Safety Factors in Public Buildings against Earthquake Risk in the City of Padang, Indonesia

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Abstract. Earthquake resistant structures for public buildings should be designed and built whereby they are supposed to withstand earthquake with minimum damage and without catastrophe collapse. As no structure can be entirely immune to damage due to earthquake, the goal of earthquake resilient building is to ensure that the risk of collapse can be minimized or reduced. Therefore, there is a need to identify all factors that could contribute to the risk of failures due to earthquake especially on public buildings. Based on code of practice, earthquake building resistant structures are intended to withstand the largest possible earthquake which is likely to occur in a particular area where in this paper discussed the study of earthquake in Padang, Indonesia. This paper presents on safety factors that need to be considered in the analysis and design of public building for the city of Padang, Indonesia due to earthquake. Recently, there are several design approaches in earthquake engineering studies such as experimental results, computer simulations and observations from past earthquakes to understand the performance of the damaged building. However, the data from past earthquake that occurred in Padang, Indonesia is to be analyzed so that the safety factors on the risk of the public building can be well understood. Factors such as height of building, type of structures, material of construction, types of soil, and method of construction are considered in this study. The research findings on the city of Padang, Indonesia have concluded that all new buildings should be designed base on earthquake code of practice where the use of base isolator and stiff construction are to be introduced for public building structures.

1. Introduction
The building was known by the people since long time ago from a very primitive one with simple function until modern building with various functions depending on their needs. The function of the building is not only for protection but also functioned for comfortable and artistic aspects [1]. As the development of the growth of the buildings establishment especially high buildings for offices, schools, hospitals and commercial purposes and etc. that is why the needs of working room, study room, and many other rooms are very important, beside it’s require an improvement toward risks especially on the medium to high rise buildings in Padang city. From the data gathered results provide the understanding on the factors for the risks of the earthquake on the high rise buildings in Padang city. Sumatera island is a risky area and prone to the tremor of earthquake. Huge earthquake was recorded that on occurred in Bengkulu on December 11, 1681.

Since that time, many times earthquake occurred that destroyed many buildings. The last big
earthquake happened on September 30, 2009 at 17.16 WIB which was centered in Pariaman area with 7.9 R.S of strength. It has caused activity in some cities in west Sumatera and one of them was Padang city which has many medium to high rise buildings. Some of these buildings fell down as the result of the earthquake which at that time. These were: Ambacak hotel, Bapedda building, LIA building, Primagama building, east part of Pasar Raya, Sela sih hospital, Adira building and many buildings were crowded and some of them are serious which includes others. Many buildings which were slightly damaged some and serious including: Inna Muara hotel, Sedona hotel, BPKP office, BNI bank on Jln A.Yani, poly clinic of M. Jamil hospital, and others. Globalization and free market require standardization for all life aspects must be placed or stated in the design and regulation in the high buildings standard in west Sumatera especially Padang city. As the result of the problem above, the safety of the earthquake risk/dangers are based on many factors, first, the location. Located at tectonic circle of the world geology map which is known as a fire circle. The coverage of this circle are the areas that close to Pacific Ocean, Aleutian Islands, Japan, Southeast Asia and Australia. Secondly, the critical condition of Indonesia area on the risk/dangers of the earthquake can be seen in the seismic map created by JP Rothe 1954 or Indonesia seismic map created by BMG 1973- 2005 [2], which figures out the earthquake risk areas in Indonesia. From these two maps can be seen that the critical areas spread around the sea and including the area of Sumatera, Jawa, Bali, Nusa Tenggara, Maluku, Irian and Sulawesi. At these critical areas, hundreds even thousands of earthquake with various level of strength happened. Besides that, the location of Indonesia that located at the plate of Indo-Australia and Eurasia where those lithospheres always move. These earthquake which frequently happen caused panicky and also caused many losses as the result of damaged buildings. First, as we know that the west Sumatera is earthquake risky area whereas Padang city is located near by the coast where many people live around his area. Secondly, based on the historical data, Indonesia has 76 volcanoes which were ever eruption. These volcano used to be erupted at least 1.171 times and positioned Indonesia as the second area after Japan as one of the earthquake risky area due to volcanic activities. In West Sumatera province, there are two still active volcanoes. They are Mount Merapi and Mount Talang.

Based on the facts above, this paper does the analysis to the factors of the safety of the buildings to detect what factors need to be focused on to reduce or possibly to eliminate the risks of accidents or disaster that can happen to a building according to the regulation; Undang – Undang bangunan gedung no. 28, 2002 and Public work minister regulation no. 29/PRT/M/2006, as well as, based on public work minister regulation, a building must meet the safety requirement with general purpose to guarantee that the building can support the burden/ the load caused by the nature or human behavior and provide the safety for people and property inside the building.

The technical and non-technical aspects which support the safety of the building toward earthquake must comply the valid standard and regulation. Generally, the impact that can be the burden of every party. If the accident risk occur at project site, it will decrease the productivity due to the load of some or one of the workers and will decreased the morale/spirit of other workers.

In the perspective of since economic and cost. The risk can increase the cost of business since some parts of the building need to be repaired or reconstructed. Probably some tools and equipment also need be changed and can affect the image of the company. And will become to worst if accident happened caused by the careless workers or caused by the constructor, who did not meet the safety standard defined issued by the government. And this could endanger each side [3, 16, 17].

Therefore, the risks factors and the root causes as well as and the analysis of the risk impacts must identify before the project started. So it is hoped that every party involved in the project can cooperate to minimize those risks. The consultant must design the building by considering, the safety of the building at the earlier stage of the project development. While the construction workers can be trained to work in the field and engaging safe method.
2. Public Building and Safety Factors Toward the Earthquake Risks

2.1 Public Building

Public Building is defined as a building which is more than 50% of its floor used for public activities. Generally the public building has the following characteristics:

- High economy value.
- Public and service area.
- High rate of occupancy
- Standard facility to guarantee the business or trading activities can be done properly.
- Good architecture.
- Special vertical building structure.
- Good protection for any disaster based on the standard and valid regulation.

The requirements of building safety stated in pasal 17 UU no. 28/2002 which are covering: the security of the building to support the burden/load and the capability of the building in preventing and solving the dangers of fire and storm or lightning. To meet those requirements, the project manager must pay serious attention to the structure of the building that referring to the load and the function of the building. Sustainability of the building to face the earthquake has to be considered. And also the need to pay attention to the usage of material and the safety/security system. But unfortunately, Earthquake was not included as one of safety factors in constitution (Undang-Undang) no. 228/2002. While based on the historical data stated previously that, the strong earthquake could shake the building and cause it to fall down if the building structure was not designed for preventing the earthquake, whereas West Sumatera areas will always have earthquake any time till the end of the world. That is why it must be included as one of the building regulation.

The construction service companies must be very responsible for guaranteeing the safety of the building which is done by playing their role in the project as Zimmerman (2005) statement:

- Owner
- Planning consultant
- Controlling consultant
- Contractor
- Workers

2.2 Building Safety Factors toward Earthquake Risks

Earthquake is the condition of the earth is shaking caused by releasing energy inside the earth suddenly [4].

There are 5 types of earthquakes:

1. Tectonic earthquake (subduction, attacking, cesarean)
2. Volcanic earthquake
3. Collapse earthquake
4. Falling down earthquake.
5. Artificial earthquake (bomb test, filling up the dam)

From five types of the earthquakes above, tectonic and volcanic earthquake are getting more attention in the field of building structure engineering. The earthquake itself does not cause risk to the people directly but the broken building and collapsed of the building which harm the occupant that can killed them and loss of properties further create a social problem as well. Earthquake can’t be avoided or prevented but with the effort of the people, knowledge and technology, we can save the building by paying attention to the structure of the building [5, 15, 18].

The strength of the earthquake is stated in their intensity scale and Magnitude. The measurement of
the earthquake intensity usually measured in two scales: Richter and Mercalli [4].

In the world, there are a number of tectonic plates which always move and produce the energy of earthquake. The main big plates are: Indo-Australian plate, South American plate, North American plate and Arctic plate. According to the activities of the tectonic plates in the world there is an earthquake lane and activity which is called “Sircum Pacific belt” [4].

Padang city is an earthquake risky area because of the friction between Eurasia and Australia plate. Which is located around Mentawai Island. And the distance between Mentawai and Padang is very close that is why if an earthquake occurred in the Mentawai will be felt to the city of Padang. So that if we want to build up a strong building, we must refer to the Indonesia National Standard (SNI) as the base – regulation for building that is strong enough to absorb earthquake.

The safety factors of the structure of the building toward the earthquake are:

1. The risk factor of soil condition (seismology data).
2. The risk factor of the building's structure.
3. Historical factor and earthquake characteristic.

3. Methodology Used in Identifying the Safety Factors of The Building
The consideration of methodology choice is based on the relevant comparing reference or the guidance has been studied based on the relevant criteria for the safety factors of the building which are stated in SNI and the valid construction regulation regarding the risk factors of public building.

The consideration of methodology choice is based on the guidelines on the relevant criteria for the safety factors of the building which are stated in SNI and the valid construction regulation regarding the risk factors of public building. The next step is to conduct the data verification and validation by using software called SPSS. Validation test is the test to obtain the rate of accuracy of the test tool. A test or research instrument can be stated having high validation if the measurement tool can function and provide the result matching with the purpose of the measurement done [14, 19]. The test of the data validity is done by using supporting tool, software SPSS and test for data correlation. The research data is valid if the percentage of correlation is positive, and correlation probability value sig. (two-tailed) significant level (a) is 0.05. Model used to reduce influencing factor until the identified risk variable is extremely high.

In the final stage, the special statistical simulation done by using random number as input parameter. Monte Carlo technique is a model scheme to calculate the stochastic and deterministic parameters in random sampling [10, 20, 21]. This simulation is done based on the model used by using software Crystal Ball. Crystal ball is a program to simulate the data which provide two options of sampling method; Monte carlo and Latin Hypercube.

**Table 1. Risk Factors of Public Building**

| Sub Factor | References |
|------------|------------|
| Factor soil condition risk factor (seismology data) | • High Soil vibration intensity scale  
• Big magnitude/ high energy of earthquake strength  
• High speed of the soil movement  
• Long duration of the soil movement  
• High rate of the relation between magnitude and soil acceleration  
• Big liquefaction happening  
Housner, G.W., P.C. Jenning  
Suwandojo Siddiq, DE. Eng.  
Housner, G.W., P.C. Jenning  
Housner, G.W., P.C. Jenning  
Suwandojo Siddiq, DE. Eng.  
Suwandojo Siddiq, DE. Eng. |
| Building structure risk factor | • Typical frequency of the soil movement is not matching with the plan.  
Housner, G.W., P.C. Jenning |
| Earthquake risk factor | Other risk factors needed |
|------------------------|---------------------------|
| • Unmatched capacity level of the building with the earthquake strength | Housner, G.W., P.C. Jenning |
| • Unmatched building capability dynamically | Dr. Ir. Bambang Budiono, |
| • Lack of capability of the structure to face deflection | Dr. Ir. Bambang Budiono, |
| • There is no Strengthening inside and outside structure | Ir. Taufik, M.T. & Ir. Effy Hidayaty, M.T. |
| • Lack of rigidity of Structure | Dr. Ir. Bambang Budiono, |
| • Element | Prof. Ir. Sarwidi MS cE PhD |
| • Unmatched calculation for the loading of soft story | Suwandojo Siddiq, DE. Eng. |
| • Unmatched calculation for the loading of structure | Esmeralda |
| • Lack of Discontinuity of the sliding wall | Suwandojo Siddiq, DE. Eng. |
| • Earthquake sustainability level used in design | Liwang, Freedy |
| • The capability of the high building to intercept the people who live in the building including their property. | Winardi A; Gatot Rahardjo dkk |
| • There are some active volcanoes in West Sumatera. | Winardi A; Gatot Rahardjo dkk |
| • The earthquake history around the area | Winardi A; Gatot Rahardjo dkk |
| • The frequency of the earthquake happened around the area. | Winardi A; Gatot Rahardjo dkk |
| • The strength level of earthquake Magnitude. | Winardi A; Gatot Rahardjo dkk |
| • No emergency guidance for evacuation available | UU Bangunan Gedung No.28 tahun 2002 |
| • No alarm to detect the strength of earthquake magnitude | UU Bangunan Gedung No.28 tahun 2002 |
| • Location of the emergency stairs in the building that is difficult to breached. Emergency exit that is difficult to be reached. | UU Bangunan Gedung No.28 tahun 2002 |
| • There is no emergency guidance for evacuation | UU Bangunan Gedung No.28 tahun 2002 |
| • No alarm to detect the strength level of the earthquake magnitude. | Sjafie, S.T., Dipl. E. Eng |
| | Winardi A; Gatot Rahardjo dkk |
4. Results and Discussion

The result analysis which is obtained from the literature study and discussion with government company, public work department, consultant, contractor, researcher/expert questionnaire analysis can be identified becoming two parts of discussions: model analysis result and simulation of building safety toward earthquake and the factors are the follows; soil condition risk factor, the scale of soil vibration intensity and the strength level of earthquake magnitude/energy. The building structural risk factor which is required in the regulation can be seen in figure 1.

![Figure 1. Chart Building on Earthquake Safety Levels](image)

From the graph above shows that overlay the most critical conditions occur in simulation c4, c6 and c2 which has the following conditions:

- c4 with condition X1 Dynamic, X10 Min, X2 Dynamic
- c6 with conditions X1 Dynamic, X10 Dynamic, X2 Min
- c2 with conditions X1 Min, X10 Dynamic, X2 Dynamic

Validation is done by submitting a questionnaire to the experts to find out the results and obtained a statement agreed to form three-variable regression equation as well as the risk factors are dominant to significantly increase building safety, as well as the input of the effects, causes and treatment of risk. From these three variables, impact, causes and correction measures can be seen in Table 2 below:

| Risk                          | Impact                                      | Causes                                                  | Correction                                                                 |
|-------------------------------|---------------------------------------------|---------------------------------------------------------|---------------------------------------------------------------------------|
| Ground shaking intensity scale | Capacity of the structure that are not able to withstand the vertical loads and horizontal seismic | Lack of data seismology and geology, less / no adequate soil investigation | The importance of involving team seismology and geology in the soil investigation. |
| Magnitude / energy of the quake | Damage to the structure building or even to the collapse of the structure | The size of the energy expended earthquake and the earthquake epicentre position | More attention to the quality of the soil investigation. Should be taken into account when planning analysis by calculating the coefficient of earthquake magnitude scale earthquake magnitude. |
| Systems structure required in the regulatory | Damage to the structure building or even to the collapse of the structure occurs | Errors in estimating the structural system that can be caused by a planner rigorous in calculating the structure building | More attention to the calculation of the structural system and loading system that occurred in the construction. |
5. Conclusions
There are several factors that significantly affect the safety of multi-storey buildings caused by the earthquake:

- Scale the intensity of ground shaking.
- The amount of power or energy magnitude earthquake.
- System structure implied in the regulation

All these factors are inputs that must be considered in the planning of the building structure. Besides these three variables, are also important to consider including building as dynamic capability, towing capability press structure and arrangement of space design that makes it easy to perform a rescue. Several causes, effects and treatment of the onset of the earthquake risk to themselves due to lack of awareness and knowledge about the dangers of the earthquake itself. Also the lack of data in the planning of the structure. While on the other hand shows the magnitude of the fact that there are threats facing the city of Padang in particular and Indonesia in general to the earthquake. In addition, many stakeholders from multi-storey buildings which do not consider the condition of the building. In terms of the building itself having no attention given to the factors or data to support planning of earthquake resistance. Therefore, all stakeholders must take into account the risks that may help to improve reliability.

References

[1] Sjafei, ST., Dipl.E.Eng, Teknologi Audit Forensik, Repair dan Retrofit untuk rumah & bangunan gedung, th 2006).
[2] Wikipedia Bahasa Indonesia, Ensiklopedia Bebas, 2009
[3] Zimmerman, Don S. Risks of Involvement in Contractor Safety. Occupational Health and Safety, Waco. US. 2005
[4] Suwandojo Siddiq, DEEng, Struktur Bangunan Tahan Gempa, tahun 1990
[5] Boen, T. Bencana Gempa Bumi : Fenomena dan Perbaikan/ Perkuatan Bangunan. Laporan Penelitian, BPPT. Jakarta 2000
[6] Housner, G.W., P.C. Jennings. Earthquake Design Criteria for Structures. California Institute of Technology. California 1977,
[7] Dr. Ir. Bambang Budiono, Konfigurasi dan Perencanaan Struktur tahan Gempa, 1992
[8] Ir. Taufik, MT& Ir. EffyHidayaty, MT, Analisis respons gempa dengan respons in- elastik. 1992
[9] Prof. Ir. SarwidiMScE PhD. Perlu Rekayasa agar Bangunan Tahan Gempa. Kompas. Jakarta 29 Mei 2007
[10] Esmeralda (2007), “Faktor-faktor keselamatan bangunan gedung komersial terhadap bahaya kebakaran dan gempa”,
[11] Liwang, Freddy. Teknologi Rumah Hunian Tahan Gempa. Kompas. Jakarta 2007
[12] Standar Nasional Indonesia (SNI), 03-2847-2002 & S-2002
[13] Winardi, A; Gatot Rahardjo dkk. GempaJogja, Indonesia dan Dunia. Gramedia. Jakarta 2006,