Stability Analysis of an RC Structure with RC Shear Walls in the Event of a Fire

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Abstract Reinforced concrete (RC) shear walls are considered as one of the main lateral load resisting structural members in RC buildings. Apart from acting as a lateral load resisting system, the RC shearwalls tend to provide ductility, stability and stiffness to the structure. In the present work, an analysis is carried out to assess the residual response of a fire exposed reinforced concrete structure, by considering the presence of RC shearwalls contributing towards the stability of such a structure exposed to fire. The analysis carried out in the present work includes the study of the stability of a multi-storeyed RC building with and without shear walls exposed to high temperatures developed due to fire . The results from this study indicates that, inclusion of shear walls in different locations in the building has a predominant effect on the stability of the RC building in the event of a fire.

Keywords :- Shear walls , shear wall combination , structural stability , fire exposure , high temperature

1 Introduction

Reinforced concrete (RC) construction is widely used in buildings and infrastructure due to various advantages it provides over other constituent forms including high fire resistance. Concrete structures, however, are susceptible to fire induced degradation in the form of spalling, cracking of concrete, which lead to high deformations at elevated temperatures[1 , 2]. Fire represents a severe hazard encountered by built infrastructure during its lifetime. Hence, structural members in buildings have to satisfy fire resistance requirements as fire safety is one of the key considerations in building design.

According to study of Sakra et al [3] a numerical model of an I section was used for the analysis that was carried out using ABAQUS,and the same was validated , the addition of dowel bars between footing-jacketing can be effective , restrain the possible sliding mechanism and improve the flexural strength. LIU Gui-rong and SONG Yu-pu [4] subjected the specimens to elevated temperatures by combustion of the liquefied petroleum gas. shear walls were tested at a horizontal position, exposed to fire on one side , Lateral load capacity , Hysteretic curves, Skeleton curves were obtained. Fire exposure reduces the ultimate load of RC shear walls, a certain increase of reinforcement can decrease the rates of reduction in the ultimate load, energy dissipation capacity and stiffness. Venkatesh k.Kodur and Ankit Agarwal[5] developed Numerical model of RC beam and analysed at three different stages through ABAQUS. The various parameters including geometry of beam, level of loading, boundary conditions, fire exposure scenario and material properties were input to the model , Effect of Fire Exposure , Effect of Load Ratio, Effect of Axial Restraint , Effect of Varying Size of Beam were studied . Sushanta Roy, Taito miura [6] tested the concrete specimens for physical and mechanical properties after being heated at different temperature , Mass loss, length change, Variation of compressive strength and modulus of elasticity with temperature etc were monitored.

By carrying out the above literature review it is learnt that that, the RC specimens are tested and studied extensively as a particular structural component form individually .Not much work has been carried out relating to use of shear walls in multi-storeyed buildings exposed to high temperature in the event of a fire. Hence , shear walls present in multi-storeyed buildings and their functional importance in case of high temperature has been studied in the present work.

In the present work, the analysis of multi-storeyed building with and without shear walls exposed to different high temperatures (550 ℃ and 750℃) at various floor levels , has been carried out to assess the stability of the building. The contribution of the presence of shearwalls in the RC building towards its stability has been assessed when the building is exposed to high temperature at different floor levels in the event of a fire.

2 Analysis of RC multi-storey building exposed to high temperature with and without shearwalls

In this section the analysis of the RC multi-storey building exposed to high temperature with and without shearwalls has been presented. The details of the RC building that was modelled and analysed in ETABS with and without shearwalls for different temperature exposure at various floor levels is as follows; RC building has the rectangular shape in plan and has 15 storeys . Each storey height is 3m and the total height of the structure is 45m the span of each bay in the both direction in plan is 5m. The total plan area of the building is 500square metre. The grade of concrete used for shear wall is M30.The grade of concrete used for slab is M30.The grade of steel used for reinforcement is Fe450.The cross sectional dimensions of the beam including the slab is 230 x 600 mm. The column dimension for all the columns for model in ETABS are 300 x 750mm.Shear wall of 250mm thickness is provided. Load combination considered for the analysis is 1.5 (DL +LL+ Temperature).The two exposure temperatures (550℃ , 750℃) are applied in the structural model as temperature loads on to the floor slab and also onto the beams , columns and shearwall of that respective floor. M30 concrete that has been adopted for beams, columns, slabs and shear walls, wall thickness of 250mm , slab thickness of 150mm , beam load of 15KN/m , slab live load of 5.75KN/m^2 are considered for analysis .Temperature loads have been applied to 1^{st}, 5^{th}, 6^{th} ,10^{th} ,11^{th} floor levels. Three models are considered with different shear wall locations in the RC building exposed to two elevated exposure temperatures, namely, 550℃ and 750℃ respectively as shown in Figures 1 ,2 and 3 respectively .

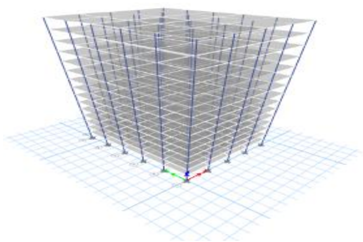


Fig -1 Multi storey building without shear wall : M1

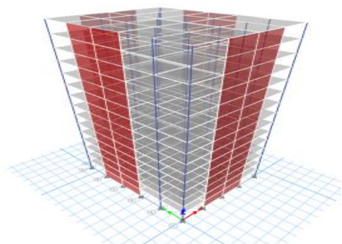


Fig – 2 Multistorey building with shearwall combination 1 : M2

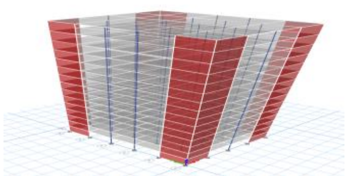


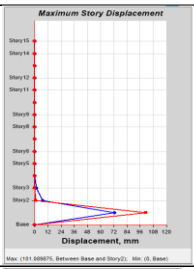
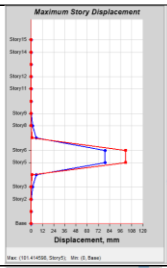
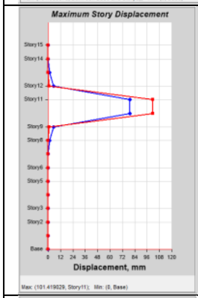
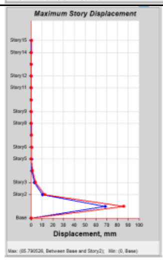
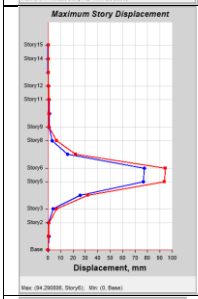
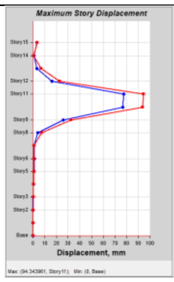
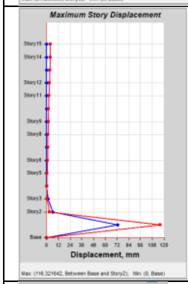
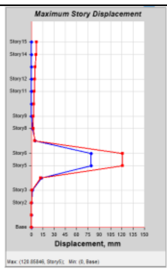
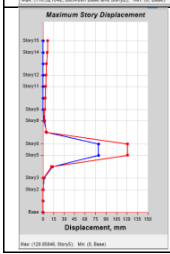
Fig -3 Multi storey building with shear wall combination 2 : M3

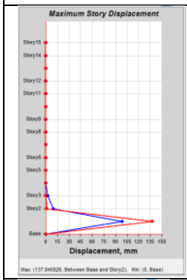
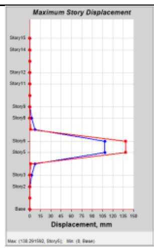
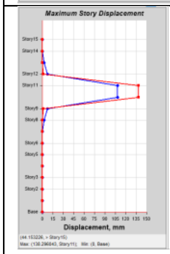
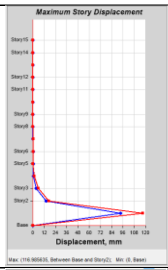
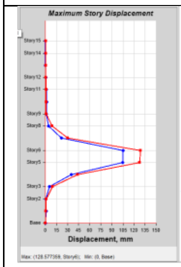
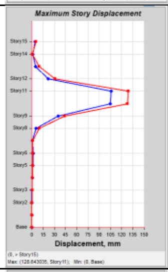
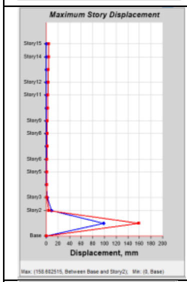
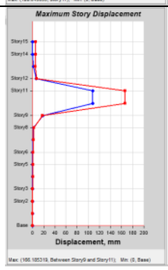
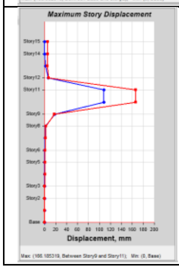
3 Results and discussion-

The displacements at different storeys in the RC building models (M1 , M2 and M3) for two different exposure temperatures 550℃ and 750℃ has been shown in Table 1 and in figures 4 to 12 (for 550℃ exposure) and 13 to 21 (for 750℃ exposure) respectively.

Table 1 – Displacements at different floor levels exposed to high temperature in the RC structure with and without shearwall combination (M1,M2,M3) has been shown.

Temperature (ºC)	Floor slabs subjected to temperature	Displacements (mm) in X and Y Directions		
		M1	M2	M3
550	1ST	X - 72.39 Y - 101.08	X - 68.61, Y -85.79	X - 72.42, Y -116.32
	5TH	X-79.19, Y-101.41	X-77.38, Y-94.29	X-79.15, Y-120.85
	6TH	X-79.19, Y-101.41	X-77.38, Y-94.29	X-79.15, Y-120.85
	10TH	X-79.19, Y-101.41	X-77.41, Y-94.34	X-79.15, Y-120.85
	11TH	X-79.19, Y-101.41	X-77.41, Y-94.34	X-79.15, Y-120.85
750	1ST	X-98.72, Y-137.84	X-93.55, Y-116.98	X-98.75, Y-158.60
	5TH	X-107.99, Y-138.29	X-104.607, Y-128.57	X-108.261, Y-166.18
	6TH	X-107.99, Y-138.29	X-104.607, Y-128.57	X-108.261, Y-166.18
	11TH	X-107.99, Y-138.29	X-105.56, Y-128.643	X-108.26, Y-166.18
	10TH	X-107.99, Y-138.29	X-105.56, Y-128.643	X-108.26, Y-166.18

TEMPERATURE AT 550℃			
	Fig 4– Storey displacements without shear wall combination , fire at Ground and 1st floor		Fig 5 – Storey displacements without shear wall combination , fire at 5^{th} and 6^{th} floor
	Fig 6 – Storey displacements without shear wall combination , fire at 10^{th} and 11^{th} floor		Fig 7- storey displacements with shear wall combination 1, fire at Ground and 1st floor
	Fig 8- storey displacements with shear wall combination 1, fire at 5^{th} and 6^{th} floor		Fig 9- storey displacements with shear wall combination 1, fire at 10^{th} and 11^{th} floor
	Fig 10- storey displacements with shear wall combination 2, fire at Ground and 1st floor		Fig 11- storey displacements with shear wall combination 2, fire at 5^{th} and 6^{th} floor
	Fig 12- storey displacements with shear wall combination 2, fire at 10^{th} and 11^{th} floor		

TEMPERATURE AT 750℃			
	Fig 13– Storey displacements without shear wall combination , fire at Ground and 1st floor		Fig 14– Storey displacements without shear wall combination , fire at 5th and 6th floor
	Fig 15– Storey displacements without shear wall combination , fire at 10th and 11th floor		Fig 16- storey displacements with shear wall combination 1, fire at Ground and 1st floor
	Fig 17- storey displacements with shear wall combination 1, fire at 5th and 6th floor		Fig 18- storey displacements with shear wall combination 1, fire at 10th and 11th floor
	Fig 19- storey displacements with shear wall combination 2, fire at Ground and 1st floor		Fig 20- storey displacements with shear wall combination 2, fire at 5th and 6th floor
	Fig 21- storey displacements with shear wall combination 2, fire at 10th and 11th floor		

From the above results we can understand that the stability of the structure has been improved with shear walls included in it .We can also notice that the shear wall combination also plays a major role in the stability of the structure. From the results it is observed that the shearwall combination M2 is effective in resisting lateral displacements of the RC structure in the event of a fire.

4 Conclusions:

- It is observed from the analysis results , the displacement of the structure exposed to high temperature (550℃ and 750℃) is seen tobe reduced due to the presence of RC shear walls in the structure
- Is learnt from this study that, the shear wall combination M2 present in the structure makes the structure more stable, resulting in terms of lower lateral displacements when the structure is exposed to high temperatures at different floors when compared to the shearwall combination M3.

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