Seismic Analysis of Multi-Story Building Exposed to Fire

Shivansh pandey[1] and Shubhranshu Jaiswal[2]

[1]Post Graduate Student, Structural Engineering, Babu Banarasi Das University, Lucknow, Uttar Pradesh, India.
[2]Assistant Professor, Dept. of Civil Engg. Babu Banarasi Das University, Lucknow, Uttar Pradesh, India

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Abstract - *It is seen that after the exposure of fire the building is usually reconstructed or demolished so by various techniques such as NDT testing method we can do health monitoring of reinforced concrete structure which is damaged by fire. After doing health monitoring we will able to predict the reduced compressive and tensile strength of RCC structure. After health monitoring, we will able to know that the building is safe for re-use after doing repair and retrofitting or else we have to demolish it. If the building is safe for reuse after doing some retrofitting works then the problem is that the building is safe for seismic forces or not. In this paper, the work is to analyze fire-damaged building at the various temperature on its reduced strength of RCC on ETABS. In this study we will first prepare a model of a building by normal building design material after that we will design three new building models by using reduced strength materials which are predicated before in various research papers at a various temperature such as 300°C,500°C,600°C. After that, we will do the seismic analysis of these four building models and do a comparative study of story displacement, story drift, story stiffness*

Key Words: Concrete, fire damaged, story displacement, story drift, story stiffness, Etab.

1. INTRODUCTION

From the first day of its existence, earthquakes have become a danger to human growth, destroying human lives, property and man-made structures. The effect of dynamic actions on the buildings on account of earthquake forces (lateral forces) are very much important from the structural engineers view point. It is widely accepted that the structural design of buildings will follow at least two specific criteria. First, the system must perform elastically to defend fairly weak non-structural elements against small earthquakes. Therefore, the structure will have good capacity and elastic flexibility to reduce structural displacements., such as interstorey drift, story displacement and fundamental time period . Second, the structure does not fail in the case of a significant earthquake. In this scenario, substantial structural and non-structural harm is acceptable. In order to keep the system from collapsing and thereby reduce the loss of life, it must have a strong energy dissipation capability during large inelastic deformations. In the earthquake design, the building is subjected to a random ground motion or vibration at its base, which causes inertia forces in the building that in turn induce stresses; this is referred to as the displacement type loading also expressed as load-deformation curve of the building or a structure The four essential characteristics in buildings or systems that architects and construction engineers can look at in order to construct an earthquake-resistant building plan are the structural design, lateral stiffness, lateral strength and ductility. Such factors can be addressed by building design IS codes.

1.1 OBJECTIVE

The purpose of this work is to concentrate on the various methods used to test the seismic activity of fire exposed buildings at the various temperature on its reduced strength of RCC on ETABS. In this study we will first prepare a model of a building by using normal building design material after that we will design three-building models according to new material properties with a reduce strength which is predicted before in my review paper which is based on the study of various literature on a various temperature such as 300 °C, 500°C,600 °C and then we will do seismic analysis these four building models and do a comparative study of story displacement, story drift and story stiffness and fundamental time period behaviour of reinforced concrete buildings with seismic zone IV of India using an equivalent static method. The final research was carried out in ETABs addressing all areas of structural engineering. The main objectives of this research are, in particular,:

1) Conduct a comparative analysis of the different seismic parameters;.
2) Comparison based on story displacement, storey drift, Storey Stiffness & fundamental time period on four models.
3) The analysis would have an estimated understanding of how the exposed fire structure would work in the seismic force.

For this study, a multi-storey residential building for earthquakes and wind loads is analyzed using an equivalent static approach for ETABs. The research is carried out by observing the seismic region IV, and for this region, the activity is measured by taking the medium soils. A different response for story displacements, story drift, story stiffness and fundamental time period is plotted for zone IV for a medium type of soil.

1.2 STRUCTURALMODELING

For analysis, the 7-story high-rise building is modelled in ETABs software. The structure is not a true existing structure. RC framed (G+6) multi-storey building having 4 grid line in X and Y direction and spacing between the grid lines in the X direction is 4.5m and in the Y direction is 6.5m. The building is 22.5 m high and has a typical story height of 3.5m and bottom storey height is 1.5m. The building is analyzed by Equivalent static, which is a linear static analysis. A dead load of a wall is taken as wall load and parapet wall load which depend upon the wall thickness and the height of the wall. The thickness of the wall is taken as 230 mm for the outer wall and 115mm for inner walls. The unit weight of brick is 20KN/m^3 and height of partition wall will be 3.1m. The live load and the Floor finish dead load are taken as 2 KN/m^2 and 1.5 KN/m^2 according to IS 875:1987 (part 2).

All the specifications of the frame are given in Table 1.For the first building model

Table -1: (First building model specification)

1.	Building type	Residential building
2.	No. of floors	G+6
3.	Bottom storey height	1.5m
4.	Total height	22.5m
5.	Story height	3.5m
6.	Measurement of column	400mm*600mm
7.	Measurement of beam	450mm*300mm
8.	Thickness of slab	130mm
9.	Masonry wall thickness	230mm Outer wall and 115mmfor inner wall
10.	Seismic zone	IV
11.	Importance factor	1
12.	Response reduction factor	5
13.	Soil type	II
14.	Concrete cube compressive strength	30MPa
15.	Grade of steel	Fe500
16.	Damping	5%
17.	Unit weight of PCC	24 kN/m^3
18.	Unit weight of brick	20 kN/m^3
19.	Modulus of Elasticity	24855.58 MPa
20.	Shear Modulus	10356.49 MPa
21.	Live load	2KN/m^2
22.	Floor finish dead load	1.5KN/m^2
23.	IS Code for concrete	IS 456:2000
24	IS Code for earthquake	IS 1893:2002 (part I)
25.	IS Code for wind	IS 875 :1987
26	Self-weight factor	1
27.	Outer Wall load	14.26 KN/m
28.	Inner wall load	7.13KN/m

Table -2: Second building model specification

1.	Building type	Residential building
2.	No. of floors	G+6
3.	Bottom storey height	1.5m
4.	Total height	22.5m
5.	Story height	3.5m
6.	Measurement of column	400mm*600mm
7.	Measurement of beam	450mm*300mm
8.	Thickness of slab	130mm
9.	Masonry wall thickness	230mm Outer wall and 115mmfor inner wall
10.	Seismic zone	IV
11.	Importance factor	1
12.	Response reduction factor	5
13.	Soil type	II
14.	Concrete cube compressive strength	25.5 MPa
15.	Grade of steel	Fe500
16.	Damping	5%
17.	Unit weight of PCC	24 kN/m^3
18.	Unit weight of brick	20 kN/m^3
19.	Modulus of Elasticity	14913.55 MPa
20.	Shear Modulus	6213.9 MPa
21.	Live load	2KN/m^2
22.	Floor finish dead load	1.5KN/m^2
23.	IS Code for concrete	IS 456:2000
24	IS Code for earthquake	IS 1893:2002 (part I)
25.	IS Code for wind	IS 875 :1987
26	Self-weight factor	1
27.	Outer Wall load	14.26 KN/m
28.	Inner wall load	7.13KN/m

Table -3 Third building model specification

1.	Building type	Residential building
2.	No. of floors	G+6
3.	Bottom storey height	1.5m
4.	Total height	22.5m

5.	Story height	3.5m
6.	Measurement of column	400mm*600mm
7.	Measurement of beam	450mm*300mm
8.	Thickness of slab	130mm
9.	Masonry wall thickness	230mm Outer wall and 115mmfor inner wall
10.	Seismic zone	IV
11.	Importance factor	1
12.	Response reduction factor	5
13.	Soil type	II
14.	Concrete cube compressive strength	18 MPa
15.	Grade of steel	Fe500
16.	Damping	5%
17.	Unit weight of PCC	24 kN/m³
18.	Unit weight of brick	20 kN/m³
19.	Modulus of Elasticity	12935.04 MPa
20.	Shear Modulus	5385.43 MPa
21.	Live load	2KN/m²
22.	Floor finish dead load	1.5KN/m²
23.	IS Code for concrete	IS 456:2000
24	IS Code for earthquake	IS 1893:2002 (part I)
25.	IS Code for wind	IS 875 :1987
26	Self-weight factor	1
27.	Outer Wall load	14.26 KN/m
28.	Inner wall load	7.13KN/m

Table -4 Forth building model specification

1.	Building type	Residential building
2.	No. of floors	G+6
3.	Bottom storey height	1.5m
4.	Total height	22.5m
5.	Story height	3.5m
6.	Measurement of column	400mm*600mm
7.	Measurement of beam	450mm*300mm
8.	Thickness of slab	130mm
9.	Masonry wall thickness	230mm Outer wall and 115mmfor inner wall
10.	Seismic zone	IV
11.	Importance factor	1
12.	Response reduction factor	5
13.	Soil type	II
14.	Concrete cube compressive strength	10.5 MPa
15.	Grade of steel	Fe500
16.	Damping	5%
17.	Unit weight of PCC	24 kN/m³
18.	Unit weight of brick	20 kN/m³
19.	Modulus of Elasticity	11185.13 Mpa
20.	Shear Modulus	4660.43 MPa
21.	Live load	2KN/m²
22.	Floor finish dead load	1.5KN/m²
23.	IS Code for concrete	IS 456:2000
24	IS Code for earthquake	IS 1893:2002 (part I)
25.	IS Code for wind	IS 875 :1987
26	Self-weight factor	1
27.	Outer Wall load	14.26 KN/m
28.	Inner wall load	7.13KN/m

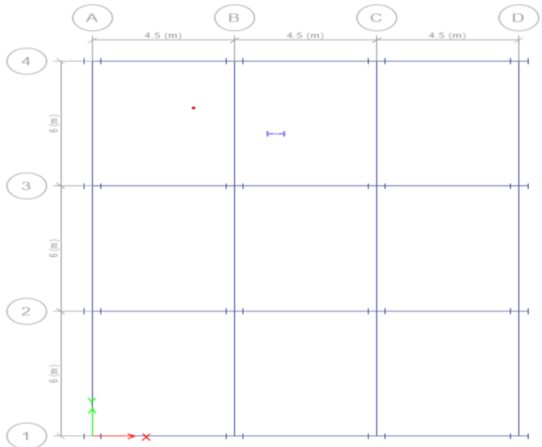

Fig -1: Plan of Building, Building dimensions

2. DEFORMED SHAPE

MODEL 1 DEFORMED SHAPE OF STRUCTURE DUE TO EARTHQUAKE LOADING

• In this model, we have applied earthquake load EQ at X+ direction. This is a simple RC framed structure without exposure to fire

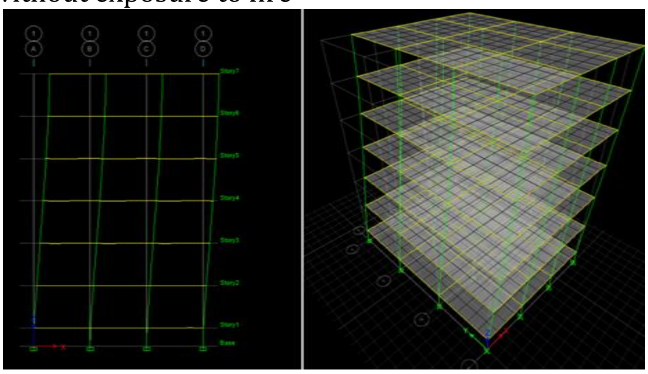

Fig -2 -3D and elevation view of model 1 at X direction

- In this model, we have applied earthquake load EQ at Y+ direction. This is a simple RC framed structure without exposure to fire

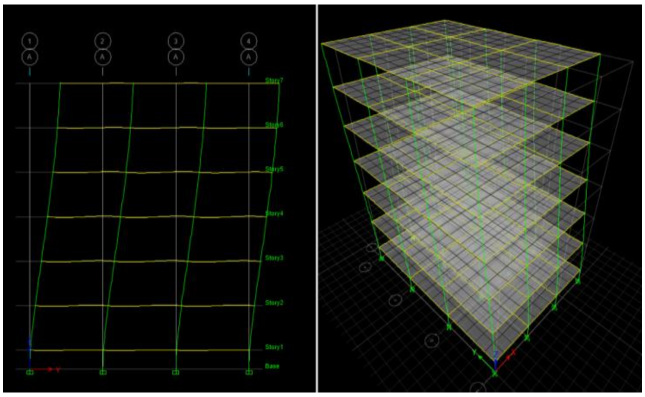

Fig -3- 3D and elevation view of model 1 at Y direction

MODEL 2- DEFORMED SHAPE OF STRUCTURE DUE TO EARTHQUAKE LOADING

- In this model, we have applied earthquake load EQ at X+ direction. This is a simple RC framed structure which is exposed to fire at temperature 300 °C

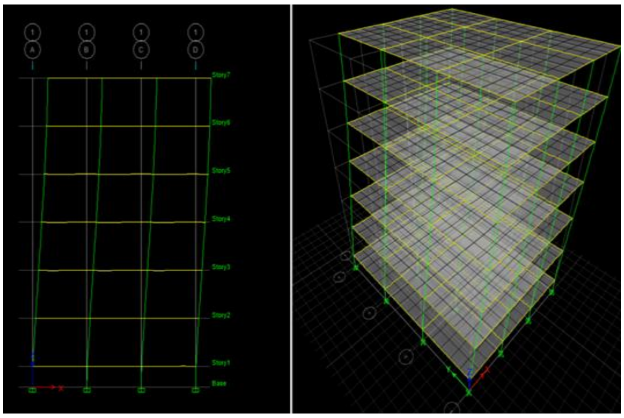

Fig -4 -3D and elevation view of model 2 at X direction

- In this model, we have applied earthquake load EQ at Y+ direction. This is a simple RC framed structure which is exposed to fire at temperature 300 °C

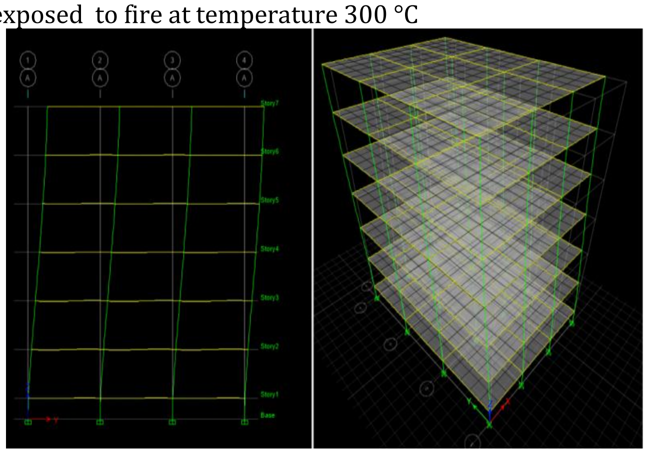

Fig -5 3D and elevation view of model 1 at Y direction

MODEL 3- DEFORMED SHAPE OF STRUCTURE DUE TO EARTHQUAKE LOADING

- In this model, we have applied earthquake load EQ at X+ direction. This is a simple RC framed structure which is exposed to fire at temperature 500 °C

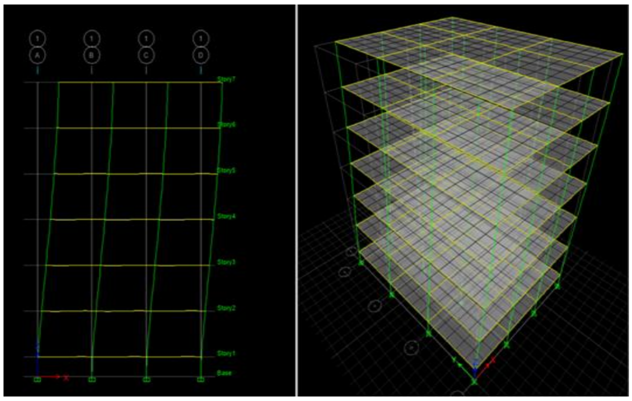

Fig -6 -3D and elevation view of model 3 at X direction

- In this model, we have applied earthquake load EQ at Y+ direction. This is a simple RC framed structure which is exposed to fire at temperature 500 °C

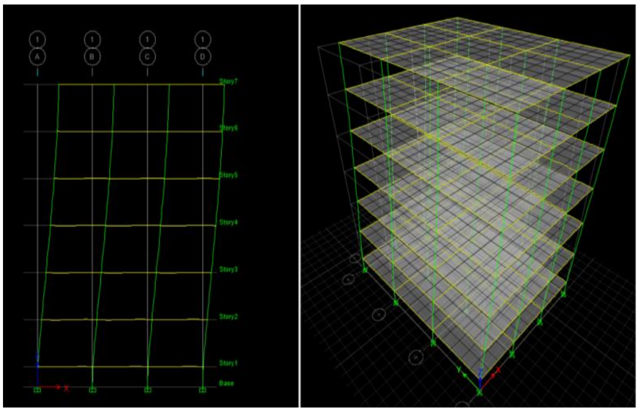

Fig -7 -3D and elevation view of model 3 at Y direction

MODEL 4-DEFORMED SHAPE OF STRUCTURE DUE TO EARTHQUAKE LOADING

- In this model, we have applied earthquake load EQ at X+ direction. this is a simple RC framed structure which is exposed to fire at temperature 600 °C.

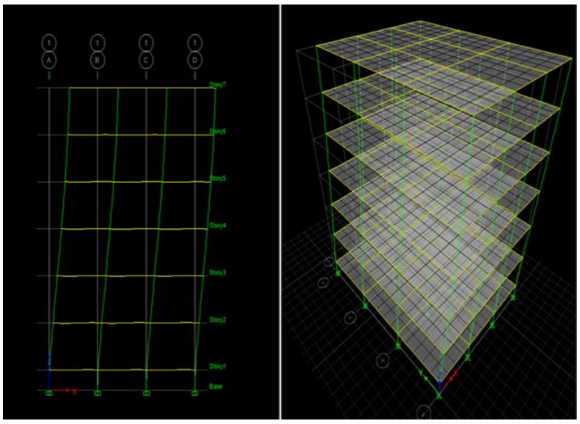

Fig -8 -3D and elevation view of model 4 at X direction

•In this model, we have applied earthquake load EQ at Y+ direction. This is a simple RC framed structure which is exposed to fire at temperature 600 °C.

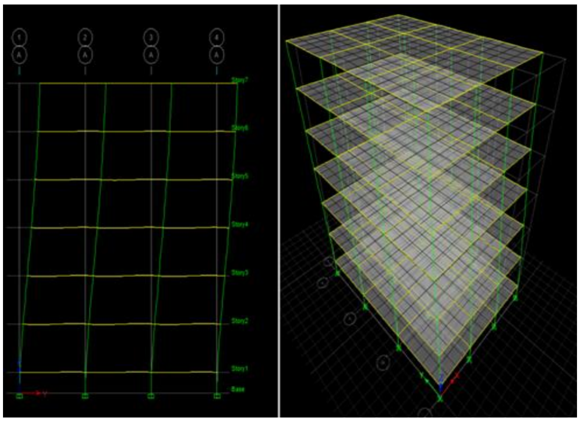

Fig -9 -3D and elevation view of model 4 at Y direction

3. ETABs Overview

ETABS is used as an Engineering software tool for multi-storey construction and design study in buildings. Can be evaluated preliminary to advanced systems under either dynamic or static conditions utilizing ETABS. ETABs are used for seismic analysis and for the evaluation of multi-storey building behaviours which are related to various analytical parameters such as story drift, story displacemen, story stiffness etc. Comprehensive research like structural simulation is done in this program.The analysis was carried out using ETABs software, which involves the following steps:-

1. Defining the dimension of the design
2. Defining the elements and properties of the material
3. Assigning load and load combinations
4. Run and check the model to locate the error
5. Run analysis
6. Extract the findings and analyze them

4. METHOD OF ANALYSIS

Equivalent static method

This method describes a set of forces operating on a building that reflect the impact of earthquake ground motion, usually represented by a seismic design response spectrum. This means that the building reacts in its simple mode of service. To order for this to be valid, the structure must be low-rise and must not be dramatically bent as the ground vibrate. The response is read from the design response spectrum, provided the building's natural frequency (either measured or specified by the building code). The applicability of this approach is generalized in other building codes by adding criteria that qualify for higher buildings with certain higher modes and low rates of twisting.. Such codes add alteration factors that minimize structural forces (e.g. force reduction factors) to compensate for results related to the "yielding" of the framework. For the determination of seismic forces, the country shall be divided into four seismic zones: each zone shall have its zone factor value and, as per IS 1893 (Part 1):2002, these values shall be given below:

Seismic Zone Factor (1)	II (2)	III (3)	IV (4)	V (5)
Z	0.10	0.16	0.24	0.36

Fig -10- Every zone has its own zone factor value and as per IS 1893 (Part 1):2002

Table 4 -As per IS Code 1893(part 1) :2002 the following were the major steps for determining the seismic forces:

Serial No	Model Description	
1	Zone	IV
2	Zone Factor	0.24
3	Type of building	Residential
4	Importance Factor	1
5	Soil Type	II
6	Soil Condition	Medium
7	Damping Ratio	5%
8	Response Reduction Factors	5

5. RESULTS

Storey drift

It is the displacement of one level relative to the other level above or below.It is defined as ratio of displacement of two consecutive floor to height of that floor. It is very important term used for study purpose in seismic engineering.According to Indian standard code 1893:2002 (part 1), the storey drift should not exceed 0.004 times the storey height.

Table 5. Max.Storey drift comparison in x-direction- The table and graph below shows the comparison between the various building models

NO OF STOREY	MODEL-1	MODEL-2	MODEL-3	MODEL-4
Story-7	0.000308	0.000398	0.000427	0.000459
Story-6	0.000505	0.000652	0.000701	0.000753
Story-5	0.000645	0.000833	0.000894	0.000961
Story-4	0.000723	0.000933	0.001002	0.001078
Story-3	0.000743	0.00096	0.001031	0.001108
Story-2	0.000637	0.000822	0.000883	0.000949
Story-1	0.000196	0.000253	0.000272	0.000292

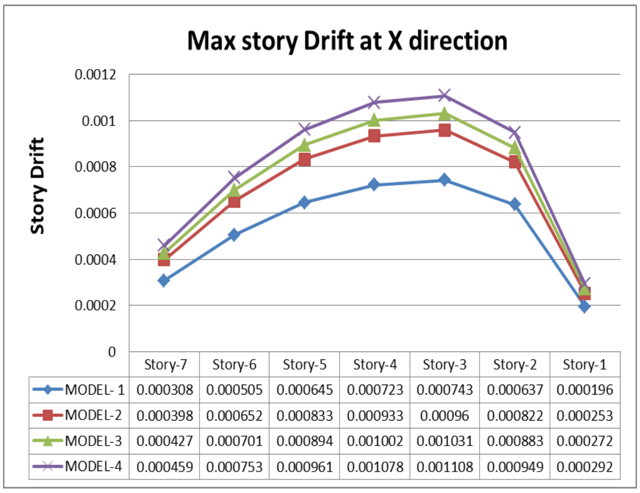

Chart -1 *Max Story Drift X direction*

Table 6 Max.Storey drift comparison in Y-direction- The table and graph below shows the comparison between the various building models

NO OF STOREY	MODEL- 1	MODEL-2	MODEL-3	MODEL-4
Story-7	0.000336	0.000434	0.000466	0.000501
Story-6	0.000512	0.000662	0.000711	0.000764
Story-5	0.00065	0.00084	0.000902	0.00097
Story-4	0.000726	0.000937	0.001006	0.001082
Story-3	0.000721	0.000931	0.001	0.001075
Story-2	0.000553	0.000714	0.000767	0.000824
Story-1	0.000175	0.000226	0.000243	0.000261

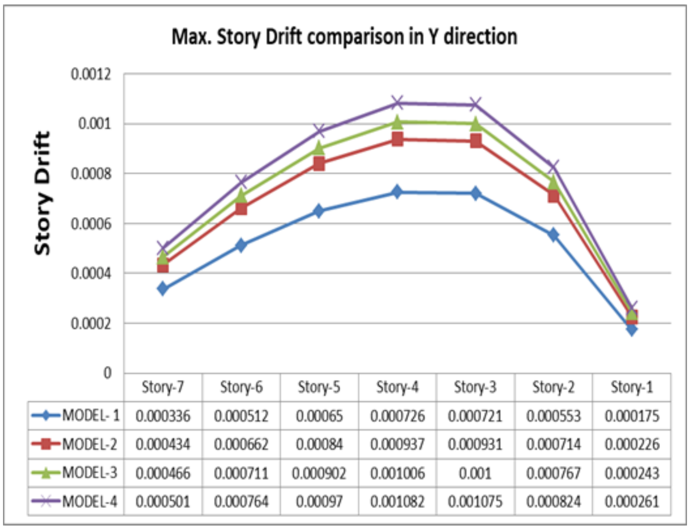

Chart -2 .Max Story Drift Y direction

Storey Displacement

It is the displacement of each floor in relation to the ground level.According to IS 1893 (part1):2002 the max value of displacement is 1/250 times of story height with respect to ground.

Table 7. Max. Storey displacement (mm) comparison in x-direction- The table and graph below shows the comparison of the various models in terms of storey displacement in X direction

NO OF STOREY	MODEL- 1	MODEL-2	MODEL-3	MODEL-4
Story-7	12.75584	16.407722	17.689075	19.015184
Story-6	11.67818	15.076465	16.194634	17.408708
Story-5	9.909554	12.793179	13.742004	14.77221
Story-4	7.65208	9.8787793	10.611468	11.406985
Story-3	5.122169	6.612692	7.103132	7.635637
Story-2	2.521748	3.255563	3.497017	3.75918
Story-1	0.294	0.379553	0.407703	0.438267

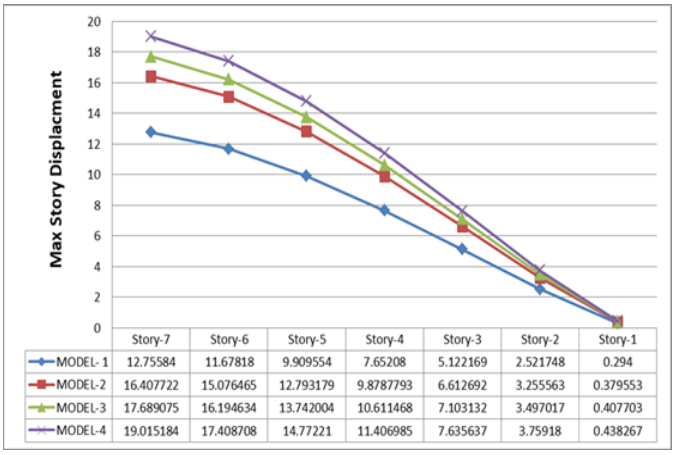

Chart -3 Max Story Displacements X direction

Table8- Max. Storey displacement (mm) comparison in Y direction- Table and graph below show the comparison of various models in terms of storey displacement in the Y direction.

NO OF STOREY	MODEL- 1	MODEL-2	MODEL-3	MODEL-4
Storey-7	12.503188	16.141546	17.338708	18.638551
Storey-6	11.328639	14.625209	15.70909	16.887645
Storey-5	9.535262	12.30497	13.222957	14.214552
Storey-4	7.258716	9.370962	10.065973	10.82596
Storey-3	4.719086	6.092313	6.544159	7.034759
Storey-2	2.197795	2.837342	3.047777	3.276262
Storey-1	0.262391	0.338746	0.363869	0.391148

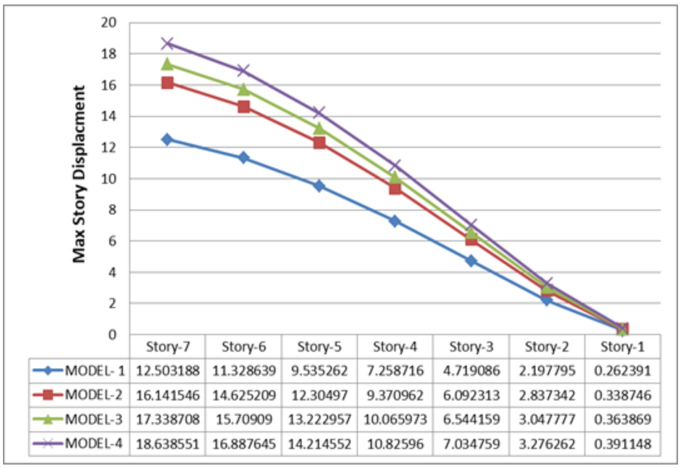

Chart -4 Max Story Displacements Y direction

Fundamental time periods

Every object has a natural vibration frequency and so has every structure. When a structure is excited by seismic forces, it starts to vibrate. The lowest natural frequency (f) of vibration of a structure corresponds to the longest time period (T) of vibration, as frequency and time period are inversely proportional (T=1/f). This is also referred to as the first mode of vibration or a fundamental period of vibration. The structure will have multiple natural modes of vibration for which frequency will be higher and time period will be shorter than the fundamental period. According to IS 1893(Part 1):2002 it is the first(longest) modal time period of vibration

Table 9-Fundamental time period (S) comparison-The table and the graph below shows the comparison of various models at a various temperature in terms of the fundamental time period

Modal	MODEL- 1	MODEL-2	MODEL-3	MODEL-4
Modal 1	0.913	1.178	1.266	1.36
Modal 2	0.874	1.128	1.212	1.303
Modal 3	0.767	0.99	1.064	1.143
Modal 4	0.294	0.379	0.407	0.438
Modal 5	0.269	0.348	0.374	0.402
Modal 6	0.244	0.315	0.338	0.363
Modal 7	0.166	0.215	0.231	0.248
Modal 8	0.143	0.184	0.198	0.212
Modal 9	0.135	0.174	0.187	0.201
Modal 10	0.112	0.145	0.156	0.167
Modal 11	0.089	0.115	0.124	0.133
Modal 12	0.088	0.114	0.123	0.132

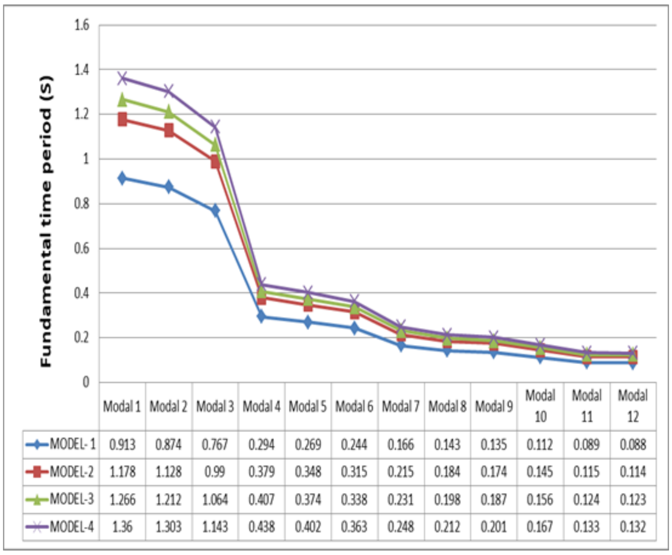

Chart -5 fundamental time period

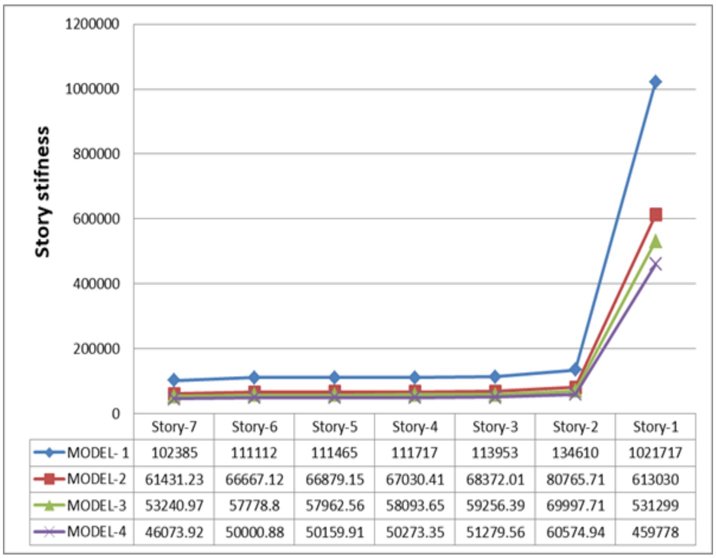

Chart -6. storey stiffness in x-direction

Story stiffness

As per IS 1893:2002 the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of average lateral stiffness of the three-storey above

Table10- Max. Storey stiffness (kN/m) comparison in x direction-The table and graph below shows the comparison of various models in terms of storey stiffness in X direction

NOOF STOREY	MODEL- 1	MODEL-2	MODEL-3	MODEL-4
Storey-7	102385	61431.23	53240.97	46073.92
Storey-6	111112	66667.12	57778.80	50000.88
Storey-5	111465	66879.15	57962.56	50159.91
Storey-4	111717	67030.41	58093.65	50273.35
Storey-3	113953	68372.01	59256.39	51279.56
Storey-2	134610	80765.71	69997.71	60574.94
Storey-1	1021717	613030	531299	459778

Table11- Max. Storey stiffness (kN/m) comparison in Y direction-the table and graph below shows the comparison of various models in terms of storey stiffness in Y direction.

NO OF STOREY	MODEL- 1	MODEL-2	MODEL-3	MODEL-4
Story-7	98054	58832.84	50989.01	44125.10
Story-6	114421	68652.43	59499.42	51489.88
Story-5	115414	69298.55	60016.06	51936.97
Story-4	116206	69723.58	60427.76	52293.26
Story-3	122717	73630.09	63813.44	55223.17
Story-2	161852	97111.35	84164.09	72834.31
Story-1	1193646	716188	620703	537147

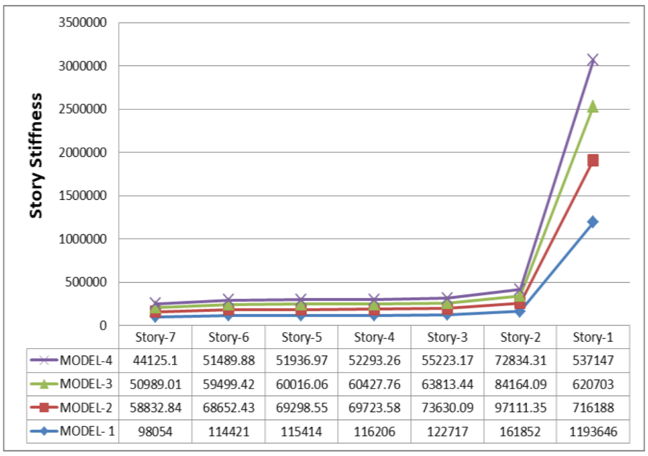

Chart -7. storey stiffness in x-direction

6. CONCLUSIONS

Several conclusions may be taken from the following analysis and findings, such as::

1) Concrete elements subjected to temperature up to 300°C or 500°C are still safe for use because at this temperature concrete moistures would have been absolved by fire and cracks will occur due to expansion and contraction of constituent materials but the entire structure will be serviceable. However, buildings subjected to temperatures above 600°C are structurally unsafe. At temperature above 600°C concrete element will have lost about 70 % of its strength
2) The model above 600°C is failed in design check Hence, buildings subjected to temperatures above 600°C are structurally unsafe
3) Max story Drift increases with increase in temperature
4)) It is seen that max story drift increases by 22.606% between model1 to mode ,6.88% in between model 2 and model 3 and 6.94% increases in-between model 3 and model 4
5) Max story Displacement increases with increase in temperature
6) It is seen that max story displacement increases by 23.460% between model1 to model2 ,7.2438% in between model 2 and model 3 and 6.93% increases in-between model 3 and model 4
7) The fundamental time period will increase with the increase in temperature
8) Story stiffness decreases with increase in temperature
9) It is seen that Story stiffness decreases by 40% between model1 to model2 ,13.33% in between model 2 and model 3 and 13.46 % decreases in-between model 3 and model 4
10) The non-destructive test is a way of testing which does not affect the overall performance of a member's entity under investigation. It could be performed during construction and after maintenance. The IRH and UPV can be used as a reliable method to predict the mechanical strength of the reinforced concrete structure
11) It is found that the slabs are mostly effected by fire and has maximum damaged it is because they are located at the highest evaluation of the room where they are exposed to the highest temperature during a fire
12) The strength of steel will start to decrease at approximately 430° C (800° F). At 590° C (1100° F) steel loses approximately 50% of its strength and stiffness when compared to normal ambient conditions. At 700° C (1300° F) the strength and stiffness are reduced to approximately 20% of the ambient condition strength and stiffness. These property reductions will likely be temporary, and the steel will regain its strength and stiffness if the temperature of the steel does not exceed 700° C (1,300° F) for longer than 20 minutes

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