Visual Abstract

Experimental studies to evaluate tensile and bond strength of Stainless-Steel Wire Mesh (SSWM)

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ABSTRACT. Structural strengthening is vital to improve the load-carrying capacity of partially or severely damaged Reinforced Concrete (RC) elements. Fiber Reinforced Polymers (FRPs) are widely used for strengthening purposes. In this study, use of Stainless-Steel Wire Mesh (SSWM) is explored, as FRPs are having limitations like high cost, less fire resistance, and brittle behavior. The experimental studies are conducted to evaluate the mechanical properties of the SSWM, to explore its feasibility as a strengthening material. Three different variants of SSWM i.e., 30×32, 40×32 and 50×34 are considered for the study. SSWM used in present study is a woven mesh made from stainless-steel wires manufactured in India. Important mechanical properties such as tensile strength and bond strength with concrete surface is experimentally evaluated in this study. Response of test specimens are evaluated with respect to ultimate load carrying capacity, corresponding deformations, rupture strain, and failure pattern. SSWM exhibits a tensile strength of 489.134-658.375 MPa which is comparable to tensile strength of various types of fibers used for strengthening. Based on experimental studies, it is found that SSWM 40×32 performs better in different aspects, so it can be a good alternative for strengthening of RC elements compared to other FRP materials.

KEYWORDS. Stainless-steel wire mesh, Mechanical properties, Ductile behavior, Epoxy adhesive, Bond strength.

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INTRODUCTION

Due to increased research on their applications, the use of composites made from Fiber Reinforced Polymers (FRPs) has become more prevalent in various industries. In many sectors like water supply, sewage disposal, commercial buildings, and industrial structures, FRPs are used. In the field of structural engineering, FRP is widely employed for strengthening purposes [1,2]. Structural strengthening involves improving the load-carrying capacity of various elements in terms of their ability to withstand axial force, shear force, bending moment, and torsional moment. The requirement for structural strengthening is commonly driven by excessive loading, improper seismic design, deterioration due to environmental conditions, change in use, or structural deficiencies caused during design and/or construction errors. Many factors are contributing to the reduction of capacity, such as excessive deterioration with age, moderate structural damage during earthquake or fire, change in code requirements, increase in load due to change in usage, low concrete strength, and misplaced reinforcement due to faulty construction, etc. In such cases, strengthening a structure can effectively enhance its ability to carry loads, enabling it to be safely used again. Therefore, the strengthening of structures and/or structural elements have been widely practiced during the last couple of decades across the globe.

FRPs consist of plastic resin and a polymer matrix of fibers. Fiber can be carbon, glass, basalt, textile, and steel. FRPs offer high-end performance at a fraction of weight. The other advantages of FRPs are easy maintenance, waterproof, recyclable, long service life, low maintenance, and durability [3]. However, due to certain limitations of FRPs like high cost, less fire resistance, and brittle behaviour, the use of the SSWM is explored as an alternative strengthening material [4]. The SSWM has advantages like low cost, high ductility, light weight, local availability etc. as compared to other FRPs. Tab. 1 shows the comparison of properties of the various types of fibers used for structural strengthening. It is observed that the strength of the stainless-steel wire mesh is around the 20%, 39% and 70% of the carbon fiber [3,5], glass fiber [3,6] and basalt fiber [3,7] respectively. Several studies were also conducted to evaluate the bond behaviour of FRP materials with concrete surface [8-10].

Material Properties	SSWM 40×32 [4]	Carbon Fiber [5]	Glass (S-class) [6]	Basalt [7]
Tensile Strength (MPa)	693.80	3528.1	1798.3	992.4
Modulus of Elasticity (GPa)	151	24	72	7.6

Table 1: Properties of various available fibers.

SSWMs are manufactured using the weaving method. Stainless-steel wires are interlaced at the right angle to form the mesh. Microscopic view of SSWM sample is presented in Fig.1 [11]. SSWM is preliminary used in various industrial applications like filters, baskets, strainers, sieves, and separators. SSWM has several advantages like (i) Stable weave (ii) Higher level of precision (iii) Controllable and limited thickness tolerance (iv) Unwavering surface area (v) Good abrasion resistance (vi) No transition and consistence appearance (vii) Easy to fabricate [12]. Stainless-steel Wire meshes are available in the roll form as shown in Fig. 2.

The designation of any type of SSWM requires two parameters - (i) gauge of wire indicating diameter and (ii) number of wires per one inch. Accordingly, different variants of SSWM, currently available in the market are 8×23, 10×25, 18×27, 20×27, 26×30, 30×30, 30×32, 40×32, 40×36, 100×42, 400×49 etc. SSWM A×B indicates stainless steel wire mesh with "A" number of wire per one inch in both the directions having gauge of wire "B". For the measurement of parameter "A" of SSWM counting glass is used as shown Fig. 3. Various materials like SS304, SS316, GI, brass, copper, bronze, aluminum, nylon, synthetic fiber, and epoxy coated wires can be used to manufacture wire mesh [13].

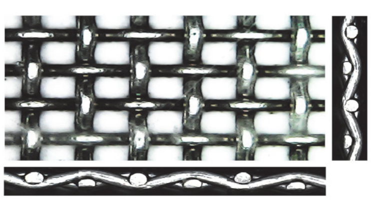


Figure 1: Microscopic view of SSWM.

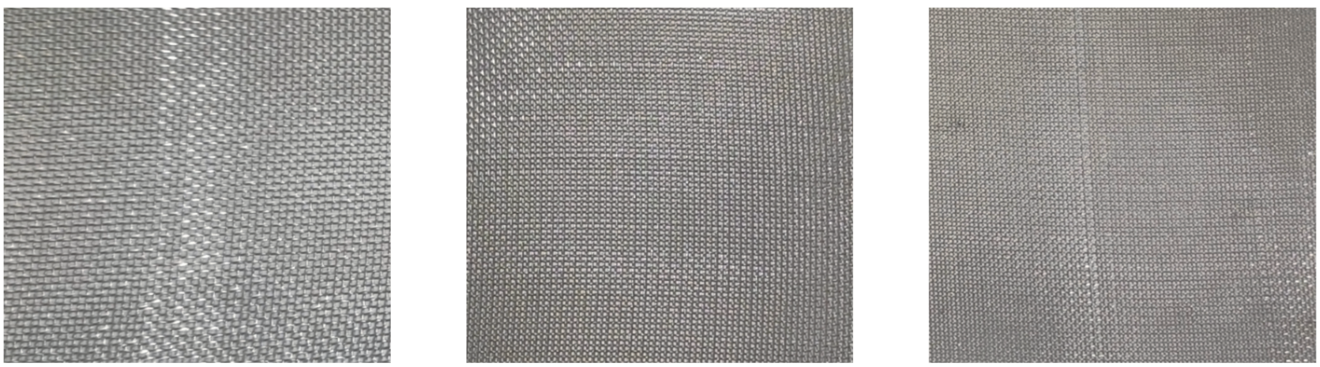

Figure 2: Roll of SSWM.


Figure 3: Counting glass for calculate number of wires.

Though, FRP materials are widely used for strengthening due to several advantages [1,2], it has been observed that brittle failure of FRPs and debonding with concrete surface restricts the utilization of its full capacity [14-16]. Further, the performance of FRP materials at elevated temperature is vulnerable and it is a concern that needs to be addressed by conducting further research [17-19].

SSWM is a cost-effective material as compared to GFRP, CFRP, BFRP etc., which can be potentially used as strengthening material, so as to avoid brittle failure and debonding problems observed with other FRP materials and to achieve superior

performance at higher temperatures. A limited investigations have been carried out and reported to examine the efficacy of SSWM for structural strengthening. Effect of SSWM strengthening on an axial compressive strength of circular columns cast using different concrete grades were evaluated by Kumar and Patel [4]. Authors found that SSWM was having better ductility and good bond with concrete surface. The successful implementation of SSWM for column strengthening inspired researchers to consider SSWM as an alternative material for GFRP and CFRP. Patel and Raiyani [20-22] carried out additional studies on the use of SSWM for flexural and shear strengthening of RC elements, and found it to be an effective material for restoring flexural and shear deficiencies of RC beams. Additionally, Patel et al. [23-24] explored the use of SSWM with different wrapping configurations for torsional strengthening of RC beams, both experimentally and numerically.
Tensile test of Stainless steel (SS) rod, SS wire and different variants SSWMs along with bond strength are not attempted to a great extent as that of FRPs. The prime focus of the present study is to evaluate the tensile properties and bond strength of SSWM by conducting experiments. The study employs plain weave wire meshes, with a three mesh types as displayed in Fig. 4(a). Fig.4(b) presents the microscopic view of three SSWM variants considered for the study. The physical properties of SSWM variants are presented in Tab. 2 [13].



30×32 40×32 50×34

Figure 4: (a) Sample of different variants of SSWM

30×32 40×32 50×34

Figure 4: (b) Microscopic view SSWM

Variants of SSWM	Wires per Inch	Wire Diameter (mm)	Opening Size (mm)	Percentage area of opening	Type of Opening
30×32	30	0.250	0.577	46.39	Square
40×32	40	0.250	0.365	33.04	Square
50×34	50	0.230	0.247	29.09	Square

Table 2: Physical properties of SSWMs [13].

The potential of SSWM as a strengthening material is evaluated with respect to tensile stress-strain behaviour and bond with concrete surface. The outcome of experimental work is presented in following sections.

Tensile Strength

In this section, tensile strength of Stainless-Steel (SS) rod, individual wire and wire mesh are evaluated. Small scale tensile testing machine is used for the tensile test of wire while tensile test of stainless-steel rod and wire mesh are performed using universal testing machine (UTM).

Tensile Test of Stainless Steel rod and wires

Tension test of Stainless Steel (SS) rod is carried out as per specifications of IS 1608 [25] using the universal testing machine of 400kN capacity. The tensile test specimen of SS-304 is having 300 mm length with 12 mm diameter at the end portions for gripping the specimen and 10 mm diameter at the central portion as test region as shown in Fig. 5. Change in length of specimens under tensile load is measured using an extensometer over a gauge length of 50 mm. Three specimens of SS rod are tested under axial tensile load.

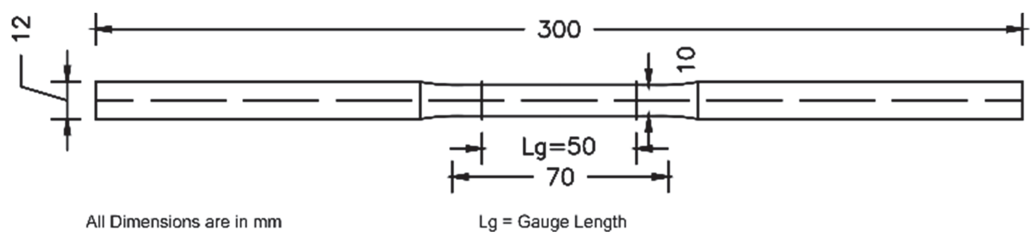


Figure 5: Dimension of stainless-steel rod specimen.

Extensometer is placed within the gauge length. During the tensile testing displacement rate of 1-2 mm/min. is maintained. Readings of extensometer are taken at the regular interval of 1 kN. Fig.6 shows the typical set up of tension test performed on stainless steel rod and failure of specimen. Photographs presenting failure pattern of all the three SS rod specimens under an axial tension is shown in Fig. 7. Partial cup-cone failure is observed for all stainless-steel rod specimens, indicating ductile failure.

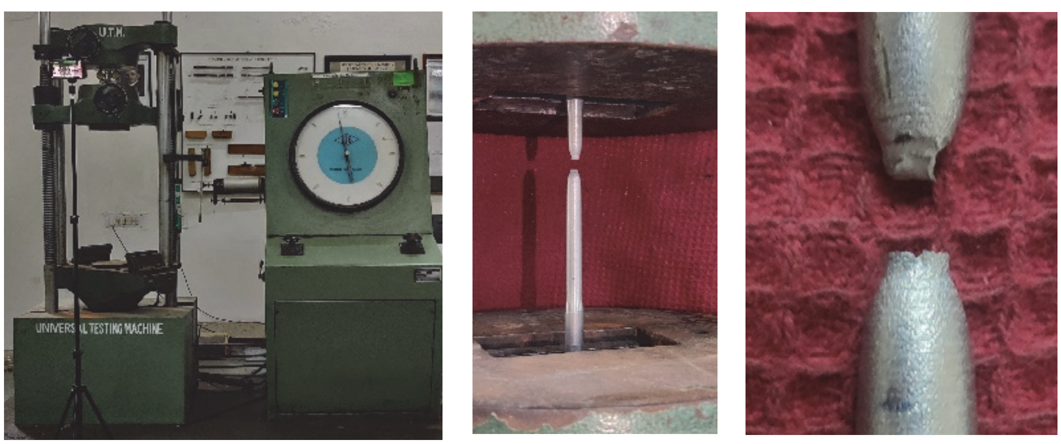


Figure 6: Tension test on stainless-steel rod specimen and failure of specimen.

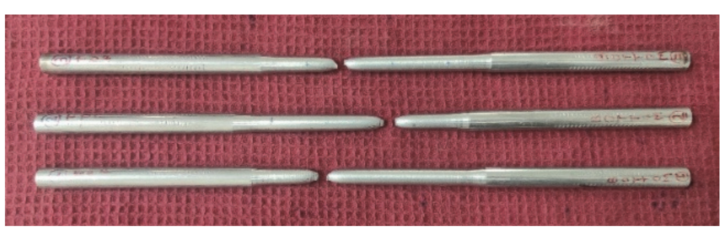
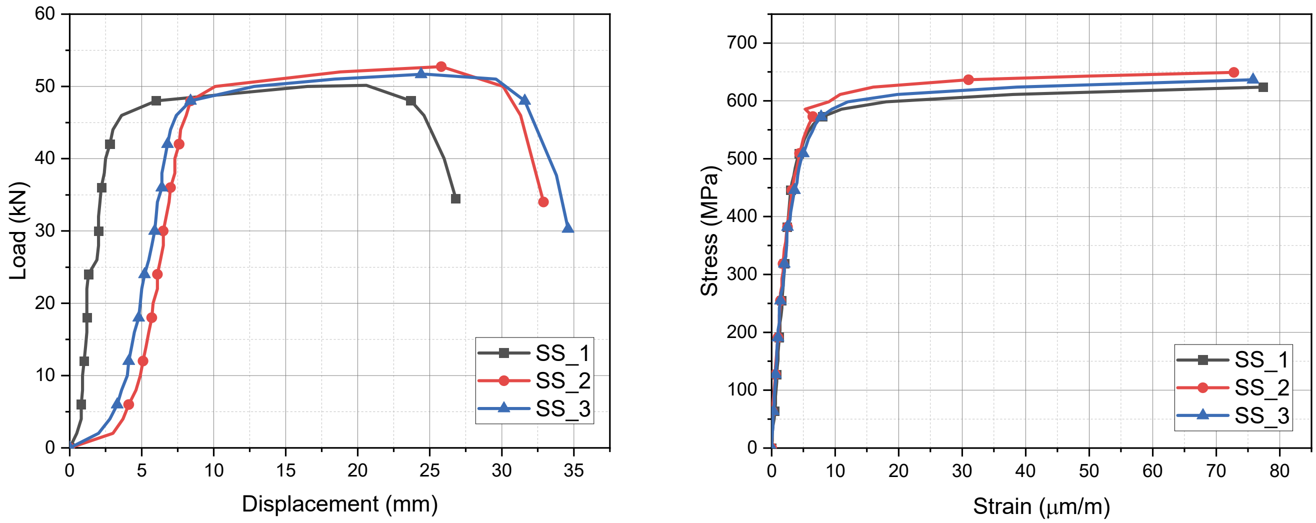


Figure 7: Failure of stainless-steel rod specimens.

Fig. 8 presents the load displacement and stress-strain curves for all the specimens of SS rod. It clearly demonstrates the ductile behavior of the SS bar specimens. On average, the SS bar specimens exhibits a tensile strength of 656.30 N/mm² and an elongation of 23.73 mm. Further, the average rupture strain at the point of failure for the test specimens is found as 75.33 μm/m. A summary of test results obtained from the tension test conducted on three SS rod specimens is presented in Tab. 3.



(a) Load vs displacement (b) Stress vs strain

Figure 8: Load-displacement and stress-strain behaviour of SS rod.

Sr. No.	Stainless Steel Rod			Unit
1.	Diameter	10		mm
2.	c/s area of rod	78.50		mm²
3.	Ultimate Load of individual specimens and average load	S1	50.14	kN
		S2	52.74	kN
		S3	51.68	kN
		Avg.	51.52	kN
4.	Average Tensile strength	656.30		N/mm²
5.	Average Elongation of rod	23.73		mm
6.	Average ultimate rupture strain	75.33		μm/m
7.	Average Young's modulus	151		GPa

Table 3: Results of tensile test for SS rod

Tension Test of 32 and 34 Gauge Stainless Steel Wires

To find the tensile strength of individual wire of 32 and 34 gauge used in manufacturing stainless-steel wire mesh, wires are taken out from both the SSWM 40×32 and SSWM 50×34 meshes. Tension tests on SS wires are carried out using the tensile testing machine having capacity of 5 kN. Three specimens are tested for each diameter of wire. For all the test specimens of wires, gauge length of 200 mm is kept. A placement of SS wire in tensile testing machine and typical failure observed are shown in Fig. 9. The load displacement curve for the three SS wire specimens of 32- and 34-gauge are presented in Fig. 10. A microscopic observation of failed stainless-steel wire as shown in Fig. 9 reveals cup-cone failure of wires. A ductile behavior of individual wire of SSWM, is also observed from the curve of load versus displacement as presented in Fig. 10. Average ultimate load of 35.26 N and 21.66 N are recorded, respectively, for the 32-gauge and 34-gauge SS wire. Based on average ultimate load, tensile strength is found as 721.416 N/mm² and 528.418 N/mm², for the 32-gauge wire and 34-gauge wire, respectively. Tab. 4 presents the summary of results for the tension test carried out on individual SS wires.

Figure 9: Tensile Test of Stainless Steel Wire and failure of wire.

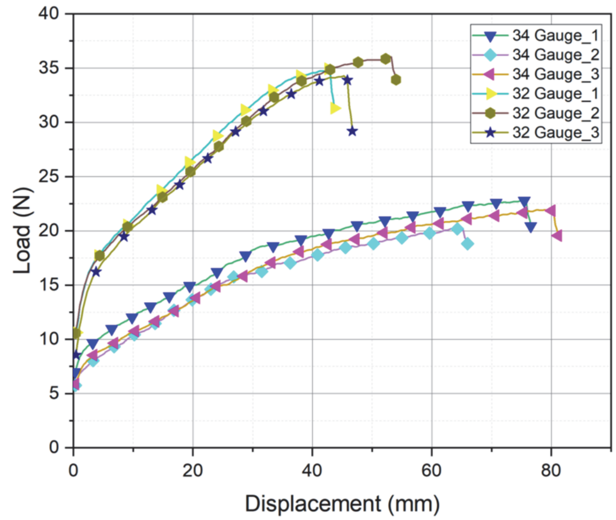


Figure 10: Load vs Displacement for Wire Testing.

Sr. No.	Stainless Steel Wire	32 Gauge Wire		34 Gauge Wire	Unit
1.	Diameter	0.250		0.230	mm
2.	c/s area of wire	0.049		0.041	mm^2
3.	Ultimate Load of individual specimen and average ultimate load	S1	35.254	21.921	N
		S2	36.257	22.821	N
		S3	34.579	20.253	N
		Avg.	35.36	21.665	N
4.	Average UTS of Wire	721.416		528.416	N/mm^2
5.	Average Elongation of Wire	48.066		74.610	mm

Table 4: Result of tensile test performed on SS wires

Tension Test of SSWM

The essential characteristic required for a material to be employed for the reinforcement of a structural component is its tensile strength. For experimental evaluation of tensile strength of SSWM, coupon specimens are prepared. Dimensions of test specimen are 500mm length and 100 mm width with 100 mm grip length at both the ends. Specimens are prepared in accordance with ASTM 3039 [26]. In the previous work no methodology is used to prepare the coupon specimens of SSWM. In this study, a novel assembly is developed to stretch SSWM strip with small amount of tension and to keep SSWM in straight position while bonding steel plates using epoxy as shown in Fig. 11. Coupon specimens are prepared by bonding steel grip plates at the ends of SSWM strip on both the sides. While bonding SSWM with grip plates using epoxy, care should be taken to keep SSWM in straight position. In the stretching assembly sample of SSWM having the size of 700 mm × 100 mm are used. Extra length is used to grip SSWM while stretching specimen using the assembly. Steel plates of 100 mm × 100 mm with 6 mm thickness are bonded on both the sides of SSWM with Sikadur 30 LP epoxy. Sikadur 30 epoxy is applied evenly on the steel plate using putty knife and placed on both sides of SSWM at each end of strip. With use of novel stretching assembly SSWM coupon specimens remaining straight after applying grip plates at both the ends. If SSWM specimen is not straight while testing, tensile force will not act uniformly across the section. Sikadur 30LP is the material composed of two parts: Part A, which is the white-colored resin, and Part B, which is the black-colored hardener. The mixed density of this material is 1.8 ± 0.1 kg/Ltr, and the mixing ratio of 3:1 (Resin : Hardener). The pot life of the material is 60 minutes, and it attains a compressive strength greater than 85 MPa and flexural strength greater than 25 MPa at 7 days. It takes 7 days for ambient curing [27].

For the experimental evaluation of tensile strength three type of SSWM i.e. 30×32, 40×32 and 50×34 are taken and specimens are prepared with stretching assembly. Square steel plate of 100 mm at both the ends of SSWM coupon specimen are used for the gripping the specimen in universal testing machine (UTM). Additional plates are connected by bolts to remove the extra space between the grip plates as shown in the Fig. 11. After the placing of steel plates in the form work, 2 other steel plates are used to compress the grip steel plates with SIKADUR 30LP on both sides of SSWM. Both the plates are connected by the bolts, so any material kept between them can be compressed based on the requirement. After placing the steel plates at both ends of the SSWM coupon specimen, a clear length of 300 mm is left, and the specimen is then cured for seven days at ambient (room) temperature. Subsequently, an axial tensile load is applied on the specimens with the help of 400 kN capacity UTM. Photograph of actual test set-up to conduct tensile test of SSWM coupon specimens is presented in Fig. 12.

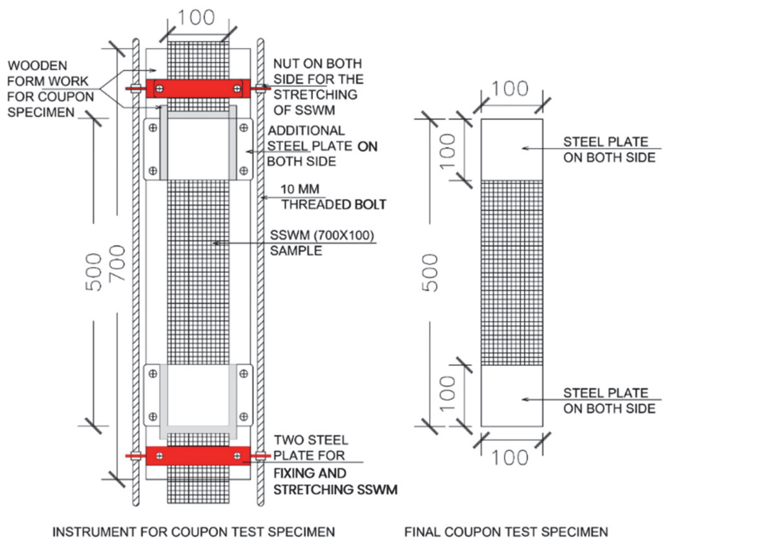


Figure 11: Stretching assembly for preparation of SSWM coupon specimens and SSWM coupon specimen

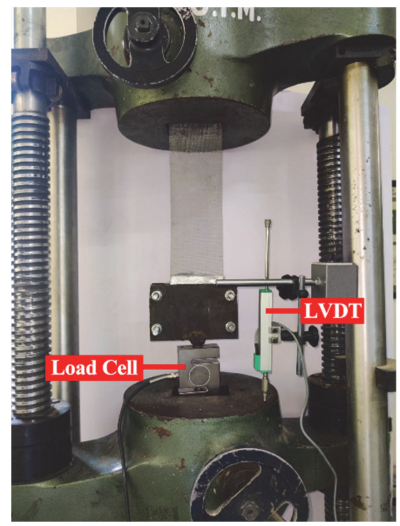
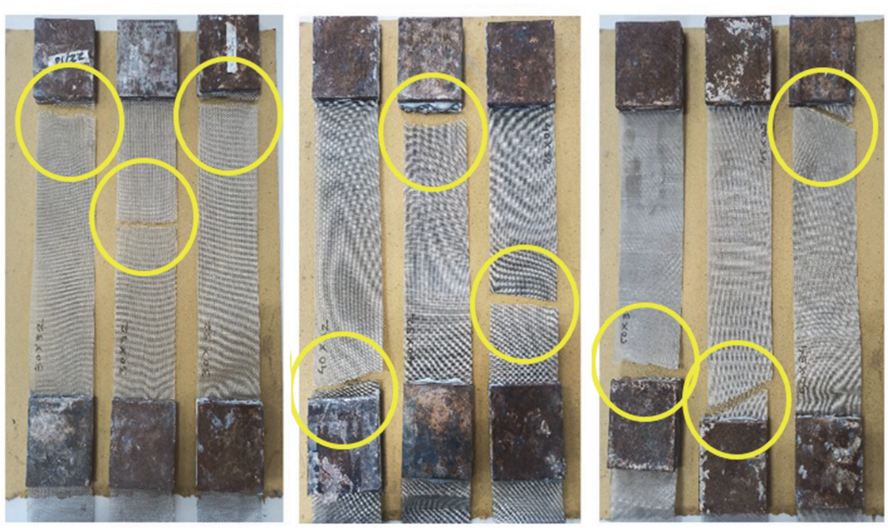


Figure 12: Application of Tensile force on coupon specimen using UTM



SSWM 30 × 32 SSWM 40 × 32 SSWM 50 × 34

Figure 13(a): Failure of different types of SSWM coupon specimens

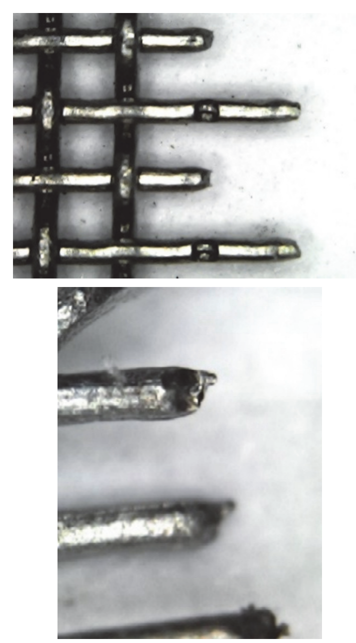


Figure 13(b): Microscopic view of failure of SSWM under microscope

For the more accuracy in measuring load on test specimen "S" type of load cell having capacity of 30 kN is connected at the bottom of coupon specimen as shown in Fig. 12. Linear Variable Displacement Transducer (LVDT) of 100 mm stroke

length is kept on the middle cross head to determine the - elongation of SSWM coupon specimens. Three samples of each type of SSWM are examined for tensile strength. Fig. 13(a) shows the failure pattern of all the three types of SSWMs. Failure of SSWM samples is also inspected at microscopic level, as presented in Fig. 13(b). It is found that, all the wires in mesh, parallel to line of action of load are contributing in load resistance. A cup-cone failure is observed for each individual wire of mesh along with neck formation. Also, impression mark on wires due to weaving is observed as shown in Fig. 13(b).
Fig. 14 shows the load displacement curve for all the three types of SSWMs. Tab. 5 presents the technical details and tensile strength of various types of SSWMs. From the results of tensile load – displacement results, better performance of SSWM 40×32 is observed as compared to other types of SSWM. Average tensile load of 3.811 kN, 4.686 kN and 4.021 kN are observed for the SSWM 30×32, SSWM 40×32 and SSWM 50×34 respectively. Tensile strength of 658.375 N/mm², 617.898 N/mm² and 489.134 N/mm² are obtained for the, SSWM 40×32, 30×32 and 50×34 respectively.

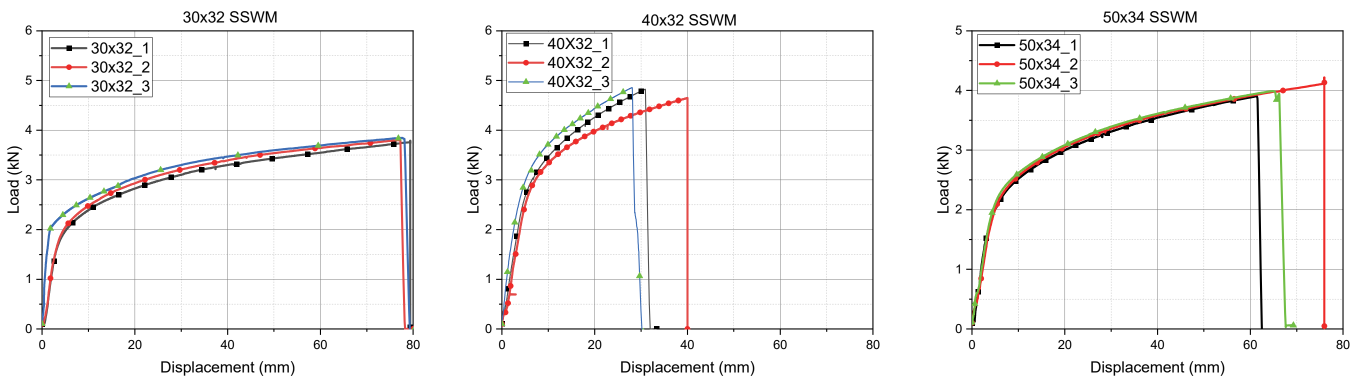


Figure 14: Load-displacement graph for all SSWMs.

	SSWM Type		30 × 32	40 × 32	50 × 34	Unit
1.	Width			100		mm
2.	Thickness of wire		0.25	0.25	0.23	mm
3.	Numbers of wires		118	158	198	No.
4.	Cross section area of wire		0.049	0.049	0.041	mm²
5.	Total cross section area		5.789	7.751	8.222	mm²
6.	Average Ultimate Load	S1	3.787	4.825	3.903	kN
		S2	3.801	4.686	4.218	kN
		S3	3.846	4.857	3.944	kN
		Avg.	3.811	4.789	4.021	kN
7.	Average UTS of Wire		658.375	617.898	489.134	N / mm²
8.	Average elongation of Mesh		78.431	34.546	68.356	mm

Table 5: Properties and tensile strength of SSWMs considered in present study.

BOND STRENGTH

The experimental evaluation involves measuring the effectiveness of the bond of SSWM on concrete surface using SIKADUR 30LP. From the failure pattern of SSWM bonded on concrete either tearing or debonding, effectiveness of strengthening material can be assessed. Dumbbell shape specimens are prepared as described by the Kumar and Patel [4]. Total nine M25 grade concrete dumbbell specimens are prepared. Mix design for the M25 grade concrete is presented in Tab. 6 [28]. The calculated Young's modulus of concrete is 28939 MPa. [29]

Material	Kg/m^3
Cement	400.87
Water	220.48
Fine Aggregate	823.78
Coarse Aggregate	938.88

Table 6: M25 grade concrete mix design proportion.

For every variant of SSWM three specimens are prepared. During the specimen preparation one mm gap is kept between the two parts of a dumbbell specimens. Sikadur 30LP with the proportion of 3:1 (Part A : Part B) by weight is applied on both the surface as shown in Fig. 15. On Both the side strip of SSWM are applied with SIKADUR 30LP. After the 7 days of ambient curing specimens are tested under tensile load in universal testing machine. A special assembly is prepared and dumbbell specimens are placed in it, so that specimen experience direct tensile load. For the measurement of tensile force in specimen, Load cell of 200 kN is used at the top of assembly. LVDT of 100 mm displacement measurement range is used to measure the displacement of dumbbells as shown in Fig 16. Fig. 17 illustrates the process of testing dumbbell specimens to measure the effectiveness of the bond between the SSWM and the surface of the concrete.

Figure 15: Preparation of dumbbell specimen for bond test.

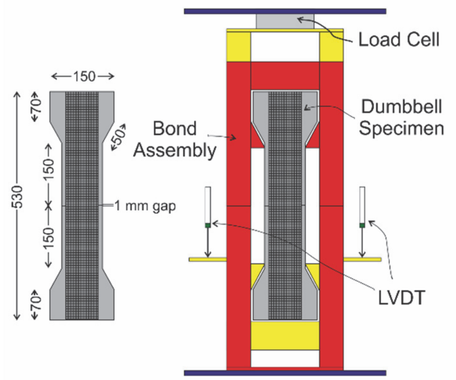


Figure 16: Schematic diagram for bond test..

Figure 17: Experimental test setup for bond test.

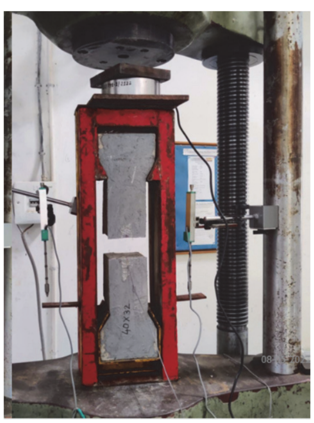


Figure 18: SSWM-Concrete Bond test failure of specimen.

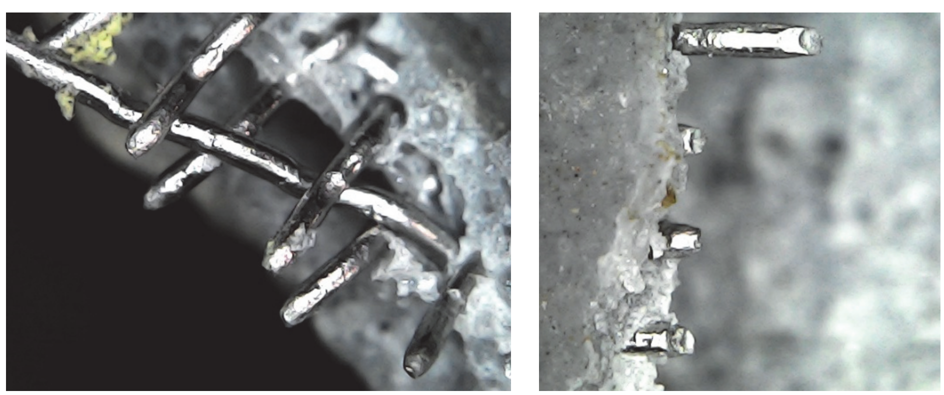


Figure 19: Failure of SSWM with SIKADUR 30 LP at microscope level.

Pace rate of 1-2 mm/minutes is maintained throughout the experiment of bond test. Fig. 18 shows that, a failure of test specimens is occurred at a location of 1 mm gap near the centre of dumbbell specimen. Tearing of all the wires of SSWM is observed as presented in Fig. 19, which indicates utilization of full strength of SSWM. Further, the visual inspection of failure pattern is carried out at microscopic level, which clearly indicates that any debonding between SSWM layer and concrete surface is not observed. Concrete crushing is also not observed during experimental studies. Fig. 18 and 19 clearly

demonstrates that failure of SSWM occurs due to tearing of all the wires parallel to line of action of load and proper bond is maintained between SSWM and concrete surface till the complete failure.
Fig. 20 shows the load-displacement behaviour of all the dumbbell shaped specimens tested to evaluate bond strength. The behaviour of specimen is mostly linear till the failure of SSMW on any one side of specimen. The drop observed in load-displacement curve, is due to failure of SSMW layer on one side. However, layer of SSWM applied on another side still contribute in load resistance and as a result curve again shows both increase in displacement and load. This indicates that, both the layers of SSWM applied on each side of specimen, contributes in load resistance. Bond strength is measured based on failure load of specimen. Bond strength is calculated from the peak load and total c/s area of corresponding SSWM. Average Bond strength of 714.530 N/mm², 859.351 N/mm² and 538.790 N/mm² are obtained for the SSWM 30×32, SSWM 40×32 and SSWM 50×34. Maximum bond strength is achieved by SSWM 40×32. Results of bond test are presented in Tab. 7. Average load, standard deviation and error of three specimens of each variant of SSWM are also presented in Tab. 7. As observed from Fig. 20, all the specimens of SSWM 40×32 shows similar behaviour up to peak loading. While specimens of SSWM 30×32 and SSWM 50×34 show variations in load-displacement behaviour from initial stage to peak load. The factors affecting behaviour of SSWM bond specimens are concrete surface preparation, application of epoxy on surface of concrete, thickness of epoxy layer, opening size of SSWM, effectiveness of bond between SSWM & concrete, and workmanship. These factors have resulted into different initial stiffness of different specimens of a SSWM 30×32 and 50×34. Additionally, slip at the gripping of specimen may also be responsible for inconsistent behaviour of specimens resulting into different initial stiffness. The results of SSWM 40×32 specimens consistently show favourable outcomes in terms of peak load and similar load-displacement behaviour due to the optimum opening area of SSWM and proper bond with concrete surface.

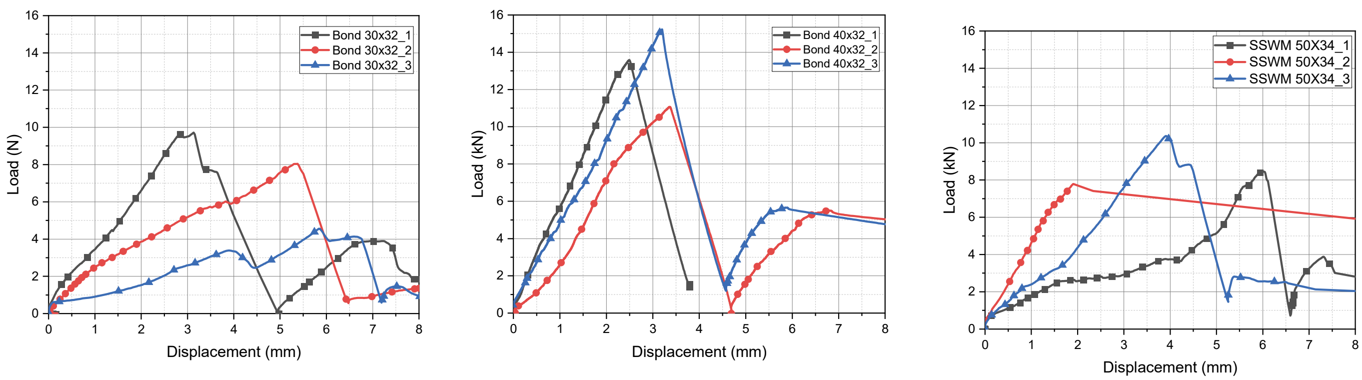


Figure 20: Load-displacement curves for bond Specimens.

No.	SSWM Type	30 × 32		40 × 32	50 × 34	Unit
1.	Average Ultimate Load	S1	9.710	13.590	8.461	kN
		S2	8.041	11.073	7.790	kN
		S3	7.052	15.240	10.371	kN
		Average	8.260	13.333	8.870	
		Standard Deviation	1.34	2.09	1.33	
		Standard Error	0.77	1.21	0.77	
2.	Half Load	4.130		6.660	4.431	kN
3.	c/s area of wire	0.049		0.049	0.041	mm²
4.	Total c/s area	7.751		5.789	8.222	mm²
5.	Bond strength	714.530		859.351	538.790	N/ mm²
6.	Failure Pattern	Tearing of Mesh		Tearing of Mesh	Tearing of Mesh	-
7.	Maximum Elongation	S1	3.133	2.503	5.272	mm
		S2	5.372	3.360	2.290	mm
		S3	5.802	3.201	3.901	mm
		Avg.	3.821	3.022	3.82	mm

Table 7: Results of bond test.

RESULTS AND DISCUSSIONS

To determine the tensile properties of 32-gauge and 34-gauge wire mesh, three wires with a length of 200 mm are subjected to tensile loading. The 32-gauge wire has a diameter of 0.25 mm and the average tensile load of all the specimens is 35.363 N, with an average tensile strength of 714.285 N/mm². The average elongation is 48.066 mm. The 34-gauge wire has a diameter of 0.23 mm, and the average ultimate tensile load of the all specimens is 21.665 N, with an average ultimate tensile strength of 528.416 N/mm². The average elongation is 74.61 mm. As depicted in Fig. 21, the average tensile strength of the 32-gauge wire is 36.57% greater than that of the 34-gauge wire.

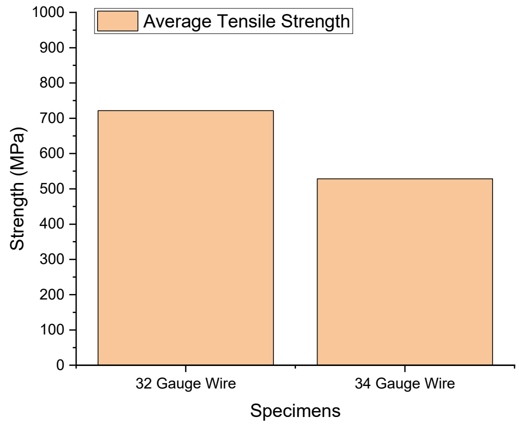


Figure 21: Average tensile strength results for SS rod and SS wires

Three different types of SSWM i.e. 30×32, 40×32 and 50×34 are considered to evaluate tensile strength and bond strength. The size of coupon specimens is 100mm × 500mm including gripping length. Three samples for each type of SSWM are prepared. The average ultimate tensile load resisted are 3.811 kN, 4.789 kN and 4.021 kN for SSWM 30×32, SSWM 40×32 and SSWM 50×34 respectively. The average ultimate tensile strength of SSWM 30×32, SSWM 40×32 and SSWM 50×34 are 658.375 N/mm², 617.898 N/mm² and 489.13 N/mm² respectively. The average mesh elongation for SSWM 30×32, SSWM 40×32, and SSWM 50×34 are 78.431 mm, 34.546 mm, and 68.356 mm, respectively. As compared with SSWM 50×34, SSWM 30×32 possesses 34% higher tensile strength and SSWM 40×32 possesses 26.32% higher tensile strength.

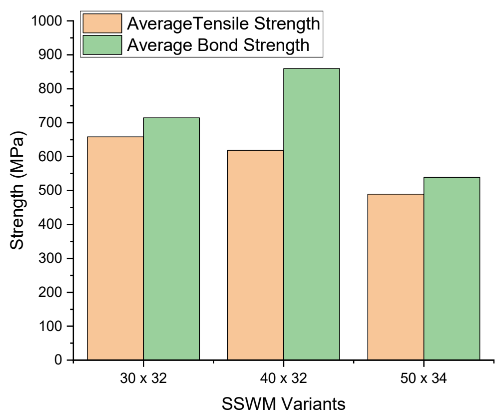


Figure 22: Average tensile strength and bond strength results for all SSWM variants

For the bond test, concrete dumbbell specimens of M25 grade are made and coated on both faces with a single layer of SSWM using SIKADUR30LP. To evaluate the effectiveness of SSWM, three dumbbell shape specimens are prepared with each of three different variants of SSWM 30×32, 40×32, and 50×34. The specimens are then subjected to direct tensile load testing using a UTM. The average breaking load of 8.26 kN, 13.33 kN and 8.87 kN are observed for SSWM 30×32, SSWM 40×32, and SSWM 50×34 respectively. There is no debonding of SSWM from concrete surface. The failure is simply caused by tearing of mesh. Bond strength for SSWM 30×32, 40×32, and 50×34 are evaluated as 714.53 N/mm², 859.35 N/mm² and 538.79 N/mm² respectively. Results for the tensile strength and bond strength are shown in Fig. 22. The average elongation are 4.76 mm, 3.02 mm and 3.82 mm for SSWM 30×32, 40×32, and 50×34 respectively. During bond test SSWM 40×32 exhibits 59.49% higher bond strength as compared to SSWM 50×34, and SSWM 30×32 exhibits 32.61% higher strength as compared to SSWM 50×34.

CONCLUSIONS

The main focus of the present study to evaluate mechanical properties like tensile strength and bond strength of SSWM through conducting experiments. Three variants of SSWM, namely SSWM 30×32, 40×32, and 50×34 are considered for this investigation. Tensile strength of SS304 rod specimen, individual wires of 32- and 34-guage SS is also determined. Based on the observations of experimental studies, the following conclusions are made:

- Average ultimate tensile strength of 32-gauge SS wire is 36.57% higher as compared to 34-guage SS wire. On the similar lines, the improved performance of wire mesh made from 32-guage SS wires is observed as compared to SSWM 50×34.
- Cup-cone failure pattern of SS rod, individual SS wires and wires in mesh demonstrates superior ductile performance of SSWM.
- SSWM attached on concrete surface using epoxy adhesive SIKADUR 30LP provides adequate bond. Any significant debonding of SSWM with concrete surface is not observed.
- Tearing of wires of SSWM and proper bonding with concrete surface indicates complete utilization of SSWM strength when used for strengthening purpose.
- Out of the three different variants considered for the study, overall performance of SSWM 40×32 is superior in terms of tensile strength and bond strength. Hence, SSWM 40×32 can be further explored as an alternative strengthening material to conventional FRP materials.

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REFERENCES

[1] Mugahed Amran, Y.H., Alyousef, R., Rashid, R.S.M., Alabduljabbar, H., Hung, C.C. (2018). Properties and applications of FRP in strengthening RC structures: A review, Structures, 16(July), pp. 208–238, DOI: 10.1016/j.istruc.2018.09.008.
[2] Siddika, A., Mamun, M.A. Al., Ferdous, W., Alyousef, R. (2020). Performances, challenges and opportunities in strengthening reinforced concrete structures by using FRPs – A state-of-the-art review, Engineering Failure Analysis, 111, pp. 104480, DOI: 10.1016/j.engfailanal.2020.104480.
[3] ACI 440.2R (2008). Guide for the Design and Construction of Externally Bonded FRP Systems for strengthening Concrete Structures.
[4] Kumar, V., Patel, P. V. (2016). Strengthening of axially loaded concrete columns using stainless steel wire mesh (SSWM)-numerical investigations, Structural Engineering and Mechanics, 60(6), DOI: 10.12989/sem.2016.60.6.979.
[5] Zhou, J., Bi, F., Wang, Z., Zhang, J. (2016). Experimental investigation of size effect on mechanical properties of carbon fiber reinforced polymer (CFRP) confined concrete circular specimens, Construction and Building Materials, 127, pp. 643–652, DOI: 10.1016/j.conbuildmat.2016.10.039.
[6] Sakthivel, M., Vijayakumar, S., Ramnath, B.V. (2018). Investigation on Mechanical and Thermal Properties of Stainless Steel Wire Mesh-Glass Fibre Reinforced Polymer Composite, Silicon, 10(6), pp. 2643–2651, DOI: 10.1007/s12633-018-9801-8.
[7] Sim, J., Park, C., Moon, D.Y. (2005). Characteristics of basalt fiber as a strengthening material for concrete structures, Composites Part B: Engineering, 36(6–7), pp. 504–512, DOI: 10.1016/j.compositesb.2005.02.002.
[8] Serbescu, A., Guadagnini, M., Pilakoutas, K. (2013). Standardised double-shear test for determining bond of FRP to concrete and corresponding model development, Composites Part B: Engineering, 55, pp. 277–297,

DOI: 10.1016/j.compositesb.2013.06.019.
[9] Biscaia, H.C., Chastre, C., Silva, M.A.G. (2012). Double shear tests to evaluate the bond strength between GFRP/concrete elements, Composite Structures, 94(2), pp. 681–694, DOI: 10.1016/j.compstruct.2011.09.003.
[10] Biscaia, H.C., Chastre, C., Silva, M.A.G. (2015). Bond-slip model for FRP-to-concrete bonded joints under external compression, Composites Part B: Engineering, 80, pp. 246–259, DOI: 10.1016/j.compositesb.2015.06.004.
[11] Standard International. (1999). ISO 9044 , Industrial woven wire cloth — Technical requirements and testing.
[12] Haver Standard, Wire Mesh Products Co., Ltd. Available at: http://www.galvanizedmetalmesh.com/.
[13] Woven wire cloth & perforated sheet product data sheet, Banaraswala metal Crafts(P) Ltd , Coimbatore. Available at: www.banaraswala.com.
[14] Antonopoulos, C.P., Triantafillou, T.C., Asce, M. (2003). Experimental Investigation of FRP-Strengthened RC Beam-Column Joints, 7(1), pp. 39–49.
[15] Ghobarah, A., Said, A. (2002). Shear strengthening of beam-column joints, Engineering Structures, 24(7), pp. 881–888, DOI: 10.1016/S0141-0296(02)00026-3.
[16] Yousef, A.-S., Tarek, A., Saleh, A., Nadeem, S. (2011). Seismic Behavior of As-Built, ACI-Complying, and CFRP-Repaired Exterior RC Beam-Column Joints, Journal of Composites for Construction, 15(4), pp. 522–534, DOI: 10.1061/(ASCE)CC.1943-5614.0000186.
[17] Correia, J.R., Keller, T., Garrido, M., Sá, M., Firmo, J.P., Abu Shahid, M., Machado, M. (2023). Mechanical properties of FRP materials at elevated temperature – Definition of a temperature conversion factor for design in service conditions, Construction and Building Materials, 367, DOI: 10.1016/j.conbuildmat.2023.130298.
[18] Hawileh, R.A., Abu-obeidah, A., Abdalla, J.A., Al-tamimi, A. (2015). Temperature effect on the mechanical properties of carbon , glass and carbon – glass FRP laminates, Construction and Building Materials, 75, pp. 342–348, DOI: 10.1016/j.conbuildmat.2014.11.020.
[19] Hawileh, R.A., Abdalla, J.A., Hasan, S.S., Ziyada, M.B., Abu-obeidah, A. (2016). Models for predicting elastic modulus and tensile strength of carbon , basalt and hybrid carbon-basalt FRP laminates at elevated temperatures, Construction and Building Materials, 114, pp. 364–373, DOI: 10.1016/j.conbuildmat.2016.03.175.
[20] Patel, P. V., Raiyani, S. (2017). Flexural Strengthening of RC beam using Stainless Steel Wire Mesh, 33rd National Convention of Civil Engineers on Recent Advances in Structural Engineering, Ahmedabad, India.
[21] Patel, P. V., Raiyani, S. (2018). Shear Strengthening of RC beam using Stainless Steel Wire Mesh, Advances in Concrete, Structural & Geotechnical Engineering, (May), pp. 452–457.
[22] Raiyani, S.D., Patel, P. V., 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.
[23] Raiyani, S.D., Patel, P. V. (2021). Torsional strengthening of reinforced concrete hollow beams with stainless steel wire mesh, Proceedings of the Institution of Civil Engineers: Structures and Buildings, DOI: 10.1680/jstbu.20.00126.
[24] Patel, P. V., Raiyani, S.D., Shah, P.J. (2018). Torsional strengthening of RC beams using stainless steel wire mesh-Experimental and numerical study, Structural Engineering and Mechanics, 67(4), pp. 391–401, DOI: 10.12989/sem.2018.67.4.391.
[25] IS 1608 - 2005. (2005). Metallic materials - Tensile testing at ambient temperature.
[26] ASTM 3039. (2014). Standard test method for tensile properties of polymer matrix composite materials.
[27] Sikadur 30 LP. (2019). Product data sheet, Adhesive for bonding reinforcement.
[28] IS: 10262. (2019). Concrete Mix Proportioning Guidelines. Bureau of Indian Standard, New Delhi.
[29] IS 456. (2000). Plain and Reinforced Concrete - Code of Practice, Bureau of Indian Standards, New Delhi.