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STRUCTURAL PERFORMANCE DUE TO ENGINE VIBRATION USING THE LEVELLING TIME HISTORY METHOD

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Abstract
In this case study, earthquake is one of the loads that is considered in designing and analyzing buildings. So that the earthquake becomes the author's calculation in analyzing the building against the strength and safety of the structure in receiving earthquake loads that occur with the anticipation of another earthquake history such as the El Centro earthquake. The author aims to analyze the performance of the structure that occurs against earthquake loads, the analysis also pays attention to the level of value that can be achieved by the building nonlinearly, namely the increase in the value of the initial acceleration of the earthquake (Level Aog) that occurred. The analysis is carried out on steel buildings that have bracing, concrete reinforcement, and there are machine activities. Structural performance analysis uses numerical methods and iterations which are assisted by a structural analysis program. The analysis is carried out by defining the hinge on the structural element. The analysis process is carried out in stages with the condition of the machine which is also considered in the leveling time history method. Time history which is also a history of vibration and machine vibration activity adds to the input parameters of the analysis carried out on the building. The response of the building due to engine vibration will be compared with the condition of the building when the engine is off which does not cause vibration. Structural performance analysis is carried out by increasing Aog until the structural elements of the building are no longer able to withstand shear forces and loads that occur when severe damage or conditions are above Collapse Prevention (CP). The results of the structural analysis will produce output in the form of Aog levels with plastic checks with color visuals, deviation checks and rotation checks based on FEMA 356 so as to produce structural strength capabilities. Based on the vibrations that occur with machine activity, the frequency can still be held by the building. The machine vibrations that occur, dampen the vibrations caused by the earthquake so that the leveling indicator becomes larger.
Keywords: *Structure, Modeling, Earthquake, Machine, Levelling Time History*

INTRODUCTION

In this case, the author wants to review the influence of vibration caused by the machine on the Coal Crusher Building. From the field analysis that has occurred in the building that also has an engine in it, there are cracks that have occurred in the surrounding buildings. In this study, buildings will be reviewed based on building behavior by providing forces to the structure in the form of dynamic loads such as spectral response and time history. Based on the analysis method used, the time history will be increased from its AOG (initial acceleration of the earthquake) to several times until the condition of the structure collapses so that the behavior can be gradually reviewed.

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MATERIALS AND METHODS

Composite Steel Structure

Steel composites with concrete are based on the assumption that steel has a good ability to tensile loads but compared to the tensile loads are smaller, so it is necessary to consider the danger of bending when receiving compressive loads, therefore this behavior can be advantageous when combined with concrete that is strong against compressive loads but not good at tensile loads (Haris B. Setiawan, 2015).This section should provide enough detail to allow full replication of the study by suitably skilled investigators. Protocols for new methods should be included, but well-established protocols may simply be referenced. We encourage authors to submit, as separate supporting information files, detailed protocols for newer or less well-established methods.

Vibration Concept

Basically, vibration is a movement that occurs back and forth at a certain interval and time. Objects generally have mass and elasticity that are able to vibrate, so usually engineering and mechanical structures vibrate to a certain degree taking into account their oscillating properties.

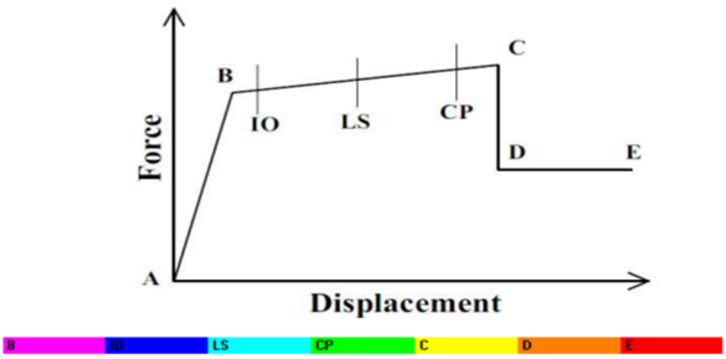
Vibrations can be distinguished into 2 types, namely:

1. Seismic vibration is a vibration that occurs on the ground due to natural events.
2. Mechanical Vibration is a vibration that occurs from a means or equipment carried out by human activities.

Structural Performance Analysis

Performance-based earthquake resilience planning is a process that can be used for planning new buildings and retrofitting existing buildings with a realistic understanding of life safety risks, occupancy and economic losses that may occur due to earthquakes. Each simulation provides information on the level of damage, structural resilience, so that it can estimate how much risk there is to life safety, habitability and property loss (Marudut, 2020).

Plastic Joints



Gambar 1. Performance stages on the structure.

The image is a performance of the stages of the performance level of the structure which is categorized with several colors as follows.

1. Elastic boundary (B), the onset of plastic joints is first marked with purple. This condition indicates the onset of molten elements in structural elements.

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2. Immediate occupancy (IO), the formation of plastic joints is marked with dark blue. This condition shows that the structure is still safe and structural repairs can still be made.
3. Life safety (LS), formed plastic joints marked with light blue. This condition causes damage to structural components, with reduced rigidity, but can still be repaired.
4. Collapse prevention (CP), the formation of plastic joints is marked with green. This condition of damage greatly affects the structure and almost causes collapse.
5. Collapse (C), plastic joints formed are marked with yellow.
6. Residual point (D), this condition plastic joints are formed marked with orange.
7. Complete collapse (E), this condition is marked by the formation of plastic joints

Deviation

Based on FEMA 356, the deviation limit ratio is based on 3 categories, namely Immediate Occupancy, Life Safety, and Collapse Prevention as shown in Table 1.

Table 1. Limitation of Deviation

Stuctural System	IO	LS	CP
Steel	0,7 %	2,5 %	5 %
Cocrete	1 %	2 %	4 %
Steel Bracing	0,5%	1.5%	2%

Rotation

Based on FEMA 356, the deviation limit ratio is based on 3 categories, namely Immediate Occupancy, Life Safety, and Collapse Prevention as contained in Table 2.

Table 2. Rotation Limitations

Element	IO		LS		CP	
	(+)	(-)	(+)	(-)	(+)	(-)
Concrete Columns	0,01	-0,01	0,025	-0.025	0,030	-0.030
Steel Colums	0,00175	-0,0017	0,014	-0,014	0,021	-0.021

Data Collection

The data obtained from the case study is the Coal Crusher Building of the Tarahan PLTU and data that uses SNI standards as loading input.

Table 3. Structure Load Data

No.	Load Type	Unit
1.	Mill Life Load (L)	400 kg/m^2
2.	Additional Dead Load (SiDl)	100 kg/m^2
3.	Wind Speed	10 m/s
4.	Eathquake Response	
	SS	0,784
	S1	0,33
	Site class	Temprate Oil (D)
	T	4 s

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	R	8
	Cd	5,5
5.	Time History	El Centro

Table 4. Machine Load Data

No.	Machine Type	Heavy	RPM
1.	CN 11 dan CN 21	7163,2 kg	994
2.	Mesin jenis TEFC	200 kg	1465
3.	Bucket Elevator	-	1465
4.	Deep Well	-	2935
5.	BF 11 dan BF 21	-	950
6.	Coal Bangker	25 Ton	1465

Flow Diagram

The process of conducting research can be seen in the following flow chart.Proses pelaksanaan penelitian dapat dilihat dalam diagram alir berikut.

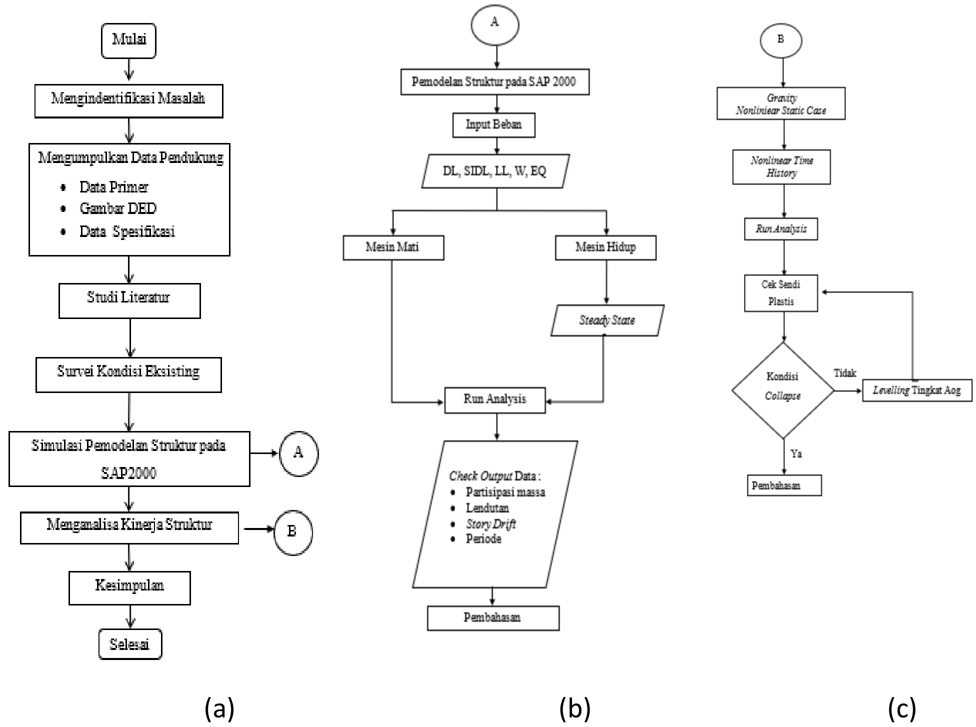

Figure 2. a) Research Flow Diagram b) Modeling Flow Diagram c) Performance Analysis Flow Diagram

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RESULTS AND DISCUSSIONS

Visual Observation Data

Observations were carried out to find out and identify problems that occurred in the Coal Crusher Building. One of the images shows the cracks that occur and the vibrations that can be felt while in the building.

Figure 3. Cracks occur in the columns and vibrations in the walls can be felt.

Data Deflection Check

The deflection test carried out on the building aims to compare the structural response that occurs on the floor slab when the engine is off and the engine is on.

Table 5. Test Results when the Engine is On and Off

No	Plate Name	Waterpass Titik a (m)	Waterpass Titik b (m)	Waterpass Titik c (m)	ΔHab (m)	ΔHbc (m)	ΔHab (mm)	ΔHbc (mm)
Difleksi – Machine state								
1	2 st Floor	1,272	1,259	1,263	0.013	-0.004	13	4
2	3 st Floor	1,243	1,262	1,269	-0.019	-0.007	19	7
3	4 st Floor	1,322	1,329	1,341	-0.007	-0.012	7	12
Difleksi – Machine is off								
1	2 st Floor	1,271	1,258	1,262	0.0129	-0.0038	12.9	3.8
2	3 st Floor	1,241	1,259	1,265	-0.0189	-0.0058	18.9	5.8
3	4 st Floor	1,314	1,320	1,329	-0.0068	-0.009	6.8	9

Quality Testing Data

The tests are also carried out to check the quality of the building structure elements so that modeling with SAP2000 program can better adjust to the existing conditions of the building and the test results can be seen in table 6.

Table 6. Hammer Test Results

No Point	Element Structure	Angle Picking (o)	Average Bounce Number (R)	R Correction	Compressive Strength (MPa)	Strength of the cube kg/cm^2
1		0	41,40	41,452	44,904	551,488
2		0	42,00	42,053	46,105	566,245
3	Coloumn Lt.2	0	35,50	35,544	34,544	424,261

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4	Coloumn CBC2-14	0	38,70	38,748	39,748	488,174
5	Coloumn CBC1-10	0	45,80	45,857	53,715	659,702
6	Plate Lt.4	-90	45,20	45,257	58,513	718,635
7	Plate Lt.2	-90	38,90	38,949	31,949	392,381

SAP2000 Modeling

With the help of the SAP 2000 V22.2 program, buildings can be modeled based on surveys and measurements of existing conditions with as-built image data obtained from this case study. The results obtained also help in analyzing the response and performance of the structure in the building.

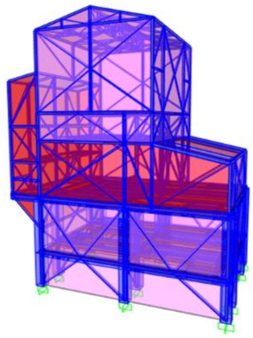

Figure 4.3D Research Building

Mass Participation, Ratio, and Period Analysis

One of the structural response analyses in this study is to check the contribution of loads to the building and the building period as follows.

Table 7. Conditions When the Engine Shuts Down

TABLE: Modal Participating Mass Ratios							
StepNum	**Period (sec)**	**UX**	**UY**	**UZ**	**SumUX**	**SumUY**	**SumUZ**
40	0.067802	0.001056	1.7E-06	0.00037	0.832	0.792	0.52
41	0.066809	0.015	0.000355	0.007189	0.847	0.792	0.527
42	0.066264	0.012	0.000773	0.019	0.859	0.793	0.546
43	0.065781	0.008599	2.27E-05	0.001431	0.868	0.793	0.548
44	0.064453	0.023	0.001345	0.012	0.891	0.794	0.56
45	0.063938	7.45E-05	0.17	7.11E-06	0.891	0.964	0.56
46	0.063747	0.042	0.000297	0.017	0.933	0.964	0.577

Table 8. Adding Modes to Buildings When the Engine Condition Is Down

MODAL	**68**	**0.049923**	**2.46E-06**	**5.93E-05**	**4.91E-06**	**0.96**	**0.97**
MODAL	69	0.049649	6.14E-06	5.47E-05	7.70E-07	0.96	0.97
MODAL	70	0.049548	9.04E-05	0.000727	5.58E-06	0.96	0.97
MODAL	71	0.048569	5.62E-07	6.63E-07	1.61E-05	0.96	0.97
MODAL	72	0.047166	1.64E-06	1.93E-10	0.000579	0.96	0.97
MODAL	73	0.04676	1.99E-06	6.27E-07	1.74E-05	0.96	0.97
MODAL	74	0.046483	0.000316	3.11E-06	9.51E-06	0.96	0.97

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MODAL	75	0.045949	0.00023	3.71E-06	4.39E-10	0.96	0.97

Based on SNI 1726:2019 when it reaches 90%, which means that earthquake conditions have contributed to buildings. By considering the value of the period that is below the value of 0.05. Therefore, in the mode when the engine condition is running reaches 90%, the value can be taken into account as an analysis if the period has been below 0.05, which is in mode 46. Meanwhile, in the state where the engine is 90% off and the period is below 0.05, it is necessary to add the number of modes up to 100 modes to get a period value of 0.05 which can be seen in the following table.

Table 9. Conditions when the engine is running

TABLE: Modal Participating Mass Ratios							
StepNum	**Period (sec)**	**UX**	**UY**	**UZ**	**SumUX**	**SumUY**	**SumUZ**
40	0.063854	0.046	0.061	0.011	0.934	0.955	0.538
41	0.063394	0.004314	0.011	0.02	0.939	0.965	0.558
42	0.060139	0.015	0.000115	0.005039	0.954	0.965	0.563
43	0.057328	0.00022	0.001741	0.000164	0.954	0.967	0.563
44	0.054485	0.005837	3.38E-07	0.012	0.96	0.967	0.575
45	0.051096	0.003168	1.19E-07	0.003428	0.963	0.967	0.578
46	0.049631	0.000171	0.000885	2.86E-05	0.963	0.968	0.578
47	0.044737	0.000579	6.69E-05	0.000893	0.964	0.968	0.579
48	0.04417	4.34E-05	0.000603	0.000223	0.964	0.968	0.579
49	0.037854	5.09E-05	0.000138	0.000181	0.964	0.969	0.579
50	0.036938	0.000384	8.32E-07	0.004191	0.964	0.969	0.584

The addition of the mode is carried out so that the period below 0.05 seconds meets the recommended by SNI to analyze the relationship between the period and vibration. Based on the mass participation ratio, in the dead machine, the building is more dominant in the X direction and when the engine is started, the building becomes more dominant in the Y direction when the load is applied.

From the equation in subchapter 2, the period value relates to vibration. The larger the value of the period, the less vibration and vice versa. And if the direction of the vibration occurs in the same direction, the vibration will be greater and if the vibration of the engine and the vibration of the earthquake are opposite, then one vibration will dampen the vibration of the other. In this case, the vibration of the engine shows the opposite direction to the direction of the earthquake load that occurred. It can be seen in the same mode when the engine is off in mode 46 of the period of 0.061 and the engine is on in the period of 0.049 which means that when the engine vibrates there is a decrease in the value of the period with an increased frequency value and when the frequency increases the vibration becomes less. The engine has the opposite direction and reduces the earthquake load that occurs on the building.

Deflection

The examination of the deflection of the dead engine condition uses the equation from SNI as follows.

$$\delta \text{ ijin (mm)} = L/240 \quad \text{(Pers.1)}$$

Table 10. Deflection that occurs when the engine is off

No.	**Location**	**Plate Thickness (m)**	**δ SAP (mm)**	**δ Akt (mm)**	**δ permit (mm)**	**Control SAP**	**Actual control**	**Information**
1	LT 2	0.3	7.32	12.9	26.04	Safe	Safe	Machine off

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2	LT 3	0.3	6.14	18.9	28.13	Safe	Safe	Machine off
3	LT 4	-	13.9	9	26.04	Safe	Safe	Machine off

The examination of the deflection of the engine condition uses the following equation.

$$\delta = \left(\frac{5}{384}\frac{wl^4}{EI}\right)$$

(Pers. 2)

Table 11. Deflection that occurs when the machine is on

No.	Location	Plate Thickness (m)	δ SAP (mm)	δ Akt (mm)	δ permit (mm)	Control SAP	Actual control	Information
1	LT 2	0.3	7.4	13	30.20	Safe	Safe	Machine on
2	LT 3	0.3	3	19	25.49	Safe	Safe	Machine on
3	LT 4	-	21	12	24.4	Safe	Safe	Machine on

Inter-Floor Junction

The analysis also pays attention to the deviation between floors that occurs in buildings using equations based on SNI as follows.

$$\delta x = \frac{Cd\delta xe}{Ie}$$

(Pers. 3)

Table 12. The accident occurred when the engine was off

Lantai	Hsx	δxe	δye	Δx	Δy	Δa (ijin)	Information	
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)		
Atap	7900	19.318	19.374	59.627	66.110	114.493	X OK	Y OK
4	2740	8.477	7.354	14.822	5.057	39.710	X OK	Y OK
Mez	7000	5.782	6.435	13.655	11.259	101.449	X OK	Y OK
3	5600	3.299	4.388	4.939	1.315	81.159	X OK	Y OK
2	3550	2.402	4.149	13.208	22.817	51.449	X OK	Y OK
1	0.00	0.000	0.000	0.000	0.000	0.000	X OK	Y OK

The deviation between floors that occurred using the Cd value of 5.5 and the earthquake priority factor was 1.

Table 13. The squeaking that occurs when the engine starts.

Lantai	Hsx	δx	δy	Δx	Δy	Δa (ijin)	Information	
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)		
Atap	7900	11.7104	19.2202	19.9282	68.1038	114.49	X OK	Y OK
4	2740	8.0871	6.8377	14.2601	6.4113	39.71	X OK	Y OK
Mez	7000	5.4944	5.6720	12.0721	7.0650	101.45	X OK	Y OK
3	5600	3.2994	4.3875	5.4023	10.9365	81.16	X OK	Y OK
2	3550	2.3172	2.3990	12.7445	13.1947	51.45	X OK	Y OK
1	0	0.0000	0.0000	0.0000	0.0000	0.00	X OK	Y OK

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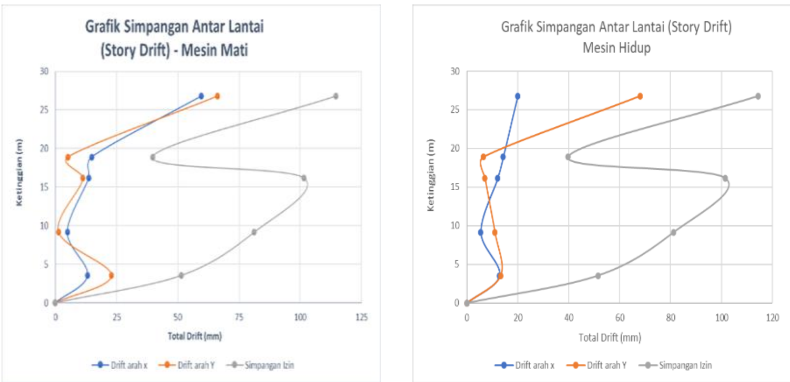

(a) (b)

Figure 5. Curve of Deviation Between Floors (a) Engine Shutdown Condition, (b) Engine Condition. From the review and data obtained, the change in joint displacement when the engine is turned on in the x direction is smaller, which is 11,704 mm compared to when the engine is off in the x direction, which is 19,318 mm. Engine vibrations that occur at the highest point dampen the displacement that occurs.

Plastic Joints

Checking plastic joints is carried out by increasing the value of Aog (initial acceleration of the earthquake) until it reaches conditions above the CP (Collapse Prevention) that occurs in the 3D model of the building.

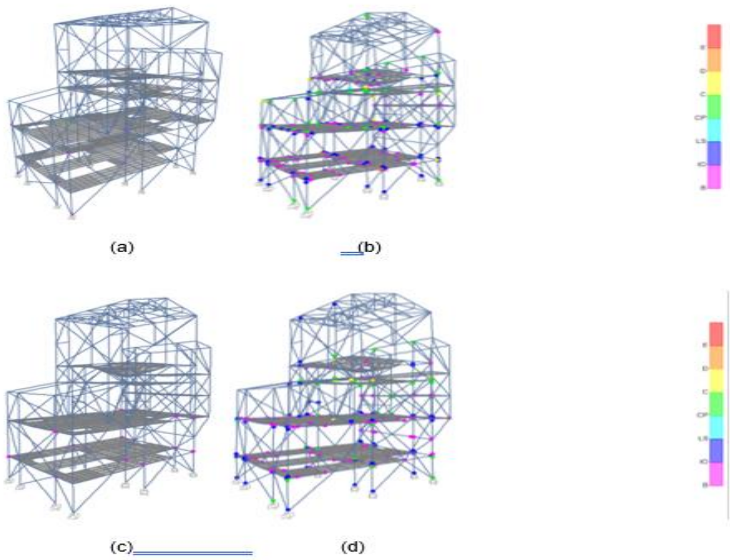

Figure 6. (a) 1xAog Indicator Direction X, (b) 10xAog Indicator Direction X, (c) 1xAog Indicator Direction Y, (d) 10xAog Indicator Direction Y

Maximum Deviation

In this study, the author reviewed 2 points of deviation that occurred as an example of the point that experienced plastic joints for the first time and the top and outermost points of the building as an example of the second point. The deviation reviewed will be compared to the FEMA 356 limit with a target above CP as the

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final stage of the performance level of the initial acceleration of the El Centro earthquake.

Table 14. The deviation that occurred at Joint 80.

Initial Acceleration of Earthquake	Maximum Deviation of El Centro Earthquake X dan Y		Permit Junction (D)		
			FEMA 356		
			Structure Performance Level		
	(Joint 80) X	(Joint 80) Y	IO=0.5%	Ls=1.5%	CP=2%
	mm	mm	mm	mm	mm
1 kali Aog	26.059	9.09	21.85	65.55	87.4
2 Kali Aog	44.672	18.836	21.85	65.55	87.4
4 Kali Aog	78.867	42.789	21.85	65.55	87.4
6 Kali Aog	120.344	72.409	21.85	65.55	87.4
8 Kali Aog	222.010	104.44	21.85	65.55	87.4
10 Kali Aog	223.449	129.22	21.85	65.55	87.4

Table 15. The deviation that occurred at Joint 100.

Initial Acceleration of Earthquake	Maximum Deviation of El Centro Earthquake		Permit Junction (D)		
			FEMA 356		
			Structure Performance Level		
	(Joint 100) X	(Joint 100) Y	IO=0.5%	Ls=1.5%	CP=2%
	mm	mm	mm	mm	mm
1 kali Aog	38.067	30.982	39.5	118.5	158
2 Kali Aog	65.255	61.681	39.5	118.5	158
4 Kali Aog	113.393	124.751	39.5	118.5	158
6 Kali Aog	166.242	194.599	39.5	118.5	158
8 Kali Aog	284.002	268.614	39.5	118.5	158
10 Kali Aog	281.923	326.307	39.5	118.5	158

From the deviation table, joints 80 and 100 during the El Centro earthquake in the direction of X and Y. Joint 80 is the joint that first experienced a plastic joint and was above the CP when the indicator reached 6x Aog for the El Centro X Earthquake and 8x Aog for the El Centro Y Earthquake. Chart of divergences that occur at joints 80 and 100.

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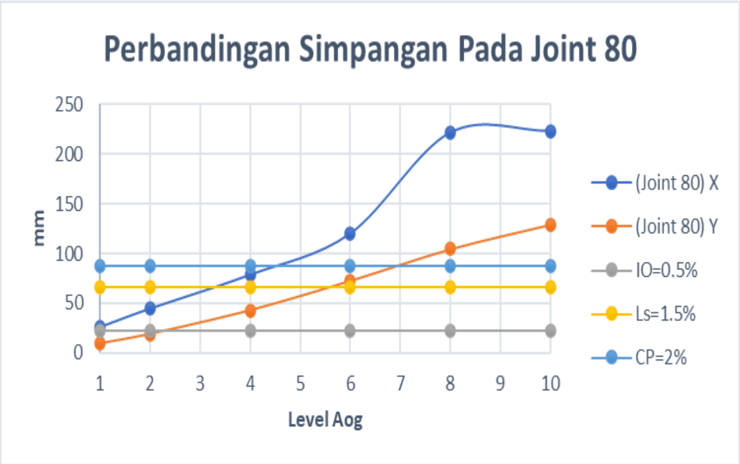

Figure 7. Joint 80 Maximum Deviation Chart with FEMA (level of damage) limits.

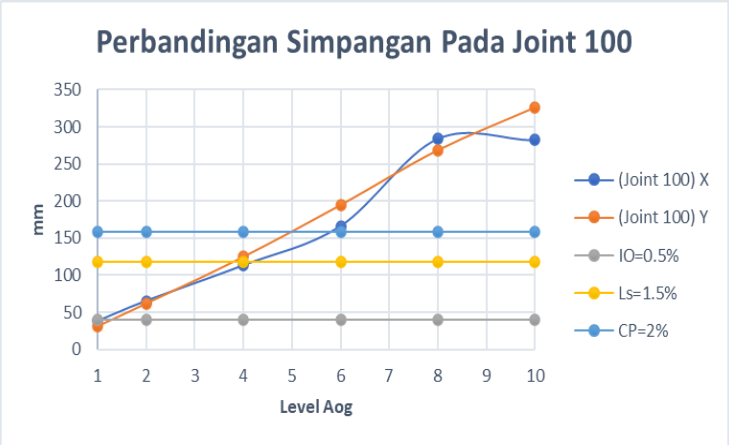

Figure 8. Joint 100 Maximum Deviation Chart with FEMA (level of damage) limits.

Rotation

The frame is reviewed based on the level of structural performance that is carried out, showing that the frame is one of the frames that experiences the condition of the indicator above the CP.

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Initial Acceleration of Earthquake	**Column Rotation Frame 6**				**Permission Rotation(θ)**					
					FEMA 356					
	length 0,05		**length 0,95**		Structure Performance Level					
					IO		Ls		CP	
	Min	Max	Min	Max						
(g)	Radian				Radian					
1 Aog	0	0	0	0	-0,0017	0,00175	-0,014	0,014	-0.021	0,021
2 Aog	0	0.00	0	0	-0,0017	0,00175	-0,014	0,014	-0.021	0,021
4 Aog	-0.0008	0.003926	0	0	-0,0017	0,00175	-0,014	0,014	-0.021	0,021
6 Aog	-0.0032	0.007616	0	0	-0,0017	0,00175	-0,014	0,014	-0.021	0,021
8 Aog	-0.00542	0.01415	0	0.00	-0,0017	0,00175	-0,014	0,014	-0.021	0,021
10 Aog	-0.0079	0.021411	-0.0002	0.003911	-0,0017	0,00175	-0,014	0,014	-0.021	0,021
12 Aog	-0.01075	0.02894	-0.0034	0.004927	-0,0017	0,00175	-0,014	0,014	-0.021	0,021

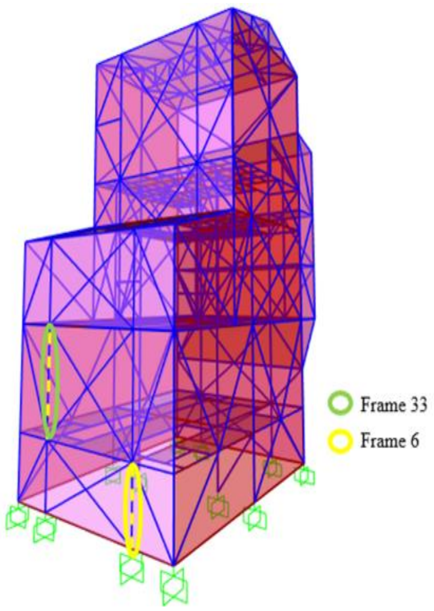

Figure 9. Review of rotation during the El Centro earthquake.

From the table above, it can be seen that the overall condition of the building during the initial acceleration of the El Centro Y earthquake was still in IO condition. However, to see to what extent the building or structural element under review has been above the CP. The CP condition was obtained during the initial acceleration of the earthquake at 8 times and was above the CP when the value of Aog El Centro Y increased at 10 times the increase in Aog.There is a difference in the behavior of the structure in the displacement and rotation checks, which means that the structure will reach the maximum plastic joint indicator if one of the structural behavior

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Capacity/Demand

Initial Acceleration of Earthquake	**Column Rotation Frame 33**				**Permission Rotation(θ)**					
					FEMA 356					
	length 0,05		**length 0,95**		Structure Performance Level					
					IO		Ls		CP	
	Min	Max	Min	Max						
(g)	Radian				Radian					
1 Aog	0	0	0	0	-0,0017	0,00175	-0,014	0,014	-0.021	0,021
2 Aog	-0.0033	0.00025	0	0	-0,0017	0,00175	-0,014	0,014	-0.021	0,021
4 Aog	-0.0088	0.00408	0	0	-0,0017	0,00175	-0,014	0,014	-0.021	0,021
6 Aog	-0.0295	0.00762	0	0.00039	-0,0017	0,00175	-0,014	0,014	-0.021	0,021
8 Aog	-0.0256	0.01194	-0.00096	0.000575	-0,0017	0,00175	-0,014	0,014	-0.021	0,021

(a) (b)

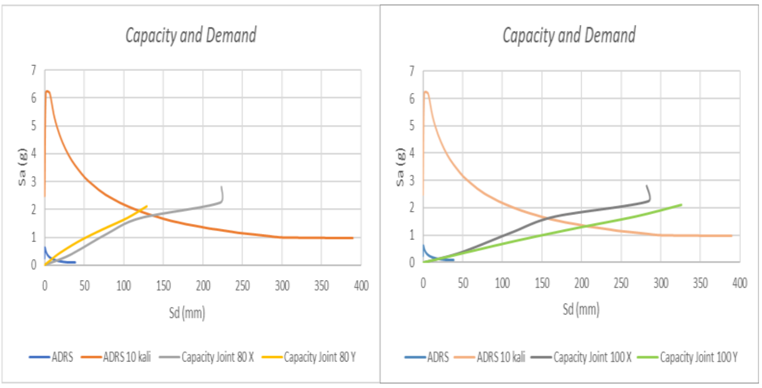

Figure 10. (a) El Centro X Capacity/Demand Curve and (b) El Centro Y Capacity/Demand Curve

The relationship curve that occurs in joints 80 and 100 shows the structural performance that occurs in the building. This is also to ensure that the performance conditions that occur (capacity) have intersected with the ADRS (Demand) line. Previously, the review and analysis carried out on the structural performance at the intersection had been above the CP (Collapse Prevention). Therefore, based on the Capacity and Demand relationship curve, the analysis of the deviation shows that there is a point of performance and the load received by the building has exceeded the strength limit of the planned structure, such as the analysis of structural performance at the deviation carried out at joints 80 and 100 during the El Centro X and Y earthquakes.

CONCLUSIONS & RECOMMENDATIONS

The conclusions that can be drawn from this study are as follows:

1. For building analysis control, the condition of the dead engine and the live engine has a difference that occurs in the form of the influence of vibration that can be observed in the mass participation data, the ratio shows that it has reached above

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90%. When the earthquake load is applied, the response that occurs when the engine condition is off, the building is more dominant towards UX, which is 0.042 in the 46th mode. Meanwhile, when the engine condition is on, the building response becomes more dominant towards UY, which is 0.061 in 40 mode.

2. Based on direct testing and output data obtained from the SAP 2000 program, by comparing the data with the SNI standard shows that there is an influence of vibration that occurs on the deflection of the floor slab, namely,
a. Deflection occurs when the machine is off, based on testing with tools of 12.9 mm, 18.9 mm, and 9 mm and based on SAP outputs of 7.32 mm, 6.14 mm, and 13.9 mm respectively on the 2nd, 3rd, and 4rd floors.
b. Deflection occurs when the machine is running, based on testing with the tool of 13 mm, 19 mm, and 12 mm and based on SAP program outputs of 7.4 mm, 3 mm, and 21 mm respectively on the 2nd, 3rd, and 4th floors.
c. Based on SNI, the deflection that occurs when the condition is off and the machine is on both in direct testing and with the help of the SAP program still meets the limit of the permit deflection calculated from equation 4.2 and equation 4.3.
d. Deflection occurs when the machine is running, based on testing with the tool, namely 13 mm, 19 mm, and 12 mm and based on the output of the SAP program, which is 7.4 mm, 3 mm, and 21 mm respectively on the 2nd, 3rd, and 4th floors.
e. Based on SNI, the deflection that occurs when the condition is off and the machine is on both in direct testing and with the help of the SAP program still meets the limit of the permit deflection calculated from equation 4.2 and equation 4.3.

3. The earthquake that can withstand the Coal crusher building structure is 8xAog (2.24g) for Direction X and 10xAog (2.107g) for Direction Y based on several components that are above CP (collapse prevention) based on checking the color of plastic joints. And based on deviation which is 6xAog (1.68g) and rotation that occurs based on FEMA 356 which is 12xAog (3.37g).

4. Whole Building Analysis
a. Based on the vibrations that occur with engine activity, it is still uncertain that the vibrations that affect the surrounding buildings come from the Coal crusher building by looking at the frequency conditions that are still able to be withheld by the building and there is bracing and concrete reinforcement on colum .
b. The vibration of the engine that occurs, dampens the vibration caused by the earthquake so that the levelling indicator becomes larger, apart from the influence of bracing factors, concrete reinforcement and the absence of reinforcement data.ns, beams, and plates that were previously only steel structures based on the As Built building.

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