RVS

By Livian Teddy

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The Application Of Rapid Visual Analysis (RVS) in the Architectural Design Process as Support Disaster Resilient in Indonesia

Livian Teddy *[1], Gagoek Hardiman[2], Nuroji[3]

[1] Lecturer, Department of Architecture, Sriwijaya University, Indonesia
[2] Lecturer, Doctoral Program of Architecture and Urban, Diponegoro University, Indonesia
[3] Lecturer, Doctoral Program of Civil Engineering, Diponegoro University, Indonesia

Abstract

As an earthquake-prone region should all stakeholders should be prepared to deal with it so that it can support better to disaster resilience. Architects as one of the pioneers of physical development should contribute it with in creating the design of earthquake-resistant buildings. So when an earthquake damaged building is not very severe or collapsed that can cause fatalities. But the evaluation method of building vulnerability to earthquakes is fast, easy, scalable and relatively accurate for the purpose of building design process procedure has not been developed by researchers. There are other ways to a much simpler method for evaluating the vulnerability of buildings to earthquakes that Rapid Visual Screening (RVS). But RVS is used to evaluate the vulnerability of existing buildings against earthquakes in a region for the purpose of disaster management. RVS is 'evaluating as you go along' that do not involve structural calculations, simple and easy to use. The question: is quite feasible to use an architect to evaluate the vulnerability of buildings in the design process and how to accuracy?

Based on these things, the interesting problems to be studied and will be described in this paper are: use RVS procedure for evaluating seismic vulnerability of the buildings in the architectural design process and testing the validity by using static analysis pushover.

From the results of research using 6 models building and quantitative method of research with strategy research simulation experiments. The comparison between procedure of RVS FEMA 2015 and pushover static simulation result indicates that the procedure is quite feasible to be applied in evaluating building's vulnerability to earthquakes in the design process.

Keywords: Earthquake; regularity; irregularity; architectural design, RVS

INTRODUCTION

In designing a building, the relationship between configuration of buildings and structures can be equated with the relationship between meat and bones; they are inseparable. Configuration errors would generate structural failure. There has been a lot of evidence in structural failure, for example: the earthquake in Yogyakarta in 2006, the 2007's earthquake in Bengkulu and Padang Earthquake of 2009, with most casualties caused by the collapse of the building. Some studies express that the fatal damage of buildings caused by earthquake in Indonesia takes place not only in "non-engineered" buildings but also in many "engineered" buildings (Boen, 2006; Boen, 2007a; Boen, 2007b; Pawirodikromo, 2007; Ismail et al., 2011). This phenomenon occurs in the world including Indonesia due to an ongoing debate that earthquake-resistant building is not the domain of architects; it is the domain of structural engineers. This dichotomy causes the development of structural engineering in Indonesia is not well integrated into the architectural development of Indonesia (Wangsadinata, 2009).

Architects and structural engineers are supposed to establish good cooperation. Architects must understand the basic knowledge of seismic engineering such as acceleration, amplification, shear force base, brittle failure, damping and other seismic terms and also concepts of earthquake-resistant structures such as shear walls, bracing, moment frames, seismic isolators and the like. On the other hand structural engineers must understand the functional needs and aspirations of architects. A good collaboration between the two would yield earthquake architecture (Arnold, 1996).

The initial step of actualizing earthquake architecture in the architect's design process is able to identify and evaluate the vulnerability of buildings to earthquakes (slak & Kilar, 2012). By knowing the vulnerability of buildings being designed to

*Corresponding author: Livian Teddy
Student Doctoral Program of Architecture and Urban, Diponegoro University, Indonesia.
e-mail: livianteddy@gmail.com

earthquakes, there will be two possible solutions that an architect can consider; first is to re-design so that the architect acquires configuration having a relatively small risk to earthquakes. Second, to leave entirely to structural engineers to handle as well as to prepare for the consequences such as the building's high cost.

The evaluation method of building's vulnerability to earthquakes which is quick, easy, measurable and relatively accurate for the purpose of building design process has not been deeply developed by researchers. There is other way to use a much simpler method to evaluate the vulnerability of buildings to earthquakes, that is Rapid Visual Screening (RVS). RVS is applied to evaluate the vulnerability of existing buildings against earthquake. RVS is 'casual evaluation' that does not involve structural calculations. This method exercises a scoring system to assess the reliability of building's main structure against seismic lateral loads (FEMA, 2002a). The other buildings' attributes that can affect the reliability of the building in response to earthquake loads are taken into account as factors that can modify the final score. In the beginning, this RVS method was created by the US Federal Emergency Management Agency (FEMA) by issuing FEMA 154 (1988a) and FEMA 155 (1988b). Then it was revised by issuing FEMA 154 (2002a) and FEMA 155 (2002b), the last ones were FEMA 154 (2015a) and FEMA 155 (2015b). With a simple method, RVS can be exercised by anyone interested and trained for it. The main purpose of RVS is for disaster management and not for architectural design thus its reliability should be investigated if it is to be applied in evaluating the vulnerability of building design result to earthquakes.

RVS AND REGULAR/IRREGULAR CONFIGURATION

Scoring list of RVS 2015 consists of two parts. Part one : scoring level 1 (SL1) which consists of basic score, modificator score (vertical irregular configuration-VL1 and horizontal-PL1 as well as soil type) and minimum score. The sum of basic score and modificator score must be greater than minimum score :

$$SL1=basicscore+VL1+PL1>0.3 \quad (1)$$

In part two : scoring level 2 (SL2) consists of adaptation of basic score :

$$S'=SL1-VL1-PL1 \quad (2)$$

and modificator score. Its structural description is more detail than vertical irregular configuration-VL2 (sloping site, weak/soft story, setback, short column, split level and other vertical irregularities), horizontal irregular configuration-PL2 (irregular torsional, non-parallel system, re-entrant corner, diaphragm opening, out-of-plane offset and other horizontal irregularities) and M part (redundancy, pounding and floor plate as beam). Final score (SL2) consists of the sum of S', VL2, PL2 and M which must be greater than minimum score :

$$SL2=S'+VL2+PL2>0.3 \quad (3)$$

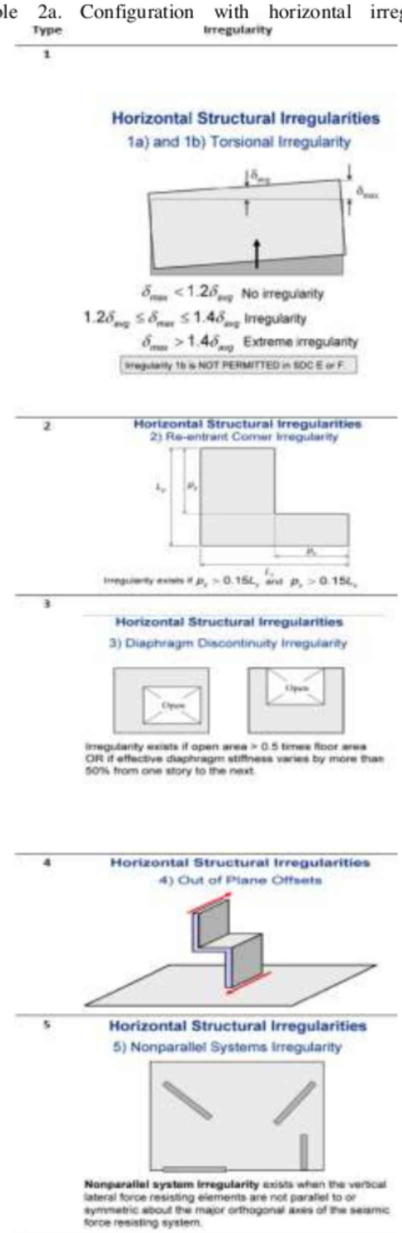
Score 0.3 is used to prevent overestimate due to multiple sum of modificator. While cut-off score from SL2 = 2 or medium damage is as shown in table 1 below :

Table 1. The relation between the scores, the probability of damage and prediction of the degree of damage

Score	Damage Probability	Damage Level	Seismic Performance-FEMA 273 (FEMA 1997)
4	0.01%	Least/Ignored Damage	< IO
3	0.10%	Light damage	IO (Immediate Occupancy)
2	1%	Medium damage	LS (Life Safety)
1	10%	Severe damage	CP (Collapse Prevention)
0	100%	Collapse	> CP

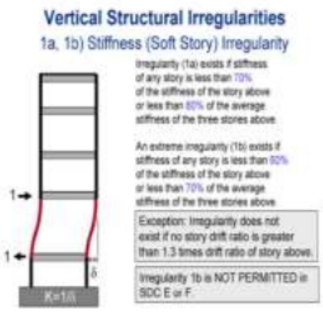
Source: Idham, 2011

Table 2a. Configuration with horizontal irregular



Source: FEMA, 2010

Table 2b. Configuration with vertical irregular

Type	Irregularity
1	
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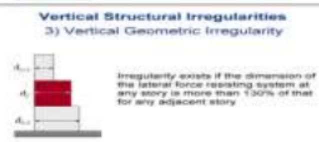
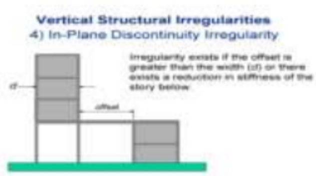
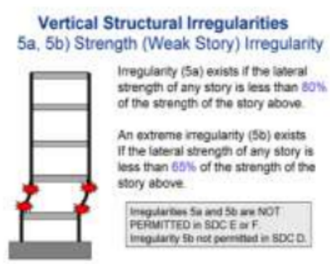
3	
4	
5	

Source: FEMA, 2010

The scoring coefficient of every seismic zone can be different. Earthquake zones used in scoring are : low, medium/moderate, moderately high, high and very high earthquake zones. To better understand the rules of regular or irregular configurations, FEMA issued FEMA 749 guidelines (FEMA 2010) (see table 2a & 2b).

MODELS AND RESEARCH METHOD

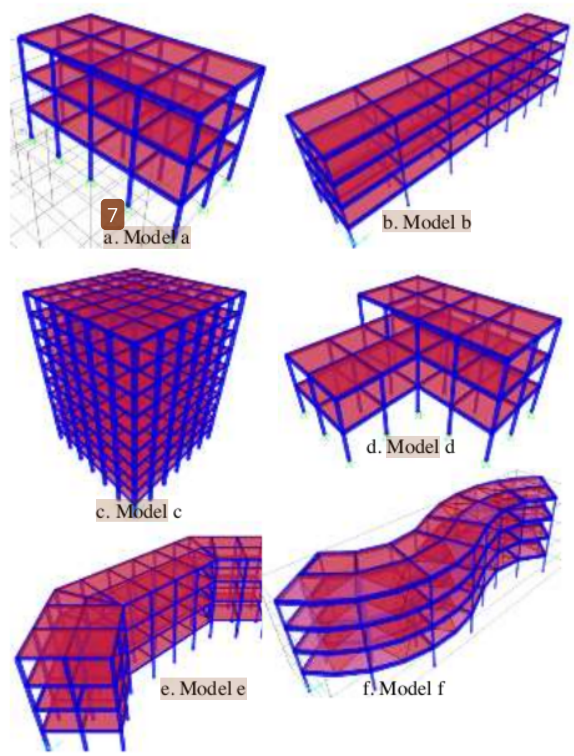


Fig. 1. Models of building with regular and irregular configurations
Source: Author data, 2016

To make it easier to understand the behavior of buildings against earthquakes, this study used 6 building models (Figure 1) with structure property as shown in table 3.

Earthquake zone used is high zone with spectra score $S_S = 0.97$ and $S_1 = 0.328$ with medium soil condition (D).

This study utilizes a quantitative method with research strategy of simulation experiments. Building structure models above are inputted in software and analyzed with the method of pushover static seismic analysis. The Nonlinear Static Procedure, often called "pushover analysis," is an incremental static analysis used to determine the force-displacement relationship, or the capacity curve, for a structure or structural element (ATC, 1996). Then the numerical results are tabulated and compared with the results of scoring calculations FEMA 2015.

Table 3. Properties of structure models ‘a’ to ‘f’

Models	Number of floors	Dimension of beams (cm)	Dimension of columns (cm)	Thickness of slabs (cm)	Moduls (m)	Quality		
						Concrete (Kg/cm2)	Longitudinal rebars (Kg/cm2)	Transversal rebars (Kg/cm2)
a	3	25X40	30X30	12	5X5	300	3000	2400
b	4	30X60	40	12	5X6 ; 5X9	300	3000	2400
c	10	25X50	70X70	12	5X5	300	4000	2400
d	3	25X40	30X30	12	5X5	300	3000	2400
e	4	25X40	40X40	12	5X5	300	3000	2400
f	4	30X60	40	12	5, 6,7, 10	300	3000	2400

Source: Author data, 2016

RESULTS

Table 4. Concrete moment-resisting frame structure : basic score, modifiers, and final level 1 score, SL1.

No	Basic score and modifiers	Coefficient	Model a	Model b	Model c	Model d	Model e	Model f
1	Basic score	1.5	1.5	1.5	1.5	1.5	1.5	1.5
2	Severe Vertical Irregularity (VL1)	-0.9	-	-	-	-	-	-
3	Moderate Vertical Irregularity (VL1)	-0.5	-	-	-	-0.5	-	-
4	Plan Irregularity (PL1)	-0.6	-	-0.6	-	-0.6	-0.6	-0.6
5	Soil Type A or B	0.4	-	-	-	-	-	-
6	Soil Type E (1-3 stories)	0.0	0.0	-	-	0.0	-	-
7	Soil Type E (> 3 stories)	-0.5	-	-0.5	-0.5	-	-0.5	-0.5
	SL1 = 1+2/3+4+5/6/7 ≥ 0.3		1.5	0.4	1	0.4	0.4	0.4
	S' = (SL1-VL1-PL1)		1.5	2.1	1.5	2.6	2.1	2.1

Source: Author analysis, 2016

Table 5. Structural modifiers to add to adjusted baseline score.

Code	Topic		Statements	Coefficient	Model a	Model b	Model c	Model d	Model e	Model f
VL2	Vertical Irregularity	Sloping Site	There is at least a full story grade change from one side of the building to the other.	-1.2	-	-	-	-	-	-
		Weak and/or Soft Story (circle one maximum)	Length of lateral system at any story is less than 50% of that at story above or height of any story is more than 2.0 times the height of the story above.	-0.9	-	-	-	-	-	-
			Length of lateral system at any story is between 50% and 75% of that at story above or height of any story is between 1.3 and 2.0 times the height of the story above.	-0.5	-	-	-	-	-	-
		Setback	Vertical elements of the lateral system at an upper story are outboard of those at the story below causing the diaphragm to cantilever at the offset.	-1.0	-	-	-	-	-	-
			Vertical elements of the lateral system at upper stories are inboard of those at lower stories.	-0.5	-	-	-	-0.5	-	-
			There is an in-plane offset of the lateral elements that is greater than the length of the elements.	-0.3	-	-	-	-	-	-
		Short column	At least 20% of columns (or piers) along a column line in the lateral system have height/depth ratios less than 50% of the nominal height/depth ratio at that level.	-0.5	-	-	-	-	-	-
			The column depth (or pier width) is less than one half of the depth of the spandrel, or there are infill walls or adjacent floors that shorten the column.	-0.5	-	-	-	-	-	-
		Split level	There is a split level at one of the floor levels or at the roof.	-0.5	-	-	-	-	-	-
		Other Irregularity	There is another observable severe vertical irregularity that obviously affects the building's seismic performance.	-1.0	-	-	-	-	-	-
			There is another observable moderate vertical irregularity that may affect the building's seismic performance.	-0.5	-	-	-	-	-	-
				∑VL2	0	0	0	-0.5	0	0
PL2	Plan Irregularity	Torsional irregularity: Lateral system does not appear relatively well distributed in plan in either or both directions.		-0.7	-	-0.7	-	-0.7	-0.7	-0.7
		Non-parallel system: There are one or more major vertical elements of the lateral system that are not orthogonal to each other.		-0.4	-	-	-	-	-0.4	-0.4
		Reentrant corner: Both projections from an interior corner exceed 25% of the overall plan dimension in that direction.		-0.4	-	-	-	-0.4	-0.4	-
		Diaphragm opening: There is an opening in the diaphragm with a width over 50% of the total diaphragm width at that level.		-0.2	-	-	-	-	-	-
		Building out-of-plane offset: The exterior beams do not align with the columns in plan.		-0.4	-	-	-	-	-	-
		Other irregularity: There is another observable plan irregularity that obviously affects the building's seismic performance.		-0.7	-	-	-	-	-	-
				∑PL2	0	-0.7	0	-1.1	-1.5	-1.1
M	Redundancy	The building has at least two bays of lateral elements on each side of the building in each direction.		0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Pounding	Building is separated from an adjacent structure by less than 1% of the height of the shorter of the building and adjacent structure and:	The floors do not align vertically within 60 cm.	-1.0	-	-	-	-	-	-
			One building is 2 or more stories taller than the other.	-1.0	-	-	-	-	-	-
			The building is at the end of the block.	-0.5	-	-	-	-	-	-
	Concrete moment-resisting frame	Flat plate serves as the beam in the moment frame.		-0.4	-	-	-	-	-	-
				∑M	0.3	0.3	0.3	0.3	0.3	0.3
				∑(VL2 + PL2 + M)	0.3	-0.4	0.3	-1.3	-1.2	-0.8
				Final skor level 2 , SL2 = (S' + VL2 + PL2 + M) ≥ 0.3	1.8	1.7	1.8	1.3	0.9	1.3

Source: Author analysis, 2016

DISCUSSION

Model a and c are 2-axis symmetrical configurations, model b and e are 1-axis symmetrical configurations, and model d and f are asymmetrical configurations. The irregularity configurations are as follow: model a and c are of regular categories; model b, e and f are of horizontal irregular categories; and model d is of vertical and horizontal irregular category. The manual calculation results of seismic performance model a-f by FEMA RVS 2015 are displayed in Table 4 and 5. In Table 4 there is no soil type D (medium) so it is assumed that it is the same as soil type E (soft).

Based on calculation results of RVS FEMA 2015 in Table 5, the score of SL2, model a=1.8, model b=1.7, model c=1.8, model d=1.3, model e=0.9 and model f=1.3. If compared with Table 1 it is concluded that model a, b, and c=2 or LS seismic performance and model d, e and f=1 or CP performance. This implies that if there is an earthquake with high intensity and magnitude, building a, b, and c will suffer moderate damage, while building d, e and f will be severely damaged.

Simulation results of model a-f in SAP2000 structure software (Table 6) indicate that model a is of CP seismic performance, model b on X-axis is of LS seismic performance and on Y-axis is of CP seismic performance. Model c, d, e and f are of LS seismic performance. With a simple configuration of model a and b with CP seismic performance it is concluded that the column shear capacity of both models is inadequate or its dimension is too small. On the other hand, a simple configuration of model c which is symmetrical 2-axis with LS seismic performance or 0.98% and quite far from the limit score of 1.5%, indicates that it is very safe. In model d, e and f even though the seismic performance is of LS category, its score is 1.23%- 1.49% which is very close to the limit score of 1.5%. The models above are configurations whose irregularities are set. In reality, the actual building may carry several irregular combinations of both horizontal and vertical and the scores may exceed the limit score. In other words, the configuration of such model d, e and f are prone to earthquakes.

If compared between the manual calculation results of RVS FEMA 2015 and SAP2000 on model a and b, manual calculations of RVS FEMA 2015 does not take into account the shear capacity of a building structure so that the seismic performance is different. On the contrary, model c with a configuration that is relatively the same as model a owns an unproblematic shear capacity therefore the seismic performance results of RVS FEMA 2015 and SAP2000 are similar. The seismic performances of RVS FEMA 2015 and SAP2000 in model d, e and f appear to be different when viewed in a glance, but when it is observed from the seismic performance score of SAP2000 which is 1.23%- 1.49%, it is very close to the limit score which is 1.5%. Thus RVS FEMA 2015 detects that configurations of model d, e and f are vulnerable to an earthquake so that its seismic performance is CP.

CONCLUSIONS

From discussions above, it can be concluded that :

- Based on calculations of RVS FEMA 2015, model a, b, and c possess LS seismic performance and model d, e and f possess CP seismic performance.
- Based on calculations of SAP2000, model a is of CP seismic performance, model b on X- axis is of LS seismic performance and on Y-axis is of CP seismic performance, model c is of LS seismic performance and model d, e and f are of LS seismic performance.

From both calculations being applied, FEMA 2015's manual calculations can predict quite well the seismic performance of a building configuration, but its weakness is unable to predict a seismic performance of a configuration with inadequate shear capacity structures. The comparison of these calculation methods exhibits that manual calculations of RVS FEMA 2015 is fairly moderate in predicting the vulnerability of buildings to earthquakes with the result that it is feasible to evaluate the vulnerability of buildings to earthquakes in the process of architectural design. The flaw of this method is recently being corrected by the author who is currently doing dissertation research to create a procedure to evaluate the vulnerability of a building in the design process from shear capacity's capabilities and its configurations.

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