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Comparative Study of Open Frame Structure Modeling with Diagonal Bracing at the Integrated Laboratory of Institut Teknologi Kalimantan

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Abstract

Generally, brick wall (hebel) is considered as non-structural element, which never be counted to bear structural load. But, if carefully calculated, brick walls take part in structure load bearing. In the purpose of reducing the main structural element properties, the brick wall needs to be considered in bearing structural load. In this article, the brick walls modelled as compressive bracings. Using the structure analysis program, the model showed some significant differences in terms of internal force. From the analysis, the differences of moment, shear, axial and torsional force between open frame model (usual model, OF) and compressive bracing (CB) model were 38.17 kN.m; 58.03 kN; 181.75 kN dan 44.18 kN.m, respectively, where the first model had the bigger numbers than the latter model. Displacement of OF model was quite larger than CB model, with the value of difference was up to 85.35% for the X direction structures, and 70.83% for the Y direction. Final properties used for the design are smaller compared than original design, 30/60 to 40/60 for the beams, 50/50 for the columns with the different reinforcements 16-D22 for the second model compared to 20-D22 for the first one. The depth of slab on the second model was 180 mm, slightly smaller than the first model, 190 mm. It can be concluded that using compressive bracing model, structural properties of ITK Integrated Laboratory Building may greatly be reduced, compared to OF model.

Keywords: compressive bracing, displacement, infilled brick-wall, internal force, open frame.

Abstrak

Dinding bata pada saat perencanaan dianggap sebagai elemen non-struktural yang tidak diperhitungkan untuk memikul beban tetapi pada kenyataannya, dinding bata juga menyumbang kekuatan untuk memikul beban pada struktur tersebut. Untuk mengefisiensi dimensi pakai elemen utama seperti balok, kolom dan pelat serta mengetahui perbedaan gaya dalam, displacement dan dimensi penampang akhir maka dilakukan kajian untuk memodelkan struktur dengan dinding pengisi menggunakan model diagonal tekan. Hasil yang didapatkan ialah gaya momen, geser, aksial dan torsi model open frame (OF) lebih besar dibandingkan model diagonal tekan (DT) dengan selisih perbandingan berturut-turut sebesar 38.17 kNm , 58.03 kN , 181.75 kN dan 44.18 kNm. Nilai displacement model OF lebih besar dibandingkan model DT dengan selisih arah X untuk tingkat atap sebesar 85.35% dan arah Y sebesar 70.83%. Dimensi akhir penampang yang didapatkan pada model DT cenderung lebih kecil yaitu 30/60 dibandingkan model OF yaitu 40/60 pada elemen balok. Pada elemen kolom, dimensi DT adalah 50/50 dengan tulangan 16-D22 dan pada OF adalah 50/50 dengan tulangan 20-D22. Tebal pelat DT juga lebih kecil yaitu 180 mm dibandingkan model OF sebesar 190 mm. Dari hasil studi dapat disimpulkan, dengan menggunakan pemodelan struktur DT dapat mengefisiensi penampang pada struktur gedung Laboratorium Terpadu ITK dibandingkan dengan pemodelan OF.

Kata Kunci: diagonal tekan, dinding pengisi, gaya dalam, perpindahan, portal terbuka.

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1. Introduction

Institut Teknologi Kalimantan Integrated Laboratory Building is going to build using reinforced concrete structure. Reinforced concrete structure is one kind of structural type using combination of concrete and rebar material with the intention of bearing loads and forces (axial, shear and moment) of the building other building elements such as brick walls as a component to divide each space in the building according to their respective functions (Amalia, 2015) (Amalia et al. 2017). The planning of the building structure of the lab has not yet taken into account the infilled brick walls as one of the structural elements and is only considered as an architectural component.

Filling walls in buildings during planning are often considered as non-structural elements that are not included in the calculation of the structure and are considered as an evenly distributed load on the slabs and beams so that they are not planned and calculated as one of the components that bear the working loads on the building structure (Pujol et al., 2010).

Several past studies stating that reinforced concrete portals with infill walls affect the actual strength and stiffness of buildings, affected by lateral loads, and have a significant role in the overall building behavior such as being able to reduce displacement of structures, inter-story drifts and increase the stiffness of the building model and are influenced by the type of material used for the infilled wall. (Dorji, 2009) This proves that the structural behavior modeled as an open frame portal with structures with infill walls will be different (Abd-Elhamed et al., 2015).

The influence of the presence of infill walls in the portal structure model is also generally able to reduce the magnitude of the bending moment and shear forces that occur in column elements on the first floor of the building structure up to 2.7 times smaller than structures that are modeled as open portals without taking into account the presence of infill walls (Sankhla et al., 2016).

One analysis model commonly used in infill wall analysis is the equivalent compressive diagonal strut model. Modeling of the infill wall as an equivalent compressive diagonal strut is to model the wall as a solid round diagonal bracing with material characteristics similar to concrete material so that portals with infill walls will be considered as portals with bracing (Dewi, 2011).

This research was carried out by comparing the structure of the Lab building modeled as an open frame model with an equivalent diagonal strut compressive (reinforced frame with infill wall as diagonal bracing) model. Both of these models are chosen to compare the forces that occur in each type of structure, the amount of displacement and the final design of the cross section of the main structural components in each model.

The purpose of conducting a comparative study of modeling an open frame building structure with a diagonal model is to:

1. Compare the force values in moment, shear, axial and torque of the main structural elements (beams, columns and slabs) in each structural model.
2. Compare the value of displacement in each structure model.
3. Compare the final dimensions of the cross-section of the main structural elements (beams, columns and slabs) in each model

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2. Methods

Comparative study of open frame building structure construction with diagonal press using ITK Integrated Laboratory planning data in the form of floor plans and material data used. The following are the stages of the research methods carried out.

2.1. Literature Review

This stage is carried out to conduct a search and understanding of the literature relating to the analysis of infill wall structures. One of the literatures used to determine the bracing dimensions, while the reference structure planning refers to SNI 2847: 2013, SNI 1729: 2015, SNI 1726: 2015 2012 and SNI 1727: 2013.

2.2. Data Collection

The planning data used in this study are the structural plan, concrete compressive strength, steel reinforcement quality, compressive strength of hebel light brick material and structural steel quality.

2.3. Preliminary Design

Initial planning is carried out to determine the initial dimensions of beams, columns and slabs that will be modeled in the SAP2000 assist program. Calculation of initial dimensions refers to SNI 2847: 2013 for concrete elements and SNI 1729: 2015 for steel elements. The dimensions of the beam for a simple pedestal calculated using following equation:

$$h_{\min} = \frac{L}{16} \times \left(0,4 + \frac{f_y}{700}\right) \text{ and } b_{\min} = \frac{2}{3} \times h_{\min} \tag{1}$$

h_{min} = minimum height of beam (m);
L = beam span (m);
f_y = strength when rebar yields (MPa);
b_{min} = minimum width of beam (m).

The initial dimensions of the column cross-section can be determined using the following equation:

$$P = 0.1 \times A_g \times f_c' \tag{2}$$

P = load combination acting on column (N);
f_c' = concrete's compressive strength (MPa);
A_g = column cross-sectional area (mm^2).

The initial dimensions of the slab cross section can be determined using the following equation:

$$h_{\min} = \frac{L_n \left(0,8 + \frac{fy}{1500}\right)}{36 + 9\beta} \geq 90mm \tag{3}$$

h_{min} = minimum cross section thickness (mm);
L_n = the longest span of the slab (mm);
f_y = yielding strength of reinforcing steel (MPa);
β = ratio of the longest slab span and the shortest slab.

The diameter of the compressed bracing used as the wall fill equivalent can be calculated with the following equation (Dewi, 2011):

$$\lambda = \left(\frac{5}{4} + \frac{3}{2}v\right)\frac{W_b}{H_b} + \left(2 + \frac{7}{4}v\right)\frac{H_b}{W_b} + \left(2 + \frac{3}{2}v\right)\frac{H_b{}^3}{W_b{}^3} \quad (4)$$

$$L_d = \sqrt{W_b{}^2 + H_b{}^2} \quad (5)$$

$$\phi = \tan^{-1}\left(\frac{H_b}{W_b}\right) \quad (6)$$

$$A_d = \frac{L_d \times T_b}{\lambda \times \cos^2 \phi} \quad (7)$$

$$D = \sqrt{\frac{4 \times A_d}{\pi}} \quad (8)$$

λ = thickness coefficient diagonal determinant of compressive diameter;
W_b = width of filler wall (m);
H_b = height of filler wall (m);
v = poisson value of the hebel wall material filling ratio is 0.25 (Patre et al, 2016);
ϕ = angle formed between the infill wall and the columns and beams;
A_d = area of diagonal cross section of press bracing for circle;
D = diagonal cross section of press bracing (m).

2.4. Loads Analysis
This stage is carried out to determine the load acting on the structure in the form of dead load, live load and environmental burden in accordance with SNI 1727: 2013 and SNI 1726: 2012.

2.5. Structure Modelling and Analysis
Structural modeling is done using the SAP2000 assist program. The structural model made is an open frame model and a diagonal press model with a cross section that has been previously calculated. After being modeled, then the model is run to find out the value of the force in moment, shear, axial and torque as well as displacement.

2.6. Section and Reinforcement Design
This stage is carried out to plan the dimensions of the cross-section use and reinforcement requirements according to the force in the SAP2000 output results on the elements of columns, beams and reinforced concrete slabs.

2.7. Structure Evaluation and Analysis
This stage is carried out to check the nominal capacity of moments, shear, axial and torque with the conformity of the requirements in SNI 2847: 2013. The discussion is based on the results of the analysis and calculations that have been done.

2.8. Conclusion
Conclusions are drawn after modeling, calculation and analysis in accordance with the formulation of the problem presented.

The flow diagram of the stages of conducting a comparative study is shown in Figure 1 as follows:

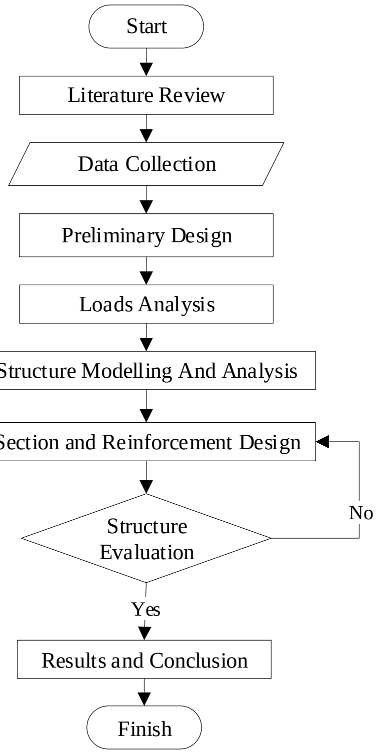


Figure 1: Research Process Flowchart

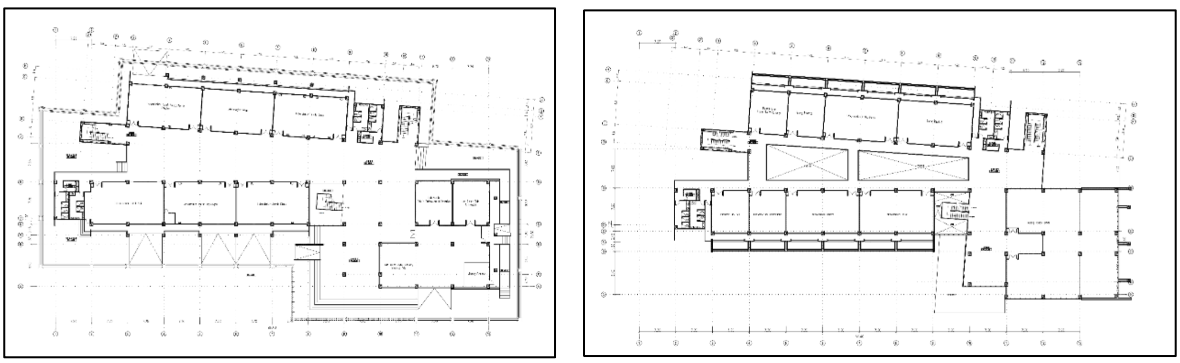
3. Result and discussion

3.1. General Data

General data used in this comparative study in the form of material characteristics and floor plans used are:

a. Steel grade : BJ-37 (f_y=240 MPa and f_u=370 MPa)
b. Concrete grade : K-300 (f'_c=24.9 MPa)
c. Deformed rebar : BJTD-39 (f_y=390 MPa)
d. Plain rebar : BJTP-24 (f_y=240 MPa)
e. Infilled wall type : lightweight brick hebel AAC
f. Hebel grade : 5 MPa
g. Building function : laboratory for campus building
h. Number of floors : 3 floors
i. Floor height : 4.25 meter

The structure plan used in this comparative study is shown in Figure 2:



(a) (b)

Figure 2: (a) First floor and (b) Second and third floor plan of ITK Integrated Lab

3.2. Preliminary Design

The cross section used in this comparative study is based on the results of preliminary design calculations. The cross-section recapitulation used for column, slab and beam elements is shown in Table 1, Table 2, and Table 3:

Table 1: Summary of coloumn dimension

No.	**Lantai**	**B (m)**	**H (m)**
A.	Exterior Column K1		
1.	1st Floor	0.55	0.55
2.	2nd Floor	0.45	0.45
3.	3rd Floor	0.20	0.20
B.	Exterior Column K2		
1.	1st Floor	0.70	0.70
2.	2nd Floor	0.55	0.55
3.	3rd Floor	0.25	0.25
C.	Interior Column K3		
1.	1st Floor	0.80	0.80
2.	2nd Floor	0.65	0.65
3.	3rd Floor	0.25	0.25

The cross-section used for beam elements based on preliminary design results is shown in the following table:

Table 2: Summary of beam dimension

No.	**Floor**	**Beam Type**	**Dimension (cm)**	
			B	**H**
1.	1st Floor	Primary Tie Beam X	30	50
		Primary Tie Beam Y	30	50
		Secondary Tie Beam X	30	50
		Secondary Tie Beam Y	30	50
		Tie Beam Alley	30	40
2.	2nd Floor and 3rd Floor	Main Beam X	30	50
		Main Beam Y	30	50
		Secondary Beam X	30	50
		Secondary Beam Y	30	50
		Cantilever Beam BC1	40	60
		Cantilever Beam BC2	20	30
		Listplank Beam	30	40
		Alley Beam	30	40
3.	Roof	Main Beam X	30	50
		Main Beam Y	30	50
		Secondary Beam X	30	50
		Secondary Beam Y	30	50
		Cantilever Beam BC1	50	70
		Cantilever Beam BC2	20	30
		Listplank Beam	30	40
		Alley Beam	30	40
		Ringbalk X	30	40
		Ringbalk Y	30	50

The cross-section thickness used for slab elements based on preliminary design results is shown in the following table:

Table 3: Summary of slab thickness dimensions

No.	Slab Type	Thickness
1.	Floor Slabs	120 mm
2.	Roof Slabs	100 mm

3.3. Loads Analysis

Loading analysis was carried out in accordance with SNI 1727: 2013 and SNI 1726: 2012. Dead load is a burden caused by the weight of the structure including SIDL (Super Imposed Dead Load). Dead load and SIDL acting on the structure are shown in the following table:

Table 4: Summary of dead loads and SIDL

No.	Dead Loads and SIDL	Unit Weight
1.	Reinforced Concrete	2400.0 kg/m^3
2.	Structural Steel	7850.0 kg/m^3
3.	Galvanum Roofing	10.0 kg/m^2
4.	Polycarbonate Roofing	1.7 kg/m^2
5.	Hebel Brick Distributed Load	115.6 kg/m^2
6.	Hebel AAC	550.0 kg/m^3
7.	Ceiling Hooks	7.0 kg/m^2
8.	Ceiling	11.0 kg/m^2
9.	Mechanical, Electrical and Plumbing	40.0 kg/m^2
10.	Concrete Rebate	21.0 kg/m^2
11.	Ceramics Tile	24.0 kg/m^2

Live workload caused by the function of each room and floor used is shown in Table 5:

Table 5: Summary of live loads

No.	Room	Loads Type SNI 1727:2013	Loading
1.	Roof	Roof Live Load	0.96 kN/m^2
2.	Auditorium	Stadium and arena/stands with chairs tied to the floor	4.79 kN/m^2
3.	Classroom	Classroom live load	1.92 kN/m^2
4.	Computer Laboratory	Computer room live load	4.79 kN/m^2
5.	Laboratory	Operating theaterand laboratory live load	2.87 kN/m^2
6.	*Lobby and* corridor	First floor corridor live load	4.79 kN/m^2
7.	Stairs	Stairs and exit	4.79 kN/m^2
8.	Stairs‘ Railing	Raling and stair handrail system	0.89 kN
9.	Balcony	Balcony and deck	1.5 (Service Load)
10.	Office room	Office space access floor system	2.40 kN/m^2
11.	*Lobby and* corridor	Corridor live load above first floor	3.83 kN/m^2

3.4. Structure Modeling

Structural modeling was modelled using the SAP2000 program. The elements being modeled were beams, columns and slabs. In this modeling, the infill wall was inserted as an even SIDL load on the beam. The results of the ITK Integrated Frame Laboratory open frame model in the SAP2000 assistance program according to the results of preliminary design calculations are shown in Figure 3:

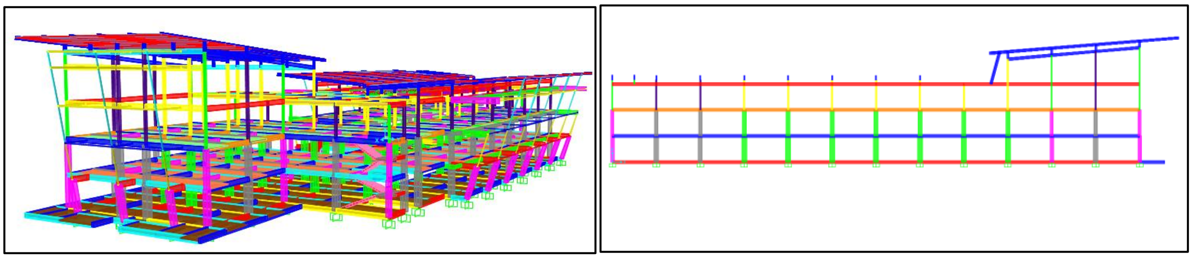


Figure 3: Modelling Open Frame in SAP2000

Structural modeling as a compressive bracing diagonal frame was calculated by assuming the fill wall functions as a diagonal press with similar lightweight concrete material with compressive strength and specific gravity following the characteristics of lightweight brick material. Examples of calculations to find the equivalent of a fill wall into a diagonal rod press for a wall with fill wall thickness, t = 150 mm, wall height, H = 4250 mm and wall width, W = 8400 mm as follows: for the equivalent wall fill constant was calculated as follows:

$$\lambda = \left(\frac{5}{4}+\frac{3}{2}(0,25)\right)\frac{8400}{4250}+\left(2+\frac{7}{4}(0,25)\right)\frac{4250}{8400}+\left(2+\frac{3}{2}(0,25)\right)\frac{4250^3}{8400^3}=4,39$$

Next, the length of the slope of the compressed diagonal bar and the angle formed were calculated by the following equation:

$$L_d=\sqrt{W_b{}^2+H_b{}^2}=\sqrt{8400^2+4250^2}=9413,95mm^2$$

$$\phi=\tan^{-1}\left(\frac{H_b}{W_b}\right)=\tan^{-1}\left(\frac{4250}{8400}\right)=26,83^\circ$$

The area of equivalent wall fill could be calculated with the following equation:

$$A_d=\frac{L_d T_b}{\lambda\cos^2\phi}=\frac{9413,95\times 150}{4,39\times\cos^2(26,83)}=403653mm^2$$

The dimensions of the bracing section were assumed to be circular, so the bracing diameter was calculated by the following equation and a bracing diameter on the wall is used with a value of 0.72 m.

$$D=\sqrt{\frac{4A_d}{\pi}}=\sqrt{\frac{4(403653)}{\pi}}=717,08mm=0,72m$$

With compressive strength f_m = 5 MPa, the modulus of elasticity of the light brick can be calculated according to the equation for the infill wall with the concrete constituent material as follows (Paulay and Priestley, 1992):

$$E_m=1000f'_m=1000\times 5=5000MPa$$

By using specific gravity of 550 kg / m^3 and Poisson ratio of 0.25, the AAC lightweight brick material can be defined in SAP2000 program for models with compressed diagonal shown in Figure 4.

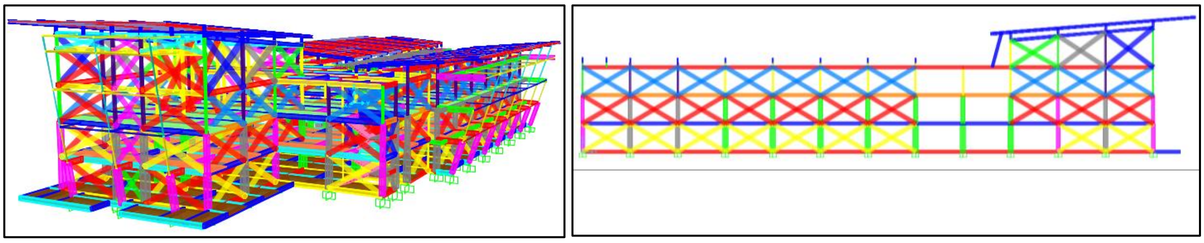


Figure 4: Modelling Compression Diagonal in SAP2000

3.5. Comparison of Internal Force and Section Design Beam Elements

The infill wall is a building component that is generally regarded as an architectural element that does not function to carry structural loads so that it is only modeled as an even load on the beam element. In this comparative study, the ITK Integrated Laboratory building structure modeling was carried out on the SAP2000 assistive program in two models, namely the open frame model and the building model with a filler wall as a diagonal bracing press equivalent. In general, the three models showed different results, both the results of internal force analysis, displacement of the structure (displacement) and also on the design of the main structure. Comparison of forces in moment, shear and torque on beam elements whose differences were relatively prominent as shown in Table 6 and Figure 5.

3.6. Comparison of Bending Moment and Torsion

From Table 6, it could be seen elements that have different bending moment styles that tend to be striking. As in the Transverse Main Beam on the 3rd Floor. The moment value on the open frame tended to be greater than the diagonal press value which is respectively -317.43 kN and -279.26 kN. This was according to the concept which states that the infill wall in the structural model can increase the structural stiffness and strength (Catagay et al., 2010) (Frapanti, 2018). The difference in force in this also resulted in differences in cross-sectional design and reinforcement design on the beam being reviewed. The cross section and reinforcement design for the Transverse Main Beams on the 3rd Floor in a row for each model are:

a. Open Frame (OF) model : 40/60 with reinforcements (5D22 dan 3D22)
b. Compressive Bracing (CB) model : 30/60 with reinforcements (5D22 dan 4D22)

Table 6: Comparison of internal force of beam element

No.	Element	OF M [kNm]	DT M [kNm]	OF V [kN]	DT V [kN]	OF T [kNm]	DT T [kNm]
A	**1st Floor**						
1	Prim. Tie Beam Y	-344.32	-319.71	258.16	-180.47	-45.61	-52.66
2	Sec. Tie Beam X	-384.94	-381.83	-171.09	-169.78	-61.68	-61.7
3	Tie Beam Alley	-94.89	-85.78	-76	-71.04	-31.7	-29.99
B	**2nd Floor**						
1	Main Beam X	-267.49	-247.25	-171.25	-157.45	75.51	55.54
2	Main Beam Y	-345.02	-340.56	234.49	192.07	-61.69	-62.36
3	Sec. Beam X	-108.61	-106.72	92.5	-85.33	-35.88	-19.58
4	Sec. Beam Y	-165.08	-136.17	-106.27	101.07	-34.81	-32.21
5	Listplank Beam	-43.9	-43.02	-40.25	-34.55	-130.88	-120.81
C	**3rd Floor**						
1	Main Beam X	-317.43	-279.26	201.55	175.74	-45.62	47.79
2	Main Beam Y	-381.36	-338.67	-250.86	-195.42	-78.57	-76.44
3	Listplank Beam	-47.15	-45.44	66.12	-35.34	-138.72	-126.11
D	**Roof**						
1	Main Beam X	-182.77	-172.86	108.13	103.87	64.66	54.98
2	Main Beam Y	-212.54	-185.58	102.97	122.96	38.76	29.17
3	Sec. Beam X	-104.2	-64.12	50.04	-37.55	-13.49	-11.1
4	Sec. Beam Y	-119.87	-105.83	-325.92	-267.89	-113.02	-68.84
5	Ringbalk Y	-161.73	-157.54	-101.39	-96.96	72.33	69.66

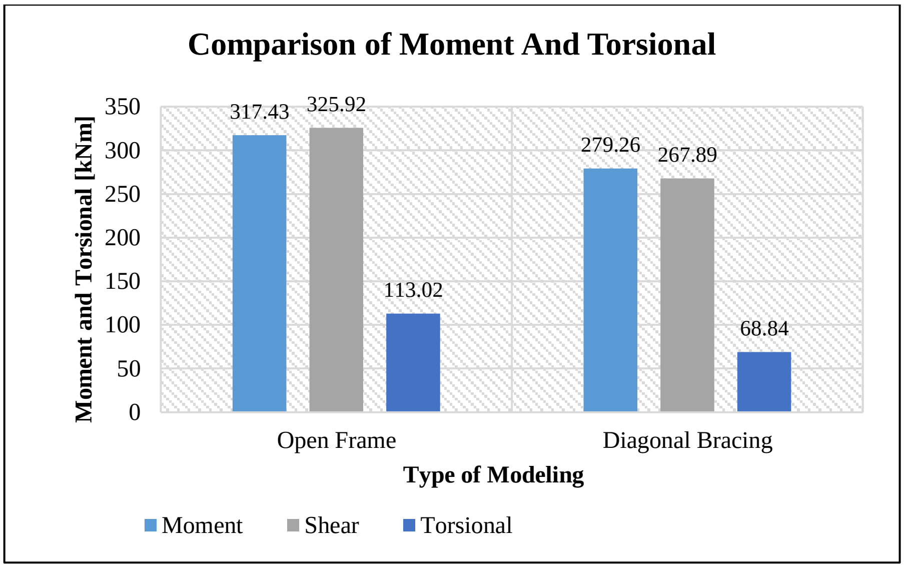


Figure 5: Comparison of Beam Elements' Internal Force

3.7. Comparison of Shear Force

From Figure 5, the elongated Secondary Beam element on the Roof Floor of the open frame model were larger, equals to -325.93 kN, whereas in the diagonal model the press was -267.89 kN. This proved that the infill wall also contributed to resist the shear forces that occur in the beam. The difference in shear force could also affect the design of the planned shear reinforcement on the beam so that it was more economical. In the review beam design, the difference was in the number of legs contained in the shear reinforcement as follows:

a. Open Frame (OF) model : 40/70 dimension, shear reinforcement (3Ø10-100)
b. Compressive Bracing (CB) model : 40/70 dimension, shear reinforcement (2Ø10-100)

3.8. Comparison of Torsional Force

Furthermore, the torque force that occurs in the beam also tended to have different values. The torque or torque moment on the beam often worked in tandem with the moment and also shear and in some planning, the effect of torque could be more decisive. From Table 6, relatively large differences occurred in the Secondary Roof Beams with an open frame value of -113.02 kNm and a diagonal press of -68.84 kNm. In this condition, the final cross-section design did not differ because the cross-sectional dimension provided can withstand both the torque value of the open frame and the compressive diagonal.

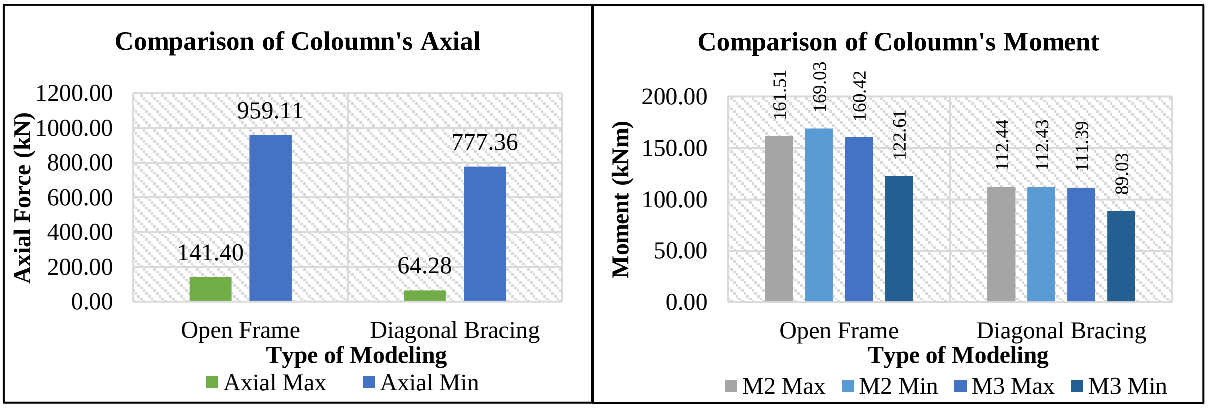
a. Open Frame (OF) model : 40/70 dimension, torsional reinforcement (3D22 and 3D22)
b. Compressive Bracing (CB) model : 40/70 dimension, torsional reinforcement (3D22 dan 3D22)

3.9. Comparison of Internal Force and Section Design Coloumn Element

Differences in force in and cross-section of columns taken review column K1 Floor 2 of the axial force and bending moment that occurred. From the two models, the smallest axial force was found in the diagonal compressive model while for the bending moment also on the diagonal compressive model shown in Table 7 and Figure 6 as follows:

Table 7: Comparison of column's internal force

K1 2^{nd} Floor		P	M2	M3
Open Frame	Max	141.40	161.51	160.42
	Min	-959.11	-169.03	-122.61
Diagonal Bracing	Max	64.28	112.44	111.39
	Min	-777.36	-112.43	-89.03



(a) Axial Force (b) Bending Moment

Figure 6: Comparison of Beam Elements' Internal Force

The difference in style in this affected the dimensions of the planned column because the design of the cross section and column reinforcement were influenced by the interaction between axial and bending moments. Dimension column K1 Floor 2 of each model:

a. Open Frame (OF) model : 50/50 dimension; reinforced with 20-D22 bar
b. Compressive Bracing (CB) model : 50/50 dimension; reinforced with 16-D22 bar

3.10. Comparison of Internal Force and Section Design Slab Element

On the slab elements, a slab review on the 2nd floor was taken for each model analyzed. The internal force compared to the slab element was the bending moment in the transverse direction (M11) and elongated slab (M22) as follows:

Table 8: Comparison of slab's internal force

2nd Floor Slab		M11	M22
Open Frame	Max	81.12	135.51
	Min	-28.03	-22.04
Diagonal Bracing	Max	75.41	126.74
	Min	-26.22	-21.72

Based on this table, the internal forces generated by the open frame model were the largest compared to the diagonal model of pressure both at the moment M11 for the X direction and M22 for the Y direction. Graphically, the comparison is shown in Figure 6.

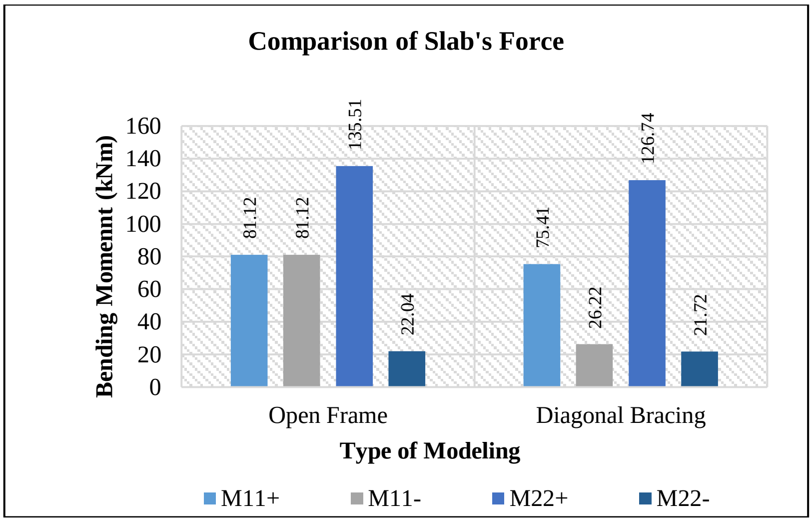


Figure 7: Comparison of Slab Elements' Internal Force

Because of the different internal forces, the thickness of the slabs and the need for reinforcement used also tend to be different. The different cross-sectional designs used as follows:

a. Open Frame Slabs' Design
   Slab thickness = 190 mm
   Reinforcement X = 4D16-300 and 10D16-100
   Reinforcement Y = 4D16-300 and 15D16-50
b. Diagonal Bracing Slab's Design
   Slab thickness = 180 mm
   Reinforcement X = 3D16-450 and 9D16-100
   Reinforcement Y = 3D16-450 and 15D16-50

3.11. Comparison of Structure's Displacement

In the comparative review of displacement in each model, the model using filler walls as diagonal bracing press had relatively smaller displacement compared to the open frame model without walls. This suggested that the presence of filler walls adds rigidity to the structure so that the behavior and performance of the structure are burdened by lateral loads such as wind loads and earthquake loads. The displacement value of the structure for the X direction and Y direction is shown in Table 9:

Table 9: Displacement value of each floor

Floor	Height	Open Frame	Diagonal Bracing	Open Frame	Diagonal Bracing
	[mm]	[mm]	[mm]	[mm]	[mm]
Roof	20700	151.29	22.17	130.60	38.12
3	8500	24.53	1.43	23.06	1.08
2	4250	7.04	0.94	9.83	1.77

In the X Direction for the roof floor, the displacement value of the open frame and diagonal compressive models were 151.29 mm and 22.16 mm, respectively. The difference of the magnitude of displacement in the direction of X on the model without a wall or open frame with the model using the wall as a diagonal equivalent to 85.35%. While the magnitude of the Y Direction for the roof floor, the displacement value of the open frame and diagonal press models were 130.60 mm and 38,118 mm, respectively. The difference in the magnitude of displacement in the direction of Y in the model without open frame walls with the model using the wall as a diagonal bracing equivalent to 70.83%. Graphically, the comparison is shown in Figure 7 and Figure 8:

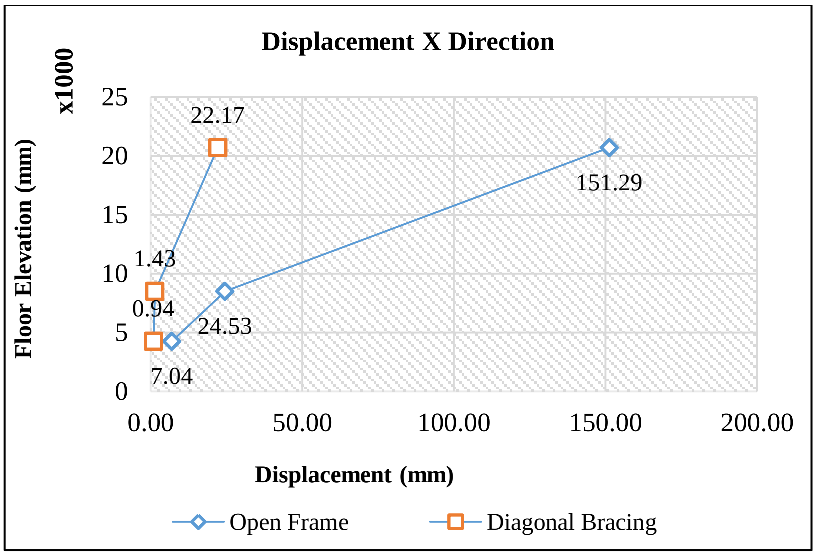


Figure 8: Structure Displacement on X Direction

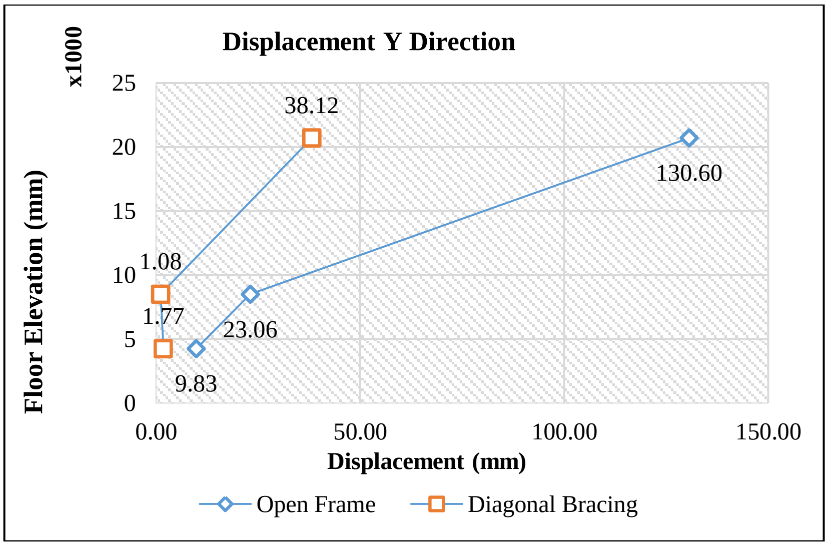


Figure 9: Structure Displacement on Y Direction

Based on the graph, it is clear that the presence of a filler wall reduces the value of displacement. This happens because the number of elements holding more lateral loads is the main structural components such as beams, columns and slabs coupled with the equivalent of the fill wall as a diagonal bracing press and evenly distributed to these elements.

4. Conclusion

Open Frame Structure Modeling with Diagonal Bracing at the Integrated Laboratory of ITK, it can be concluded that:

1. Internal force analysis shows that the moment, shear, axial and torque forces of the open frame model were greater than the compressed diagonal model with a difference of 38.17 kNm, 58.03 kN, 181.75 kN and 44.18 kNm respectively.
2. The displacement value of the open frame model was greater than the diagonal press model with the X direction difference for the roof level of 85.35% and Y direction of 70.83%.
3. The final dimension of the cross section found on the diagonal compressive model tended to be smaller that is 30/60 compared to the open frame model which is 40/60 on the beam element. In the column element, the diagonal dimensions of press were 50/50 with reinforcement 16-D22 and in open frame is 50/50 with reinforcement 20-D22. Thick diagonal slab press was also smaller that is 180 mm compared to the open frame model of 190 mm.

Overall, modeling the infill wall can have a positive impact on structural modeling so that the resulting cross section is more efficient than without a wall.

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