Assessment of Seismic Vulnerability of Reinforced Concrete Building Frames Based on European Macroseismic Scale (Case Study of Siak Regency Government Building)

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Abstract. Earthquake disasters in Indonesia are currently not only experienced in areas that often occur earthquakes, in areas that were once relatively safer also experienced earthquakes. The greater the strength of the earthquake in one area the greater the scope of the area affected by the earthquake. Riau Province, especially the Siak Regency, is one of the areas that are in a relatively safe zone. However, it can still experience an earthquake if the point of the earthquake is near the area itself or because the earthquake point has a very large area achievement due to the magnitude of the strength of the earthquake itself. Lately to evaluate buildings that have been standing, rapid assessment of vulnerability or rapid screening. One of the commonly used rapid vulnerability assessment procedures is that issued by FEMA. However, often the assessment of buildings provided by regulations, such as FEMA is less applicable to parties or communities not of civil engineering background, the procedures are complicated or cannot be underestimated for various disaster cases. So that academics in some countries develop vulnerability assessments that do not involve much mathematical analysis, simple, can be used by parties who are not of technical background, can be used in many countries, and can also be used for disasters other than seismic disasters/earthquakes. One such method of vulnerability assessment is the assessment procedures that are founded by the European Seismic Scale. Test results showed that vulnerability assessments could quickly be carried out by researchers with no civilian background. So that this calculation can be done by even ordinary people. This is very helpful for the assessment of the building against the damage caused by the earthquake.

1. Introduction

Indonesia is an archipelago in an area that has a high earthquake potential, this is because Indonesia's position is on three major world plates, namely Eurasia, Indo-Australia, and the Pacific. In addition, Indonesia's position is also located in the Pacific Ring of Fire which is a 40,000 km long area that often experiences earthquakes and volcanic eruptions in the Pacific Ocean basin region.

Earthquake disasters in Indonesia are currently not only experienced in areas that often occur earthquakes but in areas that were once relatively safer also experienced earthquakes. The greater the strength of the earthquake in one area the greater the scope of the area affected by the earthquake. Riau Province, especially Siak Sri Indrapura regency, is one of the areas that are in a relatively safe zone. However, it can still experience an earthquake if the point of the earthquake is near the area itself or...
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Lately to evaluate buildings that have been standing, rapid assessment of vulnerability or rapid screening. Academics or associations in the field of engineering/disaster in various countries develop vulnerability assessment procedures, such as ATC, FEMA, GNDT. One of the commonly used rapid vulnerability assessment procedures is that issued by FEMA. One of the studies conducted by Agustin et al applied the Rapid Visual Screening method based on FEMA 154 on four public buildings in Indragiri Hulu Regency with the conclusion that the Rapid Visual Screening (RVS) method can be used in the location of the building being analyzed in an area with moderate earthquake conditions. (Moderate Seismicity) [2]. Research by Lagomarsino and Cattari (2013) analyzes the seismic vulnerability of several existing buildings in Italy. This study proposes a structural vulnerability analysis with a macroseismic and mechanical approach. Parameters of the macroseismic approach between building regulations in a country and mechanical parameters in the form of geometry and building mechanics, but the drawback is that it still involves complex mathematical analysis [3].

Zuccaro et al (2012) proposed a building vulnerability assessment based on population census data. The research method consists of two formulations, namely method A which includes census data as a parameter, and method B which does not include census data as a parameter. The results of method calibration show good results, especially for method B in various areas or locations studied. The proposed method can at least be used for the initial policy of protecting the life of the population [4].

However, most of the assessment of buildings provided by regulations, for example, FEMA is less applicable to parties or communities that are not of civil engineering background, the procedures are complicated or cannot be assimilated for various disaster cases. So that academics in some countries develop vulnerability assessments that do not involve much mathematical analysis, simple, can be used by parties who are not of technical background, can be used in many countries, and can also be used for disasters other than seismic disasters/earthquakes. One such method of vulnerability assessment is the assessment procedure set up by the European Seismic Scale developed [1].

2. Methodology

The primary data that will be assessed in detail consists of 14 buildings located in the office area in Siak Regency that will be used in the assessment of the building. Data collection techniques use information based on direct location visualization. See the shape of the floor plan and also the façade of the building, with simple mathematical calculations.

In this study there are several stages of analysis, the initial analysis is to determine the value of seismic vulnerability using 8 assessment parameters. Divided into three groups related to the condition of the foundation, the position of the building in an area, the structure of the building. Group 1 includes parameter 1 which assesses the foundation and condition of typology. Group 2 includes P2 parameters that assess interaction with neighboring buildings. Group 3 includes parameters P3 through P8, each of which assesses the age of the building, the irregularity of the building's floor plan shape and visibility, the presence of short column potential, soft-story mechanisms, and other vulnerable elements that affect seismic vulnerability [1]. The eight parameters are classified according to the four vulnerability classes($C_i$) A, B, C, and D. For each parameter associated with weight ($\rho_i$) ranging from 0.5 for the parameter with the smallest impact to the value of 2.0 for the parameter with the greatest impact on the seismic vulnerability of the building. (see Table 1).
Table 1. Parameters of the vulnerability index, $I_v$, with respective vulnerability classes and weights

| Parameter          | Class $C_{vi}$ | Weight $p_i$ |
|--------------------|----------------|--------------|
| Group 1. Foundations |                |              |
| P1 Building implantation | 0 5 20 50     | 1.5          |
| Group 2. Position   |                |              |
| P2 Building position | 0 5 20 50     | 0.5          |
| Group 3. Building Structure | | |
| P3 Building age     | 0 5 20 50   | 1.5          |
| P4 Irregularity in plan | 0 5 20 50     | 2.0          |
| P5 Irregularity in height | 0 5 20 50     | 2.0          |
| P6 Soft-story mechanism | 0 5 20 50     | 2.0          |
| P7 Presence of short columns | 0 5 20 50     | 2.0          |
| P8 Presence of other vulnerable elements | 0 5 20 50 | 0.5 |

The parameters included in Group 1 and Group 2 are related to building buildings. Parameter P1 combines the evaluation of soil type and building foundation. The type of soil under consideration should be defined based on the available information about the soil, in case there is no information available, it should be considered type B soil [1]. Vulnerability classes are presented in Table 2.

Table 2. Vulnerability classes of P1

| Type of Soil       | Location of the Building |
|--------------------|--------------------------|
|                    | Plain Field | Landfills | Pronounced Slope |
| Soil type A        | A           | B         | C               |
| Soil type B and C  | B           | C         | D               |
| Soil type D and E  | C           | D         | D               |

The P2 parameter is related to the position of the building with adjacent buildings. The figure below is useful for characterizing a class of building vulnerabilities based on the relative position of the building to neighboring buildings [1].

Figure 1. The criterion to assess parameter P2

Figure 1 shows Criteria for assessing P2 parameters, where BM is a row building, I for insulated buildings, G for corner buildings, and BE for edge buildings. Group 3 is related to the structural characteristics of the building. Table 3 shows Parameter P3 addresses the period of design and construction of buildings [1].
Table 3. The class definition for parameter P3

| Type | Class Design                      |
|------|-----------------------------------|
| A    | With modern seismic design codes  |
| B    | With current seismic provisions   |
| C    | With minor seismic provision      |
| D    | Without seismic design            |

Table 4 shows the parameters P4 and P5 are related to the structural regularity of the building. The shape of the building plan affects the value of the P4 parameter [1].

Table 4. Class definition for parameter P4

| Class | Plan Irregularity                      |
|-------|----------------------------------------|
| A     | Building regular in plan               |
| B     | Building with one source of plan irregularity |
| C     | Building with two sources of plan irregularity |
| D     | Building with more than two sources of plan irregularity |

Regarding the parameters of P5, related to the regularity of visible shapes and the difference in height between floors of the building. The P6 parameter evaluates the existence of possible soft-story mechanisms. Soft-story mechanisms are also associated with the height irregularities of buildings. Typically, this mechanism can occur on the ground floor for architectural reasons or spaces used for commercial use. The P7 parameter is devoted to the evaluation of the existence of short columns. In many cases, due to the presence of openings (windows and doors), the walls do not meet the height of the frame completely, leaving parts of the column unrestricted. These cases can lead to unexpectedly higher shear loads that lead to column shear failure [1]. The definition of the vulnerability class for P7 is presented in Table 5.

Table 5. Class definition for parameter P7

| Class | Classification of short columns               |
|-------|-----------------------------------------------|
| A     | Buildings without short columns               |
| B     | Building with possible short columns in one of the upper floors |
| C     | Building with possible short columns on the ground floor or in several stories of the upper floors. |
| D     | Building with possible short columns on the ground floor that may lead to a stories mechanism |

P8 parameters are associated with the presence of secondary elements, namely balconies, parapets, cornices, and appendages, which can cause an increased risk to people or worsen the level of damage to structural elements [1]. The definition of the vulnerability class for the P8 parameter is given in Table 6.
\begin{equation}
V = -0.02 + \nu x 0.0104
\end{equation}

That it is obtained later the value of υD which serves as an assessment control of damage grade assessment that has a high subjective value. The value of υD is derived from the following problem (2).

\begin{equation}
υD = 2.839 x [1 + \tanh \left( \frac{1+10.79 x V-11.6}{5} \right)]
\end{equation}

3. Results and Discussions

Table 7 shows the extent of damage from each building from the previous assessment.
Figure 2 shows presents a variation of the level of damage obtained from each building.

![Figure 2. Distribution of damage value](image)

Figure 3 shows the comparative value between the damage value (D) and the average value of the damage (μD). Figure 3 it can be concluded that the value of μD is close to the value of D. so that the result of the calculation of the damage value is close to correct.

![Figure 3. Curves average damage value of buildings](image)

Figure 4 shows the relationship between the vulnerability value (V) and the average value of the damage (μD). Where the vulnerability value is directly proportional to the average value of the damage.


4. Conclusion

From the values generated in this study, it can be concluded that the D value is equal to μD which serves as control over the visual assessment carried out. Then from the assessment of damage to the building can be concluded that almost the average building in the office area of Siak Regency is vulnerable to earthquakes with EMS VII.

This study can not be separated from the advice that if the author can convey the following.

1. In designing the building so as not to use a design that is too dynamic so that the building becomes vulnerable to earthquakes.
2. In designing the building is expected to reduce non-structural components such as balconies, parapets, and so on. Because it can affect the assessment of the vulnerability of a building.
3. There needs to be strengthening - strengthening that must be done to the existing buildings in the Siak district office area so that the building is resistant to earthquakes.

References

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Figure 4. links between vulnerability value (V) and average value of the damage (μD) values