SEISMIC PERFORMANCE EVALUATION FOR HEALTH FACILITIES (CLINIC) IN MALAYSIA

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ABSTRACT

Malaysian Government focuses on earthquake disaster management after the Ranau Earthquake (6Mw) occurred on 5 June 2015. This study performed a seismic evaluation for clinic type 3 and clinic type 7 regarding the Standard for Seismic Evaluation of Existing Reinforced Concrete Building, 2001 by the Japan Building Disaster Prevention Association (JBDPA). The study also developed Malaysia index for seismic evaluation, executing column section analysis to get suitable column size and main bar specifications and searching for suitable shear wall location on each floor for guidelines development to achieve a sustainable project in the future.

Keywords: Ranau Earthquake, seismic evaluation, sustainable projects

1. INTRODUCTION

The Malaysian Government has concerned about the impact from natural disasters. They established the Natural Disaster Management and Relief Committee (NDMRC) in 1972. On 11 May 1997, Policy and Mechanism on National Disaster and Relief Management were developed and revised on 30 March 2012. National Disaster Management Agency (NADMA) was established on 1 October 2015 after the Ranau Earthquake (magnitude 6Mw according to USGS) that occurred on 5 June 2015. Public Works Department of Malaysia (PWD of Malaysia) responsible as a technical agency under the Malaysian Government to implement infrastructure development, maintenance operations for government buildings, gives technical advice and also is one of NADMA's strategic partners. Because of that in Earthquake Disaster Management Cycle, PWD of Malaysia must focus on Performance-Based Earthquake Engineering (PBEE) that contains design, evaluation, construction, monitoring the function and maintenance of engineered facilities especially for important buildings such as health facilities because the building needs to remain functional during disasters. In this study, seismic evaluation was done according to the second procedure of the Standard for Seismic Evaluation of Existing Reinforced Concrete Building, 2001 by the Japan Building Disaster Prevention Association (JBDPA). This study also developed Malaysia index and analyzing column sections to get suitable column size and main bar specification to achieve 3% drift angle for flexural column (command practice in Japan). Besides the study identified the appropriate location for shear wall to increase the I_s value for guideline development.

2. DATA

In Malaysia, clinics are divided into several types (clinic type 2 to clinic type 7) according to the resident population in the area, type of service, and patient/day rate. However, only clinic type 7 includes both health facility and staff residence because it mostly in rural areas and limited construction areas. This

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study focuses clinic type 3 (Figure 1) and clinic type 7 (Figure 2) that designed use Eurocode 2 (use concrete strength 30N/mm^2 and reinforcement strength 500N/mm^2) but Eurocode 8 (seismic code) is not applied. Therefore, it is essential to know the seismic performance for existing design and building behavior (existing building for pre-earthquake) by using appropriate seismic evaluation method.

Figure 1. Architectural concepts clinic type 3

Figure 2. Architectural concepts clinic type 7

3. METHODOLOGY

This study implemented seismic evaluation with reference to the Standard for Seismic Evaluation of Existing Reinforced Concrete Building, 2001 by the Japan Building Disaster Prevention Association (JBDPA). In the Japanese method, the seismic capacity of exiting low-rise reinforced concrete (RC) buildings are evaluated using a structural seismic index (a serial score) calculated according to the building's ultimate horizontal strength and ductility. Seismic Demand, I_{so} (Eq. (1)) and Seismic Index of Structure, I_s (Eq. (2)) are figured where $I_s \geq I_{so}$ to make sure the building is in good condition.

$$I_{so} = E_s \,.\, Z \,.\, G \,.\, U \quad (1)$$

Where;

- E_s = basic seismic demand index of structure (recommended 0.8 (first level procedure) and 0.6 (second and third level procedure))
- Z = Zone index
- G = Ground index
- U = Usage index

$$I_s = E_o \,.\, S_D \,.\, T \quad (2)$$

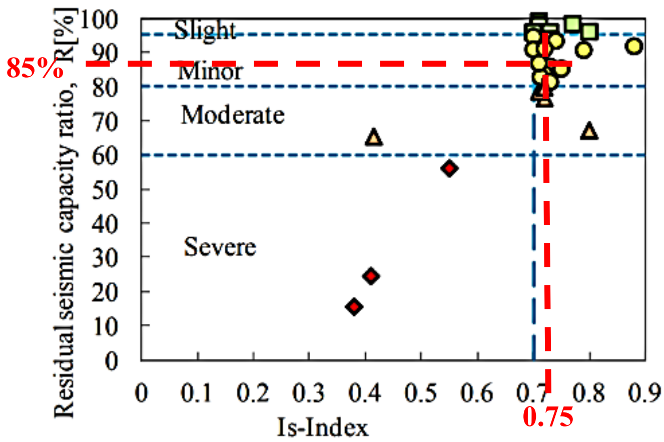
Where;

- E_o = Basic seismic index of structure $E_o = ØCF$
- F = Ductility index
- C = Strength index
- $Ø$ = Story index
- S_D = Irregularity index
- T = Time index

4. RESULTS AND DISCUSSION

4.1. Basic seismic demand index, E_s

Suitable basic seismic demand index, E_s for Malaysia needs to be obtained because this value represents earthquake damages caused by a previous major earthquake. Referring to Maeda etc.,2012, for public school buildings (used as shelter) I_s value ≥ 0.7 and for important buildings value $I_s \geq 0.75$. Because these I_s values, one of which is shown in Figure 3, are for the Japanese case, the zone index, Z, in Eq. (1) is 1.0. Furthermore, assuming the Usage index, U, and Ground index, G, are 1.25 and 1.0, respectively, we can determine E_s value as 0.6 by Eq. (1).



Source: Maeda Masaki etc 2012

Figure 3: Appropriate values I_s for Malaysia

Study by R.Roslee etc. 2018 (Malaysia researcher), when the Physical Vulnerability (V_p) is 0.55, it is categorized as a moderate vulnerability. When V_p value is compared with R value in Table 1, it is moderate damage (60% ≤ R < 80%). Because clinics are essential facilities, only minor damage is allowed. Referring to Figure 3, we can conclude that value E_s 0.6 is suitable for minor damage (80% ≤ R < 95%).

Table 1. Relation between residual seismic capacity and physical vulnerability

Class	Residual Seismic Capacity Ratio, *R*		Physical Vulnerability, V_p	
	Category	*R* Value	Category	V_p Value
I	slight damage	$R \geq 95\%$	Very low vulnerability	< 0.2
II	minor damage	$80\% \leq R < 95\%$	Low vulnerability	0.21 – 0.40
III	moderate damage	$60\% \leq R < 80\%$	Moderate vulnerability	0.41– 0.60
IV	severe damage	$R < 60\%$	High vulnerability	0.61 – 0.80
V	collapse	$R \approx 0$	Very high vulnerability	> 0.81

Source: Maeda Masaki etc. 2012 and R.Roslee etc. 2018

4.2. Zone Index, *Z*

The Zone index, *Z*, are identified using the correlation between the Japanese Method (using Seismic demand index, I_{so}) and the Eurocode 8 (using base shear force, F_b).

Seismic demand index, $I_{so} = E_s \,.\, Z \,.\, G \,.\, U$ (1)

Base shear force, $F_b = S_d(T_1)m\lambda$ (3)

Consider that the I_{so} value (Eq. (1)) corresponds to the shear force and weight ratio.

$$I_{so} = \left(\frac{F_b}{w}\right) \quad (4)$$

Where;

- m = Mass of building
- λ = Correction factor
- $S_d(T_1)$ = Design spectrum $S_d\,(T_1) = a_g.S.\left(\frac{2.5}{q}\right)$
- a_g = Design ground acceleration on type A ground $a_g = \gamma a_{gr}$
- γ = Importance factor
- a_{gR} = Peak ground acceleration on type A ground
- S = Soil factor
- q = Behavior factor

So Eq. (3);

$$F_b = \gamma_1 a_{gr}.S.\left(\frac{2.5}{q}\right)m\lambda \quad (5)$$

Eq. (5) will multiply $\left(\frac{1}{w}\right)$ and w = mg. So,

$$\frac{F_b}{w} = \gamma a_{gr}.S.\left(\frac{2.5}{q}\right)\lambda\left(\frac{1}{g}\right) \quad (6)$$

Rearrange Eq. (6)

$$\frac{Fb}{w} = \left(\frac{\lambda}{qg}\right)(2.5a_{gr}).S.\gamma \quad (7)$$

So, relationship Seismic demand index, I_{so} and Eurocode 8 as in Eq. (4)

$$I_{so} = \left(\frac{\lambda}{qg}\right)(2.5a_{gr}).S.\gamma \quad (8)$$

$$E_S\,.\,Z\,.\,G\,.\,U = \left(\frac{\lambda}{qg}\right)(2.5a_{gr}).S.\gamma \quad (9)$$

From Eq. (9) we know,

$$Basic\ seismic\ demand\ index, E_S = \left(\frac{\lambda}{qg}\right) \quad (10)$$

$$Zone\ index, Z = 2.5a_{gr} \quad (11)$$

$$Ground\ index, G = S \quad (12)$$

$$Usage\ index, U = \gamma \quad (13)$$

The Malaysia code presents the PGA for the return period of 475 in hazard map. Thus Eq. (11) the value for Zone index, *Z*, for Peninsular Malaysia and Sarawak is 0.23 (9%PGA maximum PGA) and Sabah is 0.4 (16%PGA maximum PGA).

4.3. Irregularity Index, S_D, Time index, T, Ground Index, G, and Usage Index, U

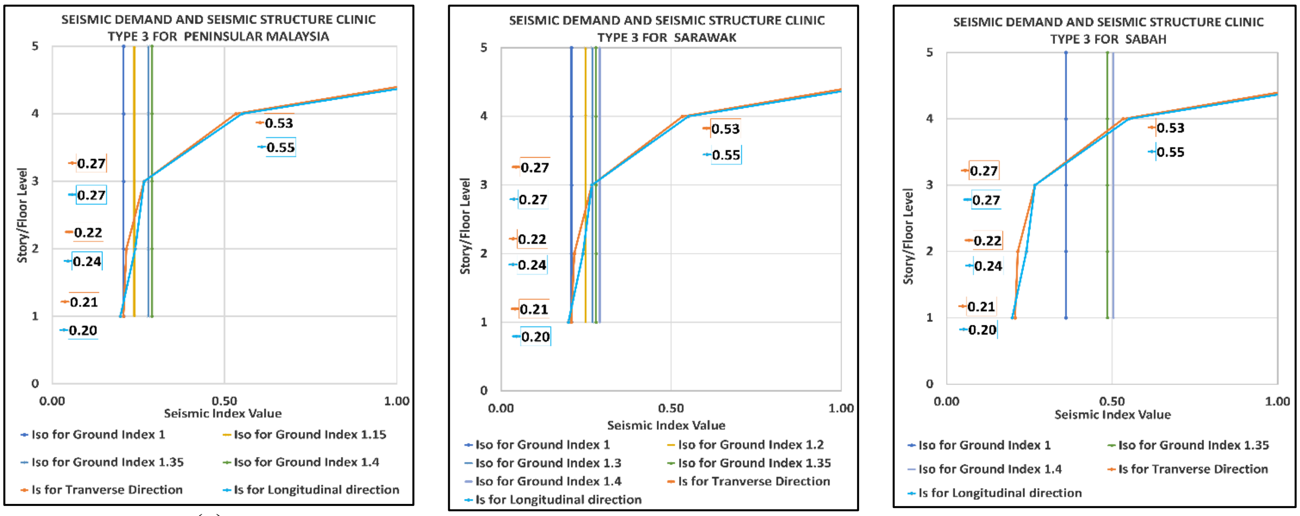
Irregularity index, S_D, and time index, *T* were calculated using the Japanese Method. S_D value for clinic type 3 is 0.86, and for clinic type 7 is 0.79. *T* value for both clinic is 1. Ground index, *G* and Usage index, *U* adopted from Malaysia Annex. All soil types (model A in Malaysia Annex) are considered in this study. Because building is category as important building, so *U* value is 1.5.

4.4. Judgement of Seismic Safety by Comparing I_s with I_{so}

Seismic Demand Index, I_{so}, is calculated for each ground index, G because this design will be used in every state in Malaysia. The result for seismic value index of structure, I_s values presented in Table 2 are compared with value seismic demand Index, I_{so} in Figure 4 and Figure 5. From the seismic evaluation, clinic type 3 is not in good condition from story three and below, but clinic type 7 is good condition in every level.

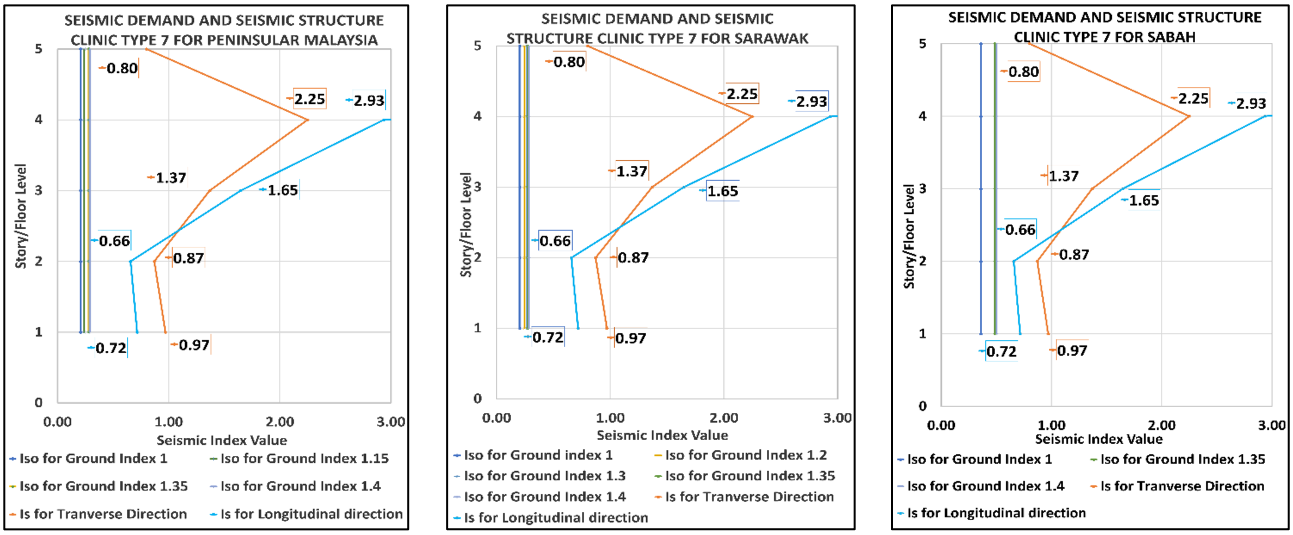
Table 2. Seismic Index of Structure, I_S for Clinic type 3 and clinic type 7

Story	Clinic type 3		Clinic type 7	
	Transverse	Longitudinal	Transverse	Longitudinal
5	1.71	1.78	0.80	15.42
4	0.53	0.55	2.25	2.93
3	0.27	0.27	1.37	1.65
2	0.22	0.24	0.87	0.66
1	0.21	0.20	0.97	0.72



(a) (b) (c)

Figure 4. Clinic type 3



(a) (b) (c)

Figure 5. Clinic type 7

4.5. Develop Earthquake Guideline (Design & Construction)

For Clinic type 3, the study is extended to get higher I_s when service/room/area repeated at every level (for lift core, staircase, AHU room & toilet). 4 layouts are used: 1. Shear wall at lift and staircase, 2.Share walls at lift and toilet, 3.Shear wall at lift and AHU room and 4.Shear wall at lift, staircase, toilet and AHU room. The results are shown in Figure 6. From these results, application of more number shear wall leads to better earthquake resistance of the building.

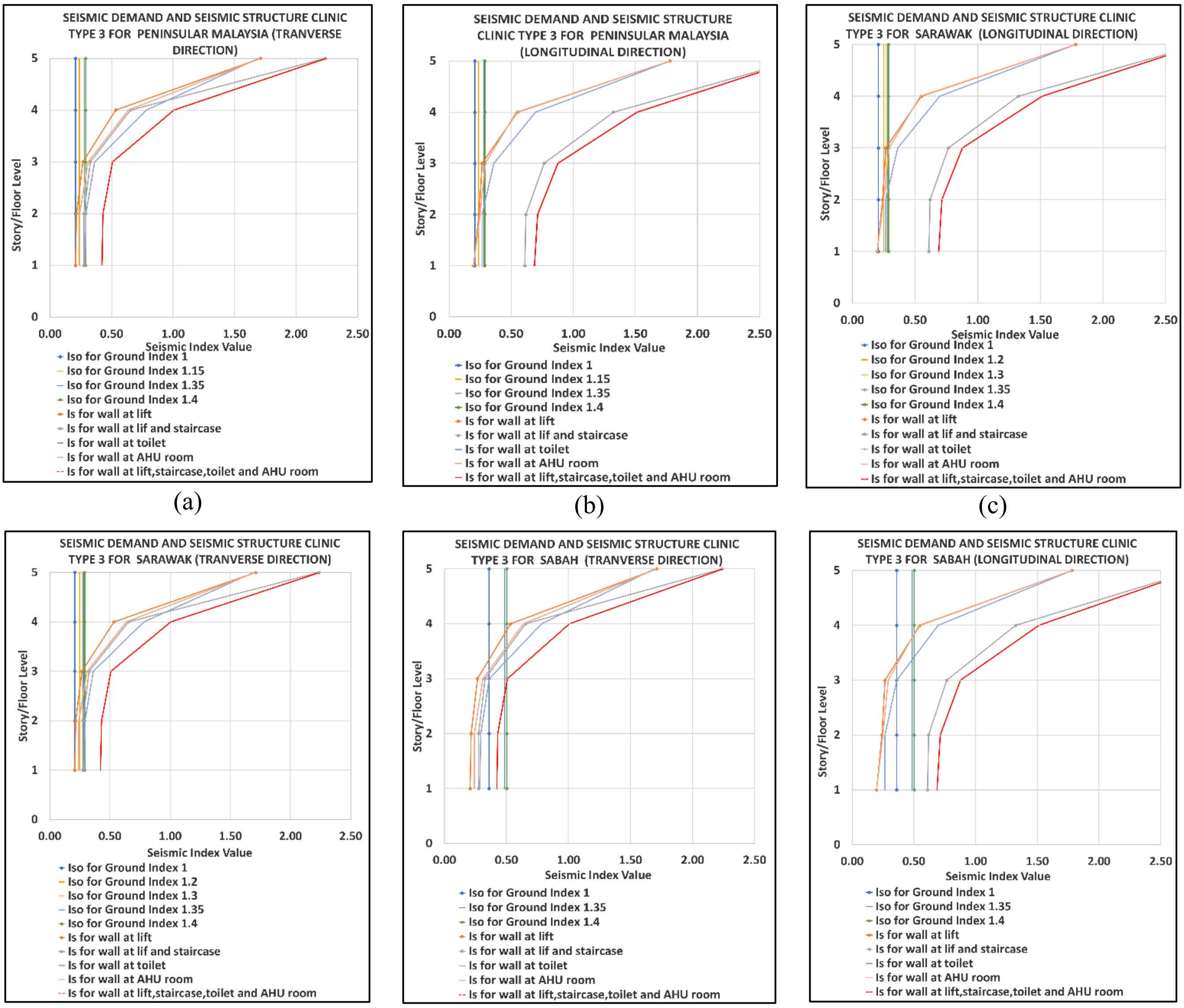


Figure 6. Tranverse and longitudinal direction

4.6. Column Section Analysis

The study is extended to get suitable size for column and main bar (Table 3). The maximum column load was used to get the flexural column's drift angle of 3% (practice implemented by Japan). This study use analysis according to the Specification for Highway Bridges Part V Seismic Design by Japan Road Association (JRA). For the result, recommended minimum column size is 400x400.

Table 3. The result from column section analysis

Clinic	Original			Recommended	
	Column Size	Maximum Colum load (kN)	Limit Drift Angle	Size and Main Bar	Limit Drift Angle
Type 3	500 x 500 (8H25)	4,046.70	0.058	NA	NA
	400 x 400 (4H25)	3,100.7	0.028	500 x 500 (8H25)	0.055
	300 x 300 (4H25)	771.20	0.013	400 x 400 (6H25)	0.045
Type 7	300 x 300 (4H25)	1,768.90	0.0069	400 x 400 (6H25)	0.045

CONCLUSIONS

The conclusion for this study is that seismic evaluation (the Japanese Method) can be used to know the behavior of the buildings in Malaysia by applying Malaysian Index. The practice implemented by PWD of Malaysia that uses reinforcement strength 500N/mm^2 and concrete strength 30N/mm^2 positively impacts the strength of the building against earthquake disasters. Building weight must be less, by reducing weight for the water tank for example, to ensure inertia force decreases when earthquakes occur. For high buildings (especially in the seismic region), the shear wall must not be focused only on the lift area. To construct earthquake resistant buildings with sufficient shear walls without disturbing building function, collaboration between all disciplines (civil, mechanical, electrical, architects, and medical planners) is essential to ensure it is achievable. Shear walls are recommended to be longer than 5 meters to increase the strength index. The minimum column size of 400x400 is recommended to make the buildings analyzed in this study more ductile

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