Performance Based Design of Hospital Building in Surabaya Under Variety Design Alternative Using SNI 1726-2019 – Case study: Redesign Building

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***Abstract*— Nowadays, at present time, the occurrence of regular earthquakes all over the world is turning into a significant problem. The structures that make up hospitals are among the most significant buildings in a living society because, in the event that a potentially dangerous scenario emerges, they help to serve as a caring and healing unit for the human population. A hospital building comprises three components: the structural component, the non-structural component, and the functional component. Each of these components can have an effect, either directly or indirectly, on the management and operation of the hospital building. Each time a natural or non-natural cause causes devastation and disaster, the globe suffers. In such cases, hospital buildings are vital in terms of treating victims and injured persons and housing those who lost their homes. Therefore, hospital facilities should be planned and constructed with enough stiffness and strength to resist disasters and serve as shelters or housing units afterward. This study analyses a hospital in the area of Surabaya, which was built using Indonesian standard provision SNI 1726-2012. Weak structural members of the hospital are identified. The analysis determined to study the behavior of hospital buildings when subjected to seismic forces using ETABS using current provision SNI 1726-2019. The investigation determined the effect of the lateral forces under P-delta effect on the hospital building. Two different conditions have been compared, e.g., the existing model and alternative configuration using the dual system method to determine the recommendation for the current building to resist seismic forces under the new regulation. As a result, the existing structure of the hospital building still meets the requirements, but to fill the condition in accordance with SNI 1726-2019, some modifications need to be improved.**

***Keywords*— Seismic assessment, hospital building, pushover analysis, retrofitting, ETABS**

I. INTRODUCTION

The behavior of the hospital building under seismic scenarios has currently been determined using a variety of approaches that have been created, updated, and used. The techniques provided the models for the analysis's purposes, which could provide discussions and results that are complex. The theories that are used mostly concentrate on reliability analysis, input-output analysis using the Leontief Model, etc [1]. In addition to these mathematics concepts, the World Health Organization (WHO), which promotes safe hospitals, has provided several recommendations for measuring natural hazards for the various nations of the world, including both developed and developing nations [2].

A process for risk mitigation techniques is established based on the references set in the scope of regulations prescribed in internationally recognized codal provisions for seismic action on existing buildings such as FEMA 356 [3-4], SNI 1726-2012 [5] and SNI 1726-2019 [6]. The following steps are involved in developing a risk reduction strategy for key buildings:

1. Building Typological Data Analysis
2. Assessing structural vulnerability and risk levels in buildings,
3. Determination of strengthening actions against the seismic environment, as well as cost analysis,
4. Making a plan that will be utilized to define priorities after the earthquake.
5. Choosing a suitable policy that results in a gradual and rapid recovery.

Due to the importance parameter of hospital building which is expected to support an important function as a public facility, the assessment and redesign of hospital building is urgently needed. The structure was firstly build using SNI 1726-2012 [5] which is no longer viable. The evaluation is conducted under rapid visual screening method according to the FEMA [3-4] and then remodel using ETABS to identify capacity in accordance with SNI 1726-2019 [6]. This study majorly fills with the basis evaluation starting from preliminary design followed by trial and error identifying the dimensions of structure [7], [8]. After that, a new alternative structure proposed to this study to compare the differences between existing model and new model after some modifications in accordance with the newest code.

A hospital is comprised of multiple distinct components, which define the levels and services delivered. As noted previously, the components include personnel, medical facilities, etc. After the hospital building has been subjected to earthquake pressures, all available resources must be utilized to restore the hospital's operation as quickly as possible so that it can treat victims of the natural disaster. As is readily apparent, the endpoint of the entire rescue chain is the hospital infrastructure, which is not only one of the most crucial aspects of the medical

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response to earthquakes but also provides shelters for those who lost their houses during an earthquake. Consequently, it is required to conduct a simple, rapid, and reliable risk assessment of the natural disaster's influence on hospital structure [9–11].

Considered to be one of the most significant structures, hospitals must be created with care to withstand the effects of any natural disaster. Each hospital component must be engineered to endure both vertical and lateral forces. The sample of the existing structural system of the hospital building is 8 stories within 1 basement using moment resisting frame design using SNI 1726-2012 [5]. Under investigation study, when it is analyzed using new regulation code SNI 1726-2019 [6], the structure's performance showed a significant deviation, especially to the function of the structural section. The existing building no longer meets the requirements.

The research performs to re-identify the hospital building using the new code SNI 1726-2019. Based on the criteria, a dual system structure is considered to be applied in the new modeling to support the criteria of the new regulation under seismic scenario as per SNI 1726-2019, considering the important factor of the hospital building. In this matter, the shear wall is considered to be added as the additional support of the dual system compared to the existing model.

II. LITERATURE REVIEW

Based on SNI 2847-2019 [12], the construction of high-rise building structures in areas with high earthquake risk needs to be considered for the presence of lateral forces acting on the structure. Earthquakes that occur not infrequently result in casualties and damage to materially detrimental infrastructure. What needs to be considered in the planning of high-rise buildings is the magnitude of the earthquake style received by the building structure [1], [13]. The strong force of such earthquakes is basically influenced by the following:

1. Characteristics of the earthquake that occurred
2. Soil characteristics of building sites
3. Characteristics of building structures

To be able to withstand the earthquake force, buildings need to use the right structural system. The structural system is a combination of various structural elements arranged to form a unified structure so that it can carry the planned load [14-15]. According to SNI 2847-2019 [12], the earthquake force retention system is a structural part designed to withstand earthquake forces that have been planned and required in accordance with the provisions and load combinations. The basic structural systems of earthquake load bearing are generally distinguished into (1) Moment resisting frames and (2) Structural Wall Systems.

Lateral Force-Resisting System In Hospital Buildings

Every structure must be planned and built to withstand horizontal and lateral loads. Several methods exist for bracing structures against lateral and horizontal forces. Stiffening is installed perpendicular to the potential force's direction. Because forces can occur from any direction, stiffening is frequently built in every direction [16–19] .

Moment frames and shear walls are two types of bracing that are utilized in reinforced concrete hospital buildings most of the time to resist lateral stresses. These are the vertical elements that carry lateral loads such as wind, seismic forces, and stability forces to the base of the building via floor or roof diaphragms. They lend a hand in preventing a structure from being blown over or falling. The illustration of the resisting frame system can be seen in Figure 1.

Moment frames or vertical frames made of reinforced moment frames often have thigh confinement in the joint of beams and columns that make up the structure. Normally, the plate, join of beam and column set in monolete as the concrete pouring implied in the same way.

The frames have a greater degree of adaptability than constructions with shear walls and brace frames. Because of the flexural strength (bending) and continuity of the frame's beams and columns, the frame is able to resist lateral loads thanks to the rigid connection points. As a result, moments are transferred from beams to columns at the connection points. It is impossible for a moment frame to move laterally without the beams or columns becoming deformed [20].


Moment frame Shear walls

Figure 1. Two common types of lateral resisting system under reinforced concrete structure

Moment frames have a variety of applications in both single-story and multi-story commercial buildings, but their primary use is in low-rise structures. Moment frames permit wider apertures and smaller wall sections while yet carrying essential loads and resisting diverse stresses. A typical application for MRF is normally to take place in massive building entrances, walls with large openings and parking that is concealed beneath the structure [20].

In accordance with the regulation code, moment frames used in seismically active regions must have pre-qualified connections or, in some situations, be confirmed through testing. In addition, they must be able to bear inelastic deformations and a particular inter-story drift angle.

Different from the moment frame, shear wall support is a member that resists cracking through the in-plane shear, such as earthquake movement allowing ground movement inside the building to shift floor diaphragms. Shear walls resist this movement and convey the forces to the foundation or diaphragm. It's a vertical beam that resists lateral forces. Shear walls stretch a building's foundation to its roof. Seismic zones are also safe.

Shear walls determine a building's strength and stiffness. Positioning encompasses the building's border or the centre encasing an elevator shaft or stairwell. The shear core is the latter in the shape of a rectangle, L-shape, and C-shape. Coupled shear walls normally have holes. The shear wall works as a wall section, while the slabs above and below the openings distribute the weight. Regularly, buildings have symmetrical shear walls to make a balance movement. Concrete, masonry, or timber framing are common shear wall materials. Shear walls are essential in medium to high-rise buildings in windy or seismic locations. Shear walls surround many homes.

III. METHOD

In this analysis, ETABS is used to evaluate the structural capacity. As per SNI 1726-2012, the existing building model followed the actual conditions. This means special conditions due to earthquake regulations pay attention to this code. The model is then stated as model control under the existing structure. The analysis used at the beginning of the investigation is static non-linear analysis evaluation for the earthquake analysis. Also, while modeling the structure after preliminary analysis using ETABS, specific considerations must be inputted as per SNI 1726-2012. Then after the design classification is finished, the dynamic analysis method in accordance with earthquake response under response spectrum analysis is approached.

After the existing model completed, the second stage modeling analysis performed following SNI 1726-2019. The same conditions parameter was followed and then continued to be investigated under a dual system structure. Before running the modeling, a similar consideration is applied using static non-linear analysis in the first place and then taken into account under the dynamic analysis approach. Following SNI 03-1726-2019, a dual system with a particular moment-bearing frame capable of withstanding at least 25% of the earthquake force set with a particular reinforced shear wall has a value of Response Modification Coefficient (R) = 7; System Strong Factor (Ω_0) = 2.5; and Deflection Enlargement Factor (Cd) = 5.5.

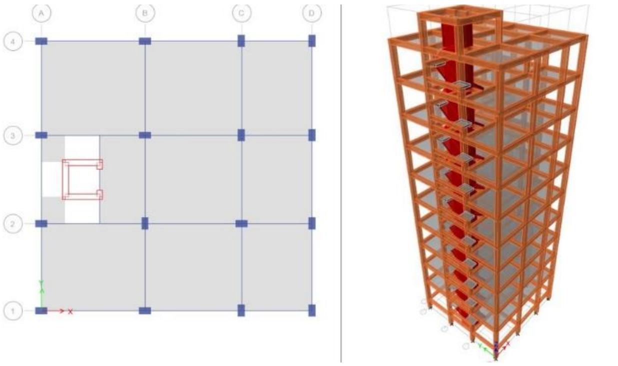
In addition, to steady the effect of ductility, hinge formation is also applied for the beam and column. The step to identify modeling using ETABS are illustrated as follows; (1) Inputted coordinate model and dimension, (2) Applied loading, (3) Control section ratio, (4) Run an analysis, (5) Updated modeling (if necessary), (6) Re-control section ratio, (7) Advance loading conditions, (8) Advance run analysis, (9) Design control, (10) Evaluation. The illustration of the loading under the hospital building can be seen in Table 1.

The step of loading needs to be adapted to evaluate the mistake. When evaluation process begins, then assigning modal source is necessary. For assigning the modal, a combination of the loading is required. The primary objective of identifying the modal source is to identify the various failure modes of a certain structure. This is considered the initial phase of the analysis, during which the loads and mode source are set, and the analysis is then done to identify any potential warnings. One may also examine the overlapping conditions of any property, such as overlapping slabs during definition or inadvertently giving two beams at one point. This viable condition needs to be clarified to mitigate the error.

After the warning is affirmative and it is determined that there is no error, the deformed shape of the structure under the various specified load situations can be readily observed. After completing the modal analysis, we may determine the various modes in which a structure can behave before to its complete failure. Additionally, the modal frequency, circular frequency, and period of each mode are readily apparent. Next, the P – Delta effect must be evaluated. The P-Delta effect describes the relationship between the load applied to a structural member and the displacement generated by that load. The deflection is the lateral displacement in either the x or y direction, or in both. Typically, these lateral displacements are accounted for by considering wind forces or seismic waves. There are three forms of iteration in the P – Delta analysis: 1. No Iteration, 2. Mass Iteration, and 3. Mass Iteration Factor.

TABLE 1.
GENERAL DETAILS OF HOSPITAL BUILDINGS MODEL

Structural member	Information
Overall plan	35 m x 16 m
Storey	8 storey 1 basement
Type of structure	Multi – storey rigid joint
Grade of concrete	f'c 35 MPa
Grade of steel	BJ 41
Slab	110 mm, 130 mm, 200 mm
Column	700 x 700 mm 450 x 450 mm
Beam	450 x 700 mm 450 x 600 mm 400 x 600 mm 300 x 550 mm



(a) (b)

Figure 2. Illustration of the hospital building; (a) site plan perspective, (b) 3D view perspective

IV. RESULTS AND DISCUSSION

After the load is applied considering the existing structural dimension, the mass participation for *x* and *y* direction need to be achieved to 100% for each step. Mass participation considered only in one iteration. This iteration followed the identification in accordance to Newton Raphson method. Then ahead of the calculation, fundamental period analysis is carried out. The result is presented in Table 2. Furthermore, the base shear and displacement of each step can also be taken to see the fully behavior of each model design. The evaluation of base shear both in *x* and *y* direction can be seen in Table 3.

The value taken to identify the base shear reaction followed specification under gravitational analysis. While defining gravity load, consider the result of P-delta analysis. Further, evaluation of inter story drift under various configurations both in *x* and *y* axis can be seen in Figure 3 and Figure 4. Where P-delta effect presented in Figure 5 and Figure 6.

TABLE 2.
FUNDAMENTAL PERIOD UNDER CONSIDERATION DESIGN IN ACCORDANCE WITH THE SNI 1726 – 2012 AND SNI 1726 – 2019

Structure design	**SNI 1726-2012**				**SNI 1726-2019**			
	T_a	**T_{str}**	**$T_a.C_u$**	**T_{use}**	**T_a**	**T_{str}**	**$T_a.C_u$**	**T_{use}**
Existing-1	1.24	1.228	1.735	1.24	-	-	-	-
Existing-2	-	-	-	-	1.24	1.228	1.735	1.24

Configuration-1	-	-	-	-	0.751	0.723	1.052	0.751
Configuration-2	-	-	-	-	0.751	0.709	1.052	0.751
Configuration-3	-	-	-	-	0.751	0.702	1.052	0.751

TABLE 3.
BASE SHEAR REACTION AND SHEAR WALL REACTION

Structure design	Base shear reaction		Shear wall reaction		Regulation used code
	x	*y*	*x*	*y*	
Existing-1	3.081	3.031	-	-	SNI 1726-2012
Existing-2	3.645	3.587	-	-	SNI 1726-2019
Configuration-1	4.862	4.696	17,31	14,11	SNI 1726-2019
Configuration-2	4.814	4.678	17,15	14,11	SNI 1726-2019
Configuration-3	4.884	4.684	18,25	14,44	SNI 1726-2019

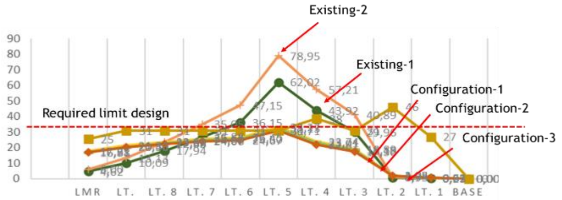


Figure 3. Inter story drift under various configurations design – *x*-axis

Following the seismic reinforcement of the hospital building using the aforementioned regulation design, the following maximum building displacement is recorded where all models meet the required limit design which is under 4 cm both in *x* and *y* direction. After redesign the hospital building with various configuration sections, it was determined that the magnitude of the maximum displacement decreased significantly. For primary structural sections, the *x*-direction maximum displacement is reduced by nearly 50 percent, while the *y*-direction maximum displacement is reduced by close to 60 percent.

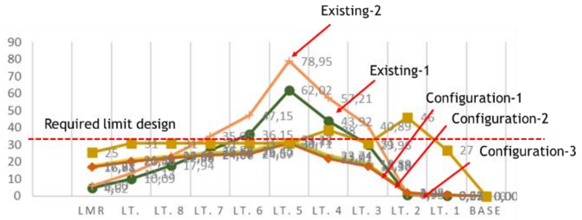


Figure 4. Inter story drift under various configurations design – *y* axis

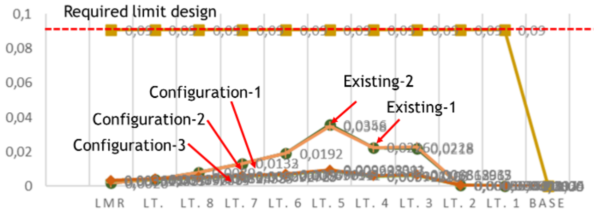


Figure 5. P-delta behaviour in *x* axis

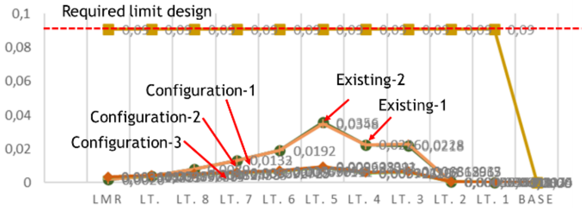


Figure 6. P-delta behaviour in *y* axis

V. CONCLUSION

Hospital structures are regarded as among the most essential structures in society. Therefore, they must be constructed to withstand all possible combinations of loads. In accordance with the design method, new regulation of code must be followed which is transferred from SNI 1726-2012 to SNI 1726-2019. In order to see the performance, the modification must be maintained. In this hospital building assessment, an existing hospital structure is studied concerning seismic forces. The frame with the lowest strength was identified. The alternative design is examined under different types of structures. With an overall reduction of maximum displacement under the new design code respectively, close to 50% and 60% in both of *x* and *y* directions. Inter story drift is also informed to reduce compared to the existing model, which less than 4 cm. As a result, the existing structure of the hospital building still meets the requirements, but to fill the condition in accordance with SNI 1726-2019, some modifications need to be improved.

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