Displacement Analysis Due To Time History Load Case Study Building C And D Itera

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Abstract. Geologically Indonesia is located on the confluence of three major tectonic plates, namely Indo-Australia, the Eurasian plate, the Pacific plate as well as a micro-plate, namely micro-Plate Philippines. The above conditions with Indonesia being one of the countries that suffers earthquakes either tectonic or volcanic. A case study of building C and D ITERA is an adjacent building, then from that researchers want to discuss about the displacement that occurred at the confluence of the structure. The purpose of this research is to know the value of displacement i.e. inter-story drifts, maximum displacement, and the junction between the building happens in the meeting structure building C and D ITERA when given dynamic load time history and to know the minimum distance between buildings so as not to occur collisions (pounding effect). Dynamic analysis for earthquake resistant building design important completed because a more accurate for evaluation against the response structure due to earthquake loads. Earthquake load (time history) used is The Loma Prieta, The Northridge, The Kobe, The Trinidad, and The Hollister has in matching with response spectrum design area of building C and D ITERA.

Keywords : displacement, inter-story drift, maximum displacement; pounding effect; time history

1. Introduction

Indonesia is one of the archipelagic countries in the world, Indonesia is located in an area with the Earth latitude position 07o N - 12o latitude and longitude 95o east longitude - 141o east longitude and is located between 2 continents, namely the continent of Asia and the continent of Australia and 2 oceans, namely the Indian Ocean, and the Pacific Ocean. Geologically, Indonesia is on the junction of three main tectonic plates, namely the Indo-Australian Plate, Eurasian Plate, Pacific Plate and one micro plate, namely the Philippine Micro Plate.

The development of development in Indonesia is increasing rapidly, such as the construction of buildings and other infrastructure. As a result of the rapid development of infrastructure, the land used is decreasing so that multi-storey buildings are built with a distance close to Building C and D of the Sumatra Institute of Technology is one example of infrastructure built close together in Indonesia that is used for educational facilities. This building was built at the Sumatra Institute of Technology, South Lampung Regency with a plan to use the SNI 1726: 2012 earthquake standard.

In this study, the authors want to analyze the behavior of structures in the form of displacement due to time history loads that have been matched with the response spectrum of the ITERA building area C and D building area.

The formulation of the problem of this research is how the effect of time history load on inter-story drifts, maximum deviation and deviation between buildings at the meeting of ITERA C and D building structures, at what joint is the meeting of ITERA C and D building structures which have the maximum horizontal deviation due to time load history, and what is the minimum distance needed so that there is no pounding effect at the meeting of the ITERA building C and D structure.
2. Literature Review

According to Edy Purnomo (2018), dynamic analysis for the design of earthquake-resistant structures is carried out if a more accurate evaluation of the earthquake forces acting on the structure is needed, and to determine the response of the structure due to earthquake loads. Analysis can be performed elastically or inelastically, which is carried out on high-level structures or irregular structures. In the elastic method it is divided into 2, namely Time History Modal Analysis where data is needed in the form of earthquake acceleration and Response Spectrum Analysis, where in this way the maximum response of each vibration variety that occurs is obtained from the Plan Response Spectrum. (Design Spectra). This elastic dynamic analysis is carried out by means of direct integration where this method is widely used because it is simpler.

Planning on a building structure must be planned against dead load, live load, wind load, earthquake load or a combination of these loads. The amount of load working on the structure is taken from SNI 1727-2013 concerning the minimum load for planning buildings and other structures, Indonesian Loading Regulations for Buildings (PPIUG) 1983, and SNI 1726: 2012 concerning procedures for earthquake resistance planning for building and non-structural structures. building.

Response Spectra is the maximum response of a Single Degree of Freedom (SDOF) structural system both acceleration (a), velocity (v), and displacement (d) with the structure being loaded by certain external forces. Referring to SNI 1726-2012, the response spectrum can be determined based on the soil type factor and the earthquake zone zoning factor.

Accelergam is a recording of ground acceleration according to the time function which is completely recorded. The parameters arising from the movement of the land range from simple to complex. According to Edi Supriyanto (2017), the parameters of ground motion are discussed mainly to determine earthquake characteristics as well as their effect on buildings. The ground acceleration due to the earthquake is very important data, especially for engineering purposes. In general, the history of time acceleration is divided into three stages, namely:

1. Initial weak stage.
2. Strong part stage.
3. Weak part final stage.

Analysis of the non-linear time history response should consist of the analysis of a structural mathematical model that directly takes into account the non-linear hysterical behavior of structural elements in order to determine their response by means of a numerical integration method to a compatible set of time history ground motion accelerations with the response spectrum design for the site under review. (SNI 1726-2012).

In SNI 1726-2012 the determination of the deviation between the floors of the design level (perbedaan) must be calculated as the difference in deflection at the center of mass at the top and bottom levels being reviewed. The deviation between design points (Δ) shall be calculated as the greatest difference from the deflection of points above and below the observed level which are in a vertical line along one edge of the wind structure. The deflection of the center of mass at the rate x (δx) (mm) must be determined according to the following equation:

\[ \delta_x = \frac{C_d \delta_{xe}}{I_x} \]  

(1a)

According to SNI 03-1726-2012, the structural separator must be able to accommodate the maximum inelastic response displacement (δM). δM must be calculated at a critical location taking into account the translational and rotational displacement of the structure, including torque magnification (if any), using the following equation:

\[ \delta_M = \frac{C_d \delta_{max}}{I_x} \]  

(1b)

According to the 2006 edition of the International Building Code and regulations around the world, the minimum separation distance (Lopez Garacia in International Journal Volume 4, Number 4, 2015) can be calculated using 2 methods, namely:

\[ \delta_M = \frac{C_d \delta_{max}}{I_x} \]  

(1c)
3. Research Method

The Indonesian territory is located at the confluence of 3 main tectonic plates and micro plates which result in frequent earthquakes. The earthquake that occurs will be a burden on the building structure and it must be ensured that the building structure remains safe if an earthquake occurs. Structures that are commonly used in infrastructure development are reinforced concrete structures, precast concrete, and steel structures where ITERA C and D buildings have been built using reinforced concrete structures. Because an earthquake is a major problem in the planning of a building and the two buildings are close together, when an earthquake occurs, it can be seen the possibility of collisions between buildings. Data is taken from asbuilt and field conditions. At this stage of data collection, the data supports the research in the form of building structure data C and D of the Sumatra Institute of Technology (existing) and data on building conditions in fact.

The as built image of building C and D of the Sumatra Institute of Technology is modeled with a reinforced concrete structure are shown in Figure 1 and 2. The data are as follows:
- Building location : South Lampung
- Building function : Lecture hall
- Soil Type : Medium Soil (SD)
- Number of floors : 4
- Floor height : 4.2 m
- Building height : 15.55 m

The quality of the concrete material used in structural modeling is reinforced concrete with
- $f_c'$ : 24.9 MPa,
- earthquake modulus, $E$ : 23.5 Gpa,
- shear modulus, $G$ : 9,792 GPa,
- modulus of elasticity, $Ec$ : $4700 f_c^{0.5}$.

Figure 1. The structural model of the ITERA C building
The loading used refers to SNI 1727-2013 and PPIUG 1983 for static loads. The live load used is 2.4 kN / m² and SIDL 100 kg / m². The wind load used in this final project is 40 kg / m² in each direction is shown in Figure 3.

Earthquake load used is response spectra and time history. The values of Ss, S1, Fa, Fv, SDs, and SD1 were taken from the web puskim.pu.go.id for the design response spectra with the following values is shown in Figure 4:

- SS = 0.718
- S1 = 0.311
- Fa = 1.226
- Fv = 1.779
- SDs = 0.368
- SD1 = 0.586
The time history used in this study is The Loma Prieta (USA), The Northridge (USA), The Kobe (Japan), The Trinidad (USA), and The Hollister (USA) which have been matched so that the response spectrum time history resembles the response spectrum of design is shown in Figure 5-9.

**Figure 5.** The Loma Prieta TH1 accelerogram

**Figure 6.** The Northridge TH 2 Accelogram

**Figure 7.** The Kobe TH 3 Accelerogram

**Figure 8.** Accelerogram TH 4 The Trinidad
4. Results

The analysis used is a time history nonlinear dynamic analysis. The analysis uses 2 earthquake directions, namely X or Y in each building according to the direction to be reviewed. The area under review is a meeting between building structures symbolized in the form of numbers, the meeting of structures can be seen in table 1.

| Joint  | Joint  | Joint  |
|--------|--------|--------|
| 53-13  | 54-9   | 52-2   |
| 70-73  | 68-57  | 55-56  |
| 265-246| 263-230| 251-229|
| 416-385| 414-104| 402-6  |
| 684-648| 839-646| 674-614|

The deviation results obtained from the analysis at the joint meeting of ITERA building C and D are:

4.1. Inter-Story Drifts

Deviation between floors that occurs can be seen in the table below:

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) | Deviation (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|----------------|
| 13    | 0,000             | 9     | 0,000             | 2     | 0,000             | 62,25          |
| 73    | 11,477            | 57    | 11,249            | 56    | 10,945            | 63             |
| 246   | 13,541            | 230   | 13,607            | 229   | 13,768            | 63             |
| 385   | 7,594             | 104   | 8,312             | 6     | 8,829             | 63             |
| 648   | 1,601             | 646   | 6,626             | 614   | 3,894             | 45             |
Table 3. Deviation between floors of building C due to the earthquake in The Northridge.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) | Deviation (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|----------------|
| 13    | 0,000             | 9     | 0,000             | 2     | 0,000             | 62,25          |
| 73    | 9,280             | 57    | 9,115             | 56    | 8,873             | 63             |
| 246   | 10,685            | 230   | 10,765            | 229   | 10,927            | 63             |
| 385   | 5,940             | 104   | 6,329             | 6     | 6,813             | 63             |
| 648   | 1,289             | 646   | 5,650             | 614   | 2,966             | 45             |

Table 4. Deviation between floors of building C due to the earthquake in The Kobe.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) | Deviation (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|----------------|
| 13    | 0,000             | 9     | 0,000             | 2     | 0,000             | 62,25          |
| 73    | 10,688            | 57    | 10,435            | 56    | 10,171            | 63             |
| 246   | 12,551            | 230   | 12,536            | 229   | 12,566            | 63             |
| 385   | 7,022             | 104   | 7,737             | 6     | 7,700             | 63             |
| 648   | 0,430             | 646   | 0,455             | 614   | 3,146             | 45             |

Table 5. Deviation between floors of building C due to the earthquake in The Trinidad.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) | Deviation (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|----------------|
| 13    | 0,000             | 9     | 0,000             | 2     | 0,000             | 62,25          |
| 73    | 8,543             | 57    | 8,419             | 56    | 8,221             | 63             |
| 246   | 10,127            | 230   | 10,245            | 229   | 10,424            | 63             |
| 385   | 5,661             | 104   | 6,230             | 6     | 6,725             | 63             |
| 648   | 1,334             | 646   | 5,709             | 614   | 2,996             | 45             |

Table 6. Deviation between floors of building C due to The Hollister earthquake.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) | Deviation (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|----------------|
| 13    | 0,000             | 9     | 0,000             | 2     | 0,000             | 62,25          |
| 73    | 10,014            | 57    | 9,878             | 56    | 9,713             | 63             |
| 246   | 12,808            | 230   | 12,896            | 229   | 12,991            | 63             |
| 385   | 7,678             | 104   | 8,569             | 6     | 8,606             | 63             |
| 648   | 0,571             | 646   | 0,997             | 614   | 3,678             | 45             |

Table 7. Deviation between floors of building D due to the earthquake in The Loma Prieta.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) | Deviation (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|----------------|
| 53    | 0,000             | 54    | 0,000             | 52    | 0,000             | 62,25          |
| 70    | 14,095            | 68    | 14,216            | 55    | 14,289            | 63             |
| 265   | 18,080            | 263   | 18,209            | 251   | 18,348            | 63             |
| 416   | 11,092            | 414   | 11,506            | 402   | 11,506            | 63             |
| 684   | 0,710             | 839   | 3,337             | 674   | 3,095             | 45             |
Table 8. Deviation between floors of building D due to the earthquake in The Northridge.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) | Deviation (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|----------------|
| 53    | 0                 | 54    | 0                 | 52    | 0                 | 62.25          |
| 70    | 11,682            | 68    | 11,781            | 55    | 11,836            | 63             |
| 265   | 14,183            | 263   | 14,311            | 251   | 14,458            | 63             |
| 416   | 8,631             | 414   | 8,624             | 402   | 9,009             | 63             |
| 684   | 1,886             | 839   | 7,953             | 674   | 2,772             | 45             |

Table 9. Deviation between floors of building D due to the earthquake in The Kobe.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) | Deviation (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|----------------|
| 53    | 0,000             | 54    | 0,000             | 52    | 0,000             | 62.25          |
| 70    | 11,689            | 68    | 11,796            | 55    | 11,876            | 63             |
| 265   | 15,305            | 263   | 15,404            | 251   | 15,525            | 63             |
| 416   | 10,630            | 414   | 10,567            | 402   | 10,527            | 63             |
| 684   | 1,888             | 839   | 7,993             | 674   | 3,142             | 45             |

Table 10. Deviation between floors of building D due to the earthquake in The Trinidad.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) | Deviation (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|----------------|
| 53    | 0,000             | 54    | 0,000             | 52    | 0,000             | 62.25          |
| 70    | 9,724             | 68    | 9,742             | 55    | 9,728             | 63             |
| 265   | 12,335            | 263   | 12,360            | 251   | 12,397            | 63             |
| 416   | 7,392             | 414   | 7,718             | 402   | 8,030             | 63             |
| 684   | 1,211             | 839   | 5,577             | 674   | 1,995             | 45             |

Table 11. Deviation between floors of building D due to The Hollister earthquake.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) | Deviation (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|----------------|
| 53    | 0,000             | 54    | 0,000             | 52    | 0,000             | 62.25          |
| 70    | 10,087            | 68    | 10,256            | 55    | 10,399            | 63             |
| 265   | 13,515            | 263   | 13,658            | 251   | 13,834            | 63             |
| 416   | 9,713             | 414   | 9,574             | 402   | 9,588             | 63             |
| 684   | 1,912             | 839   | 7,634             | 674   | 2,878             | 45             |

From the data above, it is obtained that the maximum deviation between floors in building C is at joint 229 of 13,769 mm and building D which is at join 251 is 18,348 mm, each of which was caused by the earthquake of The Loma Prieta (USA) earthquake of October 18, 1989. The irregularities that occur indicate that the deviation between floors is still allowed because it meets the requirements, namely ≤ 63 mm

4.2. Maximum Deviation

In the calculation of inter-story drifts, the maximum deviation that occurs at the meeting of ITERA's C and D building structures will be obtained. Deviation that occurs at the meeting of structures can be seen in the following table:
### Table 12. Deviation of building C due to The Loma Prieta earthquake.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|
| 13    | 0.000            | 9     | 0.000            | 2     | 0.000            |
| 73    | 11.477           | 57    | 11.249           | 56    | 10.945           |
| 246   | 25.018           | 230   | 24.856           | 229   | 24.713           |
| 385   | 32.611           | 104   | 33.169           | 6     | 33.543           |
| 648   | 38.482           | 646   | 39.794           | 614   | 37.437           |

### Table 13. Deviation of building C due to the earthquake in The Loma Northridge.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|
| 13    | 0.000            | 9     | 0.000            | 2     | 0.000            |
| 73    | 9.280            | 57    | 9.115            | 56    | 8.873            |
| 246   | 19.965           | 230   | 19.881           | 229   | 19.800           |
| 385   | 25.905           | 104   | 26.209           | 6     | 26.613           |
| 648   | 30.631           | 646   | 31.860           | 614   | 29.579           |

### Table 14. Deviation of building C due to the earthquake in The Kobe.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|
| 13    | 0.000            | 9     | 0.000            | 2     | 0.000            |
| 73    | 10.688           | 57    | 10.435           | 56    | 10.171           |
| 246   | 23.239           | 230   | 22.972           | 229   | 22.737           |
| 385   | 30.261           | 104   | 30.708           | 6     | 30.437           |
| 648   | 31.838           | 646   | 31.163           | 614   | 33.583           |

### Table 15. Deviation of building C due to the earthquake in The Trinidad.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|
| 13    | 0.000            | 9     | 0.000            | 2     | 0.000            |
| 73    | 8.543            | 57    | 8.419            | 56    | 8.221            |
| 246   | 18.671           | 230   | 18.663           | 229   | 18.645           |
| 385   | 24.332           | 104   | 24.893           | 6     | 25.370           |
| 648   | 29.223           | 646   | 30.602           | 614   | 28.365           |

### Table 16. Deviation of building C due to The Hollister earthquake.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|
| 13    | 0.000            | 9     | 0.000            | 2     | 0.000            |
| 73    | 10.014           | 57    | 9.878            | 56    | 9.713            |
| 246   | 22.821           | 230   | 22.774           | 229   | 22.704           |
| 385   | 30.499           | 104   | 31.343           | 6     | 31.310           |
| 648   | 32.593           | 646   | 32.340           | 614   | 34.987           |

### Table 17. Deviation of building D due to The Loma Prieta earthquake.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|
| 53    | 0.000            | 54    | 0.000            | 52    | 0.000            |
| 70    | 14.095           | 68    | 14.216           | 55    | 14.289           |
From the results of data processing, the maximum deviation in building C that occurs is 39,794 mm at the 646 joint and building D is 47,681 mm at the 674 joint, each of which is caused by the earthquake load (time history) The Loma Prieta (USA) earthquake of October 18, 1989.

### 4.3. Deviation Between Buildings

The minimum distance between buildings is calculated using the ABS (ABSolute Sum) method as described in the previous chapter. Deviation that occurs must be reviewed at critical points, the critical points in this study are the intersections between buildings. From equation (1b) the distance between buildings caused by each earthquake load (time history) at the points being reviewed can be seen in table 22.

### Table 18. Deviation of building D due to The Loma Northridge earthquake.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|
| 53    | 0,000             | 54    | 0,000             | 52    | 0,000             |
| 70    | 11,682            | 68    | 11,781            | 55    | 11,836            |
| 265   | 25,865            | 263   | 26,092            | 251   | 26,294            |
| 416   | 34,424            | 414   | 34,716            | 402   | 35,303            |
| 684   | 45,870            | 839   | 42,669            | 674   | 38,075            |

### Table 19. Deviation of building D due to the earthquake in The Kobe.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|
| 53    | 0,000             | 54    | 0,000             | 52    | 0,000             |
| 70    | 11,689            | 68    | 11,796            | 55    | 11,876            |
| 265   | 26,994            | 263   | 27,199            | 251   | 27,401            |
| 416   | 37,624            | 414   | 37,767            | 402   | 37,928            |
| 684   | 44,546            | 839   | 45,760            | 674   | 41,070            |

### Table 20. Deviation of building D due to the earthquake in The Trinidad.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|
| 53    | 0,000             | 54    | 0,000             | 52    | 0,000             |
| 70    | 9,724             | 68    | 9,742             | 55    | 9,728             |
| 265   | 22,059            | 263   | 22,103            | 251   | 22,125            |
| 416   | 29,451            | 414   | 29,821            | 402   | 30,155            |
| 684   | 33,891            | 839   | 35,398            | 674   | 32,149            |

### Table 21. Deviation of building D due to The Hollister earthquake.

| Joint | Displacement (mm) | Joint | Displacement (mm) | Joint | Displacement (mm) |
|-------|-------------------|-------|-------------------|-------|-------------------|
| 53    | 0,000             | 54    | 0,000             | 52    | 0,000             |
| 70    | 10,087            | 68    | 10,256            | 55    | 10,399            |
| 265   | 23,602            | 263   | 23,914            | 251   | 24,233            |
| 416   | 33,315            | 414   | 33,488            | 402   | 33,821            |
| 684   | 40,326            | 839   | 41,122            | 674   | 36,700            |
Table 22. Minimum distance between buildings

| No | Earthquake Load        | Min Distance Joint 1 | Min Distance Joint 2 | Min Distance Joint 3 |
|----|------------------------|----------------------|----------------------|----------------------|
| 1  | The Loma Prieta (USA)  | 84.352               | 87.061               | 85.118               |
| 2  | The Northridge (USA)   | 72.043               | 74.529               | 67.652               |
| 3  | The Kobe (Japan)       | 76.384               | 76.923               | 74.653               |
| 4  | The Trinidad (USA)     | 63.114               | 66.000               | 60.515               |
| 5  | The Hollister (USA)    | 72.919               | 73.462               | 71.687               |

It is obtained that the minimum distance caused by the earthquake load of The Loma Prieta (USA) earthquake of October 18, 1989 and is the greatest distance, which is 87.061 mm at meeting 2 which is calculated from the axles to the axles of each column. Therefore, the minimum distance required for building structures C and D ITERA is 587.061 mm. In order to avoid collisions between buildings, the structures must be separated by a distance greater than 587,061 mm.

5. Conclusion
The conclusions obtained from this study include:

5.1. Plastic Joints
Plastic joints formed due to earthquake loads (time history) are:
a. The Loma Prieta (USA) earthquake of October 18, 1989.
b. The Northridge (USA) earthquake of January 17, 1994.
c. The Kobe (Japan) earthquake of January 16, 1995.
d. The Trinidad (USA) earthquake of August 24, 1983.
e. The Hollister (USA) earthquake of April 09, 1961.

Shows the result where some of the dots are in the elastic boundary state followed by the first melt indicated in pink (B). This shows that the building structures C and D ITERA are still safe against earthquake loads that occur.

5.2. Inter-story Drifts (Deviation between Floors)
Deviation between floors that occurs due to earthquake loads (time history) at the meeting of ITERA building C and D structures still meets the requirements of SNI 1726: 2012. The maximum deviation value that occurs in building C is at joint 229 of 13,769 mm and in building D which is at joint 251 of 18,348 mm, each of which was caused by the earthquake of The Loma Prieta (USA) earthquake of October 18, 1989 which shows that the deviation between floors that occur is still allowed because it meets the requirements, namely ≤ 63 mm.

5.3. Maximum Deviation
The maximum deviation that occurs at the meeting of the structure caused by the earthquake load (time history) in building C that occurs is 39.794 mm at joint 684 and building D is 47.681 mm at joint 674, each of which is caused by the earthquake load (time history) of The Loma Prieta (USA) earthquake of October 18, 1989.

5.4. Minimum Distance between Buildings
The analysis carried out to determine the minimum distance between buildings due to earthquake loads (time history) shows that the recommended minimum distance between buildings is 587.061 mm due to the earthquake load of The Loma Prieta (USA) earthquake of October 18, 1989. To avoid collisions between buildings (pounding effect) the separation distance of the structures must be greater than 587,061 mm.
6. Suggestions
In this study, there were also many obstacles that occurred unexpectedly, resulting in delays in doing this final project. Therefore, the authors provide suggestions, including:
1. The earthquake load that should be used is a record of the earthquake (time history) that occurred in the area under review.
2. The structural modeling parameters in the structural analysis software used must be considered properly.
3. The observed structural behavior can be developed in order to obtain a theoretical state of the structure in line with the structure in the field.

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