Journal of Advanced Sciences and Engineering Technologies (2026): 9(1)

DOI: https://doi.org/10.32441/jaset.9.1.2

Journal of Advanced Sciences and Engineering Technologies

www.jasetj.com

Journal of Advanced Sciences and Eng. Technologies

JASET

Dimension Effect due to Temperature Change with & without Expansion Joint

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Keywords:

Expansion joint; Lateral displacement; Reinforced concrete building; Shear force; Temperature change; Thermal load

Highlights:

- (ETABS 22.5) has used an essential tool for studying the behavior of complex structures.
- the building dimension (24mx50m), the shear force decreases when use expansion joint.
- the displacement decreases when use joint.

ARTICLE INFO

Article history:

Received	13 Jun	2026
Received in revised form	31 Jul	2026
Accepted	19 Aug	2026
Final Proofreading	23 Sep	2026
Available online	21 Oct	2026

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Abstract: The expansion joint is an important matter should be take care when constructed a building. There are many factors effect on the buildings due to expansion joins and thermal load. In the present study, two building with different dimension have been analysis (24mx50m) and (12mx30m). These building have and have not expansion joints, also the buildings subjected to two different values in thermal load (50°C) and (30°C). ETABS model have been used to analysis the model. The result shows all the building with expansion joints have displacement and shear force less than the building without expansion joint. Also the decrements in the dimension of building will increase the shear force and displacement with ratio 60%. When the difference in temperature decrease with difference building and with or without expansion joint the displacement about (60%-55.5%) and shear force about (61%-60%). Therefor using expansion joint led to reduce the shear force on column base and reduce lateral displacement on the roof of the building.

INTRODUCTION

Engineering structures are systems continuously subjected to a wide range of loads and environmental factors throughout their service life. These influences extend beyond dead loads, live loads, and forces resulting from wind and seismic activity to include thermal effects. Thermal effects play a significant role in determining a building's structural behavior, particularly in large-scale structures or those exposed to substantial daily and seasonal temperature fluctuations. The importance of studying thermal effects is especially pronounced in regions characterized by high summer temperatures and relatively low winter temperatures; continuous temperature changes can cause structural elements to expand and contract, thereby generating additional deformations and stresses if the structure's movement is partially or fully restrained.

The significance of thermal effects increases with the dimensions of the structure, as the magnitude of expansion or contraction is directly proportional to the element's original length. For instance, while the change in length of a short element due to a specific temperature difference may be negligible, this change can become much more pronounced in long-span structures or buildings with large horizontal footprints. Consequently, building dimensions are critical variables when analyzing thermal loads and effects; increasing a building's length or width can heighten the expected thermal movement, thereby increasing the likelihood of generating additional forces or stresses when that movement is restrained.

However, thermal expansion or contraction does not necessarily result in the generation of internal forces within the structural element. In the case of an element free to move, the change in length can occur without inducing significant thermal stress, as the element is permitted to move without restriction. When movement is restrained, thermal deformation is partially or entirely converted into internal stresses and forces within the structure. Consequently, two fundamental scenarios can be distinguished when analyzing thermal effects: the first involves a structure or element capable of moving freely, while the second involves movement restrained by structural or architectural components, or by connection conditions with foundations and adjacent elements.

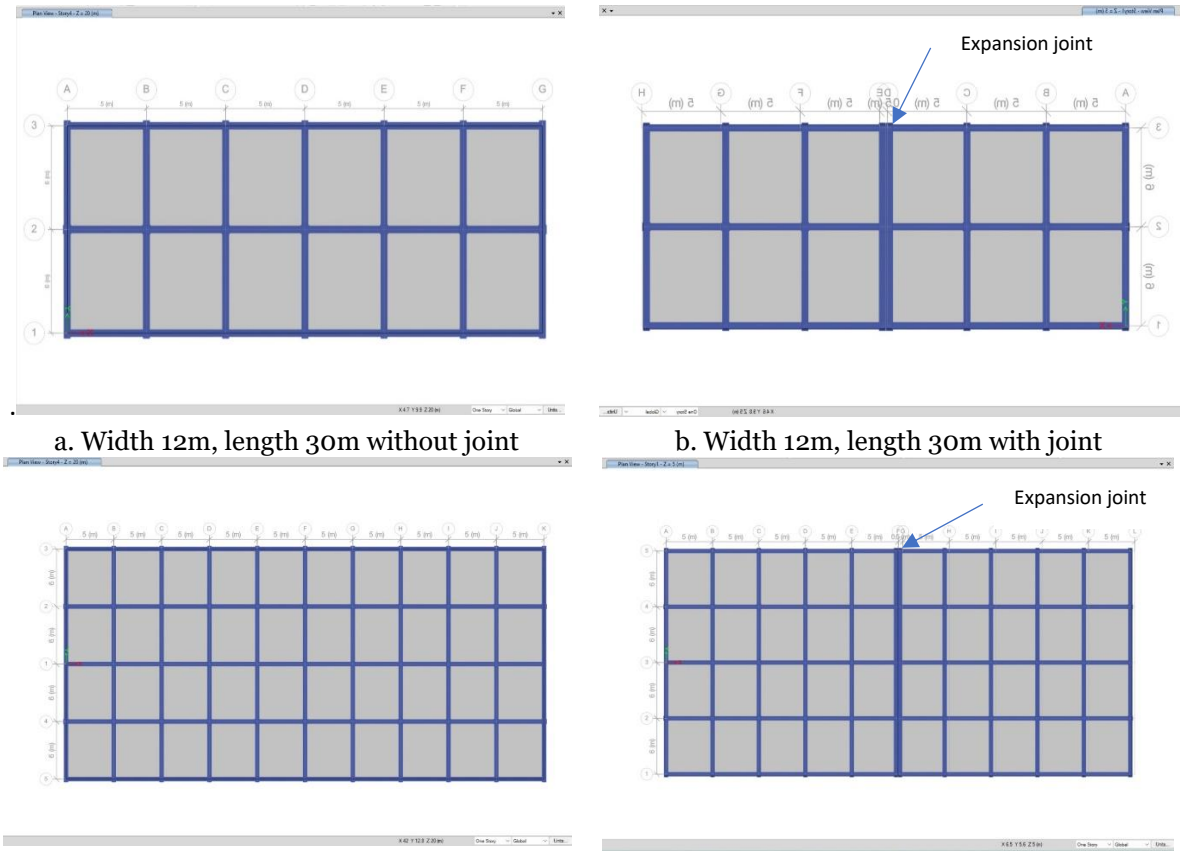
MODELING

Numerical structural analysis software (ETABS 22.5) has used an essential tool for studying the behavior of complex structures. Since ETABS is widely used for building modeling and analysis; it allows users to define the geometric and mechanical properties of structural elements, specify load cases, perform analyses, and extract various results.

Building Properties

Dimension of the Building

There are two building with dimension (12mx30m) and (24mx50m) have four story with and without expansion joint, for building with 12mx30m has two pays transversely with span length 6m and six pays longitudinally with span length 5m, but the building with 24mx50m has four pays transversely with span length 6m while the ten pays longitudinally with span length 5m as show in Fig. 1. The same two types of building have considered an expansion joint with space of 50mm at the middle of longitudinal dimension.



a. Width 12m, length 30m without joint
b. Width 12m, length 30m with joint
c. Width 24m, length 50m without joint
d. Width 24m, length 50m with joint

Fig. 1 Building classification

Material and Element Dimension

In this study adopted the properties of concrete and steel for columns, beams and slab and all members subject to a thermal load by two difference change ΔT (30°C, 50°C) as listed in Table 1.

Table 1 Properties of structural elements and applied thermal loads

Element	Dimension (mm)	Compressive Strength (MPa)	Yield Stress for Steel (MPa)	Temperature Change (ΔT) in Degrees Celsius
Column 1	500x500	35	420	30, 50
Column 2	400x600	35	420	30, 50
Beam	300x600	35	420	30, 50
Slab	Thickness=200	35	420	30, 50

Load Analysis

In the beginning all building have designed under dead load (2.5 kN/m²) and live load (4 kN/m²), the result shows this building withstand all applied load. It is noted that the effect of live and dead loads on displacement is almost negligible, but for shear force will effected due to negative bending moment so the values of shear force will be change randomly therefor the result will be Confusing as shown in Table (2). So, in present study will research only the effect of thermal load on displacement and shear force without considering the effect of live load and dead load, as shown in Fig. 2.

Table 2 shear force and displacement

Building dimension (m)	Temperature Change (ΔT) in Degrees Celsius	Combination load		Temperature load	
		Shear force (KN)	Displacement (mm)	Shear force (KN)	Displacement (mm)
12x30 with joint	30	25	2	18	2
12x30 with joint	50	36	4	30	3.6
12x30 without joint	30	44	4	38	4
12x30 without joint	50	69	7.2	62	7.2
24x50 with joint	30	37	3.2	30	3.2
24x50 with joint	50	58	6	50	6
24x50 without joint	30	74	7.2	63	7.2
24x50 without joint	50	116	12	105	12

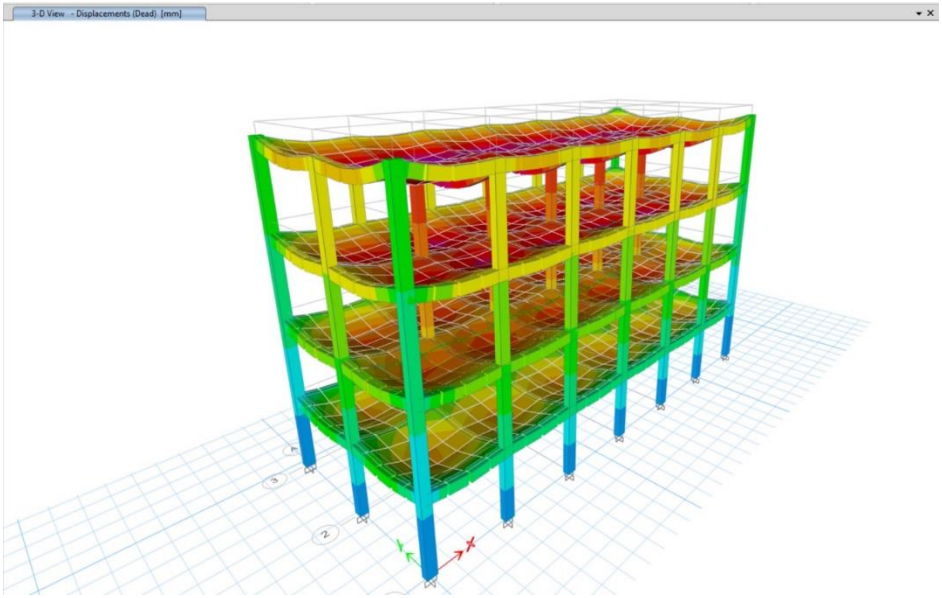


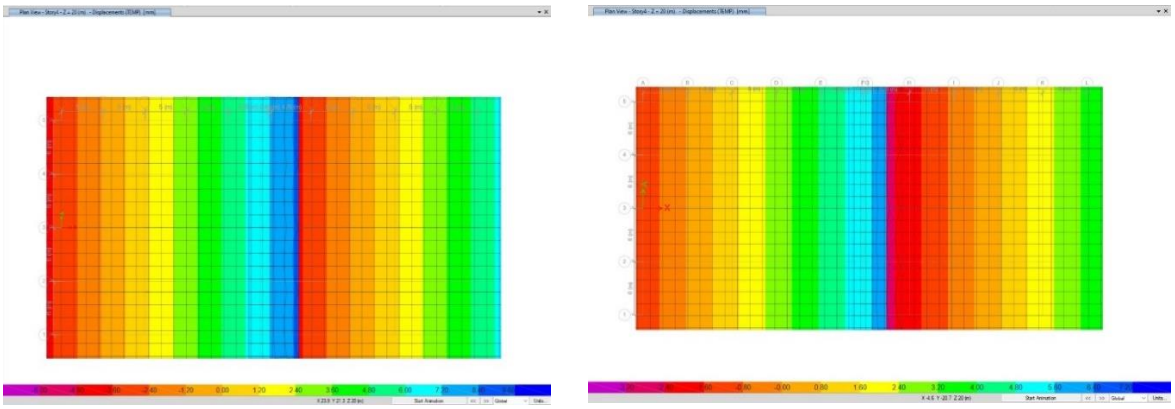
Fig. 2 3D ETABS model

ANALYSIS RESULTS

ETABS model result where adopted for displacement in 4th roof and shear force in columns bases. Since the expansion phenomena product due to thermal load this expansion makes a lateral deformation which supported on the members there by the lateral deformation causes additional lateral forces and then increase shear force. Therefor in present study will display the displacement and shear force.

Displacement Result

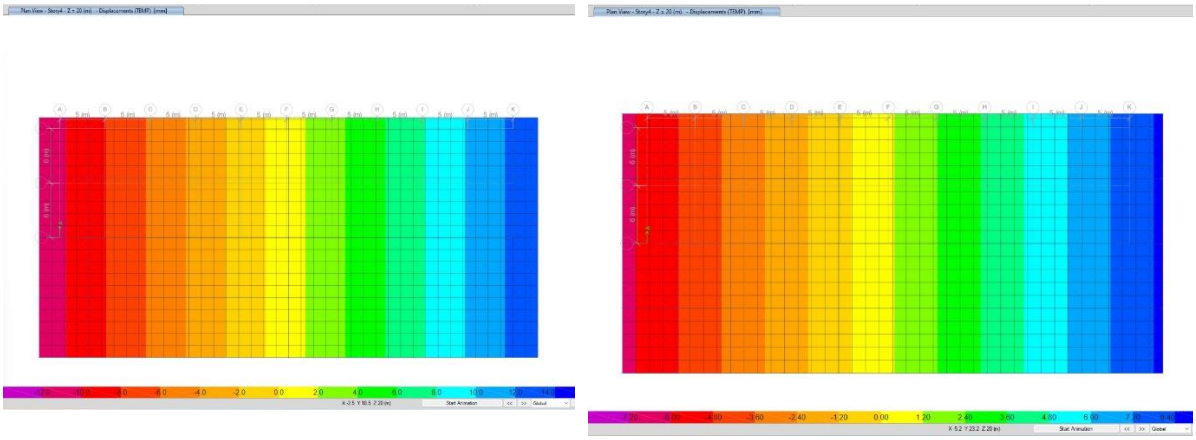
For the building with dimension (24mx50m) with expansion joint when the difference in temperature change conducted two values 50°C and 30°C, the result shows displacement of (6mm and 3.2mm) respectively, that mean the displacement proportion to the temperature as Fig. 3.



a. ΔT=50°C b. ΔT=30°C

Fig. 3 Displacement result for building 24x50m with expansion joint

While building without expansion joint for the same dimension (24mx50m) when the difference in temperature change conducted two values 50°C and 30°C, the result shows displacement of (12mm and 7.2mm) respectively, that mean the displacement proportion to the temperature linearly as Fig. 4.

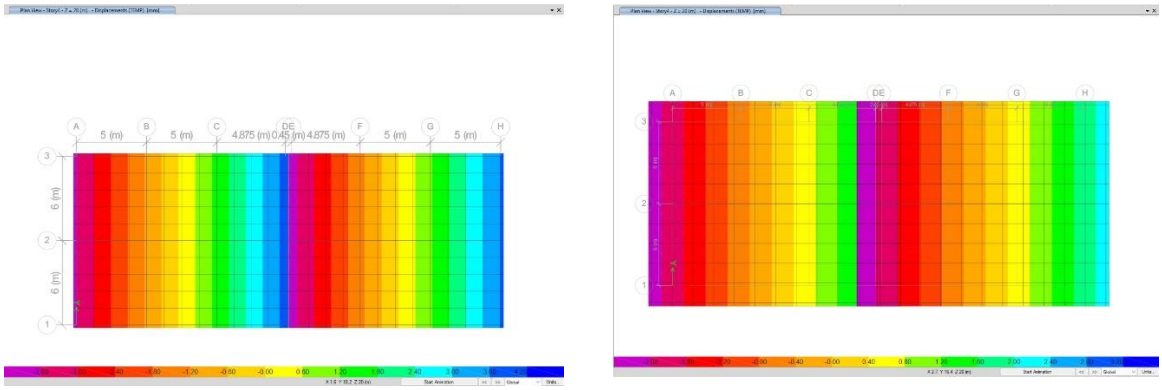


a. ΔT=50°C b. ΔT=30°C

Fig. 4 Displacement result for building 24x50m without expansion joint

Generally, the displacement decreases when use joint from (12mm) to (6mm) when ΔT of 50°C, and displacement change from (7.2mm) to (3.2mm) when ΔT of 30°C as show in Fig. 7. So the result subject to the thermal displacement model (ΔL = L α ΔT).

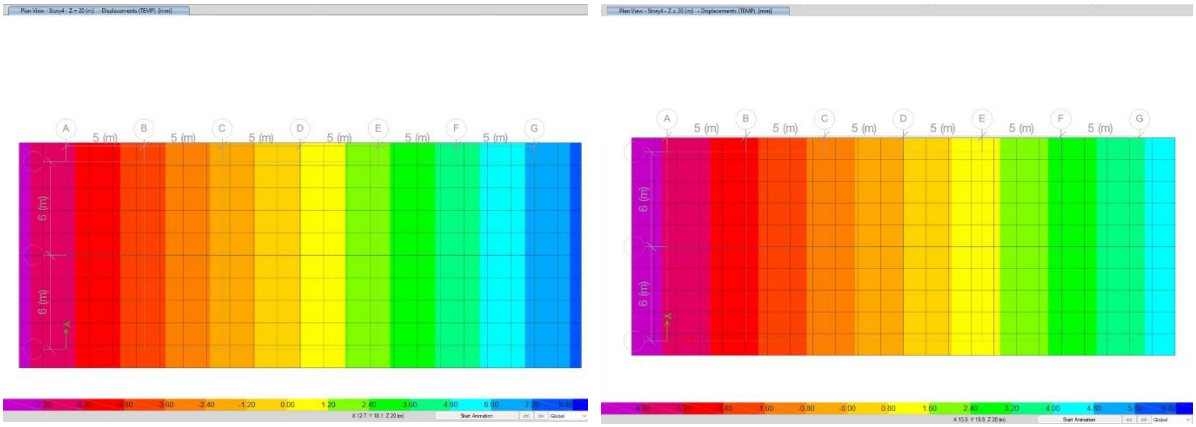
For the building with dimension (12mx30m) with expansion joint when the difference in temperature change conducted two values 50°C and 30°C, the result shows displacement of (3.6mm and 2mm) respectively, that mean the displacement proportion to the temperature as Fig. 5.



a. ΔT=50°C b. ΔT=30°C

Fig. 5 Displacement result for building 12x30m with expansion joint

While building without expansion joint for the same dimension (12mx30m) when the difference in temperature change conducted two values 50°C and 30°C, the result shows displacement of (7.2mm and 4mm) respectively, that mean the displacement proportion to the temperature linearly as Fig. 6.



a. ΔT=50°C b. ΔT=30°C

Fig. 6 Displacement result for building 12x30m without expansion joint

Generally, the displacement decreases when use joint from (7.2mm) to (3.6mm) when ΔT of 50°C, and displacement change from (4mm) to (2mm) when ΔT of 30°C as show in Fig. 7. So the result subject to the thermal displacement model (ΔL = L α ΔT).

Finally, the result shows the decrease of the dimensions of total building will reduce the displacement with the same ratio, when the building has the dimensions of 24mx50m without expansion joint under temperature change of 50°C have displacement of 12mm and for the building have dimensions 12mx30m have 7.2mm. In the same way, the displacement changes from 7.2mm to 4mm when temperature change of 30°C. While the exist expansions joint the changing in displacement will be reduce from 6mm to 3.6mm at ΔT=50°C, and change displacement from 3.2mm to 2mm at ΔT=30°C, as shown in Fig. 7.

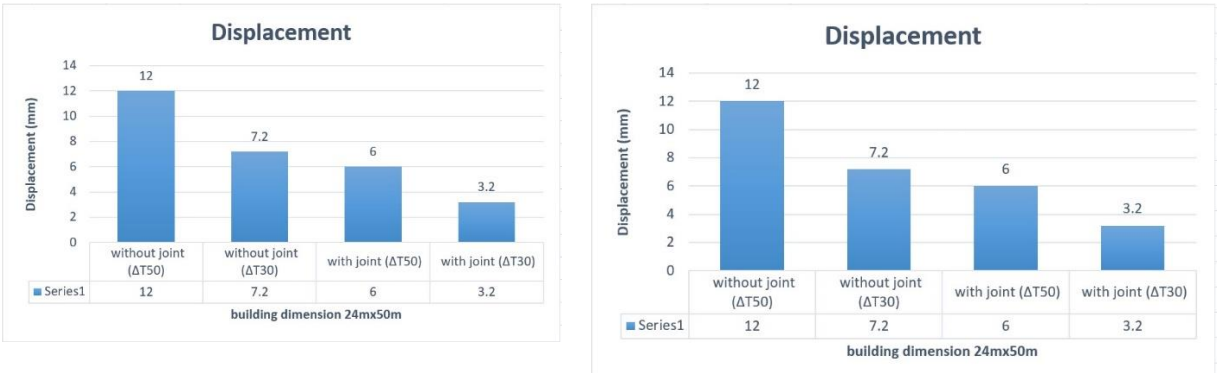
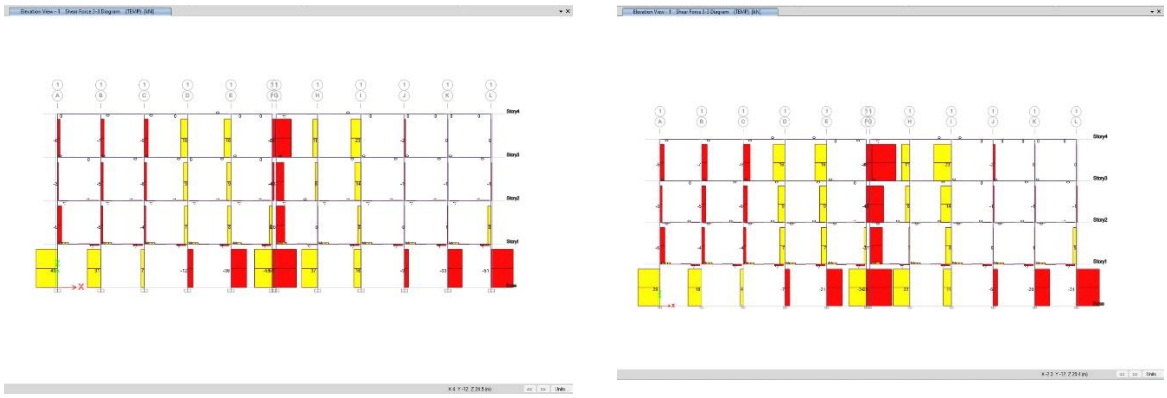


Fig. 7 Displacement result

Shear Result

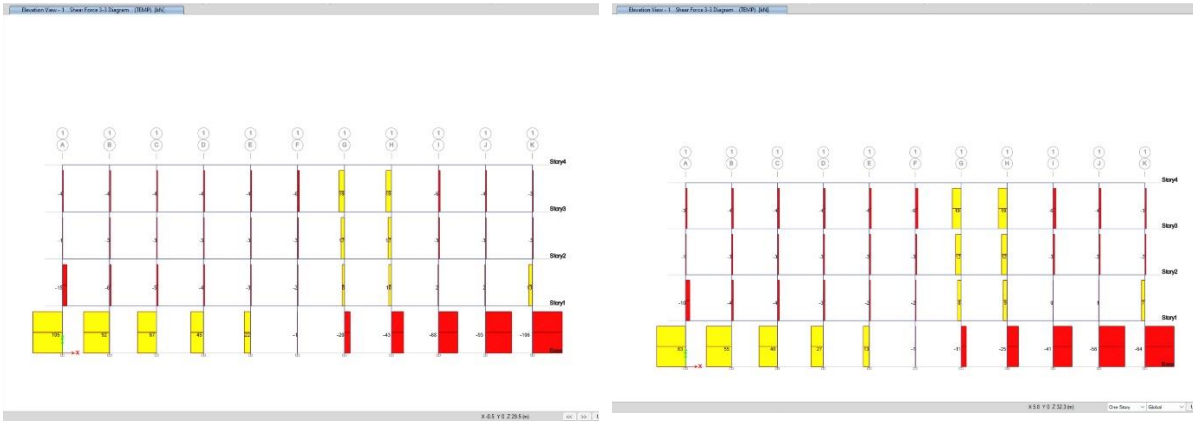
For the building has dimension (24mx50m) with expansion joint with a difference in temperature change conducted two values 50°C and 30°C, the result shows shear force of (50kN and 30kN) respectively, that mean the shear force proportion to the temperature as Fig. 8.



a. ΔT=50°C b. ΔT=30°C

Fig. 8 Shear force result for building 24x50m with expansion joint

While building without expansion joint for the same dimension (24mx50m) when the difference in temperature change values 50°C and 30°C, the result shows shear force of (105kN and 63kN) respectively, that mean the shear force proportion to the temperature as Fig. 9.

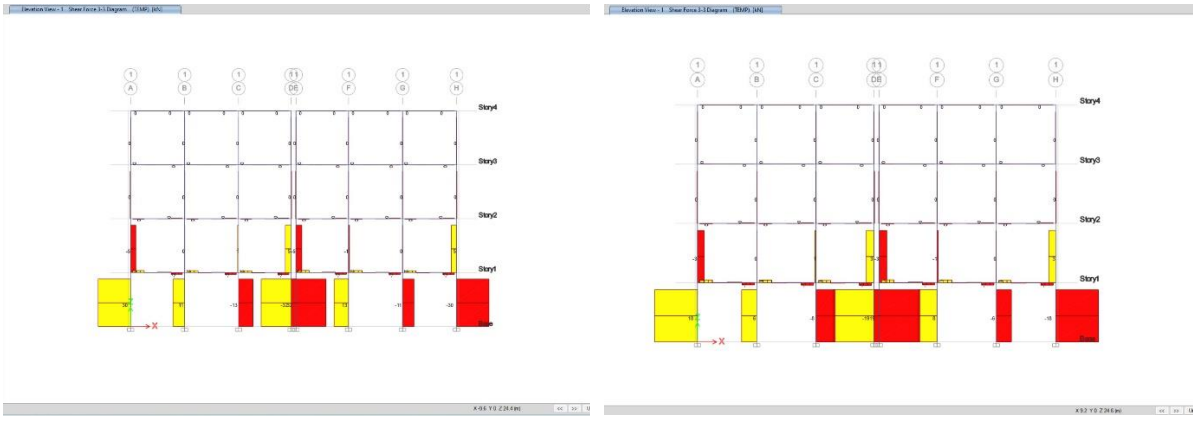


a. ΔT=50°C b. ΔT=30°C

Fig. 9 Shear force result for building 24x50m without expansion joint

Generally, for the building dimension (24mx50m), the shear force decreases when use expansion joint from (105kN) to (50kN) when ΔT of 50°C, and shear force change from (63kN) to (30kN) when ΔT of 30°C as show in Fig. 12.

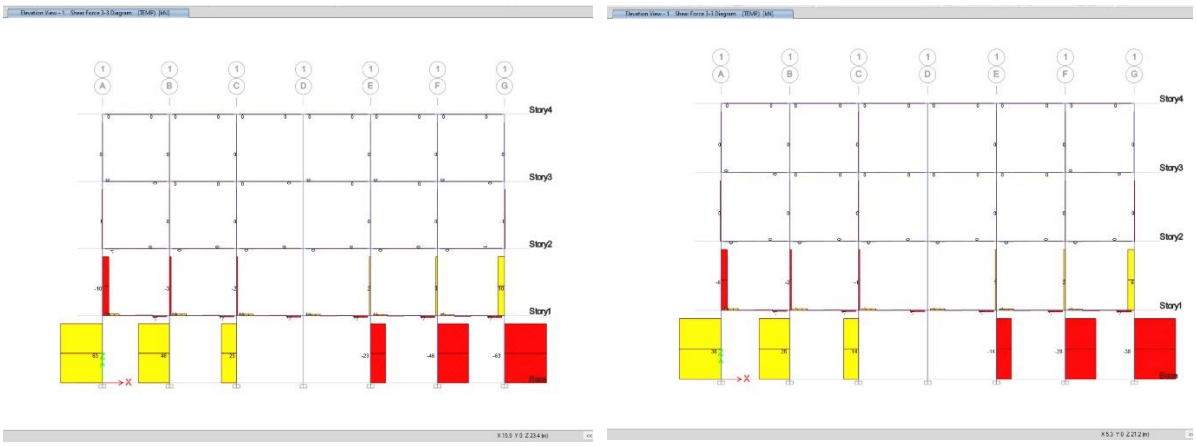
For the building with dimension (12mx30m) with expansion joint when the difference in shear force change conducted two values 50°C and 30°C, the result shows the shear force of (30kN and 18kN) respectively, that mean the shear force proportion to the temperature as Fig. 10.



a. ΔT=50°C b. ΔT=30°C

Fig. 10 Shear force result for building 12x30m with expansion joint

While building without expansion joint for the same dimension (12mx30m) when the difference in temperature change conducted two values 50°C and 30°C, the result shows shear force of (62kN and 38kN) respectively, as shown in Fig. 11.



a. ΔT=50°C b. ΔT=30°C

Fig. 11 Shear force result for building 12x30m without expansion joint

Generally, for the building has dimension (12mx30m), the shear force decreases when use expansion joint from (62kN) to (30kN) when ΔT of 50°C, and shear force change from (38kN) to (18kN) when ΔT of 30°C as show in Fig. 12.

Finally, the result shows the decrease of the dimensions of total building will reduce the shear force with the same ratio, when the building has the dimensions of 24mx50m

without expansion joint under temperature change of 50°C have shear force of 105kN and for the building have dimensions 12mx30m has 62kN. In the same way, the shear force changes from 63kN to 38kN when temperature change of 30°C. When using expansions joint the shear force change from 50kN to 30kN at ΔT=50°C, and shear force change from 30kN to 18kN at ΔT=30°C, as shown in Fig. 12.

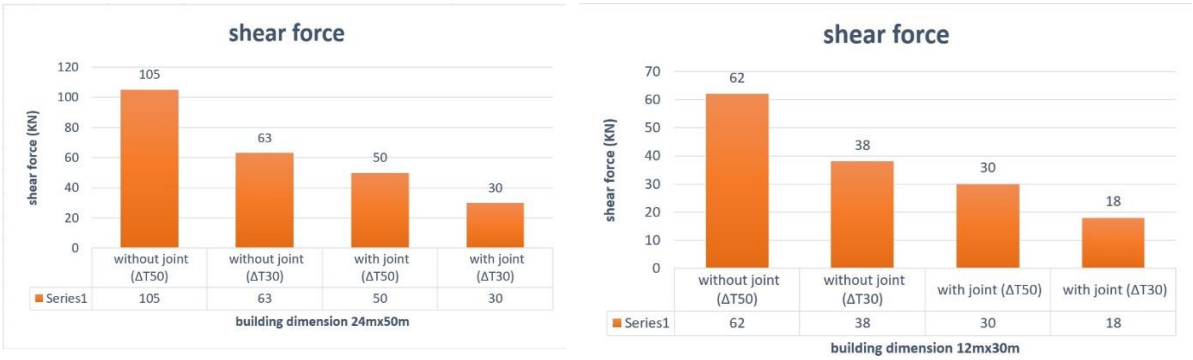


Fig. 12 Shear force result

CONCLUSION

Analysis result due to pure thermal load only shows the lateral displacement in final floor (4^{th}) and shear force in the base of columns as following:

- When use the expansion joint for the building with dimension 12mx30m at temperature change 50°C the reduction percentage in lateral displacement and shear force equal to 50% and 48% respectively.
- When use the expansion joint for the building with dimension 12mx30m at temperature change 30°C the reduction percentage in lateral displacement and shear force equal to 50% and 47% respectively.
- When use the expansion joint for the building with dimension 24mx50m at temperature change 50°C the reduction percentage in lateral displacement and shear force equal to 50% and 47% respectively.
- When use the expansion joint for the building with dimension 24mx50m at temperature change 30°C the reduction percentage in lateral displacement and shear force equal to 44% and 47% respectively.
- When reduce the floor area building about 30% without expansion joint at change temperature 50°C the reduction value of lateral displacement reduces to 60% but when change temperature to 30°C lateral displacement reduces to 55%. The same

condition when used expansion joint the lateral displacement reduced to 60% at change temperature 50°C and 62% for change temperature 30°C.

- When reduce the floor area building about 30% without expansion joint at change temperature 50°C the reduction value of shear force reduces to 60% but when change temperature to 30°C shear force reduces to 60%. The same condition when used expansion joint the shear force reduced to 60% at change temperature 50°C and 60% for change temperature 30°C.

DATA AVAILABILITY STATEMENT

All data, models, and codes created and used in the course of this study are provided in the published article.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest, financial or personal, that could have influenced the research presented in this paper.

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