The Structural Behavior of Composite Beams With Prefabricated Reinforced Concrete Plate (Connection with Bolt) In Negative Moment Zone

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ABSTRACT

Composite beam are made up by R.C shell and structural steel, and bolts are used for shear connector. Additionally several plates are placed on the bottom face of composite beam for each test. Therefore composite behaviour, comparison of experimental and numerical results, shell detachment, the impact of several displacement and shapes of bolts and plates to the structural behaviour, the crack formation are investigated.

300X80X12 cm R.C shell and 300 cm HEB 120 are joined by the help of bolts and plates, and samples are tested. These samples are 3 sets (total of 6 quantities) are made of composite beams.

Simple span beams are set for easily rotatable at the supports. At the middle of the span P point load is applied. Ultimate load of bearing capacity is determined when the minor crack is occurred.

Load - deformation, load - extension, moment - curvature diagrams are drawn and comparisons are made at the end of the tests. Eventually compatibility of plastic calculation method, the impact of situation of uprising shell to the bearing capacity, using of plate reduce the deformation and increase the crack load are investigated and bolts as a well shear connector is proved.

Keywords: Composite Beams Reinforced Concrete Plate, Steel Profile, Bolt, Negative Moment and Structural Behavior.

INTRODUCTION

In the field of composite structures, the maximum economic results can be maintained in beams. This worth can approach %50 level at the positive moment systems. On the other hand, for increasing the fire resistance of multi storey steel structures or reduce the damaging effect of the bearing elements (corrosion etc.), covering steel members with concrete provide the usage of concrete in steel structures.

In the use of multi span composite beams in steel structures negative moments are occurred at the supports. Under the effect of negative moment of R.C shell tensile stresses are occurred. As known, concrete can be easily cracked and for the ultimate service it is undesired case. The aim of this study is, For the aim of this study, under the negative moment the behaviour of the concrete shell is investigated.

THE CURRENT STUDIES ABOUT THE SUBJECT

The structural behaviour of steel fiber reinforced concrete composite beams at the negative moment area (Ahmet Necati YELGIN ve H.Yasar YALMAN). Quantity of 9 at 3 m length as test samples, taking into consideration the concrete cover at 80 cm width, the compound of 10 cm thick concrete shell and 3 m length I 120 profile test set is divided to there groups.

Eventually, as the amount of the steel fibers increase the bearing capacity's increment is observed. The most remarkable increase in this case is the time when the early crack occurs by the load value. At testing fibreless steel, composite steel started to crack at %55 bearing capacity, with 3cm short fibers bearing capacity becomes %68, with 6cm long fibers this rate increases up to %70.

Additionally various results were acquired in the displacements values of beams. As steel fibers extend, vertical displacement decreases. But as a result of these experiments, adding steel fibers into the R.C plate is not effective for increasing the bearing capacity of composite beams at the negative moment region.

Examination of the behavior and strength of R.C concrete-steel composite beams in negative moment region (Tevfik Seno ARDA and Nermin Mengene)

5 different concrete grade,4 different R.C support reinforcement, 2 different spans like 5m and 3m, 3D steel profile, colonic segment and oncologic segment as 18 samples are tested. Samples are point loaded at the middle of a single span.

Applied load is increased gradually from 0 to ultimate fracture load. At each load level, steel profile and longitudinally reinforcement's unit deformation were measured at specific locations. Hence, at negative bending region plastic design methods can be used for designing of R.C composite beams.

The theoretical design of vertical displacements were examined by considering the moment inertia of cracked section and average rate of cracked or untracked section of the moment of inertia. Calculation of vertical displacements due to the moment of inertia of cracked section gives the closest result of the experimental values.

Structural behaviour of R.C plate composite beams reinforced with steel plates at negative moment region (Ahmet Necati YELGIN and Özgür ÇETİN)

5 samples, 3 m length , 80 cm width , 10 cm thickness R.C plate , 3 m length I 120 profile , 6 pieces of U80 profile to provide the composite action, and bonded to each other by epoxy resin.

Variations of overlay dimensions and spacing's of steel plates examined to realize its effection to the bearing capacity. Consequently, the use of steel plates for this section increases the bearing capacity up to %250 were observed by the studies.

BEARING CAPACITY AT THE NEGATIVE MOMENT REGION

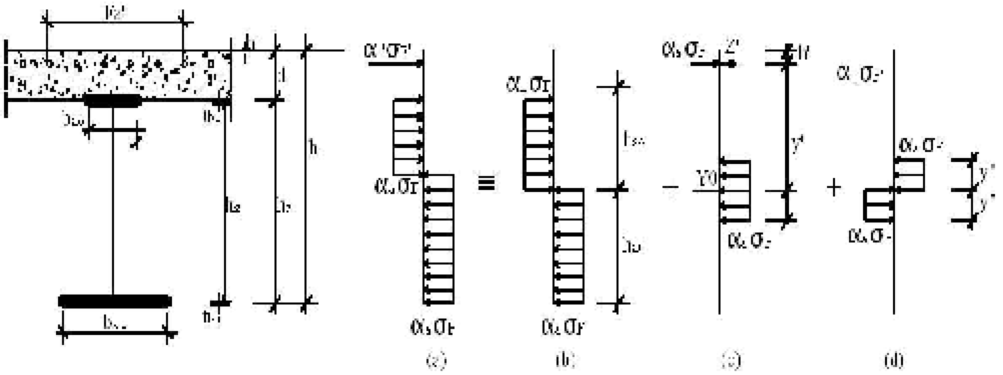

Fig.1. The Distribution of Stresses and Internal Forces in Composite Beams at Negative Moment Region

$$W_{pa} = \int_{alan} |y| dF_a = S_{x,üst} + S_{x,alt}$$

$$M_{pa} = \alpha_a \sigma_F W_{pa}$$

$$Z' = \alpha_a' \sigma_F' F_a'$$

$$y' = h_t - (h_{au} - h')$$

$$\Delta M_1 = Z'.\ y'$$

$$y'' = \frac{Z'}{2t_g\ a\ F}$$

$$\Delta M_2 = \alpha_a \sigma_F t_g y'' |y''|$$

$$|-Mu| = M_{pa} + \Delta M_1 - \Delta M_2$$

Material definitions for calculation of the beams used in tests:

Values are given at Table 1. for concrete, reinforcing, steel profile used in tests. R.C plate of composite beam is length of 3 m, width of 80 cm and thickness of 12 cm.

Table 1.

Concrete Grade	Reinforcing Steel Grade	Steel Grade
C 30	BÇ III a	St 37 HEB_{120}
σ_{br} = 380.8 kg/cm^2	σ_F' = 4.610 t/cm^2	σ_F = 2.4 t/cm^2
α_b = 0.74	α_a' = 0.95	α_a = 0.95
γ_{bet} = 2.39 t/m^3	f_a' = 6.79 cm^2 (6Ø12)	f_a = 34.0 cm^2
E_b = 321350 kg/cm^2	E_a = 2119540 kg/cm^2	H= 12 cm
h' = 1.5 cm		H_i = 9.8 cm
		t_g = 0.65 cm
		h_g =10.3 cm
		W_{pa} = 165.2 cm^3

Preparation of composite beams to be used in the experiments

Length of 300x80x12 cm R.C plate, length of 300 cm HEB 120 profile combined with bolts and plates, and this sample were tested. Composite beams consist of each sample 3 set (total of 6 pieces).

Material definition of concrete grade is C30. Vibrator is used while casting and after that curing is applied.

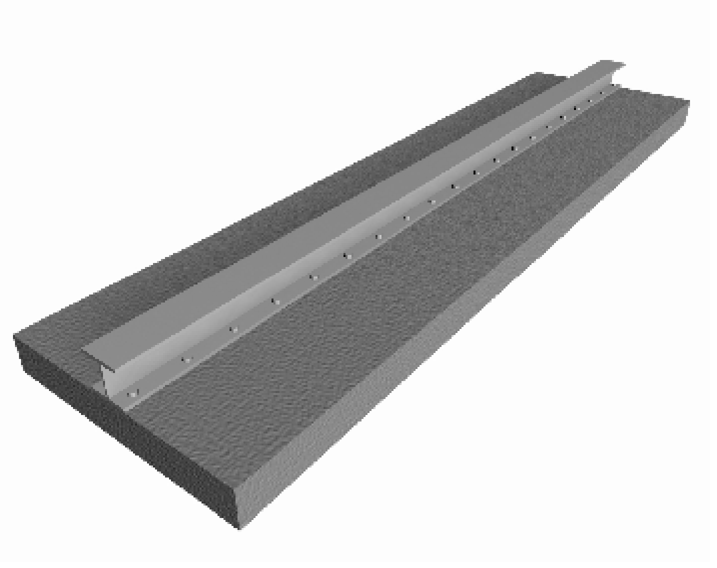

Fig.2. General View of Composite Beam

Experimental Setup

Tests have been made at the Structural Laboratory of Sakarya University. HI – TECK MAGNUS frame and ENERPAC 200 KN compression loader hydraulic presser tools were used for loading.

Records have been made by 5 channels.

1. Load cell (loader) P load as defined and applied at middle span

2. Lvdt (potansiyometric ruler, displacement measure) was used for dimensioning the maximum displacement and placed at the middle span.

3. and 4. Electronic displacement measurer is placed horizontally at the flanges of steel profile to measure the horizontal displacement and generate moment - curvature diagram.

5. Strain gage is places at the middle span of beams down flange for dimensioning the extensions in the steel beam.

CONCLUSIONS

At this section, testing results of section 3and calculations results section 4 are compared and evaluations were made.

Absolute composite action has been observed between the R.C plate and steel profile at the end of the test initially. Shear was not observed at the shear elements, and a bolt working as a very good connection element was observed.

At all of the tests, left and right side where the load is applied symmetric cracks has been observed at all of the tests.

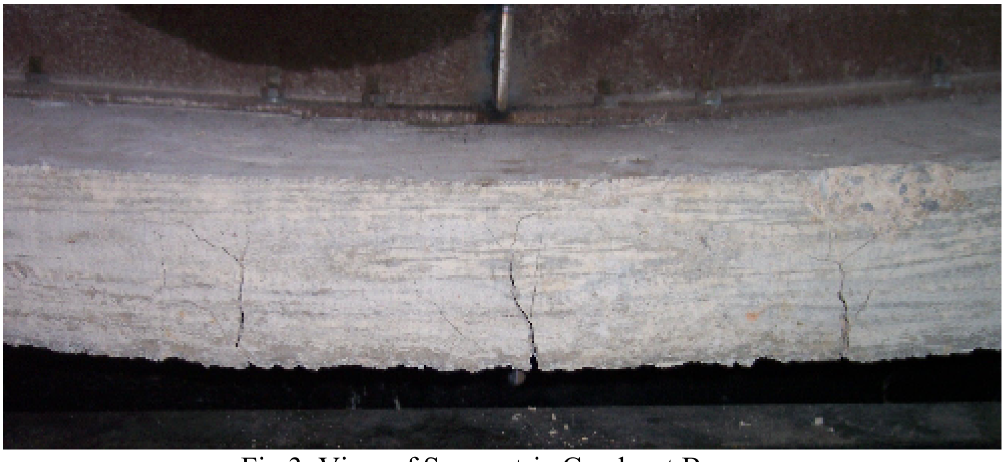

Fig.3. View of Symmetric Cracks at Beams

When the cracks in concrete were analyzed, cracks were observed near the bolts.

Fig.4. Cracks around the Bolts

General information, crack loads, experimental and theoretical values of bearing capacity are given.

Table 2. Information, crack load, experimental and theoretical values about bearing capacity

	Concrete Dimensions (cm)	Steel Profile	Steel Plate
DN1	300.80.12	HEB 120	20 pieces 150*120*2
DN2	300.80.12	HEB 120	20 pieces 150*120*2
DN3	300.80.12	HEB 120	40 pieces 120*70*2
DN4	300.80.12	HEB 120	40 pieces 120*70*2
DN5	300.80.12	HEB 120	Without plate
DN6	300.80.12	HEB 120	Without plate

	Crack Load (kN)	Experimental Bearing Load (kN) P_{ud}	Theoretical Bearing Load (kN) P_{ut}	Experimental Bearing Load (kN) P_{ud}
DN1	52	118.31	95.8	DN1 and DN2 average 112.15
DN2	46	105.99	95.8	
DN3	47	107.85	95.8	DN3 and DN4 average 103.72
DN4	44	99.6	95.8	
DN5	46	100.13	95.8	DN5 and DN6 average 98.33
DN6	43	96.53	95.8	

The difference between experimental bearing load and theoretical bearing load is minimum 0.73 kN and maximum 22.51 kN. Theoretical bearing load is minimum %0.7 maximum %23.5 more than experimental values.

This difference between the bearing capacities as told in the source book of "Plastic Design of Steel Composite Elements " : The aim of the shear connectors is to bond the steel and concrete plate for acting as a one compound..

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