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Damage Assessment of High-Rise Reinforced Concrete Buildings in Peninsular Malaysia Subjected to Ranau Earthquake

R.Ismail*[1,2], A.Ibrahim[2], A.Adnan[3]
[1] Institute for Infrastructure Engineering and Sustainable Management (IIESM)
Universiti Teknologi Mara (UiTM) Shah Alam, Selangor, MALAYSIA.
[2] Department of Civil Engineering
Universiti Teknologi Mara (UiTM) Shah Alam, Selangor, MALAYSIA
[3] Department of Civil Engineering
Universiti Teknologi Malaysia (UTM) Skudai, Johor, MALAYSIA

Abstract. This paper shows the analysis of high reinforced concrete buildings in Ranau that have experienced low intensity intensity earthquakes. This study refers to the performance of five (5) high rise reinforced concrete frame when subjected to a variation of low earthquake intensity analysis with 5% damping ground motion measurements. The IDARC software is used to study structures through nonlinear dynamic analysis. Beam-column points are examined to determine damage to the index and to build damage levels subject to varying seismic load. Result shows the first yielding occurred at 4.82 seconds for the beam element at when 0.05g load applied. Based on the result, all buildings cannot withstand seismic load when goes up to 0.2 ground acceleration. It may have arisen that the building is categorized to the extent of the major damage where there is structural affect and structural affect up to 0.15g intensity.

1. Introduction

Estimation of damage the structure is an essential demand for performance structural analysis. To better understand comprehensive, comprehensive performance criteria that are capable of predicting damage levels structures subject to earthquake excitation shall be developed. Earthquake excitations often cause a certain state of damage to structures, the extent of which is generally expressed by using a Damage Index (DI). DI becomes more frequent accepted as a powerful tool for quantitative assessment damage to the structure caused by the earthquake. In seismic area, the damage index has a major role in decide on retrofit. Some researchers have attempted study the performance of structural due earthquake effect in the last decade [1-8]. According to Li [1], in the repercussions of seismic ground motion, buildings must be properly evaluated for structural safety due building damage and collapse that might occur.

Moreno and Bairan [2] demonstrated the performance of buildings in the low earthquake area. The results show that the building is expected to cause damage due to unexpected performance.

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Ditommaso et al, [9] describes the period of reinforced concrete building to initiate structural damage and also identify non-structural elements that are expected to damage the effects of earthquakes.

Joel and Mary [10] found that flexible models produce more displacement and interstorey drift than solid frames using IDARC 2-Dimensional software for reinforced concrete buildings. Achievements usually involve decent measurement processes. Due to the reflection and expectation of injury, the values and parameters must be quantitatively made because of the performance level. Table 1 shows the degree of damage ATC-13 [12] to justify the degree of damage that has been taken to be considered in this study. The degree of damage was also used by Ismail et al., [13] in her research.

Table 1. Description of Damage levels. [12]

Damage Level	**Damage Indices**
Minor Level	< 1%
Moderate Level	1% - 3%
Major Level	> 3% < 1.0
Collapse	1.0

2. Description of Structure and Modeling

This study focuses on the performance of seismic public buildings held by the government. Random site location selected from peninsular Malaysia. To examine high performance seismic performance, one key frame is selected from each building for a model with finite element analysis. The IDARC software is used to study structures through nonlinear dynamic analysis. There were six (6) districts around peninsular Malaysia including Johor Bahru, Negeri Sembilan, Kuala Lumpu, Kuala Terengganu, Ipoh and Pulau Pinang. Table 2 shows the details of buildings analysed in this study. They are from 11 up to 17 number of storey which being categorised as high rise building with the height range from 36.20m to 73.0m . Table 3 shows the building configurations. The materials of properties are 2500N/mm^2 (E_c), 460N/mm^2 (f_y), 27.6N/mm^2 (f_c) and 25mm for concrete cover (c). Loadings applied in the analysis was determined according to British Standard 8110: Part 1 [14].

The height of the buildings will play an important part in prediction of damage indices as we know that high rise buildings will be likely affected to ground motion when earthquake incidents occurred. Beam elements and columns are modeled as nonlinear frame elements with susceptible sensitivity by specifying the plastic hinges at both ends of beams and columns. In the beam, the axial force is assumed to be zero because all floors are considered to be hard on the plan to explain the action of the concrete slab diaphragm so that the nodes in each Floor level are deformed with the same value later. The contribution of floor slabs to strength and immobility is neglected and columns are assumed to be in underground stages. The damping coefficient value of 5% RC frame structure is used. The predicted structure may not be the same as performance monitoring on the site after the earthquake incident because the model used in this study ignores the flexibility of foundations and other components helping with structural strength such as shear wall.

Table 2. Information of building

No.	Building	Floor level	Total Height (m)
1.	Wisma Persekutuan Kota Bharu	13	48.54
2.	Kuarters Polis Ipoh	11	36.20
3.	Jabatan Kerja Raya KL	17	64.20
4.	Majlis Perbandaran Ampang Jaya	17	73.00
5.	Wisma Dewan Perniagaan Seremban	12	51.00

Table 3. Configuration of Modeling concept

<table>
<tr><th rowspan="2">Building Name</th><th colspan="2">Section Element</th><th rowspan="2">Material Properties</th></tr>
<tr><th>Beam</th><th>Column</th></tr>
<tr><td>Wisma Persekutuan Kota Bharu</td><td>Ground: 230x150mm
(top:3T20), (bottom:3T20)
1st-12th: 230x150mm
(top:3T20), (bottom:3T20)
13th: 897x308mm
(top:2T32), (bottom:2T25)</td><td>610x108mm
(10T25)</td><td rowspan="5">Ec = 2500N/mm^2
fy = 460N/mm^2
fc = 27.6N/mm^2
fys = 276N/mm^2
c = 25mm</td></tr>
<tr><td>Kuarters Polis Ipoh</td><td>Ground: 900x350mm
(top:3T32), (bottom:2T25)
1st-11th: 750x350mm
(top:4T20), (bottom:3T20)</td><td>Ground: 500x1000mm
(24T25)
1st-11th: 550x300mm
(10T25)</td></tr>
<tr><td>Jabatan Kerja Raya KL</td><td>Ground: 750x350mm
(top:4T20), (bottom:3T20)
1st- 3rd: 600x300mm
(top:3T20), (bottom:3T20)
3rd-17th: 520x250mm
(top:2T25), (bottom:2T25)</td><td>Ground: 600x450mm
(16T32)
1st-17th: 550x300mm
(10T25)</td></tr>
<tr><td>Majlis Perbandaran Ampang Jaya</td><td>Ground: 750x350mm
(top:4T20), (bottom:3T20)
1st-17th: 450x300mm
(top:5T25), (bottom:3T20)</td><td>Ground: 500x1000mm
(24T25)
1st-17th: 550x300mm
(10T25)</td></tr>
<tr><td>Wisma Dewan Perniagaan Seremban</td><td>Ground: 230x150mm
(top:3T20), (bottom:3T20)
1st-13th: 768x308mm
(top:3T20), (bottom:3T20)</td><td>610x108mm (10T25)</td></tr>
</table>

3. Earthquake Data

This study used the intensity recorded by the Malaysian Meteorological Department. The intensity recorded on May 6, 2015 in Kota Kinabalu with a magnitude of 5.9 on the Richter level is shown in Figure 1 with 3538 output numbers in 0.02 steps at the time with the highest acceleration amongst others' different intensities. Ground motion data are classified into four levels of peak ground acceleration (PGA) of 0.05g, 0.10g, 0.15g and 0.20g respectively. This study uses a slower 5% spectrum acceleration.

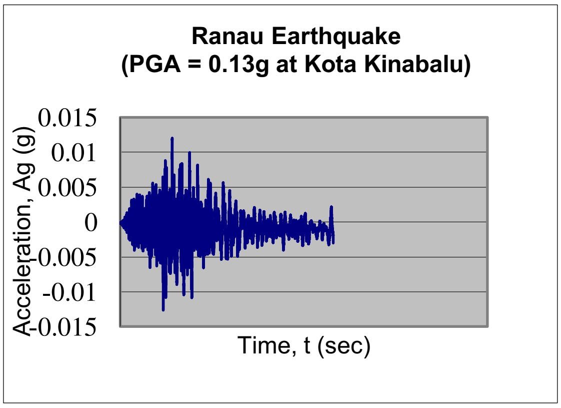

Figure 1. Data of ground acceleration for Ranau Earthquake.

4. Result

The term plastic hinges are used to describe the deformation of the frame section comprising columns and columns where elastic plastics occur. Typically, plastic hinges are currently resisting structural building types due to local structural failures occurring in beams and columns. Figure 3 illustrates the formation of damage location conditions and plastic hinges at the time of the resistance frame with four intensities of different ground acceleration. This represents the sequence of damage to the state of the frame under the loading of the earthquake.

4.1 Plastic Hinge Formation

The term plastic hinges are used to describe the deformation of the frame section comprising beams and columns where elastic plastics occur. Typically, plastic hinges are currently resisting structural building types due to local structural failures occurring in rays and columns. This study focuses on the extent of building damage and knows when yielding begins. Based on the result, for the intensity of 0.05g, no plastic hinges are formed.

Figure 4 illustrates the formation of a state of damage and plastic hinges at the time of the resistance frame at four different intensities of ground acceleration. The frame shows the location of the elemental structure where it begins to yield, crack or collapse. This represents the sequence of damage to the state of the frame under the loading of the earthquake. As a result, the concrete frame has cracked and yielded elements. The 'x' symbol indicates the appearance of cracking for concrete frames and 'o' symbols showing the results of plastic hinges constructed. For the intensity of 0.05g, it shows that the frame does not experience anything that degrades or collapse, but for the intensity of 0.10g to 0.20g, the frame has yielded and cracked. For example, at 0.05g intensity, it shows that the beams on the left begin to damage at the second floor. For 0.15g intensity, it is described as the resulting frame. However, the concrete frame undergoes infusion and cracking in the first floor when subjected to the intensity of the earthquake 0.20g (Figure 4). It shows that the structure element (beam no-1) starts to produce at 5.46 seconds when the intensity of 0.10g is used and the overall index of the recorded damage is 0.35g. All the buildings have experienced plastic hinges on the same floor level (floor 1). Table 4 shows the location of plastic hinges and the first yielding point of each building with respect to PGA.

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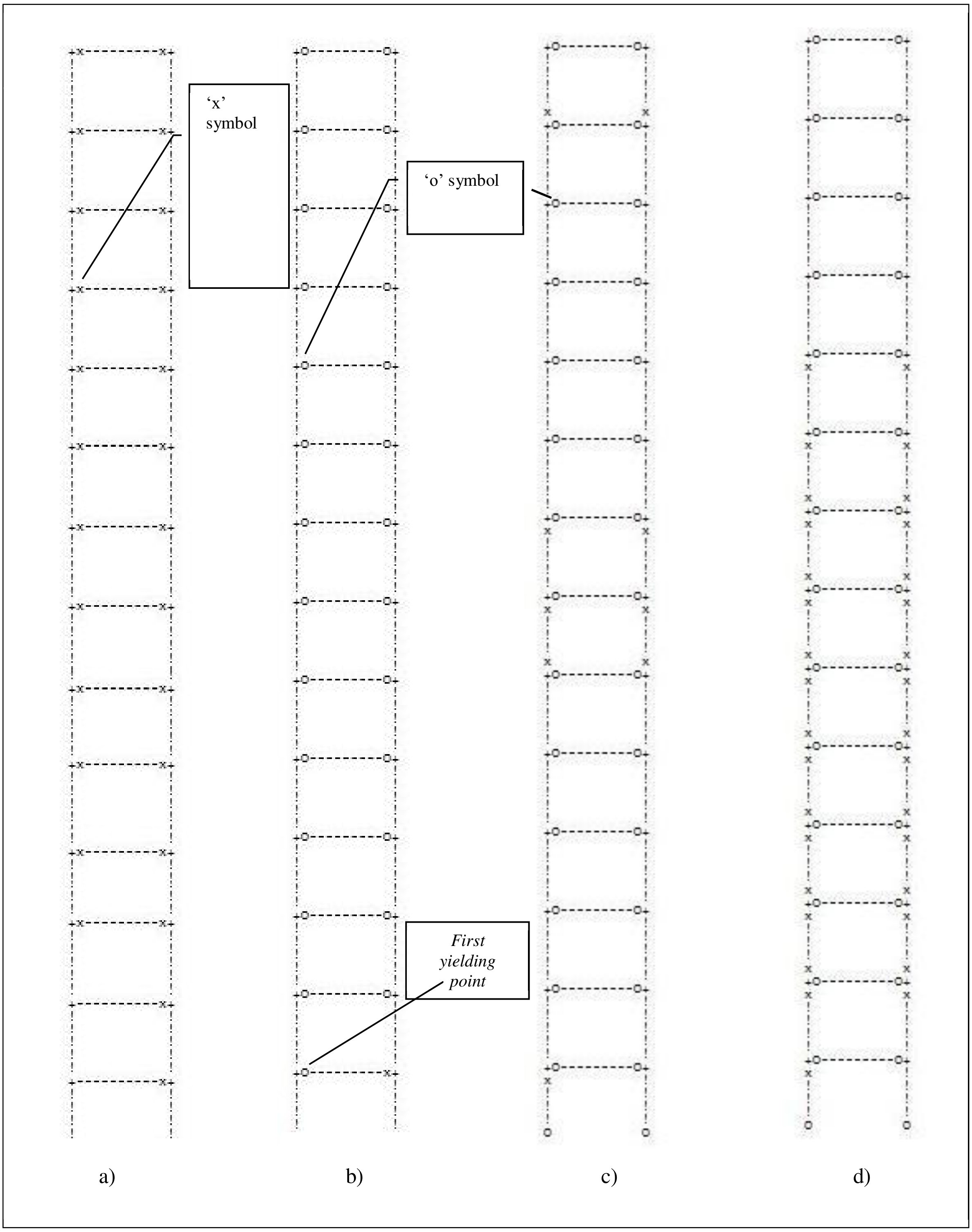

Figure 4. Illustration and the formation of a state of damage and plastic hinges for Wisma Persekutuan Kota Bahru building.

Table 4. Location and time for first yielding point.

Building Name	No. of Story	Location of Plastic Hinge	Floor level	Intensities (g)	Time of First Yielding (sec)
Wisma Persekutuan Kota Bharu	13	Column	1	0.10	5.46
Kuarters Polis Ipoh	11	Beam	1	0.05	4.82
Jabatan Kerja Raya KL	17	Column	1	0.05	6.98
Majlis Perbandaran Ampang Jaya	17	Beam	1	0.10	5.22
Wisma Dewan Perniagaan Seremban	12	Column	1	0.05	7.62

4.2 Time History Analysis

Based on the results of such an analysis, IDARC [15] defines the overall damage index for the entire structure. The overall damage index for buildings can be determined at the SEAOC Level Damage outlined in Table 1. The results are shown in Table 5. The Wisma Dewan Perniagaan Seremban has no damage when the intensity of 0.05g is enforced. The result of structural damage is referred to as the weighted index of the story and every index of the story is referred to as the weighted index. Total damage index when 0.10g intensity is used is also categorized as moderate. This means no structural damage occurs. However, some structural impairments occur but in this intensity, no elemental structure produces. The damage level has become the major damege level for intensity up to 0.15g. Local failures are often built into beam joints followed by column extensions. All buildings cannot withstand 0.20g intensity.

Table 5. Overall finding on damage index for different intensities.

No.	Building	5%	10%	15%	2%
1.	Wisma Persekutuan Kota Bharu	0.01	0.35	0.74	1.00
2.	Kuarters Polis Ipoh	0.02	0.27	0.68	1.00
3.	Jabatan Kerja Raya KL	0.01	0.26	0.72	1.00
4.	Majlis Perbandaran Ampang Jaya	0.02	0.38	0.85	1.00
5.	Wisma Dewan Perniagaan Seremban	0.004	0.21	0.63	1.00

5. Conclusion

Based on the results of the study, it can be concluded that:

- The results indicate that the potential for serious damage to the building may be indicated by the injury index.
- The highest PGA value for certain types of buildings may be appropriate to the possible damage to the structure
- IDARC results indicate that there is an approximate linear relationship between damage index and PGA
- Different plastic hinge formation patterns for different models, with better approval for larger PGAs.

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