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AN EXPERIMENTAL STUDY ON FLEXURAL BEHAVIOUR OF COMPOSITE BEAMS WITH SHEAR CONNECTOR

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Abstract:

Composite Steel-Concrete construction is widely used in buildings and bridges even in regions of high seismic risk. It is now common practice to use cold formed steel sheets as permanent formwork for the support of the soffits of reinforced concrete and also as part of the tension steel in the composite beam that is formed after the concrete has hardened. The construction should ensure monolithic action between the prefabricated steel and in-situ concrete so that they act as a single structural unit. Structural elements, such as anchors, studs, channels and spirals, intended to transmit the horizontal shear between the prefabricated member and the cast-in-situ concrete and also to prevent vertical separation at the interface. Shear connectors, anchors (hoops, loops, and struts) are used as a means for comprising steel and concrete, as well as friction through high value crews and their combination. There is a common term – Shear connectors that defines the various forms of steel structural parts connected to the upper segment of the steel plate most often by welding. In this experimental analysis the T-shape shear connectors will be used in composite beams as they have the highest characteristic resistance and the mode of failure changes for different concrete strengths and different arrangements. Moreover the shear connectors will be provided in various arrangements and the optimum location which gives the high flexural and shear strength going to be arrived. The flexural strength between conventional reinforced concrete beam and composite beams with shear connector is were compared and found that the T-Connectors facing the centre of beam (NT-2) holds the cold formed steel well with the concrete compared to other composite beams

Introduction:

The applications of composite members consisting of concrete-steel sections have become increasingly popular in civil engineering structures in recent years. This is due to their advantages over the conventional concrete sections in terms of strength, ductility, energy absorption capacity, easy construction procedure and overall economy. Composite Steel-Concrete construction is widely used in buildings and bridges even in regions of high seismic risk. It is now common practice to use cold formed steel sheets as permanent formwork for the support of the soffits of reinforced concrete and also as part of the tension steel in the composite beam that is formed after the concrete has hardened. The construction should ensure monolithic action between the prefabricated steel and in-situ concrete so that they act as a single structural unit. Steel-concrete composite beams have long been recognized as one the most economical structural systems for both multistory steel buildings and steel bridges. Considerable investigations had been carried out in the past by many researchers with different ways of bonding between steel and concrete.

Cold Formed Steel:

Cold worked steel products are commonly used in all areas of manufacturing of durable goods like appliances or automobiles but the phrase cold form steel is most prevalently used as construction materials. In the construction industry both structural and non-structural elements are created from thin gauges of sheet steel. These building materials encompass columns, beams, joists, studs, floor decking, built-up sections and other components. Cold formed steel structural members are cold formed in rolls or press brakes from flat steel, generally not thicker than 12.5mm.

Shear Connectors:

Structural elements, such as anchors, studs, channels and spirals, intended to transmit the horizontal shear between the prefabricated member and the cast-in-situ concrete and also to prevent vertical separation at the interface. Shear connectors, anchors (hoops, loops, and struts) are used as a means for comprising steel and concrete, as well as friction through high value crews and their combination. There is a common term – Shear connectors that defines the various forms of steel structural parts connected to the upper segment of the steel plate most often by welding.

Forming of the Shear Connectors:

The transmission of shear forces and the intensity of stress in he steel plate, the weld that connects the shear connector to the cold formed steel plate, material of connector itself and the surrounding concrete of the slab, which all determines the strength, are highly dependant on the form of the shear connector. There are many different forms of means for composition that are used in practice.

C. Types of Shear Connectors:

There are many types of shear connectors and they are most generally divided into rigid and flexible. The rigid shear connectors resist shear forces through the front side by shearing, and they have insignificant deformations. They produce stronger concentrated stress in he surrounding concrete that results either in failure of concrete or in failure of weld. The flexible shear connectors resist shear forces by bending, tension or shearing in the root, at the connection point of steel beam, where they are subjected to plastic deformations when they reach the ultimate strength values. The manner of failure is more ductile and is not prompt. They maintain the shearing strength even with a lot of movement between the concrete slab and the steel beam.

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T-Shape Connectors:

T-shape connectors performed very well compared to headed studs. T-shape connectors achieve the same load capacity as oscillating perfobond strip connectors, but have a much larger ductility. This type of connectors show an increase in their load capacity and ductility if the concrete used is with fibers, light weight concrete or a higher strength concrete. The T-shape connectors have the highest characteristic resistance and the mode of failure changes for different concrete strengths and different arrangements.

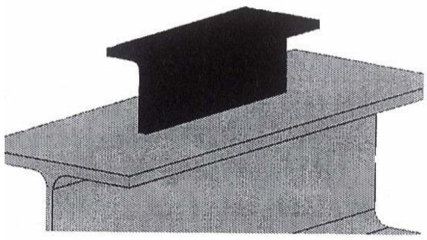


Figure 1.1: T-Shaped Shear connector

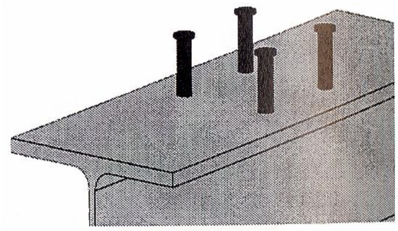


Figure 1.2: Headed Stud Connector

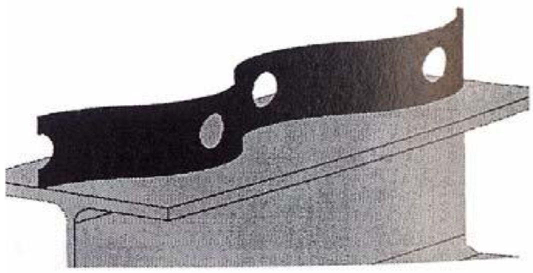


Figure 1.3: Oscillating Perfobond strip

Scope:

Though composite construction is not a very new technique, its importance in structural construction is of recent realization in our country. With the advancement in the manufacture of structural units, composite construction has assumed great importance. The fact that both the steel and concrete is used to take advantage of its positive attributes makes composite steel-concrete construction very efficient and economical. Composite beams offer several advantages over non-composite sections. A composite beam is stiffer than a non-composite beam of the same size and thus experiences less deflection and floor vibrations. An essential component of a composite beam is the shear connection between the steel section and the concrete.

Objective:

To cast 4 concrete beams (one conventional beam and three composite beams) with uniform dimensions suitable for test setu. To compare the test results of each beams and ultimately trying to find the eccentric arrangement of shear connectors suitable for composite beams. To determine the flexural strength, deflection and ductility characteristics of the composite beams with T-Shear connectors in light weight concrete. To study the effects and modes of failure of beam for the different arrangements of T-shear connectors.

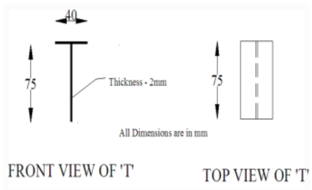
Summary of Literature Survey:

From the Literature Survey, it is summarized that

- ✓ The flexural behavior of composite beam sections exhibits good behavior than the conventional concrete.
- ✓ Compared to other types of shear connectors, T-Shear connectors gave better results which satisfies both strength and serviceability requirements.

Details of Shear Connector:

Details of T - Connector
Length, Height – 75mm
Width – 40mm
Thickness – 2mm



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FINISHED T-CONNECTORS


Material:

- ✓ Cement
- ✓ Aggregate

Cement: Ordinary Portland Cement of 53 Grade is used throughout this investigation. The important properties of the cement are given below:

Properties of Cement:

Grade of Cement used	Ordinary Portland Cement, 53 grade
Specific Gravity of Cement	3.15
Fineness of cement	3%
Initial setting time	28 min
Final setting time	310 min

For the experimental work, "ULTRATECH" (brand name) 53 grade of Ordinary Portland Cement is used. The cement samples were tested as per the procedure given in IS: 401-1996 and IS: 4032-1999.

Fine Aggregate: Fine aggregate used for the study should be properly graded to give the minimum voids ratio and shall be free from deleterious materials like clay, silt content and chloride contamination. River sand is normally preferred over crushed sand since in the former particle shape is fully water worn by attrition which helps in reduction of water content of mix and also lesser resistance to pumping.

Fine Aggregate

Locally available river sand conforming to Grading zone II of IS: 383 –1970.Weight of sample is 200g. Properties of fine aggregate. For the experimental work, locally available natural sand with 4.75 mm maximum size was used as fine aggregate. The properties of fine aggregates were tested as per IS: 383-1970.

Fineness Modulus	2.25%
Specific Gravity	2.60
Water Absorption	1%

Coarse Aggregate: The coarse aggregate is the strongest and the least porous component of concrete. Some important properties of coarse aggregate like crushing strength, gradation and bulk density need special consideration while selecting the coarse aggregate for pavement. Crushed granite aggregate with a maximum nominal size of 20mm have been used.

Coarse aggregate

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The summaries of properties of coarse aggregate are given below: As per code IS: 2386 & 383-1970 Sample of the specimen: 200g. Properties of coarse aggregate

Fineness Modulus	6.05%
Specific Gravity	2.60
Water Absorption	1%
Size Aggregate	20mm

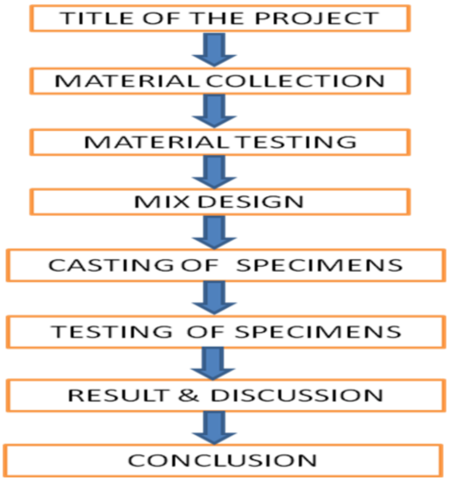
The crushed stone aggregates were collected from the local quarry. The properties of coarse aggregates were evaluated as per the procedure given in IS: 383-1970 and IS: 2386-1963 (part- I, II and III).

Water: Portable Water was used in the experimental work. A higher water-cement (w/c) ratio will decrease the strength, durability, water-tightness and other related properties of the concrete.

Mix Design: The mix design was carried out using IS codal provisions. The mix proportion is as follows:

Water	Cement	Fine Aggregate	Coarse Aggregate
165	366.66	683.06	1273.90
0.45	**1**	**1.86**	**3.87**

Experimental Methodology:



Tests on Concrete:

To evaluate the strength properties of mix properties used in this project, the following tests were performed.

- ✓ Compressive Strength
- ✓ Split Tensile Strength
- ✓ Flexural Strength Test

Compressive Strength Test: The specimen were removed from chamber after 24 hours, demoulded carefully and were kept in ambient conditions. Testing was done after 7 days, 14 days and 28 days of ambient curing. The bearing surface of the testing machine was cleaned. The specimen was placed in 2000KN capacity compression testing machine in such a manner that the load could be applied to the opposite sides of the cube. The specimen was aligned centrally on the base plate of the machine. The movable portion was rotated gently by hand that, it touched the top surface of the specimen.

Split Tensile Strength: Concrete being a brittle material is not expected to resist direct tensile forces. However tensile strength is of important with regards to cracking, due to tensile failure. Some researchers have observed that the type of coarse aggregate has a relative effect on tensile strength that on compressive strength. Generally for quality control concrete tensile strength is never made.

Results and Discussion:

Beam Name	Ast provided (mm^2)	Load (kN)		Ultimate failure moment (kNm)	% Decrease with respect to NC (First-crack load)	% Decrease with respect to NC (Ultimate load)
		First crack load	Ultimate load			
NC	226.19	14	62.795	15.698	------	------
NT-1	156.2	12	50.255	12.564	16.67%	25%
NT-2	156.2	14	52.25	13.06	0	20.18%
NT-3	156.2	10	47.98	11.99	40%	30.8%

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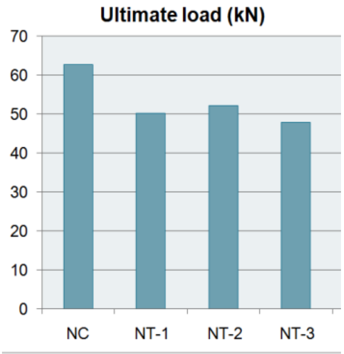
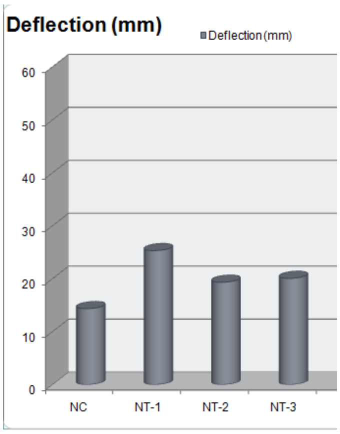
DUCTILITY INDEX

Beam Name	Mid span deflection at first-crack load, D_y(mm)	Mid span deflection at ultimate load, D_u (mm)	Ductility Index, D.I=D_u/D_y	% increase in ductility with respect to NC	Mode of failure
NC	2.16	14.34	6.64	-----	Under - reinforced
NT-1	2.1942	25.3	11.53	73.64	Under - reinforced
NT-2	2.45	19.32	7.88	18.67	Under - reinforced
NT-3	2.114	20.063	9.49	42.92	Under - reinforced

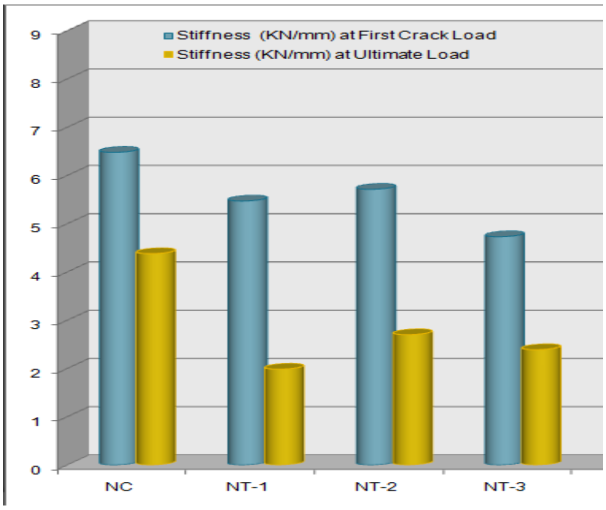
LOAD COMPARISION



DEFLECTION COMAPRISON



STIFFNESS (kN/mm)



ENERGY DUCTILITY

Beam Designation	Energy absorption upto first crack load (A) kN-mm	Energy absorption upto ultimate load (B) kN-mm	Energy Ductility I = B /A
NC	17.388	364.52	20.964
NT-1	15.111	910.69	60.22
NT-2	17.15	618.95	36.093
NT-3	11.61	611.8	52.696

- The arrangement of NT-1 shear connectors provide more energy ductility

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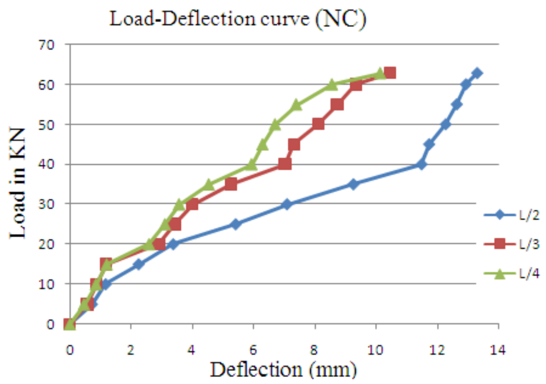
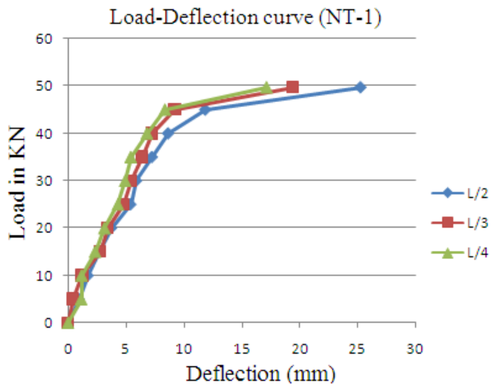
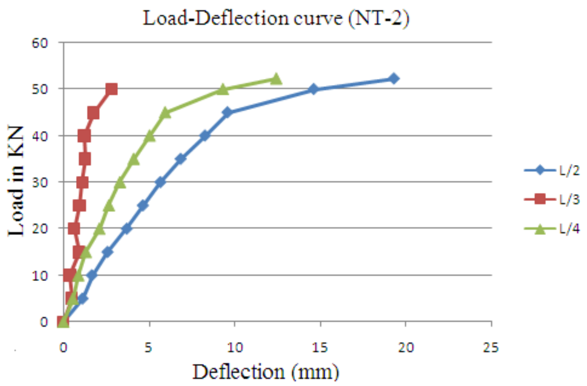
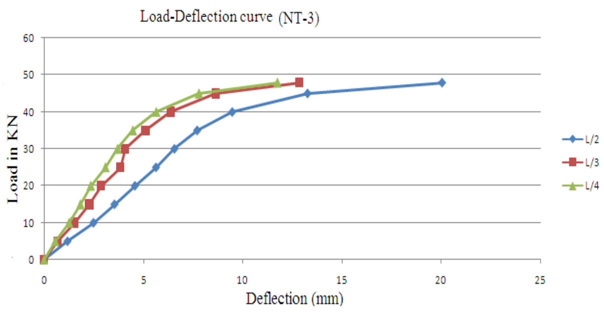
Load – Deflection curve:

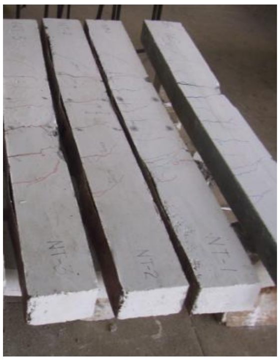








BEAMS AFTER FAILURE



Conclusion:

- ✓ The present experimental investigation has been done to determine the flexural strength, ultimate strength capacity, and deflection and ductility characteristics of the composite beams with three different arrangements of T-Shear connectors.
- ✓ Energy Ductility is more in case of NT-1 beams.
- ✓ Crushing of Concrete is more in NT-3 beam compared to other beams.
- ✓ The T-Connectors facing the centre of beam (NT-2) holds the cold formed steel well with the concrete compared to other composite beams. The shear flow at interface of concrete and steel is good. NT-2 beam has more load carrying capacity compared to others.

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