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N. Aravind*, Amiya K. Samanta, Dilip Kr. Singha Roy, and Joseph V. Thanikal

Flexural strengthening of Reinforced Concrete (RC) Beams Retrofitted with Corrugated Glass Fiber Reinforced Polymer (GFRP) Laminates

Abstract: Strengthening the structural members of old buildings using advanced materials is a contemporary research in the field of repairs and rehabilitation. Many researchers used plain Glass Fiber Reinforced Polymer (GFRP) sheets for strengthening Reinforced Concrete (RC) beams. In this research work, rectangular corrugated GFRP laminates were used for strengthening RC beams to achieve higher flexural strength and load carrying capacity. Type and dimensions of corrugated profile were selected based on preliminary study using ANSYS software. A total of twenty one beams were tested to study the load carrying capacity of control specimens and beams strengthened with plain sheets and corrugated laminates using epoxy resin. This paper presents the experimental and theoretical study on flexural strengthening of Reinforced Concrete (RC) beams using corrugated GFRP laminates and the results are compared. Mathematical models were developed based on the experimental data and then the models were validated.

Keywords: GFRP laminates; corrugated profile; load carrying capacity; epoxy resin; reinforced concrete

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1 Introduction

Strengthening of RC beams is necessary to obtain the expected lifespan of structures. Life span of RC beam may reduce because of improper beam design, ingression of chemical agents etc. Strengthening of RC beams using steel plates and FRP composites are most common globally. In order to minimize the disadvantages of steel such as corrosion, high unit weight, connection difficulties; many researchers have tried various FRP composites such as Aramid, Glass and Carbon. In future, Fibre Reinforced Polymer (FRP) materials could play an important role for the construction industry [1]. Nowadays, retrofitting work for RC structural members, GFRP composites are commonly used because of its excellent properties such as high strength, less weight to strength ratio, noncorrosive nature and easy handling.

Several investigations on strengthening of RC beams using different FRP composites and adhesives are studied and discussed. So far researchers have varied the thickness, position, orientation and number of layers for retrofitting work.

Hamid Saadatmanesh and Mohammad, have studied experimentally the characteristics of five rectangular beams retrofitted using GFRP plates at tension zone with epoxy resins [2]. It was concluded that the GFRP plate strengthened beams resist more loads and reduces crack width. Slobodan Rankovic et al., has done experimental study on RC beams strengthened with Near Surface Mounted (NSM) reinforced FRP composites [3]. Kang Seok Lee., has adopted different technique for shear and flexural strengthening of existing RC structures using chopped strand carbon or glass fibers mixed with epoxy and vinyl ester resins sprayed on sides and soffit of concrete beams with compressed air [4]. Recently, Hui Peng has done experimental study on reinforced concrete beams strengthened with pre-stressed near surface mounted CFRP strips [5]. Rami A. Hawileh has studied the behavior of RC beams strengthened with externally bonded hybrid fiber reinforced polymers [6]. Muhammad Masood Rafi and Ali Nadjai., studied high temperature effect on RC beams with CFRP bars and compared with normal temperature [7]. Previous research on strengthening works reveals that more layers of FRP materials applied, the higher flexural strength would be achieved [8]. This

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Glass Fiber Reinforced Concrete Exclusive Assets and Applications in Construction

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ABSTRACT

Glass Fiber Reinforced Concrete or (GFRC) is a composite that has glass fibers instead of steel strands for its reinforcement. Removing the steel reinforcement not only weakened, but also omitted steel erosion, corrosion, and their future repair costs, steel reinforcement costs, optimal coverage, and etc.

In this research, several sources were studied to determine and clarify GFRC's applications in order to compare its featured properties with other fibers. Different figures and tables provided that show and compare physical and mechanical properties of GFRC and other fiber reinforcement.

GFRC can be used wherever a light, strong, weather resistant, attractive, fire resistant, impermeable material is required. It has remarkable physical and mechanical assets. GFRC properties are dependent on the quality of materials and accuracy of production method. Despite its wide range applications in architecture the chief goal is to show and introduce important structural purposes, for instance: anti rust characteristics of GFRC made it a good replacement for water and sewer pipes and tanks, a thin protective layer of GFRC on concrete beams and columns can increase their durability in fire as well as low temperatures and generally it is a good replacement for susceptible materials in difficult environments.

Key Words: (Fiber Reinforcement, Glass Fiber, GFRC, Composite, Lightweight Concrete, Durable).

I. Introduction

Undoubtedly one of the most important materials in worldwide construction industry that is vastly in use is **concrete**.

[Figure 1.a], Concrete

[Figure 1.b], Concrete block

Basalt Fibre Reinforced Concrete an Alternative to the Synthetic Fiber Reinforced Concrete

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Abstract— The cost of tensile member of concrete has always attracted attention of civil engineers to be supplemented by some cheaper material. This paper focuses the advantages of using naturally available material namely basalt as fibre reinforcement to enhance the strength as well as reinforcement akin properties in the concrete. Basalt an igneous origin rock has excellent load bearing properties can be a choice for massive concrete works in the construction industry. In the paper the engineering properties of basalt fibres are worked out experimentally and were discussed as a comparable choice of already in use synthetic fiber materials. Basalt being cheap and easily available fibre may be used for the construction of structural units with cement-paste or cement mortar / concrete composites have great potential, especially for developing countries.

Key words: Cement, Composites, Compression, Mechanical Properties, Basalt and Natural Fibre, Tensile-Strength, Shrinkage, Slump

I. Introduction

Concrete is a brittle material having high compesive strength but a low tensile / flexural strength and strain capacity resulting in shrinkage and cracking. Concrete in service may exhibit failure through cracks which are developed due to brittleness i.e. the mechanical behavior of the concrete is critically influenced by crack development and their sub-sequential propagation. To improve stress – strain related properties of concrete fibre reinforced concrete (FRC) have been developed. Fibre reinforced concretes are defined as concrete containing dispersed randomly oriented fibres. Fibres in cement or in concrete serve as crack arrestor which can create a stage of slow crack propagation and gradual failure.

Fibre reinforced concrete is a cement-based composite material that has been developed in recent years. The major advantage of fibre reinforcement is to impart additional energy absorbing capability and to transform a brittle material into a pseudo-ductile material. FRC has been successfully used in construction with its excellent performance towards flexural-tensile strength, resistance to splitting, impact resistance, excellent permeability and frost resistance. It is an effective way to increase toughness, shock resistance, and resistance to plastic shrinkage cracking of the mortar.

Strength and behavior of the FRCs are highly dependent on the characteristics of the fibre reinforced. The properties of concrete matrix and of the fibres greatly influence the character and performance of FRC. The behavioral efficiency of such compact mass is much different to that of plain concrete and many other construction materials of similar nature. Peculiar properties of FRC contributes its increased application during the past few decades and its current field of application includes: airport and highway pavements, earthquake-resistant structures and explosive-resistant structures, mine strengthening and tunnel linings, bridge deck overlays, hydraulic structures and slope stabilization. Extensive research work on FRC has established that addition of various types of fibre such as steel, glass, synthetic, carbon etc., in plain concrete alters and in most of the cases improves strength, toughness, ductility, post-cracking resistance, etc.

II. History Time Line

The use of fibres for strengthening of brittle materials as reinforcement is evident from B.C. Historically. 3000 BC: Egyptians Used mud mixed with straw to bind dried bricks. They also used gypsum mortars and mortars of lime in the pyramids. Chinese Used cementitious materials to hold bamboo together in their boats and in the Great Wall. During 300 BC Babylonians & As Syrians used reed in asphalt to bind stones and bricks. In 476 AD Romans Used pozzolana cement from Pozzuoli, Italy to build the Appian Way, Roman baths, the Coliseum and Pantheon. During the Middle Ages 1000 - 1500: the quality of cementing materials deteriorated resulting in the scare use of burning lime and pozzolan (admixture). Application of masonry mortar and plaster reinforced using horsehair are quite common. 1678: Joseph Moxon wrote about a hidden fire in heated lime that appears upon the addition of water. In early 19 century Louis Vicat of France prepared artificial hydraulic lime by calcining synthetic mixtures of limestone and clay. In the year 1824: Joseph Aspdin of England invented Portland cement by burning finely ground chalk with finely divided clay in a lime kiln until carbon dioxide was driven off. Later few decades were to develop the quality of concrete. In 1836 test procedure for the tensile and compressive strength of concrete were developed in Germany and in 1867: Joseph Monier of France reinforced flower pots with wire ushering in the idea of iron reinforcing bars (re-bar). In 1880 J. Grant of England has chemically analyzed the key ingredients of concrete to show the importance of the hardest and densest portions of the clinker. Later in 1887 Henri Le Chatelier of France established oxide ratios to decide the proper amount of lime for portland cement. During 20 century air entraining agents were introduced to improve concrete's resistance to freeze/thaw damage.

In the early 1900s, asbestos fibres were used in concrete, and in the 1950s the concept of composite materials came into being and fibre reinforced concrete was one of the topics of interest. There was a need to find a replacement for the asbestos used in concrete and other building materials once the occupational health risks (asbestosis) associated with the substance were discovered. By the 1960s, steel, glass and synthetic fibres such as

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Environmental Impacts of Glass- and Carbon-Fiber-Reinforced Polymer Bar-Reinforced Seawater and Sea Sand Concrete Beams Used in Marine Environments: An LCA Case Study

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2 Key Lab of Smart Prevention and Mitigation of Civil Engineering Disasters of the Ministry of Industry and Information Technology, Harbin Institute of Technology, Harbin 150090, China
3 School of Civil Engineering, Harbin Institute of Technology, Harbin 150090, China
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Abstract: Application of glass- or carbon-fiber-reinforced polymer (GFRP/CFRP) bars makes the direct use of seawater and sea sand concrete (SWSSC) in construction feasible, which is of high interest in order to conserve the limited resources of fresh water and river sand. The present paper performed the life cycle assessment (LCA) of constructing three kinds of beams (GFRP/CFRP bar-reinforced SWSSC beams, and steel bar-reinforced common concrete (SRC) beam) in marine environments to show the environmental benefits of using FRP bar-reinforced SWSSC beams in marine environments. According to ISO 14040 and ISO 14044, stages including production, transportation, construction, use and end-of-life are within the LCA's boundary. The ReCiPe method and eight main environmental impact categories were used to characterize the environmental impacts of those beams. LCA results indicate that one cubic meter SWSSC possesses much lower environmental impacts in terms of all eight categories compared with common concrete with the same volume when used in marine environments, with reduction rates from 26.3% to 48.6%. When the two transportation distances were set as 50 and 20 km and without considering the difference in service life, compared to SRC beam, GFRP-SWSSC beam performs better in six categories and CFRP-SWSSC beam performs better in four categories. When considering increased transportation distance and the higher durability performance, the advantageous categories for GFRP-SWSSC and CFRP-SWSSC beams increase to seven and six, respectively. The environmental impacts of all the three beams are mainly affected by the production stages.

Keywords: life cycle assessment; environmental impacts; FRP bars; seawater and sea sand concrete

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1. Introduction

Concrete is one of the most commonly used construction materials because of its low cost and good durability [1]. However, application of concrete consumes great amount of fresh water, river sands, and crushed stones, bringing in severe resource depletion problems. In some areas of the world, resources of fresh water and river sands are bound to be used up due to heavy construction. For construction in marine areas, long transportation distance of river sands or crushed stones and production of desalinated seawater undoubtedly cause high costs and pollution. Therefore, replacing river sands and fresh water with sea sands and seawater is of great interest for the construction of structures under the corrosion of salt-laden air in coastal environments.

Seawater and sea sand concrete (SWSSC) has a large amount of chloride ions inside. Since heavy corrosion of traditional steel bars is expected to be occurred in SWSSC [2], SWSSC is generally strictly forbidden to be directly used for steel-reinforced concrete. Sea sands, washed with fresh water to reach a very low content of chloride ions (e.g., less than

Compression resistance Test: The compression test performed on the cube sample. It will help to counter the problem of the disposal of glass waste for the glass industry and, in addition to this, will also help to prepare the greenest cement. MIX DESIGN M20, M30 & M40 Concrete grades were considered. Balaguru and Surendra P. Swamy, Testing and Test Methods of Fibre Cement Composites, Published 1978, (pp42-43.) Muthuawamy K.R and Thirugnanam G.S,(2013) Quantity of glass 570.5.5.5 Amount of a clamp76.504 tnemeC 1 gK ni ittebuc 6 rep ÃtitnauQ 3m/gk ÃtitnauQ 12.8 76.504 otnemeC 1 gK ni ittebuc 6 rep ÃtitnauQ elairetaM .oN.S 5732 ÃtisneD 54.3 521.071 auqcA 5 602.0 02.01 ortev id arbiF 4 37.22 28.2211 onalossorg otagerggA 3 18.41 35.137 enif otagerggA 2 98.6 52.043 otnemeC 1 gK ni ittebuc 6 rep ÃtitnauQ 3m/gk 4 ÃtitnauQ .oN.S D xiM 02M rep itazzilitu ilairetam id Ãtitnauq e alecsim id inoizroporp artsom ehc 01 allebaT 2632 ÃtisneD 290.0 55.4 erotazzicitsalpreupuS 6 96.3 281 auqcA 5 481.0 1.9 ortev id arbiF 4 20.22 54.7801 onalossorg otagerggA 3 26.21 53.326 enif otagerggA 2 12.9 554 tnemeC 1 gK ni ittebuc 6 rep ÃtitnauQ 3m/gk ÃtitnauQ .oN.S C xiM 04M rep itazzilitu ilairetam id Ãtitnauq e inoizroporp odnartsoM 9 allebaT 6532 ÃtisneD 280.0 60.4 erotazzicitsalprepuS 6 98.3 55.281 auqcA 5 461.0 11.8 ortev id arbiF 4 38.22 67.7211 onalossorg otagerggA 3 37.21 97.826 enif otagerggA 2 12.8 76.504 tnemeC 1 gK ni ittebuc 6 rep ÃtitnauQ 3m/gk ÃtitnauQ .oN.S C xiM 03M rep itazzilitu ilairetam id Ãtitnauq e inoizroporp odnartsoM 8 allebaT 1732 ÃtisneD 54.3 521.071 auqcA 5 831.0 08.6 ortev id arbiF 4 37.22 28.2211 onalossorg otagerggA 3 18.41 35.137 enif otagerggA 2 98.6 52.043 otnemeC 1 gK ni ibuc 6 rep ÃtitnauQ 3m/gk ÃtitnauQ .oN.S C xiM 02M rep itazzilitu ilairetam id Ãtitnauq e inoizroporp artsom ehc 7 allebaT 7532 ÃtisneD 290.0 55.4 erotazzicitsalpreupuS 6 96.3 281 auqcA 5 290.0 55.4 ortev id arbiF 4 20.22 54.7801 onalossorg otagerggA 3 26.21 53.326 enif otagerggA 2 12.9 554 otnemeC 1 gK ni ittebuc al e asivid enoizart alla aznetsiser al ,enoisserpmoc a aznetsiser aL .K ,alwahC .ihledweN ,dradnatS naidnI fo uaeruB ,gninoitroporPxiMetercnoCroFedoC ,9002-26201SI .alecsim emoc otnemec led osep led %3 e %2 ,%1 ,%5,0 olled imuffo id ilautnecrep el odnairav 04M e 03M ,02M otnemec id idarg rep ozzurtseclac id ehcinaccem eireporp id ovitarapmoc oiduts onu ednerpmoc oiduts oL .B ,irawkeT e .liF-lif -meC DH ortev id erbif el atazzilitu atats ¨Ã oroval otseuq ni :ortev id arbiF .3891noitidE tsriF otacilbbup ,icifide de CRG ,esuohedoW .G.R e ecydroF .W.M .555002 otacilbbup ,enoizurtsoc ad ilairetam e inoizurtsoc id atsivir ,inoizacinumocelet id irrot ellen CRG id elarutturts enoizacilppA ,5002 ocnarB .A.F ,arierreF .G.J J itnemirefiR .inif etnemamertse ortev id erbif noc otazzilaer elairetam Ã .04M e 03M otnemec id odarg li rep ottegorp otseuq ni etnacifitsalp repus emoc otasu otats ¨Ã tsalpnoC :erutximdA .)872pp(,8 olotipac ,7002 enoizide adnoces ,arbif ni itazrofnir isoizerec itisopmoc ,ssdniM yendiS e rutneB nonrA .)153PP(,31 olotipac ,2991 oiarbbef ,arbif ni otazrofnir otnemec id itisopmoc ,hahS .inoisulcnoc itneuges el ettaf etats onos ,TECR RSR id otnemec ni oirotarobal len itappulivs ,ortev id arbif ni otamra otnemec lus ittodnoc itnemirepse ilgad enoisulcnoc al e enoisself alla aznetsiser allus enoissucsid id irdnilic ied asivid enoizart alla aznetsiser aL amlac id enoisuf alled amlac id enoizseclac id aruttoc id oroval id itatlusiR 7632 Ãtisned 290.0 55.4 rezicitsalprepus 6 96.3 281 auqca 5 672.0 56.31 ortev id arbif 4 20,22 54,7801 onalossorg otagergga >< 3 26,21 53,326 enif otagergga 2 12.9 554 otnemec 1 gk ni ibuc 6 rep Ãtitnauq 3m/gk elairetam id ÃtitnauQ .oN.S D xiM 04M rep itasu ilairetam id Ãtitnauq e elecsim id inoizroporp artsom ehc 21 allebaT 2532 ÃtisneD 280,0 60.4 rezicitsalprepuS 6 98.3 55,281 auqcA 5 280,0 50.4 ortev id arbiF 4 38,22 67,7211 ossorg otagerggA 3 37,21 97,826 enif otagerggA 2 the bending have increased until the addition of 1% of the glass fibres, then it gradually decreases. refined aggregate and coarse coarse : : Zone-II sand was considered for work and machine crushed stone used as coarse aggregate. 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Maheswaran, Behavioural study on the effect of AR-Glass Fibre reinforced concrete, NBW & CW October 2006, (pp 174-180). 5, No.1, pp. Chandramouli, K, Srinivasa Rao, P, Pannirselvam, N, Seshadri Sekhar,T, and Sravana, Priyadrashini,T.P, (2010), Strength and Characteristic of fiberglass concrete, International Journal of Mechanics of Solids, vol. Although its wholesale resistance and weight properties are also very favorable compared to other fibers. The size of the aggregate varies from 20 mm to 4.75 mm. The glass wool, which is commonly known as fiber glass today, however, was invented in 1938 by the Slayter of Russell Games of Owens-Corning as a material to be used as isolation. The specimens were tested for compression resistance according to 516-1959 on a 2000 kn capacity compression test machine. The addition of fiberglass improves tenacit, resistance to flexion, ductility and compression resistance of concrete. The two -point loading method is used for tests. All tests were performed under vertical movement control. After placing the sample, the compression load is applied due to the load, the sample fails and there is a mistake. The addition of 0.5%, 1%, 2% and 3% of the concrete glass fibers reduces the cracks in different load conditions. Cement of materials: the OPC 53. Shettym.s., (2012), Concretetechnology, S.Chand & Company Ltd. A.E (1997), distinctive attributes for fiber applications of cement compositions was used in this work. Armed with high performance for fiber applications, fifth international concrete on structural insufficiency, duration that Retrofitting of Singapore 27-28 November. Glass is the most ancient and familiar performance fiber. Levitt 1997 Problems and solutions for concrete materials, GRC and Alcali-Glass reaction, First Edition 1997, (PP22-24). The suitable addition of glass fiber in the matrix is 0.5 to 1%. Glass fibers have great traction resistance and an elasticity module. 448-455. The cubic sample is of the size 150 âaste 150 âalent 150 mm. 9103-1999, Indian Standard Concrete Mixing Specification, Bureau of Indian Standard, Newdelhi. The bending resistance of the prism sample is expressed as a break form. Surendra P. Newdelhi Sinha, D.A., Varma, A.K. and, Prakash, Prakash,(2013), Concrete Journal, Vol-87, August, pp.26-30. (2012), reinforced concrete fiberglass,Yahoo Group Civil Engineering Portal, pp.1-7. In this study, CEM-FIL Anti crack HD glass fibres were used during experiments. This study was done to discover the effect of glass fibers in different levels of cement. Ghare, Manufacture of glass fibre reinforced concrete products, Unit 1, Division YOGI-UAE group, August 2008. IS 456-2000, Plain and Reinforced Concrete Code or Practice(Quarta revision),BureauofIndianStandard, NewDelhi. Fine aggregate finesse module: 3.10 Form of finesse by coarse aggregate: 7.15 Specific gravity for fine aggregate: 2.62 Specific gravity for coarse aggregate:2.8 Water: Drinking water supplied by the college was used for the preparation and treatment of concrete. PP 429 -439. IS 383-1970, specific for coarse and fine aggregate from natural sources for cement (Second revision), Indian Standards Office, NewDelhi. IS 8112-1989, 43 Ordinary grade Portland Cement, Indian Standards Office, NewDelhi. INTRODUCTION Glass fibres are the members carrying loads, while the matrix keeps them intact in the desired positions and orientation, acting as a load transfer channel between the fibers and protecting them from environmental clams and chemical exposure. The mix was designed using IS 10262. The mixture proportions corresponding to M20 are 1:1.43:3.20:0.50, M30 are 1:1.58:2.75:0.45 and M40 are 1:1.37:2.39:0.40 EXPERIMENTAL PROGRAMME AND METODOLOGY After the tests were conducted on the cubes. M. Dr. P. The effect of fibers in the matrix leads to an increase in tension because the cement is weak in tension and also increases the impact force of the matrix. Flex resistance Test: ResistanceThe champion was determined with the help of the universal test machine. 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Cobalt is a chemical element with the symbol Co and atomic number 27. As with nickel, cobalt is found in the Earth's crust only in a chemically combined form, save for small deposits found in alloys of natural meteoric iron.The free element, produced by reductive smelting, is a hard, lustrous, silver-gray metal.. Cobalt-based blue pigments (cobalt blue) have been used since … 21/06/2021 · invites all interested parties to respond to a Request for Qoutation (RFQ): Full design, supply and installation of LG air-conditioning at the signals building Free of Charge: ELANDSFO NTEIN DEPOT: 2013-07-17 (12:00) 011 878 7017: Sibongile.Dlamini: RFP TPG-CON-017-2013 Preview Tender Document can be downloaded for evaluation. Click on the Red ...

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