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Seismic Evaluation of Graha 10 Nopember ITS Surabaya Building Structure Using Indonesian Earthquake Hazard Deaggregation Map (PuSGeN, 2022)

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Abstract

The occurrence of large-scale earthquakes in Indonesia is still one of the phenomena that often occurs, this can cause damage to buildings, so applying standardization of earthquake-resistant buildings during construction is necessary. This study review was carried out on Graha Sepuluh Nopember building using evaluation method to earthquake-resistant buildings regulated in Indonesian Earthquake Hazard Deaggregation Map (Pusgen, 2022). The model was evaluated using nonlinear time history analysis in order to obtain behavior in post-elastic conditions. The result of this research uses parameters of displacement and plastic hinge, indicates that the building has immediate occupancy performance level means that the building structure is safe, structural failure is not significantly damaged and can be used again immediately.

Keywords

Nonlinear time history analysis, Indonesian earthquake hazard deaggregation map, earthquake-resistant building, ground motion

INTRODUCTION

Large-scale earthquakes in Indonesia are still a phenomenon that often occurs, the earthquake can have some negative impacts, from damaging buildings to causing fatalities [1]. Like 2009 Padang earthquake, starting with two consecutive earthquakes in less than 24 hours at relatively close locations with magnitudes of 7.6 and 6.8 on the Richter Scale, claimed up to 1,117 injured people and 135,448 buildings were seriously damaged [2]. Furthermore, there was also Lombok earthquake in 2018, the earthquake which occurred gradually over approximately a month was one of the rare earthquake events, based on data from the National Disaster Management Agency, several large earthquakes were followed by small earthquakes that occur continuously have killed at least 460 people and injured 7,733 people, and 71,962 houses were damaged [3].

The occurrence of structural failures due to earthquakes reminds us of the importance of implementing earthquake resistant building standards during building construction [4]. Building construction is closely related to construction implementation, the implementation process that is in accordance with applicable regulatory standards influenced by the fact that periodic changes, so it needs to be evaluated to the latest regulation [5]. Concrete structure buildings use SNI 03-2847 regulations, steel structure buildings use SNI 03-1729 regulations and earthquake resistant building design uses SNI 03-1726 while design and evaluation of earthquake resistant infrastructure is regulated in the Indonesian Earthquake Hazard Deaggregation Map (Pusgen, 2022). A development process from design to implementation must be based on applicable regulatory standards in order to guarantee the safety of a building [6].

Graha Sepuluh November building is one of old buildings in ITS Campus Surabaya, Indonesia [7]. Using old regulations during construction means that the building needs to be evaluated against the latest regulation [8]. In this study, the latest regulation for evaluation uses Indonesian Earthquake Hazard Deaggregation Map (Pusgen, 2022), using nonlinear time history analysis in order to obtain the behavior of the building in post-elastic conditions [1, 8]. When the building is subjected to lateral loads, it will provide a response which can identify performance level of the building based on the parameters of displacement and plastic hinges of the structure.

RESEARCH SIGNIFICANCE

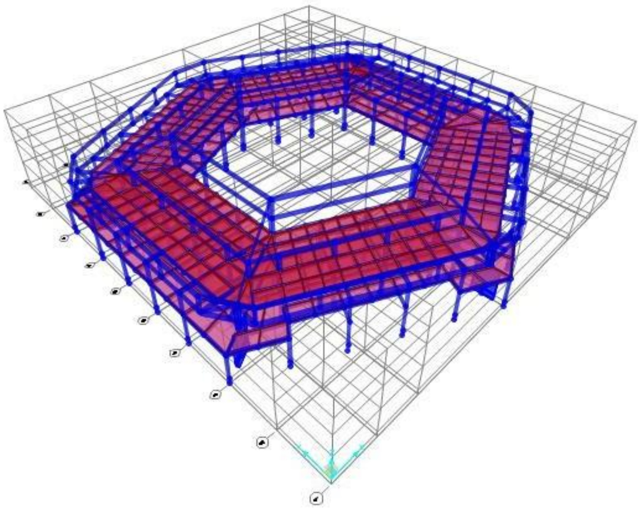
This study seeks to evaluate Graha Sepuluh Nopember building refers to Indonesian Earthquake Hazard Deaggregation Map (Pusgen, 2022) as the latest regulation for building evaluation. The postelastic behavior is used to investigate the performance level of structure. The goal is to ensure that the existing structure remains safe to occupy during earthquake.

METHODOLOGY

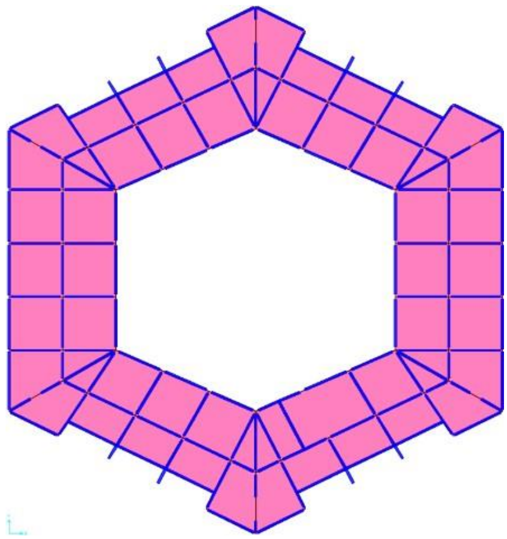
The methodology of this research includes evaluating the performance level of existing building of Graha Sepuluh Nopember. The structure is calculated by SAP2000 version 22, gravity loads such as dead load (DL) and live load (LL) refers to SNI 1727-2020, and seismic load refers to Indonesian Earthquake Hazard Deaggregation Map (Pusgen, 2022) and SNI 1726-2019 as the latest standardization. The analysis uses nonlinear time history with 11 ground motions as required in SNI 1726-2019. The observed parameters such as displacement and plastic hinges based on default parameters from SAP2000 program.

A. STRUCTURAL INFORMATION

The existing building of Graha Sepuluh Nopember building is 2-story reinforced concrete located in Surabaya. Each story has diverse height as 1st floor 4.5 m, 2nd floor 4 m, and roof 6.05 m [9], the structural configuration is as shown in Figure 1. The concrete compressive strength is 18,68 Mpa and reinforcement bar tensile yield strength is 400 Mpa. The existing building was built in 1990 [7] and it must be designed with applied regulation at that time, so it needs to be evaluated with recent regulation, Indonesian Earthquake Hazard Deaggregation Map (Pusgen, 2022).



(a)



(b)

Figure 1 Modelling of Graha Sepuluh Nopember building (a) 3D view, (b) Plan view

The structure is designed as an auditorium, which is classified as the Risk Category III and the soil condition classified as SD (medium soil). The structural system uses moment resisting frame and analysed using 1000-year return period earthquake as required for building evaluation.

B. Indonesian Earthquake Hazard Deaggregation Map (PuSGeN, 2022)

The earthquake hazard deaggregation map is conducted to obtain the mean-source magnitude (M) and mean-source distance (R), which are representing the location, Surabaya. The attenuation function used includes Next Generation Attenuation (NGA), where this attenuation function is compiled using global earthquake data (worldwide data) [10]. The deaggregation process is carried out to select suitable ground motion data as the parameters are shown in Table 1 below.

Table 1 Magnitude Parameters

Source	Magnitude		
	PGA	0.2 Sec	3 Sec
Benioff	7-7.2	7-7.2	7.4-7.6
Shallow Crustal	5.4-5.6	5.8-6	7.2-7.4
Megathrust	8.6-8.8	8.6-8.8	8.6-8.8

Table 2 Distance Parameters

Source	Distance (km)		
	PGA	0.2 Sec	3 Sec
Benioff	120-150	120-150	150-200
Shallow Crustal	40-50	40-50	40-50
Megathrust	150-200	150-200	250-300

The use of vibration period (PGA, 02 Sec, 3 Sec) is determined by structure period, as patterned:

PGA for T < T0
0,2 Sec for T0 < T < TS
3 Sec for T > TS

Known value of the structure period (T):
Period of use in X direction (T_x) = 0,4695 sec
Period of use in Y direction (T_y) = 0,6951 sec
T_0 = 0,1462 sec
T_s = 0,7909 sec

From the calculation above, it can be concluded that:
$T_0 < T < T_s$, so it uses vibration period of 0,2 sec. Then, the identified magnitude and distance can be applied for downloading and scaling ground motion database. 11 selected ground motion data as required in SNI 1726-2019 for nonlinear time history analysis is shown in Table 2, The ground motion is applied in X and Y direction, which are directions perpendicular and parallel to the building plan.

Table 3 Selected Ground Motion Data

RSN	Event	Location	Year	M	R (km)
131	Friuli	Italy	1976	5.91	41.39
2160	Chichi	Taiwan	1999	5.9	46.91
504	Whittier	Narrows-01	1987	5.99	48.96
1601	Durze	Turkey	1999	7.14	130.81
1771	Hector	Mine	1999	7.13	120.69
5856	El Mayor-Cucapah	Mexico	2010	7.2	141.04
1	Helena	Montana	1935	6	2.86
4	Imperial Valley	Imperial Valley	1938	5	34.98
12	Kern Country	Kern Country	1952	7.36	117.75
23	San Francisco	San Francisco	1957	5.28	11.02
51	San Fernando	San Fernando	1971	6.61	55.2

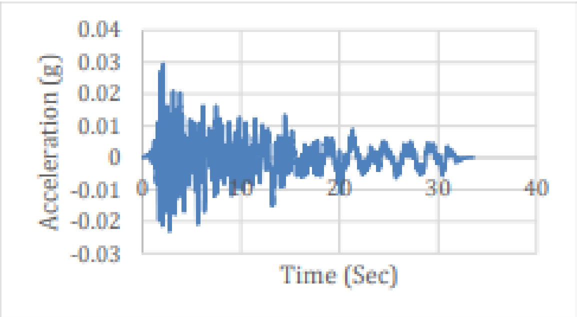


Figure 2 Friuli Earthquake

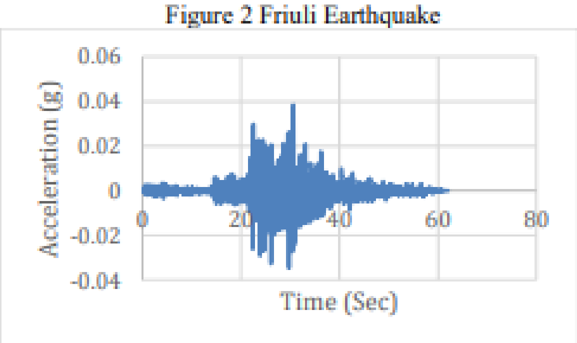


Figure 3 Chichi Earthquake

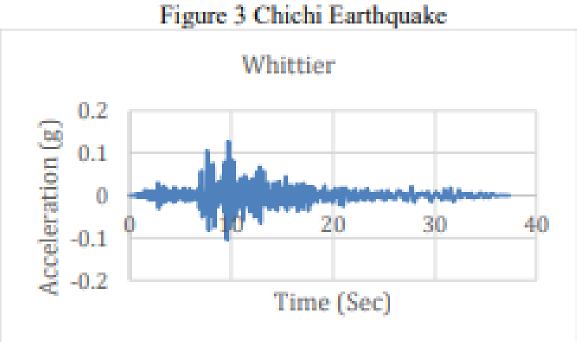


Figure 4 Whittier Earthquake

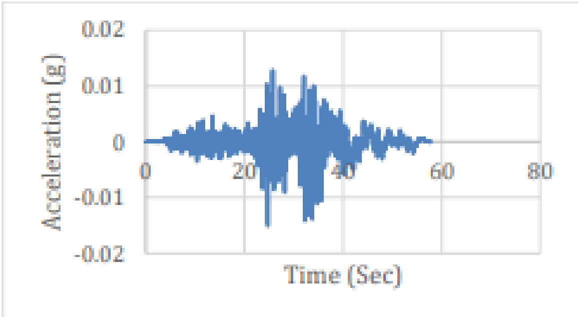


Figure 5 Durze Earthquake

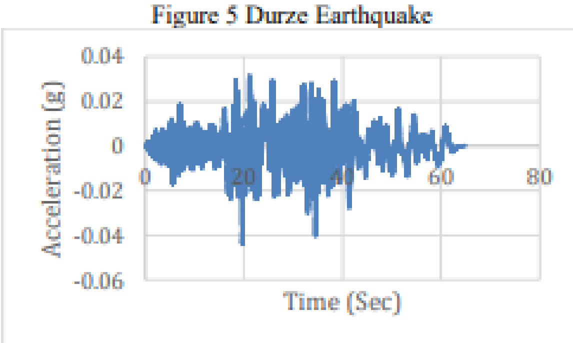


Figure 6 Hector Earthquake

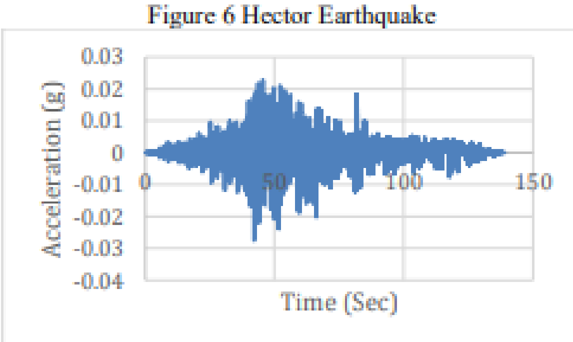


Figure 7 El Mayor Cucapa Earthquake

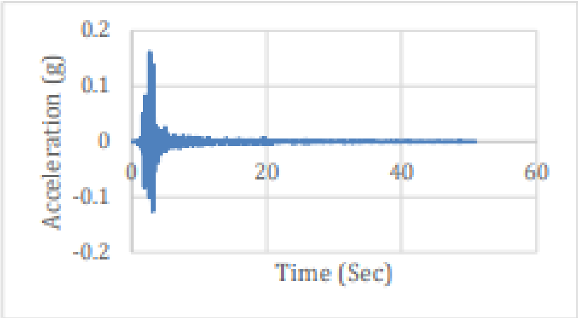


Figure 8 Helena Earthquake

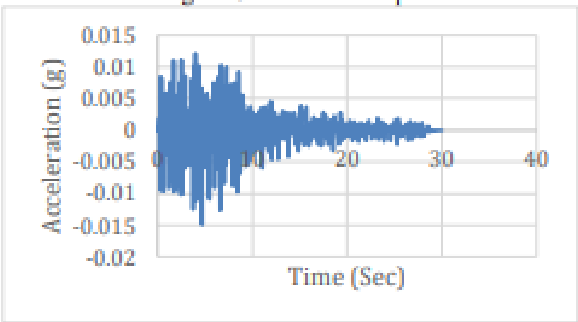


Figure 9 Imperal Valley Earthquake

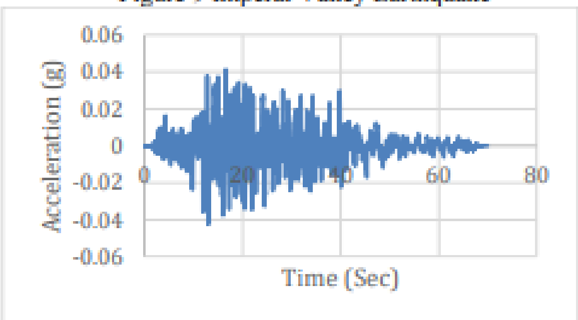


Figure 10 Kern Country Earthquake

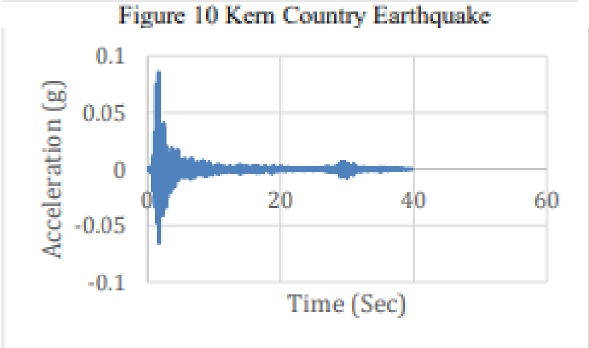


Figure 11 San Francisco Earthquake

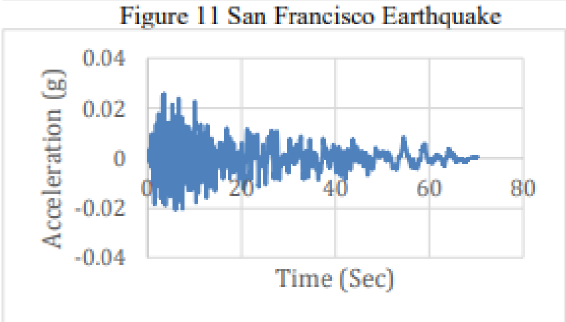


Figure 12 San Fernando Earthquake

The selected ground motions are then scaled to the target response spectra for Surabaya city with a 5% damping ratio, the following Figure 13 – Figure 23 are the result of spectral matching.

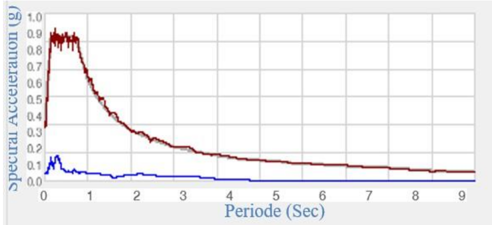


Figure 13 Spectrally Matched Friuli

Figure 14 Spectrally Matched Chichi

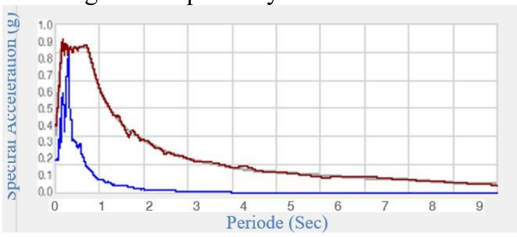


Figure 15 Spectrally Matched Whittier

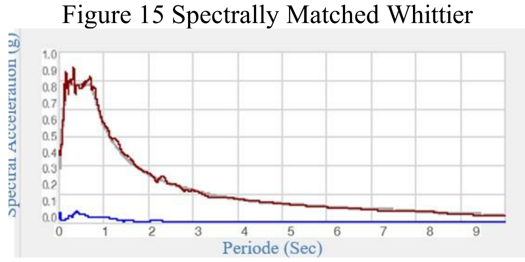


Figure 16 Spectrally Matched Durze

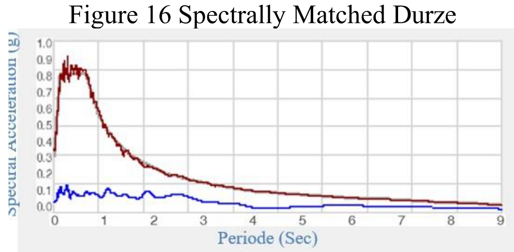


Figure 17 Spectrally Matched Hector

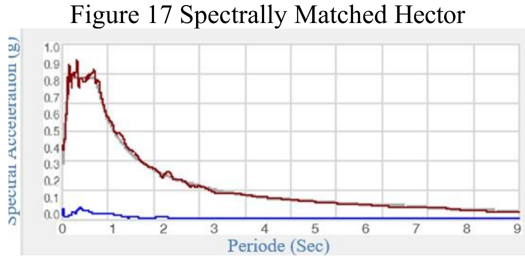


Figure 18 Spectrally Matched El Mayor Cucapa

Figure 19 Spectrally Matched Helena

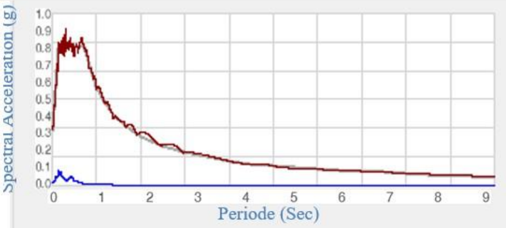


Figure 20 Spectrally Matched Imperal Valley

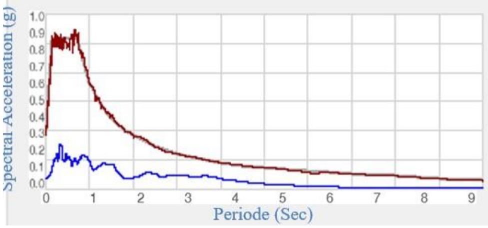


Figure 21 Spectrally Matched Kern Country

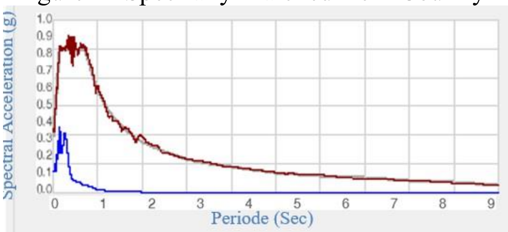


Figure 22 Spectrally Matched San Francisco

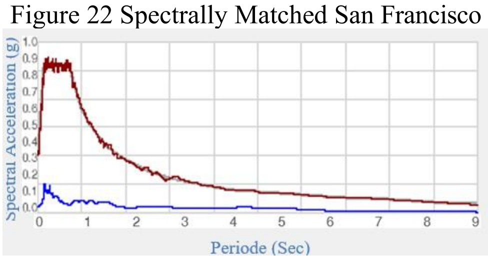


Figure 23 Spectrally Matched San Fernando

Figure Information:
Red = Matched TimeHistory
Blue = Ground Motion
Grey = Response Spectrum Design

RESULTS AND DISCUSSIONS

A. NONLINEAR TIME HISTORY ANALYSIS

Nonlinear time history analysis were completed, the analysis were run for 11 pairs of ground motion, for each of ground motions include x and y directions, thus a total of ground motions were 22 time history analysis. The analysis were conducted to determine the Performance Level of Structure using parameters of displacement and plastic hinge.

B. DISPLACEMENT

The displacement of the structures is defined at the centre of mass [6]. Figure 14 shows the comparison of X and Y direction from Chichi earthquake, from the figure can be seen that at the end of displacement does not return to its original point (point 0), indicating that there is an element that runs into plasticity.

Information:
Blue is for y direction
Red is for x direction

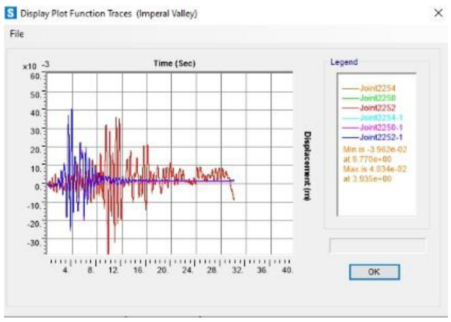


Figure 24 Centre of Mass Rooftop Displacement

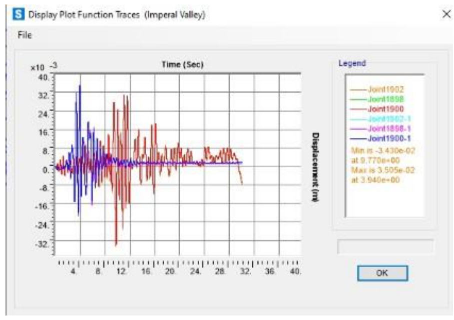


Figure 25 Centre of Mass 2nd floor Displacement

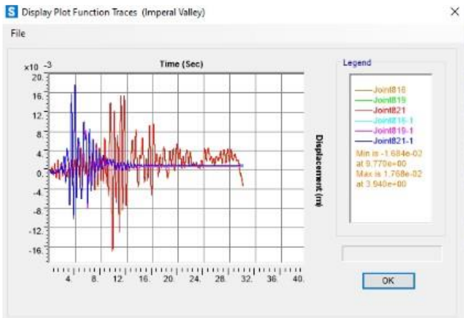


Figure 26 Centre of Mass 3rd floor Displacement

The lateral displacement results for all earthquakes (11 pairs of ground motion) are compared as shown in figure 15. It can be noticed from Figure 15 that the largest displacement was caused by Imperal Valley in Y direction.

From Figure 15 it can be concluded that all earthquakes in both x and y direction have similar lateral displacement patterns, which are on the 1st floor it is in range 0-20 mm, the 2nd floor is in range 20-40 mm and the roof floor is 25-

C. PERFORMANCE LEVEL (ATC-40)

Evaluating structural performance level is necessary to determine the performance objectives for ensuring structural safety during an earthquake. The basic performance objective is determined according to Applied 45 mm. the roof floor has the largest lateral displacement value, the storey displacements revealing that as the storey height increases lateral displacements at each storey as well as maximum lateral displacement increase [11].
Technology Council 40 (ATC-40) [12]. The global performance levels of structure are determined based on roof drift ratio values, which are obtained by dividing total displacement at the roof level by total height of structure. The Drift limits are as shown in Table 4.

Table 4 Drift Limits

Parameter	Performance Level			
	Immediate Occupancy	Damage Control	Live Safety	Structural Stability
Total drift Maximum	0,01	0,01-0,02	0,02	0,33Vi/Pi
Total Inelastic drift Maximum	0,005	0,005-0,015	unlimited	unlimited

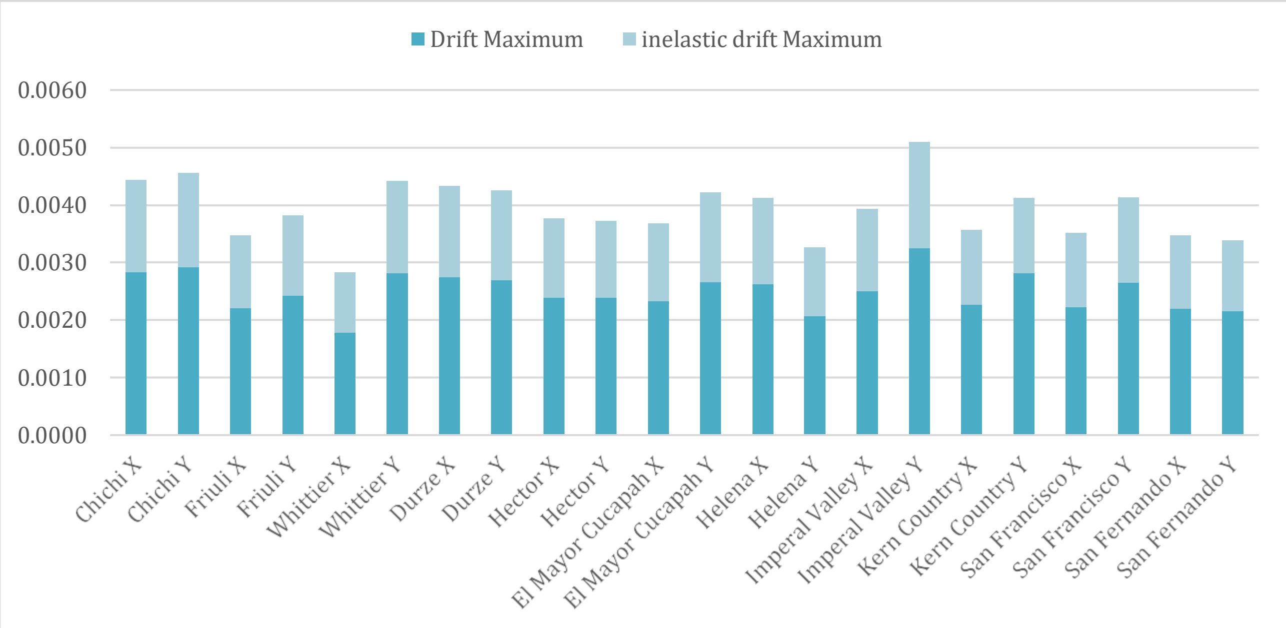


Figure 28 Performance Level of Each Earthquake

Table 5 Plastic Hinge Formed

No	Gempa	A-IO	IO-LS	LS-CP	>CP	Total
1	Chichi	2513	71	1	47	2632
2	Friuli	2522	51	3	56	2632
3	Whittier	2527	48	2	55	2632
4	Durze	2518	54	3	57	2632
5	Hector	2521	53	2	56	2632
6	El Mayor-Cucapah	2510	54	2	66	2632
7	Helena	2526	48	2	56	2632
8	Imperal Valley	2534	44	2	52	2632
9	Kern Country	2521	51	3	57	2632
10	San Francisco	2529	48	2	53	2632
11	San Fernando	2517	55	3	57	2632

Figure 28 shows the results of structural performance levels from each earthquake, in both X and Y direction are included in Immediate Occupancy (IO) level category, means the building structure is safe, the risk from failure is not very significant, and can be used again immediately [11].

D. PLASTIC HINGE

The pattern of plastic hinges formation in building structural components can be identified starting from linear conditions, immediate occupancy, life safety until the structure is no longer able to withstand shear forces and collapses. Hinge analysis is performed on all structural elements, which includes a total of 2632 elements. The nonlinear parameters of the hinges are defined using an empirical method based on ASCE 41-17 [13]. Table 6 shows the plastic hinges formed of structural elements, it can be seen that most of plastic hinge points are at level of A-IO (Immediate Occupancy), the most critical hinge condition of CP (Collapse Prevention) is also has a significant number, thus the retrofit is needed to avoid building damage during earthquake.

Symbol	Information
B	Shows a linear boundary which is then followed by the first melting of the structure
IO	There is little or no significant damage to the structure, the stiffness of the structure is almost the same as before the earthquake occurred
LS	Damage occurs ranging from small to moderate levels, the stiffness of the structure is reduced but still has a fairly large threshold for collapse
CP	Severe damage to the structure occurs so that its stiffness and strength are reduced greatly
C	The maximum limit of shear force that the structure can still withstand

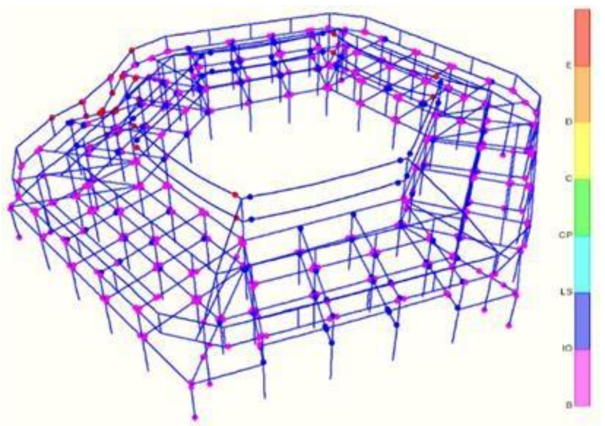


Figure 29 Scheme of Plastic Hinges

Figure 29 shows the scheme of plastic hinges as follows: The first step is the beam structural elements at the A-IO level, the next step goes up to the B-IO level up to the IO-LS level, then it is followed with the occurrence of plastic hinges in a column element at level A-IO. After that, when several beam structural elements are already at the CP level, one column element is also at the LS-CP level. So, it is necessary to strengthen the beam and column structural elements which have performance level of LS-CP in order to avoid building collapse and fatalities due to large earthquake loads [14].

CONCLUSIONS

This study has provided seismic response of Graha Sepuluh Nopember building as a result of nonlinear time history analysis, the following conclusions can be drawn:

1. The performance levels of existing building structure based on displacement as a function of roof drift ratio [15] according to ATC-40 have Immediate Occupancy (IO) level.
2. Based on the formed of plastic hinge, most of plastic hinge points are at level of A-IO (Immediate Occupancy), the most critical hinge condition of CP (Collapse Prevention) is also has a significant number, thus the retrofit is needed to remain safe to occupy during earthquake.

ACKNOWLEDGMENTS

We acknowledge to archives subsection in General Bureau and Bureaucratic Reform ITS [9] for getting access them to take the data of Graha Sepuluh Nopember Surabaya asbuilt drawing that had been archieved.

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