PERFORMANCE BASED VULNERABILITY ASSESSMENT OF MULTI STOREY STEEL BUILDING UNDER DIFFERENT FIRE EXPOSURE CONDITIONS

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Abstract - *This paper presents a numerical investigation on the structural behaviour of a multi storey steel building under different fire exposure conditions. A proposed 12-storey steel building with a floor layout of 21.945 m x 21.95 m is considered for analysis. Finite element model of 12-storey steel building were developed using ANSYS WORKBENCH 16.1.Different fire exposure conditions as per ISO-834 standard fire are investigated. They include column fire exposure condition, different compartment fire exposure condition (corner, middle and interior) and combined compartment fire exposure condition (corner-middle, middle-interior and corner-interior).Axial capacity and Time limit failure of building were discussed. This study has demonstrated the importance and necessity of considering different fire exposure conditions in fire resistance design of multi storey steel buildings*.

Key Words: Fire resistance, High rise building, Finite Element Analysis, Fire exposure conditions, Axial capacity, Time limit failure.

1. INTRODUCTION

The structural behaviour of steel building under fire depends on various parameters such as structural configuration, layout, fire intensity, duration, structural loading, fire protection distribution and boundary conditions. Fire exposure is the subjection of a material or construction to a high heat flux from an external source with or without flame impingement. Steel possesses a very low resistance to fire exposure due to high thermal conductivity, low specific heat and fast degradation of strength with temperature. The deflection is excessive in steel structure under fire due to static load present on structure.

In recent studies on the thermal response it has been found that structural members are likely to reach higher temperatures when subjected to travelling fires in comparison to uniform fires. Higher temperatures lead to a higher loss of material strength. When steel exposes to fire it absorbs thermal energy, after a certain time of cooling it return either stable or unstable condition. During this heating and cooling operation the members may be scrapped due to large deformation, perfect for its straightness behaviour after fire exposure, reusable by straightening. The strength and stiffness of steel decreases very rapidly when exposed to fire, which creates problems when the steel is needed for strength in structures.

In this study, the proposed 12-storey steel building with a floor layout of 21.945 m x 21.95 m is considered for analysis [3].Finite element model of 12-storey steel building were developed using ANSYS WORKBENCH 16.1. Axial capacity performance and time limit failure of building under different fire exposure conditions were discussed. The purpose of this study to understand the structural behaviour of building during possible fire and most critical parts of the structure for fire in fire resistance design.

2. FINITE ELEMENT MODEL

2.1 Multi storey steel building

The multi storey steel building is considered in this analysis. It is a 12 storey 3 bay frames with a floor layout of 21.945 m x 21.95 m. The plan layout and elevation of the building are shown in figure 1 and 2 respectively [3] and figure 3 shows finite element model of building .The design loads on the floor beams are 3.64 kN/m^2 (Dead) and 0.96 kN/m^2(Live) and roofs are 2.68 kN/m^2(Dead) and 0.96 kN/m^2 [4]. Different floors of the building are referred to as floor 0 to floor 11, going up from the ground floor to top floor of the building. W Properties of building are shown in Table1. The external column sections on floors 0-2, floors 3-5, floors 6-8 and floors 9-11 are W14x176, W14x132, W14X109 and W14x159 respectively. The internal column sections on floors 0-2, floors 3-5, floors 6-8 and floors 9-11 are W14x257, W14x211, W14X211 and W14x159 respectively. The beam sections on floors 0-2, floors 3-5, floors 6-8 and floors 9-11 are W30x124, W30x116, W30x108 and W30x99 respectively. The young's modulus of steel is E = 2x10^5 MPa, steel yield stress is fy = 420 MPa and Poisson's ratio is 0.3.

Table -1: W properties

Shape	Depth (inch)	Flange Width (inch)	Flange thickness (inch)	Web thickness (inch)
W14X90	14	14.5	0.71	0.44
W14X109	14.3	14.6	0.86	0.525
W14X132	14.07	14.7	1.03	0.645
W14X176	15.2	15.7	1.31	0.83
W14X189	15	15.5	1.19	0.745
W14X193	15.5	15.7	1.44	0.89
W14X211	15.7	15.8	1.56	0.98
W14X257	16.4	16	1.89	1.18
W30X99	29.7	10.5	0.67	0.52
W30X108	29.8	10.5	0.76	0.545
W30X116	30	10.5	0.85	0.565
W30X216	30.2	10.5	0.93	0.585

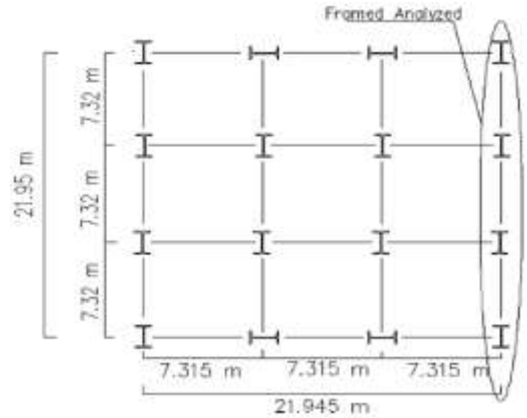


Fig-1: Plan layout of building

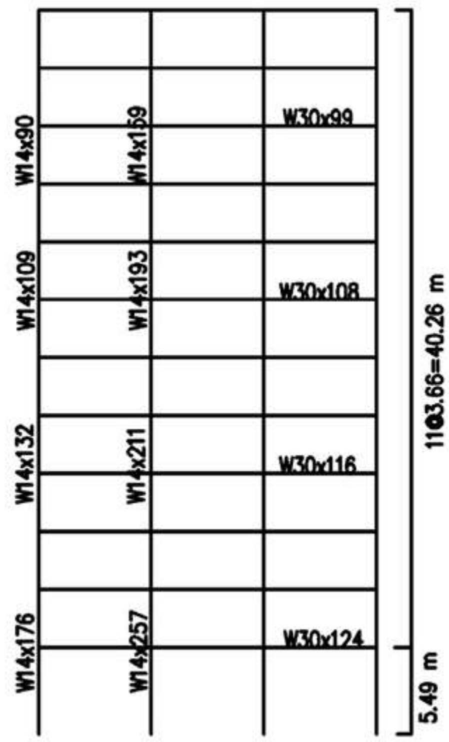


Fig -2: Elevation of building

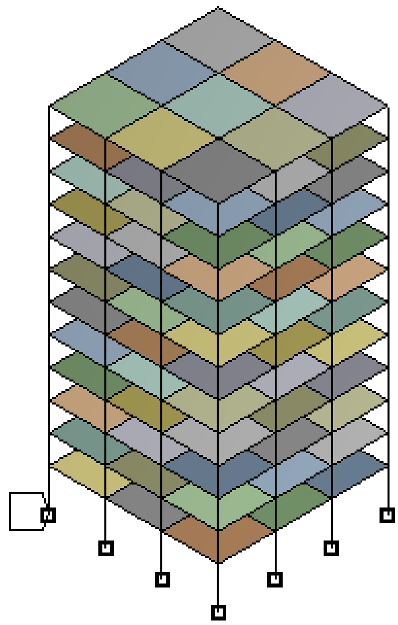


Fig -3: Finite element model

2.2 Fire scenarios

Three fire scenarios were considered in this analysis. Fire scenario 1 includes column fire exposure on each storey as shown in figure 4 and its deformation as shown in figure 7, Fire scenario 2 includes fire exposure on corner, middle and interior compartments as shown in figure 5 and its deformation as shown in figure 8 and Fire scenario 3 includes fire exposure on combined compartments as shown in figure 6 and its deformation as shown in figure 9.

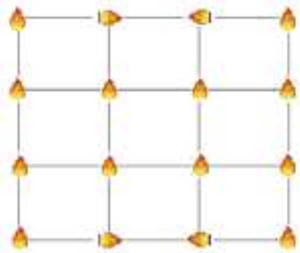


Fig -4: Fire scenario 1

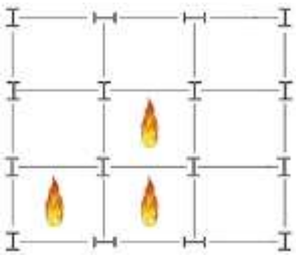


Fig -5: Fire scenario 2

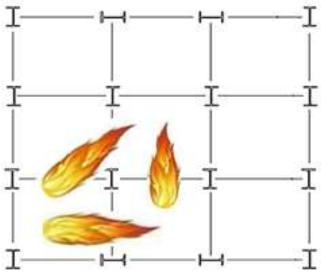


Fig -6: Fire scenario 3

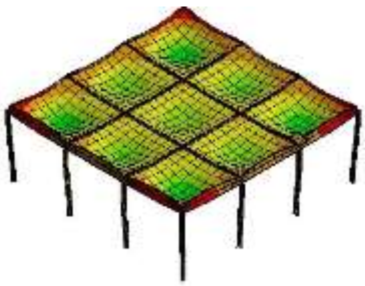
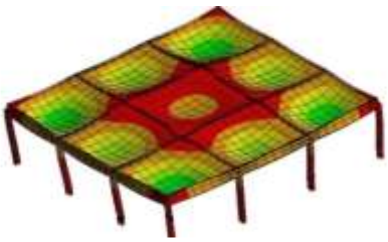


Fig -7: Deformation for fire scenario 1

a) Corner compartment

b) Middle compartment



c) Interior compartment

Fig -8: Deformation for fire scenario 2

a) Corner-Middle compartment

b) Middle-Interior compartment

a) Corner-Interior compartment

Fig -9: Deformation for fire scenario 3

3. ANALYTICAL RESULTS AND DISCUSSIONS

3.1 Time limit failure and axial loading

3.1.1 Column fire exposure on each storey

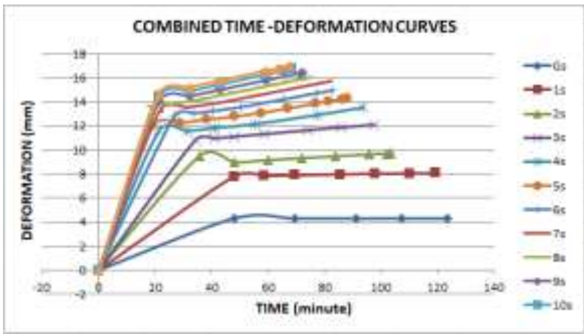


Chart -1: Comparison of Time-Deformation curves for column fire exposure on each storey

For ground storey, heated columns are collapsed at about 123.6 minute and at failure, axial deformation was 4.2965 mm and the maximum and minimum axial force of a buckled column in the ground storey were 3086.30 kN and 1060.4 kN respectively. For first storey heated columns are collapsed at about 119.2 minute and at failure, the axial deformation was 8.062 mm and the maximum and minimum axial force of a buckled column in the first storey were 2762.20 kN and 955.13 kN respectively. For second storey, heated columns are collapsed at about 103.5 minute and at failure, the axial deformation was 9.7182 mm and the maximum and minimum axial force of a buckled column in the second storey were 2392.70 kN and 827.25 kN respectively. For third storey, heated columns are collapsed at about 97.6 minute and at failure, the axial deformation was 12.098 mm and the maximum and minimum axial force of a buckled column in the third storey were 2106 kN and 718.93 kN respectively. For fourth storey, heated columns are collapsed at about 93.8 minute and at failure, the axial deformation was 13.537 mm and the maximum and minimum axial force of a buckled column in the fourth storey were 1860.10 kN and 621.93 kN respectively. For fifth storey heated columns are collapsed at about 88.2 minute and at failure, the axial deformation was 14.32 mm and the maximum and minimum axial force of a buckled column in the fifth storey was 1601.60 kN and 526.1 kN respectively. For sixth storey, heated columns are collapsed at about 82.8 minute and at failure, the axial deformation was 14.967 mm and the maximum and minimum axial force of a buckled column in the sixth storey were 1357.90 kN and 432.82 kN respectively. For seventh storey, heated columns are collapsed at about 81.5 minute and at failure, the axial deformation was 15.698 mm and the maximum and minimum axial force of a buckled column in the seventh storey were 1139.50 kN and 349.75 kN respectively. For eighth storey, heated columns are collapsed at about 74.4 minute and at failure, the axial deformation was 16 mm and the maximum and minimum axial forces of a buckled column in the eighth storey were 899.06 kN and 267.25 kN respectively. For ninth storey, heated columns are collapsed at about 72.3 minute and at failure, the axial deformation was 16.432 mm and the maximum and minimum axial forces of a buckled column in the ninth storey were 684.41 kN and 189.56 kN respectively. For tenth storey, heated columns are collapsed at about 68.5 minute and at failure, the axial deformation was 16.753 mm and the maximum and minimum axial forces of a buckled column in the tenth storey were 469.89 kN and 114.03 kN respectively. For eleventh storey, heated columns are collapsed at about 67.9 minute. After failure, the axial deformation was 17.003 mm and the maximum and minimum axial forces of a buckled column in the eleventh storey were 231.81 kN and 60.333 kN respectively.

3.1.2 Different compartment fire exposure

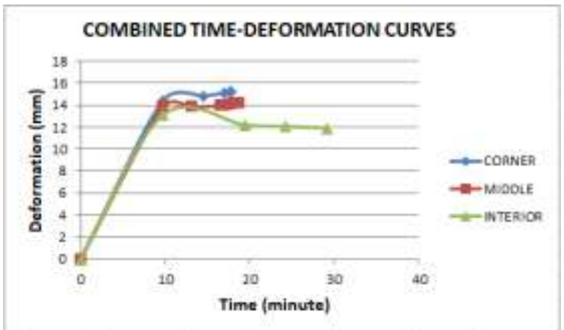


Chart -2: Comparison of Time-Deformation curves for different compartment fire exposure

For corner compartment, heated columns are collapsed at about 17.8 minute and at failure, the axial deformation was 15.236 mm and the maximum and minimum axial force of a buckled column in the corner compartment were 2550 kN and 646.80 kN respectively. For middle compartment, heated columns are collapsed ate about 18.7 minute and at failure, the axial deformation was 14.185 mm and the maximum and minimum axial force of a buckled column in the middle compartment were 2547.30 kN and 1432.40 kN respectively. For interior compartment, heated columns are collapsed at about 29.1 minute and at failure, the axial deformation was 11.914 mm and the maximum and minimum axial force of a buckled column in the interior compartment were 2875.80kN and 2847 kN respectively.

3.1.3 Combined compartment fire exposure

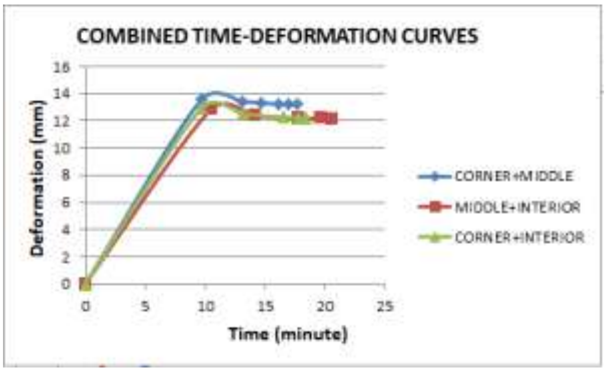


Chart -3: Comparison of Time-Deformation curves for combined compartment fire exposure

For corner-middle compartment, heated columns are collapsed at about 17.7 minute and at failure, the axial deformation was13.211 mm and the maximum and minimum axial force of a buckled column in the corner-middle compartment were 256.30 kN and 638.27 kN respectively. For middle-interior compartment, heated columns are collapsed ate about 20.6 minute and at failure, the axial deformation was 12.173 mm and the maximum and minimum axial force of a buckled column in the middle-interior compartment were 2592.40 kN and 1444.10 kN respectively. For corner-interior compartment, heated columns are collapsed at about 18.4 minute and at failure, the axial deformation was 12.263 mm and the maximum and minimum axial force of a buckled column in the corner-interior compartment were 2562.80 kN and 632.21 kN respectively.

4. CONCLUSIONS

Based on the computed results and the discussions made, the following conclusions are drawn:

- This paper numerically investigates the response of a 12- storey building subjected to different fire exposure conditions.
- For column fire exposure condition, ground storey has taken more time to collapse (123.6 minute) compared to other storeys.
- For different compartment fire exposure condition, interior compartment has taken more time to collapse (29.1 minute) compared to corner and middle compartment and corner compartment collapsed first at 17.8 minute, then middle compartment at 18.7 minute.
- For combined compartment fire exposure condition, middle-interior compartment has taken more time to collapse (20.6 minute) compartment to corner-middle and corner-interior compartment and corner-middle compartment collapsed first at 17.7 minute, then corner-interior compartment at 18.4 minute.
- After failure, there was a sudden increment in the axial deformation and reduction in the axial force of the buckled column.
- Understanding the structural behaviour of building during possible fire.
- Identifying the most critical parts of the structure for fire.
- This paper demonstrates that different fire exposure conditions as per ISO-834 standard fire should be considered in the fire resistance design of multi storey steel buildings.

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