# PERFORMANCE EVALUATION OF THE IRD RSUP DR. SARDJITO BUILDING TO THE INFLUENCE OF EARTHQUAKE

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*ABSTRACT*

*In performance-based design, the level of performance of hospital buildings is generally operational, where the buildings are expected to continue to function after the occurrence of the earthquake and do not undergo significant damage. This research evaluates the level of performance suitability of the Emergency Care Installation Buildings of Dr. Sardjito Hospital (hereinafter referred to as IRD RSUP Dr. Sardjito building) for the effects of earthquakes. First evaluation is done by Rapid Visual Screening by FEMA 154 (2002), then continued with more detailed evaluation based on FEMA 310 (1998). The building structure is modeled by SAP2000 and created in 2 models, i.e. the Models with wall and the Models without wall. The earthquake loads refers to SNI 1726-2002. The strength of structural elements is calculated with SNI 2847-2002 and Response-2000. For evaluation of structure performance levels, a pushover analysis used for nonlinear procedures, where the analysis used to the Seismicity region 3 and 4. Performance point is determined by Capacity Spectrum Method based on ATC-40 (1996), which has built-in in the SAP2000 Program. The performance level of the building is determined by drift ratio criteria required by FEMA 356 (2000) as well as ATC-40 (1996). From the research results, it is obtained that the natural period for the Model with wall is 0.592 seconds and 1.687 Hz frequency, and natural period for Model without wall is 1.291 seconds and 0.774 Hz frequency. Therefore, the level of structure performances for earthquake return period of 500 years is immediate occupancy.*

*Keywords: level of performance, pushover analysis, performance point.*

## INTRODUCTION

The Dr. Sardjito Hospital which is located in the city of Yogyakarta is a referral hospital for the people of Yogyakarta. One of the installations in this hospital has become the focus of this research, namely the Emergency Care Installation Buildings of Dr. Sardjito Hospital (hereinafter referred to as IRD RSUP Dr. Sardjito building) as shown in Figure 1. In performance-based design, the level of performance of hospital buildings is operational, where the buildings are expected to continue to function after the occurrence of an earthquake and do not undergo significant damage. This study aimed to evaluate the performance level of IRD RSUP Dr. Sardjito building, whether it is in accordance with the level of operational performance level or not.

Figure 1. The building of IRD RSUP Dr. Sardjito Yogyakarta

Target building performance levels according to the FEMA 356 (2000) consists of: (1) Operational Performance Level, (2) Immediate Occupancy Level, (3) Life Safety Level, and (4) Collapse Prevention Level. The relationship between structural performance levels to the limiting damage states for common vertical elements of lateral-force-resisting systems can be seen in Table 1. Meanwhile, the ATC-40 (1996) gives the deformation limits for various performance levels of the structure as shown in Table 2.

Table 1. The limits of drift for concrete frames (FEMA 356, 2000)

| Structural performance levels | *Drift* (%) | |
|---|---|---|
| *Immediate Occupancy* | 1.0 | *Transient* |
| *Life Safety* | 2.0<br>1.0 | *Transient*<br>*Permanent* |
| *Collapse Prevention* | 4.0 | *Transient* or *permanent* |

Table 2. Deformation limits for various performance levels (ATC-40, 1996)

| Interstory drift limit | Performance level | | | |
|---|---|---|---|---|
| | *Immediate Occupancy* | *Damage Control* | *Life Safety* | *Structural Stability* |
| Maximum total drift | 0.01 | 0.01-0.02 | 0.02 | $0.33\frac{V_i}{P_i}$ |
| Maximum inelastic drift | 0.005 | 0.005-0.015 | No limit | No limit |

Notes: $V_i$ = the total calculated lateral shear force in story *i-th*; and $P_i$ = the total gravity load (i.e. dead plus likely live load) at story *i-th*.

Satyarno (2010) explained that in general there are two concrete actions that can be done in order to mitigate the effects of an earthquake, namely the implemented evaluation for the vulnerability of buildings and reduction measures. Evaluation of seismicity can be made by 2 phases, which are Rapid Visual Screening (FEMA 154, 2002) and continued with a detailed seismic evaluation (FEMA 310, 1998). If the rapid visual evaluation decided that the buildings are vulnerable to earthquakes, then the buildings will be evaluated in detail by using the FEMA 310 procedure.

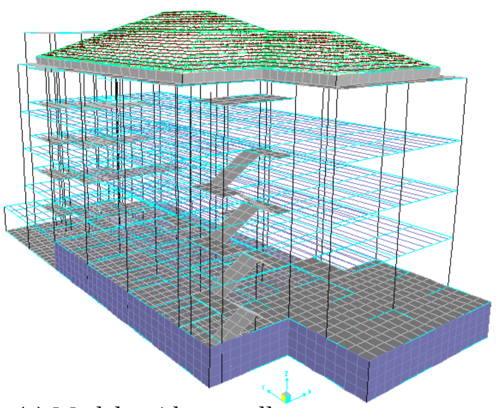
There are three phases (tiers) of evaluation required in FEMA 310, namely is a screening phase (Tier 1 Evaluation), the evaluation phase (Tier 2 Evaluation) and more detailed evaluation (Tier 3 Evaluation). Determination of the building performance to the effects of load can be done at a more detailed evaluation or Tier 3 Evaluation. The analysis that is commonly used is the nonlinear static analysis or pushover analysis.

## RESULTS AND DISCUSSION

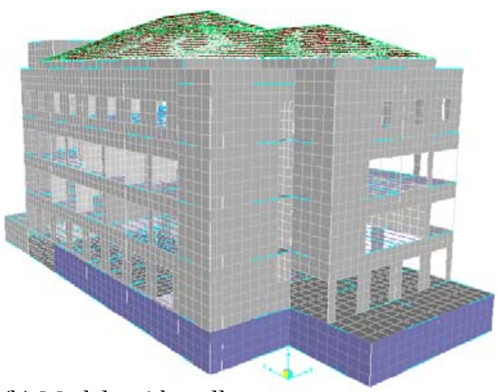
### A. Research Methods

Preliminary evaluation is conducted by the Rapid Visual Screening by FEMA 154 (2002). The results of this analysis are then compared with the cut-off score, which is an estimate of the probability that the building will collapse if ground motions occur that equal or exceed the maximum considered earthquake ground motions, and the value is equal to 2. If a building is scored more than 2, then the building is considered to have sufficient ability to resist earthquake load. Conversely if the score is less than 2, then the building should be further evaluated because it is considered vulnerable to earthquakes.

Further evaluation is the Evaluation of Tier 2 performed by FEMA 310 (1998). In this study, the Evaluation of Tier 2 performed two analyses, namely: (1) linear static analysis, using static equivalent seismic load calculated based on the SNI 1726-2002, and (2) linear dynamic analysis, where the use of dynamic earthquake load is a response spectrum earthquake load in accordance with SNI 1726-2002 for Region of Seismicity-4 with the type of soil medium. The building structure is modeled by SAP2000 and created in 2 models, i.e. the Models with wall (MD) and the Models without wall (MTD), where the modeling results can be seen in Figure 2. The structure loads refers to the SNI 03-1727-1989. Effect of seismic loading in SAP2000 modeling is given in 3-way loading, i.e. in 0° direction (X axis or north-south direction), 45° direction (diagonal axis direction of the building structure) and 90° direction (Y axis or east-west direction). The earthquake loads on the main direction is considered effective to 100%, while the effectiveness in a direction perpendicular to the main direction is considered only 30%. The strength of structural elements is calculated with SNI 2847-2002 and Response-2000. The results of analysis, i.e. internal forces in structural elements, will be compared with the capacity of these elements. The result of this comparison is referred to as Demand Capacity Ratio (DCR), which is the magnitude and distribution of inelastic demands for existing and added primary elements and components. If the DCR value obtained is greater than 2.0, this means that there is deficiency in the structural elements that need to proceed to the Evaluation of Tier 3 or detailed evaluation phase.



(a) Models without wall



(b) Models with wall

Figure 2. Structure modeling results with SAP2000

Determination of the structural performance levels can be done at the Evaluation of Tier 3. The analysis used was the pushover analysis and only performed on the Model without walls. Lateral pushover load is determined from the nominal static equivalent seismic load. Plastic hinges for beam and column elements in SAP2000 defined manually. Type of displacement control parameter is a moment-curvature parameter, where the values are determined from the analysis of Response-2000. The length of plastic hinge was defined as half of the element height. Earthquake response spectrum parameters are determined based on the SNI 1726-2002, which used two response spectrum parameters, namely Response Spectrum for Region of Seismicity-3 and for Region of Seismicity-4. Performance point is determined by Capacity Spectrum Method based on ATC-40 (1996), which is built-in in the SAP2000 Program. The performance level of the building is determined by drift ratio criteria that are required by FEMA 356 (2000) as well as ATC-40 (1996).

B. Results of Rapid Visual Screening

Some of the information obtained about the IRD RSUP Dr. Sardjito building are as follows: there are 5 floors and 1 basement, building height is 24.65 m, building floor area is about 4,410 $m^2$, occupancy class for the building is for emergency services, and occupancy load is 1-100 person/$ft^2$. There are two kinds of lateral load bearing system on the building structure, i.e. Concrete Moment Resisting Frames (C1) and Concrete Frames with Unreinforced Masonry infill Walls (C3). From the calculation, the final score for type C1 = 0.3 < 2, and type C3 = -0.7 < 2, where a value of 2 is a cut-off score specified in FEMA 154 (2002). Because the final score obtained is less than the value of the cut-off score, the building needs to be evaluated in the next phase.

C. The Evaluation Results of Tier 1

In the Evaluation of Tier 1, the results of quick check showed that the structural components have not some requirements set in FEMA 310 (1998). From the checklist of structures and nonstructural components it is also concluded that some components of structure and nonstructure do not meet the requirements (non-compliant, NC). Therefore, the building needs to be evaluated in the next phase, i.e. to the Evaluation of Tier 2.

D. The Evaluation Results of Tier 2

In the Evaluation of Tier 2, the static equivalent seismic load is calculated based on the SNI 1726-2002, and the pattern of load distribution produced by forming a proportional distribution pattern. From the modal analysis results it is obtained that the natural period of building for Model without wall is 0.59 seconds and the frequency is 1.69 Hz, and the natural period for Model without wall is 1.29 seconds and the frequency is 0.77 Hz. From the calculation of Demand Capacity Ratio (DCR) to the elements of beam and column, both with linear static analysis and linear dynamic analysis, it is obtained that the elements with DCR values are > 2.0. This is a deficiency obtained in the Evaluation of Tier 2. Therefore, they need to be evaluated in the next phase, namely the Evaluation of Tier 3.

E. The Evaluation Results of Tier 3

From the resulting pushover curve for the direction-X at the Model without wall, it is obtained that the pushover analysis stopped at step 6, when the control point displacement reached 0.13 m and the base shear force of 11,421 kN. As for the direction-Y, the analysis stopped at step 5, when the control point displacement reached 0.23 m and the base shear force 12,738 kN (Figure 3).

Performance point is the intersection of the capacity spectrum curve and spectrum demand curve in the ADRS format. The capacity curve in the ADRS format and the performance point for Model without wall can be seen in Figure 4 for Region of Seismicity-4, and Figure 5 for Region of Seismicity-3. Performance point generated by Capacity Spectrum Method of ATC-40 (1996) is summarized in Table 3.

Structural performance levels were determined through structural-drift ratio criteria, which were acquired when the performance point is reached. Structural-drift ratio is calculated from the elevation of control point of displacement. Furthermore, the calculation results are shown in Table 4.

Table 3. Performance point generated by Capacity Spectrum Method of ATC-40 (1996)

| Structure model and the direction of pushover loading | Region of Seismi-city | *Performance Point* (ATC-40) | | | |
|---|---|---|---|---|---|
| | | $V_t$ (kN) | $D_t$ (m) | $S_a$ | $S_d$ |
| MTD - X | 4 | 1,177 | 0.121 | 0.211 | 0.097 |
| MTD - Y | 4 | 11,528 | 0.125 | 0.221 | 0.095 |
| MTD - X | 3 | 10,239 | 0.102 | 0.193 | 0.081 |
| MTD - Y | 3 | 10,787 | 0.104 | 0.207 | 0.079 |

From the structural-drift ratio that obtained in the table above, where the structural-drift ratio occurs is still less than 1%, it was concluded that the performance level of the structure is Immediate Occupancy (IO).

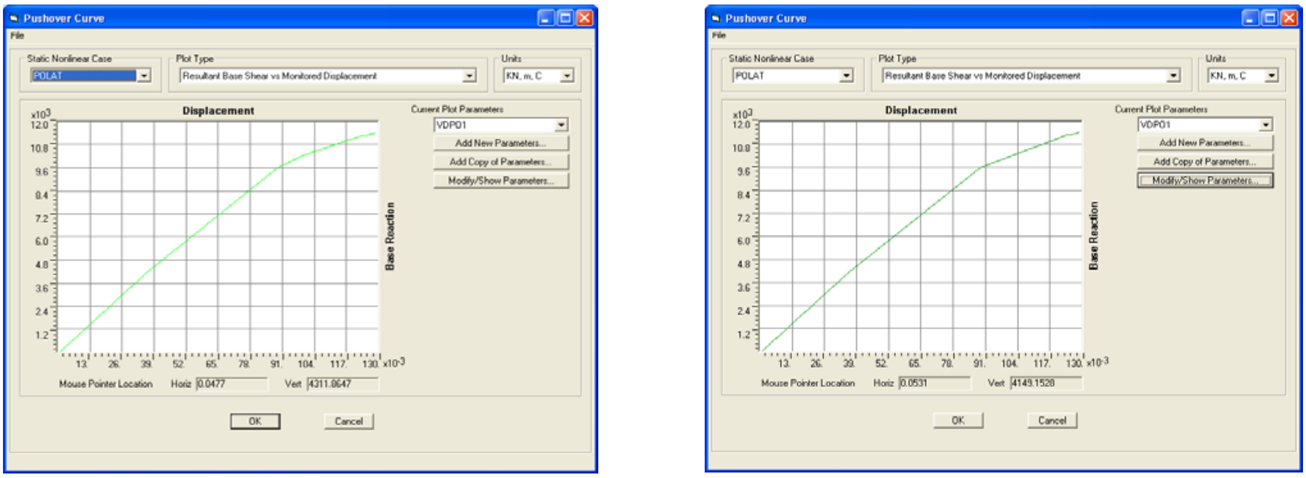
Table 4. Calculation of structural-drift ratio based on the displacement of control points

| Structure model and the direction of pushover loading | Region of Seismicity | Displacement of control points (m) | $D_t$ (m) | Structural drift Ratio (%) |
|---|---|---|---|---|
| MTD - X | 4 | 22.18 | 0.12 | 0.55 |
| MTD - Y | 4 | 22.18 | 0.13 | 0.56 |
| MTD - X | 3 | 22.18 | 0.10 | 0.46 |
| MTD - Y | 3 | 22.18 | 0.10 | 0.47 |

CONCLUSIONS

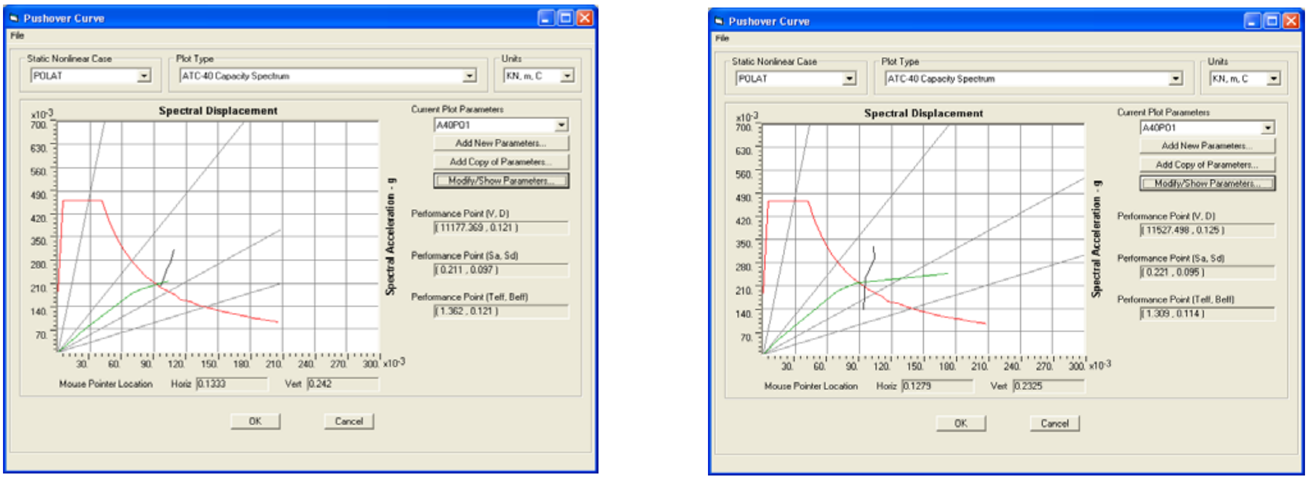
From the results of evaluations conducted on the IRD RSUP Dr. Sardjito building structures, we can conclude several things as follows:

1. Based on the Rapid Visual Screening Evaluation (RVS) in accordance with FEMA 154 (2002) it is obtained that the final score is less than 2.0. Therefore the building needs to be evaluated in detail according to the provisions of FEMA 310 (1998).
2. Based on a checklist and quick check conducted during Evaluation of Tier 1 (FEMA 310, 1998) for structure and nonstructural components, it is found that some components of the structure and nonstructure do not meet the requirements (or non-compliant, NC), so the building should be evaluated in the next phase,



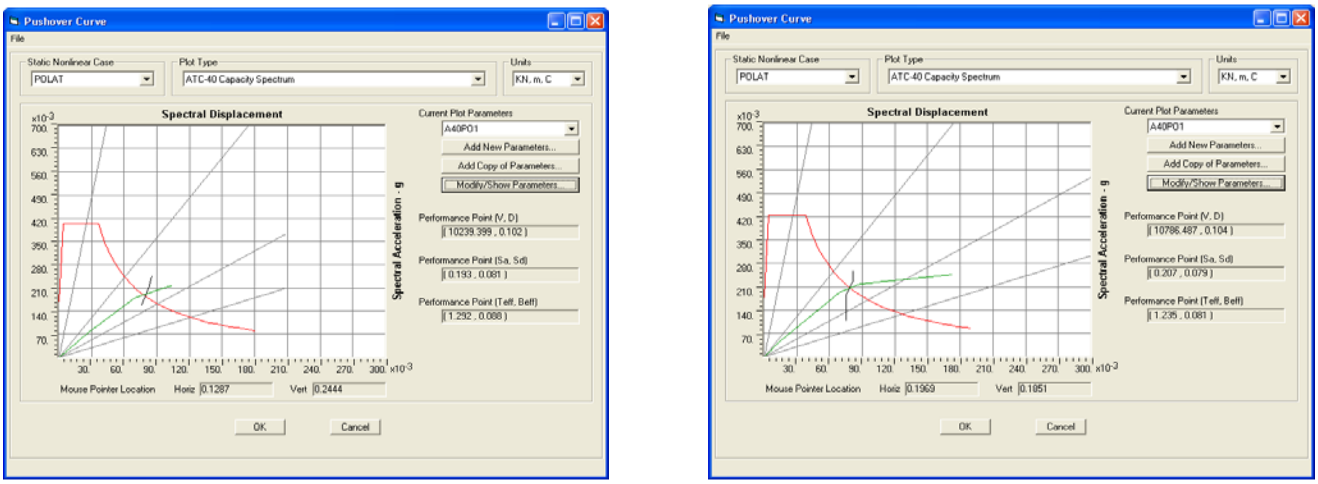

(a) Pushover curve for the direction-X (b) Pushover curve for the direction-Y

Figure 3. Pushover curve produced by SAP2000




(a) Performance point of direction-X (b) Performance point of direction-Y

Figure 4. Performance point in Region of Seismicity-4




(a) Performance point of direction-X (b) Performance point of direction-Y

Figure 5. Performance point in region of Seismicity-3

namely the Evaluation of Tier 2, which involves the linear analysis.

3. From the results of modal analysis it is obtained that the natural period for the Model with wall are 0.592 seconds and 1.687 Hz frequency, and the natural period for Model without wall of 1.291 seconds and 0.774 Hz frequency.
4. Based on the results of linear analysis (FEMA 310, 1998) using equivalent static analysis and dynamic response spectrum analysis, it is obtained the value of Demand Capacity Ratio (DCR) is greater than 2.0, so the analysis is needed in Tier 3 Evaluation (FEMA 310, 1998) by using nonlinear analysis procedures.
5. From the analysis using nonlinear pushover analysis and Capacity Spectrum Method (ATC-40, 1996), it is concluded that the structural-drift ratio that occurs is still smaller than the limit of structural-drift ratio as required by FEMA 356 (2000) and ATC-40 (1996) for level of Immediate Occupancy, which is 1.0%. Therefore, the structure level of performances for earthquake return period of 500 years is the Immediate Occupancy.

For the development of further research on evaluation of IRD RSUP Dr. Sardjito building structures, some recommendations are as follows:

1. The modeling of the building structures has not included nonstructural component in it. This is because the data of nonstructural component obtained is still limited. To produce a more accurate structure model, it is necessary to obtain more adequate data of nonstructural components.
2. Evaluation of Tier 3 (FEMA 310, 1996) is based on nonlinear static analysis. To get more accurate results, the evaluation can proceed with the additional nonlinear dynamic analysis.
3. Evaluation the performance of this structure should refer to some standards prevailing abroad. It is necessary to develop an evaluation method in accordance with the standards and conditions in Indonesia.

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