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STRENGTH DEGRADATION OF MECHANICAL PROPERTIES OF GLASS FIBRE REINFORCED POLYMER COMPOSITES UNDER HYDROTHERMAL LOADING

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ABSTRACT

Carbon Fibre-Reinforced Polymer (CFRP) and Glass Fibre-Reinforced Polymer (GFRP) have been used as an alternative to steel in concrete due to a high strength-to-weight ratio, high stiffness-to-weight ratio, and corrosion and fatigue resistance, thus making it most suitable for use in coastal environments. GFRPs have been found to be more attractive in the Asian region due to their cost competitiveness in comparison to CFRP. Thus considerable data is available with only one or a combination of some of these parameters. Hence effort is required to fully comprehend the GFRP response under natural and accelerated moisture and temperature conditions of tropical climates. To achieve the objective, an experimental setup was prepared. The aim of the present research work was to study the combined effect of chosen parameters such as moisture, alkali and temperature, and also to study the rate and magnitude of damage of GFRP composites. This will help in studying the response of the composite to the given hydrothermal load. The changes occurring in the physical composition of the composite material were also studied in the present research work. The SEM (scanning electron microscope) images at different loading and EDX (Energy-Dispersive X-Ray) analysing images for different periods were studied for samples immersed in both potable water and NaOH solution to observe the damage done to the fibre.

Keywords

Unidirectional E-Glass Fiber, Epoxy Resin, Hardener, Mechanical Properties, SEM (Scanning Electron Microscope)

1.0 INTRODUCTION

The corrosion of steel in reinforced concrete structures reduces the service life of the structure, which causes high repair costs and can sometimes even endanger the structural integrity of the structure. However, Glass Fibre Reinforced Polymer (GFRP) offers a number of advantages over steel especially when used in marine and other coastal environments, making it a very durable reinforcement material. A Fibre-Reinforced Polymer (FRP) is a composite material comprising a polymer matrix reinforced with fibres. The fibres are usually fibreglass, carbon, or aramid, while the polymer is usually an epoxy, vinyl ester or polyester thermosetting plastic. FRPs are commonly used in the aerospace, automotive, marine, and construction industries. The strength properties of FRP collectively make up one of the primary reasons for which civil engineers select them in the design of structures. A material's strength is governed by its ability to sustain a load without excessive deformation or failure. When an FRP specimen is tested in axial tension, the applied force per unit cross-sectional area (stress) is proportional to the ratio of change in a specimen's length to its original length (strain). When the applied load is removed, the FRP returns to its original shape or length. In other words, FRP responds linear-elastically to axial stress. The response of FRP to axial compression is reliant on the relative proportion in volume of fibres, the properties of the fibre and resin, and the interface bond strength. FRP composite compression failures occur when the fibres exhibit extreme (often sudden and dramatic) lateral or sides-way deflection called fibre buckling. FRP's response to transverse tensile stress is very much dependent on the properties of the fibre and matrix, the interaction between the fibre and matrix, and the strength of the fibre-matrix interface. Generally, however, tensile strength in this direction is very poor. Shear stress is induced in the plane of an area when external loads tend to cause two segments of a body to slide over one another. The shear strength of FRP is difficult to quantify. Generally, failure will occur within the matrix material parallel to the fibres. According to Vaddadi et al.[1] the transient hydrothermal stresses induced in fibre-reinforced composites are studied in detail by adopting a novel heterogeneous characterisation approach. This approach incorporates two distinct features: transient moisture absorption analysis of actual composite materials exposed to a humid environment, and highly detailed computational analyses that capture the actual heterogeneous microstructure of the composite. The latter feature is carried out by modelling a uniaxial laminate having more than one thousand individual carbon fibres that are randomly distributed within an epoxy matrix. Results indicate that these computational models are essential in capturing the accurate moisture absorption process of the actual specimen. In the analysis, the evolutions of thermal residual stresses and moisture-induced stresses within the humidity and thermal exposed composites were analysed. It was observed that high stress concentration develops in the epoxy phase where high fibre density or fibre clustering exists and its

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AN EXPERIMENTAL STUDY OF THE FLEXURAL BEHAVIOUR OF DAMAGED RC BEAMS STRENGTHENED WITH BASALT FIBER REINFORCED POLYMER (BFRP) SHEETS

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ABSTRACT

This paper presents the flexural behaviour of Basalt Fiber Reinforced Polymer (BFRP) strengthened Reinforced Concrete (RC) beams. For flexural strengthening of reinforced concrete beams, a total of twenty-two beams were cast and tested over an effective span of 900 mm up to failure of the beam under two-point loading. The beams were designed as under-reinforced beams. The beams were bonded with BFRP sheets in single and double layers along the length at the bottom face of the beam. Out of the twenty-two beams, two beams were control beams and the remaining beams were strengthened after being damaged to various degrees (0%, 70%, 80%, 90% and 100%). The experimental results show that the strengthened beams showed high load carrying capacity.

Keywords

Basalt Fiber Reinforced Polymer (BFRP), Control beam, Strengthened beam, Reinforced concrete, Ultimate load carrying capacity

1.0 INTRODUCTION

Much of our current infrastructure is constructed with reinforced concrete. As time passes, deterioration and change of use requirements facilitate the need for new structures. Demolition of existing and construction of new structures is a costly, time consuming and resource intensive operation. If existing structures could be reinforced to meet new requirements, then the associated operating costs of our infrastructure would be reduced [1]. In recent years, the repair and retrofitting of existing structures such as buildings, bridges, etc., have been amongst the most important challenges in civil engineering. The main reason for strengthening of RC structures is to upgrade the resistance of the structure to withstand underestimated loads and increase the load carrying capacity for structural strengthening, structural up-gradation and seismic retrofitting. The maintenance and rehabilitation of structural members, is perhaps one of the most crucial problems in civil engineering applications [2].

2.0 BASALT FIBERS

Basalt is a natural, hard, dense, dark brown to black volcanic igneous rock originating at a depth of hundreds of kilometres beneath the earth and reappearing on the surface as molten magma. It's grey, dark in colour, formed from the molten lava after solidification. The production of basalt fiber consists of melt preparation, extrusion, fiber formation, application of lubricates and finally winding. This method is also known as spinning. A fiber is a material made into a long filament with a density generally in the order of 300g/cm^2 of 50 cm [2].

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Experimental studies conducted by David E. etal. [3] focused on the flexural behaviour of RC beams strengthened using Carbon Fibre Plates. Esfahani M.R. etal. [2] investigated the flexural behaviour of reinforced concrete beams strengthened using Carbon Fibre Reinforced Polymers (CFRP) sheets. Jadhav H.S. etal. [4] presented the results of experimental studies carried out to investigate the effect of length, width and number of layers of Glass Fiber Reinforced Polymer strips.

3.0 EXPERIMENTAL PROGRAM

The experimental programme consisted of casting reinforced concrete beams, damaging them to various degrees, strengthening those damaged specimens by applying the BFRP sheets and testing them under two point loading.

3.1 Details of the Beam Specimen

The experimental work consisted of a total of twenty-two rectangular beams under reinforced concrete. The under-reinforced beams were selected so that they could be strengthened with Basalt Fiber Reinforced Polymer (BFRP) sheets. All beams were of the same size (100 mm x 150 mm x 1200 mm). 2-8 mm diameter bars were used for flexural reinforcement at the bottom of each beam - 2-8 mm at the top of each beam and 6 mm diameter stirrups spaced 150 mm center-to-center for shear reinforcement. Typical beam reinforcement details are illustrated in Figure 1. The casting of beams was made as per the IS code specification using M20 grade concrete with 20 mm maximum size coarse aggregate, locally available sand and 53 Grade Ordinary Portland cement. These beams were cured for 28 days in potable water at room temperature.

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USE OF CERAMIC (SANITARYWARE) WASTE IN MAKING GREEN CONCRETE

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ABSTRACT

The use of recycled aggregates is a natural step towards solving part of the problem of depletion of natural aggregates. Concrete which contains waste products as aggregate is called "Green Concrete". The use of unhazardous waste in concrete making will lead to a green environment and sustainable concrete technology and so, such concrete can also be called "Green Concrete". It has been estimated that about 30% of the daily production in the ceramic industry goes to waste due to improper mixing of raw materials, excess water, improper drying and too much heating which is not recycled at present. Reusing these wastes in concrete could be a win-win situation. The conservation of natural resources and prevention of environmental degradation is the essence of any developed country. Concrete made from ceramic (sanitary ware) waste as a coarse aggregate has been studied for compressive strength, split tensile strength and flexural strength. The laboratory tests have followed the provisions of Indian Standards. In this research study the coarse aggregates (20 mm) have been replaced by ceramic (sanitary ware) waste in the range of 0%, 10%, 20%, 30%, 40%, 50%, 70% and 100% by weight for M-20 grade concrete. Concrete samples have been tested and compared in terms of compressive strength, split tensile strength, flexural strength. The test results have reflected that the compressive strength and other strengths achieved for 50% replacement of coarse aggregate (20 mm) with ceramic waste will be optimum without affecting the properties of fresh and hardened concrete.

Keywords

Recycled aggregate, Depletion of natural resources, Green concrete, Sustainability, Mechanical properties of recycled aggregate concrete

1.0 INTRODUCTION

Each year thousands of tonnes of waste is disposed of in landfills, which results in the occupation and degradation of valuable land [1]. Depletion of natural resources is a common phenomenon in developing countries like India, due to rapid urbanization and industrialization involving the construction of infrastructures and other amenities.

The cost of natural resources is increased day by day [2]. Currently, waste handling and utilization are burning ecological problems. The need to develop concrete with non-conventional aggregates is urgent for environmental as well as economic reasons [3]. Therefore, intensive investigations are being carried out in order to utilize industrial, domestic waste for concrete mix. The grained rubber of tyres, modified sawdust, crushed ceramic bricks (brick bats), plastic waste and remains of glass (broken glass), fly ash, blast furnace slag, quarry dust, tile waste, waste aggregates from the demolition of structures and ceramic insulator wastes, etc., are utilized to produce concrete.

The reuse of wastes as inputs to other processes would alleviate disposal concerns and reduce the need for virgin resources. There is government as well as community pressure to reduce the volume of the waste by recycling the same. We can see from the study of Harappa, Mohenjo-Daro and Dhola-Veera (Kutch) cultures that after thousands of years in a buried position, the things (pieces of pots and other items made up of soils) are not degraded. So in reality these materials are not degradable. Meanwhile, conventional crushed stone aggregates reserves are being depleted rapidly, particularly in some desert regions of the world. There is a growing demand for aggregates which, together with increased environmental restrictions on quarrying, have led to the consideration of reusing certain residues in order to obtain alternative primary materials [4]. Concrete which contains waste products as aggregate is called "Green" concrete [5].

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2.0 EXPERIMENTAL PROGRAMME

The experimental programme comprises the following two stages:

- Characterization of ceramic waste aggregate and comparison with crushed stone natural coarse aggregates.
- Study of the behaviour of fresh and hardened concrete with ceramic waste coarse aggregate and comparison with the respective properties with conventional concrete.

3.0 MATERIALS

3.1. Ceramic Waste as Coarse Aggregate

Ceramic sanitary ware wastes (Figure 1) are generally too big to be fed into a crushing machine. They are broken into small pieces of about 100 – 150 mm sizes by a hammer and the surface can be deglazed manually with a chisel and hammer. These small pieces are then

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RECYCLED CONCRETE AGGREGATE: A SUSTAINABLE ALTERNATIVE TO NATURAL AGGREGATE

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A B S T R A C T

The production processes of major ingredients of concrete, i.e. cement and aggregates, involve un-sustainable methods. Aggregates occupy about 3/4th of the volume of concrete. With construction activity increasing all over the world, including India, the demand for cement and aggregates is also increasing. Supplementary Cementitious Materials are being used as alternative materials for cement and are addressing environmental sustainability concerns. However, no viable alternative materials for aggregates were available which could impart properties similar to concrete, like natural aggregates. The recycled concrete aggregates produced from construction and demolition waste are emerging as viable alternative to the natural aggregates. The manufacturing and the properties of the recycled concrete aggregates, and the properties of the recycled aggregate concrete, the impedance in the use of recycled concrete aggregates, and the available specifications of these aggregates are discussed in this paper. Some test results of an experimental study carried out in CRRI on these aggregates are also presented.

K e y w o r d s

Sustainability, Construction and Demolition Waste, Natural Aggregate, Recycled Concrete Aggregate, Recycled Aggregate Concrete

1.0 INTRODUCTION

Although there are many definitions for the term sustainability, the one put forth by Bruntland [1] in the context of sustainable development is very appropriate, where "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". In this context, the production process of the major ingredients of concrete are considered un-sustainable.

Concrete is made using cement (binding material), water and aggregate, and it is the second most widely used material in the world after water. While cement is the most expensive material, the aggregate is the least expensive material in the concrete mix, and the latter occupies about 3/4th of the volume of concrete. The concrete is largely consumed by the construction industry which is made up of three sectors namely infrastructure, industry and real estate. If the scale of the investment is any indication of growth, the construction industry in India is expected to attract one trillion US dollars during 2012-17, with the first two sectors accounting for 57% of the same, at an estimated Compounded Annual Growth Rate (CAGR) of 17.2% [2].

With the increased growth of the construction industry (by way of increase in investments), the demand for construction aggregates has been increasing steadily from 1.1 billion metric ton (bmt) in 2006 to 1.4 bmt in 2008 and to 1.6 bmt in 2011. The aggregates for concrete are generated by crushing the naturally occurring resources such as stones / hillocks etc. Such aggregates are called Natural Aggregates (NA). The large scale exploitation of natural resources for concrete aggregates has been in vogue for many years, but if the same continues the way it is, it will soon result in environmental and ecological imbalance. The depletion of natural resources also leads to the vanishing of flora and fauna. Hence, finding an alternate for the NA for use in concrete has caught worldwide attention in order to maintain sustainability.

As far as cement is concerned, several supplementary cementitious materials (SCM) such as silica fume, fly ash, ground granulated blast furnace slag, rice husk ash etc are available [3], and are being used as part replacement of Portland cement in concrete, which reduces the usage and in turn the production of Portland cement. The use of such SCMs has been encouraged and has also been put into practice keeping in view the sustainability considerations.

However, in the case of aggregates, the construction industry has not been so fortunate. Although they are considered inert, the (natural) aggregate imparts to concrete its dimensional and volumetric stability by controlled thermal movements (which are compatible with the steel reinforcement), by reduction of shrinkage and creep, and by imparting the wear resistance. Also, aggregates are generally the more durable and stable of the materials incorporated into concrete mixtures, and thus provide durability [4]. Hence, to find suitable alternative materials to replace NA with the ability to impart similar properties to concrete as that of NA

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