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Fire Behaviour of Composite Structure

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***Abstract*— In recent years, the use of steel concrete structure has increased significantly due to its advantages such as speed in construction, improvement in performance, protection from corrosion etc. Several research are carried out to understand the behaviour of such structure in earthquake but not many on fire. This research mainly concentrates on the effect of temperature on the composite structure. A single storey structure consisting of encased steel column and concrete filled steel column with composite beam with solid and filled deck were analyzed for gravity and temperature changes. The analysis were carried out by finite element method and American institute of steel construction 2016 method. The result of the analysis shows that at ambient temperature both the column system behave similar to each other but as the temperature increases the encased steel column system has better behaviour also the beams behaviour was similar irrespective to the solid or deck slab system.**

Keywords*— Composite column, composite beam, composite frame, fire.

I. INTRODUCTION

In recent years, the use of composite structure has increased significantly in India. Composite structure/member are member that are made up of two or more different material. The main advantage of composite elements is that the properties of every material are often combined to make one unit that performs better overall than its separate constituent parts. The most common kind of composite element in construction could also be a steel-concrete composite, however, other kinds of composites include; steel-timber, timber-concrete, plastic-concrete, and so on. As a material, concrete works well in compression, but it's less resistance in tension. Steel, however, is extremely strong in tension, even when used only in relatively small amounts. Steel-concrete composite elements use concrete's compressive strength alongside steel's resistance to tension, and when tied together this leads to a highly efficient and light-weight unit that's commonly used for structures such as multi-story buildings and bridges.

The main composite elements in buildings are column, steel concrete beams and slabs.

Composite columns can have high strength for a relatively small cross-sectional area, meaning that useable floor space can be maximized. There are several differing types of composite columns; the foremost common being an open steel section encased in concrete or a hollow section steel tube which is filled with concrete. Steel reinforced concrete column also known as concrete encased steel composite column were studied extensively experimentally and numerically over the decade. However the study focused on the structural behaviour in fire condition [1-3] and post fire [4-5].For example the effect of eccentric load[5], load [3], restrain to thermal elongation[6],axial restrain [7-8], effect of 3 sided heating [9].Further the SRC were compared with steel reinforced ultrahigh toughness cementitious composite column[10].Concrete filled steel tube fire resistance is influenced by cross section shape, size[11] axial load[12],3-side heating[13],strength of concrete[14]. Hai Han et al [15] studied the flexural and compression behaviour of CFST. Various type of CFST such as concrete filled double skin column, Double tube hollow steel column [16-17], CFST with steel core[18], concrete filled Rectangular hollow section [13],elliptical concrete filled steel column[19], RCC confined with steel tube[20] were studied. Yang et al [21] studied the post fire behaviour of CFST column. Analytical modelling [22], numerical modelling [23-24], and nonlinear analysis [25, 26] were studied for SRC and CFST column

Composite beams are normally hot rolled or fabricated steel sections that act compositely with the slab. The composite interaction is achieved by the attachment of shear connectors to the highest flange of the beam. These connectors generally take the form of headed studs. Most of the study of composite beam focused on the effect of restrain [27-29], and shear tab/connector [30-33] in the fire condition. Composite beam were studied experimentally [34-35] and by OPENSEES [36].Castellated beam [37] and cellular beam [38] were also study for effect of fire load on them. Modelling of composite beam is studied rom [39-4]

Composite slabs are typically constructed from reinforced concrete sew top of profiled steel decking, (re-entrant or trapezoidal).The decking is capable of acting as formwork and a working platform during the construction stage, also as acting as external reinforcement at the composite stage. Studies showing the fire behaviour of composite slab to fire [41-54] were reviewed. Composite structure consisting of various orientation and condition were studied [55-64] for fire. The study aims to model a composite structure using analytical and numerical method for gravity load and temperature changes. The software used for the analysis is E-Tabs 2018 and numerically by AISC (American institute of steel construction) 360-16.After the analysis both the results are compared.

II. FEM ANALYSIS

A single storey composite structure of dimension 22 m×22.2m and Floor to floor height 3.6 m subjected to gravity and temperature change. The modelling is done using ETABS 2018 software Load considered are self-weight of member and a uniformly distributed load of 12 ken/m2 and a temperature

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change from ambient temperature i.e. 25ºC to 525ºC with an interval of 100ºC.Loads and its combinations are considered as per Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE/SEI 7). Two types of composite column is used viz. encased steel column and concrete filled steel column both of dimension 609mm×609 mm. The section used for composite girder is W24×94 and composite beam is W21×62. The slab is of 190mm thickness.

III. NUMERICAL ANALYSIS

Numerical analysis is carried out using AISC (American standard of steel construction) 360-16.

IV. RESULT AND DISCUSSION

A. *FEM Result*

The result after evaluating the system are as follows:

Table I: Behaviour of Composite Girder with Solid Deck to Fire

Temperature (ºC)	Shear Ratio	Bending ratio	Total Deflection (mm)	Section
25	0.161	0.62	12.4	Pass
125	0.203	0.71	14.3	Pass
225	0.246	0.8	19.6	Pass
325	0.288	0.88	20.5	Pass
425	0.345	0.92	23.9	Pass
525	0.453	0.98	45.5	Fail

Table II: Behaviour of Composite Girder with Trapezoidal Deck to Fire

Temperature (ºC)	Shear Ratio	Bending ratio	Total Deflection (mm)	Section
25	0.161	0.62	12.5	Pass
125	0.203	0.71	14.3	Pass
225	0.246	0.8	19.7	Pass
325	0.288	0.88	20.5	Pass
425	0.345	0.92	23.9	Pass
525	0.453	0.98	45.5	Fail

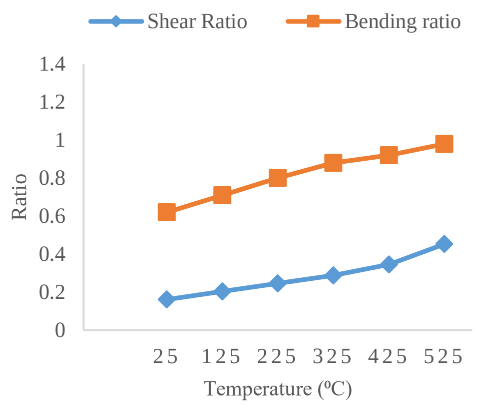

Fig 1: Shear and Bending Ratio of Composite Girder with Solid Deck

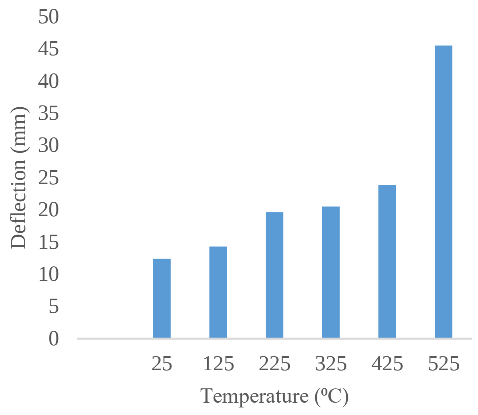

Fig 2: Deflection of Composite Girder with Solid Deck

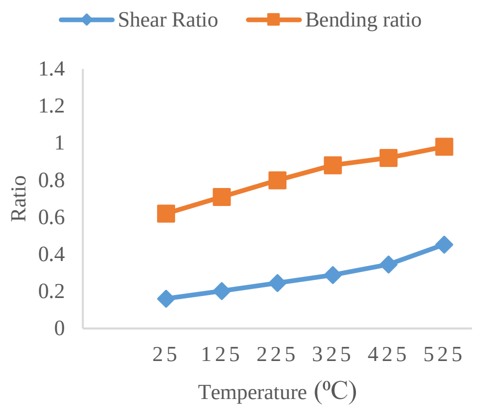

Fig 3: Shear and Bending Ratio of Composite Girder with Trapezoidal Deck

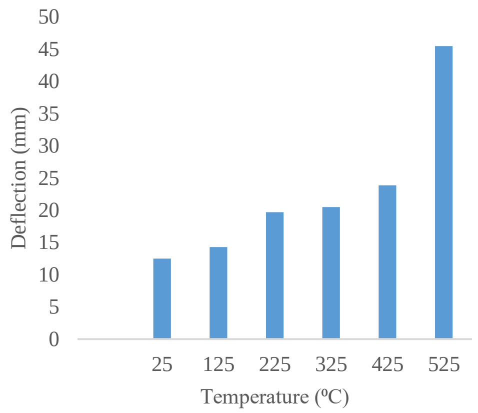

Fig 4: Deflection of Composite Girder with Trapezoidal Deck

Similarly calculation were carried out for composite beam with solid and trapezoidal deck.

Table III: Behaviour of Composite Column (C6) to Fire

Temperature (ºC)	Demand/Capacity Ratio	
	Encased Steel Section Column	Concrete Filled Steel Column
25	0.153	0.345
125	0.383	0.657
225	0.765	0.995
325	0.814	1.346
425	0.953	1.856
525	1.751	2.345

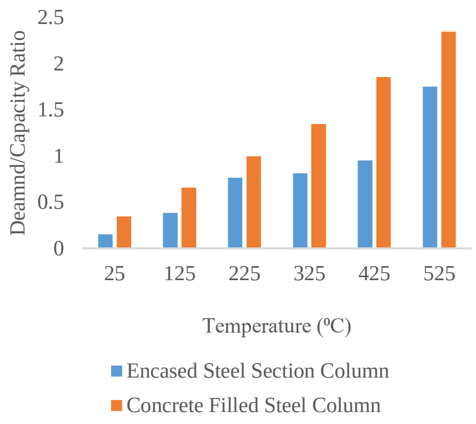

Fig 5: Demand/Capacity Ratio of Composite Column

B.Numerical Result

The result are as follows:

Table IV: Behaviour of Composite Girder to Fire Numerically

Temperature (ºC)	Bending Ratio	Section
25	0.87	Pass
125	0.89	Pass
225	0.899	Pass
325	0.93	Pass
425	0.98	Pass
525	1.23	Fail

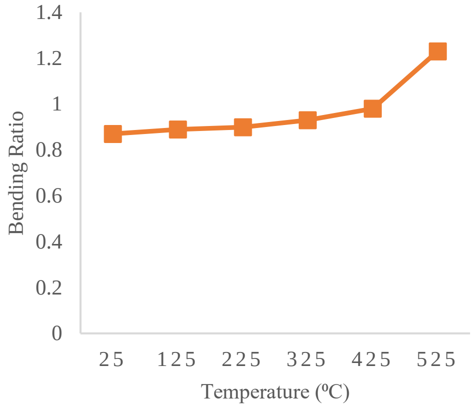

Fig 6: Bending Ratio of Composite Girder

Table V: Shear Ratio at 25ºC

	Shear Ratio
Beam	0.11
Girder	0.2

V. COMPARISON OF FEM AND NUMERICAL RESULT

The comparison between the FEM and numerical results were carried out in table VI and VII.

Table VI: Comparison of FEM and Numerical Bending Ratio of Girder

Temperature (ºC)	Bending Ratio	
	FEM result	Numerical Result
25	0.62	0.87
125	0.71	0.89
225	0.8	0.899
325	0.88	0.93
425	0.92	0.98
525	0.98	1.23

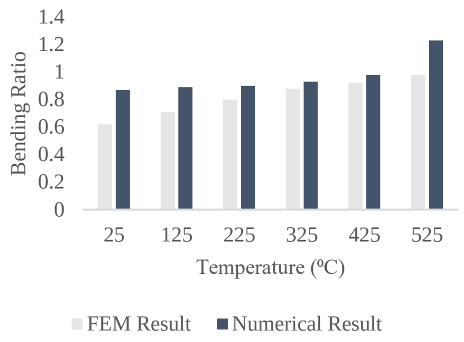

Fig 6: Comparison of Bending Ratio

Table VII: Comparison of Analytical and Numerical Shear Ratio at 25ºC

		Beam	Girder
Shear Ratio	FEM	0.12	0.16
	Numerical	0.11	0.2

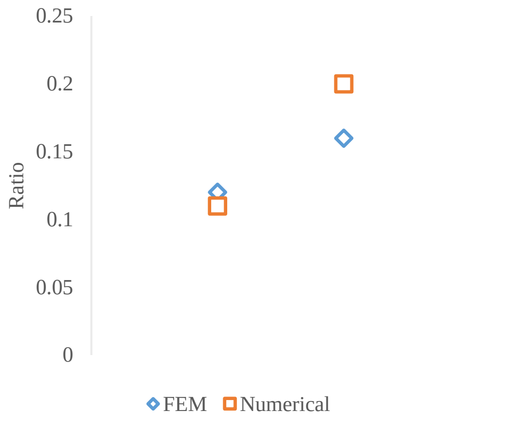

Fig 7: Comparison of Shear Ratio

From the above table we can say that the bending ratio of Composite beam and Composite Girder subjected to temperature change of analytical result are slightly different from numerical result. The decrease in the moment carrying capacity at elevated temperature is calculated by using the retention factor whereas in analytical method the decrease in capacity is calculated using DM which gives more accurate result. This can be due to more conservative values i.e. retention factor used in numerical analysis. At 25ºC the difference between shear ratios is equal for composite beam but difference is more for girder. The difference between the analytical and experimental is approximately 20% for composite beam and girder.

V. CONCLUSION

Considering above result following conclusion may be drawn:
1. Irrespective of the slab type i.e. solid slab deck or trapezoidal filled deck slab the shear ratio, deflection ratio and deflection for composite slab and girder is similar.
2. At 25ºC the difference in the shear ratio is low for composite beam but it is more for composite girder.
3. For encased column system, the demand/capacity ratio at ambient temperature is low i.e. 0.153 and as the temperature increases, the demand/capacity ratio also increases to 1.751 at 525ºC.
4. For encased column system, the demand/capacity ratio at ambient temperature is 0.345 and as the temperature increases, the demand/capacity ratio also increases to 2.345 at 525ºC.
5. For given load condition, the encased column system is more thermally resistant then the concrete filled steel column.

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