Experimental Analysis, Design And Comparison of RCC, Composite And Steel Beam

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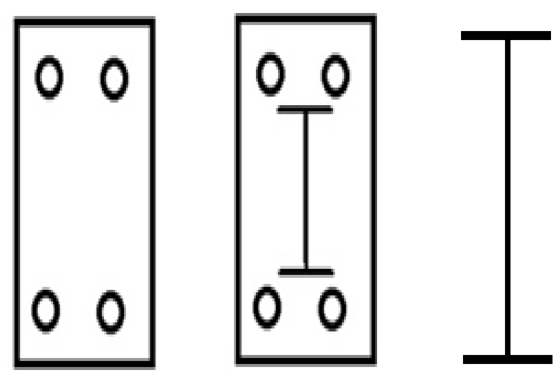
Abstract- *This experimental investigation deals with RCC, composite and steel beams. Now a day architect requires as thin structure as possible. For this they demand more thin sections for aesthetical view but as a structural engineer it also strengthen and it should be well within economical limits. Thus this dissertation topic is also supposed to work in same direction that is toward different sectional combination for the said loading condition to achieve thin and still economical and practical solution for a kind element to fulfill the architectural criteria. As we know beam is a flexural member mainly and it requires more depth to resist more moment. Hence in this study focus is mainly toward to minimize depth of beam section by exercising on material combination. One of the major alternate is to go with composite section or to use steel girders as beam. Here the concept is such that composite beam means a regular RCC beam with inbuilt or in between a steel girder to be consider as composite section and use steel girder as beam.*

Keywords- beam, composite, steel beam, RCC.

I. INTRODUCTION

Architectural beauty is prime important of customer orientation but the structural point of view it also strengthen to support its architectural beauty. Now a day architect requires as thin structure as possible. For this they demand more thin sections at one hand and at other hand owner needs it should be well within economical limits. In most of the cases we have to compromise the section to full fill architectural aspects without hammering strength of the structure. Thus this practice leads to a structural consultant to develop and practice different structure and sectional combination etc. Thus this topic is also supposed to work in same direction that is toward different sectional combination for the said loading condition to achieve thin and still economical and practical solution for a kind element. As number of times in a building almost every construction fractioned demands mainly for lesser depth of beam but actually as we know beam is a flexural member mainly and it requires more depth to resist more moment. And all other members like slabs, column, footing are doesn't have any psychological size effect or any kind of depth issue. This study focuses mainly toward the minimization of depth of beam section by exercising on material combination. One of the major alternate is to go with composite section or steel girder. Thereby the concept is such that composite beam i.e. a regular RCC beam with inbuilt or in between a steel girder as (it may be readily available or built up steel girder as call may be) to be consider as composite section. Fig 1 thus this kind of composite section and steel section one can get depth reduction for the same moment.



a) Regular RC b) Composite RCC beam c) Steel

Fig. No 1.1 Conceptual beam section used for experiment.

II. METHEDOLOGY

Experimental work: - Here the RCC beam, Composite beam and steel beam is taken from a structural frame for analysis, design and experiment. It has uniformly central point load of magnitude say 90 kN and span of 4 m. concrete grade M20, reinforcing steel Fe 500 and structural steel girder grade Fe 250 (ISMB 250) which is available in market thus for the given loading, span, end conditions, beam is analyzed and ISMB 300 is steel beam section is design for the same bending moment. As this study is mainly focusing on flexural behavior of RCC beam, composite beam and Steel beam. The experiment is done mainly for flexure for same loading, moment and support condition and results are interpreted.

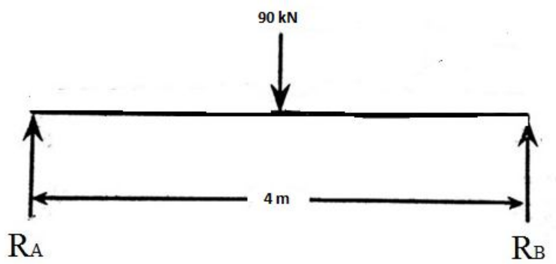


Fig. No.2.1 beam with Point load

Given data: -
Span= 4m
Fy = 500 N/mm^2
Fck = 20 N/mm^2

Regular RCC beam:-

Section assumed 230×450
b = 230 mm
D = 450 mm
d = 430 mm

For simply support point load moment is, M_u

$M_u = \frac{wl}{4}$

$= \frac{90\times4}{4}$

M_u = 90 kN.m.
Final design for RCC beam:-
Section 230×450
5 ϕ12, 2 ϕ8 @200 mm c/c.

Composite beam:-

In this beam there is combination as,
RCC+ISMB
Let us choose ISMB 250
Hence check RCC section for 230$\times$ 300
Here assumed that steel beam section that is ISMB 250 and RCC section is concentric and acting as monolithic as a single member only and not acting individually for flexure.
Also it is assumed that ISMB 250 will carry loads to its designed flexural strength that is moment.
Moment resisting capacity of ISMB 250 @ 37.30 kg/m

$M=\frac{I}{y} \times \sigma$

But,

$\frac{I}{y}$ =Z

Therefore,

M= Z $\times \sigma$

Z available for ISMB 250 =410.50×10^3 mm^3

M= 410.50 $\times 10^3 \times 165$ =67.73 $\times 10^3$ N.mm

Therefore Moment resisting capacity of
ISMB 250 = 67.73 kN.m
Then
Moment to be resisted by RCC =90-67.73=22.27 kN.m

A_{st} required= $\frac{0.5 f_{ck}}{f_y} \times \left[1-\sqrt{1-\frac{4.6Mu}{f_{ck} b d^2}}\right] b \times d$

=207.87 mm^2

A_{st} min. = $\frac{0.85\times b\times d}{fy}$

=109.48 mm^2

$A_{st\ max}$. For f_e 500;

=0.04$\times b \times D$

=2760 mm^2

Provide area 207.87 mm^2
Final design for Composite beam:-
Section 230×300 +ISMB 250 @37.30 kg/m
2 ϕ12, 2 ϕ8 @200 mm c/c

Steel Beam:-

Here for steel beam section
Total moment to be resisted =90 kN.m
δ =165 Mpa

Z required = $\frac{M}{\sigma}$

$= \frac{90\times10^6}{165}$

Z=0.545$\times$10^6 mm^3
Z =545 cm^3
Therefore provide
ISMB 300 @44.20 Kg/m where z available is 573.6 cm^3.

III. RESULTS AND DISSCUSSION

In this experimental program RCC, Composite and Steel beam having 4m span are casted and flexural test is carried out.

TESTING PROCEDURE:- 1) The RCC beam of cross section 230mm × 450 mm and composite beam of cross section 230 mm ×300 mm are casted & flexure resistance of the section is carried out after 28 days of curing.2) The third beam i.e. ISMB 300 is directly purchased and tested.3) All three beams tested under mid-point loading system. For all beam testing procedure is same.4) The beam is placed in such manner the point load is applied at uppermost face at exactly center of each beam.5) The load to be increase until the beam fails. The load when first crack developed and the load applied till the beam brakes.6) The deflection is measured at the center of the beam and the load is gradually increased.7)1000kN capacity load cell is attached to load applying machine and load gradually applied.

Failure Modes of RCC Beam: The regular RCC beam of cross section 230×450 of length 4 meter is tested for flexure. The load cell is attached and shown in above. The beam is designed for 90 kN center point load. When load increases the deflections are noted. The overall span of beam is 4.4meter but the effective span is 4meter.The 400 mm length is for simply support arrangement. The load is applied up to the failure beam. The beam is failed in flexure. The flexural cracks are developed on beam. Initially the flexural cracks are developed but at ultimate load the shear failure occurs for beams. The tension crack occurs on tension side for the beam. The cracks developed on tension sides are recorded. The failure modes of beam are shown in photos.

Photo No. 3.1: RCC beam rested on simple support.

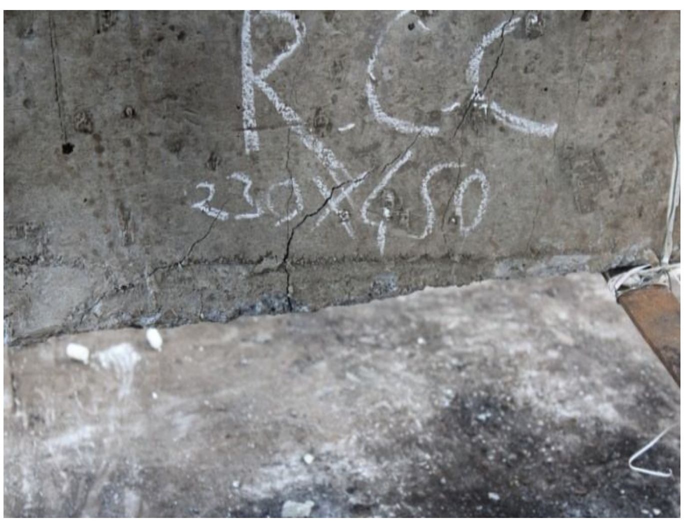


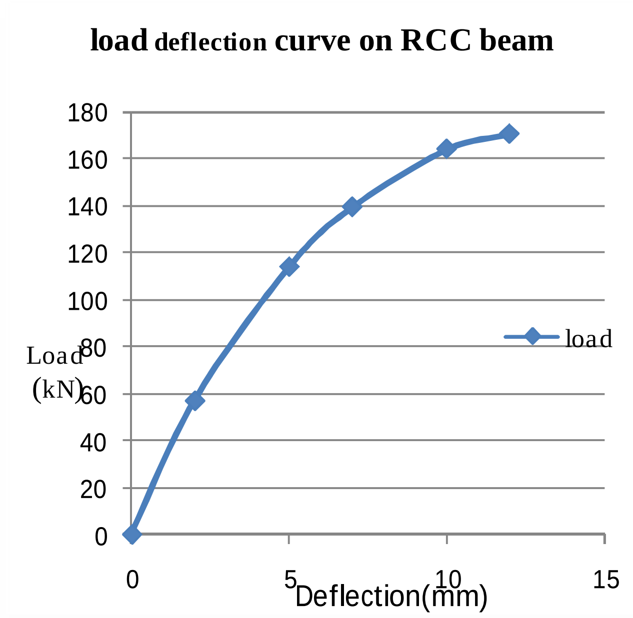
Photo No. 3.2: First crack at centre of beam.

Photo No. 3.3: Reinforcement after failure of beam.

Experimental Observation of Load and Deflection for RCC Beam

Table No.3.1 Load and deflections for RCC beam

Sr. No	load (kN)	deflection(mm)
1	0	0
2	61.6	4
3	102.2	8
4	108.3	12
5	102.2	16
6	102.2	20



Graph No.1 Load Vs deflection of RCC beam.

Failure Modes of composite Beam: After completion of 28 days curing the beams were subjected to midpoint loading by hydraulic load is applied linearly we measure the deflection of beam and also observe the first crack at which load and corresponding deflection this process is continue for all beams and also note the ultimate load with corresponding deflection for all beam sections.

Photo No. 3.4: First crack at centre of beam.

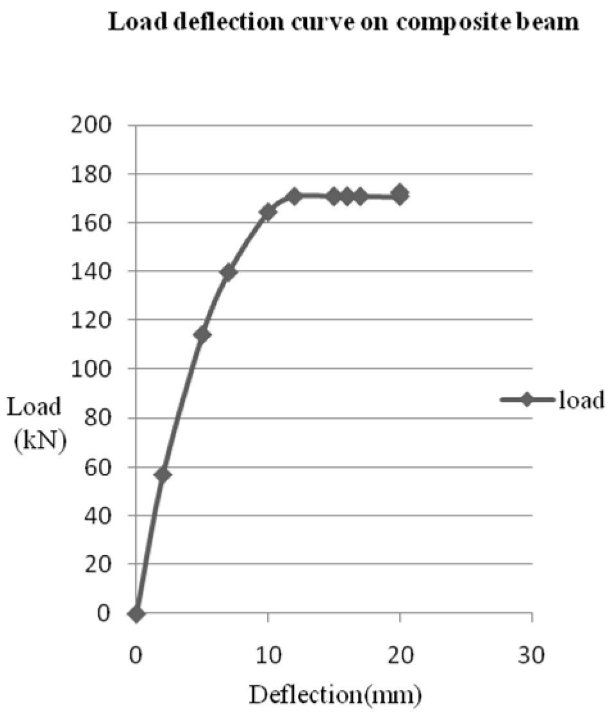
Photo No. 3.5: Beam failure at maximum load.

The composite beam of cross section 230×300 of length 4 meter is tested for flexure. The testing procedure is same as RCC beam. The beam is designed for 90kN center point load. When load increases the deflections are noted. The overall span of beam is 4.4meter but the effective span is 4meter.The 400 mm length is for simply support arrangement. The applied at 2meter and dimension at center ·In composite beam because of ISMB 250 the first crack developed at very high loading i.e. 170.6 kN. It is very high than that of regular RCC beam. The first crack is developed at center of the beam. The rate of deflection of composite beam is also very low as compared to the regular RCC beam.

Experimental Observation of Load and Deflection for composite Beams:-

Table No.3.2 Load and deflections for Composite beam.

Sr. No	load (kN)	Deflection (mm)
1	0	0
2	56.9	2
3	114	5
4	139.5	7
5	164.2	9
6	170.6	11
7	170.6	15
8	170.6	15
9	170.6	16
10	170.6	16
11	170.6	17
12	170.6	20
13	172.2	20



Graph No.3.2 Load Vs deflection of Composite beam.

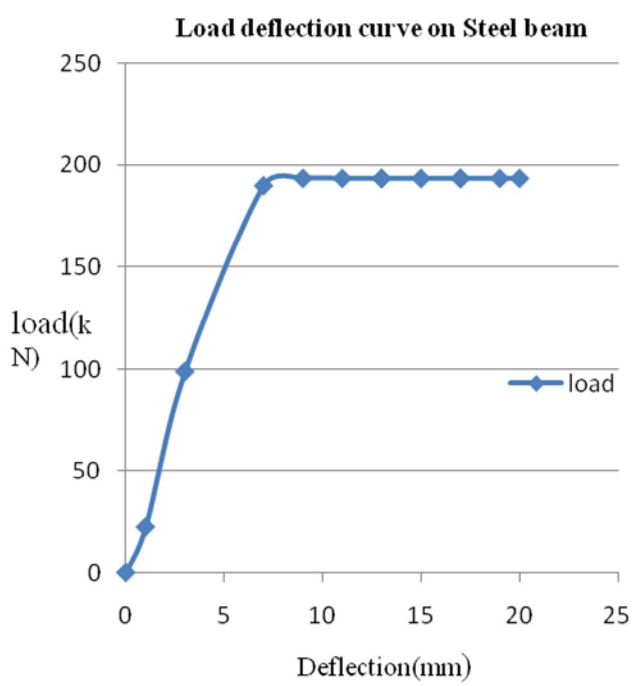
Failure Mode of Steel Beam or Steel Girder: - For this experimental work as per design choose ISMB 300 as steel beam keeping same span. Repeat the same procedure of loading as RCC and composite beam and we got following results. Beam rested on simply support. As load increases gradually beam starts bending and after maximum loading after load removes beam bends completely.

Photo No. 3.6: Beam started bending as load increases.

Photo No.3.7 bending of beam after load removes.

Table No.3.3 Load and deflections for Steel beam

Sr .no	load (kN)	Deflection (mm)
1	0	0
2	22.50	1
3	98.86	3
4	190.032	7
5	193.58	9
6	193.58	11
7	193.58	13
8	193.58	13
9	193.58	15
10	193.58	17
11	193.58	17



Graph No.3.3 Load Vs Deflection on Steel beam,

IV. CONCLUSION

1. As main object of the experimental work to minimize depth, Steel beam and composite beam takes more load than that of RCC beam with reduced section.
2. Designed sections of RCC, Composite and steel beam are safe for loading with load factor 1.2, 1.8 and 2.1 respectively.

3. As steel is stronger than concrete in flexure significant depth reduction is achieved hence members are slender and thin it helps to achieve architectural aspect.

4. Steel section is more economical than RCC and composite beam. As steel beam is directly purchased and used as it is there is no need of curing and casting procedure which are time consuming process

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