17th World Conference on Earthquake Engineering, 17WCEE

Sendai, Japan - September 13th to 18th 2020

EARTHQUAKE PERFORMANCE ASSESSMENT OF RENTAL LOW-COST HOUSING FLATS IN LOMBOK, INDONESIA

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Abstract

Since 2002, the Ministry of Public Works and Housing has had a program to build rental low-cost housing flats on a regular basis in each fiscal year. The structures of those buildings were designed to be earthquake-resistant and used various structural systems that include conventional reinforced concrete, precast concrete, or prestress precast concrete. Some of these rental low-cost housing flats were affected by a series of strong earthquakes between 29 July 2018 and 5 August 2018 taken place in Lombok and its surrounding area. This paper presents the performance of the structure of rental housing flats in Lombok and Sumbawa islands based on the results of a qualitative and quantitative survey conducted from October to December 2018 in 25 towers at 25 different locations. The study shows that the performance of the rental low-cost housing flat structures is good if design development and implementation fully complies with the requirements of design codes and construction specifications set by the Indonesian National Standard. Rental low-cost housing flats built by the Ministry of Public Works and Housing are seen to be performing quite well compared to other buildings around them. In addition, the use of precast technology in rental low-cost housing flat structures results in better performance compared to that of conventional system because of better quality control during construction.

Keywords: lombok earthquake; precast structure; conventional structure; damage level; retrofitting

1. Introduction

The Ministry of Public Works and Housing has had a program to build rental apartments on a regular basis in each fiscal year since 2002. The structures of those housing flats were designed to be earthquake-resistant according to building code applicable at the time of construction. The structures were constructed using concrete materials that is either in the form conventional reinforced concrete, precast concrete, or prestressed precast concrete as shown in Fig. 1. Before being used, these precast and prestressed technologies had been tested against earthquake loads at Research Institute of Housing and Human Settlement, Indonesia.

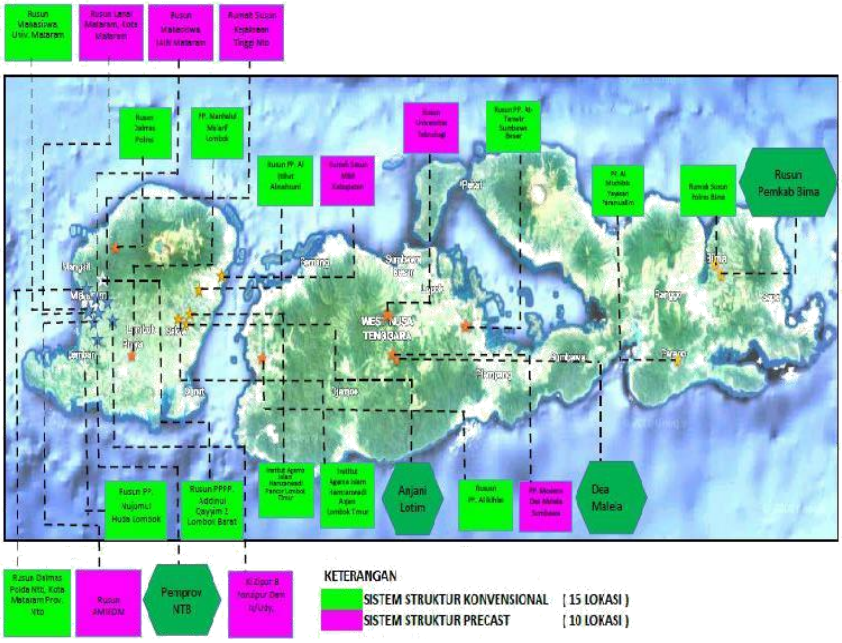

Fig. 1 – Structural system and locations of 25 housing flats in Lombok, Sumbawa, Bima dan Mataram post-earthquake

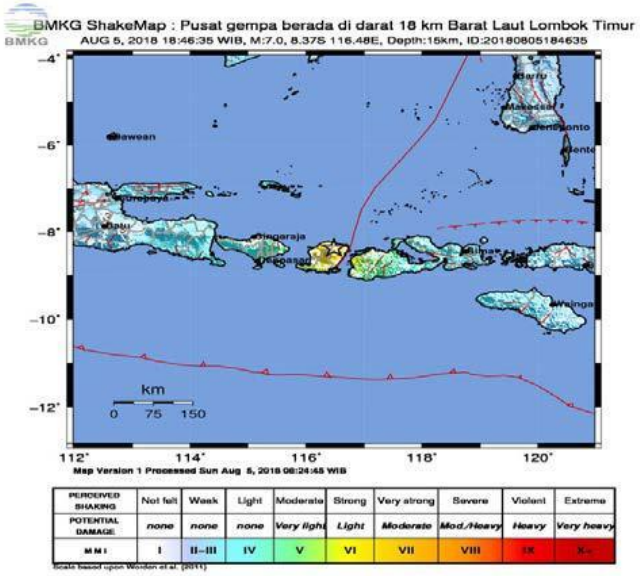

Fig. 2 – Earthquake source location in Lombok

Between July 29, 2018 and August 5, 2018 a series of strong earthquakes took place in Lombok and its surrounding area. The source location of earthquake is shown in Fig. 2. Those strong earthquakes affected many infrastructures and buildings in the area including rental low-cost housing flats built by The Ministry of Public Works and Housing. Level of damages on buildings caused by earthquake vary from minor to major. To measure the performance of housing flats against earthquake, qualitative and quantitative surveys were conducted on 25 rental low-cost housing flats in Lombok, Sumbawa, Bima and Mataram.

2. Damage Assessment Method

Damage assessment of concrete building structure affected by natural disaster such as earthquake can be carried out using visual inspection and simple tools based on practical criteria and secondary earthquake data. Using this approach, available guidelines [2-6] and previous work [7-10], building conditions can be assessed and categorized into several damage levels and their required repair actions as follows:

- Minor damage of building
  a. No significant settlement of foundation
  b. No structural damage
  c. Architectural damage such as crack and spalling of skim coat cement and crack and spalling of plaster

  The required actions are to repair the damaged architectural components

- Moderate damage of building
  a. No significant settlement of foundation
  b. Cracked on structural component, but no significant change of shape
  c. Architectural damage in the form of crack on the wall and even hole on the wall on certain conditions, but no significant slope

  The required actions are to repair architectural and structural components

- Major damage of building
  a. Significant settlement of foundation
  b. Spalling of structural components and even failed structural components, but no failure of overall structure
  c. Architectural damage in the form of crack through the wall thickness, slope wall and even failure

  There are several alternative actions that can be done on building experiencing major damage as follows:
  a. If structural component damages do not cause significant change of shape on reinforcing bar and the overall building, then further investigation needs to be conducted to assess building structure
  b. If there is significant settlement of foundation, then further investigation needs to be conducted to assess building structure
  c. If structural component damages cause significant change of shape on reinforcing bar and the overall building, then the building can be stated as not functioning structurally.

- Failure of building
  a. Failure of foundation
  b. Fail on one or more structural components causing building failure

  Several failure modes of structures that are critical and thus may cause buildings cannot function anymore are:

  1. Soft story effect
  2. Weak column strong beam

3. Failure at beam-column joint
4. Compressive failure

3. Assessment Methodology

The purpose of this study is to assess structural and architectural performance of housing flats post-earthquake in Lombok, Sumbawa, Bima and Mataram by means of qualitative and quantitative surveys conducted in July – August 2018 at 25 different locations in Lombok and its surrounding area.

In this study, the following assessment methodology was used:

1. Conduct visual investigation to record structural and non-structural (architectural) damages
2. Compare between recorded damage data and damage criteria
3. Determine the level of damage criteria
4. Propose actions that need to be done based on the damage level

Data employed in this study:

1. Secondary earthquake data from Meteorological, Climatological, and Geophysical Agency, Indonesia.
2. Pictures taken during survey of visual examination.

Condition assessment surveys of housing flat buildings in di Lombok, Sumbawa, Bima and Mataram post-earthquake were conducted at 25 different locations during the months of July – August 2018. From these surveys, it was found that structural and non-structural (architectural) damage conditions vary from minor to major damages.

Table 1 – Summary of damage levels on 25 housing flats investigated in this study.

Damage Level	Structural Damage	Architectural Damage
Minor	23	17
Moderate	1	3
Major	1	5

4. Results And Discussions

Table 1 presents the summary of investigation results from 25 housing flats considered in this study. Overall the rental housing flats perform well against earthquake load. Only 2 buildings suffered structural damage beyond minor level, one building at moderate level and the other at major level. Meanwhile 3 buildings suffer architectural damage at moderate level and 5 building at major level.

Location and structural system of housing flats that underwent structural damage beyond minor level are:

- Housing flat PP. Al Iklhlas, moderate damage level, conventional reinforced concrete structural system
- Housing flat Dalmas Polres Lombok Barat, North Lombok Province of NTB, major damage level, conventional reinforced concrete structural system

Location of housing flats that underwent architectural damage at moderate and major levels are:

- Moderate damage: Housing flats Dalmas Polda NTB, Kota Mataram NTB Province, Ki Zipur B Yonzipur Dam Ix/Udy, Kota Mataram Nusa Tenggara Barat Province, PP. Al Iklhlas

- Major damage: Housing flats Universitas Mataram, Lanal Mataram Kota Mataram, MBR Kabupaten Lombok Timur, PP. Addinul Qayyim 2 Lombok Barat, Dalmas Polres Lombok Barat, Lombok Utara NTB Province

Fig. 3 shows the example of housing flat that suffered major structural damage while Fig. 4 the example of housing flat experiencing moderate to major achitectural damage. On the other hand, Fig. 5 and 6 show the examples of housing flats that have minor or no damage.

Fig. 3 – Example of major damage to structure caused by the earthquake: Crushing at beam-column joints at the North Lombok Police Station housing flat

Fig. 4 – Example of architectural damage caused by the earthquake: Ceiling damage due to the falling of the material above it at the rental low-cost housing flats

Fig. 5 – Example of minor damage caused by the earthquake: Hairline Cracks on the wall and falling of ceiling list at Sumbawa Technology University flats

Fig. 6 – No earthquake damage to housing flats of (a) UTS and (b) Dea Malela Sumbawa

Fig. 7 shows distribution of 25 housing flats undergone structural damage. In general, the housing flats only have minor damage (92 %). These findings show that the structural performance of housing flats built by Ministry of Public Work and Housing in Lombok, Sumbawa, Bima and Mataram are quite good considering that many buildings in the surrounding area showed worse structural performance. In other word, these housing flats have proven to be earthquake resistance as designed. It should be noted that housing flats built using precast structural system show better structural performance compared to those built using conventional reinforced concrete structural system. Only housing flats built using conventional reinforced concrete system undergone moderate and major structural damage.

Fig. 8 shows distribution of 25 housing flats suffered architectural damage. As can be seen there are several housing flats underwent moderate (3 buildings) and major (5 buildings) damage. Meanwhile the other 17 buildings only suffered minor damages.

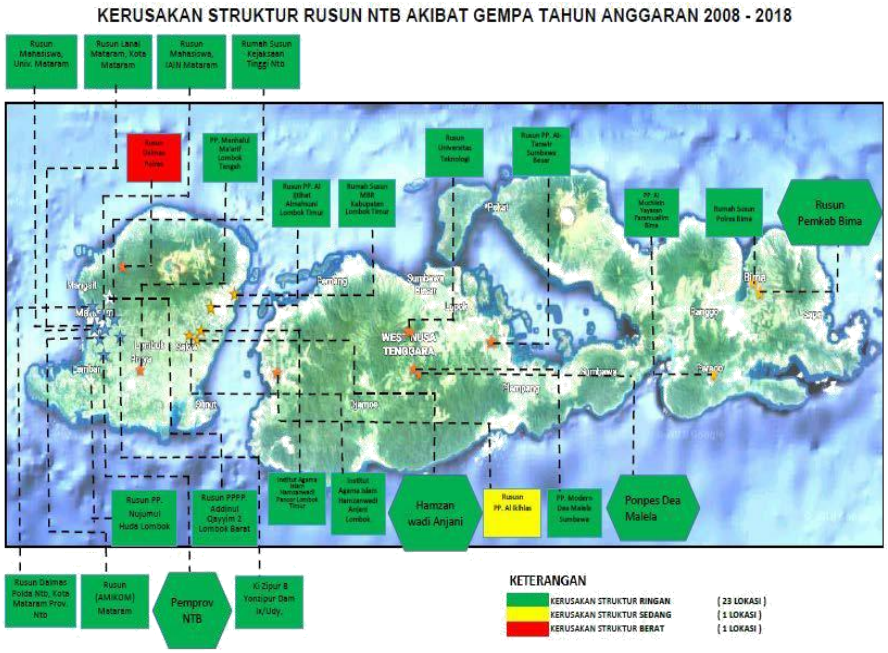

Fig. 7 – Map of structural damage on housing flats in Lombok, Sumbawa, Bima and Mataram due to earthquake

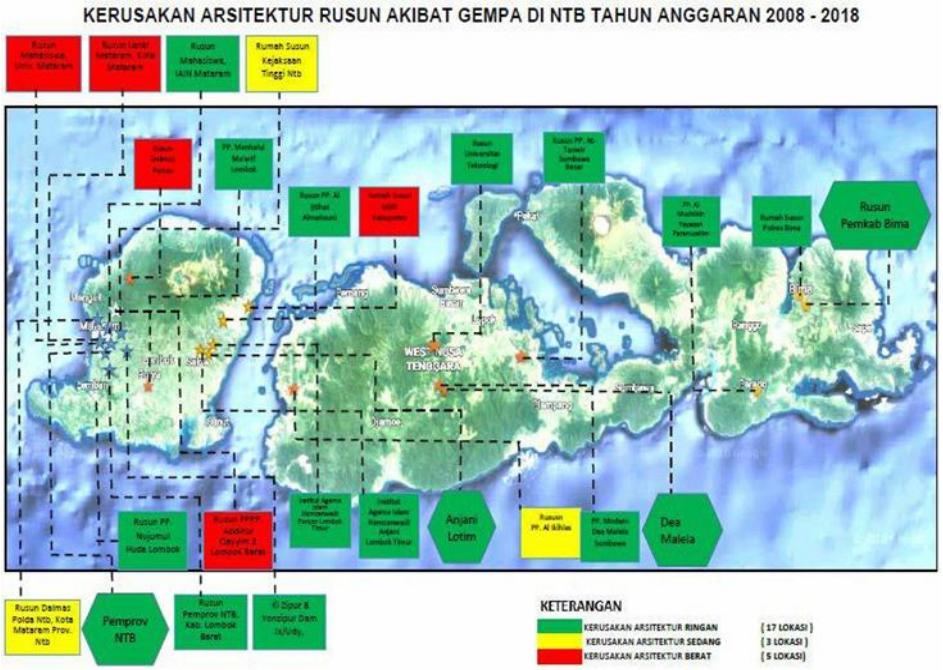

Fig. 8 – Map of architectural damage on housing flats in Lombok, Sumbawa, Bima and Mataram due to earthquake

5. Conclusions

Overall the structures of housing flats built by Ministry of Publick Work and Housing in Lombok, Sumbawa, Bima and Mataram perform quite well against earthquake load, especially the ones using precast concrete system. This can be attributed to the fact that precast concrete system normally produces better quality as a

result of better quality control during the construction. This study also proves that buildings designed according to the building design codes published by Indonesian National Standard will perform well against the expected seismic design loads.

6. Acknowledgements

Financial support provided by Ministry of Public Works and Housing for this research is highly appreciated.

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