International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

Cost Comparison of RCC Framed Structure with & without Expansion Joint subjected to Thermal Loads

Sarath Poduval[1], Prof. Deepa Raval [2]

[1]Post Graduate Student, Department of Applied Mechanics, L.D. College of Engineering, Ahmedabad, Gujarat, India
[2]Assistant Professor , Department of Applied Mechanics, L.D. College of Engineering, Ahmedabad, Gujarat, India

---***---

Abstract - *Due to development of new techniques and architectural needs now a days long buildings are very common. Long buildings are sensitive to thermal stress because of which either expansion joints need to be provided or the building needs to be designed for thermal stress. Most common practice by the designer is to introduce Expansion joints to avoid the effects of large lateral displacements and limit the internal stresses caused by the expansion and contraction of its elements due to temperature changes and to permit the relative motion of the building members without disturbing functional continuity and structural integrity. According to Indian codes Expansion joints become mandatory every after 45m in long buildings in absence of thermal analysis. Once the building is separated by providing expansion joint it is essential to check the building against seismic pounding effect and provide necessary gap to avoid the damage. Present study basically focuses on the behavior of long building in the presence and absence of an expansion joint under seismic, wind and temperature loading using MIDAS Gen software with an objective to investigate the effect of various temperature loading on the structure and compare the cost of structure. In this study different plan shapes and height of building are considered subjected to uniform, linear and system temperature gradient. The main parameters evaluated in this study are story displacement, story drift, combined stress, base shear, & cost comparison.*

***Key Words*: Expansion joint, Thermal analysis, Temperature stresses, Long buildings, MIDAS Gen.**

1. INTRODUCTION

Due to the continuity of reinforced concrete members with the assumption of rigid connections between beams and columns, the members are not completely free to move under temperature variation. Hence additional stresses due to thermal loads, either uniform temperature variation or temperature gradients, will be produced in the beams and columns. In order to release restrained stresses from temperature variation, various codes set limits on the maximum length between expansion joints in a building. IS 456:2000 restricts the length of the building to 45m and if the length exceed the limit, one or more expansion joints need to be introduced. Expansion joints are also recommended at the corners of L,H,T and C shaped buildings where stress concentration develops. However , once the building is separated by providing expansion joint it is essential to check the building against seismic pounding effect and provide necessary gap to avoid the damage. Usually it is observed that the gap required to avoid pounding is much more as compared to the expansion joint which results in loss of valuable area which otherwise can be used for revenue generation.

Due to the complexity of the problem and the limitations for using expansion joints in addition to its bad appearance and difficulty of construction and maintenance, designers become interested in the design of buildings without expansion joints and take the effect of temperature variations and additional stresses into account during the design stage.

1.1 Aim & Objective of study

The work is mainly focused on comparative study on buildings with and without expansion joint subjected to different temperature gradients using MIDAS Gen software.

The aim of this study is to compare the cost of building with and without expansion joint by varying building plan geometry and storey height under uniform, linear and system temperature gradient.

2. MODELING IN SOFTWARE

Rectangular and C-shape models with and without expansion joint of thirty, forty and fifty storey heights were considered for the study. Three different temperature gradient i.e. uniform, linear and system temperature were applied on the models.

Table -1: Geometric parameters for Rectangular building

		Without Without expansion joint	With expansion joint
Plan dimension		120m X 60m	120m X 60m
Size of beams(m)		0.8*0.3 0.7*0.3 0.45*0.25	0.6*0.25 0.45*0.25
Size of	G+30	1,0.8,0.6	0.9,0.8,0.7
	G+40	1,0.8,0.7,0.6	0.9,0.8,0.7,0.6

columns(m)	G+50	1,0.8,0.7,0.6,0.5	0.9,0.8,0.7,0.6,0.5
Shearwall thickness(m)	G+30	0.5, 0.4, 0.3	0.5,0.4,0.3
	G+40	0.5,0.4,0.3,0.25	0.5,0.4,0.3,0.25
	G+50	0.5,0.4,0.3,0.25	0.5,0.4,0.3,0.25
Grade of reinforcement		Fe500	
Concrete grade		M45	

Table -2: Geometric parameters for C-shape building

		Without Without expansion joint	With expansion joint
Plan dimension		7200 m^2	7200 m^2
Size of beams		0.7*0.3 0.45*0.25	0.6*0.25 0.45*0.25
Size of columns	G+30	0.9,0.8,0.6	0.9,0.8,0.7
	G+40	1,0.9,0.7,0.6	0.9,0.8,0.7,0.6
	G+50	1,0.9,0.8,0.7,0.6	0.9,0.8,0.7,0.6,0.5
Shearvwall thickness	G+30	0.5, 0.4, 0.3	0.5,0.4,0.3
	G+40	0.5,0.4,0.3,0.25	0.5,0.4,0.3,0.25
	G+50	0.5,0.4,0.3,0.25	0.5,0.4,0.3,0.25
Grade of reinforcement		Fe500	
Concrete grade		M45	

2.2. Loading Conditions

A super-imposed load of 2.5 kN/m^2 is applied at all floors. The static wind loads are applied with basic wind speed of 39 m/s as per IS 875 (Part 3) : 2015. The factor for basic wind speed is 1 and the terrain category considered is 4. Static seismic loads are applied as per IS 1893(2016) with response reduction factor of 5. Uniform, Linear and System temperature gradient is applied with a temperature change of 32° C.

3. ANALYSIS AND RESULTS

Analysis of various models were conducted using MIDAS Gen software. In this the behavior of structures is observed and the obtained results are of different parameters such as Storey drifts, Storey displacements, Maximum bending moments, maximum combined stress, Base shear and Material consumption. The values for the respective parameters are taken and represented in tabular form and graphs are plotted.

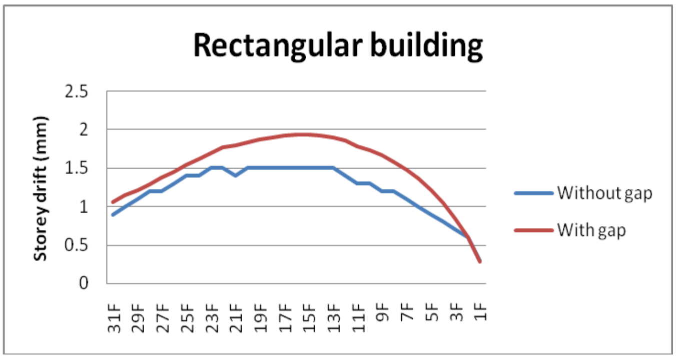


Chart 1 Comparison of story drift for 30 storey Rectangular building with and without expansion gap.

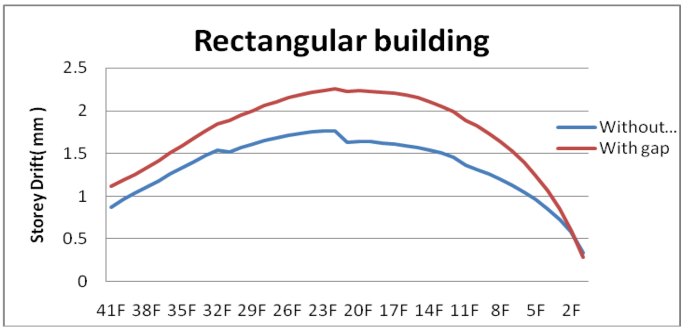


Chart 2 Comparison of story drift for 40 storey Rectangular building with and without expansion gap.

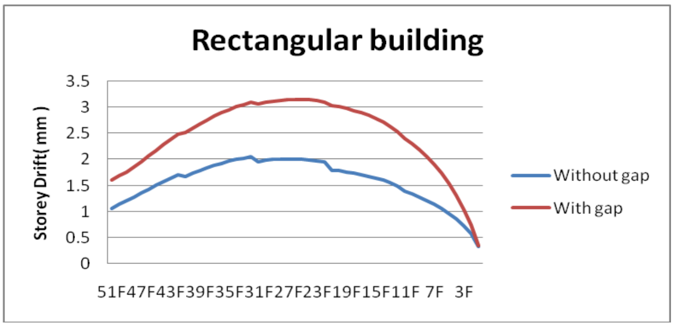


Chart 3 Comparison of story drift for 50 storey Rectangular building with and without expansion gap.

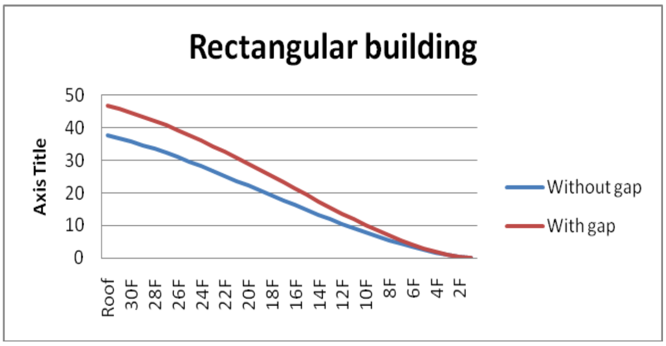


Chart 4 Comparison of story displacement for 30 storey Rectangular building with and without expansion gap.

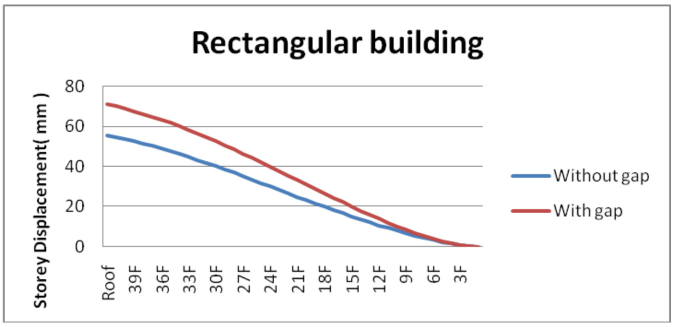


Chart 5 Comparison of story displacement for 40 storey Rectangular building with and without expansion gap.

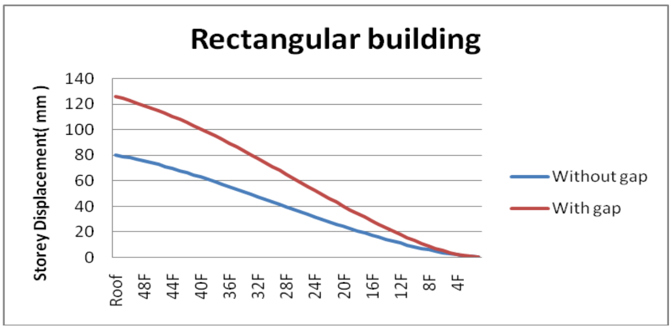


Chart 6 Comparison of story displacement for 50 storey Rectangular building with and without expansion gap.

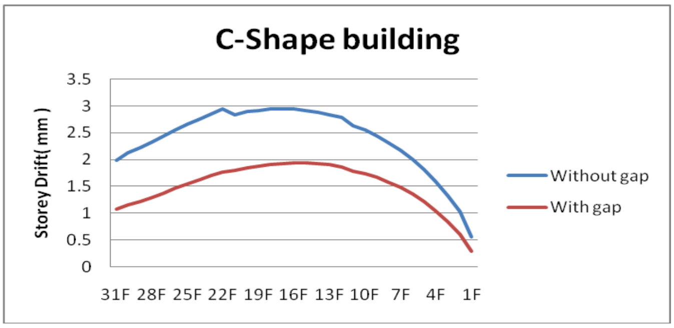


Chart 7 Comparison of story drift for 30 storey C-shape building with and without expansion gap.

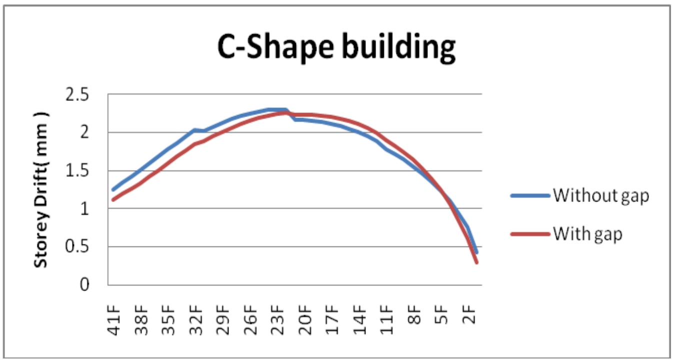


Chart 8 Comparison of story drift for 40 storey C-shape building with and without expansion gap.

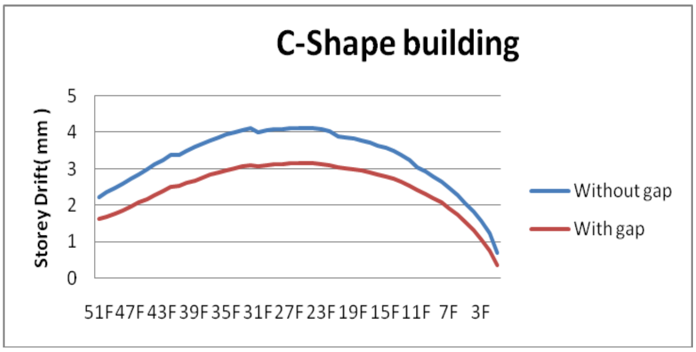


Chart 9 Comparison of story drift for 50 storey C-shape building with and without expansion gap.

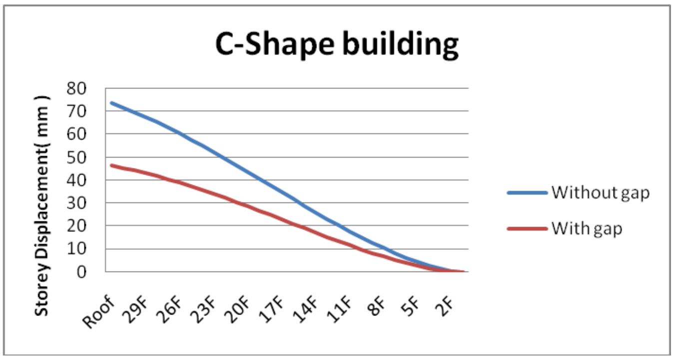


Chart 10 Comparison of story displacement for 30 storey C-shape building with and without expansion gap.

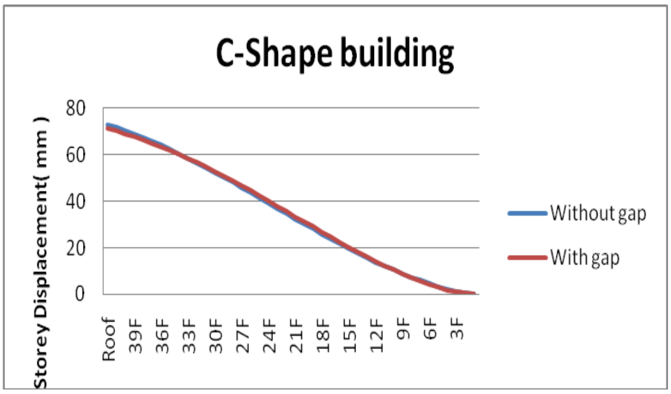


Chart 11 Comparison of story displacement for 40 storey C-shape building with and without expansion gap.

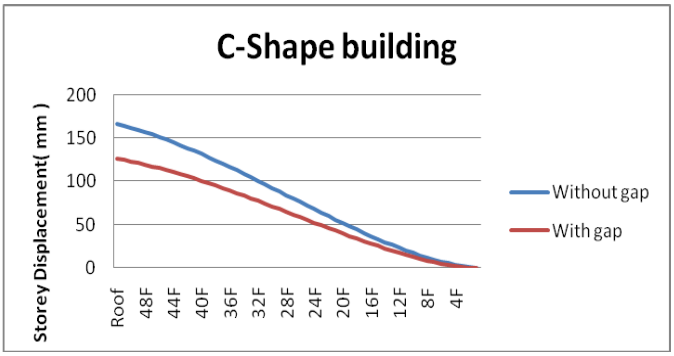
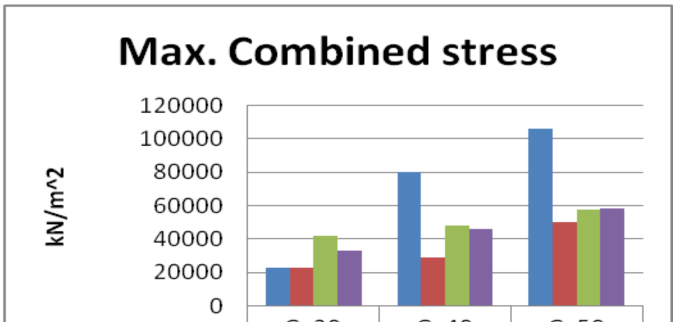
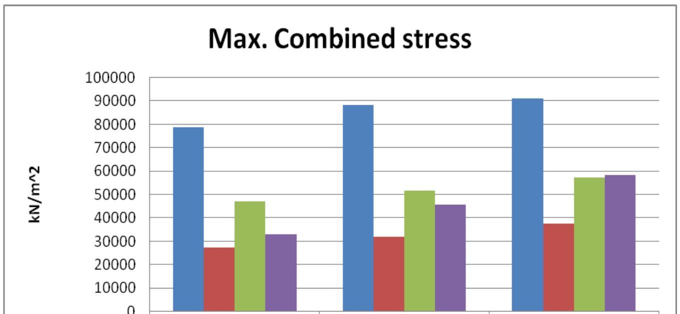


Chart 12 Comparison of story displacement for 50 storey C-shape building with and without expansion gap.



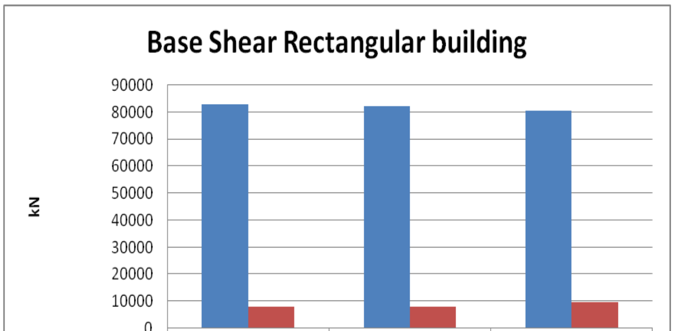
	G+30	G+40	G+50
Uniform temp.	22627.9	80178.73	106050.6
Linear temp.	22619.8	28778.4	50335.7
System temp.	41951.04	48159.45	57604.46
Without temp.	33147.57	45701.17	58502.12

Chart 13 Comparison of Combined stress of 30, 40 and 50 storey Rectangular building for different temperature gradients.



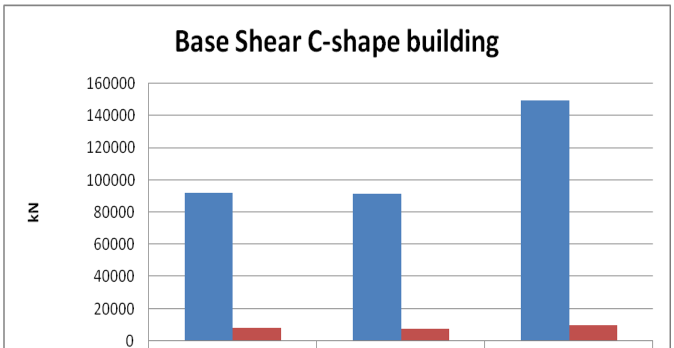
	G+30	G+40	G+50
Uniform temp.	79018.77	88460.79	91304.48
Linear temp.	27616.75	31904.09	37660.17
System temp.	47353.28	51594.51	57302.61
Without temp.	33147.57	45701.17	58502.12

Chart 14 Comparison of Combined stress of 30, 40 and 50 storey C-shape building for different temperature gradients.



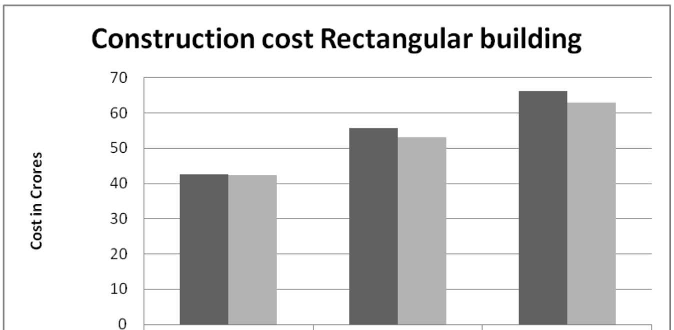
	G+30	G+40	G+50
Without gap(Rec)	82803	82359	80726
With gap(Rec)	8180	7982	9724

Chart 15 Comparison of Base Shear for Rectangular building with and without Expansion gap.



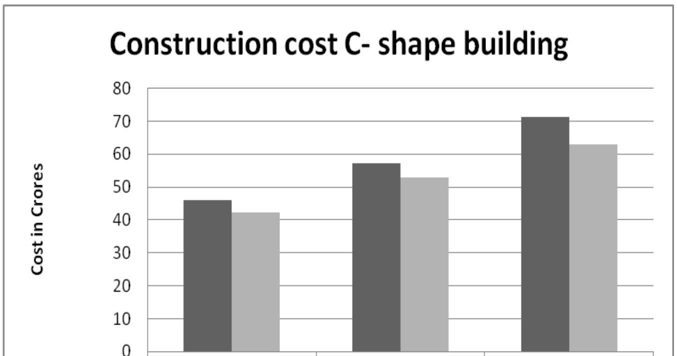
	G+30	G+40	G+50
Without gap(C)	92141	91348	149749
With gap(C)	8180	7982	9724

Chart 16 Comparison of Base Shear for C-shape building with and without Expansion gap.



	G+30	G+40	G+50
Without gap	42.7	55.82	66.2
With gap	42.33	53.05	63

Chart 17 Comparison of Construction cost (steel +concrete) (Rs. in Crores) for Rectangular building with and without Expansion gap.



	G+30	G+40	G+50
Without gap	46	57.3	71.3
With gap	42.33	53.05	63

Chart 18 Comparison of Construction cost (steel +concrete) (Rs. in Crores) for Rectangular building with and without Expansion gap.

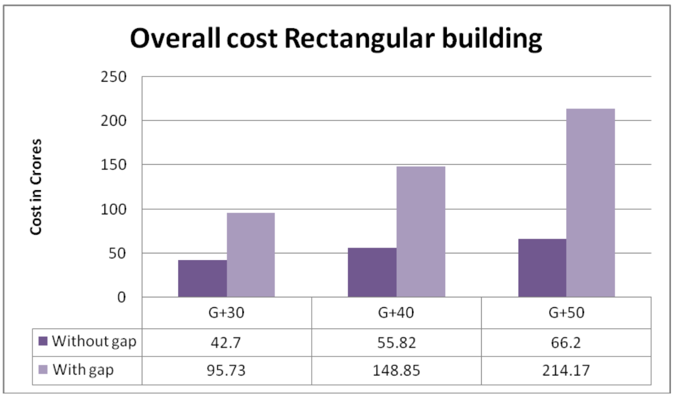


Chart 19 Comparison of Overall cost including land cost (Rs. in Crores) for Rectangular building with and without Expansion gap.

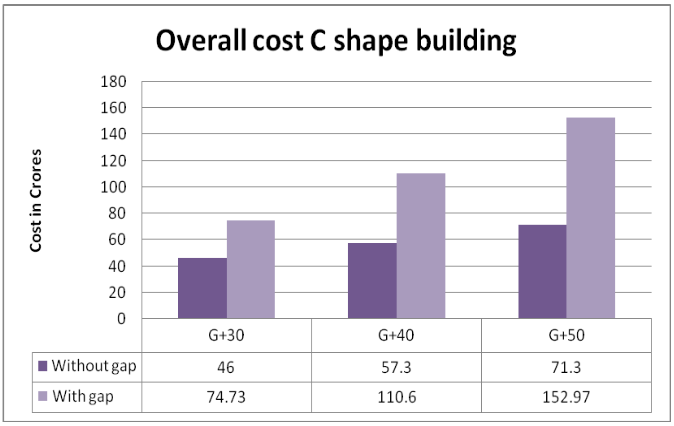


Chart 20 Comparison of Overall cost including land cost (Rs. in Crores) for C-shape building with and without Expansion gap.

Combined stress - Maximum Combined stress among:

1. Axial+ Bending(-y)+ Bending(+z).
2. Axial+ Bending(+y)+ Bending(+z).
3. Axial+ Bending(+y)+ Bending(-z).
4. Axial+ Bending(-y)+ Bending(-z).

4. CONCLUSIONS

The following conclusion can be drawn from the above results:

1. For 30 storey Rectangular building the storey drift and displacement increased by about 22% and 19% respectively for model with expansion gap as compared to model without the same. While for C-shaped building the storey drift and displacement increased by about 34% and 36% respectively for model without expansion gap as compared to the model with units separated. There is no change in story drift and storey displacement for different temperature gradients as the lateral loads remains the same.
2. For 40 storey Rectangular building the storey drift and displacement increased by about 22% for model with expansion gap as compared to model without the same. While for C- shaped building the storey drift and displacement increased by about 9% and 3% respectively for model without expansion gap as compared to the model with units separated. There is no change in story drift and storey displacement for different temperature gradients as the lateral loads remains the same.
3. For 50 storey Rectangular building the storey drift and displacement increased by about 35% and 36% respectively for model with expansion gap as compared to model without the same. While for C-shaped building the storey drift and displacement increased by about 24% and 25% respectively for model without expansion gap as compared to the model with units separated. There is no change in story drift and storey displacement for different temperature gradients as the lateral loads remains the same.
4. The Combined stress (axial + bending x + bending y) was observed to be reduced by about 46% for uniform & linear gradient while an increase of 21% was observed in case of system temperature gradient for 30 storey rectangular building. While for C- shaped building it was observed to be increased by 58% & 30% for uniform gradient and system gradient respectively and reduced by about 20% in case of linear temperature gradient.
5. The Combined stress (axial + bending x + bending y) was observed to be increased by about 43% for uniform gradient and reduced by 59% for linear temperature gradient while negligible change in case of system temperature gradient for 40 storey rectangular building. While for C- shaped building it was observed to be increased by 48% & 11% for uniform gradient and system temperature case respectively reduced by about 43% for linear temperature gradient.
6. The Combined stress (axial + bending x + bending y) was observed to be increased by about 45% for uniform gradient and reduced by 16% for linear temperature gradient and negligible change in case of system temperature for 50 storey rectangular building. While for C- shaped building it was observed to be increased by 36% for uniform gradient and reduced by about 55% for linear gradient while negligible change in case of system temperature.
7. As the building was divided into six units when expansion joint was introduced the base shear decreased significantly about 90% decrease in the base shear was observed in both Rectangular as well as C-shape building.

8. Initial construction cost and maintenance cost of buildings without expansion joint is less compared to buildings with expansion joint. This was majorly because of the area lost for the purpose of providing provision for expansion and seismic pounding considerations which otherwise would have contributed in revenue generation.
9. The above point is valid for both geometric variation (i.e. rectangular & C-shape) & storey variation (i.e. G+30, G+40 & G+50) buildings considered in this study.
10. The total amount of reinforcement and concrete remained same when the model were designed for Uniform, Linear and System temperature gradients which shows that the applied thermal loads were not dominant over the regular loads to which the buildings are subjected (i.e. dead, live and lateral loads).
11. The above point was also verified by designing the same buildings without applying temperature loads and the quantity of reinforcement steel and concrete were same.

REFERENCES

[1] ACI (American Concrete Institute) (2002). "Joints in concrete construction", ACI 224.3R-9, USA.

[2] IS 3414 (1995), "Code of practice for Design and Installation of joints in Buildings", Bureau of Indian Standards, 5-26.

[3] IS 456 (2000): "Code of practice for Plain and Reinforced concrete", Bureau of Indian Standards, 16, 55.

[4] IS 1893 (2016): "Criteria for Earthquake Resistant Design Of Structures", Bureau of Indian Standards.

[5] ACI-318 (2011): "Building code requirements for structural concrete and commentary, American Concrete Institute, Farmington Hills, MI.

[6] Davco Construction Materials (2007): ("Expansion joint…Why Bother?").

[7] Merrill, W.S. 1943, "Prevention and control of cracking in Reinforced Concrete Buildings", Eng News-Record, 131, 91-93.

[8] Temperature effects in multi-story buildings (K. Ahmed, Journal of Engineering Sciences, Assiut University, Vol. 39 No 2 pp.249 -267 March 2011).

[9] Thermal analysis of reinforced concrete beams and frames (Essam H. El-Tayeb, Salah E. El-Metwally*, Hamed S. Askar, Ahmed M. Yousef, Housing and Building National Research Center , Elsevier-2015).

[10] National Academy of Sciences, Washington D.C. (1974): "Technical Report No. 65 - Expansion joints in Buildings", prepared by the Standing Committee on Structural Engineering of the Federal Construction Council.

[11] Expansion Joints: Where, When and How (James M. Fisher, THE STEEL CONFERENCE 2005).

[12] Effect Of Temperature Load on Beam Design in Thermal Analysis (SANJAY SHIRKE, 2H.S.CHORE, 3P.A. DODE 12th IRF International Conference, 29th June-2014).