A REVIEW ON STRENGTHENING OF RCC STRUCTURAL COMPONENTS WITH GFRP

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Abstract—**Reinforced Cement Concrete (RCC) structures are deemed no longer having the ability to sustain current capacity demands. Several factors can lead to the judgment of concrete structure as having insufficient capacity. Load increase is an important factor. Further factors that can have detrimental effects on capacity are corrosion of internal reinforcing steel due to the use of de-icing salts, changes in use, poor initial design and more stringent design codes. Replacement of every strength deficient structure is not only impractical, but also has serious economic consequences.Fiber Reinforced Polymers (FRP) has been seen as an excellent way of improving the function as well as the life span. FRP has some advantages compared to the conventional strengthening material. High strength, stiffness, corrosion resistance, ease of installation, simple repair methods, excellent durability, long service life, minimum maintenance and lower life cycle costs are among them.**
Glass Fiber Reinforced Polymers (GFRP) to strengthen RCC structures externally. The use of GFRPs is advantageous since the combination of high-strength, high-stiffness structural Fibers with low-cost, lightweight, environmentally resistant polymers results in composite materials with excellent mechanical and durability properties. One of these applications is Glass Fiber Reinforced Polymer (GFRP) sheets used in strengthening of reinforced concrete beam and column.RCC beams strengthened using glass Fiber reinforced polymer (GFRP) sheets were carried out. This paper reviewed on Strengthening of RCC Structural Components with GFRP.

Index Terms—FRP, GFRP, RCC Beam, RCC Column, Structural Components

I. INTRODUCTION

Great deals of society's resources have been invested in existing concrete structures, such as bridges, tunnels, different kind of buildings etc. All these structures have both an expected function and an expected life span. However, both the function and the life span can be influenced by external factors, e.g. degradation and altered load situations. Deficiency of structures may be the result of insufficient reinforcement, excessive deflections, poor concrete quality, reinforcement corrosion, or insufficient bearing capacity. In some cases, strengthening and repairing are necessary to make up for human mistakes at the designing stage or to solve execution errors during the construction [1]. For these purposes, various strengthening techniques have been developed to satisfy the increasing demand for load carrying capacity and/or fulfillment of certain serviceability requirements.
Repairing or strengthening of these structures could maintain or improve the function as well as the life span. A convenient and recognized technique of repairing or rehabilitation is the bonding of steel plates using cementations material or epoxy adhesives. But, this technique has some problems such as corrosion of steel, excess size and weight, undesirable formation of welds, partial formation of composite action with the surface concrete, de-bonding etc.
In recent years strengthening of concrete structures by using adhesively bonded fibers or Fiber Reinforced Polymers (FRP) [2] has proved to be excellent for improving the function as well as the life span. FRP has some advantages compared to the conventional strengthening material. High strength, stiffness, corrosion resistance, ease of installation, simple repair methods, excellent durability, long service life, minimum maintenance and lower life cycle costs are among them. Composite materials formed by the mixture of two or more different materials in a very small range have gained escalating popularity in the engineering field. FRP is quite a new range of composite matter manufactured from fibers and its resins proved to be effective and reasonable materials for the expansion and repair of new and failing structures in civil

engineering. The mechanical properties of fiber reinforced polymer make them ideal for wide applications in construction worldwide.

A fiber reinforced polymer composite is defined as a polymer (plastic) matrix, either thermo set or thermoplastic, reinforced (combined) with a fiber or other reinforcing material with a sufficient aspect ratio (length to thickness) to provide a discernable reinforcing function in one or more directions. FRP composites are different from traditional construction materials such as steel or aluminum. They are anisotropic (properties apparent in the direction of the applied load) whereas steel or aluminum is isotropic (uniform properties in all directions, independent of applied load). Therefore, properties of FRP composites are directional, meaning that the best mechanical properties are in the direction of the Fiber placement.

Only a few years ago, the construction market started using FRP for structural reinforcement, generally in combination with other construction materials such as wood, steel, and concrete. FRPs exhibit several improved properties, such as high strength-weight ratio, high stiffness-weight ratio, flexibility in design, non-corrosiveness, high fatigue strength and ease of application. The use of FRP sheets or plates bonded to concrete beams has been studied by several researchers. Strengthening with adhesive bonded fiber reinforced polymers has been established as an effective method applicable to many types of concrete structures such as columns, beams, slabs and walls. Because the FRP materials are noncorrosive, non-magnetic, and resistant to various types of chemicals, they are increasingly being used for external reinforcement of existing concrete structures.

The use of externally bonded fiber reinforced polymer composite plate or sheets for the strengthening of Reinforced Concrete (RC) [8] has become very popular in recent years. This popularity has been due the well-known advantages of FRP composite over conventional materials when used for strengthening projects. Since the early 1990s, tests on a wide variety of shear strengthening schemes have been undertaken with the goal to increase shear capacity of reinforced concrete beams. Shear is actually a highly complex problem that has not found a complete solution for simple reinforced concrete beams. Finding a reasonable method for estimating the contribution of externally bonded FRP in shear is not an easy task. Several researchers have proposed design equations and analytical models for evaluation of FRP shear strengthening of reinforced concrete beams. These are reviewed in this study. Strengthening schemes, consist of strengthening application to side faces, U-jacketing to both sides and soffit and wrapping FRP around entire cross-section of structural components.

The technique of bonding steel plates using epoxy adhesives is recognized as an effective and convenient method for repair and rehabilitation of reinforced concrete structures. However, the problems associated with the steel corrosion, handling due to excessive size and weight, undesirable formation of welds, partial composite action with the surface concrete and de-bonding lead to the need for alternative materials and further research in this field. The high strength-to-weight ratio, resistance to electro-chemical corrosion, larger creep strain, good fatigue strength, potential for decreased installation costs and repairs due to lower weight in comparison with steel and nonmagnetic and non-metallic properties help Glass Fiber Reinforced Polymer (GFRP) offering a viable alternative to bonding of steel plates. The emergence of high strength epoxies has also enhanced the feasibility of using GFRP mat for repair and rehabilitation.

II. Literature Review

This part presents critical review of literature on the performance assessment of RCC Beam and Column. There are different materials available like FRP, steel, concrete etc., for retrofitting of the structure, but the use of FRP is increasing rapidly. A series of analytical and experimental studies on various Fiber reinforced plastic strips have been made by various authors. The overall objective of these studies is to understand the structural response and interaction of the concrete and FRP under loading conditions. This literature review is limited to the research of FRP material externally bonded to the tensile face of concrete beams. In particular, research studying the effect of externally applied FRP materials on the flexural performance of reinforced concrete beams is reported.

Malek et al. (1998) found epoxy bonding a composite plate to the tension face as effective techniques for repair and retrofit of reinforced concrete beams. Experiments have indicated local failure of the concrete layer between the plate and longitudinal reinforcement in retrofitted beams.

Balasubramanian et al. (2007), examined the performance of the GFRP wraps used for retrofitting of the beams and concluded that the performance of the RC beams improved after retrofitting using FRP wrapping. In the case of the shear strengthening, the RC beams provided with GFRP wrap along the entire span was found to be best among the various methods of carbon Fiber wrap that were investigated.

Chen and Teng (2003) investigated the failure of strengthened beams in shear mainly in one of the two modes: FRP rupture and FRP debonding. They were concerned mainly with the development of a simple, accurate and rational design proposal for the shear capacity of FRP-strengthened beams which failed due to FRP debonding. The Existing strength proposals were reviewed and their deficiencies highlighted. A new strength model was then developed. The model was validated against experimental data collected from the existing literature. Finally, a new design proposal was presented.

Mariappan et al. (2013) present the results of an experimental investigation conducted on Steel Fiber Reinforced Concrete (SFRC) beams with externally bonded Glass Fiber Reinforced Polymer (GFRP) laminates with a view to study their strength and ductility. A total of ten beams, 150×250 mm in cross-section were tested in the laboratory over an effective span of 2800 mm. Three Fiber reinforced concrete beams were used as reference beams. Six Fiber reinforced concrete beams were provided with externally bonded GFRP laminates. One concrete beam was left virgin without any Fiber reinforcement and external GFRP laminates. All the beams were tested until failure. The variables considered included the volume fraction of Fiber reinforcement and stiffness of GFRP laminates. The static responses of all the beams were evaluated in terms of strength, stiffness and ductility. The test results showed that the beams provided with externally bonded GFRP laminates exhibiting improved performance over the beams with internal Fiber reinforcement.

Djamaluddin et al. (2015) focused on Fiber reinforced polymer (FRP) applied to many purposes in civil engineering structures not only new structures but also for strengthening of the deteriorated structures. The application of FRPs in various forms such as rod, grid and sheet are widely accepted solution due to its corrosion resistance as well as high tensile strength to weight ratio. Glass composed FRP (GFRP) sheet is most commonly used due to its relatively lower cost compared to the other FRP materials. GFRP sheet is applied externally by bonding it on the concrete surface.

Deepak and Govind (2019) have presented a paper on use of GFRP (Glass Fiber Reinforced Polymer) for Strengthening of Reinforced Concrete Beam. The use of Fiber reinforced polymer (FRP) reinforcements in concrete structures has seen rapid increases in the last 10 years due to their excellent corrosion resistance, high tensile strength, and good nonmagnetization properties. Further they explained about Fiber-reinforced polymer (FRP) application and advanced method for the purpose of repair and strengthens structures which are weak during their life span. FRP repair systems provide an economical and effective method for repairing repair systems and as a material.[2]

Prathamesh and Srivastava (2016) point out that structures get dilapidated with time for which repairs is not feasible. Some structures cannot be kept closed for longer downtime required for reconstruction. Retrofitting is the efficient method which can be adopted to combat all these defiance. The author's article appends a comparative study of percentage increase in strength after adopting RC jacketing and FRP wrapping. Percentage increases in strength achieved after RC jacketing and FRP wrapping were determined and compared. Their study was fruitful in gauging the suitability of the two retrofitting methods for weakened structural members. The study will be handy to help the structural engineer to decide which method of retrofitting should be adopted for acquiring the required increase in strength.

Antonio and Antonio (2011) evaluated a single parameter methodology for the prediction of the stress-strain behaviour of FRP confined RC square columns and concluded that transverse or diagonal dilation ratio of axial strain curves are influenced not only by the modulus of elasticity and the thickness of the jacket but also by the Fiber type.

Lei ming and Yu fei (2008) have demonstrated the direct proportion of the corner radius ratio of square column to increase in confined concrete strength. Furthermore, they revealed and explained that confinement provided by CFRP jacket with sharp corners is significant in increasing the ductility of column.

Athira et al. (2016) made an experimental study of reinforced concrete columns wrapped with Hybrid FRP Sheets. One of the techniques of strengthening reinforced concrete structural member involved external wrapping with high strength Fiber composites. In this paper, an attempt was made to study the behavior of RC columns wrapped hybrid Fiber sheets. The experiment consisted of 14 columns including 2 control columns, 2 columns wrapped with single layer of CFRP sheets, 2 columns wrapped with single layer of BFRP sheets, 2 columns wrapped with 2 layer of BFRP sheets, 2 columns wrapped with 2 layer of CFRP, 2 columns wrapped with BFRP-CFRP hybrid sheets and 2 columns wrapped with CFRP-BFRP hybrid sheet. Effects of number of layers of individual FRP sheets and effectiveness of using hybrid FRP sheet to confine RC columns are investigated. All the test specimens loaded to fail in axial compression and the ultimate load carrying capacity, axial deformation and failure or crack patterns were investigated and the test results are compared with unwrapped specimens. The result obtained shows that the hybrid wrapping increases the load carrying capacity as well as reduces the sudden collapse of columns during loading.

III. Glass Fibre Reinforced Plastic

Among the fibre composites, glass fibre reinforced plastics (GFRP) [5] is more popular due to ease of construction, ease of availability of all ingredients and cost effectiveness. One of the greatest advantages of GFRP is its high strength to weight ratio. Not only it has tensile strength but also it is highly corrosive resistant.

GFRP is a structural material that incorporates the versatile chemical, electrical and other properties of plastic with mechanical Strength, chemical inertness and electrical resistance of glass fibres to create a synergistic material, which can be engineered for specific applications. The tensile strength of GFRP can be varied from 34 to over 220 MPa.

The standard properties of GFRP like, low maintenance cost, lightweight, high strength, translucency, good resistance to chloride, chemical attack, transparent to magnetic fields and radio frequencies, good impact, compression strength, fatigue and electrical properties make it an ideal material for use in constructions (Saadatmanesh, 1997).

Figure 1: Glass Fiber Reinforced Polymer Mat

Glass fibre reinforced plastic composites are made of resins, reinforcements, fillers, and additives. Each of these constituent materials or ingredients plays an important role in the processing and final performance of the end product. The resin or polymer is the "adhesive" that holds the composite together and influences the physical properties of the end product. The reinforcement provides the mechanical strength. The fillers and additives are used to impart special properties to the end product.

The application of composite materials has been developed in strengthening and retrofitting of concrete structures through recent years, so that many of concrete structures would be strengthened by these materials. One of these applications are Glass Fiber Reinforced Polymer (GFRP) [10] material used in the strengthening of reinforced concrete beam and column. Results of studies have shown that wrapping of reinforced concrete beam increases shear strength and load carrying capacity. Load, deflection, strain in concrete and GFRP are observed up to failure of beams and increase in shear strength of beam is thus arrived.RCC columns with GFRP show enhanced ductility and compressive strength of columns. Since, almost all RCC columns are affected by axial force and moment bending.Studies of interaction curve of wrapped RCC columns with GFRP shows that just compressive control region in interaction curve as enhancing and wrapping of columns with GFRP has no effect on tension control region of RCC columns.

IV. MATERIALS USED FOR RCC COLUMN AND BEAM

Properties and characteristics of cement, aggregates, water, steel, GFRP and GP resin are discussed below.

- **Cement**

Ordinary Portland cement 43 grade is used for design mix. The fineness modulus of cement is 5 % and the specific gravity of cement is 3.15.

- **Aggregates**

Size of coarse aggregate is 20mm, Specific gravity is 2.6, and water absorption is 0.5%. Specific gravity of fine aggregate is 2.6, water absorption is 1%, and free surface moisture is 2%

- **Water**

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Water cement ratio is 0.49.

- **Steel**

Used Fe 456 Grade steel tested in UTM. 12 mm bars were used for longitudinal reinforcement and 8 mm bars used as transverse reinforcement.

- **GFRP**

Glass fibers also available as thin sheets are called mats. A mat may be made of both long continuous and short Fibers randomly arranged and kept together by a chemical bond. The width of such a mat varies from 5 cm to 2 m. Density of the mat is roughly 0.5 kg / m^2. Fibers undergo sizing treatments for enhancing the bond between the fiber and the matrix and protecting fiber itself against alkaline agents and moisture. Such treatments are useful in the enhancement of durability and fatigue performance of the composite material. Fiber reinforced polymer composites based on Fiberglass are usually denoted as GFRP.

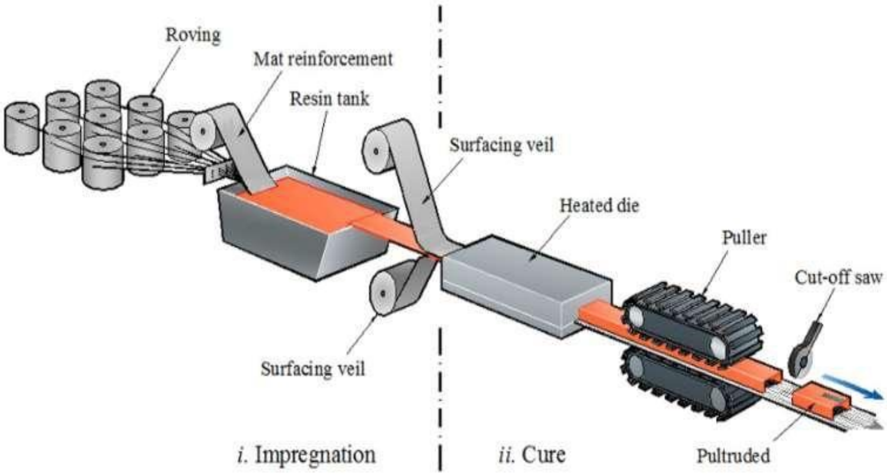


Figure 2: Pultrusion Process of Glass Fiber Reinforced Polymers (Alexandra et. al 2015)

GFRP is a category of plastic composite that specifically uses glass fiber materials for mechanical improvement to the strength and stiffness of plastics. The resin provides additional protection to the Fiber due to the bounding between materials. Among the different methods of forming GFRP members, pultrusion, which emerged in the USA in the 1950, was used for producing the GFRP profiles. Figure 3.5 illustrates the two-step fabrication process: (i) impregnation, where the glass Fiber package and slit fabrics material are manufactured and pulled through a wet bath of resin matrix, formed into the irregular part shape (*i.e.*, they are bonded with the matrix during molding) and (ii) cure, where saturated material obtained is extruded from a heated mold, while being continuously pulled through die fibrous materials, resulting into some of the end products of pultrusion – structural Fiber glass predefined shapes (*e.g.*, *I*-shape, angle, channel and flat sheet profiles) and lengths.

Characteristics and specification of GFRP are obtained from manufacturer. These details are discussed below.

Characteristics- Uniform Fiber distribution, smooth surface, soft and pliable feel, Low binder and strainer content, fast resin impregnation and good mould obedience.

Specifications- Weight is 30 g / m2, Binder content is 7 %, Resin wet out time is 10 s, Tensile strength is20 N / 5 cm, Moisture content is 2 % and maximum Width is 1 m.

- **GP Resin**

General Purpose Orthopthalic Polyester Grade - PX GP 002 is used as resin. Its characteristics are clear to light, Yellow, Medium reactivity, High impact and bonding strengths suitable for hand lay-up. Polyester resins are the most widely used resin systems, particularly in the marine industry. By far the majority of dinghies, yachts and workboats built in composites make use of this resin system.

Polyester resins such as these are of the ‘unsaturated’ type. Unsaturated polyester resin is a thermoset, capable of being cured from a liquid or solid state when subject to the right conditions. It is usual to refer to unsaturated polyester resins as 'polyester resins', or simply as ‘polyesters’. There is a whole range of polyesters made from different acids, glycols and monomers, all having varying properties. There are two principle types of polyester resin used as standard laminating systems in the composites industry. Orthophthalic polyester resin is the standard economic resin is widely used. Isophthalic polyester resin is now becoming the preferred material in industries such as marine where its superior water resistance is desirable.

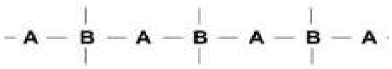
Most polyester resins are viscous, pale coloured liquids consisting of a solution of a polyester in a monomer which is usually styrene. The addition of styrene in amounts of upto 50% helps making the resin easier to handle by reducing its viscosity. The styrene also performs the vital function of enabling the resin to cure from a liquid to a solid by cross-linking the molecular chains of the polyester, without the evolution of any by products.

These resins can therefore be moulded without the use of pressure and are called 'contact' or 'low pressure' resins. Polyester resins have a limited storage life as they will set or 'gel' on their own over a long period of time. Often small quantities of inhibitor are added during the resin manufacture to slow this gelling action.

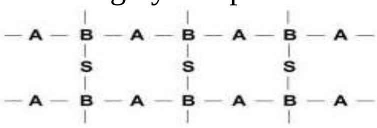
For use in moulding, a polyester resin requires the addition of several ancillary products. These products are generally: Catalyst, Accelerator and Additives (Thixotropic; Pigment; Filler; Chemical/fire resistance)

A manufacturer may supply the resin in its basic form or with any of the above additives already included. Resins can be formulated to the moulder's requirements ready simply for the addition of the catalyst prior to moulding. As has been mentioned, given enough time, an unsaturated polyester resin will get set by itself. This rate of polymerisation is too slow for practical purposes and therefore catalysts and accelerators are used for achieving the polymerisation of the resin within a practical time period. Catalysts are added to the resin system shortly before use to initiate the polymerisation reaction. The catalyst does not take part in the chemical reaction but simply activates the process. An accelerator is added to the catalysed resin to enable the reaction to proceed at workshop temperature at a greater rate. Since accelerators have little influence on the resin in the absence of a catalyst they are sometimes added to the resin by the polyester manufacturer to create a 'pre-accelerated' resin.

The molecular chains of the polyester can be represented as follows, where 'B' indicates the reactive sites in the molecule.



With the addition of styrene ‘S’, and in the presence of a catalyst, the styrene cross-links the polymer chains at each of the reactive sites to form a highly complex three-dimensional network as follows:



The polyester resin is then said to be cured. It is now a chemically resistant (and usually) hard solid. The cross-linking or curing process is called ‘polymerisation’. It is a irreversible chemical reaction. The ‘side-by-side’ nature of this cross-linking of the molecular chains tends to means that polyester laminates suffer from brittleness when shock loadings are applied.

Great care is needed in the preparation of the resin mix prior to moulding. The resin and any additives must be carefully stirred to disperse all the components evenly before the catalyst is added. This stirring must be thorough and careful as any air introduced into the resin mix affects the quality of the final

moulding. This is especially, so as air bubbles can be formed within the resultant laminate during laminating with layers of reinforcing materials. The air bubbles can weaken the structure. It is also important to add the accelerator and catalyst in carefully measured amounts to control the polymerization reaction to give the best material properties. Too much catalyst will cause too rapid a gelation time, whereas too little catalyst will result in under-cure.
Colouring of the resin mix can be done with pigments. The choice of a suitable pigment material, even though the addition is about 3% resin weight, must be carefully considered as may easily affect the curing reaction and degrade the final laminate by use of unsuitable pigments.
Filler materials are used extensively with polyester resins for a variety of reasons including:

- To reduce the cost of the moulding
- To facilitate the moulding process
- To impart specific properties to the moulding

Fillers are often added in quantities up to 50% of the resin weight although such addition levels will affect the flexural and tensile strength of the laminate. The use of fillers can be beneficial in the laminating or casting of thick components where otherwise considerable exothermic heating can occur. Addition of certain fillers can also contribute to increasing the fire-resistance of the laminate.

V. RCC Beam

The casting of beam as shown in Figure 3, three control beam designated as CB-1, CB-2 and CB-3 and six beams strengthened with different layers of GFRP designated as S-1a, S-1b, S-1c, S-2a, S- 2b and S-2c were fabricated. The concrete beams designated as S-1a, S-1b and S-1c were ‘U’ wrapped with a single layer of GFRP and that the beam designated as S-2a, S-2b and S-2c were ‘U’ wrapped with two layers of GFRP. Fig 4 shows the beam s-1a after demoulding.

Figure 3: Casting of Beams

Figure 4: Beam (S-1) after de-moulding

Surface Preparation of Test Specimen

Surface preparation was an important task in this experimental work. This task was done with the help of coarse sand paper, Carborandum stone (for smooth surface). Blower machine was used to clean the dust. Before applying the GP resin (Px GP 002), the concrete surface was smoothened and cleaned to ensure a good bond between the resin and the concrete surface. The bonding surface of the GFRP mat was cleaned with acetone. Resin was applied uniformly over the concrete surface of the beams S-1(1a, 1b and 1c) and S-2(2a, 2b and 2c) using brush prior to the fixing of the GFRP mat shown in Figure 5. Excess epoxy was squeezed out along the edges assuming complete resin coverage.

Figure 5: Application of GP Resin

Fixing of GFRP

After applying the resin coat, the GFRP mat was 'U' wrapped over the specimens S-1a, S- 1b and S-1c in single layer and over specimen S-2a, S-2b and S-2c in two layers pressed into place at the centre and moved towards each end. The GFRP mat was kept tight and wrinkle free as shown in Figure 6. A paint roller was used for removing any trapped air pockets.

Figure 6: Rolling after U Wrapping GFRP mat for Beam S-1

Strain Gauge

The strain in the concrete and in the GFRP mat was monitored using electrical strain gauges. The strain gauges for concrete (20 mm) were pasted to the concrete surface of the beam prior to the wrapping of GFRP mat. The strain gauges for composite (5 mm) were pasted on the GFRP mat. Numbers of strain gauges used for each beam are shown in Table 3. The positioning of the strain gauges on GFRP mat is shown in the Figure 7.

Figure 7: Beam S-1 after U Wrapping and resin application

VI. RCC Column

Three control columns were designated as CC-1, CC-2 and CC-3 as shown in Figure 8 and three columns strengthened with single layers of GFRP were designated as SC-1, SC-2 and SC-3 as shown in Figure 11.

Figure 8: Control Columns

Figure 9: Wrapping of GFRP Mat

Figure 10:GFRP Sheet

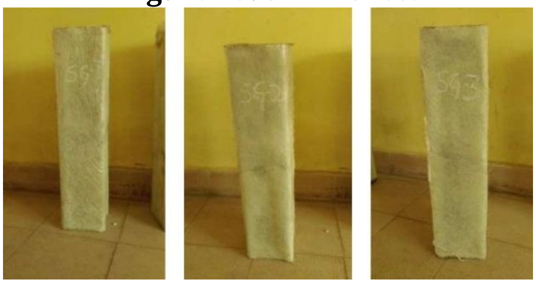


Figure 11: Single layered GFRP wrapped columns

Three columns strengthened with double layer of GFRP were designated as DC-1, DC-2 and DC-3 as shown in Figure 12.The bonding surface of the GFRP sheet as shown in Figure 10 was cleaned with acetone. Three chemical were used for the preparation of the epoxy resin. Epoxy = 1000ml, Polyurethane coating = 20ml and Vinylester = 20ml.

The mixed epoxy resin was applied uniformly over the concrete surface. After applying resin coat, the GFRP sheet was wrapped over the specimen shown in Figure 9. The specimens were allowed to dry for seven days under natural atmosphere conditions.

Figure 12: Double layered GFRP wrapped columns

The main use of light weight concrete in construction is to reduce the dead load of load bearing elements. Cellular concrete, also known as aerated concrete is a light weight material composed of cementations mortar surrounding disconnected bubbles as a result of either physical or chemical processes during

which air is introduced into the mortar mixture (Tikalsky et al. 2004). The future need for construction materials to be light, durable, economic and environmentally sustainable was identified by many groups around the world (Jones & McCarthy 2005). With the possibility of producing a wide range of densities (400-1600 kg/m3) and strength achievement of upto 25 MPa, foam concrete (FC) has the potential to fulfill these requirements in the construction industry and is classified as light weight concrete. Though FC was first patented in 1923 (Valore 1954) and its construction applications as non and semi-structural material are increasing only in the last few years.
The basic constituents of the mix are Portland cement, fine aggregate and water. Coarse aggregates are not used and the fine aggregate can be partially or fully replaced with recycled or secondary materials. Foam concrete is a free flowing, self-leveling material created by uniform distribution of air bubbles of size 0.1–1.0 mm (using foaming agents) throughout the mass of concrete. Due to its porous internal structure, FC has very low thermal conductivity value of 0.23 and 0.42 w/mK at 1000 and 1200 kg/m^3 dry densities respectively (Jones & McCarthy 2005) for use as insulating or fire resisting material. Natural or synthetic foaming agents are used to generate foam. Foam stability in concrete is one of the important aspects to ensure the fine and uniform texture throughout the whole hardening process.Due to the brittle failure of FC, a suitable method of using FC in load bearing construction would be to use it in composite action with steel, which has high ductility. Because of the low density of FC, pressure on the steel sheet of composite panel would be much lower than using normal strength concrete, allowing lower thickness of sheet. Moreover, the structural light weight FC provides more efficient strength-to-weight ratio for composite panels. Reduction of weight will result in reduced foundations and overall cost benefits. Hence, it is proposed to use FC as infill material in the present study for sandwiching between the profiled steel sheets.

VII. Conclusion

Glass Fiber Reinforced Polymer (GFRP) sheets use in strengthening of reinforced concrete beam and column. This paper concludes on Strengthening of RCC Structural Components with GFRP.GFRP wrapped RCC beam enhances the ductility to a considerable extent due to additional confinement effect. Effective procedure of GFRP wrapping in beam increases shear strength of the beam.GFRP sheets around the RCC column increases the ductility of the column. Wrapping of RCC columns with GFRP increases the load carrying capacity of the column. Increasing the number of GFRP layers results in increasing the load and performance of the column.

References

[1] Prathamesh, D &Srivastava, A 2016, ‘Retrofitting – Comparative study of RC jacketing and FRP wrapping’, International Journal of Civil Engineering and Technology, vol. 7, no. 5, pp. 304 – 310.
[2] Athira, MA, Meera, CM &Sreepriya, M 2016, ‘Experimental Study on RC Columns Wrapped With Hybrid FRP Sheets’, International Journal of Innovative Research in Science, vol. 5, no. 8, pp. 54 – 60.
[3] Ankush, RP &Bhagyashri, D 2015, ‘Retrofitting of Concrete Short Column Using Glass Fiber Reinforced Polymer’, International Journal on Recent and Innovation Trends in Computing and Communication, vol. 3, no. 3, pp. 950 – 953.
[4] Djamaluddin, R, Mufti Amir, S, Rita, I & Hino, S 2015, ‘Bond Characteristics of GFRP Sheet on Strengthened Concrete Beams due to Flexural Loading’, IACSIT International Journal of Engineering and Technology, vol. 7, no. 2, pp. 110 -115.
[5] Kannan, S, Jagannathan, S &Raghunath, N 2014, ‘Effect of slenderness on Fiber reinforced polymer wrapped Reinforced concrete columns’, International Journal of Engineering and Applied Sciences, vol. 5, no. 4, pp. 35 – 49
[6] Manikandan, T &Balajiponraj, G 2013, ‘Strengthening of RC Beam Using GFRP Wraps’, International Journal of Engineering Trends and Technology, vol. 4, no. 5, pp. 1527 – 1530.
[7] Manish kumar, T, Rajiv, C &Yadav, RK 2014, ‘Strengthening of reinforced concrete circular columns using glass Fiber reinforced polymers’, International Journal of Engineering Research and Applications, vol. 4, no. 4, pp. 50 – 54.

[8] Mariappan, M, Ragunath, P &Suguna, K 2013, 'Ductility Behavior Fiber Reinforced Concrete Beams Strengthened With Externally Bonded Glass Fiber Reinforced Polymer Laminates', American Journal of Applied Sciences, vol. 1, no. 10, pp. 107 – 111.

[9] Vinodhini, M, Tamizhazhagan, T &Saranya, R 2016, 'Strengthening of RC Columns with Glass Fiber Wrapping System', International Journal of Emerging Technologies in Engineering Research, vol. 4, no. 10, pp. 7-11.

[10] Ahir, MD, Perikh, KB &Jhummarwala, RA 2016, 'Strengthening of RC square column with GFRP sheet with different configuration', International Journal of Engineering Science and Computing, vol. 6, no. 7, pp. 85-90.

[11] Owais, R &Zakir, MD 2017, 'Columns Retrofitting with Glass Fiber and Carbon Fiber Composite Laminates', International Journal of Engineering Trends and Technology, vol. 45, no. 2, pp. 57 – 62.

[12] Syed Ibrahim, S, Eswari, S &Sundararajan, T 2015, 'Experimental Investigation of FRC Beams strengthened with GFRP laminates', Journal of Structural Engineering, vol. 1, no. 15, pp. 112-117.