

# Evaluation of R.C.C Flat Slab & Conventional Slab Subjected to Seismic & Temperature Load

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**Abstract**— In today's construction the use of flat slab has become quite common. Flat-slab building structures possesses major advantages over traditional slab-beam-column structures because of the free design of space, shorter construction time, architectural-functional and economical aspects. Flat slab construction is a developing technology in India. The conventional slab has more stiffness and higher load carrying capacity. Due to urbanization and aesthetic reasons flat slab have become quite common. Because of the absence of deep beams and shear walls, flat-slab structural system is significantly more flexible for lateral loads than traditional RC frame system. The performance of flat slab system under temperature loading is also very poor. It is necessary to analyse seismic behavior of buildings for various heights to see what are the changes that are going to occur for the conventional RC frame building, flat slab building with and without drops. In this comparative study, the seismic behavior of R.C.C flat slab and conventional slab is evaluated by nonlinear time-history analyses with different temperature loading with the help of SAP 2000 v18 software. The main parameters evaluated in this study are lateral displacement, inter story drift, axial force, and bending moment. A total of 12 models with three different structural systems i.e., conventional slab system, flat slab system without drops and flat slab system with drops are considered. For each structural system 150mm and 200mm thickness of the slab is taken, so we have six basic models. For each basic model G+4, G+8 stories are considered. The performance of flat slab and conventional slab has to be studied when subjected to Seismic loading due to occurrence of varying magnitudes of earthquakes having different frequencies. The temperature loading is being considered due to frequent occurrences of fire accidents and also due to the need for knowledge in people about fire hazards. Fire will not only cause casualties but also effect the structure predominantly leading to its destruction. From results it can be concluded that conventional slab of 150 mm thickness is more effective for G+4 & G+8. For normal and high temperature 150mm thickness is good for G+4, G+8.

**Key words:** Seismic Design, Temperature Loads, Flat Slab, Conventional Slab, Non-Linear Time History

## I. LITERATURE REVIEW

Kang et al. (2003) studied the constitutive model of concrete subjected to elevated temperature. The model is composed of four strain components: free thermal strain, mechanical strain, thermal creep strain, and transient strain due to moisture. The thermal creep strain of concrete is derived from the modified power-law relation for steady state creep. Mathematical description on the multi-axial creep behavior of concrete is also presented. The transient strain component is made in order to consider rapid irreversible strain change of moisture diffusion and evaporation. Some applications

for the proposed model are carried out by a nonlinear analysis and compared with the test results and it shows that the proposed model gives a good agreement and the influences of inelastic strain changes at elevated temperatures are very important for the structural response at elevated temperatures.

Levesque (2006) presented a simplified design tool which assesses the fire performance of reinforced concrete. An Excel-based spreadsheet application was developed for thermal analysis of concrete slabs. It accounts for different aggregate types, slab thicknesses, and fire exposures. Several analyses were performed with the spreadsheet application to examine the affect slab thickness and aggregate types have on the fire performance of concrete slabs in standard and natural fires. The results were compared with published test data and finite element software simulations to benchmark the accuracy of the proposed tool. Furthermore, methods for the design of reinforced concrete slabs in fire conditions are presented. 11

Wang (2006) studied that the membrane forces and the redistribution of bending moments in the slabs considerably affected the behavior of the slabs in fire conditions. Consequently, the fire resistance of the slabs can be enhanced if tensile membrane behavior is mobilized. This thesis uses a non-linear finite element program, SAFIR, developed at the University of Liege, Belgium, to model reinforced concrete flat slabs and one-way slabs at elevated temperatures. The slabs were modeled as 3-D shell elements in the numerical structural models. It was found that the location of the fire under flat slabs and the arrangement of reinforcing bars in flat slabs significantly affect the distribution of bending moments and membrane forces in flat slabs. It was also found that the worst scenario of fire exposure could be when the flat slabs are exposed to fire with a decay phase or after the fire was exhausted or extinguished. The fire resistance of flat slabs is significantly increased if tensile membrane action can be mobilized. However, the distribution of membrane forces in the slabs is nonlinear.

Rizk (2010) studied the development in concrete technology over the twentieth century covering materials, structural systems, analysis and construction techniques made it possible to build concrete tall buildings such as Petronas towers(452m), jin Mao(421m) and bhurj Dubai (800+).

Manley (2014) presented the use of prescribed solutions for fire design and has allowed engineers to simply provide an assembly of elements which meets a building codes required fire resistance without necessarily understanding or evaluating the development of a fire in a compartment, the corresponding temperatures reached and the implications of such temperatures. A process is presented which uses simple thermal and mechanical models to determine the fire resistance of simply supported

reinforced solid concrete slabs. The calculated fire resistance is compared to prescribed provisions for slabs exposed to the standard fire and an equivalent fire severity method for slabs exposed natural fires.

## II. COMPARATIVE STUDY OF FLAT SLAB AND CONVENTIONAL SLAB

The Flat slab building in which slab is directly supported by columns, have been adopted in many building constructed recently, due to the advantage of reduced floor to floor height. conventional slab system consists of thin beams spaced at regular intervals in perpendicular directions, monolithic with slab. The seismic performance of buildings having conventional slab and flat slab is comparable but the differences exist. Tall buildings with flat slab system are weaker in shear whereas those with conventional floor system are robust but taller and functionally less friendly. Flat slab is quite common which enhances the weight reduction, speed up construction, and economical. Conventional slab has got features like more stiffness, higher load carrying capacity, safe and economical also. Conventional Reinforced Concrete (RC) frame buildings are commonly used for the construction. The use of flat slab building provides many advantages over conventional RC frame building in terms of architectural flexibility, use of space, easier formwork and shorter construction time. The weight of flat slab structure is less compared to conventional slab structure.

## III. SEISMIC EFFECTS

Earthquakes are natural hazards due to which damage occur to buildings and other man-made structures. Experience has shown that for new constructions, establishing earthquake resistant regulations and their implementation is the critical safeguard against earthquake-induced damage. As regards existing structures, it is necessary to evaluate and strengthen them based on evaluation criteria before an earthquake. Earthquake damage mainly depends on parameters such as intensity, duration and frequency of ground motion, geologic and soil condition, quality of construction, etc.

The April 2015 Nepal earthquake of India was an eye opener killed over 8,000 people and injured more than 21,000. It occurred at 11:56 Nepal Standard Time, with a magnitude of 7.8Mw or 8.1Ms and a maximum Mercalli Intensity of IX. Its epicenter was east of Gorkha District at Barpak, Gorkha, and its hypocenter was at a depth of approximately 8.2 km (5.1 mi). It was the worst natural disaster to strike Nepal since the 1934 Nepal–Bihar earthquake.

## IV. TEMPERATURE EFFECTS

With the increased incidents of major fires and fire accidents in buildings; assessment, repair and rehabilitation of fire damaged structures has become a topical interest. This specialized field involves expertise in many areas like concrete technology, material science and testing, structural engineering, repair materials and techniques etc. Research and development efforts are being carried out in these related disciplines. Any structure can undergo fire accident,

but because of this the structure cannot be denied neither abandoned. To make a structure functionally viable after the damage due to fire has become a challenge for the civil engineering community. The problem is where to start and how to proceed. It is vitally important that we create buildings and structures that protect both people and property as effectively as possible. Annual statistics on losses caused by fires in homes and elsewhere make for some unpleasant readings and sadly through these events we learn more about fire safety design.

## V. OBJECTIVES OF THE STUDY

A. *The present work aims at the following objectives:*

To investigate and compare seismic behavior of RCC flat slab and conventional slab using the Non-linear time history analysis with different thickness.

To investigate and compare the effect of Temperature load on RCC flat slab and conventional slab with different thickness.

To investigate and compare the behavior of both structure for the parameters like lateral displacement, inter story drift, axial force, and bending moment.

1) *Flat slab and Conventional slab models are prepared. Models are analyzed by nonlinear time history analysis.*

S.no	Variable	Data
1.	Type of structure	Moment Resisting Frame
2.	Seismic Data	Nepal Earthquake data
3.	Number of Stories	G+4 & G+8
4.	Floor height	3m
5.	Plan Dimensions	18m x 24m
6.	Total height of Building	15m & 27m
7.	Live Load	3.0 kN/m <sup>2</sup>
8.	Dead load	1 kN/m <sup>2</sup> & wall load of 10 kN/m
9.	Materials	Concrete (M30) and Reinforced with HYSD bars (Fe500)
10.	Size of Columns	460x460 mm (for 4 & 8storey frame)
11.	Size of Beams	300x460 mm
12.	Depth of slab	150mm thick & 200mm thick
13.	Depth of drop	150mm
14.	Specific weight of RCC	25 kN/m <sup>3</sup>
15.	Zone	II
16.	Importance Factor	1
17.	Response Reduction Factor	5
18.	Type of soil	Medium

Table 1: Preliminary Data Considered in The Analysis of the Framed Structure for Seismic Load

2) *Temperature load case is also considered of 280C and 4000C.*

S.no	Variable	Data
1.	Type of structure	Moment Resisting Frame
2.	Temperature Data	280C and 4000C
3.	Number of Stories	G+4,G+8
4.	Floor height	3m
5.	Plan Dimensions	18m x 24m

6.	Total height of Buildings	15,27 & 39m
9.	Materials	Concrete (M30) and Reinforced with HYSD bars (Fe500)
10.	Size of Columns	460x460 mm (for 4 & 8storey frame)
11.	Size of Beams	300x460 mm
12.	Depth of slab	150mm & 200mm thick
13.	Specific weight of RCC	25 kN/m <sup>3</sup>

Table 2: Preliminary Data Considered for Temperature Load

### VI. RESULTS & DISCUSSIONS

- 1) Firstly, the results for Seismic effects are obtained by using SAP-2000 software. In this models are generated based on the variables assumed i.e.; flat slab with and without drop and conventional slab. Loads are imposed and after application of loads on the structure, analysis of the models is carried out by using Non-Linear Time History Analysis and the results are obtained. Therefore, values for the respective parameters are taken and graphs are plotted.
- 2) Secondly, the results obtained by carrying out analysis based on different Temperature effects for the Flat slab with and without drop and conventional slab are illustrated. In this case temperature effects on buildings are observed by Normal (280C) and High (4000C) Temperatures.

Subsequently discussions are made for the results obtained for lateral displacement, inter storey drift, bending moment, axial force.

#### A. Displacement of G+4 Storey Structure with 150mm Thickness Under Seismic Load

Storey	Displacement in mm for Conventional Slab	Displacement in mm for Flat Slab without Drop	Displacement in mm for Flat Slab with Drop
1	9.4	16.4	14.9
2	23.5	52.3	46
3	35.7	93.7	79.7
4	44.7	132.5	108.8
5	50	165.7	131.5

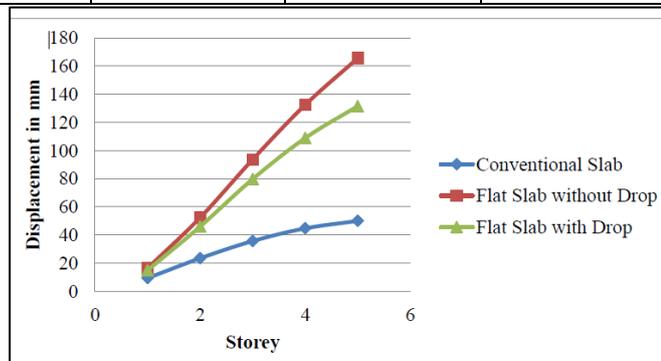


Fig. 5.1: Displacement of G+4 Storey Structures with 150mm thickness under seismic load

#### B. Displacement of G+4 Storey Structures with 200mm Thickness Under Seismic Load.

Storey	Displacement in mm for Conventional Slab	Displacement in mm for Flat Slab without Drop	Displacement in mm for Flat Slab with Drop
1	10.6	18.4	15.6
2	25.8	57.6	44.9
3	38.5	101.2	74.3
4	47.4	140.7	97.5
5	52.3	173.7	113.3

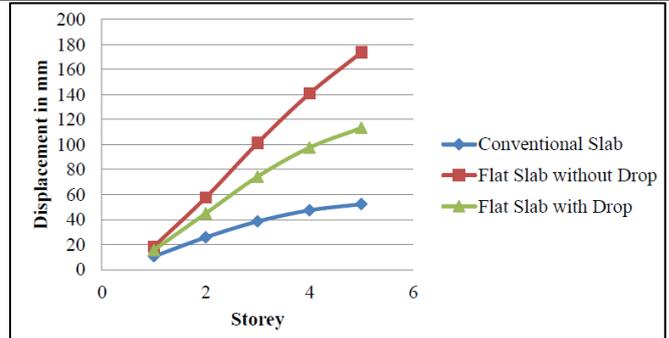


Fig. 5.2: displacement of G+4 storey Structures with 200mm thickness under seismic load

#### C. Displacement of G+8 Storey Structures with 150mm Thickness Under Seismic Load

Storey	Displacement in mm for Conventional Slab	Displacement in mm for Flat Slab without Drop	Displacement in mm for Flat Slab with Drop
1	16.1	35.3	26.1
2	41.4	116.3	83.2
3	66.1	216.9	151.5
4	87.6	321.1	219.9
5	107	419.7	282.2
6	123.7	510.7	335.4
7	136.7	590.2	377.9
8	145.8	656.1	409.7
9	151	709.9	434

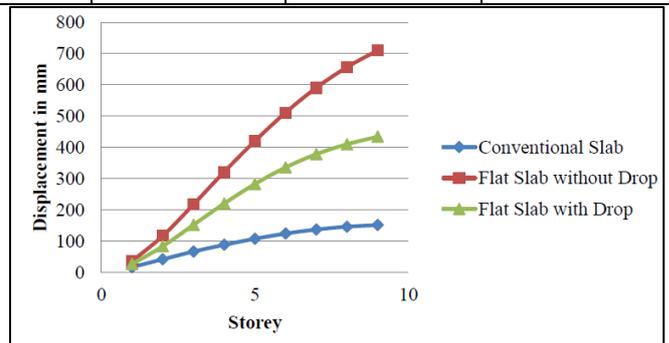


Fig. 5.3: displacement of G+8 storey Structures with 150mm thickness under seismic load

#### D. Displacement of G+8 Storey Structures with 200mm Thickness Under Seismic Load.

Storey	Displacement in mm for Conventional Slab	Displacement in mm for Flat Slab without Drop	Displacement in mm for Flat Slab with Drop
1	10.6	18.4	15.6
2	25.8	57.6	44.9
3	38.5	101.2	74.3
4	47.4	140.7	97.5
5	52.3	173.7	113.3

	Slab	Drop	
1	18.3	49.7	27.2
2	46.3	161	81.3
3	73.4	296.6	141.7
4	97.5	434.4	201.2
5	118.1	562.9	256.3
6	135.1	679.6	304.3
7	149.4	777.5	342.9
8	159.4	855.2	370.6
9	165.1	916.1	388.7

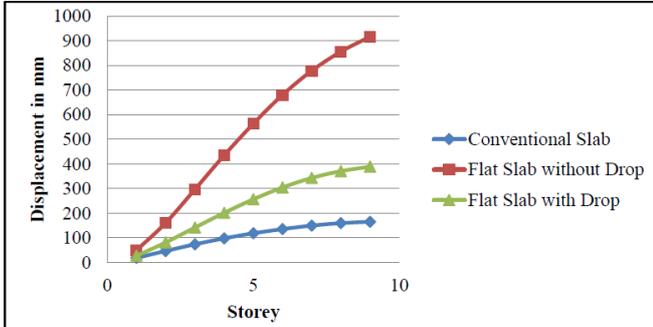


Fig. 5.4: displacement of G+8 storey Structures with 200mm thickness under seismic load

E. Displacement of G+4 Storey Structures with 150mm Thickness Under Normal Temperature.

Storey	Displacement in mm for Conventional Slab	Displacement in mm for Flat Slab with and without Drop
1	1.2	1.5
2	1.1	1.4
3	1.1	1.4
4	1.1	1.4
5	1.1	1.4

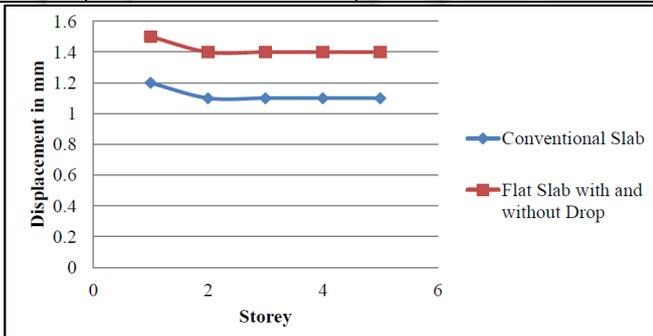


Fig. 5.25: displacement of G+4 storey Structures with 150mm thickness under normal Temperature

F. Displacement of G+4 Storey Structures with 200mm Thickness Under Normal Temperature.

Storey	Displacement in mm for Conventional Slab	Displacement in mm for Flat Slab with and without Drop
1	1.3	1.5
2	1.2	1.4
3	1.2	1.4
4	1.2	1.4
5	1.2	1.4

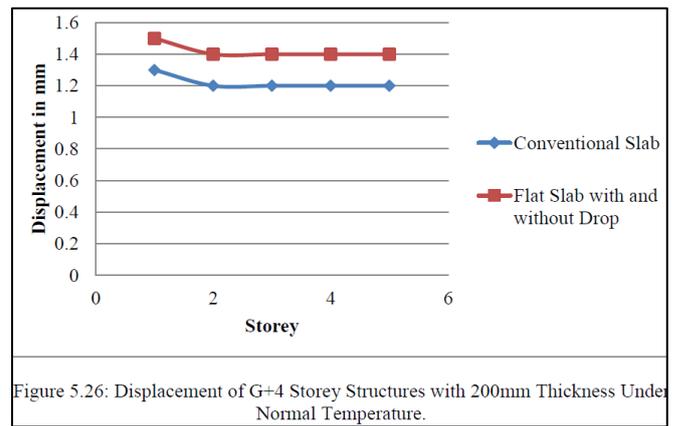


Fig. 5.26: displacement of G+4 storey Structures with 200mm thickness under normal Temperature

G. Displacement of G+8 Storey Structures with 150mm Thickness Under Normal Temperature.

Storey	Displacement in mm for Conventional Slab	Displacement in mm for Flat Slab with and without Drop
1	1.3	1.5
2	1.2	1.4
3	1.2	1.4
4	1.2	1.4
5	1.2	1.4
6	1.2	1.4
7	1.2	1.4
8	1.2	1.4
9	1.2	1.4

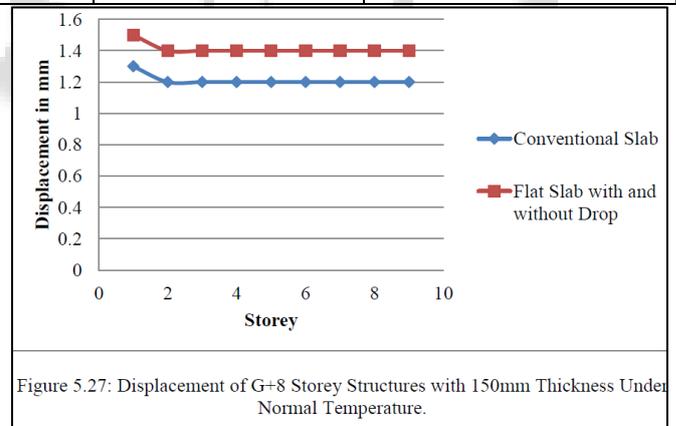


Fig. 5.27: displacement of G+8 storey Structures with 150mm thickness under normal Temperature

H. Displacement of G+8 Storey Structures with 200mm Thickness Under Normal Temperature.

Storey	Displacement in mm for Conventional Slab	Displacement in mm for Flat Slab with and without Drop
1	1.3	1.5
2	1.2	1.4
3	1.2	1.4
4	1.2	1.4
5	1.2	1.4
6	1.2	1.4
7	1.2	1.4

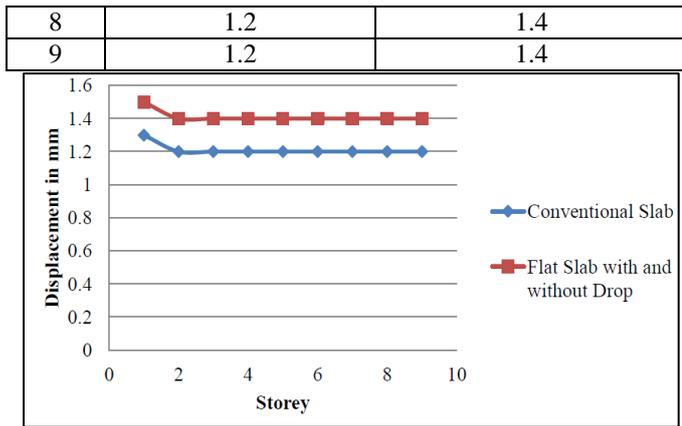


Fig. 5.28: displacement of G+4 storey Structures with 150mm thickness under normal Temperature

**I. Displacement of G+4 Storey Structures with 150mm Thickness Under High Temperature.**

Storey	Displacement in mm for Conventional Slab	Displacement in mm for Flat Slab with and without Drop
1	16.5	19.4
2	16.9	19.9
3	16.8	19.8
4	16.8	19.8
5	16.8	19.8

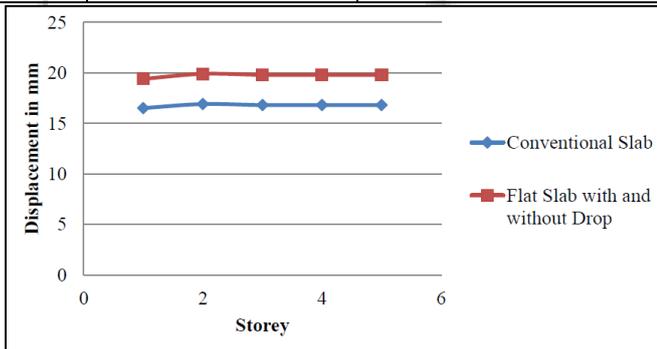


Fig. 5.43 Displacement of G+4 Storey Structures with 150mm Thickness Under High Temperature.

**J. Displacement of G+4 Storey Structures with 200mm Thickness Under High Temperature**

Storey	Displacement in mm for Conventional Slab	Displacement in mm for Flat Slab with and without Drop
1	17.2	19.5
2	17.5	19.9
3	17.4	19.8
4	17.4	19.8
5	17.4	19.8

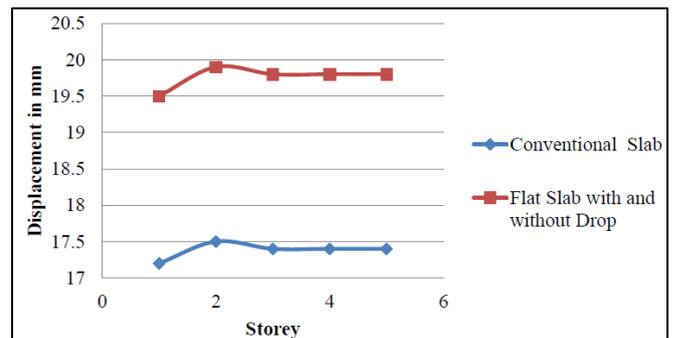


Fig. 5.44: Displacement of G+4 Storey Structures with 200mm Thickness Under High Temperature

**K. Displacement of G+8 Storey Structures with 150mm Thickness Under High Temperature.**

Storey	Displacement in mm for Conventional Slab	Displacement in mm for Flat Slab with and without Drop
1	16.5	19.4
2	16.9	19.9
3	16.8	19.8
4	16.8	19.8
5	16.8	19.8
6	16.8	19.8
7	16.8	19.8
8	16.8	19.8
9	16.8	19.8

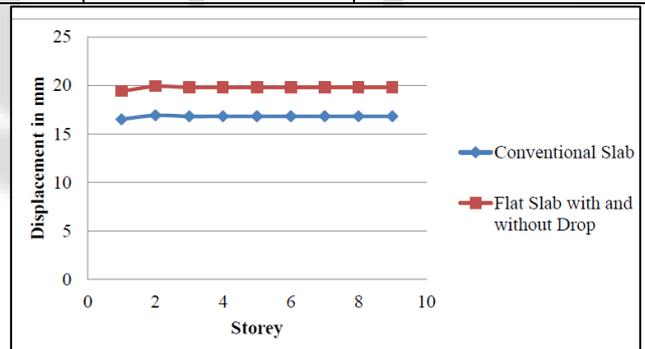


Fig. 5.45: Displacement of G+8 Storey Structures with 150mm Thickness Under High Temperature

**L. Displacement of G+8 Storey Structures with 200mm Thickness Under High Temperature.**

Storey	Displacement in mm for Conventional Slab	Displacement in mm for Flat Slab with and without Drop
1	17.2	19.5
2	17.5	19.9
3	17.4	19.8
4	17.4	19.8
5	17.4	19.8
6	17.4	19.8
7	17.4	19.8
8	17.4	19.8
9	17.4	19.8

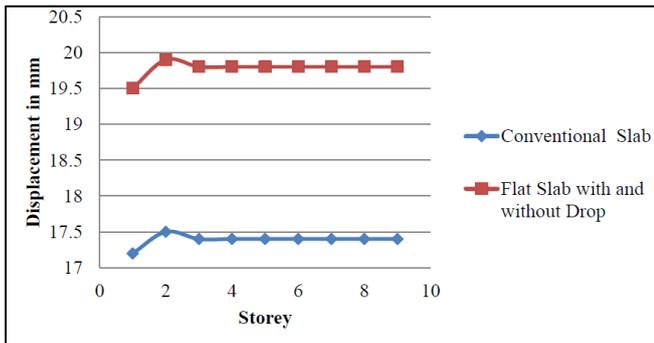


Fig. 5.46: Displacement of G+8 Storey Structures with 200mm Thickness Under High Temperature.

## VII. RESULTS & CONCLUSIONS

Lateral displacement in column increases as the storey level increases. The lateral displacement will increase drastically as the height increases. Lateral displacement will be minimum at plinth level and maximum at terrace level.

Lateral displacement of conventional R.C.C Slab is less than the flat slab buildings. About 68% to 70% of displacement is less in conventional slab than in flat slab is observed considering G+4 & G+8 with 150mm thickness of slab as shown in Figures 5.1, 5.3 and Tables 5.1, 5.3

About 70% to 82% of displacement is less in conventional slab than in flat slab is observed considering G+4 & G+8 with 200mm thickness of slab as shown in Figures 5.2, 5.4 and Tables 5.2, 5.4. It is because of the presences of beam in conventional slab which has more stiffness compared to flat slab. Conventional slab also has higher load carrying capacity.

### A. Conventional Slab and Flat Slab Subjected to Normal Temperature:

When temperature load is applied to the structure, the weight of the columns goes on increasing which makes the lowest column bulge and at that point displacement is maximum in the structure.

It is observed that Displacement of conventional slab of 150mm thickness is less, about 14% to 21% compared to the flat slabs building as shown in Figures 5.25, 5.27 and Tables 5.25, 5.27 .

It is observed that 7% to 14% of Displacement of conventional slab is less compared to Flat slabs of same thickness 200mm as shown in Figures 5.26, 5.28 and Tables 5.26, 5.28.

Axial force in conventional slab will be more compared to flat slabs. For 150mm thickness of slab about 76% to 80% and for 200mm thickness of the slab 60% to 66% as shown in Figures 5.37 to 5.42 and Tables 5.37 to 5.42.

Bending moment in conventional slab is less compare to flat slabs. For 150mm thickness of slab about 9% to 10% and for 200mm thickness of the slab 6% to 8% as shown in Figures 5.31 to 5.36 and Tables 5.31 to 5.36.

### B. Conventional Slab and Flat Slab Subjected to High Temperature:

It is observed that Displacement of conventional of 150mm thickness is less, about 15% compared to the flat slabs as shown in Figures 5.43, 5.45 and Tables 5.43, 5.45 .

It is observed that 12% to 14% of Displacement of conventional slab is less compared to flat slabs of same thickness 200mm as shown in Figures 5.44, 5.46 and Tables 5.44, 5.46 .

Axial force in conventional slab will be more compared to flat slabs. For 150mm thickness of slab about 76% to 80% and for 200mm thickness of the slab 60% to 66% as shown in Figures 5.55 to 5.60 and Tables 5.55 to 5.60. 91

Bending moment in conventional slab is less compare to flat slabs. For 150mm thickness of slab about 9% to 10% and for 200mm thickness of the slab 6% to 8% as shown in Figures 5.49 to 5.54 and Tables 5.49 to 5.54.

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