International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.8, pp 359-366, 2017

Retrofitting of solid waste based RC beams using CFRP laminates.

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Abstract : Reinforced Concrete structural components are found to exhibit distress, even before their service period is over due to several causes. This present study is focused on the usage of solid waste material as cement replacement and aggregate replacement in concrete. The GGBFS is used for about 30% as the partial replacement of cement and 20% of recycled aggregate is used as course aggregate. After the occurrence of distress strengthening are essential. The technique used for strengthening of structural components is known as Retrofitting. Carbon fiber reinforced polymer(CFRP) is used as the Retrofitting material which can be applied quickly to the surface of the damaged element without the requirement of any special bonding material and also it requires less skilled labour.

The flexure and shear deficient of RC beams initially stressed to a prefixed percentage of the safe load are retrofitted using CFRP to increase the strength of beam in both shear and flexure.

Keywords : Flexure, shear, CFRP laminates, Solids waste, GGBFS and recycled aggregate.

1.0 Introduction

The strengthening and enhancement of the performance of deficient structural elements in a structure or a structure as a whole is referred to as retrofitting. Repair refers to partial improvement of the degraded strength of a building after an earthquake. In effect, it is only a cosmetic enhancement. Rehabilitation is a functional improvement, wherein the aim is to achieve the original strength of a building after an earthquake. Retrofitting means structural strengthening of a building to a Pre- defined performance level, whether or not an earthquake has occurred. The seismic performance of a retrofitted building is aimed higher than that of the original building[1].

Distress in the structure occurs due to erroneous design, improper workmanship in construction, lack of maintenance, over loading, exposé to abnormal environment and natural disasters. The choice of a particular method for retrofitting depends largely upon the cause and the extent of their damage. Several researchers have investigated the problem of rehabilitation of distressed R.C beams in flexure[2]. But very little information is available in case of shear failures. Thus the objective of the present work is to study the behavior of R.C beams deficient in both flexure and shear, strengthened using GGBFS and Recycled Aggregate while maintaining the original cross sectional dimensions.

A survey of existing residential buildings reveals that many buildings are not adequately designed to resist earthquakes. In the recent revision of the Indian earthquake code (IS1893:2002), many regions of the country were placed in higher seismic zones.

In present RC beams initially stressed to a prefixed percentage of the ultimate load are retrofitted with GGBFS and Recycled Aggregate to improve the performance of RC beam in shear and flexure, the CFRPs laminatesis wrapped around the beam[3].

2.0 Ground Granulated Blast Furnace Slag

Ground Granulated Blast Furnace Slag (GGBFS) is a by-product of the steel industry. Blast furnace slag is defined as "the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition simultaneously with iron in a blast furnace." In the production of iron, blast furnaces are loaded with iron ore, fluxing agents, and coke. When the iron ore, which is made up of iron oxides, silica, and alumina, comes together with the fluxing agents, molten slag and iron are produced. The molten slag then goes through a particular process depending on what type of slag it will become. Air-cooled slag has a rough finish and larger surface area when compared to aggregates of that volume which allows it to bind well with portland cements as well as asphalt mixtures. GGBFS is produced when molten slag is quenched rapidly using water jets, which produces a granular glassy aggregate.

In accordance with ASTM C989, GGBFS has three strength grades which are determined by their respective mortar strength when they are mixed with equal mass of portland cement[4]. The three grades, 80, 100, and 120, are classified according to their slag activity index which is average compressive strength of the slag-reference cement cubes (SP), divided by the average compressive strength of the reference cement cubes (P), multiplied by 100

Slag activity index, % $= \frac{SP}{P} \times 100$

Slag is primarily made up of silica, alumina, calcium oxide, and magnesia (95%). Other elements like manganese, iron, sulphur, and trace amounts of other elements make up about other 5% of slag. The exact concentrations of elements vary slightly depending on where and how the slag is produced.

When cement reacts with water, it hydrates and produces calcium silicate hydrate (CSH), the main component to the cements strength, and calcium hydroxide ($Ca(OH)_2$). When GGBFS is added to the mixture, it also reacts with water and produces CSH from its available supply of calcium oxide and silica. A pozzolanic reaction also takes place which uses the excess SiO_2 from the slag source, $Ca(OH)_2$ produced by the hydration of the portland cement, and water to produces more of the desirable CSH making slag a beneficial mineral admixture to the durability of concrete.

Concrete is one of the most widely used construction material. However, the manufacture of Portland cement (main component of concrete) is highly energy intensive and involves the emission of CO2 to the atmosphere. Nowadays, energy saving in building technology is one of the most important problems in the world. Reduction of energy usage can take place even by design methods or using waste materials. To save energy and reduce CO2emission, the mineral admixtures such as fly ash (FA), silica fume (SF), ground blast-furnace slag (GBFS) and metakaolin (MK)are commonly used as a partial substitution of Portland cement. Also, these admixtures are often added to change the physical and chemical properties of the concrete [5]. GBFS has been used for many years as a supplementary cementitious material (SCM) in concrete, either as a mineral admixture or a component of blended cement. GBFS typically replaces 35–65 mass% of Portland cement in concrete. Thus 50 mass% replacement of Portland cement would result in a reduction of approximately 500,000 t of CO2 over the world of cement production. Using GBFS as a partial replacement takes advantage of the energy saving in Portland cement and is governed by AASHTO M302. Blast-furnace slag (BFS) is produced from the manufacture of pig iron. It forms when the slagging agents are added to the iron ore to remove impurities. In the process of reducing iron ore to iron metal, a molten slag forms as nonmetallic liquid that floats on the top of the molten iron. It is then separated from the liquid metal and cooled. Depending on the cooling mode, three types of slag are produced, i.e., air-cooled slag (ACS), expanded or foamed slag and granulated (sand-like) slag. The rapid cooling of molten slag by water prevents the formation of large crystals, and the resulting slag normally contains more than 95% of glass (amorphous calcium aluminosilicates). This type of slag is called water-cooled slag (WCS) or granulated blast furnace slag (GBFS). The chemical composition of slag can vary over a wide range depending on the nature of the ore, the composition of the limestone flux coke and the type of iron being made. The main constituents include: CaO, SiO2 andAl2O3. In addition, it contains a small amount of MgO, FeO and sulfides such as CaS, MnO and Fe . GBFS is widely used around the world as a cement replacement material in blended cements and shows both cementitious behavior and pozzolanic activity (reaction with free portlandite). Pure slag reacts with water at a slow rate. The presence of highly alkaline medium is required to disintegrate its acidic silicate–aluminate network.

2.1 CFRP laminates

CFRPs can be expensive to produce but are commonly used wherever high strength-to-weight ratio and rigidity are required, such as aerospace, automotive, civil engineering, sports goods and an increasing number of other consumer and technical applications[5,6].

The binding polymer is often a thermoset resin such as epoxy, but other thermoset or thermoplastic polymers, such as polyester, vinyl ester or nylon, are sometimes used. The composite may contain other fibers, such as an aramid (e.g. Kevlar, Twaron), aluminium,ultra-high-molecular-weight polyethylene (UHMWPE) or glass fibers, as well as carbon fiber. The properties of the final CFRP product can also be affected by the type of additives introduced to the binding matrix (the resin). The most frequent additive is silica, but other additives such as rubber and carbon nanotubes can be used. The material is also referred to as graphite-reinforced polymer or graphite fiber-reinforced polymer (GFRP is less common, as it clashes with glass-(fiber)-reinforced polymer). In product advertisements, it is sometimes referred to simply as graphite fiber for short.

Fig.1 CFRP laminates

2.2 Disposal and Recycling

CFRPs have a long service lifetime when protected from the sun. When it is time to decommission CFRPs, they cannot be melted down in air like many metals. When free of vinyl (PVC or polyvinyl chloride) and other halogenated polymers, CFRPs can be thermally decomposed via thermal depolymerization in an oxygen-free environment. This can be accomplished in a refinery in a one-step process[7]. Capture and reuse of the carbon and monomers is then possible. CFRPs can also be milled or shredded at low temperature to reclaim the carbon fiber; however, this process shortens the fibers dramatically. Just as with downcycled paper, the shortened fibers cause the recycled material to be weaker than the original material. There are still many industrial applications that do not need the strength of full-length carbon fiber reinforcement. For example, chopped reclaimed carbon fiber can be used in consumer electronics, such as laptops. It provides excellent reinforcement of the polymers used even if it lacks the strength-to-weight ratio of an aerospace component[8].

2.3 Recycled Aggregates in Concrete

Any construction activity requires several materials such as concrete, steel, brick, stone, glass, clay, mud, wood, and so on. However, the cement concrete remains the main construction material used in construction industries. For its suitability and adaptability with respect to the changing environment, the concrete must be such thatit can conserve resources, protect the environment, economize and lead to proper utilization of energy. To achieve this, major emphasis must be laid on the use of wastes and byproducts in cement and concrete used for new constructions. The utilization of recycled aggregate is particularly very promising as 75 per cent of concrete is made of aggregates. In that case, the aggregates considered are slag, power plant wastes, recycled concrete, mining and quarrying wastes, waste glass, incinerator residue, red mud, burnt clay, sawdust, combustor ash and foundry sand[9]. The enormous quantities of demolished concrete are available at various construction sites, which are now posing a serious problem of disposal in urban areas. This can easily be recycled as aggregate and used in concrete. Research & Development activities have been taken up all over the world for proving its feasibility, economic viability and cost effectiveness[10].

Fig.2 Recycled aggregates

3.0 Importance of Retrofitting

- Saving on capital expenditure while benefiting from new technologies
- Optimization of existing plant components
- Adaptation of the plant for new or changed products
- Increase in piece number and cycle time
- Guaranteed spare parts availability.
- Increasing the global capacity (strengthening). This is typically done by the addition of cross braces or new structural walls.

3.1 Objective

The objective of this investigation is

- To find out an effect on strength of the RC beam retrofitted with CFRP wrapping by comparing the load carrying capacity of the retrofitted beam and control beam.
- To determine the flexural rigidity of the RC beam retrofitted with CFRP wrapping on three sides by measuring deflection of the retrofitted beam and compare with control beam.
- To observe behavior of the RC beam retrofitted with CFRP, wrapping on three sides and control beam with respect to first crack load, crack pattern and crack width.
- To determine the ductility ratio.

3.2 Scope

The experimental investigations are planed:

- To retrofit the beams by using ferrocement laminates.
- To have a comparison of the results between control beams and retrofitted beams.

4.0 Methodology

The present research work is experimental and requires preliminary investigations in a methodological manner.

4.1 Cement

The cement used in this experimental work is “Ultratech53 grade Ordinary Portland Cement”. All properties of cement are tested by referring IS 12269 - 1987 Specification for 53 Grade Ordinary Portland cement. The specific gravity of the cement is 3.15. The initial and final setting times were found as 74minutes and 385 minutes respectively. Standard consistency of cement was 30%.

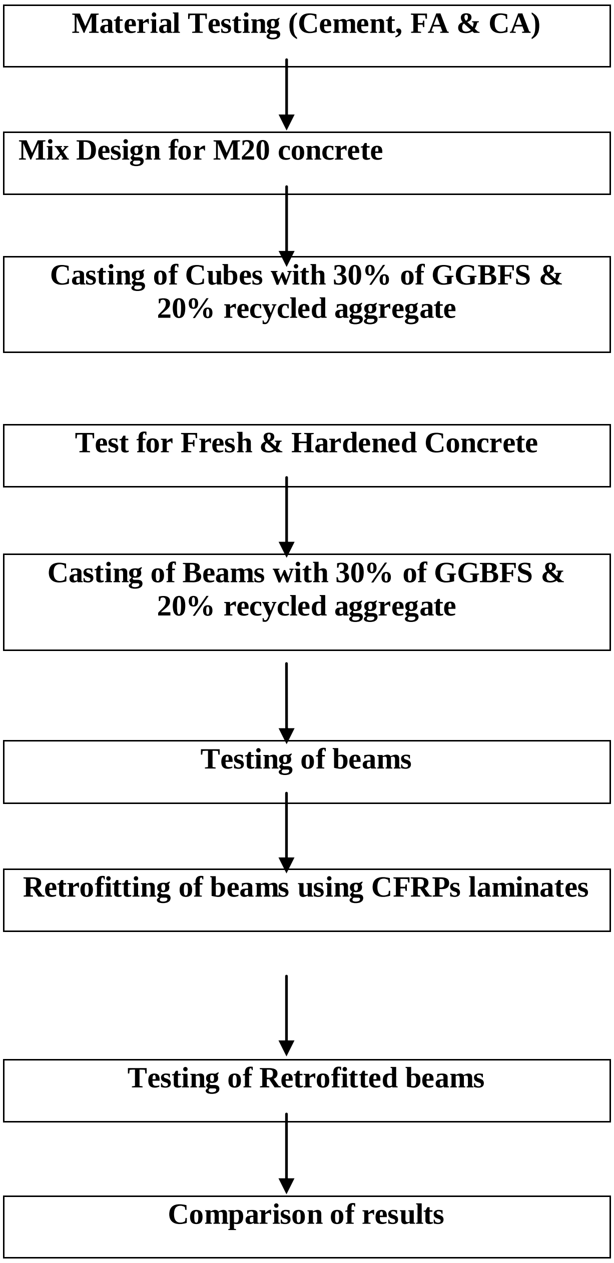
4.2 Fine aggregate

Locally available sand of river passed through 4.75mm IS sieve is used. The specific gravity of 2.75 and fineness modulus of 2.806 are used as fine aggregate. The loose and compacted bulk density values of sand are 1600 and 1688 kg/m3 respectively, the water absorption of 1.1%.

4.3 Mixture Proportion

Cement: Sand: Coarse Aggregate:

1: 1.433: 2.816.



5.0 Result and Discussions

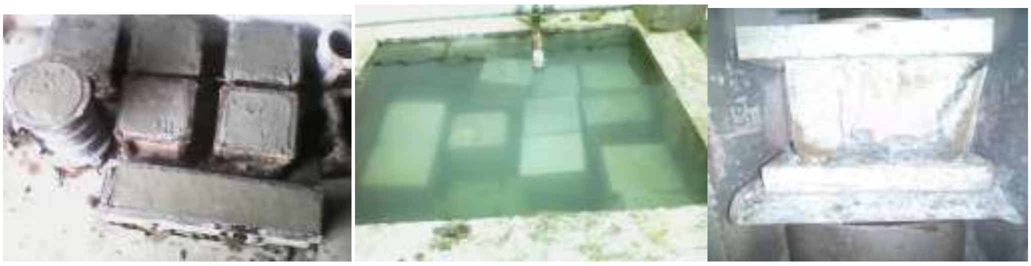
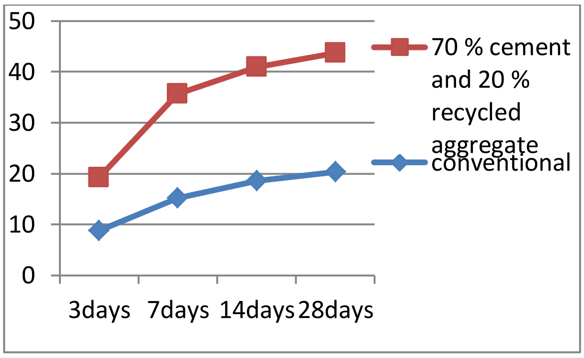


Fig.4 Casting, Curing, Testing of cubes

Table: 1Compressive Strength of Cube

S. NO	CEMENT	GGBS	Recycled aggregate	Compressive Strength Of Cube (N/mm^2)			
				3days	7days	14days	28days
1	100	0	0	**8.720**	**15.132**	**18.620**	**20.264**
2	70%	30%	20%	**10.42**	**20.464**	**22.312**	**23.431**



The optimum percentage is founded and the beam is casted. Here the optimum percentage for which the compressive strength is high is 30% of GGBFS and 70% of cement. So the beam is casted and compared with the conventional beam.

4.1 REINFORCEMENT DETAILS

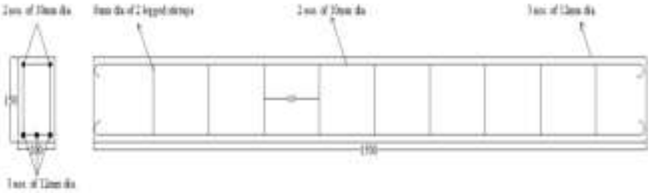


Fig.5 Casting of Beams

4.2 Experimental Set Up

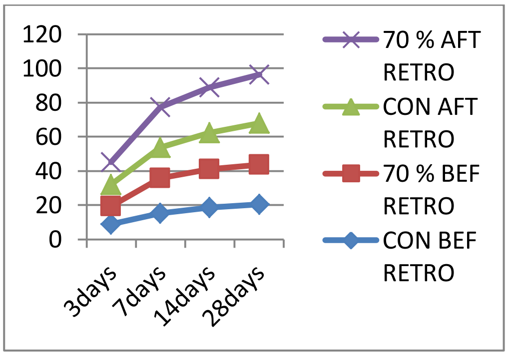
Table: 2 Flexural Strength of Beam

S. N O	CEMENT	GGBS	Recycled aggregate	Flexural Strength (N/mm^2)			
				3days	7days	14days	28days
1	100	0	0	**8.720**	**15.132**	**18.620**	**20.264**
2	70	30%	20%	**10.42**	**20.464**	**22.312**	**23.431**

Results of Retrofitted Beams

Table: 3 Flexural Strength of Retrofitted beams

S. NO	CEMENT	GGBS	Recycled aggregate	Flexural Strength (N/mm^2)			
				3days	7days	14days	28days
1	100	0	0	**12.7**	**18.2**	**21.30**	**24.31**
2	70%	30%	20%	**13.20**	**23.46**	**26.78**	**28.24**



5.0 Conclusion

The control specimens have been tested and load vs deflection graph is obtained. The ductility ratio and flexural rigidity parameters are observed and compared. It is proved that the retrofitted beams possess high strength and load carrying capacity and likely proved that they are economical.

6.0 References

1. G Haque. ‘Optimum Use of Flyash Concrete in Pavement’. ARRB Proceedings, vol12, pt 2, 1984, pp 19–26.
2. F P Zhou, R V Balendran and A P Jeary. ‘Size Effect on Flexural, Splitting Tensile and Torsional Strengths of High–strength Concrete’.Cement and Concrete Research, vol 28, no 12, January 1998, pp 1725–1736.
3. A D Cengiz. ‘High Volume Flyash Abrasion Resistance Concrete’. Journal of Materials in Civil Engineering, vol 14, no 3, June 2002,pp 274–277.
4. M Maslehuddin, M A Sharif, M Shameen, M Ibrahim and M S Barry. ‘Comparison of Properties of Steel Slag and Crushed Limestone Aggregates Concretes’. Construction and Building Materials, August 2002, pp 105–112.
5. S Rafat. ‘Effect of Fine Aggregate Replacement with Class Flyash on the Abrasion Resistance of Concrete’. Cement and Concrete Research, June 2003, pp 1877–1881.
6. J Xianyu and Li Zongjin. ‘Effects of Mineral Admixtures on Properties of Young Concrete’.Journal of Materials in Civil Engineering, vol 15, no 5, October 2003, pp 435–442.
7. The American Society for Testing and Materials, ASTM, C989-99
8. Elliot, D. F., Ground Granulated Blast-Furnace Slag for Use in Airfield Pavements, Lone Star Industries, New Orleans, LA
9. Douglas, E., Bilodeau, A., Malhotra, V. M., “Properties and Durability of Alkali-Activated Slag Concrete,” ACI Materials Journal, V. 89, No 5. September-October 1992. pp 509-516
10. Concrete Technology – M.S. Shetty

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