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# Experimental study on strength and flexural behaviour of reinforced concrete beams using "Deflected structural steel" as reinforcement

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***Abstract:*** *Strength and flexural behaviour of reinforced concrete beams using deflected structural steel reinforcement and the conventional steel reinforcement are conducted in this study. The reinforcement quantity of both categories was approximately equalised. Mild steel flats with minimum thickness and corresponding width are deflected to possible extent in a parabolic shape and semi-circular shape are fabricated and used as deflected structural steel reinforcement in one part, whereas the fabrication of ribbed tar steel circular bars as conventional reinforcement on the another part of the experiment for comparison in the concrete beams. All the beams had same dimensions and same proportions of designed mix concrete, were tested under two point loading system. As the result of experiments, it is found that the inverted catenary flats and their ties, transfers the load through arch action of steel from loading points towards the supports before reaching the bottom fibre at the centre of the beam as intended earlier. Thereby the load carrying capacity and the ductility ratio has being increased in deflected structural steel reinforced beams when compared with ribbed tar steel reinforced concrete beams, it is also observed that the failure mode (collapse pattern)is safer.*
***Keywords --****Arch profile, Conventional steel reinforcement, Cracks, Collapse, Deflected structural steel, Ductility ratio.*

## I. Introduction

In general, reinforced concrete structural elements are made with steel reinforcement and designed mix concrete. The reinforcement is designed to resist maximum bending moment, shear force, torsion, and sometimes for compression as required. Ribbed tar steel or mild steels of circular sections or square sections are used as conventional reinforcement and the members are formed with uniform cross section.

A support in the form of a curved link with convexity towards the point of external force or the point of concentration of all external forces or point of resultant thrust is a well-known load transmission mechanism (external load resistance system).

All of us know that the arch profile of a support, makes itself a tension free, and uniform compressive stressed throughout the longitudinal section, commonly known as linear arch (theoretical arch).

This mechanism is widely used one in the formation of many bridges and structures along with architectural visualization. But it is not at all suitable and possible that forming all the elements of a framed structure or a load bearing structures. So it is intended to adopt the same principle in the reinforcement alone inside the uniform cross sectional concrete in order to reduce the tensile stress, shear stress and trying to make a member subjected to uniform stress distribution along with arch action of steel, and an intellectual tying system in the reinforcement, and thereby improving the load carrying capacity and ductile behaviour of the member. To met out the above criteria, it was selected that the fabrication of flattened mild steel strips in the deflected shape (arch profile) with necessary ties according to the action of external load as most suitable reinforcement and decided to use inside the concrete instead of usual ribbed tar steel reinforcement. Following this, the experiments on both reinforcement categories in similarly characterised elements were prepared and necessary test had been conducted and the results are compared with each other.

## II. Experimental program

### II.1 Materials

#### II.1.1 Steel

Ribbed tar steels and mild steel flattened strips were selected for reinforcement. The properties are shown in Table-III

#### II.1.2 Concrete

Designed mix concrete $M_{20}$ as per Indian Standard code of practice with maximum size of 20 mm Coarse aggregate, fine aggregate belongings to zone II were selected. The properties of cement, fine aggregate and coarse aggregate are shown in Table-I. The proportion of designed mix concrete ingredients is shown in Table-II.

### II.1.3 Fabrication

Flattened mild steel strips are deflected to required arch profile and fabrication is carried out by shop welding. Fabrication schedule is shown in Fig-I. Ribbed tar steels are straightened and fabrication was carried out with usual fabrication method which is shown in Fig-II.

### II.2 Test specimen

A conventional rotary concrete mixer machine was used to mix the concrete. The dry coarse aggregate, cement, and fine aggregates in proportion were mixed first for one minute before mixing the required water the mixing is continued for three minutes after mixing the water to achieve uniformity. The concrete was then casted in six moulds, each having size of 750 mm X 150 mm X 150 mm. containing the reinforcement in the form of deflected structural steel fabrication and ribbed tar steel fabrication, alternatively as test beams. In addition to test beams concrete was also casted in the standard cube moulds for cube test.

All beam specimen and cubes casted were demoulded next day and immersed in water for curing up to 28 days.

### II.3 Test procedure and measurements

The size of test beams is 750mm Length, 150 mm Breadth and 150 mm depth. The effective span length is 630 mm (between centres of supports). Dimensions and loading details are shown in Fig-III. The beam was placed for testing in universal testing machine having 1000 KN capacity. A constant load of 10 KN (approximately about 10% of the capacity of the beam) was applied to hold the specimen in position and to simulate the load. A deflecto meter with least count of 0.01 mm was installed exactly at the centre of the beam to measure the maximum deflection at the bottom. The loading was given gradually at the top of the beam. Loading and corresponding deflections were observed and recorded. The safe values among three specimens had been taken for comparison.

## III. Results and Discussion

### III.1 Cracking strength and cracking patterns

Fig-IV, V and VI shows the crack pattern in tested beams at failure stage. It was noted that the first crack was observed in ribbed tar steel reinforced beams at loading range of 60 KN and70 KN the central deflection is 1.5 mm to 1.85 mm. At the same time in deflected structural steel reinforced concrete beams, the first crack formation observed at the loading range of 75 KN and 85 KN, the central deflection level was also 1.5 mm to 1.86 mm. This shows the higher cracking strength of the deflected structural steel reinforced beams.

The development of the first crack in ribbed tar steel reinforced concrete was in a rapid manner and formation of further cracks were very few and the development of later cracks were also very slow and their extent is not to the full section except the first and one or two successive cracks . Finally the section fails in same cracked plane. Mostly this plane passes through one of the loading point, and nearest support. This shows the shear crack pattern and the neck point formation in the beam. This type of collapse is unwanted. Whereas in deflected structural steel reinforced beams unlike RTSR beams the first crack formation and its development was not in rapid manner but formation of further cracks were as quicker and large in numbers at bottom and few in the top than in RTSR Beams. The crack pattern at bottom was almost tension cracks and their extent is up to the reinforcement only

At top the cracks were due to crushing mostly in between loading points. At the time, before yielding starts in steel deflected shape gets straightened by distressing the cover concrete at multiple locations simultaneously all cracks are restrained by the widened strips of steel.

At final stage 3 to 6 equally spaced cracks had been developed to full section, and the beam collapsed. The equally spaced cracks formation and the occurrence of multiple failure planes and their similarity shows us an even stress distribution in whole section is achieved with DSS reinforcement, but it is very difficult with RTS Reinforcement. When seeing the occurrence of multiple failure planes and the profile of the collapsed beam (after failure) showed an even curvature by bending, sustainability possessed by the reinforcement at the time of collapse is appreciable and failure mode is safe.

### III.2 Load-deflection behaviour

Table-IV shows the maximum deflection of the tested beams at centre of the span at different loading levels (load. Vs. Deflection- at concrete distressed, yield, and ultimate stages).

Graph shows the load Vs deformation behaviour of both types of reinforced sections distinctly. From chart it is observed that the deflection at initial stage of loading is lesser in DSS RCC Beams than RTSRCC Beams. At final stage it is too larger. This shows that DSSRCC sections has more stiffness initially and flexible at failure stage than the RTSRCC beam sections.

### III.3 Ductility of beams

Ductility is the ability of the member to sustain deformation beyond the elastic limit while maintaining the reasonable load carrying capacity until total failure. In reinforced concrete beam the deformation most suited for measurement of ductility is the curvature of the beam. Alternatively here the deflection is used to measure the ductility.

Ductility ratio, $\mu = \Delta u/\Delta y$

Where, $\Delta u$- Maximum deflection occurred at failure stage.

$\Delta y$- deflection occurred at member yields.

Ductility behaviour of the test specimens are shown in Table –V.

From the ductility ratio calculation, it is found that the ductility of DSSRCC Beams are more than 2.5 times the conventional steel reinforcement beams, even the ductility of flattened steel strips had very lesser value , compared to circular bars, which is shown in the table-III. This is because the deflected strip length is higher than the length of straight bars inside the concrete. When deformation in the whole section takes place the strips having deflection towards forces are tends to straightened by distressing the concrete where ever possible, the strips having deflection in the same direction of forces will tends to yield, the strips having neither former case nor latter case will tends to rotate.

Hence the major part of reinforcement in DSSRCC Beams was belonging to the above said first case the beams were performed well in ductile behaviour.

## IV. Tables and figures

Table-I Properties of cement, sand and coarse aggregates

| Sl.No. | Material | Property | Experimental value | Limiting value |
|---|---|---|---|---|
| 1 | Cement | (a)Fineness<br>(b)Normal consistency<br>(c)Initial setting time<br>(d)Final setting time<br>(e) soundness<br>(f) compressive strength<br>(g)Specific gravity | 7.33%<br>27.00%<br>30.Minutes<br>585. Minutes<br>8.mm<br>43 N/mm$^2$<br>3.15 | 10.00 %<br>-<br>30.Minutes<br>600. Minutes<br>10.mm<br>-<br>- |
| 2 | Fine aggregate | (a)Fineness<br>(b)Specific gravity<br>(c)Moisture absorption | 3.220<br>2.740<br>1.00% | - |
| 3 | Coarse aggregate | (a)Fineness modulus<br>(b)Angularity number<br>(c)Angularity index<br>(d)crushing value<br>(d)abrasion value<br>(e)impact value<br>(f)flakiness index<br>(g)elongation index<br>(f)Specific gravity | 5.00<br>7.20<br>2.08<br>33.08<br>4.32%<br>34.33%<br>11.14%<br>5.59%<br>2.75 | -<br>11.00<br>-<br>-<br>-<br>-<br>-<br>-<br>- |

Table-II Concrete mix proportion

| | Water | Cement | Fine aggregate | Coarse aggregate |
|---|---|---|---|---|
| Ratio | 0.50 | 1.00 | 1.48 | 3.26 |
| Weight in kg/m$^3$ | 191.60 | 383.00 | 566.88 | 1250.00 |

Table-III Properties of steels

| Sl.No. | Type | Grade | Size of the section | Area | Weight/m | Elongation |
|---|---|---|---|---|---|---|
| 1 | RTS-bar | Fe 250 | 10.mm ϕ | 78.54 mm$^2$ | 0.62 kg | 20% |
| 2 | RTS-bar | Fe 250 | 8. mm ϕ | 50.27 mm$^2$ | 0.39 kg | 18% |
| 3 | MS-Flat | Fe 250 | 25.40mmX 3.00mm | 76.20 mm$^2$ | 0.61 kg | 06 % |
| 4 | MS-Flat | Fe 250 | 12.70mmX 3.00mm | 38.10 mm2 | 0.30 kg | 05% |

Table-IV Deflection at different stages

| Beam specimen | Deflection in mm | | | |
|---|---|---|---|---|
| | Cracking | Yield | Ultimate | Maximum crack width |
| RTSRCC-1 | 1.50 to 1.80 | 3.20 | 4.20 | 3.00 |
| RTSRCC-2 | 1.58to 1.86 | 3.40 | 4.50 | 2.80 |
| RTSRCC-3 | 1.52 to 1.80 | 3.20 | 4.40 | 3.20 |
| DSSRCC-1 | 1.50 to 1.86 | 4.80 | 18.00 | 11.00 |
| DSSRCC-2 | 1.66 to 2.12 | 5.20 | 22.00 | 15.00 |
| DSSRCC-3 | 1.50 to 1.86 | 5.00 | 16.00 | 14.00 |

Table-V Ductility ratio

| Beam specimen | Yield deflection | Ultimate deflection | Ductility ratio |
|---|---|---|---|
| RTSRCC-1 | 3.20 | 4.20 | 1.31 |
| RTSRCC-2 | 3.40 | 4.50 | 1.32 |
| RTSRCC-3 | 3.20 | 4.40 | 1.38 |
| DSSRCC-1 | 4.80 | 18.00 | 3.75 |
| DSSRCC-2 | 5.20 | 22.00 | 4.00 |
| DSSRCC-3 | 5.00 | 16.00 | 3.30 |

Figure-I Deflected M.S Flats fabrication

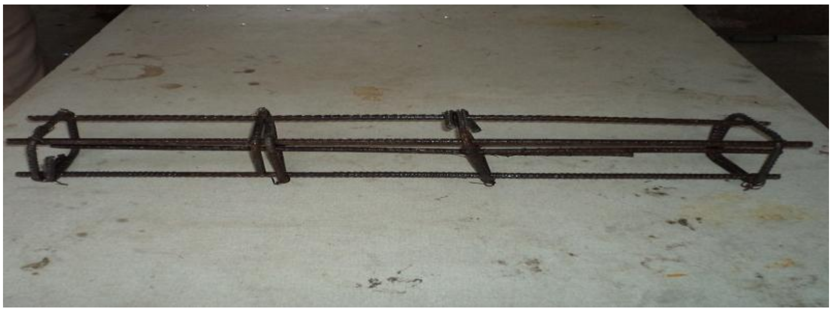


Figure-II Conventional RTS Bar fabrication

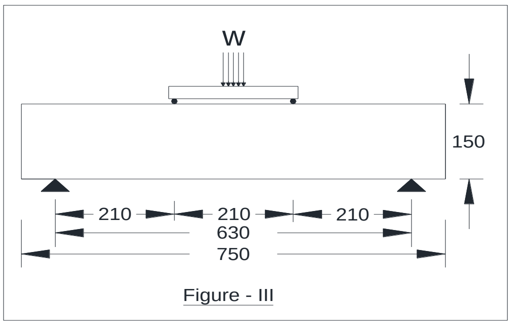


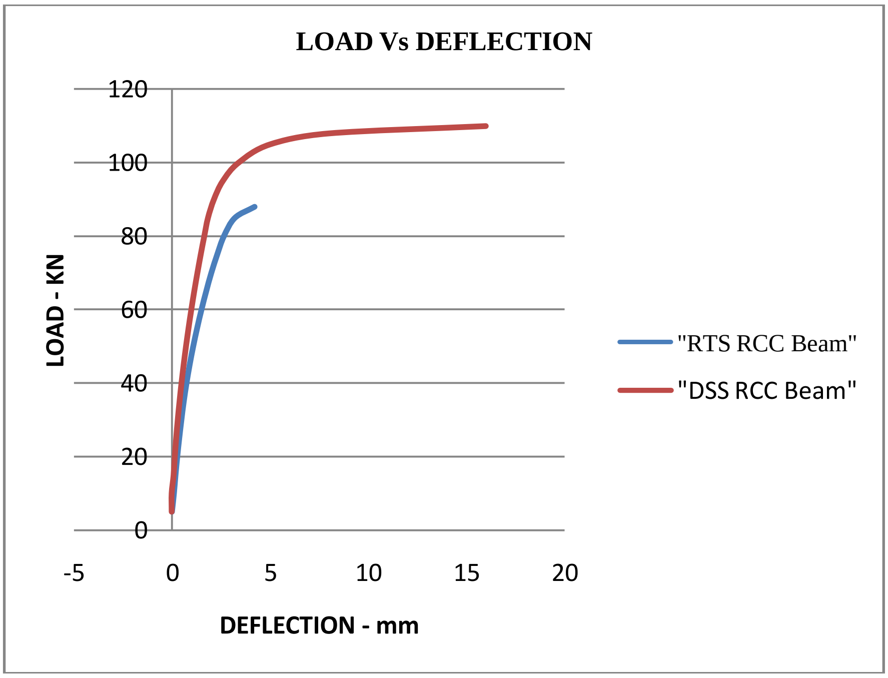

Figure-III Details of test beam

Figure-IV Failure of DSSR Beam-1

Figure-V Failure of DSSR Beam-2

Figure-VI Failure of RTSR Beam-2

DEFLECTION OF DSS RCC BEAM AND RTS RCC BEAM



## V. Conclusion

In this experimental study properties of all the materials had been found, the materials having same properties were used to prepare the test specimens, in same dimension and same procedure had been followed to test the beam specimens. The only change was made in the similar beam sections are reinforcement in two distinguished patterns using same grade steel and approximately in same volume. The first pattern used was in the form of "fabrication of flattened mild steel strips with deflected profile" Which is called DSSRCC Beams. Second one was in the form of "fabrication of ribbed tar steels" (conventional reinforcement), which is called RTSRCC Beams.

From the test results and observations the following conclusions are valuable

1. The cracking strength of a reinforced concrete section can be increased by using deflected structural steel flats as reinforcement. Arch action of steels and provision of links from high stressing zones to less stressing zones inside the sections with proper analysis are favourable to achieve high strength.
2. Since the contact surface between flat and concrete is more than circular bar and the concrete stress transmission among them in DSSRCC Beams is easier and in broad sense. Hence well confinement, wide range of stress distribution, in some situation stress conversions can be achieved in DSSRCC Beams results in increased load carrying capacity of the beams.
3. In a DSS Fabrication system probably the main strips are lies normal to the direction of the action of shear forces, thereby shear resistance can be increased without providing shear reinforcement in DSSRCC Beams.
4. Ductility ratio of DSSRCC Beams was too higher than the RTSRCC Beams. DSSRCC Beams are suitable to design as seismic resistant structural element.
5. Crack patterns and their developing system, failure mode and the sustainability leads to select the DSSRCC Beams as safer and serviceable than the RTSRCC Beams.
6. Perhaps DSSRCC Beams are very little costlier than RTSRCC Beams, because of the welding process(approximately 10% on fabrication cost or 2% on steel cost),the construction errors like insufficient cover, jig-jag positioning of reinforcement, uneven spacing of bars and ties, loose binds can be completely eliminated.