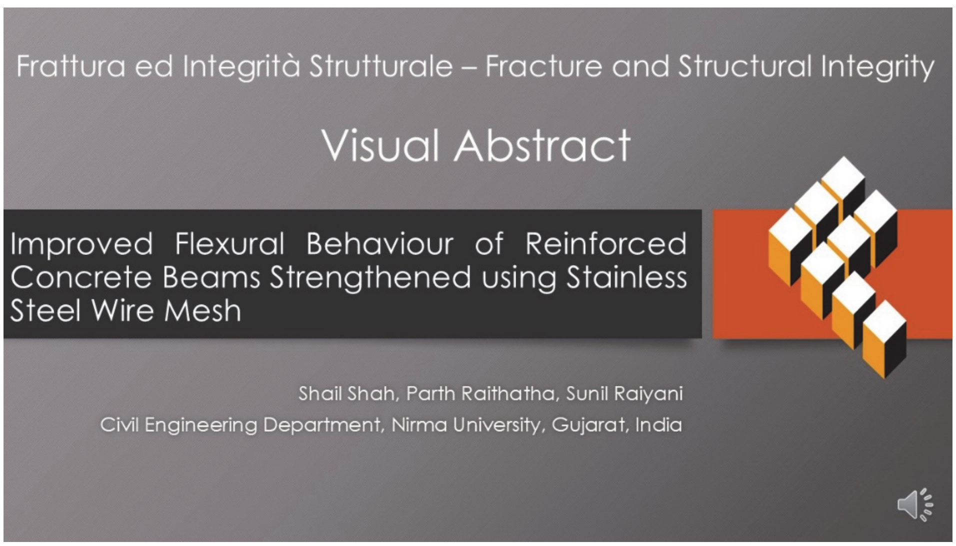
Improved flexural behaviour of reinforced concrete beam strengthened using stainless steel wire mesh

Shail Shah, Parth Raithatha, Sunil D. Raiyani
Nirma University, India
20BCL102@nirmauni.ac.in, 20BCL095@nirmauni.ac.in, sunil.raiyani@nirmauni.ac.in



OPEN ACCESS

Citation: Shah S., Raithatha, P., Raiyani, S., Improved flexural behaviour of reinforced concrete beam strengthened using stainless steel wire mesh, Fracture and Structural Integrity, 72 (2025) 34-45.

Received: 11.09.2024
Accepted: 13.12.2024
Published: 09.01.2025
Issue: 04.2025

KEYWORDS. Stainless Steel Wire Mesh, Reinforced Concrete, Flexural Strength, Shear Strength.

INTRODUCTION

Reinforced concrete (RC) structures are the utmost fundamental to the modern infrastructure landscape, owing to their versatility and ability to withstand heavy loads. However, as these structures age or as the operational demands increase, they may exhibit signs of distress or deterioration in strength, compromising their structural integrity and safety. To address such challenges and to ensure the longevity of these critical assets, the implementation of effective and innovative strengthening techniques has become essential. The strengthening of RC structural elements plays a crucial role in the rehabilitation and enhancement of the existing structures. Conventional strengthening methods like jacketing, on the other hand, which were proven effective, often came with practical limitations and economic constraints. Due to the limitations of the conventional strengthening methods, researchers began to explore alternatives. Saadatmanesh and Ehsani [1] conducted experimental studies on Glass Fiber Reinforced Polymer (GFRP) for the strengthening of RC beams and concluded that there was an increase in shear and flexural strength of the RC beams. Further, Spadea et al. [2] conducted research on Carbon Fiber Reinforced Polymer (CFRP) in a similar manner and observed that there was an increase in the capacity of the beams. Fiber-reinforced polymers (FRP) have primary advantages such as being light in weight, ease of application, corrosion resistance and minimal effects on structural aesthetics, which are shown by Babaeidarabad et al. [3].

FRP has been widely used for strengthening of RC elements, but it was found to be less effective in fire, and debonding was observed. Though FRP has higher tensile strength, full strength cannot be utilized. Buyukozturk and Hearing [4] carried out experiments for various strengthening techniques of FRP for beams and reviewed various failure modes of the beams, including brittle behaviour, as well as debonding of the FRP used. Researchers started exploring new alternatives due to the disadvantages of the FRP materials used. Zhao and Zhang [5] conducted research on evaluating different wrapping patterns for strengthening of RC beams by using a combination of CFRP sheets and inorganic matrix as bonding material. The mechanical and durability properties of the Fiber-Reinforced Cementitious Matrix system (FRCM) have been investigated by Arboleda [6] and it was found to be suitable for strengthening. However, there are few cases where debonding and premature failure of FRP was observed. Therefore, Qeshta et al. [7, 8] have conducted an experimental study on flexural strengthening of RC beams with wire mesh epoxy composite having one to five layers of the wire mesh and compared the results to CFRP strengthening technique and found better results in terms of flexural strength and ductility. Steel wire mesh with polymeric mortar for strengthening of reinforced concrete T-beams has been tested by Xing et al. [9] and it was found that there was an enhancement in the strength of the wrapped beams compared to the control beams. The use of meshes to reduce the cover spalling of high-strength concrete columns has been investigated by Hadi and Zhao [10] and the results showed that the specimens with galvanized steel wire mesh had the highest strength gain compared to other mesh materials. The flexural and shear behaviour of stainless steel wire mesh (SSWM) strengthened beam combined with polymeric mortar was explored by Yao et al. [11] and Liu et al. [12] and it was found that there was an increase in flexural and shear strength compared to the unstrengthened beam. Raiyani et al. [13, 14, 15] explored the tensile and bond strength of SSWM to characterize the material and found that SSWM 40×32 with SS304 was good for strengthening materials. They have also explored that SSWM has better ductility, stiffness, better bond behaviour, and provides adequate strength. SSWM has non-linear stress-strain behaviour which gives a warning before failure, contrary to that of CFRP/GFRP. Different wrapping patterns of SSWM to strengthen the RC beams were explored by Raiyani and Patel [16]. SSWM is chosen as a strengthening material as well as full wrapping and strip wrapping configurations are adopted to strengthen the RC beams for the present study because SSWM has better bond behaviour with concrete, lower cost, and better fire and corrosion resistance in comparison to hybrid composites or other FRP composite.
The paper presents an experimental study on the application of SSWM as a viable solution for strengthening RC rectangular beams. The SSWM material used is new compared to the widely used strengthening materials and various wrapping patterns are considered for the strengthening of RC beam. The experimental program involved testing eight rectangular RC beams, both before and after the application of different wrapping configurations of SSWM. Two specimens for the control beam and two specimens for each of the three wrapping patterns are cast and tested, respectively. This aided in a direct comparison of the load-deflection behaviour, failure modes, ductility, initial stiffness, and energy absorption capacity of the unstrengthened and strengthened beams.

MATERIAL PROPERTIES

Materials used for the study include concrete, reinforcement and SSWM with a combination of epoxy-resin Sikadur 30 LP.

Concrete

Concrete mixes used for casting of RC beams are as per the code of practice IS 10262:2019 [17] and data is shown in Tab. 1. The average 28-day compressive strength of 3 cubes having 10 mm maximum nominal aggregate size with water cement ratio of 0.45 of M25 concrete grade is 34.19 MPa.

Particulars	Quantity	Proportion
Cement - OPC 53 (kg/m^3)	330	1
Coarse aggregate -10 mm (kg/m^3)	1047	3.17
Fine aggregate (kg/m^3)	911	2.76
Water (kg/m^3)	154	0.468
Admixture (kg/m^3)	3.5	0.01
Water cement ratio	-	0.45

Table 1: Concrete mix proportion for preparing RC beam specimens.

Steel reinforcement

High yield strength deformed (HYSD) bars are used in the present study. The grade of steel reinforcement used is Fe500. The quality of the reinforcement and tests to be performed are done as per IS 1786:2008 [18]. 10 mm diameter HYSD bars are used for longitudinal reinforcement in both compression and tension regions. 2 legged-8mm diameter bars are used for transverse reinforcement.

Stainless steel wire mesh and bonding material

Different locally available SSWMs are explored for strengthening of RC rectangular beam. Raiyani et al. [13, 14, 15] explored the tensile and bond strength of SSWM to characterize the material and found that SSWM 40×32, with a grade of SS304, is good as a strengthening material. In 40×32 mesh size, 40 denotes the amount of mesh per inch, and 32 denotes the standard wire gauge in mm. The specification of SSWM 40×32 is shown in Tab. 2. The good bond strength between the concrete surface and SSWM is observed using Sikadur 30LP [19]. Therefore, Sikadur 30 LP [20] is selected for the bonding between concrete and SSWM. Sikadur 30LP is a solvent-free, thixotropic epoxy-based adhesive. The characteristics of Sikadur 30 LP are long pot life, high-temperature resistance, hardened without shrinkage and good adhesion between SSWM and the concrete surface. The physical and mechanical properties of Sikadur 30LP are shown in Tab. 3 and Tab. 4, respectively, as supplied by the manufacturer [20].

Specification	Woven type	Mesh per inch	Standard wire gauge	Diameter of wire (mm)	Size of opening (mm)	Approximate open area %
SSWM40×32	Square	40	32	0.27	0.4	33

Table 2: Specification of SSWM provided by the manufacturer [20].

Physical Properties	
Part A (resin)	White color
Part B (hardener)	Black color
Mixed density (kg/l)	1.8+0.1 (at 23°C)
Mixed ratio (A: B)	3:1 (3 minutes mixing time)
Pot life	60 min
Shrinkage	0.04%
Coefficient of thermal expansion	2.5×10^{-5} per °C (-20°C to +40°C)

Table 3: Physical Properties of SSWM provided by the manufacturer [20].

Mechanical Properties at + 25°C		Standard Designation
Compressive strength	> 85 MPa (7 days)	EN 196
Flexural strength	> 25 MPa (7 days)	EN 196
Shear strength	> 85 MPa (7 days)	FIP 5.15
Tensile strength	15-18 MPa (7 days)	ISO 527-1:2012
Bond strength	Tensile adhesive strength > 2.5 MPa (1 day) – concrete fracture	EN 1542
Flexural modulus	10,000 MPa	ISO 527-1:2012
Poisson's ratio	0.22	ISO 527-1:2012

Table 4: Mechanical Properties of SSWM provided by the manufacturer [20].

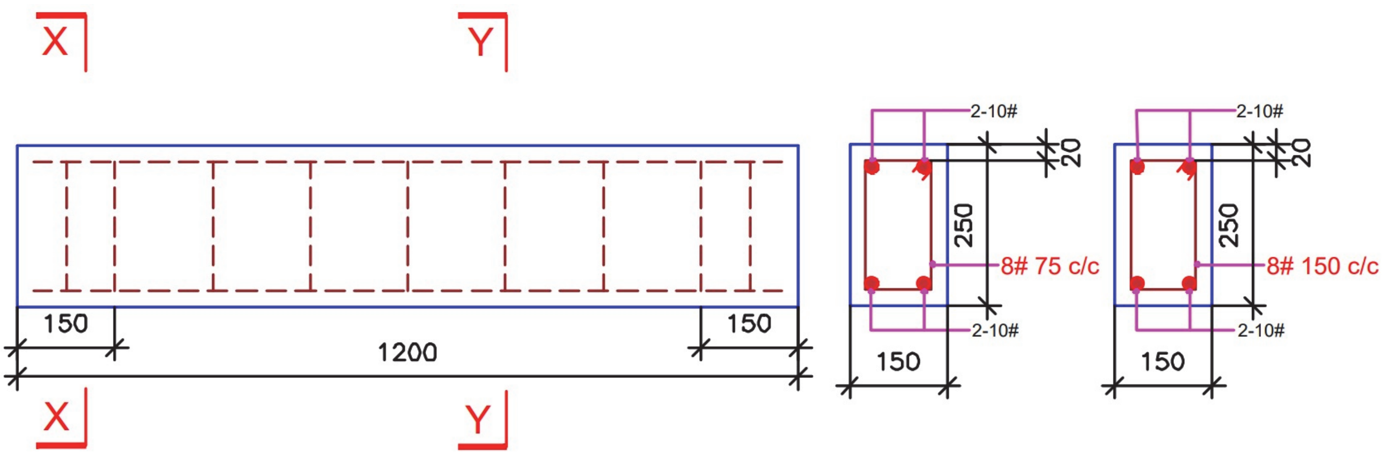
TEST BEAMS AND WRAPPING CONFIGURATIONS

Eight beams are cast using M25 concrete grade. The length, width and depth of the beam are 1200 mm, 150 mm and 250 mm, respectively. Transverse and longitudinal reinforcement are designed as per IS 456:2000 [21]. Both the tension and the compression regions of the beam are reinforced with two longitudinal bars of 10 mm diameter

(2-10#). 2-legged 8 mm diameter stirrups at a spacing of 150 mm center to center are provided. At the end regions of the beams, for the span of 150 mm, stirrups are provided at the spacing of 75 mm center to center to avoid local crushing failure. A clear cover of 20 mm to longitudinal reinforcement is provided for all the beams. Six RC beams with three wrapping configurations are used in the present study based on Raiyani and Patel [16] work. A gap of 50 mm is provided between two consecutive SSWM strips to facilitate the equal distribution of SSWM throughout the span of the beams as per the desired wrapping pattern. A single layer of wrapping is applied to the beams. Wrapping configurations for the different test specimens are shown in Fig. 1. The nomenclature for the beam is shown in Tab. 5.

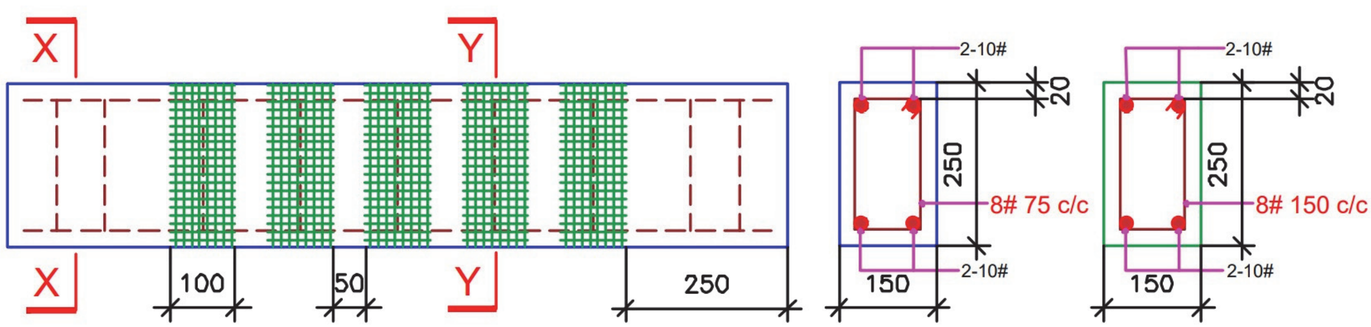
Specimen identification	Number of beam specimens prepared	Description of wrapping configuration
CB (Control Beam)	2	No SSWM wrapping
100SAS (Strips Above Stirrups)	2	100 mm wide strips of SSWM above transverse reinforcement having a gap of 50 mm between two consecutive strips
100SIS (Strips In between Stirrups)	2	100 mm wide strips of SSWM in between transverse reinforcement having a gap of 50 mm between two consecutive strips
FW (Full Wrapping)	2	SSWM wrapping covering the whole beam and leaving 150 mm from both ends

Table 5: Nomenclature of RC beams and specifications.



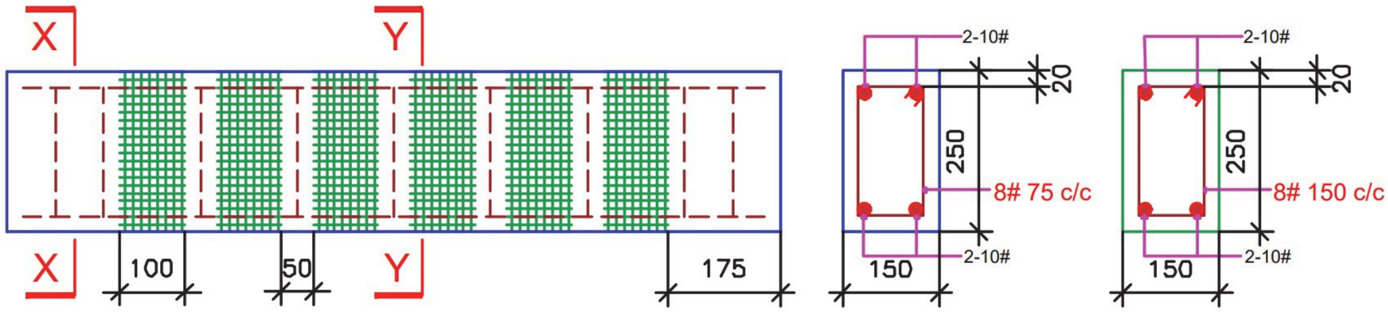
Longitudinal Section of CB | Cross Section X:X | Cross Section Y:Y

(a) CB



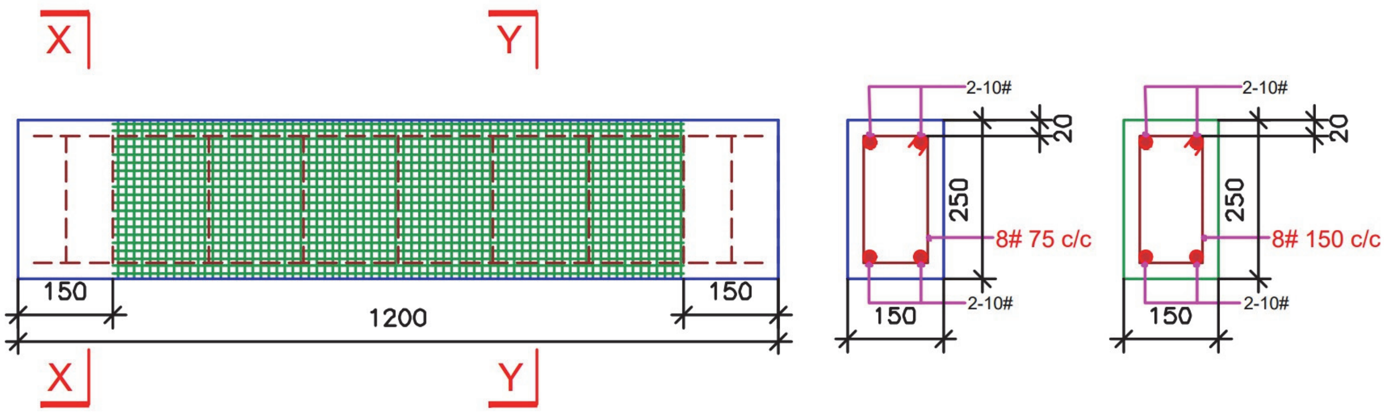
Longitudinal Section of 100SAS | Cross Section X:X | Cross Section Y:Y

(b) 100SAS



Longitudinal Section of 100SIS Cross Section X:X Cross Section Y:Y

(c) 100SIS



Longitudinal Section of FW Cross Section X:X Cross Section Y:Y

(d) FW

Figure 1: Schematic representation of different wrapping configurations of SSWM with longitudinal reinforcement detailing, (a) CB, (b) 100SAS, (c) 100SIS, (d) FW; (All dimensions are in mm.).

STRENGTHENING PROCEDURE

Concrete specimens are cured for 28 days after casting and are ground for smoothening of the surface. After grinding, dust on the surface is removed using clean water. SSWM strips of the required width are cut from the roll of SSWM. Strengthening of RC beams is carried out by externally applying strips to the surface of the beams using an epoxy resin, Sikadur 30LP, as a bonding material [20]. The resin part and hardener part of Sikadur 30LP are mixed in the proportion of 3:1 and stirred until the epoxy resin achieves uniform grey colour. The coating thickness should be sufficient for the adhesion of SSWM on concrete surfaces. It completely depends on the surface of the concrete. One layer of epoxy resin having a thickness of 1-2 mm is applied, followed by a layer of SSWM strip having a thickness of 0.27 mm. Subsequently, another layer of Sikadur 30LP is applied with 2-3 mm thickness to cover SSWM and to have a levelled surface [16]. While applying the layers, gently press SSWM composite against concrete to remove air voids.

TEST SETUP AND INSTRUMENTATION

The experimental investigation on the RC beams is carried out at the Structural Engineering Research Center of Nirma University, India. The beams are tested in the loading frame having a capacity of 250 kN, where they are placed on two simply supports at a distance of 1100 mm, as shown in Fig. 2. The markings are made for the steel rods and are placed at a center-to-center distance of 300 mm and 450 mm from the end of the beams, as shown in Fig. 3. The markings of linear variable differential transducers (LVDT) are also made simultaneously. At the neutral axis depth of the beam, clamps are glued to the beam surface, and LVDTs are connected right below the two-point loads to measure the deflection of the beam. A steel spreader beam (ISMB 150) is used to apply load evenly by the hydraulic jack through two-point loads using rollers, and above it, the load cell is attached to the hydraulic jack. The load cell and LVDTs are connected to the data acquisition system (DAQ), and further, the DAQ is connected to the laptop, as shown in Fig. 2, to acquire data from the sensors. DAQ is used to convert the deflection values of the test specimens obtained through the LVDTs into quantifiable data, which is further used for plotting the graphs of load vs deflection to understand the behaviour of the beam.

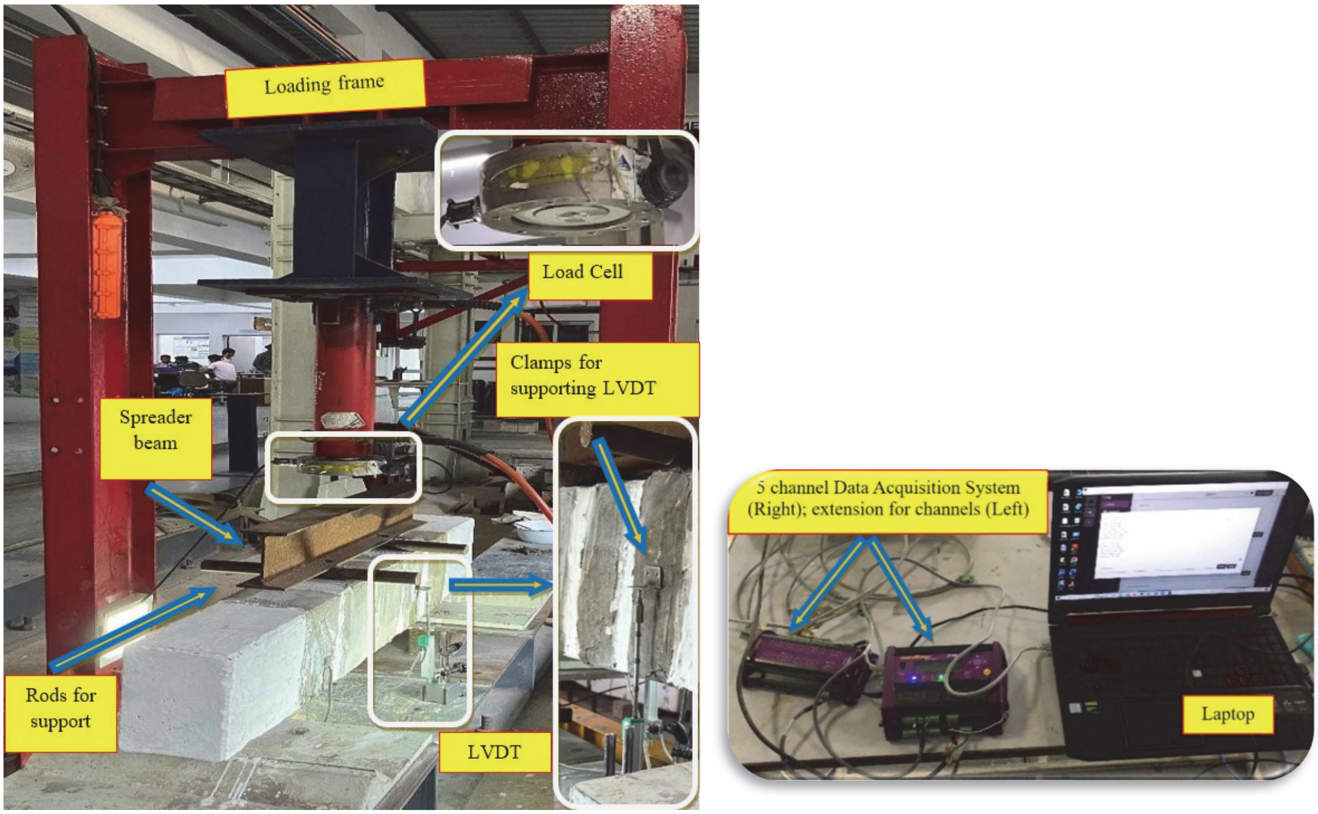


Figure 2: Test Setup for applying Flexural Load.

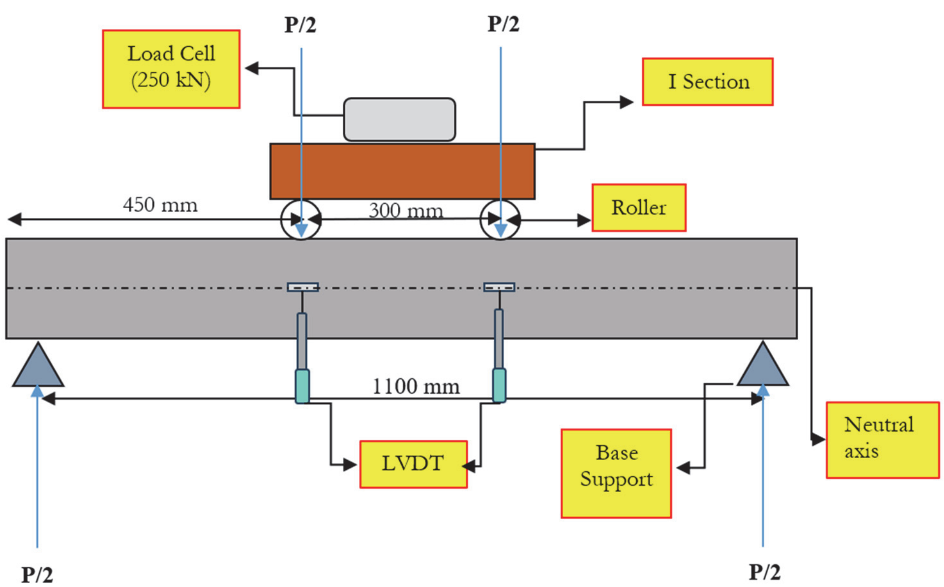


Figure 3: Longitudinal section of test setup.

RESULTS AND DISCUSSION

In the present study, load vs deflection behaviour for all the beams tested under static transverse loading conditions are measured at regular intervals of loading up to failure. Further, the load at first crack and ultimate load for all specimens, as well as corresponding deflection, are recorded. Furthermore, ductility index, initial stiffness, energy absorption ratio, failure modes and ultimate & cracking load of different wrapping configurations are compared to understand the effectiveness of different wrapping patterns.

Load-deflection behaviour

For each SSWM wrapping pattern, two beams are cast, and an average of two test specimens are considered for comparison. The load-deflection behaviour for the tested beams is shown in Fig. 4. The first crack observed in the Control Beam (CB) is at 28 kN. Initial cracks are developed due to flexural failure, which is further converted into flexural shear cracks, as shown in Fig. 5(a). The initial stiffness of the beam is observed to be slightly lower than other wrapped beams. The yielding of reinforced steel started at 80 kN with a corresponding displacement is 5 mm. Just after the yielding of reinforcement, a slight improvement in load-carrying capacity, as well as a sudden increase in deflection, is observed. Steel reinforcement yielded in cup cone failure mode. CB failed in pure flexure at 104.29 kN with a deflection of 12.39 mm.

Similarly, the first crack in Strips Above Stirrups (100SAS) is observed at 40 kN. Initial cracks are propagated due to flexural failure with cracks developing on the SSWM strip denoted by "Crack 1", as shown in Fig. 5(b). The initial stiffness of 100SAS is observed to be greater than CB. However, deflection at cracking load and ultimate load is 26% and 18% less, respectively, compared to the CB specimen. Further, cracks are developed due to shear failure on the concrete surface region between two consecutive SSWM strips denoted by "Crack 2", as shown in Fig. 5(b). The absence of steel between two strips of SSWM, containing only the concrete region, is responsible for the shear crack propagation, unlike 100SIS and FW, in which steel is concentrated through the span of the beam either through SSWM or through the stirrups, making flexural cracks dominate the beam specimen. The shear crack started at 71 kN with a corresponding deflection of 1.79 mm. The yielding of reinforced steel in 100SAS started at 119 kN with a corresponding displacement of 2.64 mm. After the ultimate load, an increase in displacement can be seen with no significant increment in load indicating that SSWM made the specimen more ductile. Finally, the specimen failed in the central region of the beam in pure flexure at 130.71 kN with a deflection of 10.10 mm with cracks propagated on the surface adjoining concrete and SSWM strip along with crushing on the end regions, as shown in Fig. 5(b). The cracking load and the ultimate load of the 100SAS specimen are 43% and 25% more, respectively, compared to the CB specimen, as shown in Tab. 6.

Furthermore, in Strips in between Stirrups (100SIS), the first crack is observed at 45 kN. Initially, the cracks are developed due to flexure failure on the concrete surface, followed by multiple cracks developed in the mid-span of the beam on the concrete surface between two consecutive SSWM strips. All the cracks are developed due to flexural failure on the concrete surface only. No crack is propagated on SSWM nor on the surface adjoining concrete and SSWM, as shown in Fig. 5(c). The initial stiffness of the beam is greater than CB, having similar stiffness as 100SAS. However, deflection at cracking load and ultimate load is 23% and 5% less, respectively, compared to the CB specimen, as shown in Tab. 6. The yielding of the reinforcement starts at the load of 124 kN with corresponding displacement at 3 mm, which is slightly higher than that of 100SAS. After yielding, an increase in ductility can be seen due to the action of SSWM. Finally, the specimen fails in pure flexure at 134.91 kN with corresponding displacement at 11.76 mm. The cracking load and the ultimate load of the 100SIS specimen are 61% and 29% more, respectively, compared to the CB specimen, as shown in Tab. 6.

Lastly, Full Wrapping (FW) specimens failed in one single crack due to pure flexure at the center of the beam with no crushing at support, as shown in Fig. 5(d). Comparing the load-displacement behaviour of FW with SAS and SIS, it is found that continuous wrapping is more effective in enhancing the cracking load, post-cracking stiffness and ultimate load than the strip wrapping; this is due to the incessant confinement provided along the beam length. It is also noted that the spacing, location and width of SSWM strip affect the confinement of concrete and post-cracking load capacity. Comparing SAS and SIS beams with wrapping configurations based on the location of the transverse reinforcement while keeping other parameters such as width and spacing constant, the configuration SIS improved the post-cracking stiffness and strength more effectively than SAS. The better performance of SIS is due to the confinement of concrete due to SSWM in between the transverse reinforcement of the beam. SSWM has steel wires in both directions, which helps to confine concrete through circumferential wires and reinforce concrete through longitudinal wires.

The initial stiffness of FW is much higher compared to CB, 100SAS and 100SIS specimens. It may be due to the FW wrapping configuration making the test specimen stiffer compared to the other wrapping patterns. FW specimen exhibits a lesser displacement compared to the other specimen at crack and ultimate load, indicating greater stiffness. This could be attributed to the presence of continuous external reinforcement, which aids in improving stiffness. However, deflection at cracking load and ultimate load is 94% and 37% less, respectively, compared to the CB specimen, as shown in Tab. 6. The displacement increases without significant improvement in load due to the redistribution of forces from the concrete to reinforcement after initial cracking. Subsequently, prior to reaching the ultimate load, load-displacement behaviour becomes non-linear, accompanied by a reduction in stiffness. In the post-cracking stage, SSWM-strengthened RC beams demonstrate a ductile response, owing to the active presence of internal reinforcement and external SSWM wrapping. Along with having more initial stiffness, the ductility also improves compared to the control beam specimen. The high initial stiffness is responsible for lower deflection at the ultimate load compared to other wrapping patterns. Initially, a single crack started to propagate at 54.3 kN from the bottom region of the FW beam surface. Other initial cracks are not visible due to the continuous wrapping covered throughout the beam, unlike other test specimens. The yielding of reinforcement starts taking place at 148 kN with the corresponding displacement at 0.64 mm. Finally, FW fails in pure flexure at 166.9 kN with a corresponding displacement at 7.83 mm. The action of SSWM can be seen in the initial stiffness of the strengthened beams compared to CB with an increase in load in the pre-cracking phase of the specimen. The cracking load and the ultimate load of the FW specimen are 94% and 60% more, respectively, compared to the CB specimen, as shown in Tab. 6.

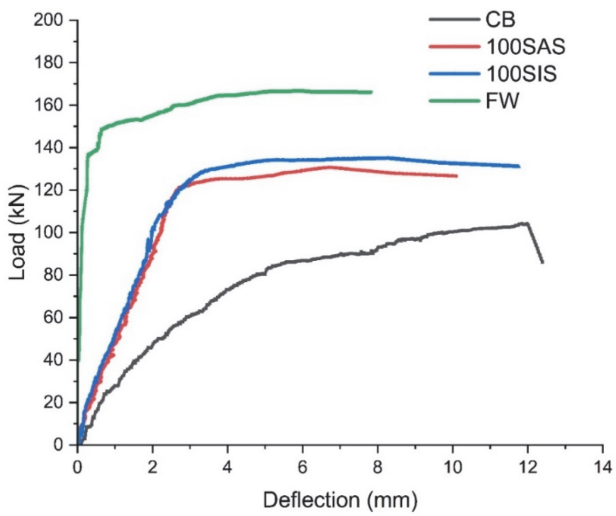
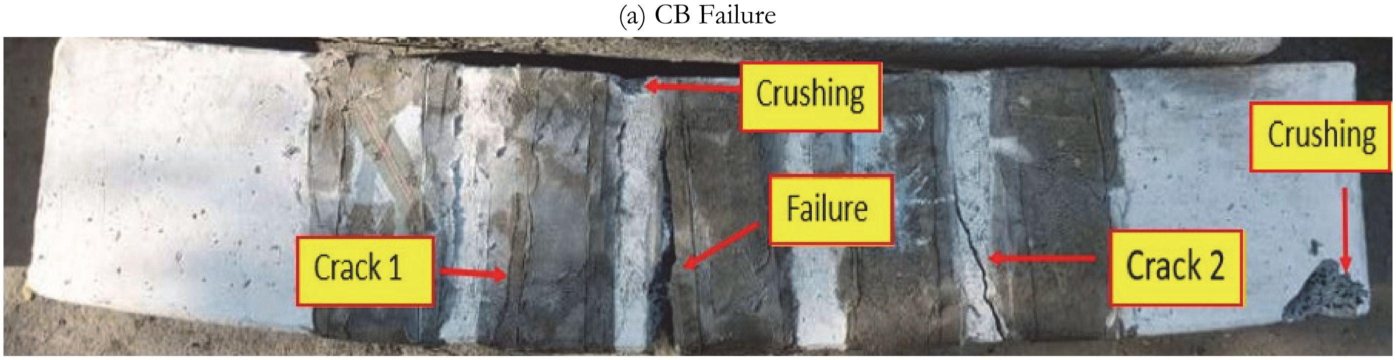
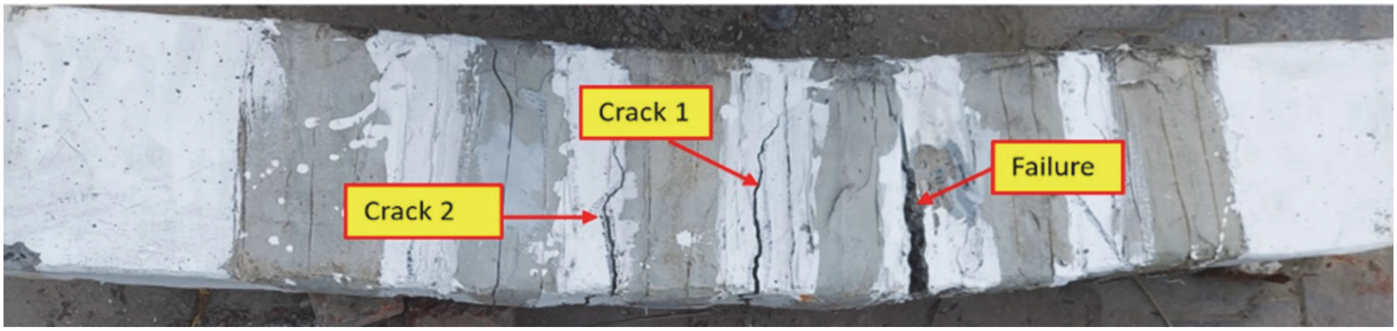


Figure 4: Load vs Deflection behaviour of RC Beams- Experimental Results.

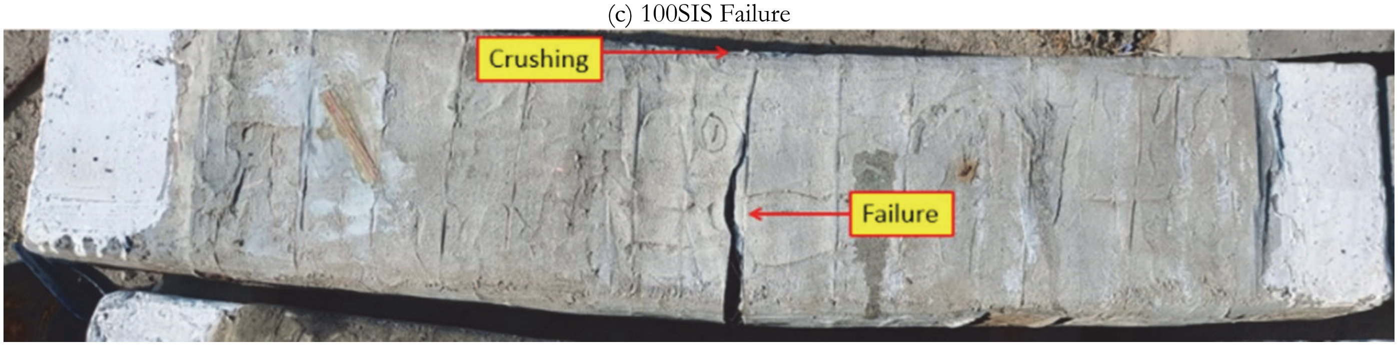
(a) CB Failure



(b) 100SAS Failure



(c) 100SIS Failure



(d) FW Failure

Figure 5: Failure Mode of Experimental Test Specimens: (a) CB, (b) 100SAS, (c) 100SIS, (d) FW.

Initial stiffness, ductility index and energy absorption ratio

The initial stiffness (k) of beams in the elastic phase is calculated as the ratio of cracking load to the cracking deflection as per Raoof et al. [22], which is presented in Tab. 6. From the values of initial stiffness, it is observed that SSWM strengthening enhances the initial stiffness of RC beam specimens. The stiffness of the RC beam with 100SAS and 100SIS wrapping configurations are 94.33% and 107.67% higher as compared to the control beam, respectively. The initial stiffness of the RC beam strengthened with the full wrapping configuration of SSWM shows superior performance as compared to all other beams, being 36 times stiffer than the control beam.

Rectangular Beam	First Crack				Ultimate				Ductility Index	Initial Stiffness
	P_{cr} kN	$P_{cr}/(P_{cr})_{CB}$	Δ_{cr} mm	$\Delta_{cr}/(\Delta cr)_{CB}$	P_u kN	$P_u/(P_u)_{CB}$	Δ_u Mm	$\Delta_u/(\Delta_u)_{CB}$	$\mu=\Delta_u/\Delta_y$	$k=P_{cr}/\Delta_{cr}$
CB	28	1	1.10	1	104.29	1	12.39	1	2.48	25.57
100SAS	40	1.43	0.81	0.74	130.71	1.25	10.10	0.82	3.82	49.69
100SIS	45	1.61	0.85	0.77	134.91	1.29	11.76	0.95	3.92	53.10
FW	54.3	1.94	0.06	0.05	166.90	1.60	7.83	0.63	12.23	920.34

Table 6: Summary of Experimental Test Results.

The ability of a structural member to withstand load without experiencing further distortion after the occurrence of the maximum load stage is often referred to as the ductility index [23]. The ductility index (μ) is used to understand the plastic deformation capacity of reinforced concrete beams. In the present study, the method proposed by Poongodi et al. [23] is used to calculate the ductility index of the beams given in Eqn. 1, and the results are shown in Tab. 6.

$$\mu = \frac{\Delta_u}{\Delta_y} \tag{1}$$

The ductility index in 100SAS and 100SIS is almost similar because the cracks develop on concrete surfaces due to the same amount of exposed concrete areas. 100SIS shows a slightly higher ductility index due to the transverse confinement of SSWM in between the stirrups, making the specimen consistent with equal proportionate of steel throughout the length of the beam, delaying the cracking on the surface of the beam. After the yielding of reinforcement and SSWM, FW shows more ductility which indicates that SSWM enhanced deformable capacity. Even after reaching the ultimate load, the ability to deform continues as both SSWM and reinforcement bars contribute to resisting flexural and shear force developed within the specimen.

The energy absorption capacity of beam specimens is calculated from the area under the load-deflection curve. The energy required by the pre-cracking stage is known as the energy absorption capacity for the elastic region. After cracking in the post-cracking stage, the stiffness of the specimen is reduced, and the ductility is increased. More energy is required to cause damage in this region, which is called post-cracking energy absorption, as per the method suggested by Hosen et al. [24]. A comparison of energy absorption for all the reinforced concrete beam specimens is given in Fig. 6.

The total energy absorption of 100SIS, 100SAS and FW is higher than CB, as shown in Fig. 6. After the pre-cracking stage and during the post-cracking stage, steel reinforcement and SSWM are in action for bearing the load imposed on the beam. The enhancement in energy absorption by 100SAS, 100SIS and FW compared to the control beam represents the contribution of different wrapping configurations of SSWM in resisting the flexural load. From Fig. 6, it can be observed that there is an increase in total energy of 17.01% for 100SAS, 45.32% for 100SIS and 30.64% for FW compared to the total energy of the control beam. In the 100SAS wrapping configuration, the concrete surface is not completely confined with steel reinforcement or SSWM along the length of the beam, and some areas are unstrengthened between two strips. This makes steel reinforcement concentrated on specific regions throughout the beam, resulting in less ductility compared to the 100SIS wrapping configuration in which the specimen is uniform with SSWM and steel reinforcement throughout the length of the beam. 100SAS wrapping configuration shows less energy absorption before cracking compared to 100SIS. It is observed due to the early stage of cracking in the unstrengthened area between the two stirrups. Post-cracking energy absorption is more in 100SIS, and FW compared to 100SAS due to more amount of SSWM used.

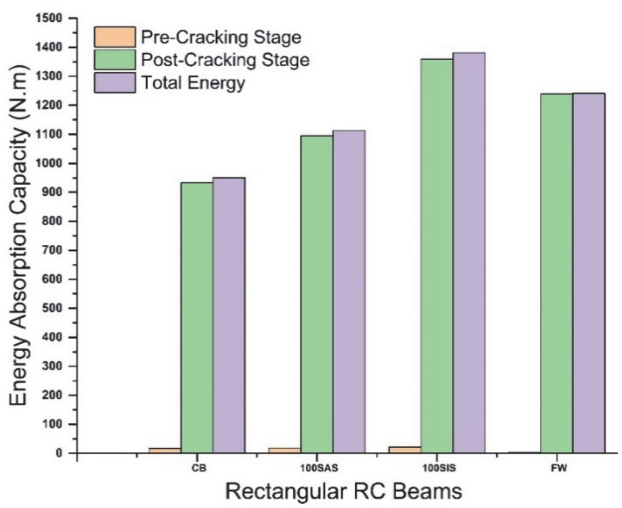


Figure 6: Comparison of energy absorption of reinforced concrete beam specimens.

After cracking, 100SIS absorbs more energy compared to the FW specimen, as shown in Fig. 6. This indicates that the ultimate load and post-peak deformable capacity are enhanced by providing SSWM strips. Even after reaching the ultimate load, the ability to deform continues as both SSWM and reinforcement bars contribute to resisting flexural and shear force developed within the specimen. While comparing the energy absorption capacity of FW with 100SIS, it is observed that strip wrapping is more effective in enhancing post cracking stage. Achieving full adhesion of SSWM on the large concrete surface area is difficult in the case of FW, which leads to a reduction in SSWM effectiveness.

CONCLUSION

The present study demonstrated an experimental investigation of SSWM-strengthened RC beams under transverse load. The study examines the influence of continuity of SSWM wrapping along the beam length and configuration of SSWM wrapping on load-deflection response and mode of failure. Additionally, the contribution of the SSWM strengthening system to flexural strength is evaluated through the ductility index, initial stiffness, and energy absorption capacity of tested specimens. Based on the study, the following conclusions are drawn:

1) In the case of vertical strip configuration of SSWM wrapping, load-deflection behaviour is improved when the vertical strip is provided in between the stirrups rather than providing a vertical strip at the location of stirrups. 100SIS resists 12.5% more load compared to the 100SAS specimen. When SSWM strips are provided between the stirrups, more volume of concrete is confined due to SSWM and steel stirrups. As a result, the flexural resistance of the specimen is increased.
2) Concrete crushing governs the failure of the unstrengthened control specimen, whereas rupture of SSWM followed by concrete crushing, preceded by longitudinal reinforcement yielding with cup and cone failure, governs the failure of SSWM strengthened RC beam specimens.
3) Flexural failure of fully wrapped beam occurred by tearing of SSWM wrapping, whereas in 100SAS and 100SIS SSWM wrapping, cracks are formed in a concrete surface before tearing of SSWM. No debonding of SSWM from the concrete surface is observed, indicating full utilization of SSWM strength.
4) From the results of cracking load, ultimate load, ductility index and initial stiffness, it is demonstrated that fully wrapped SSWM strip wrapping configuration enhanced as compared to other wrapping configurations.
5) Based on the experimental results, more research is encouraged on the behaviour of SSWM under the static load and its usage as a strengthening material. Furthermore, the outcome of the present study can be employed to develop a Finite Element and analytical model for the flexural behaviour of RC beams strengthened with different wrapping configurations of SSWM.

REFERENCES

[1] Saadatmanesh, H. and Ehsani, M. R. (1991). RC Beams Strengthened with GFRP Plates. I: Experimental Study, Journal of Structural Engineering, 117, DOI: 10.1061/(asce)0733-9445(1991)117:11(3417).

[2] Spadea, G., Bencardino, F., and Swamy, R. N. (1998). Structural Behaviour of Composite RC Beams with Externally Bonded CFRP, Journal of Composites for Construction, 2, DOI: 10.1061/(asce)1090-0268(1998)2:3(132).

[3] Babaeidarabad, S., Loreto, G., and Nanni, A. (2014). Flexural Strengthening of RC Beams with an Externally Bonded Fabric-Reinforced Cementitious Matrix, Journal of Composites for Construction, 18, DOI: 10.1061/(asce)cc.1943-5614.0000473.

[4] Buyukozturk, O. and Hearing, B. (1998). Failure Behaviour of Precracked Concrete Beams Retrofitted with FRP, Journal of Composites for Construction, 2, DOI: 10.1061/(asce)1090-0268(1998)2:3(138).

[5] Toutanji, H., Zhao, L., and Zhang, Y. (2006). Flexural behaviour of reinforced concrete beams externally strengthened with CFRP sheets bonded with an inorganic matrix, Eng Struct, 28, DOI: 10.1016/j.engstruct.2005.09.011.

[6] Arboleda, D., Babaeidarabad, S., DiLaurenzio Hays, C., and Nanni, A. (2014). Durability of Fabric Reinforced Cementitious Matrix (FRCM) composites, in Proceedings of the 7th International Conference on FRP Composites in Civil Engineering, CICE, International Institute for FRP in Construction (IIFC).

[7] Qeshta, I. M. I., Shafigh, P., Jumaat, M. Z., Abdulla, A. I., Ibrahim, Z., and Alengaram, U. J. (2014). The use of wire mesh-epoxy composite for enhancing the flexural performance of concrete beams. Mater Des, pp. 250–259, DOI: 10.1016/j.matdes.2014.03.075.

[8] Qeshta, I. M. I., Shafigh, P., and Jumaat, M. Z. (2015). Flexural behaviour of RC beams strengthened with wire mesh-epoxy composite, Constr Build Mater, pp. 104–114, DOI: 10.1016/j.conbuildmat.2015.01.013.

[9] Xing, G., Wu, T., Liu, B., Huang, H., and Gu, S. (2010). Experimental investigation of reinforced concrete T-beams strengthened with steel wire mesh embedded in polymer mortar overlay, Advances in Structural Engineering, 13, DOI: 10.1260/1369-4332.13.1.69.

[10] Hadi, M. N. S. and Zhao, H. (2011). Experimental Study of High-Strength Concrete Columns Confined with Different Types of Mesh under Eccentric and Concentric Loads, Journal of Materials in Civil Engineering, 23, DOI: 10.1061/(asce)mt.1943-5533.0000234.

[11] Yao, B. S. Z.H., Yao, Q.L., Huang, S.M. (2008). Experimental study on flexural behaviour of RC beams strengthened with SMPM, The 14th World Conference on Earthquake Engineering, 14.

[12] Liu, M., Huang, H., Hou, J., and Liu, B. (2011). Experimental study on shear behaviour of RC beams strengthened with stainless steel wire mesh, in Advanced Materials Research. DOI: 10.4028/www.scientific.net/AMR.243-249.5582.

[13] Patel, P. V. and Raiyani, S. D. (2018). Shear strengthening of RC beam using stainless steel wire mesh, Proceeding in Bloomsbury India, pp. 452–457.

[14] Patel, P. V. and Raiyani, S. D. (2017). Flexural strengthening of RC beam using stainless steel wire mesh, The Institution of Engineers, India.

[15] Raiyani, S. D., Patel, P. V., and Vora, S. D. (2020). Effectiveness of stainless steel wire mesh in shear strengthening of reinforced concrete flanged beam. International Journal of Structural Engineering, 10(3), pp. 195-216, DOI: 10.1504/IJSTRUCTE.2020.108525

[16] Raiyani, S. D. and Patel, P. V. (2023). Torsional strengthening of reinforced concrete hollow beams with stainless steel wire mesh, Proceedings of the Institution of Civil Engineers - Structures and Buildings, pp. 584–600, DOI: 10.1680/jstbu.20.00126.

[17] IS 10262: 2019, Concrete Mix Proportioning- Guidelines, Bureau of Indian Standards (BIS), Second Rev.

[18] IS 1786:2008, High strength deformed steel bars and wires for concrete reinforcement, Bureau OF Indian Standards, no. Fourth revision.

[19] Kumar, V. and Patel, P. V. (2016). Strengthening of axially loaded circular concrete columns using stainless steel wire mesh (SSWM) – Experimental investigations, Constr Build Mater, pp. 186–198, DOI: 10.1016/j.conbuildmat.2016.06.109.

[20] Sikadur 30 LP, Product Data Sheet. Adhesive for Bonding Reinforcement, version GCC, Edition 10/09/2016. Accessed: Sep. 11, 2024. [Online]. Available: https://gcc.sika.com

[21] IS 456:2000, Plain Concrete and Reinforced Concrete - Code of Practice.

[22] Raoof, S. M., Koutas, L. N., and Bournas, D. A. (2017). Textile-reinforced mortar (TRM) versus fibre-reinforced polymers (FRP) in flexural strengthening of RC beams, Constr Build Mater, pp. 279–291, DOI: 10.1016/j.conbuildmat.2017.05.023.

[23] Poongodi, K., Murthi, P., and Gobinath, R. (2020). Evaluation of ductility index enhancement level of banana fibre reinforced lightweight self-compacting concrete beam, in Materials Today: Proceedings. DOI: 10.1016/j.matpr.2020.06.397.

[24] Hosen, M. A., Jumaat, M. Z., Islam, A. B. M. S., Obaydullah, M., Darain, K. M., and Huda, M. N. (2016). Investigation on energy absorption capacity of reinforced concrete beams by the near-surface mounted technique using ductile materials, Sci Adv Mater, 8, DOI: 10.1166/sam.2016.2757.