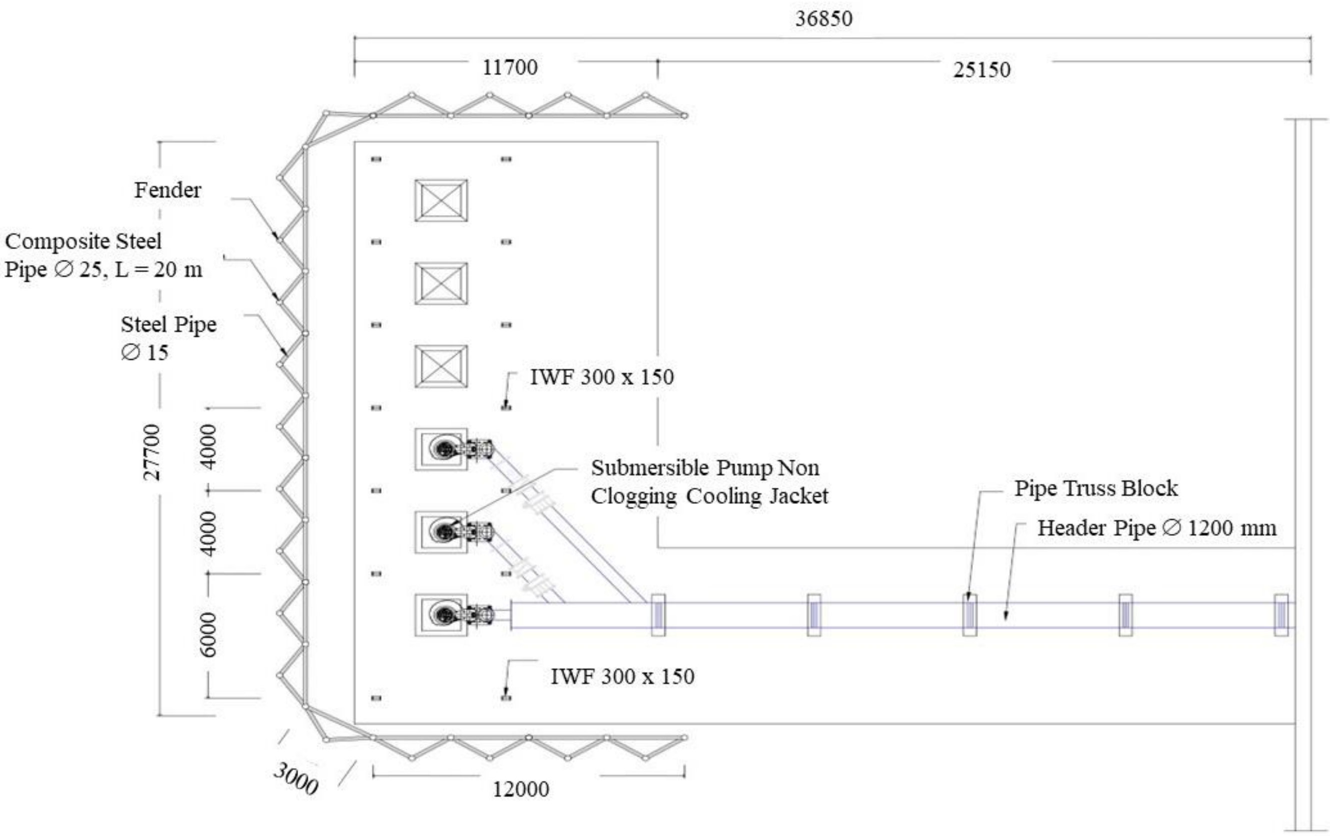
In the intake structure area, El Centro's peak ground acceleration in 1940 was N–S for the 475-return period. The scale factor value was 1532.289, which was scaled based on the response spectra of the Palembang area, site class B.

B. Capacity Analyzed of Intake Structure

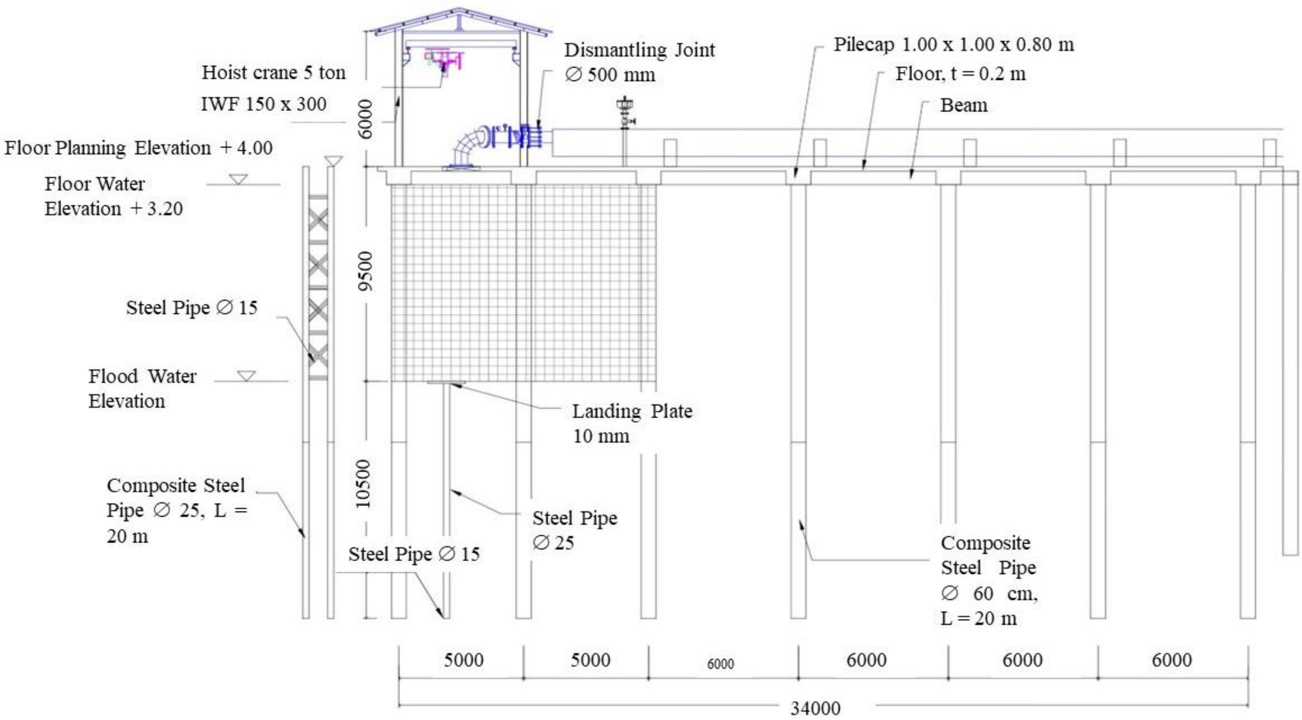
After all the structural loads are distributed in the model, the next step is to determine the combined load as a form of structural failure analysis, capacity, or serviceability. The load combination data used in this numerical modeling are presented in Table 1.

TABLE 1
LOAD COMBINATION OF STRUCTURE

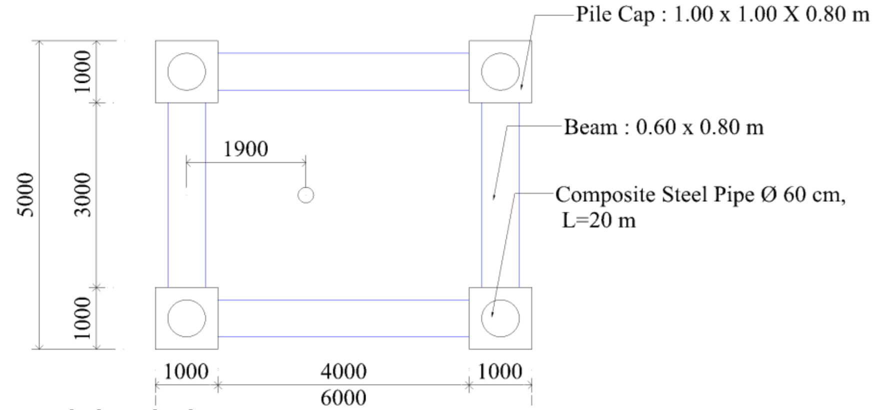
No	Load Type	Combination				
		Combo 1	Combo 2	Combo 3	Combo 4	Combo 5
1	Dead	1.4	1.2	1.2	1.2	1.2
2	Live	-	1.6	1.0	1.0	1.0
3	Water	-	-	-	1.0	1.0
4	Soil	-	-	1.6	-	1.0
5	Earthquake	-	-	-	-	± 0.7



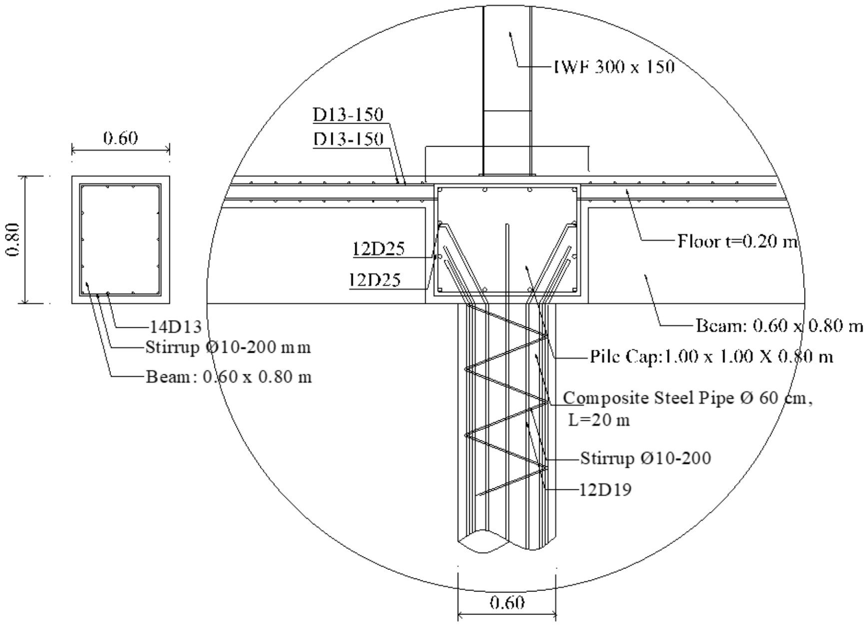
a. Top view



b. Side view
Fig. 1. Intake structure



a. Beam and pilecap detailing



b. Pilecap and compposite detailing

Fig. 2. Beam, pilecap, and composite detailing

Fig. 3. The 3D intake structure modelling

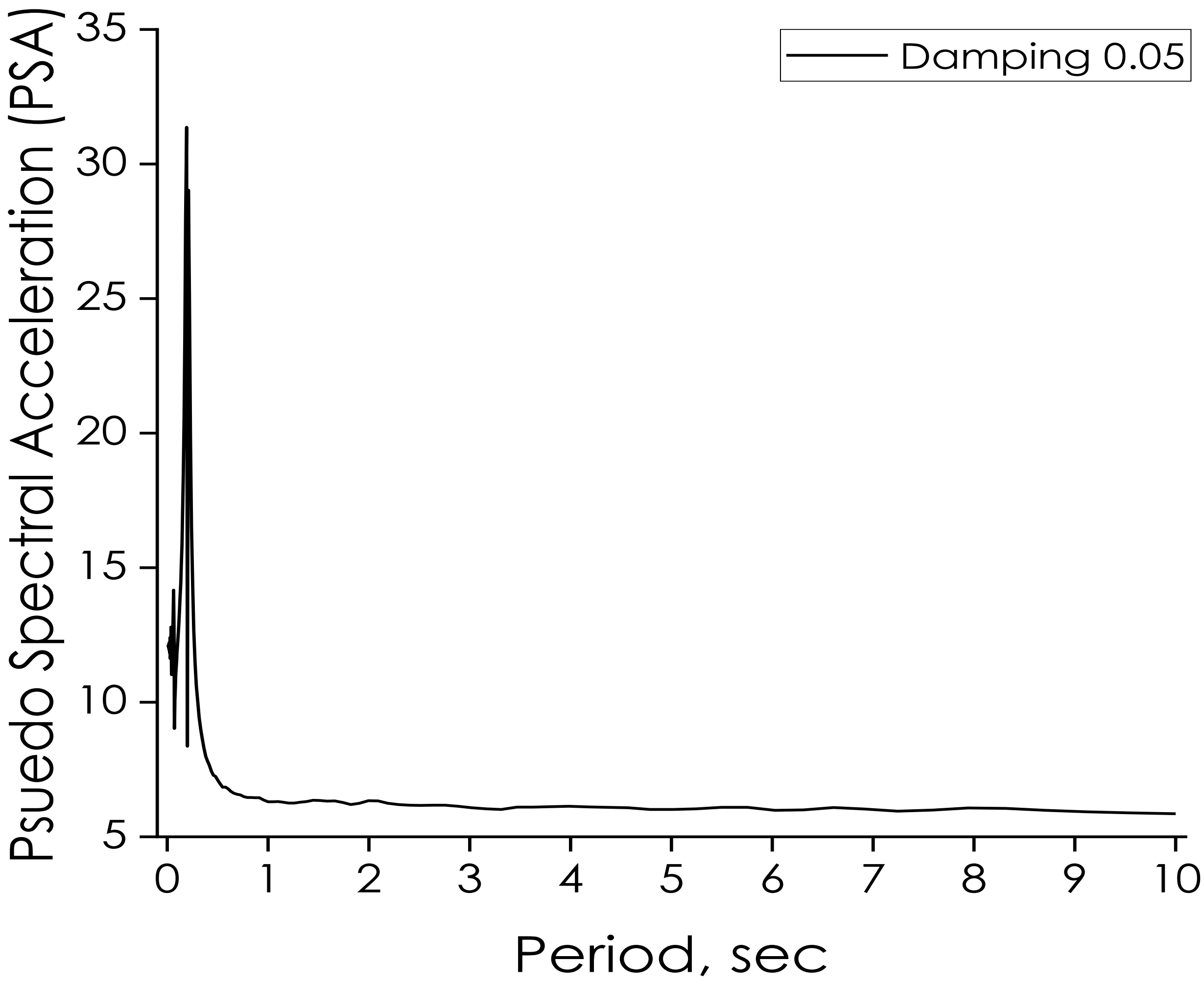
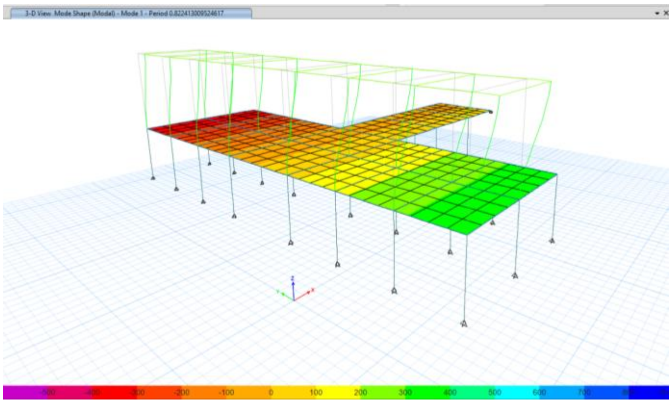
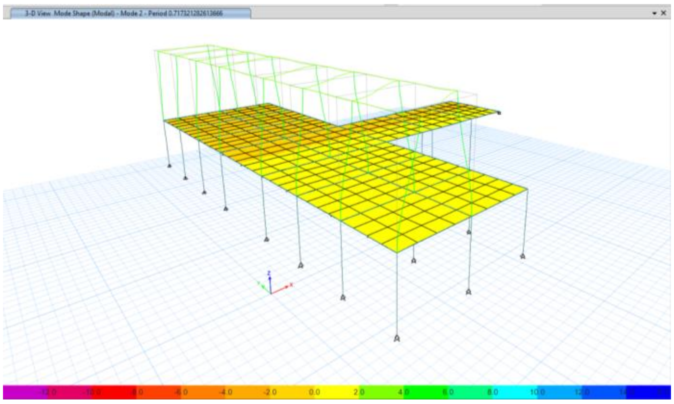


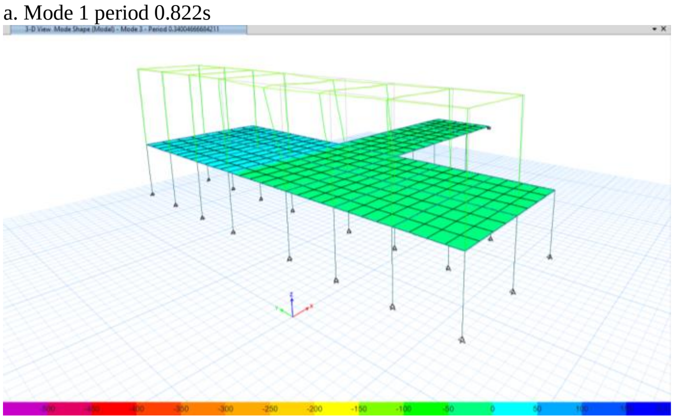
Fig. 4. The design and scaled spectrums



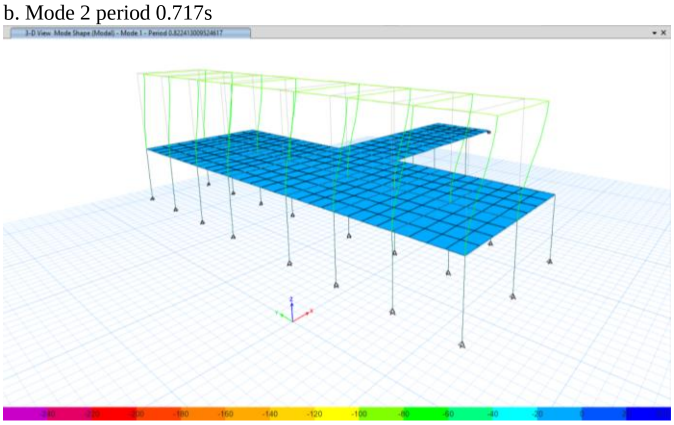
a. Mode 1 period 0.822s



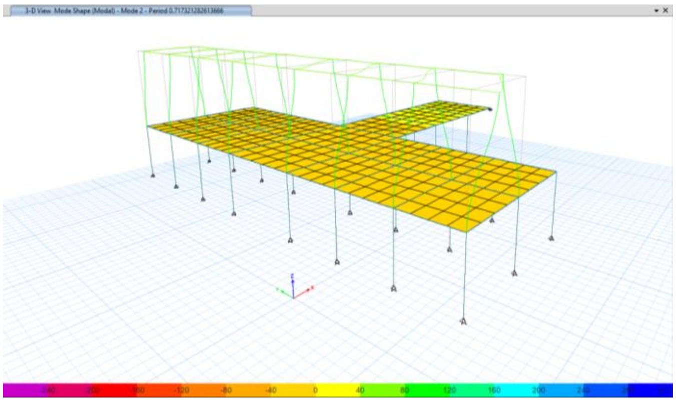
b. Mode 2 period 0.717s



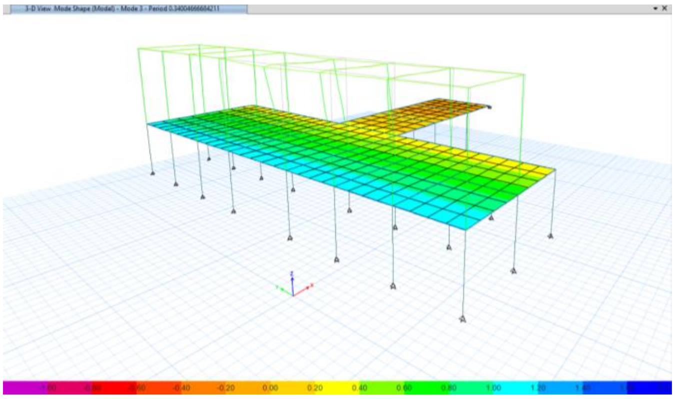
c. Mode 3 period 0.340s



d. Mode 1 period 0.822s

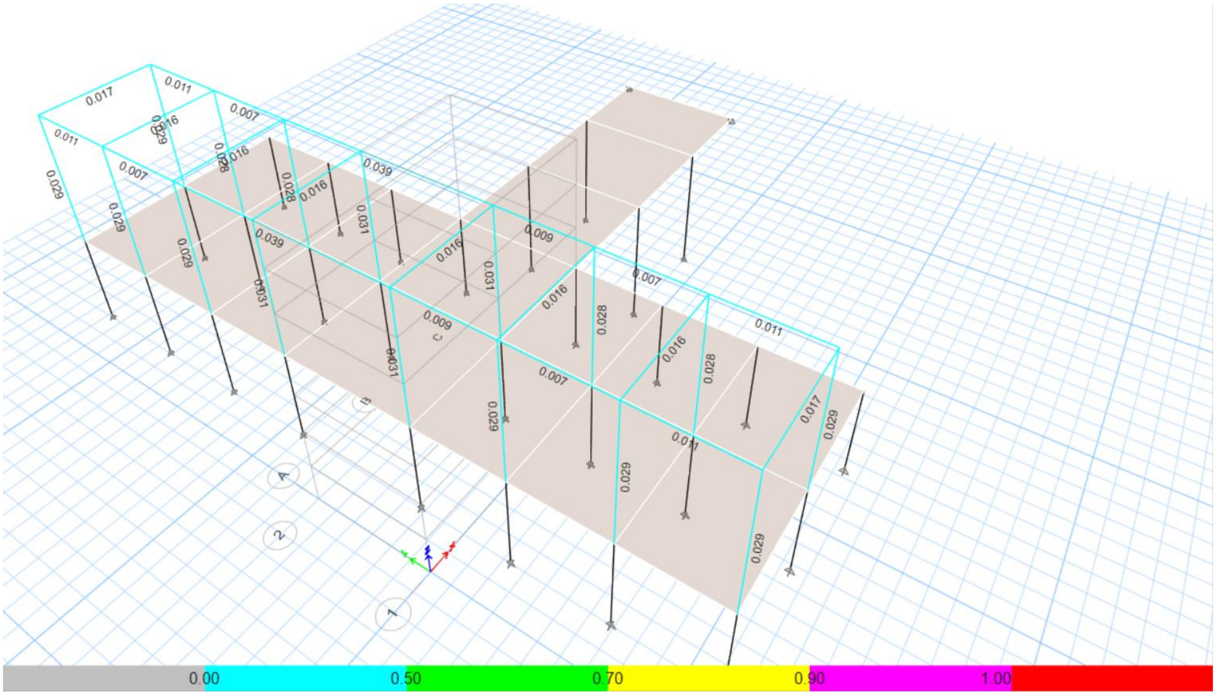


e. Mode 2 period 0.717s

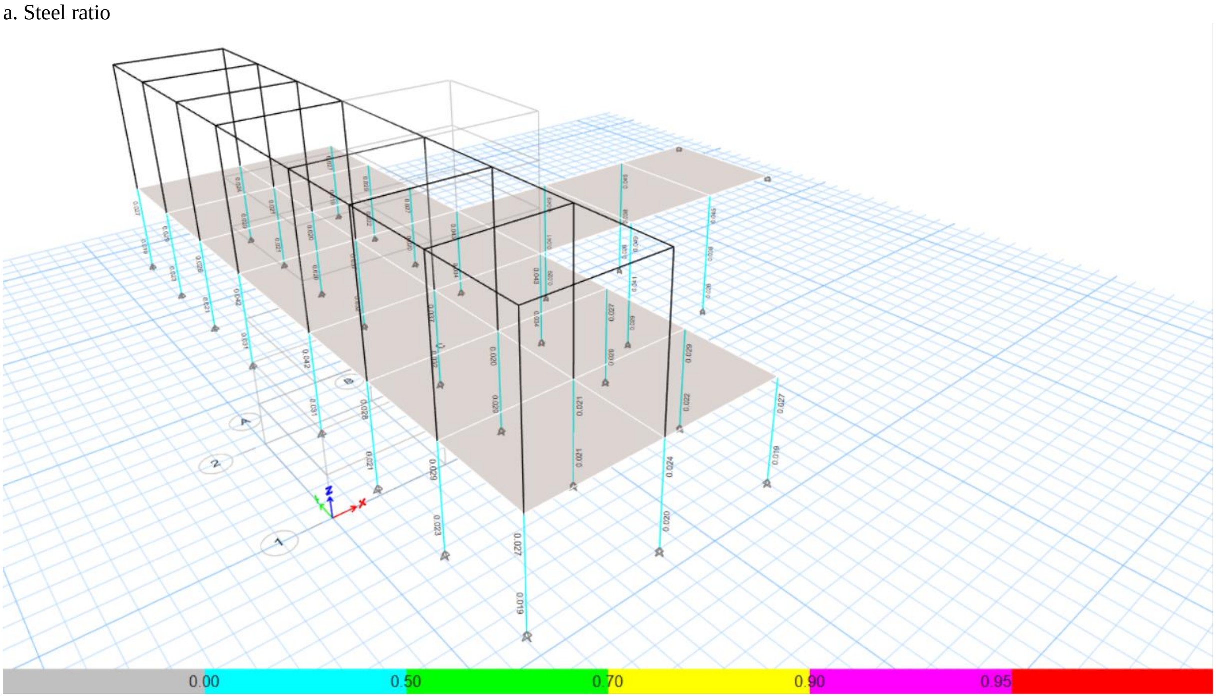


f. Mode 3 period 0.340s

Fig. 5. Vibration mode shape and periodes x and y directions



a. Steel ratio



b. Composite ratio

Fig. 6. Steel ratio and composite ratio

The next stage was the capacity and structural failure analyses, which referred to conditions such as the following:

1) Steel and composite steel (R) profile safety ratio with safe condition ≤ 1.
2) Determination of the values of deflection, mode period, and drift that occur in the structure as proof of plastic deformation against an NLTHA [18].

V. Results and Discussion

The analysis of structural modeling results can be measured when the structure exceeds the value of the displacement permitted and the period mode that occurs due to plastic deformation [19]. The value of the fundamental period mode that should not be exceeded based on Indonesian National Standard (SNI) number 1726-2020 article 7.8.2.1 is:

$$T_a = C_t \cdot h_n^{\ x} \tag{1}$$

The fundamental period in seconds in Equation (1) is T_a, where C_t and h_n^x are the approximate period parameters based on the construction type and height. An analysis of the structural period that occurs in the modeling of the permit requirements for the fundamental period can be seen in Table 2 and Figure 5.

TABLE 2
MODE PERIOD ANALYSIS

No	Mode Periode (s)		Scale Factor (Ao.g)	Status
	Structure Period (Ts)	Fundamental Period (Ta)		
1	0.822	0.0304	1532.89	Not OK!
2	0.822	0.0304	2298.434	Not OK!
3	0.822	0.0304	3064.578	Not OK!
4	0.822	0.0304	7661.445	Not OK!

Previous research stated that the response of L-shaped buildings to equivalent static loads and response spectra resulted in a higher response than regular-shaped buildings [20]. For T- and L-shaped buildings, the taller the building, the greater the structural and stress responses [21].

Based on Table 2 and Figure 4, the structural response in the form of the period mode generated in this finite element model shows greater results and exceeds than the fundamental period permit requirements by scaling the natural peak ground acceleration (PGA). However, the value of the damage performance produced by the structure still meets the limit for steel and composite structures, as seen in Table 3 and Figure 6.

TABLE 3
RATIO OF STEEL AND COMPOSITE STRUCTURE

No	Permit Terms of Structure Ratio < 1		Scale Factor (Ao.g)	Status
	The Ratio of Steel Structure	The Ratio of Composite Structure		
1	0.039	0.049	1532.89	OK!
2	0.039	0.049	2298.434	OK!
3	0.039	0.049	3064.578	OK!
4	0.039	0.049	7661.445	OK!

Composite columns are made by encasing steel in concrete or filling steel with concrete; composite columns made of steel tubes filled with concrete are efficient and useful as fire protection layers. The implementation of this method is fast [22].

Buildings with conventional dimensions produced small deflections during the 1940 N–S El Centro earthquake. Conversely, buildings with irregular dimensions produce large deflections caused by their response and performance, which depend on the structural design type, location, and degree of irregularity [23].

The results show that the ratio of steel and composites obtained after exposure to the El Centro nonlinear time-history earthquake load is still below the limit permitted by the ratio. This is because the strength ratio must be compared to a nominal strength of < 1 [18]. The next step is to analyze the value of the allowable drift ratio and deflection limits that occur in the intake structure. This is also one of the methods for predicting a building's failure [24].

When a structure standing on hard ground is exposed to earthquake forces, the stiffness of the hard soil layer has little impact on design deformation. Conversely, if the structure stands on a subgrade with low stiffness, the soil will fail to accommodate excess deformation, and the basic motion of the design will deviate beyond the allowable movement. This phenomenon—structural responses influenced by soil motion—is called soil–structure interaction [14]. The requirements of the drift permit limit and structural deflection on the beam can be seen in the following equations:

$$\Delta = 0.02 \times h_{sx} \tag{2}$$

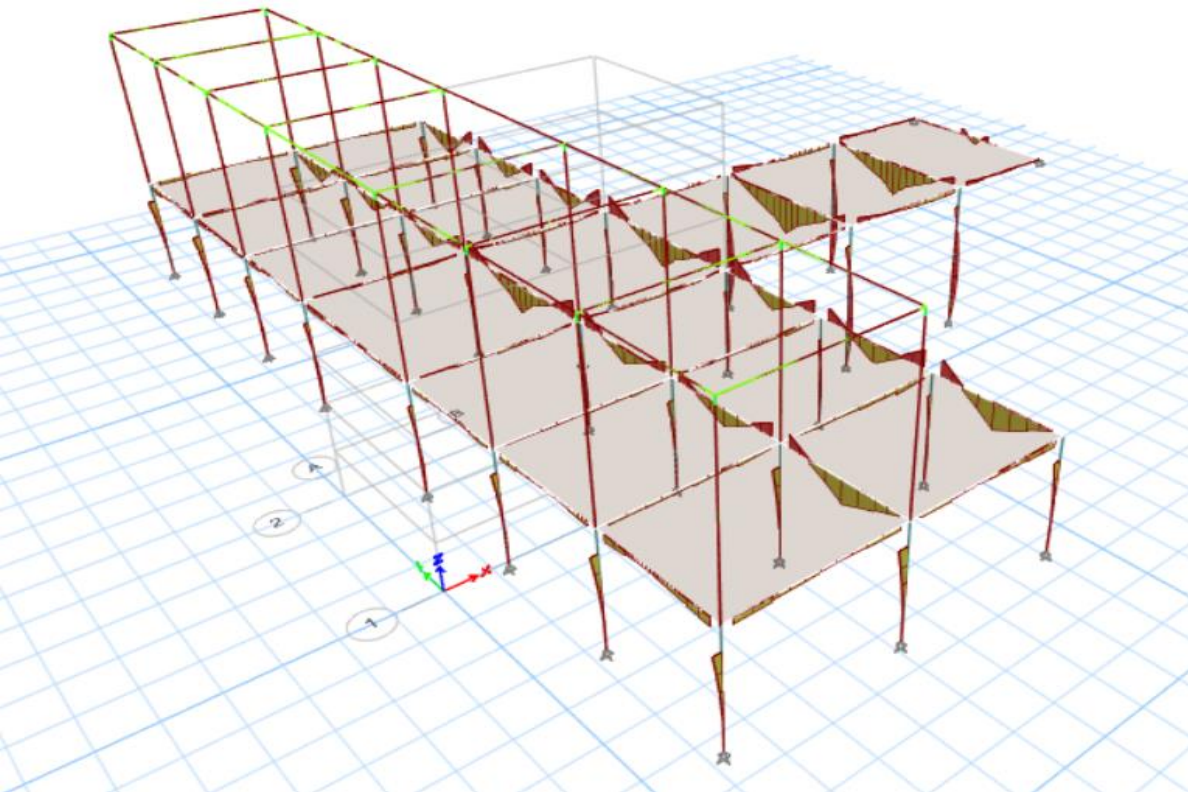
$$\delta = L_n \div 240 \tag{3}$$

In Equation (2), Δ is the allowable drift, and h_{sx} is the structure height. In Equation (3), δ is allowable deflection, and L_n is the beam span in the design. The results of the drift and allowable deflection analyses are shown in Table 4 and Figure 7.

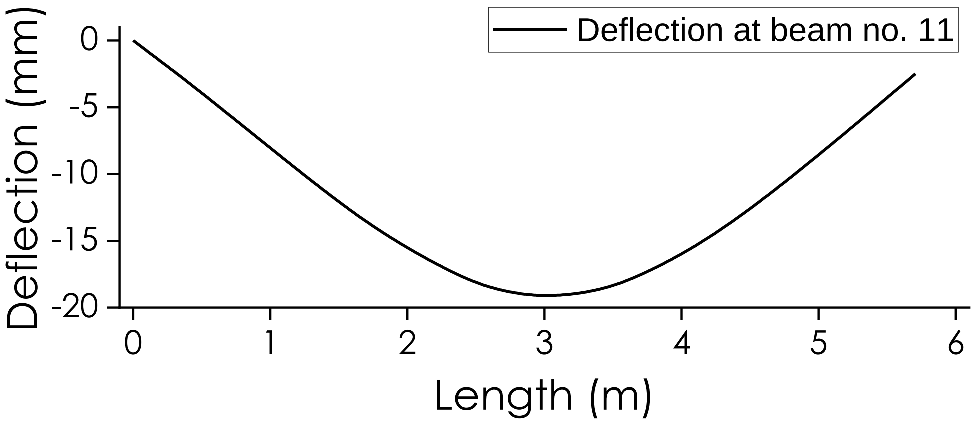
TABLE 4
DRIFT PERMIT LIMIT AND ALLOWABLE DEFLECTION AT BEAM

No	Drift and Allowable Deflection at Intake Structure (mm)			
	Structure Drift	Permit Drift	Beam Deflection	Allowable Deflection
1	120	57	19.211 (B11)	12.5

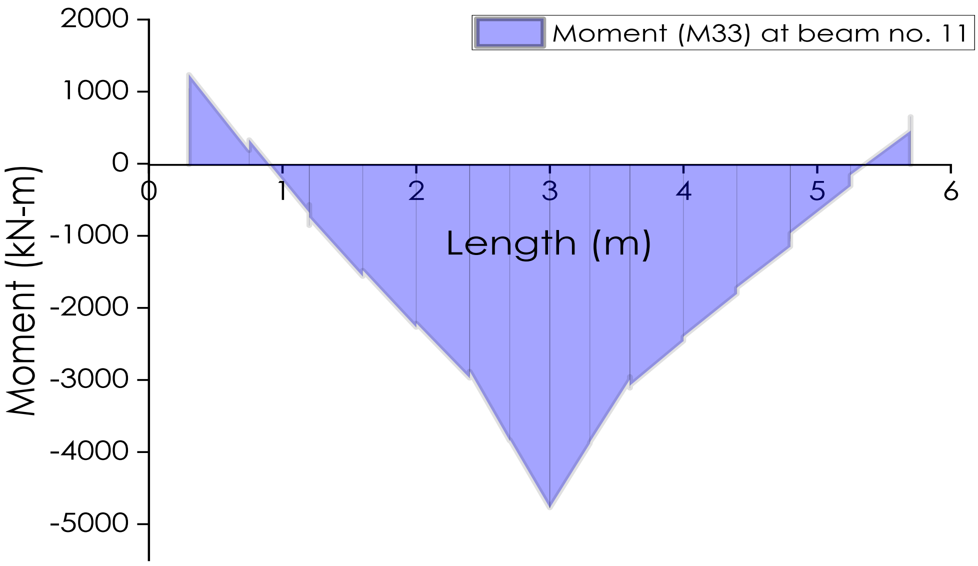
Deflected or deformed beam shapes—especially a cantilever beam under a distributed vertical load—indicate structure failures. Deflected or deformed beam shapes caused hinged and fixed ends of the beam to move, and when the hinged end moved horizontally with a certain displacement, the vertical reaction and horizontal force maintained beam balance [25].



a. Output moment and axial at intake structure



b. Maximum deflection at Beam 11



c. Maximum moment at Beam 11

Fig. 7. Maximum load and force distribution at Beam 11

Based on Table 4, the drift value of the structure that occurs in the modeling still meets the safety requirements. In structural engineering, the value of the deflection received by the beam due to the combined load is usually caused by the maximum stresses, which occur at the bending point of the beam [26]. In contrast, the maximum deflection in beam B11 exceeds the safety requirements. In the time-history load analysis, ground motion excitation caused the building structure to receive alternating earthquake movements, spreading out the forces on the structural elements. The maximum load and force distribution in the pile cap beam are shown in Figure 7. Meanwhile, a higher cross-sectional capacity and material on steel columns, beams, and composite piles produces smaller movement, shear, and axial outputs.

VI. CONCLUSIONS

This study aims to analyze the capacity of a jetty intake structure consisting of reinforced concrete, steel, and composite steel after being subjected to the El Centro earthquake load. The earthquake failure prediction was made using ETABS, a finite element-based program. Nonlinear time-history studies of structural loading are widely used to develop structural loads and predict concrete's susceptibility to earthquakes. This study's results indicate that the pump intake structure satisfies the seismic design requirements, namely strong columns and weak beams. Failures are caused by structures' deflection values deviating from and exceeding building safety permit requirements. Selecting composite-type piles for intake pier structures is highly effective because it reduces deformation in soft soil and produces smaller structural deviation values. The pump performance capacity, after being given a nonlinear time-history El Centro load with the earthquake scale increased to 5xAog, indicates damage to the pile cap beam (B11) with reinforced concrete construction. However, the steel and composite constructions were still within the safe ratio limit. This structural failure also occurs because the value of the permit drift exceeds the safety limit of the drift building.

ACKNOWLEDGMENT

Thanks to Dr. Dendy Adanta from Department of Mechanical Engineering, Universitas Sriwijaya for help in writing and reviewing this manuscript.

REFERENCES

[1] R. Gabl, B. Gems, F. Birkner, B. Hofer, and M. Aufleger, “Adaptation of an existing intake structure caused by increased sediment level,” *Water*, vol. 10, no. 8, p. 1066, 2018.

[2] A. Vytiniotis, A.-I. Panagiotidou, and A. J. Whittle, “Analysis of seismic damage mitigation for a pile-supported wharf structure,” *Soil Dyn. Earthq. Eng.*, vol. 119, pp. 21–35, 2019.

[3] V. S. Sarode, A. A. Yadav, E. M. V. Dehadrai, and A. A. Adekar, “Analysis and Design of,” *Int. J. Creat. Res. Thought*, vol. 8, no. 4, pp. 3443–3451, 2020.

[4] L. H. Chie and A. K. Abd Wahab, “Derivation of engineering design criteria for flow field around intake structure: A numerical simulation study,” *J. Mar. Sci. Eng.*, vol. 8, no. 10, p. 827, 2020.

[5] A. Costa and A. Yudi, “Analisa Kapasitas Struktur Intake Rumah Pompa Karang Anyar, Pulokerto,” *J. Proy. Tek. Sipil*, vol. 4, no. 2, pp. 49–56, 2021.

[6] J. M. Carrillo, J. T. García, and L. G. Castillo, “Experimental and numerical modelling of bottom intake racks with circular bars,” *Water*, vol. 10, no. 5, p. 605, 2018.

[7] S. Zareie, R. Ahmad, A. Zabihollah, and A. S. Issa, “Dynamic response of frame structures with shape memory alloy-magnetorheological fluid-based bracing system by nonlinear time-history analysis,” *J. Build. Eng.*, vol. 43, p. 102914, 2021.

[8] O. Idels and O. Lavan, “Performance based formal optimized seismic design of steel moment resisting frames,” *Comput. Struct.*, vol. 235, p. 106269, 2020.

[9] E. Bruschi, P. M. Calvi, and V. Quaglini, “Concentrated plasticity modelling of RC frames in time-history analyses,” *Eng. Struct.*, vol. 243, p. 112716, 2021.

[10] P.-C. Nguyen, T.-T. Tran, and T. Nghia-Nguyen, “Nonlinear time-history earthquake analysis for steel frames,” *Heliyon*, vol. 7, no. 8, p. e06832, 2021.

[11] X. Chen, Y. Liu, B. Zhou, and D. Yang, “Seismic response analysis of intake tower structure under near-fault ground motions with forward-directivity and fling-step effects,” *Soil Dyn. Earthq. Eng.*, vol. 132, p. 106098, 2020.

[12] L. Lin and F. Wang, “A Finite Element Based Study on Concrete Filled Steel Tube (CFST) Pile Used in Wharf Structure,” 2022.

[13] L. Ge, H. Chen, S. Chen, and H. Liu, “A Study on the Calculation Method of Wave Crest Height and Panel Wave Force of a New Barrel-Pile Foundation Composite Structure Wharf,” *Appl. Sci.*, vol. 12, no. 3, p. 1060, 2022.

[14] T. A. Ansari and S. Jamle, “Performance Based Seismic Analysis of Regular RC Building,” *Int. J. Manag. Technol. Eng.*, pp. 342–351, 2019.

[15] B. Budiono and E. B. Wicaksono, “Perilaku Struktur Bangunan dengan Ketidakberaturan Vertikal Tingkat Lunak Berlebihan dan Massa Terhadap Beban Gempa,” *J. Tek. Sipil ITB*, vol. 23, no. 2, pp. 113–126, 2016.

[16] Badan Standardisasi Nasional, *SNI 1727-2020: Beban Desain Minimum dan Kriteria Terkait untuk Bangunan Gedung dan Struktur Lain*. Jakarta: Badan Standardisasi Nasional Republik Indonesia, 2020.

[17] Kevin and Sanci Barus, “Kajian Perbandingan Respon Dinamik Linier dengan Analisis Riwayat Waktu (Time History Analysis) Menggunakan Modal Analisis (Mode Superposition Method) dan Integrasi Langsung (Direct Time Integration Method),” *J. Tek. Sipil USU*, vol. 3, no. 3, pp. 1–15, 2014.

[18] P. H. Simatupang, A. R. P. Kaputing, and A. Kumalawati, “Respon Struktur Bangunan Beraturan 2 Dimensi Menggunakan Time History Gempa El-Centro,” *J. Tek. Sipil*, vol. 8, no. 1 SE-Articles, Jul. 2019, doi: 10.35508/jts.8.1.29-42.

[19] Ş. Sözen, “Assessment of Seismic Load Capacity of a Slender Masonry Clock Tower,” *Period. Polytech. Civ. Eng.*, vol. 66, no. 2 SE-Research Article, pp. 491–501, Aug. 2022, doi: 10.3311/PPci.19670.

[20] M. M. M. Ahmed, S. E. Abdel Raheem, M. M. Ahmed, and A. G. A. Abdel Shafy, “Irregularity effects on the seismic performance of L-shaped multi-story buildings,” *JES. J. Eng. Sci.*, vol. 44, no. 5, pp. 513–536, 2016.

[21] S. Patil, A. Mujawar, P. A. Mali, and M. R. Katti, “A Study Of Torsional Effect On Multi-Storied Building With Plan-Irrgularity.,” *Int. J. Adv. Res.*, vol. 5, pp. 1625–1632, Jan. 2017, doi: 10.21474/IJAR01/2928.

[22] R. P. Johnson, *Composite Structures of Steel and Concrete: beams, slabs, columns and frames for buildings*. John Wiley & Sons, 2018.

[23] N. M. Abraham and A. K. SD, “Analysis of irregular structures under earthquake loads,” *Procedia Struct. Integr.*, vol. 14, pp. 806–819, 2019.

[24] M. Ridwan and F. Ramadhana, “Seismic Performance of Existing R/C Building with Irregular Floor Plan Shape,” in *MATEC Web of Conferences*, 2018, vol. 215, p. 1035.

[25] Y. Liu, M. Wang, and L. Meng, “Spectral Collocation Method in the Large Deformation Analysis of Flexible Beam,” *IAENG Int. J. Appl. Math.*, vol. 48, no. 4, pp. 416–423, 2018.

[26] M. C. Agarana, S. A. Bishop, and A. I. Ehigbochie, “Mathematical Investigation of Area and Mass Moments of Inertia of Beams,” *Lect. Notes Eng. Comput. Sci.*, vol. 2242, pp. 57–61, 2021.

Bimo Brata Adhitya was born in South Sumatera, Indonesia on March 10th 1981. Bachelor Degree. (2003) in Civil Engineering from Universitas Sriwijaya, Indonesia. M.Eng. (2007) in Infrastructure Management from Institut Teknologi Bandung, Indonesia. He has been working as a lecturer in the Department of Civil

Engineering, Faculty of Engineering, Universitas Sriwijaya, Indralaya 30662, South Sumatera, Indonesia. Bimo Brata Adhitya, B.Eng., M.Eng. have publication had written in: several international conference.

Anthony Costa was born in South Sumatera, Indonesia on July 22th 1990. Bachelor Degree. (2013) in Civil Engineering from Universitas Sriwijaya, Indonesia. Master Degree (2017) in Structural Engineering from Institut Teknologi Bandung, Indonesia.

He has been working as a lecturer in the Department of Civil Engineering, Faculty of Engineering, Universitas Sriwijaya, Indralaya 30662, South Sumatera, Indonesia. Anthony Costa, B.Eng, M.Eng. have publication had written in: POTENSI Journal, Journal of Management Transportation & Logistic, and Cantilever Journal Nasional.

Kencana Verawati was born in South Sumatera, Indonesia on February 25th 1991. Bachelor of Applied Science (2012) in Business Logistic from Politeknik Pos Indonesia, West Java. Master Degree (2017) in Management of Transportation, Institute of Transportation and Logistics, Universitas Trisakti, Jakarta, Indonesia.

She has been working as a lecturer in the Department of Transportation, Faculty of Engineering, Universitas Negeri Jakarta, Jakarta - Indonesia. Kencana Verawati, B.App.Sc., M.M.Tr. have publication had written in: Atlantis Press Series: Advances in Engineering Research; Journal of Management Transportation & Logistic, IOP Science.

Wadirin was born in South Sumatera, Indonesia, on April 11th, 1991. Degree: B.Edu. (2014) in Mechanical Engineering Education from Universitas Sriwijaya, Indonesia. M.Edu. (2017) in Mechanical Engineering Education, Universitas Negeri Yogyakarta, Indonesia.

He has been working as a lecturer for the Study Program of Mechanical Engineering Education, Faculty of Teacher Training and Education, Universitas Sriwijaya, Indralaya 30662, South Sumatera, Indonesia. Wadirin, B.Edu., M.Edu. had publication written in: International Journal on Advanced Science, Engineering and Information Technology; and CFD Letters.