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COMPARISON STUDY ON DAMAGE PATTERN OF TWO STORIES BUILDING: SIMULATION VS FIELD RECORD

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ABSTRACT: A study on the damage pattern of the two-story building is needed for quick assessment soon after the earthquake. In Indonesia, quick assessment is needed at least for two reasons: to determine the Government subsides Fund and to retrofit the damaged houses. The previous article has been analyzed and simulated the case study of the two-story building due to earthquake load base on Indonesia Earthquake Code by considering the soil conditions. It shows that the influence of soil conditions as well as column properties, especially at a lower level, are an important factor in determining the damage patterns. However, that study was not verified yet with the damage data of the two stories building in the field. This paper discussed the comparison between the simulation results with the field record of two stories building damage in Indonesia. The data are collected base on the recent earthquakes in Indonesia: Padang Earthquake (2009) and Palu Earthquake (2018). It shows that they are confirmed the damage patterns are in line with the simulation results. Base on this study, the guidance for quick assessment of a two-story building then is developed.

Keywords: *Earthquake, Quick assessment, Non-engineered two-story building, Indonesian code*

1. INTRODUCTION

This study is the continuation of the previous study regarding the quick assessment of two stories building [1]. Two stories building model has been analyzed, including the soil-structure interaction [2] and [3] .

The soil categories are differed based on the average soil strength in terms of either Standard penetration value, Nspt, Shear wave velocity, Vs, or, Soil strength, Su. Based on those values, the numerical simulation is then conducted to take the advances of soil-structure interaction methods [4].

The structural elements of the building are designed as reinforced concrete with the minimum reinforcement. This design then gives the minimum capacity required for a two-story building and will be discussed in the results section. The typical soil-structure interaction model for numerical simulation are shown in Fig. 2

The geometry of the finite element model shown in Fig. 2 has a height of 3.5m every level and 4.0m between columns.

The applied loads on the models are the self-weight load, live load, and earthquake load. The earthquake load is adopted from the calculation results by the Ministry of Public Service of Indonesia. The values of Acceleration Spectrum in a unit of g are plotted on Y-axis respect to the period, T in second on X-axis.

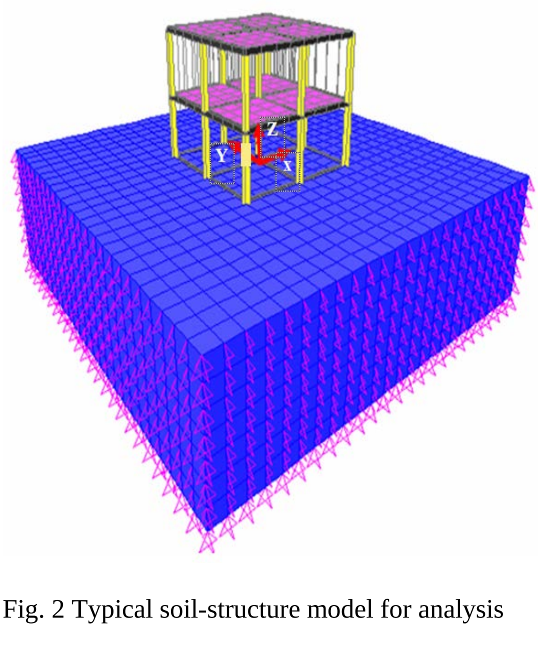


Fig. 2 Typical soil-structure model for analysis

The displacement pattern due to the earthquake load is shown in Fig. 4. Meanwhile, the typical internal moment is shown in Fig. 5. The values of displacement and internal forces due to the applied load are given in Table 3.

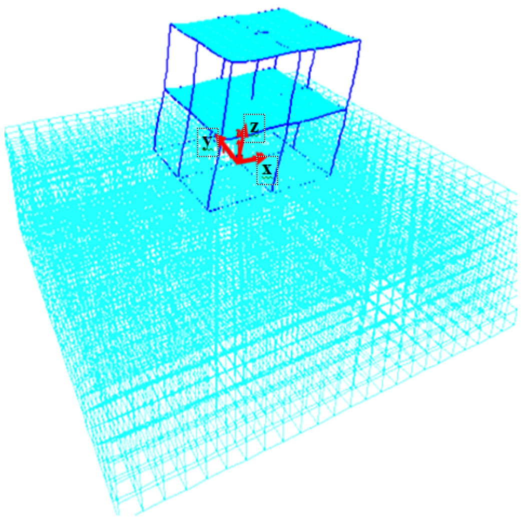


Fig. 4 Typical displacement of the models due to applied earthquake load.

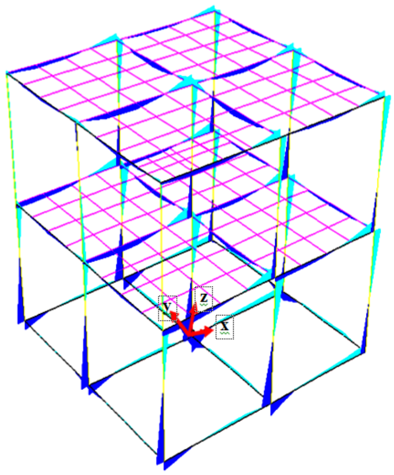


Fig. 5 Typical internal moment due to loads.

Table 3. Internal force values in column

Column position	Axial	Shear	Moment
Hard soil site			
Edge 2nd storey	-3497	306	-1068
Edge 1st storey	-5704.	2876.	5879.
Side 2nd storey	-10455	-345	-977
Side 1st storey	-18904	2744	5800
Middle 2nd storey	-28915	2778	-5281
Middle 1st storey	-56483	4559	8236
Medium soil site			
Column position	Axial	Shear	Moment
Edge 2nd storey	-3661	208	-918
Edge 1st storey	-5973	2937	5918
Side 2nd storey	-10474	-490	-1261
Side 1st storey	-18821	2913	6132
Middle 2nd storey	-28095	2777	-5305
Middle 1st storey	-54976	4708	8429
Soft soil site			
Column position	Axial	Shear	Moment
Edge 2nd storey	-3990	-36	-569
Edge 1st storey	-6739	2720	5505
Side 2nd storey	-10625	-805	-1776
Side 1st storey	-19247	2761	5920
Middle 2nd storey	-27204	2506	-4807
Middle 1st storey	-53316	4359	7744

From the numerical results, it can be seen that even though the applied earthquake loads for medium soil site and hard soil site are the same, but the response of the structure give different values. The medium site gives larger internal forces in general. Furthermore, the earthquake load applied to the structure in the soft soil is 10% less than the others. But the responses regarding internal forces give bigger in some points.

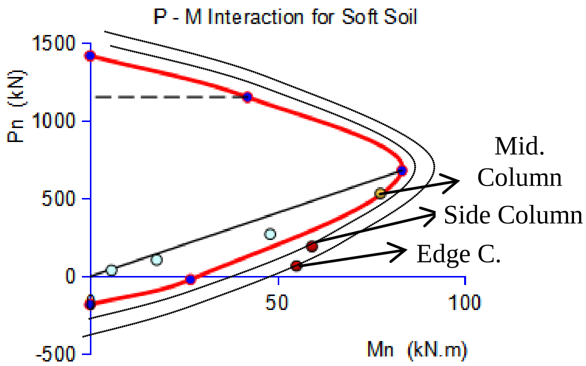


Fig. 6 Typical axial-moment interaction diagram.

The numerical simulations then are compared to the strength of the structural element to give the idea to built the quick assessment procedure, as presented in Fig. 6. These results in P-M diagram have given the idea to see the soil characteristic in the location of the building while investigating the building assessment, especially soon after the earthquake. The quick assessment is a very important task to be conducted after the earthquake [5] and [6]. It can be seen that the edge column is at the most critical position in the P-M diagram, followed by the side and the middle columns. These results then applied to the building assessment during quick investigating soon after the earthquake, as seen in Fig. 7.

Then, in order to validate the result, this study is purposed to compare the simulation results with the field record of two stories building damage in Indonesia. There are two cities that have experienced a big earthquake that is Padang in 2009 [7] and Palu in 2018.

2. ASSESSMENT METHODOLOGY

The methodology used for quick assessment of damaged analysis after the earthquake can be built based on the results of the numerical simulation as shown in Fig. 7. First, check the earthquake intensity. There are three categories of earthquake intensity: small, medium, and high. The criteria are used base on MMI scale. Second, the soil type is checked. There are three types of soil: soft, medium, and hard. Third, the column condition is identified. In this case, there are three positions of the column to be checked: edge, side, and middle, including the first and second floor.

This study will then be comparing the results of numerical analysis with the collected facts in the field. This study may compare the simulation results with the field record of two stories building damage in Indonesia. There have been records of the damaged building for two cities in Padang (2009) and Palu (2018). The discussion of this study will be described in the next section.

3. RESULT AND DISCUSSION

In this study, there are a number of two stories building are evaluated. The taken samples of two stories building are collected from the most earthquake impacted areas in Indonesia, Padang earthquake 2009 (M7.9) and Palu earthquake 2017 (M6.1). The building selected is located in 3 types of soil, that is, soft, medium, and hard. Building evaluation then applied using the procedure in Fig.6.

A. *Earthquake Intensity*

In general, the bigger the intensity of the earthquake, the havier the damage of a building. In the case of an un-proper constructed building, it will collapse severely. It can be seen during the Padang earthquake (M7.9 in 2019) with intensity in certain areas reaches MMI 7. A similar thing happens during an earthquake in Palu 2018.

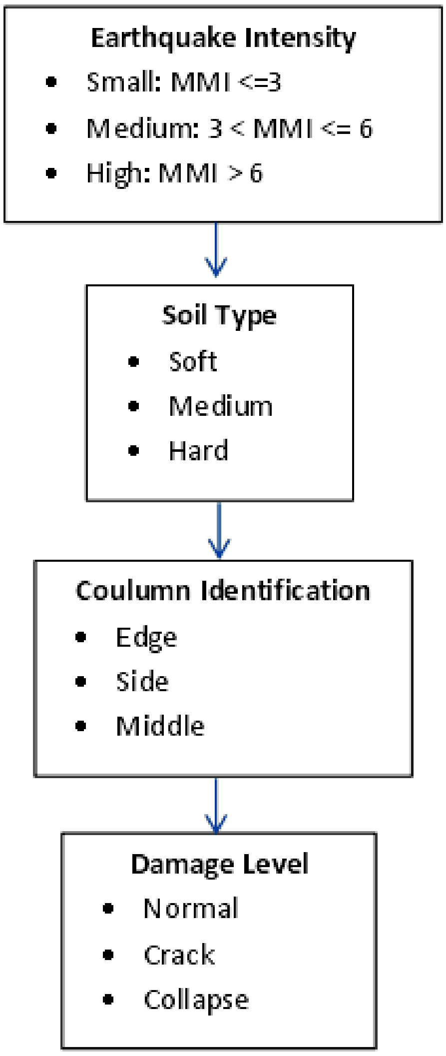


Fig. 7 Field Assessment Procedure

B. *Soil Type*

Soil type will influence the shaking of the earthquake. The softer the soil, the bigger the shaking is very affecting to the buildings. Building on the soft soil will experience more vibration due to its amplification. Fig. 8 shows how the building collapse built on soft soil.

In the case of medium soil, due to a big earthquake, the building may still survive especially its structural component. However, its non-structural components are collapse since they are not designed to withstand the big earthquake load. Fig 9 shows the non-structural components are collapsed due to earthquakes.

a. Soft Soil

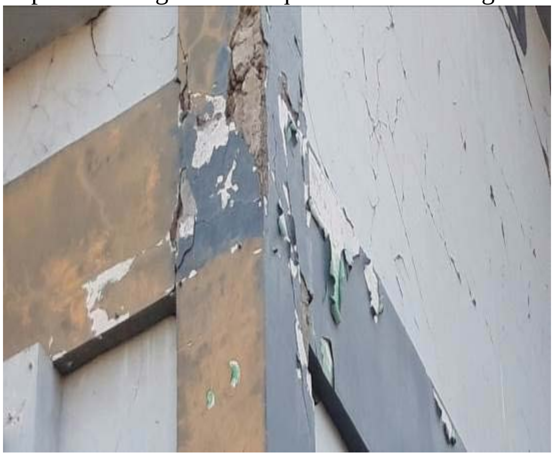
b. Medium Soil

c. Hard Soil

Fig. 8 Damaged building in Assessment

Not all building stayed on hard soil and properly design according to earthquake code, can withstand the earthquake load. Hard soil will keep the shaking constant, and the good design can absorb the earthquake energy properly.

Clearly, the location of the buildings is not much related to the damaged. However, the strength in proper design and application are more important things for earthquake safer buildings



a. Edge Column

b. Middle Column

C. Column Position

Based on the analysis, the column type or location in the building seems very important to be taken in to account for damage assessment. The position of the column at the edge will damage at first prior to the others during the earthquake. The side column will damage before the middle one. Those phenomena exactly notice in the field record of damage building in Padang and Palu earthquakes.

Damage of column of building in Padang can be seen in the detail in Fig. 9. It shows the edge column was damaged badly due to the shaking compared to the others, even though the internal forces in the edge column are smaller compared to the others. The side column showed the crack only on the top. Meanwhile, the middle column seems still in good condition. It is in line with simulation analysis.

A similar thing happened in Palu where some buildings suffer from the edge column damage badly compare to the side column. Meanwhile, the middle columns are still good (Fig. 10 a). It also showed that a building has only damage at the edge column; meanwhile, the others are good (Fig. 10 b). Then it can be concluded in general that due to an earthquake, the first damage will happen in the edge column, then the next damage will experience the side column, and the last is the middle column. For the purpose of quick assessment, it can be stated that the investigation of damaged buildings can be conducted further if the outside column clearly shows damage. On the other hand, if there is no sign of damage from the outside column, then it can be quickly assessed that the building is still in good condition.

c. Side Column

Fig. 9 Damaged column in Padang.

a. Damaged out side column

b. Damaged edge column

Fig. 10 Structural damaged of building in Palu.

4. CONCLUSIONS

For the purpose of building a quick assessment tool, it is very important to accomplish numerical simulations of typical building structures in the different soil type sites. Two stories building generally destroyed by the earthquake. In this paper, the earthquake loaded building in Padang become the main point. The numerical results show that for the medium soil site and hard soil site with the same load, give different responses to the structure. Furthermore, for the soft soil with 10% less earthquake load, the responses regarding internal forces give bigger in some points.

This study has been comparing the results of numerical analysis with the collected data of damaged buildings in the field, that are taken from field investigation of a damaged building for two cities in Padang (2009) and Palu (2018). The comparison field's data and analysis result in this study showed a good correlation between them. Event more data of damaged buildings to be compared to the analysis are still needed, but the quick procedure given in this study is a good idea to develop more or applied to the building assessment due to the earthquake. This procedure will save the consumed time in the damage assessment of the building in which are very important to finish the damage analysis and loss assessment as soon as possible with a very good results.

5. ACKNOWLEDGMENTS

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