An Experimental Study on Strengthening of RCC Beam using Waste PVC Flex Banner and Steel Wire Mesh

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Abstract – *The results of experimental testing of RCC beams strengthened using Waste Flex Banner and Steel Wire Mesh are presented in this paper. Total 12 number of RCC Beam specimen are prepared and tested under flexure. Commonly available steel wire mesh - Chicken Mesh and Weld Mesh are bonded on the surfaces of different beams using carpet/tile adhesive. Beams other than control beams are finally wrapped and pasted with Waste PVC Flex Banners. Load carrying capacity of different beam specimen are compared. It is found that the load carrying capacity increases by 6% by wrapping and pasting PVC flex banner, by 21% when chicken mesh and flex banner are provided on beam and by 147% when weld mesh and flex banner are provided on beam. It is shown that by using commonly available material and simple techniques the load carrying capacity of RCC beams can be significantly increased in an economical manner. Waste flex banner wrapping adds to the durability of the RCC beams besides helping in plastic waste management.*

Index Terms – Strengthening, Reinforced Concrete Beam, Flex Banner, Chicken Mesh, Weld Mesh, Plastic Waste Management, flexure test.

1.Introduction

Strengthening of Reinforced Concrete Beams is required for several reasons. It may be required to compensate deterioration of existing RCC beam due to weathering action or due to lack of maintenance, to overcome shortcomings in design, to accommodate increase in loading etc. Several studies have been made in the past to strengthen beams using ferrocement, steel wire mesh with cement mortar, fixing fiber reinforced polymer sheets around beams like aramid fiber reinforced polymer (AFRP), carbon fiber reinforced polymer (CFRP), and glass fiber reinforced polymer (GFRP) sheets. The suggested methods have got limited acceptance in commercial applications due to economy, availability, debonding and other shortcomings.

In the present study commonly available material like steel chicken mesh, steel weld mesh, tile adhesive and rubber-based carpet adhesive are used. These materials are readily available in any hardware shop at much cheaper rates as compared to the other alternatives. Additionally, this study makes use of waste PVC flex banners for final wrapping of beams. It not only provides a little bit of more strength but also protection against ingress of water and harmful atmospheric gases enhancing the durability.

In the present research flexure strength tests are conducted on 12 RCC beams made of M20 grade nominal mix concrete and nominal steel reinforcement bars. Flexure tests are conducted after 28 days of curing of RCC beams. Tile adhesive is found to be very effective for bonding steel weld mesh and RCC beams. Rubber based carpet adhesive is found effective in bonding the flex banner over the surface of RCC beams. Flexure strength tests are conducted on the beams on Universal Testing Machine (UTM). Results of flexure tests are compared with refence to control RCC beams which are not provided with steel wire mesh or flex banner. It is found that the beams with flex, with a combination of flex & chicken mesh and with a combination of flex & weld mesh gave better results and show improvement in flexure strength in increasing order.

2. Literature Review

Numerous studies have been conducted by the researchers in the field of increasing the flexural strength of RC beams. Many researchers studied the increase in flexural strength by fixing FRP sheets on external surface of RC beams. Many used ferrocement or steel wire mesh bonded over RC beam using cement mortar or polymer modified mortar. Following are reviews of some of some of these research studies.

Ahmad E. and Sobuz H. (1) conducted an experimental study in which they analyzed the flexure strength of reinforced concrete beams strengthened by CFRP sheets at different degrees. Total 6 RC beams of effective span of 1900 mm bonded externally with CFRP sheets were used for testing purpose. Epoxy Adhesive was used in the experimental work to fix the CFRP sheets on RC beams. They found that no delamination of CFRP sheets happened during testing procedure and flexural strength, ultimate load and yield load increased with increase in CFRP sheets layers. At the time of failure, no layers came apart and RC beam reinforced by CFRP sheets failed apart in a sudden way.

Esfahani et al. (2) studied the effect of use of CFRP sheets on RCC beams in an experiment study. Total 12 RCC beams of size 150 mm x 200 mm x 2000 mm reinforced by CFRP sheets in different lengths, width and number were tested. It was found that the beams which were strengthened by CFRP sheets resulted in higher flexural strength and stiffness in comparison to plain RCC beams. They also found that for small length reinforcement of CFRP sheets in increasing flexure strength of concrete, provision given in ISIS Canada and ACI code 440 were overestimated.

Aboutaha et al. (3) conducted an experimental study using CFRP sheets as a strengthening material to increase the flexural strength of the reinforced beams. They conducted tests on 9 RC beams reinforced by CFRP sheets. They provided anchors in strengthening system which helped in stopping delamination of the CFRP sheets. The results of experiments showed that there was improvement in the flexural strength of the RC beams by strengthening with CFRP sheets and that the anchors helped in stopping delamination of sheets.

Leung [4] studied the effect of providing Glass Fiber Reinforced polymer (GFRP) plates on flexural strength and shear behavior of RCC beam. In their experimental work, they found in flexure test result that GFRP helped in increasing the flexure strength and stiffness of the RC beams. They also found that GFRP plates also helped in reducing the deflection when GFRP plates were bonded on sides and bottom on RC beams.

Hawileh et al. (5) conducted an experimental study in which their focus was to find out the effect of CFRP-GFRP sheets on the flexural strength of the RCC beams. They tested 5 RC beams under 4 points loading system. Out of the 5 beams, 1st was unstrengthen beam, 2nd was reinforced by CFRP plates, 3rd beam was reinforced by GFRP plates, 4th beam was reinforced by GFRP & CFRP sheets and 5th and last beam were reinforced by 2 layers of GFRP and 1 layer of the CFRP plates. It was found that there was an increase of 30% to 98% in strength of the beams. It was also observed that the ductility at failure loads of the beams strengthened with glass and hybrid sheets is higher than that with a single carbon sheet.

Ganapathy and Sakthieswaran (6) studied the effect of fiber ferrocement laminates on the flexure strength of RCC beams. They used wire meshes with fiber ferrocement laminates and mortar. They tested total 6 numbers of RCC beams using 2-point loading system. Five out of six RCC beams got cracks when 70% of ultimate load was applied while overloading on it. The last beam was used as control beam. They used polymer fiber ferrocement laminates on the cracked beams with 2 different Volume fractions of (7.41% & 4.94%). On comparing control beam and cracked beam strengthened with Ferrocement laminate, they found that the RCC beams which were reinforced by the fiber ferrocement laminates achieved more flexure strength in comparison to the control beam.

Ezz-Eldeen et. al (7) conducted an experimental study in which they used steel wire mesh and longitudinal steel angle for strengthening and retrofitting of RC beams completely damaged under two-point loading. In the strengthening process, firstly the cracks were filled with mortar and thereafter the damaged RC beams were reinforced with external galvanized steel wire mesh in U-jacket form. They found that using 2 and 3 steel wire mesh plies fixed with 2, 4 and 6 vertical clamps resulted in an increased beam carrying capacity from 26.59% to 49.55%. Also, increasing the angle size used at the bottom corners of beams inside the wire mesh increased the beam carrying capacity up to 72.51% and 172.51%.

Malathy et al. (8) studied the effect of the galvanized square shaped ferrocement laminates and partial replacement of fine aggregate by steel slag on the flexure behavior of the RCC beam. The percentage of the use of ferrocement laminates was 1.88% and 2.35%, while replacement of fine aggregate by steel slag was 0% and 30%. Epoxy resin was used as bonding adhesive. Total 5 beams were tested under two points loading for flexure strength, out of that four beams were reinforced by laminates and rest 1 beam was control beam. They found that the beams achieved maximum strength when 30% of steel slag used as replacement of fine aggregate and 2.35% volume fraction of ferrocement laminate reinforcement was used.

Mishra and Jain [9] conducted an experimental study on improving durability of concrete using PVC waste flex banner. They conducted water absorption test on concrete cubes with and without wrapping of flex banner to find out usefulness of waste flex banners in reducing water absorption. It was found that the waste PVC flex banner can be effectively used in increasing the durability of concrete by reducing the water absorption.

3. Materials Properties

Following materials are used in this experimental work -

3.1. Cement – Cement works as binding material in concrete. In this experimental work commercially available Portland Pozzolana Cement conforming to IS 1489 Part I is used for preparing the concrete mix.

3.2 Coarse aggregate – Locally available 20 mm nominal size coarse aggregate conforming to IS: 383 is used in this experimental work.

3.3 Fine Aggregate – Locally available fine aggregate (sand) conforming to zone II as per IS: 383 is used in this work.

3.4 Water - Water that is being used in the curing and mixing process should be free from any impurities according to IS: 3025. In this experiment drinking water available in the laboratory is used which is pure, fresh and free from any impurities which may affects the quality of the work.

3.5 Flex Banner – Polyvinyl Chloride (PVC) flex banner are made of Poly vinyl chloride sheets and polyester fabric. There are various types of flex available in market. In this research work flex banner is used wrapping around the concrete beam to increase its flexure strength as well as durability. Waste flex banners of 220 gsm available in the institute are utilized for this purpose.

3.6 Reinforcement Steel Bars – HYSD Steel bars of grade Fe415 are used as reinforcement in RCC beams in this experimental research work. 2 number steels bars of 10 mm diameter and 650 mm length are used in each beam as a bottom reinforcement at a clear cover of 20 mm.

3.7 Steel Chicken Mesh – Chicken Mesh is a mesh of thin steel wire. It has a honeycomb structure in which 2 steel wires are twisted for at least 4 times to form it. The impressive property of chicken mesh is that if one of its 2 wires get cut due to any reason it will not lead to the failure of whole chicken mesh. The major benefits of chicken mesh in the construction industry is that it prevents cracking and stops plaster layers to come out of the wall.

3.8 Steel Weld Mesh – Steel Weld mesh is a series of parallel longitudinal steel wires which are welded to cross steel wires by electric fusion method with proper spacing between them. In this experiment steel weld mesh is used as strengthening reinforcement and it is fixed on all the 4 sides of the beams with tile adhesive. Weld mesh with steel wires of thickness 1.35 mm and placed at 16 mm center to center both ways is used.

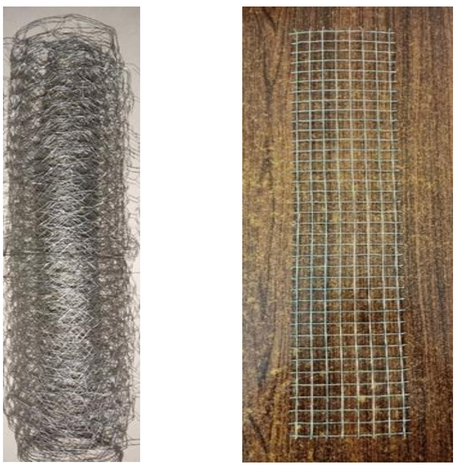

Fig. 1 Steel Chicken Mesh and Weld Mesh used in the study

3.9 Tile Adhesive – Tile adhesive is a special type of adhesive that is used in fixing the tiles at various places. It is made up of polymer modified Portland cement. It is a single component ready to use mixture which can be used after mixing specified quantity of water. It can be used to fix tiles in walls, floors, swimming pools etc. It has a good bonding and shear strength. It gets set quickly in a day or two without needing extensive curing. Its special formulation prevents shrinkage cracks. Thus, it is much better alternative to normal or polymer modified mortar. In this experiment commercially available tile adhesive (conforming to IS 15477: 2004) of Asian Paints namely SmartCare is used to fix the weld mesh on all 4 sides of the beams.

3.10 Rubber Based Carpet Adhesive – Adhesive which are rubber based whether it is natural or synthetic are known as rubber adhesive. In this experimental work locally available rubber based carpet adhesive is used for fixing PVC flex banner and chicken mesh on concrete beams.

4. Experimental Investigations

4.1 Concrete Mix – Nominal mix concrete of grade M20 is prepared using cement, fine aggregate and coarse aggregate (sand) in the proportions of 1:1-1/2:3 (1 cement: 1-1/2 fine aggregate: 3 coarse aggregate). To achieve proper workability, the water cement ratio is kept as 0.5.

4.2 Cube Test on Concrete – The strength of the concrete mix is ascertained through cube test on a compression testing machine. 3 cubes of size 150 mm x 150 mm x 150 mm are prepared from the concrete mix, cured for 28 days and tested. The results are shown in Table 1.

Table 1. Result of cube test on concrete

Specimen	Load at Failure (kN)	Comp. Strength (N/sqmm)	Average Comp. Strength (N/sqmm)
Cube 1	605	26.9	27.0
Cube 2	575	25.5	
Cube 3	645	28.7	

4.3 – Preparation of the RCC beam specimens – From the concrete mix prepared as above, 12 numbers of RCC beam specimen of size 150 mm x 150 mm x 700 mm are prepared. Nominal steel reinforcement in the form of 2 numbers of HYSD bars are provided at beam bottom at a clear cover of 20 mm in each beam. The same are cured in submerged condition in the water tank after removing from the moulds. The specimens are taken out after gaining the age of 28 days. Out of these beams, 3 bare specimens are tested for flexure load capacity as control beams. On 3 beam specimens waste PVC flex banners are wrapped and pasted using rubber-based carpet adhesive, 3 specimens are wrapped with chicken mesh and waste PVC flex banner and pasted on the beam surface using same adhesive. These specimens are air dried for 3 days before testing. On remaining 3 specimens, the weld mesh is provided on all four sides and bonded to the beam surface using tile adhesive with an average thickness of 12 mm. These specimens are cured under moist environment for 2 days and thereafter air dried for another 2 days before testing.

4.4 Flexure Test – Flexure test is conducted to find out flexure load capacities of the RCC beams. The test is conducted on the Universal Testing Machine (UTM) under center point loading, on the same lines at which the flexure test is conducted for unreinforced concrete beams (AASHTO T-177 or ASTM C293).

Fig. 2 Universal Testing Machine - test setup

3 beam specimens, on which no flex banner or steel wire mesh is fixed, are treated as control beams for comparing the results. These are named as RCC_Plain beams. Table 2 shows result of flexure test on these beams.

Table 2. Test results of RCC plain beams

Sr. No.	Specimen No.	Load at Failure (kN)	Average Failure Load (kN)
1	RCC_Plain_1	25.0	25.2
2	RCC_Plain_2	26.0	
3	RCC_Plain_3	24.5	

Fig. 3 Test on RCC plain beam

On 3 RCC beam specimens, waste PVC flex banners are wrapped and pasted. These are named as RCC_Flex beams. Table 3 shows result of flexure test on these beams.

Table 3. Test results of RCC beams with PVC flex banner

Sr. No.	Specimen No.	Load at Failure (kN)	Average Load at Failure (kN)
1	RCC_Flex_1	27.5	26.8
2	RCC_Flex_2	26.5	
3	RCC_Flex_3	26.5	

On 3 RCC beam specimens, chicken mesh and waste PVC flex banners are wrapped and pasted. These are named as RCC_Flex_CM beams. Table 4 shows result of flexure test on these beams.

Table 4 Test result of RCC beam with steel chicken mesh and PVC flex banner

Sr. No.	Specimen No.	Load at Failure (kN)	Average Load at Failure (kN)
1	RCC_Flex_CM_1	30.5	30.5
2	RCC_Flex_CM_2	32.0	
3	RCC_Flex_CM_3	29.0	

On 3 RCC beam specimens, weld mesh is provided on all four sides which is bonded with tile adhesive. These beams are finally wrapped and pasted with waste PVC flex banners. These beams are named as RCC_Flex_WM

beams. Table 5 shows result of flexure test on these beams.

Table 5 Test result of RCC beams with weld mesh and PVC flex banner

Sr. No.	Specimen No.	Load at Failure (kN)	Average Load of Failure (kN)
1	RCC_Flex_WM_1	63.0	62.2
2	RCC_Flex_WM_2	61.0	
3	RCC_Flex_WM_3	62.5	

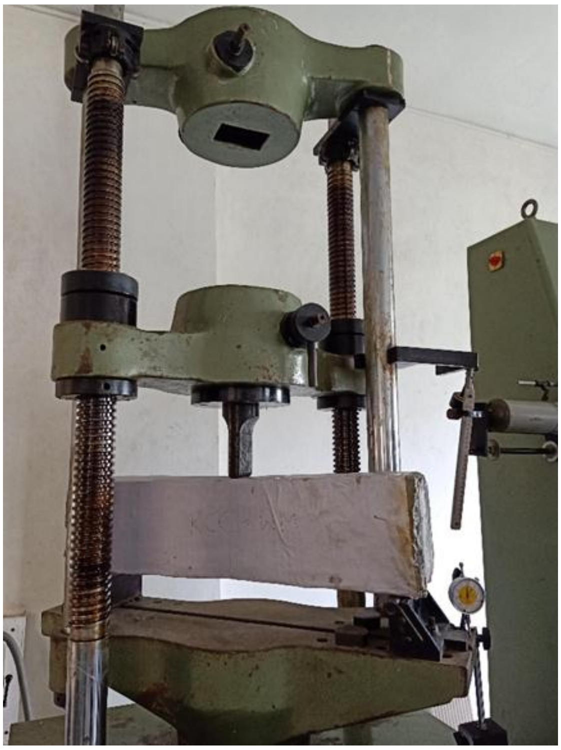

Fig. 4 Test on RCC beam with steel weld mesh and PVC flex banner

In all these tests no delamination of flex banner was observed, and the adhesive worked perfectly. The tile adhesive used to bond the weld mesh with the RCC beam also worked perfectly without any slip or delamination or failure.

5. Results and Discussions

The results of flexural strength test on the RCC beams are shown in Tables 2 to 5. These results are compiled in Table 6 to show the comparison of average load at failure under flexure test in different beam specimens and % increase in load capacity with reference to the control beams.

Table 6. Comparison of failure loads under flexure for different beams

Sr. No.	Specimen No.	Average Load at Failure (kN)	% increase in load capacity
1	RCC_Plain (Control Beams)	25.2	-
2	RCC_Flex	26.8	6.3 %
3	RCC_Flex_Chicken Mesh	30.5	21.0 %
4	RCC_Flex_Weld Mesh	62.2	146.8 %

Thus, it is found that wrapping and pasting of waste flex banner improves the load capacity of the beam marginally by 6.6%. Providing chicken mesh in addition to flex banner improves the load carrying capacity by 21%. Providing weld mesh bonded with tile adhesive around the beams and wrapping & pasting with flex banner increases the load carrying capacity substantially by 146.8%. Fig. 5 depicts the comparative load capacities of different beams under flexure.

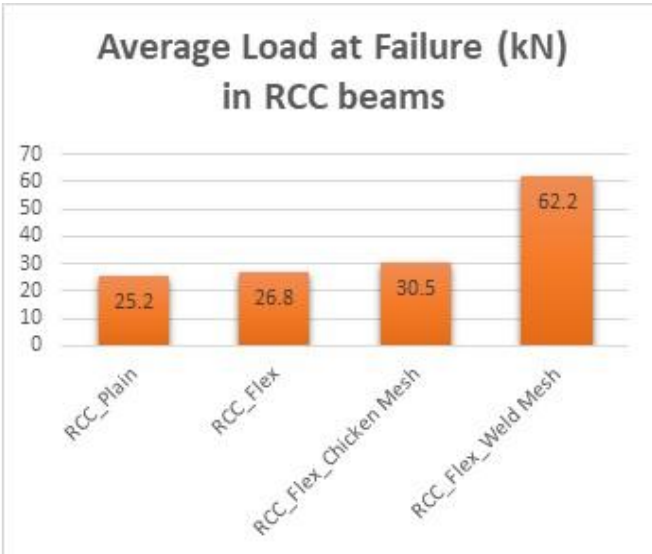

Fig.5 Comparative load capacities of different beams

Wrapping of PVC waste flex banner also improves durability of concrete by reducing water absorption [6].

However, it is observed during the experiments that use of PVC flex banner hides the development and propagation of cracks during failure. As these cracks act as warning signs, flex wrapping may be done leaving cracking zones or transparent flex may be applied in that area.

6. Conclusions

Following are the important findings from this experimental research investigation.

1. Wrapping and pasting of PVC flex banner on RCC beams improves the load carrying capacity marginally.
2. Wrapping and pasting of steel chicken mesh and PVC flex banner improves the load carrying capacity of RCC beams slightly.
3. Providing steel weld mesh on the external faces of RCC beams using tile adhesive increases load carrying capacity of beams significantly.
4. Strengthening of RCC beams can be carried out using commonly available material like PVC flex banner, chicken mesh, weld mesh, rubber-based carpet adhesive and tile adhesive. As all these materials are quite cheap as compared to other alternatives available, the strengthening using these materials can be carried out economically.
5. Rubber based carpet adhesive and tile adhesive are found to be quite effective without causing any slip, delamination or failure during failure.

   Further, wrapping and pasting of PVC flex banner around the concrete beams improves durability of the beam by reducing water absorption [6]. Also, it acts as a shield against adverse atmospheric exposure. In view of the same it can be recommended that;

1. For protecting undeteriorated RCC beams exposed to adverse atmosphere, it may be wrapped and pasted with PVC flex banner.
2. For strengthening and protecting RCC beams having nonstructural cracks it may be wrapped and pasted with chicken mesh and PVC flex banner.
3. For strengthening and protecting deteriorated or overloaded beam it may be provided with weld mesh bonded with tile adhesive on its surface and finally wrapped and pasted with PVC flex banner.

To maintain visibility of warning cracks during failure, those areas may either be kept unwrapped or wrapped with transparent flex.

In some beams all sides may not be exposed due to monolithic casting with slab. In such beams exposed sides may be covered in above manner. Extent of increase in strength in such cases may be found in further study. Similarly, optimum size of weld mesh may be found in further study.

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