

COMPARISON OF THE REINFORCED CONCRETE BUILDING STRUCTURE WITH A CONVENTIONAL CONCRETE FLOOR PLATE AND KALSI FLOOR PLATE

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ABSTRACT

One option for the reduced weight of building structures is the structure of a reinforced concrete building using KALSI floor plates. The floor plate, which usually uses conventional concrete, can be replaced with a 20 mm thick KALSI floor product (Kalsi floor 20). In this research conducted an analysis of the behavior of the structure of the reinforced concrete building by using conventional concrete floor plate and Kalsi floor 20. The structure of the building model in this research is a four-story building structure and is designed following the regulation of SNI 2012. The evaluation of seismic behavior following the earthquake regulation of SNI 2013 is conducted by applying push load analysis (pushover analysis) using SAP 2000 software. The results of the study indicate the model drift ratio of concrete floor plate structure is smaller than the structure of the KALSI floor plate. The pushover analysis results show the level of performance of all structural models according to FEMA-356 / ATC-40 able to provide nonlinear behavior which is indicated by the initial phase of the majority of plastic joints on beam elements and beam sway mechanism. The performance level of the structure with conventional concrete slab includes at immediate occupancy level, while the performance level of the structure with with kalsi floor plate includes at life safety level.

Keywords: Reinforced Concrete, Building Structure, Kalsi.

INTRODUCTION

In line with the development of construction technology in Indonesia, it is marked by the growing and development of high-rise buildings, requiring practitioners in the construction sector to have adequate skills in planning high-rise buildings. Therefore, proper planning in a building is essential for practitioners to pay attention to, especially with earthquake-resistant designs. Earthquake resistant building planning uses non-linear static analysis (pushover analysis) to determine the behaviour of structures due to large earthquakes. Pushover analysis is a performance-based design that aims to find the capacity of a structure. The basis of this pushover analysis is simple, namely by giving a load pattern in the lateral direction at the centre of mass of each floor of a building. The additional load will be increased gradually until the

collapse of the structural element is achieved because there are plastic hinges in the beam or column elements, or it reaches a specific displacement target.

The development of building materials technology greatly affects the creation of new ideas or ideas in the field of construction. One of them is by creating a Kalsi board. Some possible applications of the use of Kalsi are for walls, listplank even for the floor (Kalsi floor). KalsiFloor 20 is a floor covering fibre cement board with a thickness of 20 mm which is used for indoor applications in homes, apartments and public buildings with large loads.

KalsiFloor 20 is applied by attaching KalsiScrew FL screws to the steel frame (the design is adjusted to live load and other parameters). KalsiFloor 20 can also be used for mezzanines, additional rooms and others with faster construction preparation.

On a 600 x 1200 mm module, the KalsiFloor 20 installation can withstand even loads of up to 800 Kg (Eternit Gresik, PT. (2012). The application of Kalsi floor 20 is displayed in Figure 1 to 2.



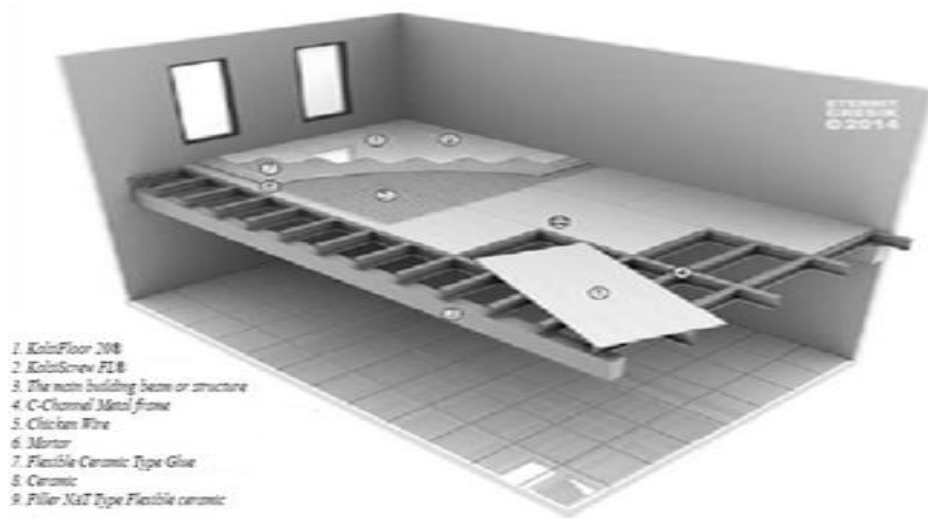
Figure 1. Warehouse building



Figure 2. Library building

The advantages of using KalsiFloor 20 are lighter load structures, secure installation system, clean, flexible and earthquake resistant. If it is used for floors with large loads, KalsiFloor 20 must be coated with cement mortar and chicken wire before covering it with ceramic, vinyl floor mats, parquet to prevent friction and collisions (Fig 3).

Reinforced concrete building structures using Kalsi floor slabs (Kalsi floor) is an option to reduce the weight of the overall building structure. With the reduction in weight of the structure, the overall behaviour of the structure also changes.



(a)



(b)

Figure 3. How to install a kalsi floor

Planning earthquake-resistant buildings are now common using performance-based building planning or performance-based design. According to Oktopianto & Andayani (2013), a performance-based plan can provide information to the extent an earthquake affects the structure. Since the beginning of the building owners, planners and users get information about how the

building behaves when there is an earthquake. Dewobroto (2005) also argues that performance-based earthquake-resistant planning is a process that can be used for planning new buildings and upgrading existing buildings.

The pushover nonlinear static analysis is one of the performance-based design components, which is the means to calculate the capacity of a structure. The basis of the pushover analysis is straightforward, which is to provide specific static load patterns in the lateral direction that are gradually increased in a structure until the structure reaches a particular target of displacement or achieve a specified pattern of collapse. From the results of the analysis can be known as fundamental shear-style values for absolute roof floor displacement. The acquired values then mapped into a capacity curve of the structure of the. Besides that, pushover analysis can also show the behaviour of the structure in the moment of elastic conditions, plastic, and until the collapse of the structural elements visually. Pushover analysis can be used as an earthquake-resistant planning tool that is still an approach since the behaviour of the earthquake is alternating through a specific cycle. In contrast, the pushover analysis is monotonic static (Mamesah et al., 2014). Although the basis of this analyst is straightforward, the information produced will be useful because it can describe the inelastic response of buildings when experiencing an earthquake.

Static Non-Linear Pushover Analysis

The first step in this analysis is to determine the capacity curve. The capacity curve is a curve that describes the capacity of a structure that is given lateral loads and then given a concentrated load on the roof, which is gradually increased to a defined deformation limit. The capacity curve is obtained by converting the displacement-base shear curve to the ADRS curve. Non-Linear Pushover Static Analysis Is a performance-based design that aims to find the capacity of a structure. Basically, the analysis is carried out by applying loads in the lateral direction whose value is increased gradually proportionally to the structure until it reaches the displacement target or reaches a mechanism on the verge of collapse due to the occurrence of plastic hinges in beam or column elements. The analysis procedure describes how to identify the structural elements that will experience failure first. As the load increases, other elements undergo melting and inelastic deformation.

1. Procedure A

In this procedure, it is carried out with the assistance spreadsheets as well as using the trial inside determine the coordinates of the point AY-DY, API-DPI which will be used as a performance point with using a specific formula. To change the capacity curve into spectral coordinates using the formula as the following:

$$S_2 = \frac{v}{\alpha_1} \dots \dots \dots (1)$$

$$S_d = \frac{\Delta_{roof}}{PF_1 \phi_{roof}} \dots \dots \dots (2)$$

Dengan :

$$\alpha_1 = \frac{\left[\sum_{i=1}^N \frac{w_i \phi_{1i}}{g} \right]^2}{\left[\sum_{i=1}^N \frac{w_i}{g} \right] \left[\sum_{i=1}^N \frac{w_i \phi_{1i}^2}{g} \right]} \dots \dots \dots (3)$$

$$PF_i = \frac{\sum_{i=1}^N \frac{w_i \phi_{1i}}{g}}{\sum_{i=1}^N \frac{w_i \phi_{1i}^2}{g}} \dots \dots \dots (4)$$

With:

Sa : Spectral Acceleration
Sd : Spectral Displacement
PF1 : Modal Participation Factor
 α_1 : Modal Mass Coefficient
 ϕ_{li} : Amplitude Of Mode Level 1
V : Base Shear
W : Gravity Load
 Δ_{roof} : Roof Displacement
 w_i/g : Mass At Level i

2. Procedure B

In this procedure, it is carried out with the help of the SAP 2000 program. The output produced from this program is in the form of performance point base shear-displacement, Sa-Sd, and Teff-Beff. Demand curves based on SNI 2847: 2013 and SNI 1726-2012 are plotted on the program and then produce a performance point when they intersect with the capacity curve of the pushover analysis that is carried out. In addition to generating performance points, this procedure also identifies the sequence of occurrence of plastic hinges in the building structure. This is when it is useful to control certain parts that are very weak and then hopefully it will be better planned so that the building structure has stronger resistance.

The result of the pushover analysis is a capacity curve depicting the relationship between the fundamental Shear forces (force) against the displacement of the reference point on the roof (deformation) shown in Figure 4. The nonlinear shaped curve shows an increase in post-elastic load up to plastic conditions. The pushover curve does not always reach the shape of the plastic, depending on the displacement target you want to achieve. The relative pushover analysis is conducted on the model of the structure with irregular classification because static loads are applied to the mass centre of each floor.

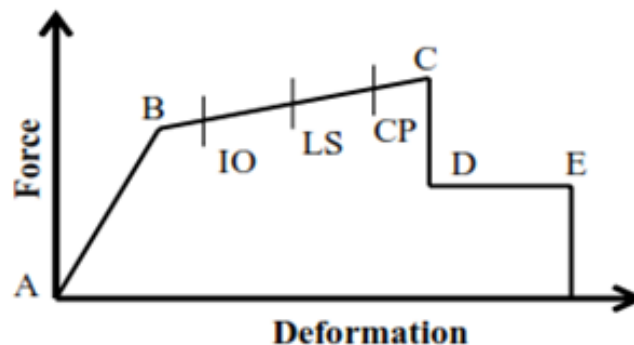


Figure. 4. Pushover Analysis Capacity Curve

The ATC-40 and FEMA-356 documents have made acceptable procedures and criteria for pushover analysis. This document defines the deformation criteria used in the pushover analysis, as shown in Figure 4. The five dots named A, B, C, D and E are used to define deformation behaviour in the plastic joints. Between points A and B, the structure of the elastic deformations during loading. At Point B, the first plastic joints begin to form similarly at points C and D. Between points B and C, the structure crosses the elastic boundary and starts deforming inelastic.

During this inelastic deformation, the ATC-40 and FEMA-356 define three structural conditions, i.e. IO = immediate occupancy (immediately usable), LS = Life safety, and CP =

collapse prevention (avoid total collapse). After inelastic deformation, the structure will enter the plastic state (D-E) until it reaches the failure. Some studies have been conducted before (Muntafi, 2012; Pranata 2006; Nurdianti, 2013; Laresi, 2017) by using pushover analysis can evaluate the performance of the buildings reviewed. From the analysis of such calculations obtained the performance point (target switching), which is an essential parameter for the evaluation of the performance of both structures included in IO, LS and CP.

Table 1. The degree of structural damage due to the formation of plastic joints in SAP 2000 program

Description	Symbol	Color	Explanation
B		Pink	Shows the linear boundary which is then followed by the first meeting of structures
IO		Dark blue	The occurrence of minor or meaningless damage to structures, structure stiffness is almost the same when there is no earthquake
LS		Blue Young	The damage occurred from a small to moderate level. Structure stiffness decreases but still has a considerable threshold against collapse.
CP		Green	Severe damage to the structure so that strength and rigours diminished much
C		Yellow	Maximum sliding style limits that are still able to hold buildings
D		Brown	The occurrence of sizeable structural strength degradation so that the condition is unstable and almost collapse.
E		Red	Structures have been unable to withstand shear forces and were destroyed.

Table 2. The deviation between floor permits

Structure		Risk categories		
		I/II	III	IV
1	Structures other than four-level brick sliding wall structures or less with interior walls, partitions, ceilings and exterior wall systems have been designed to accommodate between floor levels	$0.25h_{sx}$	$0.20h_{sx}$	$0.15h_{sx}$
2	Sliding wall brick cantilever structure	$0.10h_{sx}$	$0.10h_{sx}$	$0.10h_{sx}$
3	Other bricks sliding wall structure	$0.07h_{sx}$	$0.07h_{sx}$	$0.07h_{sx}$
4	All other structures	$0.20h_{sx}$	$0.15h_{sx}$	$0.10h_{sx}$

For building structures when receiving an earthquake load at a certain level or condition, there will be a plastic joint (hinge) on the beam of the building. A plastic joint is an inability form of the beam structure element, and the column withstands interior style. In SAP 2000, the level of damage structure due to the formation of the plastic joint is outlined in table 1. Planning a building should conform to the concept of a robust column design weak beam. If there is a

collapse of the structure, then the destruction is the is first. As some research has been done before (Wibowo and Febriana, 2016, Manalip et al., 2014, Oktopianto 2013, Mamesah et al., 2014) mentioned that the distribution of the plastic joint has been as expected, namely according to the robust column system of weak beams.

The research is to find out how the structure of the building structures conventional concrete floor plates and the floor plate of the KALSI using pushover analysis. In this study discussed changes in the behavior of structures between conventional structures with concrete floor plates compared to concrete structures of the KALSI floor plate. In addition to discussing the comparison of building structure behavior with conventional concrete floor plates and KALSI floor plates, it also discusses the performance of building structures against earthquakes using FEMA356 and ATC-40.

MATERIALS AND METHODS

In this study conducted an analysis of the behaviour of the structure of the reinforced concrete building by using conventional concrete floor plate and KALSI floor with pushover analysis. The seismic behavioural study is conducted with SAP 2000 (CSI,2013) which refers to the regulation of SNI 2847:2013, and Earthquake 1726:2013, SNI, method of displacement FEMA-356 and the capacity spectrum method of ATC-40 (FEMA-356, 2000; ASCE, 2000). The Model of the building structure is made four floors and symmetrical against the x-direction and y-direction. Each of the X and Y directions consists of three spans with a distance between six meters. The height of each floor – every 3.6 meters except for the level 1-2 is 4 meters tall. Modelling of the structure of structures for conventional concrete floor plates is shown in Figure 6 and for modelling of the construction of buildings with a KALSI floor plate shown in Figure 6.

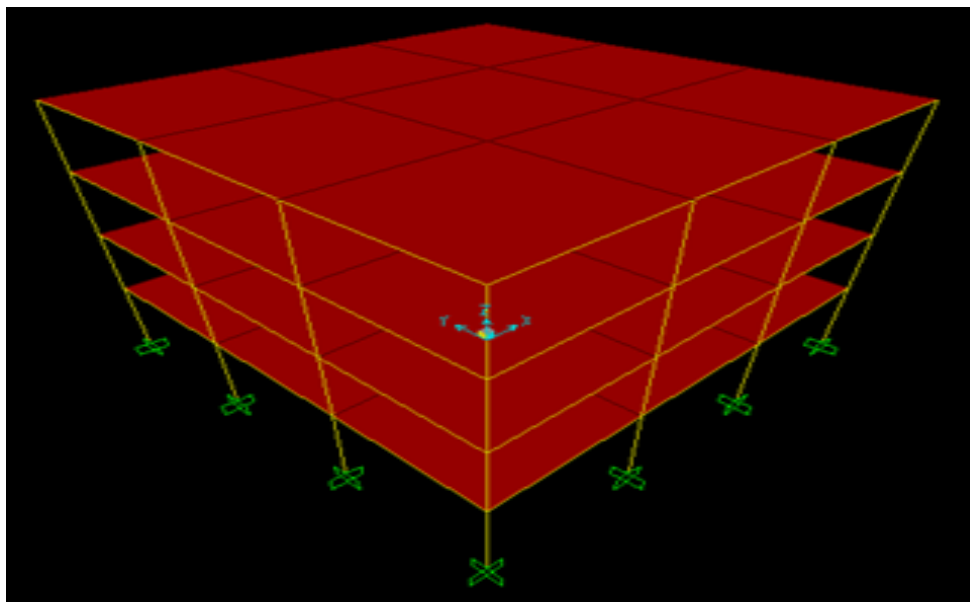


Figure 5. Modelling of 4-storey building structures with conventional concrete plates

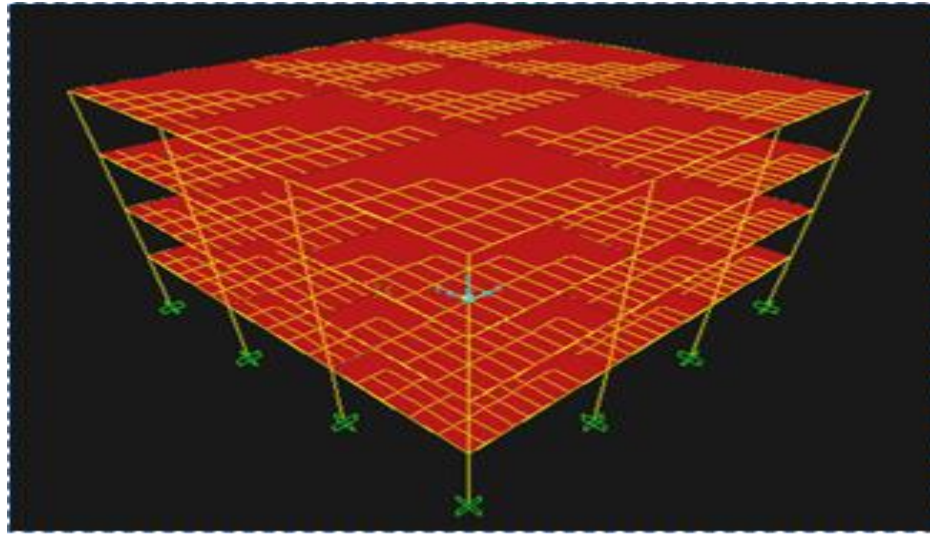


Fig. 6. Modelling of 4-storey building structures with a KALSI plate 20 (Kalsi floor 20)

RESULT AND DISCUSSION

Capacity Curve

Based on the pushover analysis with the SAP 2000 program acquired capacity curve. The following are displayed capacity curves of each type of structure. In Figure 7 and 8, each features a building capacity curve due to push-X on the building with a conventional concrete floor plate and a KALSI floor plate. The curves are shown only in the x-direction because buildings are symmetrical. From the capacity curves in Figures 5 and 6, the basic displacement and shear forces such as can be seen in Table 3.

Table 3. Necessary shifting and sliding styles

Building Type	Displacement U_1 (m)	Displacement U_2 (m)	Displacement U_3 (m)	Basic Max sliding style Kn
Conventional concrete plates	0,592	0,000	0,000	58,297
KALSI Floor Plate	1,000	0,000	0,000	59,465

Method Of Displacement Coefficient FEMA-356

From the results of the analysis with the SAP 2000 program obtained the FEMA-356 capacity curve that only reviews the direction of the X axis because the building is symmetrical. Performance points are derived from the intersection point between Bilinier Force curve (red line) most with capacity curve (green Line). Target displacement by method of displacement coefficient of each modeling is displayed in table 4.

Table 4. Target displacement with FEMA-356

Description	Building with floor plate type	
	Concrete Plates Conventional	KALSI Floor Plate
C_0	1.12	1.13
C_1	1.35	1.4
C_2	1	1
C_3	1	1
S_a	1,1	1.1
T_e	0.24	0.2
T_i	0.24	0.18
K_i	468.939,8	460.509
K_e		
Alpha	414.306,2	460.616
R	0	0.2
V_y	9.2	5.7
Weight	938.17	893.43
C_m	8.008.2	5.510.68
V	526.06	964.31
D	0.02	0.2

Capacity Spectrum Method ATC-40

From the SAP 2000 program, you can also see the ATC-40 capacity spectrum curve that only reviews x-axis direction as buildings are symmetrical. Performance points are obtained from the intersection point between demand spectra (blue line) with the capacity curve (green line). The capacity spectrum curve can be seen in Figure 7 and 8.

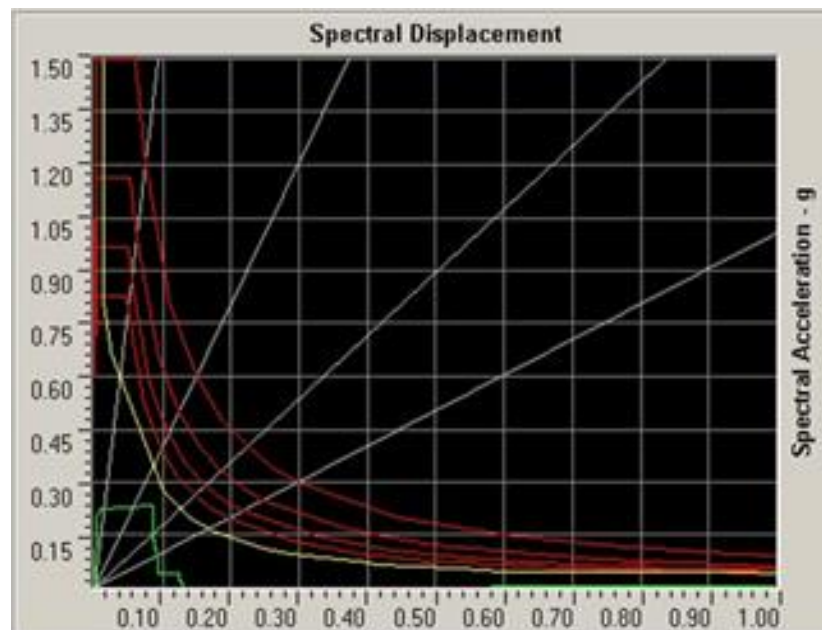


Figure 7. ATC-40 capacity spectrum due to Push-X on conventional concrete plates

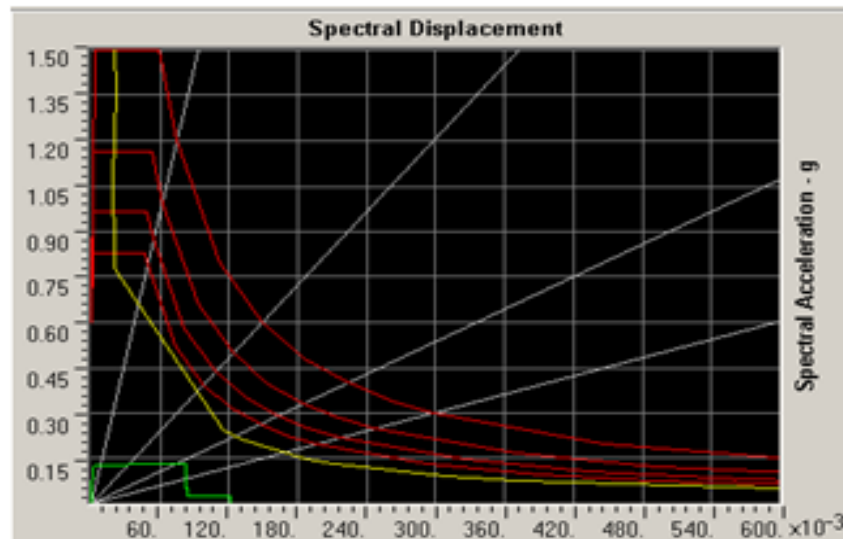


Figure 8. ATC-40 capacity spectrum due to push-X on the Kalsi plate

Drift Ratio

From the size of the known deformation, it can be calculated the magnitude of the drift ratio. For example, the calculation of the drift ratio estimated the size of the drift ratio that occurs in solid modelling due to the pushover load, as shown in table 5 and 6. The chart summary for each modelling is shown in Figure 9 and 10. From the results of the analysis, intersects between the maximum level of each modelling are for conventional concrete plates of 7.80 mm and the Kalsi plate of 27.00 mm. This value is still smaller than the value limit requirement of SNI 1726-2012, for the structure of the building with a height of fewer than four levels is $0,025 * HSX$ ($0,025 * 3600\text{mm} = 90 \text{ mm}$).

Table 5. Comparison of drift ratios for conventional concrete floor plates

Description	Conventional concrete floor plates				
Floor to	L_i (mm)	δ_i (mm)	$\delta_i \cdot C_d/I_e$	Δ_i (mm)	Rasio Δ_i/L_i
4	4.600	2.290	12.595	0.660	0.002
3	4.600	2.170	11.935	1.320	0.004
2	4.600	1.930	10.615	2.805	0.008
1	4.000	1.420	7.810	7.810	0.020

Table 6. Comparison of drift ratios for kalsi floor plates

Description	KALSI Floor Plate				
Floor to	L_i (mm)	δ_i (mm)	$\delta_i \cdot C_d/I_e$	Δ_i (mm)	Rasio Δ_i/L_i
4	4.600	9.140	50.270	1.645	0.005
3	4.600	8.841	48.626	5.506	0.015
2	4.600	7.840	43.120	16.115	0.045
1	4.000	4.910	27.005	27.005	0.068

Performance Levels And Mechanisms Of Plastic Joints

Based on the pushover analysis of the SAP 2000 program that has been shown in the image, the performance level for the structure of the building with reinforced concrete floor plates is at the IO level while the floor plate of the Kalsi is at the LS level. As for the mechanism of the plastic joint, it will be shown in figures 11 and 12 depicting the distribution pattern of the plastic fittings in each modelling of the structure of the building with the conventional concrete floor plates and the Kalsi floor plates in the x-axis direction.

Figure 9. Deviation of each model

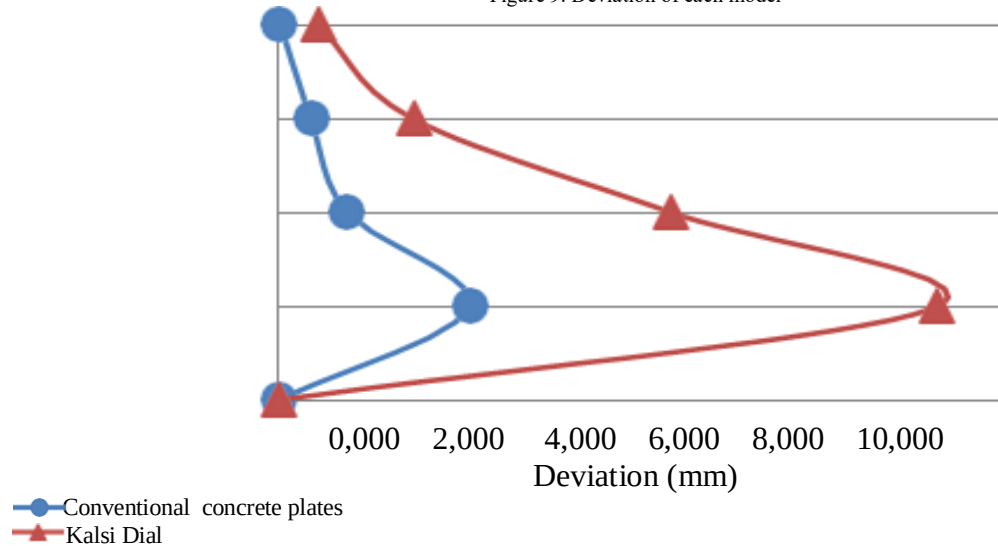
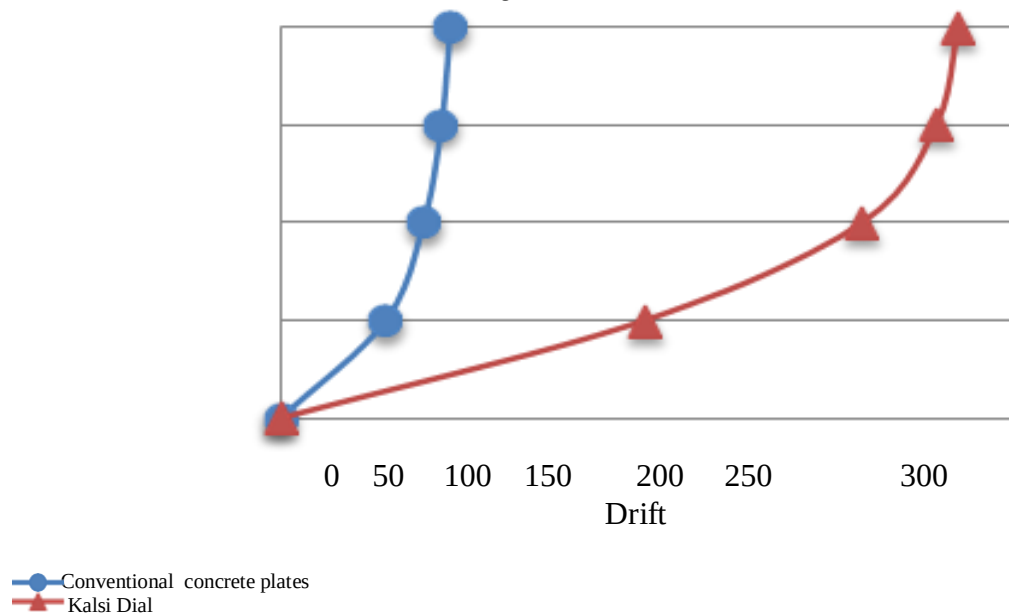


Figure 10. Drift ratio of each model



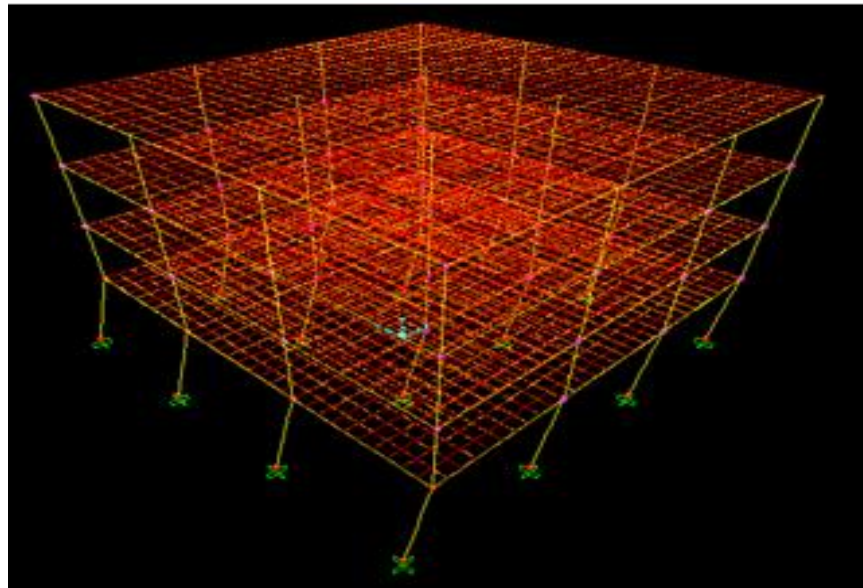


Figure 11. Distribution of plastic joints of building types with conventional concrete slabs (step 11)

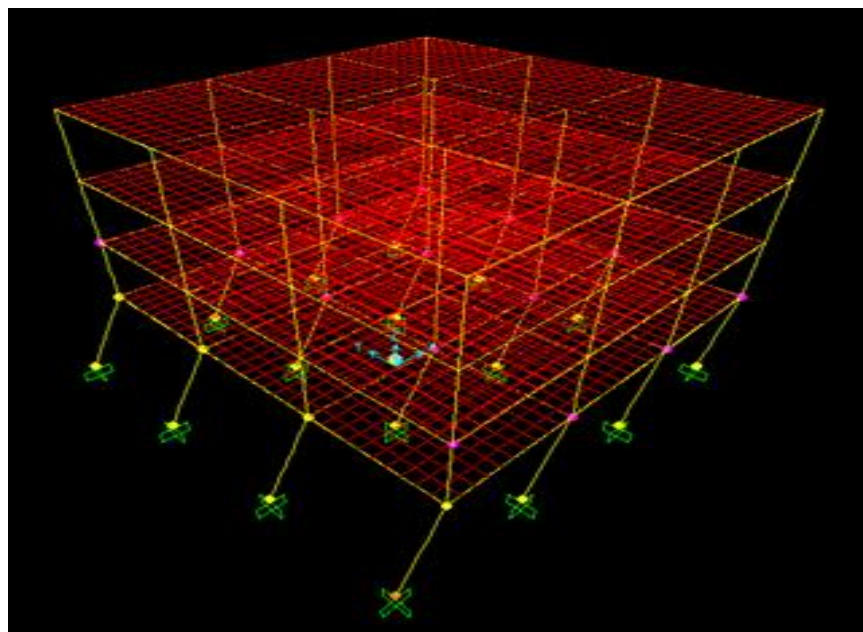


Figure 12. Distribution of plastic joints of building types with kalsi plates (step 27)

CONCLUSIONS

From the results of the analysis and discussion of 2 building slab modeling, namely with conventional concrete floor slabs and Kalsi floor plates, it can be concluded that in buildings with conventional concrete floor slabs, they have a maximum shear force of 58.297 kN, while in

buildings with Kalsi floor plates have a force value. Maximum shear 59,465 kN. The drift ratio for building structures with conventional concrete slabs is smaller than for buildings with Kalsi floor slabs. The maximum deviation that occurs before the collapse in each building meets the requirements according to SNI 1726-2013 regulations.

The structure performance level based on the displacement target of the capacity spectrum method of ATC40 and FEMA 356 shows that the building structure with conventional concrete floor slabs is at the IO level while the building structure with Kalsi floor plates is at the LS level. The distribution of the plastic hinge that occurs in each of the modeling is as expected, namely the strong column weak beam system because the beam collapses first and then the column is followed.

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