Structural Performance Monitoring System Using Android RViSITS For High Rise Building

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Abstract. In 2017, Indonesia’s National Earthquake Study Center (PuSGeN) issued an updated Indonesian sources and potentials of earthquake map which shows the possibility of new earthquake hazards potentials. This triggers the assessment of building’s vulnerability towards that new earthquake hazard potential. The assessment of building vulnerability towards earthquakes is divided into two types; quick check using Rapid Visual Screening (RVS) and thorough check. In its development, RVS method was chosen because it does not require a lot of personnel, reduce time for survey, and requires lower research costs. However, RVS method that uses manual form is considered less effective for buildings with a large numbers. Nevertheless, with the existence of RViSITS android application which has developed by ITS’s RVS Team based on FEMA 154, the assessment of building vulnerability and the result can be done and accessed by all sectors quickly and easily. This article aimed to assess the vulnerability level of three high-rise buildings (8-15 floors) in East Java using RViSITS android application by comparing the result of numerical analysis based on earthquake regulations applicable in Indonesia according to SNI 1726:2012. The result of analysis using RViSITS showed that the level of vulnerability of three high-rise buildings studied is “qualified” or earthquake safe. Generally, RViSITS can be used to map the vulnerability of high-rise buildings throughout the region in Indonesia.

1. Introduction
An earthquake is a threat to human being. It can cause injury or death for victims as well as being a threat to the destruction of standing buildings [1]. In reality, no one can prevent the happening of earthquakes but the impact of an earthquake disaster can be minimized through the right steps and methods [2]. There are many buildings in Indonesia are not designed considering to the existing earthquake regulations. In addition, each buildings is not equipped with data about the vulnerability which is cause a lot of damage to buildings during earthquake happens [3]. In 2007, Indonesia’s National Earthquake Study Center (PuSGen) has issued an update on seismic maps. It has led to the emergence of sources and potential for new earthquake hazards in Indonesia. One of them is the emergence of Surabaya and Waru faults that cross Surabaya city [4]. Thus, it is necessary to make an early effort to minimize the impact of earthquake. One step to anticipate the impact of earthquake is to analyze the vulnerability of a building.
There are two types for examination of building’s vulnerability towards earthquake namely a thorough check and quick check using Rapid Visual Screening (RVS). Some things that must be considered on a thorough check are involve specialist in the field of structure, takes longer time and also more expensive cost. However, quick check using RVS does not involve a lot of personnel in research, saving time and relatively cheap [3,5]. In examining building vulnerability, researchers have combined several methods such as visual examination, probability and numerical analysis [1,3,5–12].

In its development, RVS method is widely applied to assess building vulnerability since its application is quite simple and fast [3,5]. RVS method is most popular method used because it works fast, does not require a lot of personnel or structural expert, and cheaper cost. The use of RVS is intended to determine two possibilities of a building that is ensuring the level of building vulnerability in a safe condition or as a recommendation for the percentage of building vulnerability to be followed up further [13]. However, RVS method is considered less effective and efficient for buildings with large numbers. Since, its implementation requires a long time and a lot of time also needed to process all field data from surveyors into digital data in the database, data are still vulnerable to errors in verification or calculation phase. In addition, if there are changes or errors in some of field data, surveyors have to change with new form because the old form cannot be used for several surveys [14]. Furthermore, with RViSITS android application developed by RVS Team of Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia based on FEMA 154, the building vulnerability assessment can be done simpler and faster since the surveyor only need a smartphone without using manual form as many buildings as surveyed. Besides, in this application equipped with features connected to camera so that it is possible to document the object under study during the survey. This application is also connected to Global Positioning System (GPS) to determine the coordinates of building’s location automatically, all field data from surveyors will be stored automatically after saving and uploading to the database, and the result can be accessed by public, government and private sector quickly and easily [3].

Therefore, the main purpose of this research is to implement RViSITS android application to assess the vulnerability towards three high-rise buildings (8-15 floors) in East Java. Then, it is compare to numerical analysis result based on earthquake regulations applied in Indonesia according to SNI 1726: 2012 using SAP 2000 which is use to verify the accuracy of the application.

2. Material and Method

2.1 Rapid Visual Screening/RVS Method

Quick check using rapid visual screening (RVS) method was initially developed by Applied Technology Council (ATC) in late 1980s to evaluate the percentage of building vulnerability due to potential earthquake [15]. RVS is one method to evaluate the safety of the building structures easily, quickly and cheaply due to an earthquake. This method can be completed in a fairly simple way by surrounding the building from the outside of the buildings and determining whether the structure requires further examination [3].

RVS method has been widely applied by several researchers to evaluate the vulnerability of seismic buildings in many places [1,3,5–12]. In this research, RVS method is applied on different types of buildings such as hospitals and various types of brick buildings, etc. Although RVS method can be done quickly, but there are some disadvantages including its implementation requires a long time and a lot of time also needed to process all field data from surveyors into digital data in the database, data are still vulnerable to errors in verification or calculation phase. In addition, if there are changes or errors in some of field data, surveyors have to change with new form because the old form cannot be used for several surveys, so RVS method with manual form is less effective and efficient [3]. In figure 1, it is a manual form that is commonly used to assess buildings vulnerability using RVS method.
RViSITS is an android application developed based on FEMA 154. This application serves to simplify the process of checking building vulnerabilities sent via the internet. Then, there is a server as the center for collecting and processing the data. From this data, it is possible to map vulnerability and can be used to detect affected areas which can be accessed by various sectors such as government, private sectors, and public. The development of RViSITS android application is made by adapting to the rules at FEMA 154 with conditions and rules that have been adjusted to existing regulations in Indonesia [3].

The step that must be considered before conducting research is to prepare in advance the existing data of the building to be reviewed. Data needed include years of building construction, address, number of floors, building function, soil data to determine the type of soil at the location being reviewed, and asbuild drawing as a reference for numerical modeling [3,14].

Afterward, there are 8 further steps that will be conducted after obtaining the existing data [3,15]: 1) update the data and information regarding with the considerate building based on the existing data obtained and take picture of the building; 2) walk around the building for taking picture and observe the building condition; 3) determine the building function and the floor number; 4) determine the land type; 5) determine the type of non structural elements which has potential to fall down by the earthquake; 6) identify the building type in B score and choose the appropriate one; 7) identify and choose by click on the list menu in M score in the RViSITS (e.g: the time of building set up, number of floor, and land type); 8) the final score on the S score are obtained based on B score, M score, and being modify as stated in the step 7, thus, the last result will appear automatically in RViSITS program. However, if the deep evaluation is needed, the menu “insert comment” can be applied.

Figure 1. Manual Form of RVS Method According to FEMA 154
2.3 Research Method

The primary aim of this research is to evaluate susceptible building structure against three high rise building. These three building has 8th up to 15th floors in the zone D and E using the RViSITS android program. Further, this research is divided into three steps. The first step is collecting the data and conducting preliminary study deal with the building evaluation which has potential to fall cause by earthquake. The preliminary study can be described as collecting references as well as relevant regulation used in this research. Then, the second step is surveying the location, collecting others existing data as like land, shop drawing data and information relate to building. Moreover, the third step is conducting evaluation using RViSITS android program. Then, result verification numerically is obtained using SAP 2000 to control the performance of these three high rise buildings according to SNI 1726:2012. At last, numerically result analysis using SAP 2000 being compared to evaluate the RViSITS’s accurate performance [3].

The research steps using RViSITS android program can be seen in the figure 2.
The research factor in FEMA 154 for every building structure is analyzed to obtain the most significant factors which has influenced on RVS score. There are three scores existed in RVS including basic score (B), modifiers score (M), and final score (S). Basic score (B) is determined based on building structure type and the earthquake potential in the considerate area. The kind of building based on the RVS method is divided into 15 kinds, namely [15,16]: 1) W1 (wood frame with acreage < 5000 ft²); 2) W2 (wood frame with acreage > 5000 ft²); 3) S1 (steel moment frames); 4) S2 (steel bracing frame); 5) S3 (light metal); 6) S4 (steel frame with concrete shear wall); 7) S5 (steel frame with un-reinforced masonry infill); 8) C1 (Concrete moment-resisting frame); 9) C2 (concrete shear wall); 10) C3 (concrete frame with un-reinforced masonry infill); 11) PC1 (tilt-up structure); 12) PC2 (precast concrete frame); 13) RM1 (Reinforced masonry buildings with flexible floor and roof diaphragms); 14) RM2 (Reinforced masonry buildings with rigid floor and roof diaphragms); 15) URM (Unreinforced Masonary).

**Figure 2.** The Steps in Using RViSITS Androrid Program (a) to (n)
Modifiers Score (M) is influenced by several factors such as the type of building (mid-rise building and high rise building), shape of building (vertical irregularity, and plan irregularity) pre-code, post-benchmark, and land type (type C, D, and E). The last score (S) is obtained based on the basic score (B) and modifiers score (M) chosen. Moreover, the last score usually range from 0 up to 7, in which the S score is higher, hence, the structure is better. Based on the recent seismic design criteria, final score (S) is allowed if the score is no more than 2. The building with the S score is 2 or less should be evaluated by structural expert in the earthquake planning [3,15].

3. Result and Discussion

3.1 Analysis Using RViSITS Android Program

Based on the result analysis using RViSITS android is described in the figure 3.

Figure 3. Output Basic Score of RViSITS Android Program a) Marine Science Faculty, Universitas Airlangga; b) At-Tauhid Building, Universitas Muhammadiyah Surabaya; c) Trauma Center & Intensive Care Building, dr. Soedono Hospital

From the figure 3, the basic score of each building shows that: (1) the score of Marine Science Faculty Building, Universitas Airlangga is 5.2; (2) the score of At-Tauhid building, Universitas Muhammadiyah Surabaya is 5.2; (3) the score of Trauma Center & Intensive Care Building, dr. Soedono Hospital, Madiun is 5.6. Based on the basic score, the three buildings have score higher than 2, hence, the susceptible of building considered to be safe against the earthquake pressure as regulated in FEMA 154 [3,15].

3.2 Numerical Analysis Using SAP 2000

The numerical analysis is aimed to verify the analysis using RViSITS android program. The case study used involving three high rise building with the number of floor is 8th up to 15th in the East Java province. These three buildings are: 1) Marine Science Faculty Building, Universitas Airlangga; 2) At-Tauhid building Universitas Muhammadiyah Surabaya; 3) Trauma Center & Intensive Care Building, dr. Soedono Hospital, Madiun.

The analysis of the three buildings was obtained based on numerical analysis using SAP 2000. This analysis was used to control whether the building structure had fulfilled the earthquake regulation requirements as stated in SNI 1726:2012, and also fulfill the requirement of reinforced concrete building’s structure planning as stated in SNI 2874:2013. Figure 4 presents the model of three
considerate buildings using SAP 2000. Base shear control from the three buildings have score higher than 85% which means that the building has fulfill basic sliding control. In the mass participation control, the result has fulfilled the requirement given by SNI 1726:2012, in which the score of these buildings are more than 90%. Afterward, period control structure from the three buildings has exceeded the permission period. Then, in drift control, the deviation of x and y of the three buildings has not exceeded the permission limit. The three buildings categorize as new building which is firstly set up in 2003 namely Marine Science Faculty, Universitas Airlangga. Therefore, the building planning structure has considered the earthquake regulation in Indonesia. It can be seen according to the several conducted control (base shear, mass participation, structure and drift period). However, the three building are considered to be safe as required by SNI 1726:2012.

The result of numerical analysis according to SNI 1726:2012 compared with RViSITS android program analysis are present in the table 1.

### Table 1. The Comparison Between RViSITS Analysis and Numerical Analysis as Required by SNI 1726:2012

| Name of Building                          | RViSITS Score | Final Score | SNI 1726:2012 |
|------------------------------------------|---------------|-------------|---------------|
| Marine Science Faculty Building          | 5.2 > 2       | Qualified   | Qualified     |
| AT-Tauhid Building                        | 5.2 > 2       | Qualified   | Qualified     |
| Trauma Center & Intensive Care Building  | 5.6 > 2       | Qualified   | Qualified     |

4. Conclusions

Based on the analysis that has been adjusting to the renewal of Indonesian earthquake source map 2017, the three buildings including 1) Marine Science Faculty Building, Universitas Airlangga; 2) At-Tauhid Building, Universitas Muhammadiyah Surabaya, and 3) Trauma Center building, dr. Soedono Hospital are categorized as high earthquake zone based on FEMA 154. The final score in the RViSITS android program shows that the index higher than 2, while based on numerical analysis using SAP 2000 is obtained the base shear control, mass participation, structure period, and drift control has fulfill the requirement of SNI 1726:2012. Hence, the three buildings are qualified as safe building from earthquake. In this study, it should be known that Marine Science Faculty, Airlangga University is the
The oldest building which was set up in 2013. Meanwhile, another two buildings are being set up in 2016. However, these three buildings are still considered as new buildings so that the planning of building structure has considered earthquake regulation in Indonesia. Furthermore, the result analysis using RViSITS shows the same result with numerical analysis. Generally, RViSITS android program can be used to map the vulnerability of high rise buildings throughout the region in Indonesia.

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