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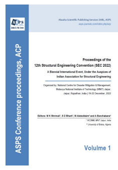

Vulnerability of Multistory RCC Framed Building with Shear Wall During Fire

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Abstract

Fire in a building is a casual phenomenon but cannot be completely ruled out in spite of the facts that buildings are provided with mandatory fire safety measures. A symmetrical in plan with 5 bays with 20 stories regular RCC building has been considered with fire at three different level that is at the bottom, middle and top. The building has been designed for gravity loads and lateral loads having three different configuration of shear walls and columns. Fire temperature of 700 ^{0}C was considered. The minimum value of maximum fire temperature for failure of vertical members has been found out by iterations. The worst verticals members due to fire has been identified and their displacement calculated. Best location of shear walls using commercial software etabs is used for the analysis and design.

Keywords: Fire Vulnerability, temperature loading, etabs, vertical deflection, lateral displacements, shear walls,

1. Introduction

In the five years between 2010 and 2014, over 1.13 lakh people have died across the country in fire accidents [11]. Fire is one of the most severe hazards that building structures may experience during their lifetime. Though fire in a building is a casual phenomenon yet fire safety provisions are mandatory provided in all the buildings. However, fire service in most of the buildings is found to be dysfunctional. Recently government of India introduced the provision for fire insurance of the buildings. The policy provides coverage for any damage caused due to the fire (9), but at times it has been noticed that the fire tenders not able to reach at the site of fire due to various reasons such as heavy traffic, narrow roads, roads under repairs etc. The setting up of Industrial Plants at a fast pace with extensive use of hazardous materials and the construction of larger and taller buildings have increased the fire accidents in recent times. The fire hazards are no longer confined to big cities and manufacturing centers only. Reinforced concrete structure performed better then steel structure during fire. Its behavior as fire resisting element caused most of fire damaged structure being reused after the fire, provided structural assessment has been carried out. Buildings are planned to minimize danger to life from fire, smoke, fumes or panic before the buildings can be evacuated. The building Code recognizes that safety of life is more than a matter of means of exits and accordingly deals with various matters which are considered essential to the safety of life (2). Buildings are also provided by fire staircase, water hose, water sprinklers, fire extinguishers, but nevertheless the fire do occur. If a structure is damaged by fire, it is necessary to investigate its cause, and evaluation of the damaged structure for its reuse is necessary.

In terms of structural efficiency, it may be a better approach to retrofit the damaged components of the structure, instead of demolishing it partially or completely. This decision must be made based on the result of investigations such as the visual inspection of the damaged structure, tests on the remaining material, and finite element simulations of the structure or its structural components. Reinforced concrete (RC) shear walls are considered as one of the lateral loads resisting structural members in RCC buildings. Apart from acting as a lateral load resisting system, the RCC shear walls tend to provide stability and stiffness to the structure (1). The displacement of the structure exposed to higher temperatures (550℃ and 750℃) have reduced due to the inclusion of RC shear walls in the structure (1).

Based on this discussion, this work attempts to identify the best configuration of shear walls in a twenty story symmetrical regular RCC Buildings from Fire hazard view point, considering the fire limited to specific stories such as first, ninth and tenth, and ninetieth and twentieth Reason of the fire has been considered unknown The stories considered under fire are exposed to fire of 700 ℃ temperature. RCC structures exposed to high temperature

Beyond 400 C temperature, a definite loss of strength of concrete occur due to formation of CaO from loss of water of free $Ca(OH)2$, which upon wetting rehydrates to its earlier form resulting into expansion in its volume (12) The temperature in the concrete mass of an RCC building rises, causing thermal expansion of its constituents. Evaporation of

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moisture, and pore pressure in concrete builds up. RCC elements exposed to fire generally suffer strength loss of the matrix by degradation of the hydrate structure and spalling or “shelling” of the concrete. Other important properties of reinforced concrete (RC) structures which deteriorate are loss in compressive strength, loss of elastic modulus, cracking and spalling of the concrete cover, reduction of yield strength, ductility and tensile strength of the steel and loss of the bond between the concrete and steel [(1)].At temperatures of 550°C, aggregates begin to deteriorate. Unsound aggregate particularly siliceous aggregates having quartz polymorphically change with a volumetric expansion causes damage. In limestone aggregate concrete, $CaCO_3$ turns into CaO at 800-900°C, and further expands with temperature. The loss in compressive strength results in the deflection of beams and columns in vertical and lateral direction.

2. Details of Models

A symmetrical regular building having five bay in each direction with spacing 4 m.the height of the building is 60 meters with 20 stories. The first having shear wall at the corner of the building, second model having shear walls at the bay 2 and 4 on periphery of the building, third model have the shear walls at the bay 4 on periphery of the building. There is no interior shear wall in the building.

In present work 12 numbers of structural models have been considered. The first three models are base models with three different configurations of the shear walls.in which the shear walls re located at different location. The naming of these models are 2.Model_Corner SW, 3.Model_Middle SW, 4.Model_Outer SW, the term SW is stands for shear wall. These models are identical in terms of loading (dead load as 1.2 kN/m2, live load 3 kN/m2 and wall load as 7 kN/m), beam size 300mmx500 mm, slab thickness 150 mm, grade of concrete M30, grade of steel Fe500, zone of earthquake i.e. Z=0.24, plan of building, height of building and foundation support i.e. fixed at the bottom. The size of columns and walls are varying to make the lateral deflection of building same in all three models within its permissible limit of H/250 i.e. 250 mm. Fire with temperature 700 °C has been considered.

The fire has been considered at first story, 9th and10th story, 19th and 20th story in each of the three-basic model of the building. The model named as 5.Model_Corner SW-Fire@1Floor, 6.Model_Corner SW - Fire@9 and 10 Floor and 7.Model_Corner SW - Fire@19 and 20 Floor. Similarly, other models naming is done in the same manner to avoid the confusion. To compare the results a small part is consider which is marked in the Figure (1). The deflection and rotation have been obtained and compared in the considered portion of the models.

Figure (2), Figure(3) & Figure(4) are the different configuration of model by changing columns size and shear wall location with different size to maintain the same lateral displacement in all frames.

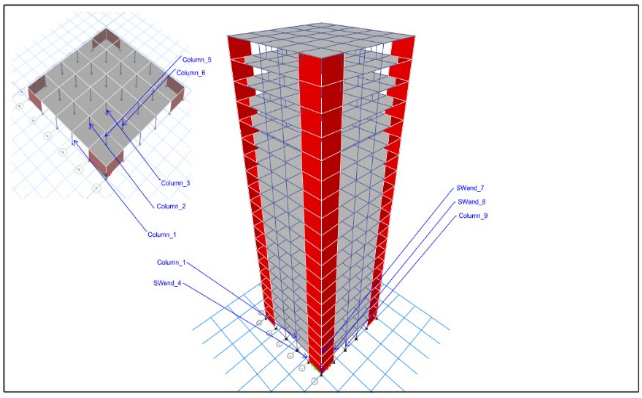


Figure (1) Structural model

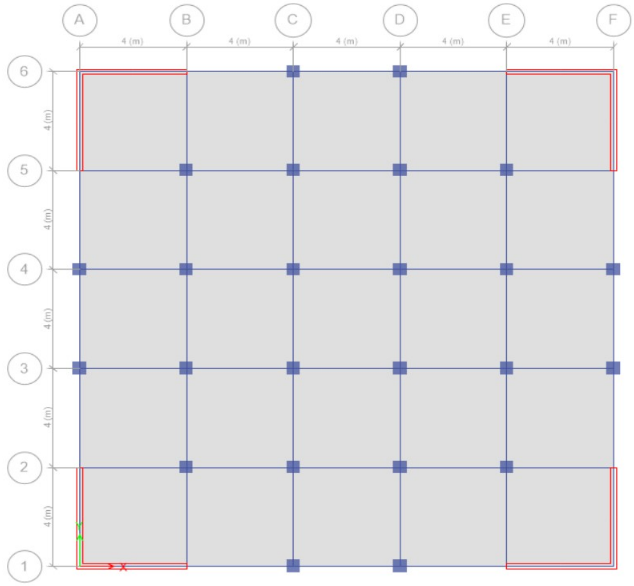


Figure (2): 2. Model_Corner SW

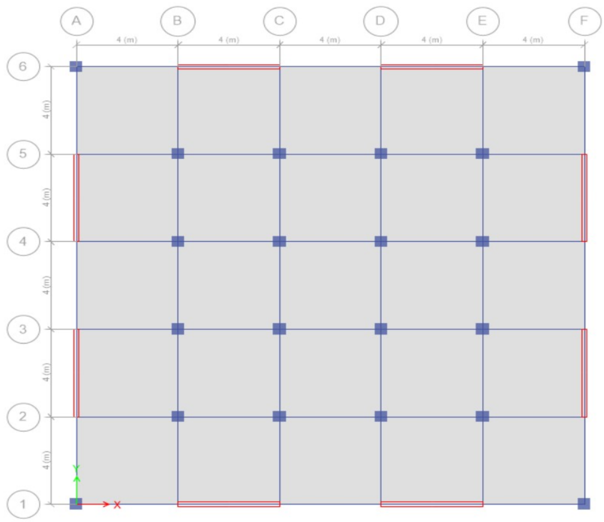


Figure (3): 3. Model_Middle SW

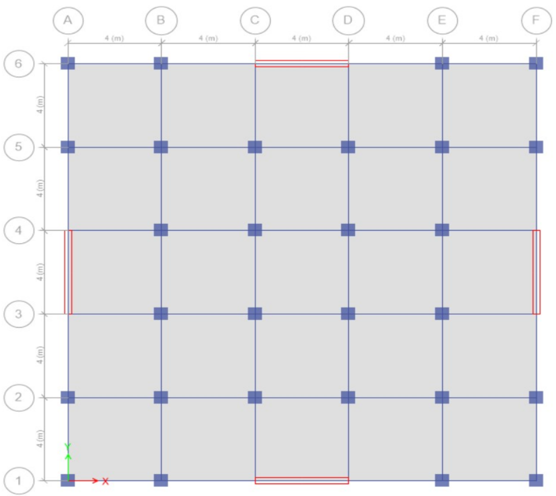


Figure (4): 4.Model_Outer SW

4. Fire Temperature considered

First, 9th and 10th, 19th and 20th story of the buildings with three different configurations of shear walls modelled have been given an exposure of 700 ^{0}C, considering one at a time to measure the vulnerability of the building by analysing the results for displacements in the story. Fire temperatures has been increased to 950 ^{0}C, 1100 ^{0}C and 1350 ^{0}C, to find maximum temperature in a story which makes lateral displacements exceed the permissible value. Minimum value of fire temperature which causes the failure of a story has been found 1350 ^{0}C.

5. Results and discussion

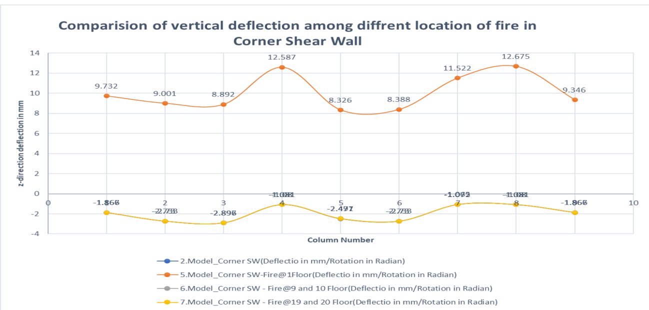


Figure (5): Vertical deflection in different stories with fire of building having Corner Shear Walls configuration

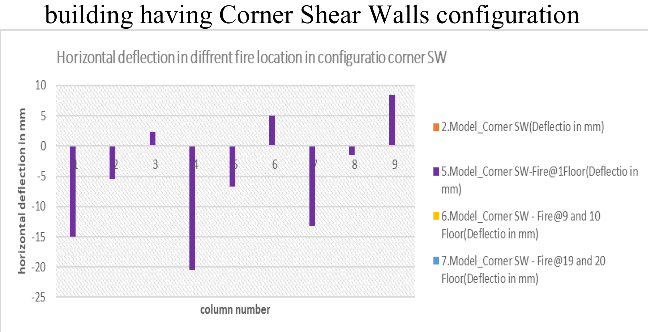


Figure (6): Horizontal deflection, x-direction in different location of fire in Corner Shear Wall

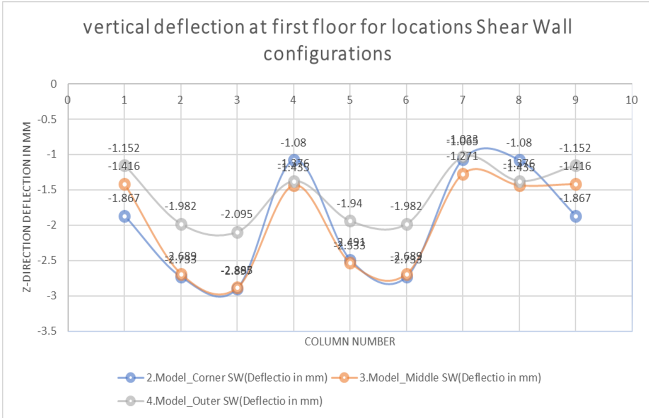


Figure (7): Vertical deflection at first floor for different configurations of Shear Wall

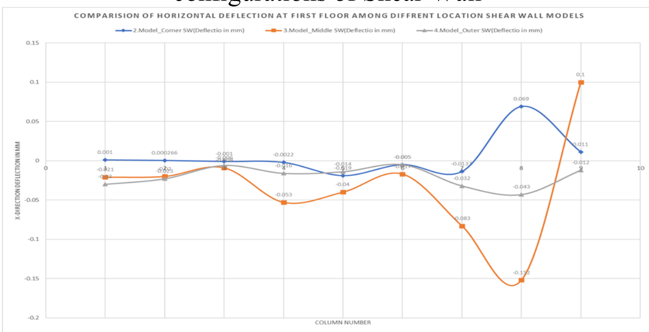


Figure (8): Horizontal deflection at first floor in different location Shear Wall models

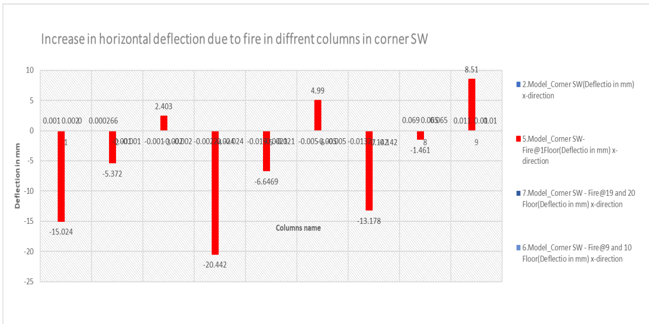


Figure (9): Horizontal deflection at first floor in different columns in corner SW

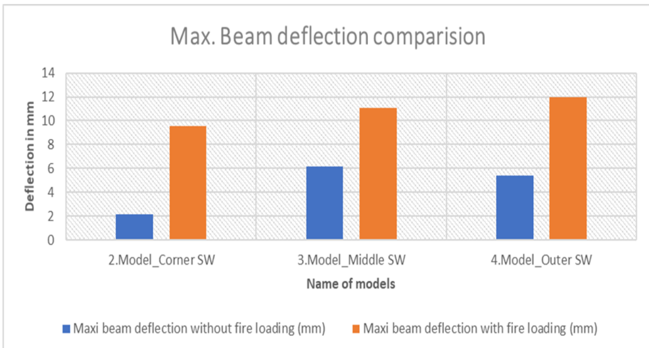
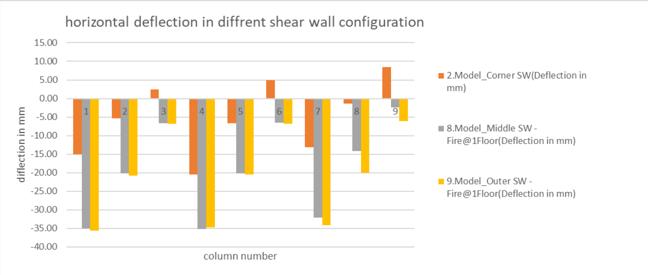


Figure (10): Maximum beam deflection at first floor among different models



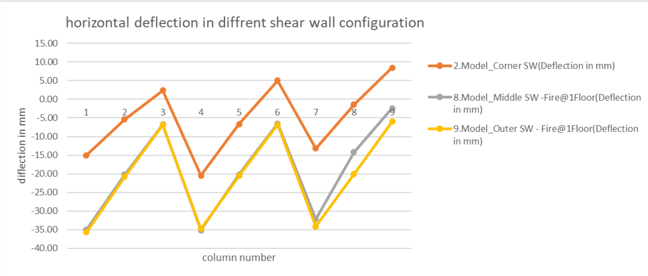


Figure (11): Maximum horizontal deflection at first floor in different shear wall configuration

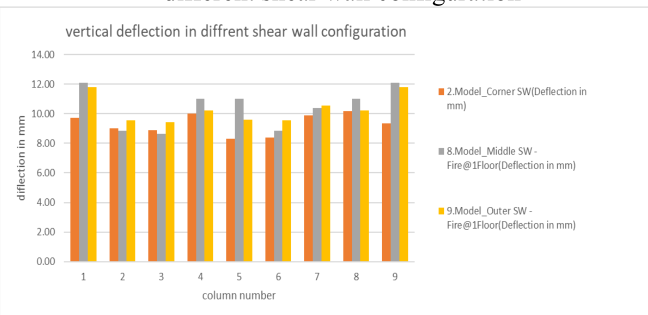


Figure (12): Maximum vertical deflection at first floor in different shear wall configuration

Table 1: deflection in Model_Corner SW before fire

Column	2.Model_Corner SW(Deflection in mm)					
	x-direction	y-direction	z-direction	θx	θy	θz
1	0.001	0.011	-1.867	-2.2E-05	0.000246	-1E-06
2	0.000266	-0.005	-2.733	-5E-06	0.000009	-1E-06
3	-0.001	-0.001	-2.897	-5E-06	0.000005	0
4	-0.0022	0.069	-1.08	-1.2E-05	0.000772	-9E-06
5	-0.019	-0.019	-2.491	-1.1E-05	0.000011	0
6	-0.005	0.000266	-2.733	-9E-06	0.000005	0.000001
7	-0.0137	-0.137	-1.065	0.00001	-0.00001	0
8	0.069	-0.022	-1.08	-0.00077	0.000012	0.000009
9	0.011	0.001	-1.867	-0.00025	0.000022	0.000001

It has been observed that the effect of the fire in a story remains localized in the sense it affects the members associated with the story. The effect of the fire in the considered stories other than first story is found negligible. The members connected to the adjacent floors are not influenced by the fire of the story. Variations of horizontal and vertical displacements in vertical members in the story of fire at 700 ^{0}C that is first story, 9th and 10th and in top two stories of the buildings with three configuration of shear walls has been shown in figures. The results obtained from analysis show that the building with SW at the corners have least values of horizontal and configuration of shear walls has been shown in figures. The results obtained from analysis show that the building with SW at the corners have least values of horizontal and vertical displacements as compared to the buildings with other configuration of shear walls

Table 2: deflection in Model_Corner SW-Fire@1Floor after fire

Column	2.Model_Corner SW(Deflection in mm)					
	x-direction	y-direction	z-direction	θx	θy	θz
1	-15.024	8.528	9.732	-0.00032	-0.00071	-0.00228
2	-5.372	4.951	9.001	-3.1E-05	-0.00029	-0.00049
3	2.403	2.419	8.892	0.000035	0.000032	0
4	-20.442	-1.439	12.587	0.000315	-0.00036	-0.00079
5	-6.6469	-6.455	8.326	0.000319	-0.00025	0
6	4.99	-5.36	8.388	0.000356	0.000098	0.000488
7	-13.178	-13.165	11.522	0.000642	-0.00066	0.000003
8	-1.461	-20.426	12.675	-0.00041	-0.00033	0.000791
9	8.51	-15.01	9.346	0.000679	0.000404	0.002285

Table 3: Maximum beam deflection

S.No	Model Name	Maxi beam deflection without fire loading (mm)	Maxi beam deflection with fire loading (mm)
1	2.Model_Corner SW	2.14	9.55
2	3.Model_Middle SW	6.13	11.09
3	4.Model_Outer SW	5.43	11.94

Table 4: Maximum horizontal and rotational displacement

Column	2.Model_Corner SW(Deflection in mm)				
	x-direction	z-direction	θx	θy	θz
1	-15.02	9.73	0.00	0.00	0.00
2	-5.37	9.00	0.00	0.00	0.00
3	2.40	8.89	0.00	0.00	0.00
4	-20.44	10.00	0.00	0.00	0.00
5	-6.65	8.33	0.00	0.00	0.00
6	4.99	8.39	0.00	0.00	0.00
7	-13.18	9.90	0.00	0.00	0.00
8	-1.46	10.20	0.00	0.00	0.00
9	8.51	9.35	0.00	0.00	0.00

Table 5: Maximum horizontal and rotational displacement

Column	8.Model_Middle SW -Fire@1Floor(Deflection in mm)				
	x-direction	z-direction	θx	θy	θz
1	-34.97	12.08	0.00	0.00	0.00
2	-20.22	8.84	0.00	0.00	0.00
3	-6.70	8.63	0.00	0.00	0.00
4	-35.16	11.03	0.00	0.00	0.00
5	-20.14	11.00	0.00	0.00	0.00
6	-6.53	8.84	0.00	0.00	0.00
7	-32.13	10.39	0.00	0.00	0.00
8	-14.22	11.03	0.00	0.00	0.00
9	-2.36	12.08	0.00	0.00	0.00

Table 6: Maximum horizontal and rotational displacement

Column	9.Model_Outer SW - Fire@1Floor(Deflection in mm)				
	x-direction	z-direction	θx	θy	θz
1	-35.65	11.81	0.00	0.00	0.00
2	-20.84	9.56	0.00	0.00	0.00
3	-6.86	9.43	0.00	0.00	0.00
4	-34.79	10.20	0.00	0.00	0.00
5	-20.56	9.59	0.00	0.00	0.00
6	-6.77	9.55	0.00	0.00	0.00
7	-34.14	10.57	0.00	0.00	0.00
8	-20.10	10.20	0.00	0.00	0.00
9	-6.03	11.81	0.00	0.00	0.00

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Variation of maximum deflection in beams for the fire in first story of the buildings with three different configuration of shear walls is shown in figure (10) shows the variations of maximum deflection in beam corresponds to fire at first floor in three different configurations. Displacements in the first story of the building with corner shear walls before and after the fire are given in table 1 and table 2 respectively. Content of the table 1 reveals that the displacements in story before fire is negligible. Maximum translations in the nine vertical typical members in first story of fire with the three considered configurations of shear walls in the buildings are given in are given in table 4 and table 6. Negative values indicate the compression in vertical members in vertical direction while positive values are the tension due to fire. The results show that there is negligible rotational displacement after the fire. The maximum horizontal displacement has been found in the vertical member 1 and 4 in the first story of the fire of the building with shear walls at the third configuration of shear walls while the minimum horizontal displacements has been found in in vertical member 8 of the building with shear wall configuration 1. The vertical displacements of the vertical members have been found maximum in column 1 and 9 in the first story of configuration 2 while the minimum vertical displacements are in vertical members 5 and 6 with the fire in first story.

Conclusions

From the analysis of 20 storied RCC building with three different configuration of shear walls considering the fire at first, 9^{th} and 10^{th}, and 19^{th} & 20^{th} story following conclusion are summarized:

(i) the effect of fire in a story remain localised i.e. if fire is breakout at 9th story then its effect is within the 9th story.
(ii) Fire in the first story has been found the most severe case of the fire
(iii) The minimum value of the maximum temperature of fire in a story which make the displacement exceed the permissible value has been found 1350 ^{0}C.
(iv) Corner shear wall configuration is found to be the best one out of the three configurations considered as a displacement in this one is minimum.

It is therefore finally concluded that the location of the shear walls needs to be decided taking consideration of fire.

Disclosures

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