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An Experimental Study on Strengthening of Reinforced Concrete Flexural Members using Steel Wire Mesh

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Abstract: Reinforcing reinforced concrete (RC) beams with galvanized welded steel wire mesh is one of the latest technologies applied in retrofitting. For each sample, the experimental evaluation of 18 small reinforced concrete beam samples with a total length of 1200 mm was carried out to study the bending strength under static load conditions. Experimental testing has been carried out to the activated failure mode, with 11 reinforced samples, 4 integrally cast control beams and three original control beams. Based on the test variables, namely SWM characteristics and connection mechanism, the reinforced beams are divided into two groups A and B. This study also clarified the bending resistance, ductility, stiffness, crack width and deflection. According to the test results obtained, all reinforced beams are designed to fail ductilely. The first group of reinforced beams recovered to an average of 110% of the bearing capacity of the original control beam, while the second group of reinforced beams recovered to an average of 163%. Furthermore, it was found that the reinforcement beam functions in the same way as the general control beam and works as a unit. Therefore, the bottom line is that this reinforcement technology can be used confidently in real-life applications, especially in low- cost buildings.

I. INTRODUCTION

Infrastructure construction is an inevitable part of industrial growth because it provides users with good services and comfort, and needs to be strengthened and modernized to return to the original planned position. The deterioration of concrete structures is one of the main problems in today's construction industry. Today, modern technologies are developed and applied to achieve effective reinforcement and repair methods. The development of composite wire mesh requires a clear understanding of the behavior of reinforced concrete beams in different loading stages. The type of reinforcement material significantly affects the performance of the reinforced beam. Therefore, the focus of this work is to study the effectiveness of wire mesh composites in strengthening RC structural elements, which facilitates further development and makes it more acceptable in practice. This fabric is quick and easy to install. Once in place, workers cannot easily move when pouring concrete, as often happens when using steel bars. The mesh cloth is fixed in place, has good adhesion to the concrete, and also reduces the consumption of steel bars, so it can also achieve economic efficiency. The economic growth of any country mainly depends on the development of buildings, transportation facilities and other infrastructure. Although the design of the building meets life expectancy standards, structural components may fail due to a variety of reasons. Incorrect design and environmental conditions are the main reasons for failure. By analyzing the lack of initial load-bearing capacity and adopting appropriate reinforcement technology,structural failure can be avoided. The reinforcement and repair of reinforced concrete structural members is one of the most difficult and important tasks in civil engineering. The focus of this research is to strengthen and repair damaged reinforced concrete beams by using steel wire mesh with or without additional longitudinal steel angles. In recent years, some experiments and analysis studies have been carried out on the reinforcement and adjustment of beams. The damage level studied ranges from cracking of the beam under service load to complete failure of the beam.

II. LITERATURE REVIEW

To date, many studies have adopted many techniques to strengthen CR beams using steel plates, FRP composites, and wire mesh, and critical evaluations and discussions were conducted at this meeting. 1. Saranya M and Periasmy: the authors Saranya M and Periasmy L (2015) used a carbon mesh with a diameter of 2.4 mm to reinforce RC beams with three different directions, such as 0\u2218, 45\u2218 and 60 2. Khan S. U: Khan S. U. (2013) RC beams were reinforced by bending with two and three-story ferrocement. 3. Mohana R: Mohana R. (2013) conducted experiments on iron cement slabs with geopolymer under flexural loads and tested the compressive strength of geopolymer samples, the deflection of the load under different molar concentrations and different thicknesses.

Behavior curve cracking. Four. Aravind N: Aravind N. (2015) conducted an experimental study on RC beams reinforced with GFRP corrugated laminates using epoxy resin. 5. Murali G: The author Murali G (2012) carried out an experimental study on concrete mixed with fibers using waste materials. 6. Heshmi and ALMahaidi: Heshmi and AlMahadi (2012) conducted an investigation on reinforced concrete beams reinforced with CFRP textiles and fabrics at high temperatures using cement-based adhesives. Most researchers use epoxy resin to reinforce bending members with FRP panels \/ laminates. In this work clamp, the steel mesh is connected to the ceiling of the reinforced concrete beam and mortar is used to fill the roof portion and protect the steel mesh. 7. Dr. M.M. Awati, S.S. Mohite and Dr.

R.A. Patil: M. M. Awati, SS Mohite and R. A. Patil (2014) on R.C. edge beams Bonded G.F.R.P. lamination. They found that compared with the reference beam, the load- bearing capacity of the M20 concrete beam was increased by 50% after being reinforced with a complete GFRP U- shaped wrap.

Thus far many researches adopted many techniques for strengthening RC beams using steel plates, FRP composites and wire meshes are evaluated critically and discussed in this session. Table 1 shows the details of literature review which includes description of works. Table 1 shows the size of beam, types and dimensions of FRP/steel plate used and techniques adopted for strengthening works and test results done by various researchers. Authors Saranya M and Periasamy L (2015) have used carbon wire mesh with 2.4 mm diameter bars for strengthening RC beams with three different orientations such as 0 ∘ , 45∘ and 60∘ [4]. Khan S. U. et al. (2013) have done strengthening of RC beams in flexure using two and three layers of Ferro-cement [5]. Mohana R. (2013) have done experimental work on Geopolymer ferro-cement panels under flexural loading and Geopolymer specimens are tested for compressive strength, load deflection cracking behavior for different molar concentrations, and different thicknesses [6]. Aravind N. et al. (2015) have done experimental study on RC beams strengthened with corrugated GFRP laminates using epoxy resin [7]. Author Murali G (2012) has done experimental investigation on concrete mixed with fibre using waste materials [8]. Heshmi & Al-Mahaidi, (2012) have done a research work on reinforced concrete beams strengthened with CFRP textile and fabrics using cement based adhesives at high for strengthening flexural members with FRP sheets/laminates [1]. In this work clips were used to attach the steel mesh with the soffit of the RC beam and mortar is used to fill the cover portion and protect steel mesh.

Ahmed et.al. (2015) studied the square column specimens confined with welded wire mesh material. In single layer of confinement increase the ultimate load capacities with 11.02% and 18.55% for slenderness ratio 7 and 14.Wraping with WWM increase the energy dissipation with 85.36% and 450.80% for slenderness ratio 7& 14.By confining EMM layer provide 80% reduction in ties volumetric ratio. With the confinement the column specimens failed in a ductile manner as compared to brittle failure of specimen. Mourad et.al. (2012) studied the column specimens for the ultimate load capacity and stressed samples confined with ferrocement using welded wire mesh as the confining material. In case of pre-stressed specimens, the results showed that the confining increased the load carrying capacity to 33%. Ductility of the specimens also increased. In case of stressed samples to a value of 60% and 80% of the ultimate load capacity, the confinement enhanced the ultimate load capacity to 28% and 15% respectively. With the confinement the column specimens failed in a ductile manner. Kaish et.al. (2012) studied the effect of ferrocement jacketing with some modifications. Three types of ferrocement jacketing techniques were used to confine the column specimens that are; square jacketing with single layer wire mesh and rounded column corners (RSL); square jacketing using single layer wire mesh with shear keys at the centre of each face of column (SKSL) and square jacketing with single layer wire mesh and two extra layers mesh at each corner (SLTL) are considered for this purpose. The specimens were tested under concentric and eccentric modes of loading. These methods of confinement significantly improved the ultimate load capacity, axial deflection and lateral deflections.This report concluded that improved square ferrocement jacketing schemes introduced in this study are effective to overcome the drawbacks of conventional square ferrocement jacketing of square RC column and could be used effectively for re- strengthening of square RC column subjected to both concentric and eccentric loadings after taking proper care in jacketing schemes.

Xiong et.al. (2011) studied the load carrying capacity and ductility of circular concrete columns confined by ferrocement including steel bars (FS) where they are proposed to increase the compressive strength along with the ductility. The behaviour of the ferrocement strengthened columns was compared with the bar mat-mortar (BS) and fibre reinforced polymer (FRP) wrapped columns under uniaxial compression. The dimensions of the concrete cylindrical columns were, 105 mm (dia) x 450mm and 150 mm (dia) x 450mm. After wet- curing (24 hrs), the samples were transferred to curing room temperature [3]. Most of the researchers used epoxy resins for 27 days. The specimens with 105 mm (dia) were confined with FS or BS whereas 150mm (dia) with FRP. The comparative analyses of these samples show that the compressive strength of FS columns was enhanced by 30% than that of BS columns. Due to ferrocement caging along with steel bars specimens showed higher ductility, compressive strength and energy absorbing capacity than BS or FRP strengthened circular columns.

Turgay et.al. (2010) studied the effect and failure mechanisms of large-scale square/ rectangular columns wrapped with fibre reinforced polymer (FRP). The experimental research program studied the performance of large-scale square RC columns wrapped with carbon fibre reinforced polymer (CFRP) sheets. Moreover, the research was mainly focused on the investigation of the total effect of longitudinal and transverse reinforcement and FRP jackets on the behaviour of concentrically loaded columns.All the specimens were subjected to monotonically increasing compression up to the fracture. Fully wrapped specimens with a slenderness ratio of 5:1 fractured at the top or bottom quarters whereas the partially wrapped columns show failure at the ends of confined regions. The partial wrapping with one-layer of CFRP results an increase in ductility and this is much more pronounced for RC columns with eight longitudinal bars. Finally, for all RC columns fully wrapped with one layer of CFRP, transverse reinforcement with a diameter of 12 mm clearly enhances the beneficial effect of CFRP on ductility.

Khan S.U: Khan S. U. (2013) have done strengthening of RC beams in flexure using two and three layers of Ferro- cement.

Aravind N: Aravind N. (2015) have done experimental study on RC beams strengthened with corrugated GFRP laminates using epoxy resin.

Murali G: Author Murali G (2012) has done experimental investigation on concrete mixed with fibre using waste materials.

Heshmi and AL-Mahaidi: Heshmi And Al-Mahaidi (2012) have done a research work on reinforced concrete beams strengthened with CFRP textile and fabrics using cement based adhesives at high temperature. Most of the researchers used epoxy resins for strengthening flexural members with FRP sheets/laminates. In this work clips were used to attach the steel mesh with the soffit of the RC beam and mortar is used to fill the cover portion and protect steel mesh.

Dr. M.M Awati, S.S.Mohite And R.A.Patil : Dr. M. M. Awati, S.S.Mohite and R. A. Patil(2014) conducted study on flexural behaviour of R.C. beams with side carrying capacity for the M20 grade concrete beams is increased by 50 % after strengthened with full U wrapping of GFRP compared with the reference beam.

Ismail M.I. , Qeshta , Payam Shafigh ,Mohd Zamin Jumaat,Aziz Ibrahim Abdulla Zainah Ibrahim And Ubagram Johnson Alengaram : Ismail

M.I. Qeshta, Payam Shafigh, Mohd Zamin Jumaat, Aziz Ibrahim Abdulla, Zainah Ibrahim and Ubagaram Johnson Alengaram (2014) carried out work on the use of wire mesh– epoxy composite for enhancing the flexural performance of concrete beams. The use of wire mesh–epoxy composite constitutes a new technique to significantly enhance the performance of concrete in flexure. All specimens bonded with wire mesh exhibited an increase in first crack load. This increase is associated with the increase in the number of wire mesh layers.

III. METHODOLOGY

18 beams with a cross section (100mm x 150mm) and a total span of 1000mm were cast and tested. All beams have two ordinary low-carbon steel bars with a diameter of 10 mm as the bottom reinforcement, and two ordinary low-carbon steel bars with a diameter of 6 mm as the top reinforcement. In addition, the beam is equipped with common mild steel stirrups with a diameter of 6 mm and a spacing of 50 mm, as shown in the figure. All beams are tested under a two-point load. Before strengthening, all beams are tested and loaded to failure. The cracks in the beam were filled with grouting mortar. After that, the beams were reinforced and remodeled with steel mesh. As shown in the figure, use steel bolts and vertical steel clamps to fix the steel mesh on the deformed beam. Reinforcing bars and modern beams are divided into the following groups: Group 1: Four beams were strengthened and modified using galvanized steel welded wire mesh with a diameter of 3.5 mm. Group 2: The use of 3.5 mm diameter galvanized steel welded wire mesh to strengthen and modify six beams. Group 3: Five beams were reinforced and modified with welded galvanized steel mesh of 5.5 mm in diameter. The table shows all the details of the test beam. During the test, the applied load, the vertical deflection of the beam at the midpoint of the span, the deformation of the internal steel bars, and the deformation of the steel angle were recorded. In addition, the last measured load and the maximum vertical deflection in the middle of the control beam are also recorded.

IV. TEST RESULT

A Ultimate load capacity and initial cracking: Inferred from Table 4, the flexural bearing capacity of the reinforced specimens in group A increased by 110.24% on average, while the bearing capacity of reinforced beams in group B increased by 162.96% on average compared to the control beam. In the bonded G.F.R.P. laminates. They found that the load same way, the average ductility is increased by 179.43% compared with that of the A group of reinforced beams, and the B group of reinforced beams is increased by 117.67%, as shown in Table 4. The load-deflection curves of each sample in Figure 9 and Figure 10 show the steel bars tested in group A and group B compared with the control beam. Compared with the control beam detailed in Table 4, the reinforced specimens showed an average increase of 10.39% and 13.50% in the initial cracking load of group A and group B.

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The average cracking load of the reinforced samples in the A and B groups is at the same level as the average cracking load obtained by the integrally cast beam. The increase in bending resistance and ductility of the two groups is attributed to the addition of SWM reinforcement in the sheath, which increases the effective depth of the reinforced beam, and is improved due to the constraints of all three beam surfaces provided by SWM. According to the results obtained by the two groups, the higher the SWM reinforcement rate, the higher the ultimate bearing capacity reached. B. Deflection: In the final stage, the average deflection of the steel bar specimens in group A is 60.28% higher than the average deflection of the control beam, while the average deflection of the steel bar specimens in group B is as high as 59.93%. In a different sense, these specimens are more ductile than control beams.

Table: Main test results.

Beam Code	Type	Cracking load (kN)	Cracking deflection (mm)	Capacity "Ultimate" load (kN)	Capacity "Ultimate" deflection (mm)	Ductility ratio	Failure mode
C.B0	Control	28.76	4.01	34.31	9.05	2.257	Flexural
C.B1		28.67	3.73	44.12	10.1	2.708	Flexural
C.B2		24.06	3.45	38.78	8.65	2.507	Flexural
MA.B1	Monolithic Control Beams	24.25	1.82	81.83	13.765	7.563	Flexural
MA.B2		31.96	2.31	87.18	13.11	5.675	Flexural
MB.B1		28.51	1.62	110.55	13.47	8.315	Flexural
MB.B2		31.06	2.13	103.65	12.196	5.726	Flexural
GA.B1	Strengthened beams Group A	35.62	2.69	79.99	12.75	4.740	Flexural
GA.B2		30.92	2.32	82.88	14.815	6.400	Flexural
GA.B3		28.53	2.03	79.46	12.85	6.330	Flexural
GA.B4		30.93	2.14	84.98	12.465	5.838	Flexural
GA.B5		27.75	1.99	84.60	20.95	10.528	Flexural
GA.B6		26.17	1.93	80.92	15.29	7.922	Flexural
GB.B1	Strengthened beams Group B	26.19	2.08	99.15	15.7	7.566	Flexural
GB.B2		35.65	2.98	107.98	16.99	5.701	Flexural
GB.B3		33.84	2.90	95.97	14.42	4.972	Flexural
GB.B4		33.14	2.68	107.33	13.08	4.881	Flexural
GB.B5		40.35	3.49	103.27	13.91	3.986	Flexural

*Ductility ratio is defined herein and after as the ratio between mid-spans deflection at the ultimate stage to that at first cracking load stage.

V. CONCLUSION

Based on results for the beams strengthened in flexure with wire mesh, the following conclusions are drawn:

A. The flexural strength of beam strengthened with wire mesh is increased when compared with control beam.
B. The flexural strength found to be increasing when the spacing of wire mesh reduces and the numbers of layers of wire mesh increases.
C. The ultimate load of strengthened beam increases with decreasing the spacing of wire mesh and increasing the number of layers of wire mesh.
D. The first crack load increases with decreasing the spacing of wire mesh and increasing the number of layers of wire mesh. But the more significant increase identified when the number of layers increases.

It can be concluded that use of wiremesh enhances flexural strength, decreasing size of wiremesh is found to be more economical than increasing layers of wiremesh.

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