RT&A, Special Issue № 1 (60)
Volume 16, Janyary 2021

A REVIEW ON "TORSIONAL BEHAVIOR OF RECTANGULAR REINFORCED CONCRETE BEAMS WITH ENCASED WELDED WIRE MESH FIBER."

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Abstract

It is well known that there are four structural actions like axial force, shear, bending and torsion are developed with respect to their nature of loading on the structure. Torsion is always considered as a secondary effect up to 1960's. After that we proceed from working stress method to limit state method and shall go to ultimate load one to reduce the factor of safety. Also the novel structures are designed by Architects, designers having attractive overhanging components prone to torsion effect in the structures. Concrete is probably the most used man made construction material in the world. Concrete is homogenous in nature and strong to resist compression but posses Quassi brittleness in tensile strength such deficiency can overcome by introduction of fibers in the body of concrete. Since from last three decades a lot of research has been done on fiber reinforced concrete subjected to pure torsion but if fibers proportion is more, then difficulties in proper concreting get increased and chances of producing balling effect of fibers which affects the homogeneity of concrete. In other hand the considerable studies laid on FRP techniques by using Glass fibers, Carbon fibers and recently ferrocement jacking utilized for strengthen the existing structures subjected to predominant torsion effect. Although such techniques are very effective for existing structures but requires more additional cost for FRP materials with adhesive and also tend to fire except ferrocement jacketing. But such FRP techniques not overcome the inherent weakness of concrete. However there is also way to utilization of encased Welded Wire mesh in the concrete due to its high tensile strength and can produced the micro cracks behaviour like fiber reinforced concrete for proposed new construction. Here is an attempt to study the behaviour of encased Welded Wire mesh in the concrete subjected to pure torsion.

Keywords: Quassi brittleness, Polymer fiber jacket, ferrocement jacket, WWMF.

I. Introduction

1.1 Concrete

Concrete is probably the most used man made construction material in the world. Concrete is homogenous in nature and also strong in compression. In spite of this, it has some serious deficiencies with respect to tensile strength, flexibility, resilience and ability to redistribute stresses. Generally such deficiency like low tensile strength of the concrete material is overcome by introducing the systems like reinforced concrete and pre-stressed concrete systems. But these systems can counter balance the tensile resistance by introduction of reinforcement and tendons in the body of concrete and not improving the inherent weakness of the concrete matrix.

1.2 Fiber Reinforced Concrete

To improve the material strength of matrix, the fibers were used from ages together such as straws, horse hair, jute fibers, etc. The structural use of concrete containing fibers started as late as in 1960's. The fibers are having various types out of which there is also categorization like metallic and non metallic fibers. The non metallic generally having less young's modulus than concrete which give high resistance to toughness and metallic fibers have higher young's modulus than concrete which acts as high tensile resistance. Such fibers having the shapes like hook ended, crimped shape, notch on ends etc. The shapes are useful to increase their mechanical bond with concrete matrix. Concrete with discrete fibers, as an additional ingredient in it, is known as fiber reinforced concrete (FRC). Out of the several types of fibers, the experimentations have proved the superiority of steel fibers and have been used extensively in engineering applications which is called Steel fiber reinforced concrete (SFRC). However if fibers proportion is more, then difficulties in proper concreting get increased and chances of producing balling effect of fibers which affects the homogeneity of concrete.

1.3 Concrete Jacketing

It is a one type of composite material can be used to strengthen of existing structural member. It can be categorized with utilization different materials to strengthen reinforced concrete structural members like reinforced concrete jacketing, steel jacketing, FRP confining or jacketing and ferrocement jacketing etc As per research topic concern here study get concentrated to polymer fiber jacking and ferrocement jacketing.

1.3.1 Polymer fiber jacketing

It has more than one century history since from 1905 but such material came in utilization for concrete structure effectively since from last three decades. The fibers are generally glass fiber, carbon fiber, aramid. Also other fibers produced from papers, woods, asbestos sheets have been used. But all above said fiber sheets required good quality adhesive to achieve proper surface bonding with concrete body. FRP materials have very high tensile resistive property but also having relatively less young's modulus than concrete. Again they posses poor compressive stability so there is need to use as a composite material with concrete. The FRP can be differentiating with respect utilization of types of materials like GFRP, CFRP, aramid etc.

1.3.2 Ferro-cement jacketing

Since the mid-nineteenth century the ferrocement concept gets raised. Ferro- means containing iron. Hence ferro-cement which is made with wire mesh of small diameters having the ratio 1:3 of cement and sand. Ferrocement is used in making boats, planks for shelves in low cost housing projects, construction of sewage manhole covers etc. However there is also utilization of Ferro cement full, U shaped jacketing with full wrapping or in strips for structural members.

All above said concrete jacketing can be used in civil engineering application with respect to their raw materials availability, exact need, costing and suitability etc.

1.4 Torsion

In our structural mechanics concern there is consideration of axial, flexural, shear and torsional loads and with respect to that there is requirement of efficient structural designs. Out of which torsion is of paramount importance in the design of beams curved in plan, long span overhangs of balconies, canopies for auditoriums, stadiums, mezzanines, extra wide deck bridges with single piers, clear span gantry shops in factories, deck overhangs for aero planes hangers and so on. Although torsional stresses occur in many reinforced concrete structures, torsion was mostly neglected by design engineers before 1960's. It was assumed that torsional effects were minor and could be taken care of by the large safety factors used in flexural design. This assumption has been the principal reason for many cases of torsional distress and failure. It was only in the late 1950's that the torsional load began to attract serious interest of the design engineers. Also researchers moved from working stress to limit state and shall go to ultimate one to reduce the factor of safety and the novel structures are designed by Architects, designers having attractive overhanging components prone to torsion effect in the structures. So the negligence of torsional effects was no longer acceptable as the safety factors were more rationally defined.

II. Literature review

Before going to a detailed discussion on types of concrete Jacketing by various researchers of rectangular beams subjected to pure torsion. First there is need to considered various theories[10] developed to predict the torsion strength of plain concrete members. There are three theories available to calculate the torque carrying capacity of plain concrete. First one elastic theory considering Saint venant's elastic coefficient in year 1855 then plastic theory considering membrane and sand heap analogy from year 1903 to 1923 and lastly Skew bending theory considering with experimental observation in year 1968.

However test on specimens showed that elastic theory gives every times underestimates and plastic theory gives higher value which is not get in actual experiments means failure strength of plain concrete is between both theories. Then Hsu [2] proposed the equation based on skew bending theory for the plain concrete. In this theory he considered that beam specimens get failed similar like that specimens failed due to bending of beam. Only here the bending axis is considered as a skew axis acted 45° with longitudinal neutral axis of beam subjected to transverse loading. Based on the experimental investigations he formulated an empirical equation given as

$$T_c = 0.13\, x^2\, y \sqrt{f_{cu}} \tag{2.1}$$

Where,

T_c = Ultimate torsional strength of plain concrete.
x = Overall width of the cross section of the beams.
y = Overall depth of the cross section of the beams.
f_{cu} = Cube strength of plain concrete.

For the estimation of ultimate torsional strength of rectangular concrete beams with conventional reinforcements, various theories were developed to overcome the limitations of classical theories. Rausch and Cowan proposed theories based on space truss analogy and whereas the one proposed by Hsu is based on skew bending theory.

Based on skew bending theory, Collins et. al [4] proposed the following model for the ultimate torque.

$$T_{u3} = 2.A_{lt}.f_{lty}.z_3.\sqrt{\frac{k_3.p_3.b}{d}} \tag{2.2}$$

Where,

T_{u3} = Ultimate torsion moment available in mode3.
A_{lt} = C/s area of top longitudinal bar.
f_{lty} = Yield stress of top longitudinal steel.
$k_3 = \dfrac{b}{2d+b}$ = Torsion constant.

$z_3 = d - c_{lt} =$ Distance of Lever arm

c_{lt} = Concrete cover measured from the centre

$p_3 = (a_s . f_{sy} . d)/(A_{lt} . f_{lty} . s)$

b ,d = width and depth of rectangular section.

The space truss theory for torsion in concrete is any single theory which has received general and worldwide acceptance. Pandit G.S. [7] research is carried out to check influence of symmetrical and unsymmetrical reinforcement in rectangular section. The study is based on unsymmetrical reinforcement so the formula is generated by him to determine the ultimate torque or load carrying capacity given as follows

$$T_{ut} = 2.A_o \sqrt{\frac{a_{lt} . f_{lty}}{l_t} \frac{a_s f_{sy}}{s}} \tag{2.3}$$

Where,

T_{ut} = Ultimate torque carrying capacity.

$A_o = b_1 \times d_1$ = Area enclosedby shear flow.

$b, d =$ Shorter and longer dimensions of rectangle formed by connecting the corner longitudinal bars.

a_{lt} = Area of one longitudinal bar near top.

f_{lty} = Yield stress of longitudinal bar near top.

l_t = Spacing of longitudinal bar near the top.

a_s = Area of one leg stirrups.

f_{sy} = Yield stress of Stirrup steel.

s = Spacing of Stirrup steel.

In due course time Lampert-Thurlimann [3] and also Kuyt [6] modified Hsu's model by proposing a coefficient of reinforcement factor given as below

$$T_{urs} = 2\sqrt{m}\ \frac{x_1\ y_1\ A_t\ f_{sy}}{s} = 2\sqrt{m}\ T_R \tag{2.4}$$

Where,

T_R = reinforcement factor

$$m = \frac{\rho_l\ f_{ly}}{\rho_s\ f_{sy}}$$

Also,

ρ_l = volumetric fraction of longitudinal reinforcement; and

ρ_s = volumetric fraction of transverse reinforcement.

f_{ly} = yield stress of transverse reinforcement.

f_{sy} = yield stress of transverse reinforcement.

2.1 Steel fiber reinforced concrete (SFRC)

On the basis of significant and considerable study has been laid on steel fiber reinforced concrete rectangular beams since from three to four decades back in very well manner. As discussed earlier

that steel fiber contains higher yield strength and good bond property relationship with plain concrete so obviously steel fiber reinforced concrete give improvement in ductility effect, durability and strength etc. of concrete means to overcome the inherent weakness of concrete. Various Authors has studied well and also made theoretical analysis in the form of Hsu's skew bending theory with modification depends upon aspect ratio and volume fractions of steel fibers. Some of them laid steel fibers contribution in torque carrying capacity in the form of cube, split tensile and flexural strength means not directly correlated with fiber mechanical properties.
However in later study by Narayanan and Kareem Palanjian [12] who proposed the model to calculate torque carrying capacity of SFRC beam specimens with considering plain concrete contribution before cracking and steel fibers contribution after cracking individually. The ultimate torque or load carrying capacity is given by the equation.

$$T_{uf} = T_c + T_f = 0.13\, x^2\, y\sqrt{f_{cu}} + \frac{0.22\,\lambda\, x_0\, y_0\, x\, y\, F\sqrt{f_{cu}}}{(x_0 + y_0)} \quad (2.5)$$

Where,
Tc = Contribution of concrete same as that proposed by Hsu for plain concrete.
Tf = the contribution of fibers formulated equation based on space truss analogy.
F = $\frac{l}{d}\ \rho d_f$, Fiber factor directly proportional to volume fraction of fibers.

They replaced term of cube strength of plain concrete in Hsu's skewing bending theory by introducing fiber factor of cube strength of fibrous concrete and developed space truss model to calculate contribution of steel fibers containing their fiber aspect ratio and volume fractions. Such authors produced fiber factor 'F' due to which torque carrying capacity is directly proportional of that fiber factor. After that Pant and Parekar [18] carried out experimentation and comparison with previous research works and concluded that at a certain stage due to combination of aspect ratio and volume fraction of steel fibers, the balling effect get produced in the concrete body. The fiber coefficient 'Γ' is given as follows

$$\Gamma = 1/0.17 * \sin(15.25/(l/d.vf)) \quad (2.6)$$

So steel fiber contribution in torque carrying capacity is not directly proportional with fiber factor means fiber factor not increases the torsional strength linearly. Hence the ultimate torque or load carrying capacity is given by the equation.

$$T_{uf} = T_c + T_f = 0.13\, x^2 y\ \sqrt{fcu} + \frac{0.22\Gamma\,\lambda\, x_0\ y_0\, F\sqrt{fcu}}{(x_0 + y_0)} \quad (2.7)$$

Also Ghugal [19] has carried out analysis on steel fibers effects on different mechanical strength of concrete in that he mentioned the balling effect of steel fibers due to excessive percentage in the concrete body. So if fibers proportion is more, then difficulties in proper concreting get increased and chances of growing balling effect of fibers which affects the homogeneity of concrete.

2.2 Polymer fiber jacketing or FRP like CFRP, GFRP, ARAMID fiber etc.
As already mentioned above that strengthening of reinforced concrete beams with FRP reinforced systems have been utilize from around 1980s. FRP systems can be used for increasing shear strength of reinforced concrete beams in the form of completely or partially wrapping FRP systems around reinforced concrete member. Polymer fiber jacketing can be utilized four sided completely wrapped, three sided U-shaped wrapped and two sided vertically wrapped as per working condition, requirement and costing etc. ACI 440.2R-08 provides the guild line to shear design procedure by using FRP material. So with respect to concern topic the review of polymer fiber jacketing is carried out as follows.

Constantin E.Chalioris [20] has carried out experimentation on reinforced concrete beams

specimens. Such testing specimens are strengthen with fiber reinforced polymer material. He took experimental values from twenty four specimens which was taken from other researcher's documents with respect to that he casted and tested twelve numbers of specimens. As a results of that he proposed two different numbers theoretical models .first is a smeared crack model and second one is soften truss model . smeared crack model is considered up to pre cracking stage of specimens and second model useful for for post cracking stage for reinforced concrete specimens. Such prediction of models done on the basis of comparisons between analytically predicted behaviour curves and experimentally obtained results. This study offered elastic and after cracking response of reinforced concrete beams strengthen by FRP materials under the torsion phenomena.
Constantin E.Chalioris et al [21] concentrated the investigation on influence of carbon reinforced fibers used to contribute torque carrying capacity of specimens. In the experimentation they casted fourteens numbers rectangular and T-shaped beams without stirrups reinforcements but containing bonding of carbon reinforced sheets and strips acted as an external transverse reinforcement. All beam specimens tested under pure torsion action and made theoretical analysis of that. In the study they checked various parameters like cracking torque, ultimate torque with respect to their twists, and also observed the failure modes of the beams. The results concluded that the performance of rectangular beams having fully continuous wrapping are well in manner against ultimate torque as compare to beams which wrapped with FRP strips. Again the study showed that there is debonding failure gets occurred in U-shaped jacketing but FRP bonding could be effective in under reinforced elements.

A.R. Zojaji, M.Z. Kabir [22] has developed a theoretical model known as Softened Membrane Model for Torsion (SMMT) used to determine ultimate torque capacity of RC beams strengthen by FPR materials. Such SMMT developed by using tension stress equilibrium equations. To validate this proposed model they compared the test results obtained from both solid and hollow rectangular shaped beams. At last study showed that the proposed softened membrane model is reliable to determine the cracking and ultimate torques of RC beams strengthen by FRP fabrics. They studied about strengthening of beam specimens with various configuration varieties and observed each variety of configuration illustrated as well.

Shraddha B. Tibhe , Vijaykumar R. Rathi [23] investigated the performance of rectangular reinforced concrete beams contained with FRP as an external reinforcement to increase the torque carrying capacity. They casted total 39 numbers of specimens having the size of 1500mm x 300mm x 1200mm.In that three numbers of beams are known as control beams and remaining 36 numbers casted with FRP materials. Such FRP materials has categorized in two groups with utilization of CFRP and GFRP fabrics in various wrapping patterns. The wrapping patterns like U-shaped jacketing, vertical strips having particular spacing and combination of edge strips with vertical strips throughout the length of beam specimens. The study of beams has carried out with consideration of factors like torsion moment, angle of twist and ductility. Finally they concluded that beams bonded with CFRP fabrics showed more torsion resistant than GFRP bonded specimens.

Rafid Saeed Atea[24] has done experimentation to study about contribution of carbon fiber reinforced polymer (CFRP) against torsion resistant of beam specimens. They casted and tested total 12 numbers of reinforced beam specimens having T shaped do not contain and contained with CFRP fabrics. The study considered the continuity effect of beam and slab elements so here three sided wrapping by CFRP fabric are considered. In the test program two numbers of beams are controlled specimens no containing of CFRP fabrics and remaining are casted with various varieties. They checked effect of orientation of CFRP strips like 90° & 45° with respect to longitudinal axis, combination of transverse and additional longitudinal strips, effect of bolt anchorage and effect of utilization of continuous sheet between wed and flange. They studied the behavior of specimens in the form of torque-twist curves, strains produced in fabrics and concrete, torque in cracking and in ultimate respectively.

Sachin B. Kandekar , Rajshekhar S.Talikoti [25] investigated the behaviour of beam specimens covered with aramid fiber sheet. They selected mix design M30 grade for the same. The research 53 mentioned that the aramid fiber is the first organic fiber with high enough young modulus and strength which can be used as reinforcement in composite materials. The research concentrated to sudden failure occurrence at due to excessive loading and also affected due to seismic prone area. Hence the beams specimens get strengthen by aramid fibers sheet using of U shaped sheets. They casted and tested total 12 numbers beams specimens out of that three beams were designed for torsion moments and remaining nines were designed as conventional beams. Such design of beams were carried out as per IS456-2000 .The size of specimens kept 150mm x 300mm and 1m in length. The epoxy resin adhesive was used to maintain proper bonding of armaid fiber with concrete surface. The specimens were covered by such fiber sheets in continuous forms and in the form of 100mm wide strips along three sided faces of beams. The parameters like cracking and ultimate torque, angle of twist and twisted shapes of beams were observed. . Results showed that continuous wrapped RC beams sustain more torsional resistant with repect to other one. Also it is observed that beams in wrapped strips showed significant improvement in torsional strength.

2.3 Ferro-cement jacketing

As above said that ferrocement is used in making boats, planks for shelves in low cost housing projects, construction of sewage manhole covers etc. It can be also utilized for ferro cement full, U shaped jacketing with full wrapping or in strips for structural members. Such strengthening of RCC beams by using ferro-cement jacketing is one types of the alternative technique to polymer fiber jacketing. This system can overcome the tendency of fire than polymer fiber jacketing system. Hence as per topic concern let review ferro-cement jacketing technique as follow.

Dr. Gopal Charan Behera [29] attempted a research study on ferro cement jacketing which improves the torsion capacity of RC beams. In this research U wrapping technology has used for the same. Also this study gave an alternative technique instead of utilization of polymer jacketing to overcome their demerit. In experimentation program they casted beam specimens containing variation in different number of wire meshes and different reinforcement systems. The conventional reinforcement having variation like only longitudinal, fully under, partial and over reinforcement are considered. Again variations of the number wire mesh layers, size aspect ratio, mortar strength, concrete strength are considered. The three, four and five wire mesh layers are considered in the specimens. The author also developed the analytical model and soft computing method MARS to predict the analysis of beams. The analytical model is based on softened truss model of Hsu with modification on material properties. The test results get compared with theoretical one and observed in good agreement with experimental test results.

G.C. Behera, M.R.Dhal [26] investigated the ductility of beam specimens i.e. angle of twist at ultimate loads. The beams were strengthen by wrapping with U shaped ferrocement jacketing system. The test program contained with normal strength as well as high strength mortar and concrete grades. The total thirty numbers of beam specimens were casted and tested having variation in wire mesh layers and variation in torsion, shear and flexural reinforcement with and without U-shaped ferrocement wrapping. The MARS soft computing method is used to compute the theoretical values of specimens. The comparisons of angle twist at ultimate torque showed good in agreement with experimental test results.

Gopal Charan Behera et al. [27] concerted the study about ferro cement U shapped jacketing as a replacement of FRP jacketing used for retrofitting, repair and rehabilitation purpose etc. There are some demerits of FRp jacketing like it requires special adhesive, prone to fire and high in cost etc. However such ferrocement jacketing which has better cracking capacity, high in strength and good

bonding with concrete surface etc. So in the experimentation author has casted and tested total six numbers beam specimens containing with and without wire mesh covering. The all beams including control beam made up by utilizing only shear reinforcement and also author used variation of numbers of wire meshes. The observation showed that the torque twist response of ferrocement U-jacketing beams is just seems like that response given by reinforced concrete beams. So they concluded that only introduction of transverse reinforcement is not an effective way of increasing the torsional strength but only increase in toughness is found to be marginal.
Gopal Charan Behera et al. [28] has done the experimentation in that twelve numbers of rectangular beams were casted and tested under pure torsion. The variation in beam casting has been done by keeping variation in longitudinal, transverse and fully reinforcement with and without ferrocement U-jacketing. The study of research is aimed to determine the effectiveness of the using U-shaped wrapping of number of wire mesh layers under pure torsion.. The results concluded that "U" shaped wrap jacketing are found to better contribution in torque carrying capacity under the torsion. The under reinforced concrete beams provide better toughness over other types of tested specimens. Also over reinforced beams showed more torque resistive than the others. The improvement in torsional strength contained with number of mesh layers in ferrocement "U" wrap is minimal.

2.4 Encased Weled wire mesh influenced on shear strength of RCC beams

The considerable work has been done in the utilization of welded wire mesh as shear reinforcement which influenced on shear as well as flexural strength of RCC beams. The study of this topic showed that WWMF can use as shear reinforcement of the replacement of conventional stirrups. However as per research topic concern there is need to study the effect of encased WWMF in torsional strength of the RCC beams. As per reviewing of concern topic literature till date effect of encased WWMF in torsional strength is not investigated by anyone of the researchers but as per mentioned above that sufficient amount of research is available on the welded wire mesh allotted a good shear strength to RCC beams. It is well known that the torsional capacity of RCC beams is totally depends upon shear reinforcement and not on flexural reinforcement. So here is an attempt to study the behaviour of RCC beams under shear load mentioned as below.

M. A. Mansur et al [39] studied the anchorage of U shaped welded wire fabric as shear reinforcement in the beams. Seventy numbers of pull-out tests were made to investigate the influence of various parameters that affect the anchorage. Also four numbers of simply supported overhanging beams were tested to study their cracking behaviour and ultimate strength. Test results indicate that welded cross wires can provide adequate anchorage with respect to their relative size and spacing of these wires and the beams can attain the desired shear capacity for the same. They were utilized the plain and deformed welded wire for experimentation purpose. The use of deformed welded wire fabric significantly improves the cracking characteristics of a beam with comparison of an equivalent amount of smooth welded wire fabric. On the basis of the investigation the conclusive remarks has been drawn by the authors that Stirrups can be adequately anchored by using welded cross wires instead of the conventional way of providing a bend or a hook. However, a decrease in the diameter of cross wire decreases its effectiveness. As a result, cross wires of the same diameter as the main wires can provide equally effective anchorage.
When two cross wires are used, the ratio of the diameter of cross wire to that of stirrups should be at least 0.8 for both smooth and deformed welded wire fabric. The 90° bend showed the marginal improvement in the anchorage than 45° and 135° respectively. The results also showed that the performance of an anchorage of welded wire mesh has significantly improved with an increase in the grade of concrete. Also deformed welded wire fabric as web reinforcement in beam provides a significant improvement in the control of diagonal cracking than an equivalent amount of smooth welded wire fabric.

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Xuan et al [40] tested a total six pre-tensioned prestressed T-beams with identical flexural reinforcements and carious shear span to depth ratio statically up to failure to investigate the effectiveness of welded wire fabric as shear reinforcement. The tested beams contained one beam without shear reinforcement and remaining five beams with different types of shear reinforcements. It included conventional double-legged stirrups, single-legged stirrups, and three different types of commercially available welded wire fabric. They studied the experimentation with various factors like Crack widths, stiffness, ductility and ultimate shear strength of the beam. The results indicated that the effectiveness of WWF as shear reinforcement is just like the same as that of conventional stirrups under static loading conditions. The contribution of the shear reinforcement based on the ratio of the difference between measured Ultimate Vu and corresponding cracking load Vcr to the yield strength (Av.fy) of the stirrups is compared. As per showed in Fig.2.1 the values of mentioned ratio confirm the fact that the shear-carrying mechanism is not as simple as assumed by the 45 deg truss analogy according to the ACI Building Code. However, the consistency of the results indicates that the effectiveness of WWF as shear reinforcement is similar to that of conventional stirrups but improvement in the distribution of the diagonal cracks. The Crack widths observation concluded that these are essentially the same for all types of shear reinforcement configuration up to the initiation of major diagonal cracks. However, beyond that, the slight differences in the crack widths were developed with respect to shear reinforcement and not by the type and configuration of shear reinforcement. Also observed that the stress concentration created due to tack-welds and limited ductility of the cold-drawn wires does not influence the effectiveness of WWF as shear reinforcement. The additional horizontal wire at the mid height of WWF had no significant influence on crack pattern, crack width, and the stiffness of the beam. However, it could enhance the ductility as well as the ultimate shear strength of the beam.

Hence the welded wire fabric used as shear reinforcement should exhibit adequate ductility to insure the overall ductility of the member.

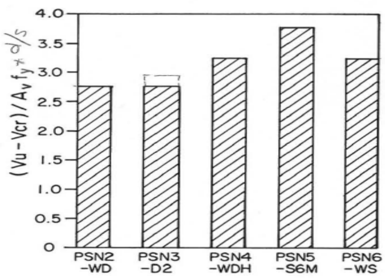

Fig.2.1: *Measured contribution of shear reinforcement*

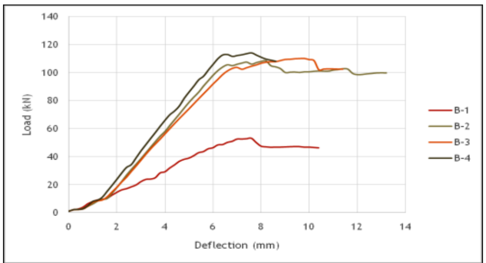

Fig.2.2: *Load vs Displacement for beams*

M.P.Sridhar et al [41] studied shear performance of RC beams specimens containing with and without welded wire mesh. They used variation of shear reinforcement like beams with stirrups alone, only using of wire mesh and combination of both wire mesh and stirrups. The wire mesh proportion has been taken with respect to weight with stirrups. To achieve better performance of concrete in workability, placing and even to achieve good compressive, tensile strength the high rage water reducing agent (HRWRA) is used in the concrete mix. In the experimentation there were four numbers of beams specimens casted. The results showed that utilization of welded wire mesh increases the shear capacity compared with others. The specimen contains only wire mesh as a shear reinforcement observed well in ductility as compared to conventional stirrups beam. Also there is considerable effect can be observed on crack patterns by using of wire mesh. The observed effects are increase in numbers of cracks, delaying in cracks and reduction in cracks width etc. Fig.no.2.2 showed the load vs displacement graph of the readings obtained from the testing of specimens. The

results also showed that the performance of beam using only wire mesh and beam using combination of stirrups and wire mesh are similar in nature which failed due to flexural failure.
Balasubramanian and Radhakrishnan[44] studied structural behavior of welded wire reinforcement in reinforced concrete beams which has been divided into two aspects: the effect of different types of reinforcement grids in rectangular beams and the effect of structurally performing grids in T – beams. In the first aspect, all the models with normal strength concrete (4500 psi), and the effect of different types of reinforcement grids (B1RC, B2WWR, B3WWR, and B4WWR) and strength (60 ksi and 80 ksi) has been evaluated and in the second aspect, T-beam specimens have been subjected to a four point bending test. Concrete and steel properties are kept the same for all models subjected to the four points bending test and uniformly distributed loading. They checked the beam behavior with respect to various parameters like moment capacity, shear capacity, Maximum strain and ductility etc. Also they carried out non-linear finite element analysis performed using ABAQUS for both the control beam (B1RC) and the WWR beam (B4WWR) which behaves similarly in load and strain patterns.

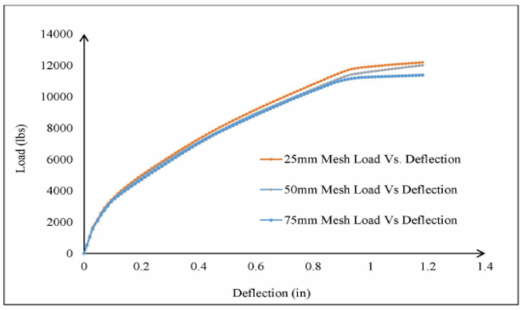

Fig.2.3: *Load Vs Deflection Graph for control Beam B1RC*

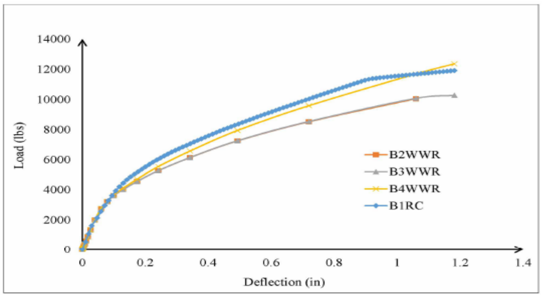

Fig.2.4: *Load Vs Deflection Graph for for Rectangular Beams*

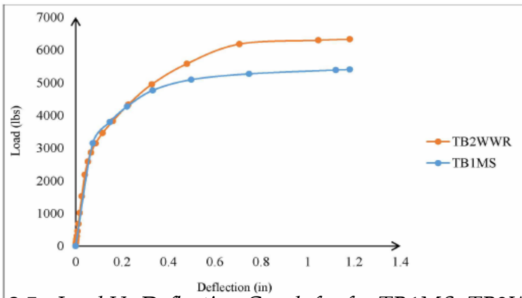

Fig.2.5: *Load Vs Deflection Graph for for TB1MS, TB2WWR*

Above figures showed the load verses deflection curves of the mentioned types of beam specimens. WWR beams B2WWR and B3WWR follow the same pattern of load versus deflection behavior, but being reinforced with 50% of the flexural reinforcement and the percentage difference in the load carrying capacity between the two beams is minimal. B2WWR and B3WWR have a 21.94% decrease in moment capacity when they were compared to B1RC beam. The ductility increase was 16.55% between B2WWR, B3WWR and B1RC when subjected to a four point bending test. B2WWR and B3WWR carrying 50% of flexural reinforcing on the tension side have a 3.44% decrease in moment capacity and a 17.19% increase in shear capacity when compared to B1RC beam subjected to a uniformly distributed load. Based on the mentioned comparison, WWR beam B4WWR can be used as an alternative for the control beam B1RC. Being reinforced with 75% of flexural reinforcing of TB1MS beam, there is a 42.93% increase in moment capacity between TB2WWR and TB1MS beams. According to the results of the present study, it can be concluded that WWR (80,000 psi) can be a better alternative over traditional reinforcing bars (60,000 psi). Welded wire reinforcement grids have a highest flexural capacity with less reinforcing area and with smaller diameter bars, which enhances load transfer mechanism.

III. Conclusion

3.1) Steel Fiber Reinforced Concrete

After observing the literature about SFRC various researchers has been study well about said subject and carried out in the form of cube ,split tensile and flexural strength means not directly correlated with fiber mechanical properties. However Narayanan and Kareem Palanjian who laid their theoretical investigation on the basis of space truss analogy with separate contribution of torque carrying capacity by steel fibers. They proposed that the increase in torsion strength is linearly depends upon the percentage increase in volume of fiber. After that Pant and Parekar carried out experimentation and comparison with previous results of researcher and concluded that torsion strength by SFRC is non-linearly with fiber percentage and also concluded that chances of producing balling effect of fibers due to excessive percentage of fibers in the concrete body.

3.2) Polymer and ferrocement Concrete jacketing

After studying the literature review retrofitting techniques can be classified in two groups 1) Retrofitting by polymer fiber jackets 2) Retrofitting by Ferrocement jackets.. The first group contains various materials like carbon reinforced polymer, fiber reinforced plastics/polymer, glass reinforced fiber polymer and aramid fibers etc and ferrocement wire meshes can be available in various sizes. Researchers considered from both categories has investigated well and some of them has formulated theoretical analysis in the form of FEM models and one of researcher developed softened truss model which is based Hsu model with material properties modification. Remaining some researcher produced equilibrium and compatibility equations based on elastic theory. fiber polymer jacketing materials showed their good effects in crack arresting mechanism, ductility and in contribution of torque carrying capacity but other hand some specimens get deboned before reaching up to ultimate loads. In case of jacketing done by ferrocement it is observed that ferrocement can be utilized as a replacement of polymer fiber jacketing to avoiding demerits created due to such materials. But ferrocement jacketing cannot achieve by using one layer of wire mesh. There may require numbers of wire mesh layers to acquire considerable enhance in torque capacity of beam specimen. Again there is no exact correlation between the ratio of percentage increase in torque carrying capacity with increase in number of wire mesh layers.

3.3) Encased Welded wire mesh influenced on shear strength of RCC beams.

As per concern of using of WWMF in concrete beams various authors has done well research work for the same .Some of them using of cold-drawn steel wire mesh some of using deformed with same size of main and cross wire and/or different sizes of main and cross wire etc. obviously the shear capacity of welded wire mesh is depends due to its high tensile strength but it should be properly anchored. So in M. A. Mansur's research the 90° bend showed the marginal improvement in the anchorage than 45° and 135° respectively. Also Investigation proved that the utilization of wire mesh made significant effect on crack pattern of the reinforced concrete beams with delaying the crack appearance, increasing the number of crack and reducing the crack width etc. Again some researchers observed that due to the stress concentration created by tack-welds and limited ductility of the cold-drawn wires does not influence the effectiveness of WWF as shear reinforcement. So there is necessary to use the additional horizontal wire at the mid height of WWF which could enhance the ductility as well as the ultimate shear strength of the beam. One of author on the basis his experimentation observed that beams with wire mesh as shear reinforcement and combination of both wire mesh and stirrups exhibited some amount of increase in shear capacity with respect to the beams with stirrups alone as shear reinforcement.

Hence after studying the literature the welded wire mesh gives an effective contribution in shear load carrying capacity of reinforced concrete beam. Also encased WWMF acted as a crack arrester on the surface of reinforced beam which produces micro crack behavior in the concrete.

References

[1] Anderson, P "Rectangular concrete sections under torsion." Journal of American concrete Institute, September-October 1937, Proc. Vol.34, pp.1-11.

[2] Hsu, T.T.C., (1968), "Torsion of structural plain concrete rectangular sections." American concrete Institute, Detroit, Special Publication SP 18, PP 203-238.

[3] Lampert and Thurlimann,B."Torsion tests on reinforced concrete beams."Bericht No. 6506-2,Institute of Baustatik (ETH),Zurich,June 1968 (in German).

[4] Collins M.P.;WalshP.F.;Archer F.E.and Hall A.S."Ultimate strength of reinforced concrete beams subjected to combined torsion and bending."Torsion of structural concrete ,SP-18,American concrete institute ,Detroit,1968,pp.307-336.

[5] Iyenger K.T.S. and Rangan B.V. "Strength and Stiffness of reinforced Concrete beams under combined bending and Torsion." Torsion of Structural concrete, SP-18, American Concrete Institute, Detroit,1968,Pp. 403-440.

[6] Kuyt B(1971); "A theoretical investigation of ultimate toque as calculated by truss theory and by the Russian ultimate equilibrium method";Magazine of the concrete research,23,No.77,pp 155-160.

[7] Pandit G.S.(1974);"Ultimate torque of rectangular reinforced concrete beams containing steel fibers."Journal of the Structural Division,ASCE 96,ST9; pp 1987-1995.

[8] Pandit G.S. and Venkappa V.(1980);" Ultimate torque expression-A critical reappraisal "; Indian concrete Journal; 54,No.12;pp 320-325.

[9] Hsu, T.T.C. and Mo Y.L,"Softening of Concrete in Torsional Members-Theory and Tests," Journal of American concrete Institute, Proc. Vol. 82, No.3 May-June 1985,pp,290-303.

[10] Hsu, T.T.C., Y.L.Mo,"Unified Theory of concrete structure," @2010 John Wiley & Sons, Ltd.

[11] M.A. Mansur and P. Paramasivam "Steel fiber reinforced concrete beams in pure torsion" International Journal of Cement Composites and Lightweight concrete, Vol.4, No.1, February 1982, Pp.39-45

[12]] R. Narayanam and Kareem palanjian(1983): "Steel fiber reinfoerced concrete beams in torsion" International Journal of Cement composites and Lightweights concrete, Vol. 5, no. 4, November 1983, pp. 235-245

[13] Mansur M.A. and Lim T.Y. " Torsionalbehaviours of reinforced concrete beams" International Journal of Cement Composite and LightweughtsConrete. Vol .7, no. 4, November 1985, pp. 261-267

[14] Wafa, Hasant and Tarabolsi "Prestressedfuber concrete beams subjected to torsion" ACI Structural Journal, Title no. 89-S26, May-june 1992, pp. 272-286

[15]] EI-NIEMA(1993). E.I.Fiber reinforced concrete beams under pure torsion. ACI structural journal. September-october 1993. Pp261-267.

[16] Constantin E. Chalioris (2006). C.I Fiber reinforcement beams under pure torsion .stutctural jourmal.2006.

[17] S. pant avinash, R Suresh parekar (2009). Journal of civil engineering (IEB) , 38(1)(2010) 31-38

[18] A.S. Pant,S.R.Parekar "Steel fiber reinforced concrete beams under pure torsion"Indian concrete journal,June 2016,Volume 90,Number 6,Page no.30 -37.

[19] Ghugal Y.M. "Effect of Steel Fibers on Various strength of Concrete",ICI Journal (Indian Concrete Institute)-2003,Vol.no.,Octomber –Decemeber 2003,pp.No. 23-29.

[20] Constantin E.Chalioris,"Analytical model for the torsional behaviour of reinforced concrete beams retrofitted with /FRP materials." Engineering Structures 29(2007)3263-3276 proceeding by

Elsevier Ltd.

[21] Constantin E.Chalioris,"Torsional strengthening of rectangular and flanged beams using carbon fibre-reinforced-polymers – Experimental study." Construction and Building Materials 22(1):21-29 · January 2008.

[22] A.R. Zojaji, M.Z. Kabir "Analytical approach for predicting full torsional behavior of reinforced concrete beams strengthened with FRP materials." Scientia Iranica A (2012) 19 (1), 51–63.

[23] Shraddha B. Tibhe , Vijaykumar R. Rathi "Comparative Experimental Study on Torsional Behavior of RC beam usingCFRP and GFRP Fabric Wrapping." International Conference on Emerging Trends in Engineering, Science and Technology (ICETEST - 2015).

[24] Rafid Saeed Atea "Torsional behavior of reinforced concrete T-beams strengthened with CFRP strips." Case Studies in Construction Materials 7 (2017) 110–127.

[25] Sachin B. Kandekar , Rajshekhar S. Talikoti "Torsional behaviour of reinforced concrete beam wrapped with aramid fiber." 2018 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University. This is anopen access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

[26] G.C. Behera, M.R.Dhal "Prediction of Twist at Ultimate Torque of Ferrocement "U" Wrapped RCC Beams"International Journal of Engineering and Applied Sciences (IJEAS),ISSN: 2394-3661, Volume-3, Issue-6, June 2016.

[27] Gopal Charan Beheraa, Rao T.D.Gunneswarb and Rao C.B.Kb "Torsional strength of Ferro cement "U" wrapped Normal strength beams with only Transverse Reinforcement." The 2nd International Conference on Rehabilitation and Maintenance in Civil Engineering, sciverse science direct, Procedia Engineering 54 (2013) 752 – 763.

[28] Gopal Charan Beheraa,T.D. Gunneswara Raob, C.B.K. Rao "Torsional behaviour of reinforced concrete beams with ferrocement U-jacketing—Experimental study"ã 2016 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

[29] Dr. Gopal Charan Behera"Ultimate Torque Calculation of RCC Beams with Ferrocement "U" Wraps: Experimental and Analytical Study." IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 5, May 2016.

[30] Mane V V et .al. "A Literature Review on Various Types of Materials used for Full/U-Shaped Beam Jacketing Subjected to Pure Torsion." (IJRASET) ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177 Volume 7 Issue VII, July 2019- Available at www.ijraset.com.

[31] Mansur, M. A, Leong T. W., Lee S. L. and Tink, R. K.S. "Welded wire fabric as stirrups in beams.", Proceedings of the International Conference on Tall Buildings. Singapore, The Institution of Engineers, October 22-26 1984. pp. 387-392.

[32] "British standards institution.", The structural use of concrete CPI 10 : 1972. London.

[33] BS 4483:1985," Specification for Steel fabric for the reinforcement of concrete.", ISBN 0-580-14683-9.

[34] "Building code requirements for reinforced concrete.", American Concrete Institute Detroit, 1984. ACI Publication 318-84.

[35] "Hard-drawn steel wire reinforcing fabric for concrete.", Standards Association of Australia, Sydney, 1973. AS1304-1973.

[36] "Specification for hard-drawn steel wire fabric for concrete reinforcement", IS:1566–1982,(reaffirmed 2004), indian standard(second revision),second reprint march 1992,UDC 669.14-426-124.3:666.982.24.

[37] "Welded steel wire fabric for general use specification ", (second revision), IS:4948:2002 ,ics 77.140.55 q bis.

[38] "Structural Welded Wire Reinforcement.",wire reinforcement institute, inc., manual of

standard practice,excellence set in concrete, www.wirereinforcementinstitute.org, © copyright december 2016, wire reinforcement institute, inc.wwr-500, 9th edition.

[39] M. A. Mansur, C. K. Lee and S. L. Lee "Anchorage of welded wire fabric used as shear reinforcement in beams.", Magazine of Concrete Research: Vol. 38, No. 134: March 1986.

[40] Xiaoyi Xuan, Sami Rizkalia, and Kyuichi Maruyama "Effectiveness of welded wire fabric as shear reinforcement in pretensioned prestressed concrete T·beams.", ACI structural journal, July-August 1988, Title no. 85-S41, Page no.429 -436.

[41] M.P.Sridhar, K.P.Senthilnathan, M.Priyaadharashini, "Shear behaviour of RC composite beams.", International Journal of Chem Tech Research, 2016,9(3),pp 342-349.

[42] Elavarasi D, Sumathi A, "Behaviour of reinforced concrete beams with wire mesh as shear reinforcement.", International Journal of Innovative Technology and Exploring Engineering (IJITEE),ISSN: 2278-3075, Volume-8 Issue-12, October 2019.

[43] Mingzhe Cui, Xin Nie, Jiansheng Fan, Shengyong Li, Jun Liufu, Zhonghai Huang, "Experimental study on the shear performance of RC beams reinforced with welded reinforcement grids.", Construction and Building Materials 203 (2019) 377–391, journal homepage: www.elsevier.com/locate/conbuildmat.

[44] Balasubramanian, Radhakrishnan, "Numerical analysis of structural behavior of welded wire reinforcement in reinforced concrete beams.", Thesis, University of Alaska, Link to Item: http://hdl.handle.net/11122/6598.

[45] K.Soundhirarajan, Mr.T.Sathieshkumar, S.Karthikeyan."Flexural behaviour of RC beam with welded mesh as shear reinforcement.", International Research Journal of En`gineering and Technology (IRJET), Volume: 05 Issue: 05, May-2018,www.irjet.net p-ISSN: 2395-0072, e-ISSN: 2395-0056.

[46] Nithin K.R. , N Saravana Kumar, "Flexural behaviour of self compacting concrete beam using welded wire mesh as shear reinforcement.", International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064.

[47] Ajin.M,H. Gokulram," Flexural Behaviour of RC Beam With Welded Mess As Shear Reinforcement", International Journal of Engineering Sciences & Research Technology, March, 2015,ISSN: 2277-9655, http: // www.ijesrt.com,Pp no. 242-246.

[48] Alexander. D and Ramakrishnan.S., "Design of RC beam with and without welded mesh as shear reinforcement in flexural and shear behaviour.", International Journal of Advanced Engineering Research and Technology (IJAERT), Volume 4 Issue 6, June 2016, ISSN No.: 2348 – 8190, pp no. 214-217.

[49] Raveendiran.N, I.baragathulla, " Flexural behaviour of rc beam with welded mesh as shear reinforcement.", International Journal on Applications in Electrical and Electronics Engineering, Volume 4: Issue 2 : May 2018, pp 42- 44 www.aetsjournal.com ISSN (Online) : 2395 – 3527.

[50] "Welded wire fabric Concrete reinforcement with a new look", by Richard A. Ramsey, Manager, engineered sales, Ivy steel and wire company publication# c810803,Copyright © 1981, The Aberdeen Group,All rights reserved.

[51] "Welded wire mesh",Welded wire Retrieved from "https://en.wikipedia.org/w/index.php?title=Welded_wire_mesh & oldid=942995573" Content is available under CC BY-SA 3.0 unless otherwise noted.

[52] Frederic S. Merritt, M. Kent Loftin, Jonathan T. Ricketts, Standard, Handbook for Civil Engineers, Fourth Edition, McGraw-Hill Book Company, 1995, Page 8.17.

[53] Jassal, M., Ghosh, S., 2002. Aramid fiber – an overview. Indian J. Fiber Tex. Res. 27, 290–306.