Retrofitting of 8-Storey Bumi Minang Hotel Building (Numerical Simulation)

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SUMMARY:
Bumi Minang hotel is the tallest multi-stories building in Padang City experiencing structural damage due to 30 September earthquake with epicenter 100 km offshore of Padang City. Survey has been conducted to assess the damage of the building a few days after the earthquake. The paper explains the cause of the damage and recommendation for retrofitting. Base on field observation, some parts of the building have been damage. To know the cause of the damage, re-analysis of structure was conducted using numerical simulation. Compilation between numerical simulation and field survey showed that the main factor causing the damage is unsymmetrical of building plan. Numerical simulation was also conducted to find out the retrofitting recommendation. The study showed that the building can be retrofitted using some methods, that is, changing the plan, strengthening by using additional shear wall in some parts of the building and combination.

Keywords: *Earthquake, numerical simulation, retrofitting*

1. INTRODUCTION

The earthquake M 7.6 on September 30, 2009, has struck the West Sumatra province. The earthquake is then known as the G30S’09 has the epicentre on the coordinates 0o 50 '24" NS and 99o 39' 0" EW. The areas that most severely damaged by the quake were along the coast of West Sumatra Province. Padang as the Capital city of the province is also located on the west coast. The distance between the earthquake epicentre to the City is less than 100 km. The G30S’09 earthquake with a depth of 70 km was recorded as the strongest earthquake ever hit the city of Padang since the founding of this city. Based on an analysis released by the USGS (2009), Padang is located approximately in the MMI scale of 7 to 8 (Figure 1).

Bumi Minang Hotel has seven floors to the main structure plus a couple of floors (presidential suite, mezzanine, floor, roof, engine room and engine room) with a height of 36 m. The hotel building is located at coordinates 0o 57 '19 NS and 100o 21' 31" EW with a distance of about 80 km from the epicenter. Bumi Minang Hotel is the tallest building in Padang at the moment. The main structure of the building is made of reinforced concrete.

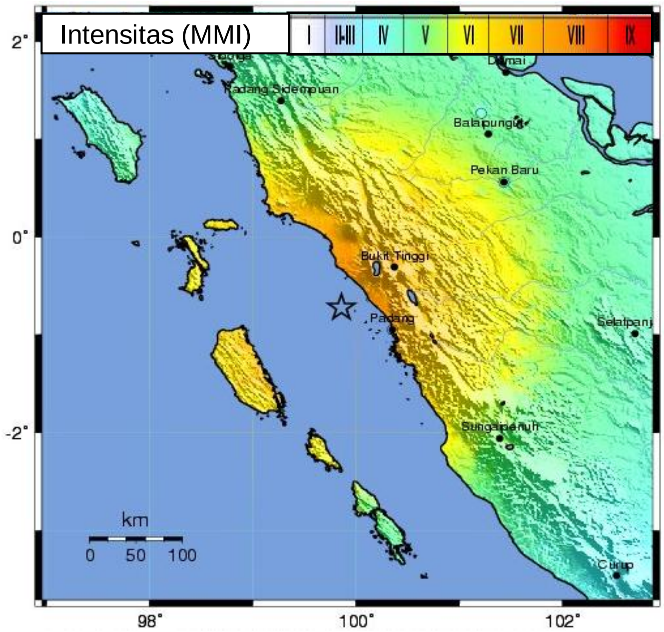


Figure 1. MMI Scale of G30'S 2009

The Bumi Minang Hotel was founded in 1992. The hotel was built on the ground with a soil profile as shown in Figure 2. Based on the analysis of the classification of the soil under the building according to SNI 03-1726 - 2002, then the condition of the soil under the building classified as medium soil (Table 1).

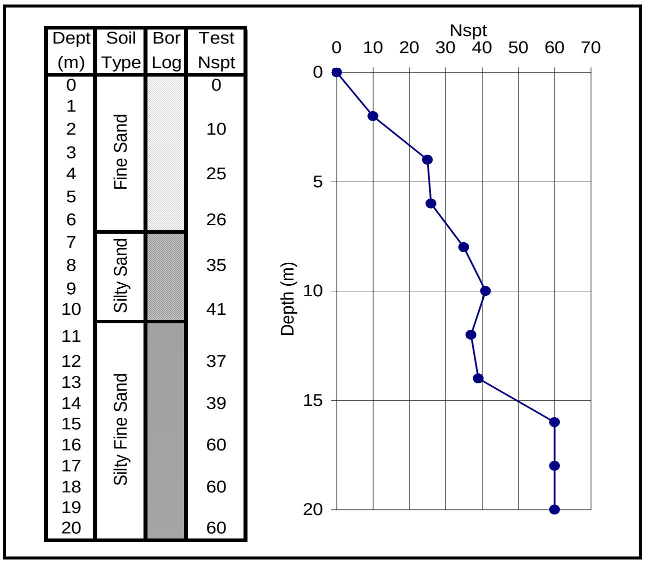


Figure 2. Soil profile and Nspt

Besides the Buildings Hotel Bumi Minang, there are many multi-storey buildings (3 floors or more) that also suffered from the earthquake G30S'09. Those buildings are generally made of reinforced concrete material. The wall of the building were made of brick material. In the past, the damage of reinforced concrete buildings have been reported. For example, the Chi-Chi 921 Earthquake in Taiwan has destroyed more than 25 modern buildings made of reinforced concrete (Tsai et. al., 2000). The damage buildings in Taiwan is caused by too heavy of death load contributed by the brick walls.

Specific research on the damage of reinforced concrete buildings due to Hyogoken-Nambu earthquake in 1995 in Japan has also been reported (Lee et. al., 1995). Lee et al suggested the procedure to classify the degree of damage of reinforced concrete buildings. That study concluded that the buildings were made in 25 years before the earthquake would be more damaged than the newer buildings. However, that level of damage still needs further refinement to be applied in the other region.

Table 1. Soil classification analysis

D (m)	N_{spt}	t_i (m)	t_i/N_i	N = Σti/Σ(ti/Ni)	Soil Type
0	0	-	-		
2	10	2	0.200		Hard:
4	25	2	0.080		$N_{rata2} \geq 50$
6	26	2	0.077		
8	35	2	0.057		Medium
10	41	2	0.049	29.93	$15 \leq N_{rata2} < 50$
12	37	2	0.054		
14	39	2	0.051		Soft
16	60	2	0.033		$N_{rata2} < 15$
18	60	2	0.033		
20	60	2	0.033		
	Σ	20	0.668	$N_{rata2} \simeq 30$	

2. DAMAGE INVESTIGATION

To asses the damage level of buildings must firstly be made the definition of the level of damage. In Indian, the level of damage can be determined by using the bear eye only. There is no mathematic approach to define the level of damage. It is the simple way and investigation of the damage can be done by non-engineer.

Table 2. Indian damage level (Great, 2001)

Level	Category	Description
I	Light	Small crack on the wall
II	Moderate	Many crack on the wall
III	Heavy	Wide crack on wall and collapsing chimney
IV	Collapse	Many wall separated and/or collapse
V	Total Damage	The building is fully destroyed

By compiling the level of damages from some references and expert consensus in Indonesia, then the level of damage in the city of Padang has been developed (Table 3). The levels are also formulated with many considerations of purposes for rehabilitation and reconstruction funding. The formulation is used as a guidance to assess the damage all types of buildings due to earthquake in Padang city and surrounding areas.

Field investigations is then conducted to the building Hotel Bumi Minang using those criteria. The building suffered from major non-structural damage and minor structural damage. Almost all non-structural of buildings, especially on the inside of the building suffered from damage that are large cracks and collapsed. The damage of building elements were including the outer and inner walls, ceiling, doors and windows. Non-structural of buildings were damaged more than 80%.

Table 3. Damage classification in Indonesia – Padang

Level	Description
Light	Small crack (0,075 cm s/d 0,6 cm) on the wall. The cracking area is wide enough The damage on non-structural element No damage on main structural element < 30 % damage on building
Moderate	Medium crack (> 0,6 cm). Column and beam was cracked Part of main structural element is cracking Collapse in wall 30 - 70 % damage on building
Heavy	Separated on the supporting wall The building take a part > 50% main structural is destroyed Collapse in most of wall > 70 % damage on building

The investigation on the building found no significant deterioration in the foundation. There were many main structural (columns, beams and slabs) damaged. Damage to structural elements were located on the floors 1 and 2. This damage resulted in a settlement in the floor plate in the middle of the building by more than 25 cm. A special case is for the elevator in the building (Figure 3), the concrete in this section has been broken. The damage resulted the floor 2 to 7 has dropped more than 40 cm. The level of structural damage in the middle part of the building is estimated to 90%. Overall it can be concluded that the Hotel Bumi Minang can be categorized as heavy damage.

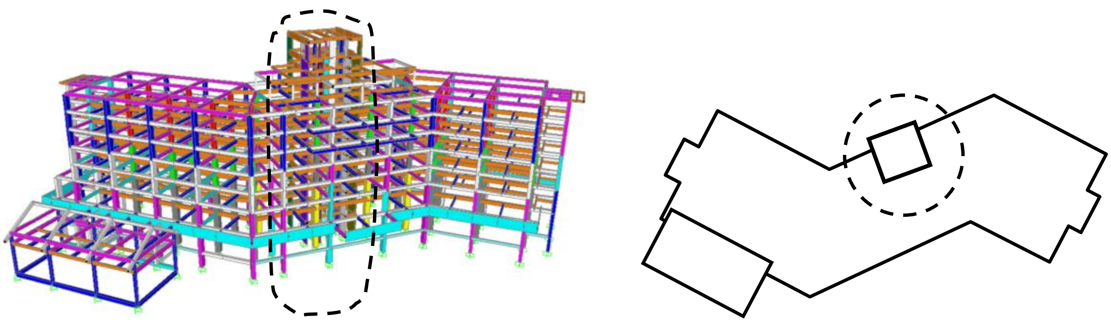
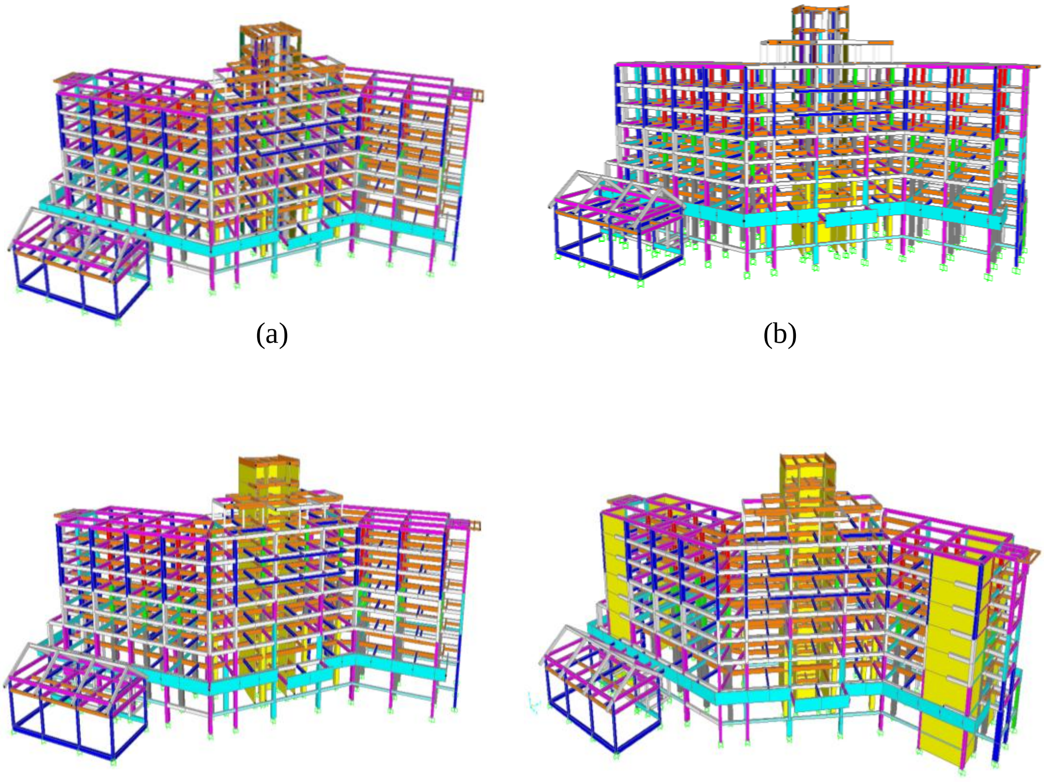


Figure 3. Damage core lift

3. RETROFIT ANALYSIS USING NUMERICAL SIMULATION

Numerical simulation on the dynamic behaviour of Bumi Minang Hotel using the finite element program (SAP'09) has been carried out. Geometry data of the structural elements obtained from direct measurements in the field. Similarly, the mechanical data of the building material obtained from the direct testing in the field as well as in laboratories. The concrete strength of structural elements are fc '= 30 MPa. The steel reinforcement strengths are f_y = 390 MPa (deformed bar) and f_y = 240 MPa (rounded bar). Numerical simulations carried out using an equivalent static load and dynamic load in the frequency domain (the earthquake zone is 6 according to SNI-1726-2002).

Three-dimensional numerical simulations performed by modelling the building into five models. The first model is a building with the structural as same as the one in the field (Figure 4.a). The second model is with the addition of shear walls on the bottom of the lift area (Figure 4.b). The third model is with the addition of shear walls in all parts of the lift area (Figure 4.c) and four models with the addition of shear walls on the left and right wings (Figure 4.d).

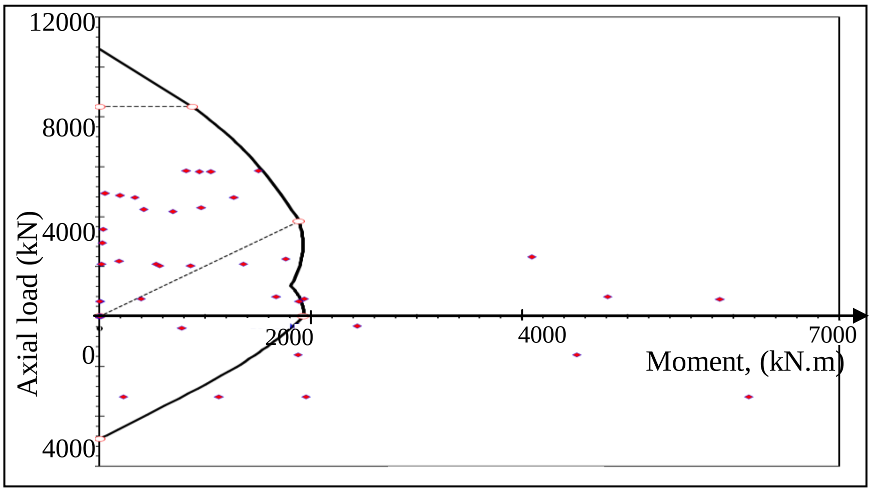


(a) (b)

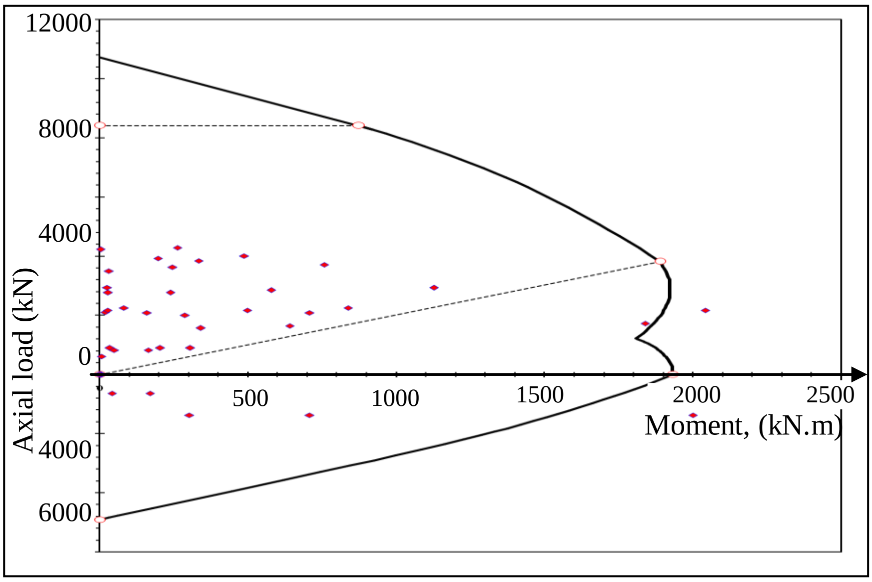
(c) (d)

Figure 4. Structural models

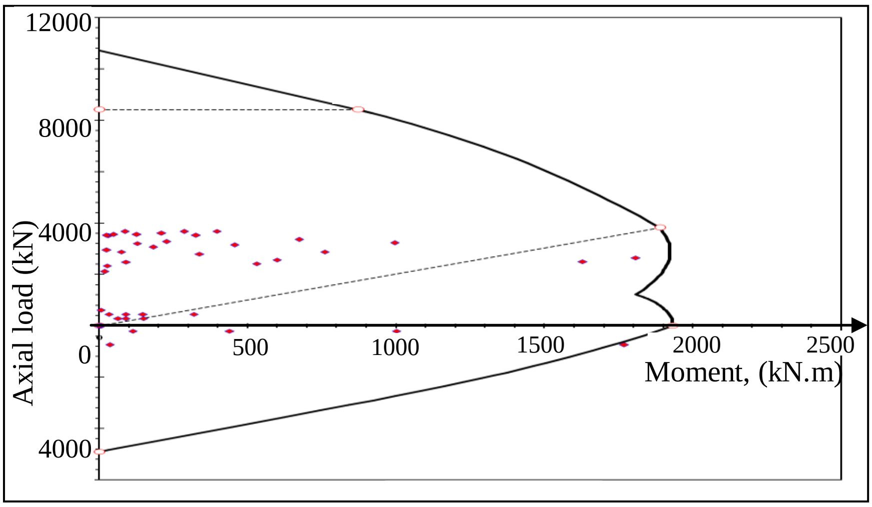
Figure 5 (a) to (d) show the figures of the curves of column capacity and spots of working load-moment. In those figures, the red spots are the value of the moment and axial loads in the columns elements. These values are resulted from the numerical simulations of the models. The straight curve in the figures represents the typical capacity of the bottom column. When the spots of the working load-moment are inside the capacity curves, it means the typical column of the model is strong enough to carry the external loads, and vice versa. Numerical simulation results show that the building suffered from over load on the first model (original type). The capacity of the column element was not sufficient to withstand the forces (both axial forces, moments as well as shear forces) due to earthquake loads. In the 2^{nd} model is still showing the higher working moment-load than the column capacity. The structure of the models 3 and 4, show the maximum working forces are less than the capacity in which mean the structure can retain the applied external loads.



(a). 1st model

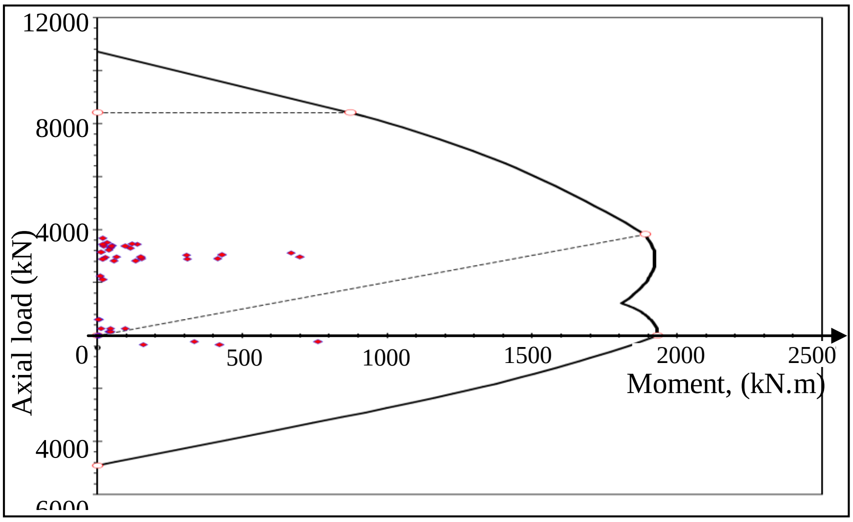


(b). 2nd model



(c). 3rd model

Figure 5. Load – Column Capacity (continues)



(d). 4th model

Figure 5. Load – Column Capacity (continued)

4. CONCLUSIONS

Hotel Bumi Minang has suffered from damage on non-structural and structural elements. However, the damage on structural part was mainly in the center of the building. The structural damage is still possible to be retrofitted. Numerical simulations show that the elements of the building (especially column) has a smaller capacity than the working load. The addition of shear walls in the middle portion of the building can reduce the working forces. While the addition of more shear walls in the middle-upper and the left and right side of the building, provide a response even smaller dynamic forces. This study demonstrates the Bumi Minang Hotel still can be retrofitted to withstand the earthquake loads.

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