

FLEXURAL STRENGTH OF GLASS FIBER REINFORCED POLYMER WRAPPED RC BEAM BY REPLACING CEMENT WITH GROUND GRANULATED BLAST-FURNACE SLAG

Submitted in partial fulfillment of the requirements for the award
of Masters of Engineering degree in
Structural Engineering

by

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**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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BONAFIDE CERTIFICATE

This is certify that this Project Report is the bonafide work of **B.VIJAYATHA (40380005)** who is carried out the Project entitled “**FLEXURAL STRENGTH OF GLASS FIBER REINFORCED POLYMER WRAPPED RC BEAM BY REPLACING CEMENT WITH GROUND GRANULATED BLAST-FURNACE SLAG**” under my supervision from November 2021 to May 2022.

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ABSTRACT

Presently a day concrete is generally and profoundly required thing in the development. The principal parts of cement will be concrete, coarse total, fine total and water. The use and assembling of concrete will instigate the ecological issues like co₂ and intensity outflow. Thus, the common ventures are needing great substitution of concrete. The GGBS is great halfway substitution of concrete. This study made sense of going to utilize this technique for fix and restoration process during the actual development. For this wrapping of GFRP sheets over the primary individuals to reinforcing it, increment the existence season of designs and disregard the future fix works. So this task portrays the exploratory and logical investigation of "halfway substitution of concrete by GGBS and GFRP wrapped on RC radiates.

The GFRP is the composite material. This venture work centers around strength attributes, examination of M30 grade concrete with supplanting of concrete by GGBS with 20%, 30%, 40% and half and GFRP wrapping with RC radiates. Glass fiber wrapping can be utilized where cement loses its ability/plan strength because of consumption changes being used and the plan codes requests expansions in load conveying limit. From our trial results 20%, 30%, 40% and half GGBS with 6 mm thick GFRP layer will gave improved results while contrasting with traditional cement.

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LIST OF SYMBOLS

L	Length of the reinforced beams,
D	Depth of the reinforced beams & concrete cubes
T	Thickness of the structural elements
W/C	Water cement ratio
V	Absolute volume of fresh concrete
C	Mass of cement (kg)
S _c	Specific gravity of cement
W	Mass of water (kg)
F _{fu}	Design ultimate strength of FRP
C _E	Environmental reduction factor
A	Area, of the cross-sectional (in ² , ft ² , mm ² , m ²)
R	Modulus of rupture (N/mm ²)
P	Maximum applied load (N/mm ²)
B	Width of specimen (mm)
'	Symbol for feet
"	Symbol for inches

CHAPTER 1

INTRODUCTION

Cement plays the vital role in construction industry. It acts as a binding material in all concrete structural. Concrete made with Portland cement is relatively strong in compression but weak in tension. It acts as a binding material in all concrete structural, which is produced by raw material like lime and silica. Once a situation may occur there will be no lime on earth for production of cement. So that now, we are selecting the material for partial replacement of cement. The GGBS, flyash are good partial replacement of cement. Where the GGBS was an industrial waste material in steel & copper industries. The GGBS chemical properties are similar to the chemical properties of the cement.

Modern civilization relies upon the continuing performance of its civil engineering infrastructure ranging from industrial buildings to power stations and bridges. Concrete was having basic cheaply and easily available ingredients as cement, sand, aggregate and water. After the water, cement is second most used material in the world. But this rapid production of cement creates two big environmental problems for which we have to find out civil engineering solutions. First environmental problem is emission of CO_2 in the production process of the cement. 1 tone of carbon dioxide is estimated to be released to the atmosphere when 1 tone of ordinary Portland cement is manufactured.

Concrete is probably the most extensively used construction material in the world with about six billion tones being produced every year. The concrete industry is constantly looking for supplementary cementations material with the objective of reducing the solid waste disposal problem.

1.5 tonnes of limestone and clay. Today's construction industry, use of concrete is going on increasing rapidly. Demolition or reconstruction means complete replacement of an existing structure may not be a cost-effective solution and it is likely to become an increasing financial burden if upgrading is a viable alternative. Therefore repair and rehabilitation of bridges, buildings, and other civil engineering structures is very often chosen over reconstruction for the damage caused due to degradation, aging, lack of maintenance, and severe earthquakes and changes in the current design requirements. Previously, the retrofitting of reinforced concrete structures, such as columns, beams and other structural elements, was done by removing and replacing the low quality or damaged concrete or/and steel reinforcements with new and stronger material.

However, with the introduction of new advanced composite materials such as fibre reinforced polymer (FRP) composites, concrete members can now be easily and effectively strengthened using externally bonded FRP composites. Retrofitting of concrete structures with wrapping FRP sheets provide a more economical and technically superior alternative to the traditional techniques in many situations because it offers high strength, low weight, corrosion resistance, high fatigue resistance, easy and rapid installation and minimal change in structural geometry. In addition, FRP manufacturing offers a unique opportunity for the development of shapes and forms that would be difficult or impossible with the conventional steel materials.

Several investigators took up concrete beams and columns retrofitted with carbon fibre reinforced polymer (CFRP) glass fibre reinforced polymer (GFRP) composites in order to study the enhancement of strength and ductility, durability, effect of confinement, preparation of design guidelines and experimental investigations of these members.

The results obtained from different investigations regarding enhancement in basic parameters like strength/stiffness, ductility and durability of structural members retrofitted with externally bonded FRP composites, though quite encouraging, still suffers from many limitations. This needs further study in order to arrive at recognizing FRP composites as a potential full proof structural additive. FRP repair is a simple way to increase both the strength and design life of a structure. Because of its high strength to weight ratio and resistance to corrosion, this repair method is ideal for deteriorated concrete structure.

1.1 GENERAL

Modern structural engineering tends to progress toward more economical structures through gradually improved methods of design and the use of higher strength materials. Such developments are particularly important in the field of reinforced concrete; the limiting features of ordinary reinforced concrete have been largely overcome by the development of pre stressed concrete. The GGBS, fly ash are good partial replacement of cement. Where the GGBS was an industrial waste material in steel & copper industries. The GGBS chemical properties are similar to the chemical properties of the cement. Pre stress applies a pre compression to the member that reduces or eliminates undesirable tensile stresses that would otherwise be present. Cracking under service load can be minimized or even avoided entirely. Deflections may be limited to an acceptable value.

Reinforced cement concrete is an extremely popular construction material used for structural components of a building like beams, columns and slabs etc. One major flaw of RCC is its susceptibility to environmental attack. This can severely decrease the strength and life of the structures.

The repair of structurally deteriorated RC Structures becomes necessary since the structural element ceases to provide satisfactory strength and serviceability. Some of these structures are in such a bad condition that they need to be replaced. Two techniques are typically adopted for the strengthening of beams, relating to the strength enhancement desired: flexural strengthening or shear strengthening. In many cases it may be necessary to provide both strength enhancements. For the flexural strengthening of a beam, FRP sheets or plates are applied to the tension face of the member (the bottom face for a simply supported member with applied top loading or gravity loading). Principal tensile fibres are oriented in the beam longitudinal axis, similar to its internal flexural steel reinforcement. This increases the beam strength and its stiffness (load required to cause unit deflection), however decreases the deflection capacity and ductility.

The objective of the FRP wrapping is to improve the flexural strength and stiffness of deficient beams due to various causes. Carried out the investigation on different issues with GFRP and CFRP confinement on the flexural behaviour of reinforced and plain concrete beams and using GFRP and CFRP in the flexural member as confined materials can minimize the amount of cracks and eventually enhance the performance of the structure.

1.2 BACKGROUND

A large number of structures constructed in the past using the older design codes in the different parts of the world are structurally unsafe according to the new design codes. Since replacement of such deficient elements of structures incurs a huge amount of public money and time, strengthening has become the acceptable way of improving the load carrying capacity and service lives.

Wrapping Techniques of Flexural concrete elements is traditionally accomplished by externally bonding steel plates to concrete. Although this technique has proved to be effective in increasing strength and stiffness of RC Beam, it has the disadvantages of being susceptible to corrosion and difficulty in installation. Recent developments in the field of composite materials together with their inherent properties which include high tensile strength, good fatigue strength, corrosion resistance, ease of use make them an alternative to the steel plates in the field of repair and strengthening of concrete beams. For the past studies conducted it has been shown that externally bonded glass fibre reinforced polymers (GFRP) can be used to increase or enhance the Flexural Strength, shear strength, and torsional capacity of RC beams.

1.3 TORSIONAL STRENGTHENING OF BEAMS

Early efforts for understanding the response of plain concrete subjected to pure torsion revealed that the material fails in tension rather than shear. Structural members curved in plan, members of a space frame, eccentrically loaded beams, curved box girders in bridges, spandrel beams in buildings, and spiral staircases are typical examples of the structural elements subjected to torsional moments and torsion cannot be neglected while designing such members. Structural members subjected to torsion are of different shapes such as T-shape, inverted L-shape, double T-shape and box sections.

These different configurations make the understanding of torsion in RC members of complex task. In addition, torsion is usually associated with bending moments and shearing forces, and the interaction among these forces is important. Thus, the behaviour of concrete elements in torsion is primarily governed by the tensile response of the material, particularly its tensile cracking characteristics.

Spandrel beams, located at the perimeter of buildings, carry loads from slabs, joists, and beams from one side of the member only. This loading mechanism generates torsional forces that are transferred from the spandrel beams to the columns. Reinforced concrete (RC) beams have been found to be deficient in torsional capacity and in need of strengthening. These deficiencies occur for several reasons, such as insufficient stirrups resulting from construction errors or inadequate design, reduction in the effective steel area due to corrosion, or increased demand due to a change in occupancy.

Similar to the flexure and shear strengthening, the FRP fabric is bonded to the tension surface of the RC members for torsion strengthening. In the case of torsion, all sides of the member are subjected to diagonal tension and therefore the FRP sheets should be applied to all the faces of the member cross section.

1.4 ANALYTICAL INVESTIGATION

The process of modelling with ANSYS begins with identification of input parameters and the output to be predicted by the network. The input and target data are organized to suit the order of input and output parameters. The present model was developed using General Regression Neural Network (GRNN), which belongs to the family of Radial Basis Neural Networks. The GRNN contains two layers to process the input data. The architecture and functions associated with GRNN are presented in the following section.

The input parameters were the steel reinforcement ratio and the thickness of GFRP laminates. One more aspect of the training was that the control specimens did not have any GFRP laminate. This would result in zero thickness values for all control specimens.

This would make the data for CSMGFRP, WRGFRP and UDCGFRP a complete set, where the thickness value ranges from 0 mm to 5 mm. The prediction parameters of static test results were the first crack load, deflection at first crack load, yield load, deflection at yield load, ultimate load, deflection at ultimate load, crack width at ultimate stage, number of cracks, average spacing of cracks, deflection ductility, deflection ductility ratio, energy ductility and energy ductility ratio.

A new technique has emerged recently which uses fibre reinforced polymer (FRP) sheets to strengthen the beam-column joints which have a number of favourable characteristics such as ease to install, immunity to corrosion and high strength. The results obtained that the FRP strengthening technique is highly efficient and effective. Based on the review of literature it is found that experimental investigation on FRP wrapped reinforced beam column joints. Hence an attempt has been made to carry out an investigation on beam column joints specimens wrapped with GFRP.

1.5 APPLICATIONS

GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials. GGBS has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its superiority in concrete durability, extending the life span of buildings from fifty years to a hundred years.

Two major uses of GGBS are in the production of quality-improved slag cement, namely Portland Blast furnace cement (PBFC) and high-slag blast-furnace cement (HSBFC), with GGBS content ranging typically from 30 to 70% and in the production of ready-mixed or site-batched durable concrete.

Concrete made with GGBS cements sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period in production conditions. This results in lower heat of hydration and lower temperature rises, and makes avoiding cold joint easier, but may also affect construction schedules where quick setting is required.

1.6 USES OF GGBS

The major use of GGBS is in ready mixed concrete, and it is utilized in a third of all “ready-mix” deliveries. Specifiers are well aware of the technical benefits, which GGBS imparts to concrete, including:

- Better workability, making placing and compaction easier.
- Lower early age temperature rise, reducing the risk of thermal cracking in large pours.
- Elimination of the risk of damaging internal reactions such as ASR
- High resistance to chloride ingress, reducing the risk of reinforcement corrosion
- High resistance to attack by sulphate and other chemicals
- Considerable sustainability benefits.

1.7 AIM

The major aim of the project is to study the behaviour of R.C.C. beams in partial replacement of GGBS for cement, retrofitted with GFRP overlays so that to obtain best procedures for strengthening of R.C.C. beams using GFRP overlays. To improve the load carrying capacity of the R.C.C. Beam using GFRP overlays is the aim of the project.

1.8 OBJECTIVES

1. The main objective of GGBS replacement of cement is to reduce the CO_2 emission in the environment.
2. To study the effect of different sized layers of GFRP, which can be wrapped on both shear deficient beams and flexural deficient beams.
3. By using the GGBS in concrete to minimize the corrosion in reinforcement steel.
4. To study the behaviour of reinforced concrete beam partial replacement of GGBS by cement.
5. To study the effect of GFRP sheet in improving the strength of the reinforced concrete beam.
6. To study the effect of RC beam and GFRP sheet wrapped RC beam deflection, crack pattern.
7. To analyse the percentage of increase in load carrying capacity of GFRP wrapped RC beams under two point loading system.

1.9 SCOPE OF STUDY

The investigations as well as studies conducted on the retrofitting of the RCC beams using Glass Fibre reinforced polymer overlays are limited. And the amount of emission of CO_2 & heat in the concrete was reduced in the partial replacement of GGBS by cement. That's also important in this studies. So it is essential to study the shear carrying capacity, Flexural carrying capacity and ductility of flexural beams in partial replacement of GGBS by cement, by retrofitting with GFRP using ANSYS software.

CHAPTER 2

LITERATURE REVIEW

Mahesh.k, et.al,(2013) conducted to investigate Strengthening of Reinforced Concrete Beams Using GFRP Wraps. Concrete is one of the oldest and widely used construction materials. It plays a vital role in the field of civil industry. Concrete can be manufactured to an inexhaustible range of specifications to suit all applications. This is possible by using different proportions of the natural ingredients or by the use of different materials. Concrete can be moulded into any shape by using appropriate formwork. Well designed and well placed concrete offers exceptional durability and long life in any structure. At present Worldwide, a great research is being conducted concerning the use of fibre reinforced plastic wraps, laminates and sheets in the repair and strengthening of reinforced concrete members. Experimental investigation of the cube and cylinder of concrete beams with and without glass fibre carried out. Glass fibres were used as the polymer composite in this project. The glass fibres were arranged as externally in a wrapping manner here. Epoxy resins are used to wind the glass fibre mat with concrete beam. In phase 1 project the mechanical properties of cube and cylinder were found out.

Sonali K, et.al,(2014) To Study the Partial Replacement of Cement by GGBS & RHA and Natural Sand by Quarry Sand. In Concrete is the most widely used construction material in civil engineering industry because of its high structural strength and stability. The concrete industry is constantly looking for supplementary cementitious material with the objective of reducing the solid waste disposal problem. Ground granulated blast furnace slag (GGBS) Rice husk ash (RHA) and Quarry sand (QS) are among the solid wastes generated by industry.

To overcome from this crisis, partial replacement of natural sand (NS) with Quarry sand and partial replacement of cement with GGBS and RHA can be an economic alternative. This research is carried out in three phase, in first phase mix of M40 grade concrete with replacement of 0%, 30%, 45%, 90% and 100% of quarry sand with natural sand is carried out to determine the optimum percentage of replacement at which maximum compressive strength is achieved. It is observed that when natural sand is partially replaced with 60% quarry sand maximum strength is achieved. In second phase, cement is partially replaced with GGBS by 10%, 20% and 30%. In phase three, combination of GGBS and RHA is partially replaced with cement. The composition of 22.5% GGBS + 7.5% RHA with 60% of quarry sand gives good strength results.

Kamadri Sriveena and Dr. S. Sunil Pratap Reddy (2013) determine Experimental and Analytical Study On Torsional Behaviour Of RC Flanged Beams With Strengthened With Glass FRP. Environmental degradation, increased service loads, reduced capacity due to aging, degradation owing to poor construction materials and workmanship and conditional need for seismic retrofitting have demanded the necessity for repair and rehabilitation of existing structures. Fibre reinforced polymers have been used successfully in many such applications for reasons like low weight, high strength and durability. Many previous research works on torsional strengthening were focused on solid rectangular RC beams with different strip layouts and different types of fibres. Various analytical models were developed to predict torsional behaviour of strengthened rectangular beams and successfully used for validation of the experimental works. But literature on torsional strengthening of RC T-beam is limited. In the present work experimental study was conducted in order to have a better understanding the behaviour of torsional strengthening of solid RC flanged T-beams.

Santosh Kumar Karri, et.al,(2015) investigated strength and Durability Studies on GGBS Concrete is probably the most extensively used construction material in the world with about six billion tones being produced every year. It is only next to water in terms of per-capita consumption. However, environmental sustainability is at stake both in terms of damage caused by the extraction of raw material and CO₂ emission during cement manufacture. This brought pressures on researchers for the reduction of cement consumption by partial replacement of cement by supplementary materials. These materials may be naturally occurring, industrial wastes or by-products that are less energy intensive. This needs to examine the admixtures performance when blended with concrete so as to ensure reduced life cycle cost. The present paper focuses on investigating characteristics of M20 and M40 grade concrete with partial replacement of cement with ground granulated blast furnace slag (GGBS) by replacing cement via 30%, 40%, 50%. The cubes, cylinders and prisms are tested for compressive strength, split tensile strength, flexural strength. Durability studies with sulphuric acid and hydrochloric acid were also conducted.

Monu Malvia and Prof. H. S. Goliya (2014) investigated the durability of geopolymer concrete manufactured using class F fly ash and alkaline activators (NaOH and Na₂SiO₃) when exposed to sulphate and acidic environment and comparison was made with normal Ordinary Portland Cement (OPC) concrete. In total four tests were conducted to determine acid and sulphate resistance of geopolymer concrete. The tests involved immersion for a period of 30 to 60 days into 5% solution of sodium sulphate, 5% solution of magnesium sulphate, 5% solution of sulphuric acid and 5% solution of phosphoric acid. The evolution of weight loss and compressive strength loss were studied. The most significant degradation of compressive strength and weight were determined in acid solution. The least strength changes and weight loss were found in the sulphate solution. The OPC concrete more deteriorated in acid as well as in sulphate solution in compared with geopolymer concrete, thus geopolymer concrete is more durable than the OPC concrete. The results obtained and the observations made in this study show that OPC concrete has suffered more deterioration in acid as well as sulphate solution as compared to Geopolymer concrete thus Geopolymer Concrete is more durable than OPC concrete.

V.A.Shanmugavelu and N.Ramachandran (2014) determine Experimental and Analytical studies on Reinforced Concrete Beams with GFRP Laminates. This paper presents ANN model for predicting the performance characteristics of reinforced concrete beams strengthened with glass fibre reinforced polymers (GFRP) laminates. A total of seven beams of dimension 150mm x 250mm x 3000mm were cast and tested to study the effectiveness of GFRP on reinforced concrete beams. Beams were strengthened with CSM GFRP, WRGFRP and UDCGFRP laminates of 3mm and 5mm thickness. All the beams were subjected to four-point bending and tested up to failure. Deflections were measured through appropriate instrumentation at all stages of loading. The GFRP strengthened RC beams exhibit increased strength and composite action until failure. The proposed model provides satisfactory prediction of the performance parameters. The maximum decrease in deflection for GFRP strengthened reinforced concrete beams was 44.68%. The GFRP strengthened reinforced concrete beams exhibited an enhanced ductility up to 94.36%.

J.Vengadesh Marshall Raman and V.Murali Krishnan (2016) Partial Replacement of Cement with GGBS in Self-Compacting Concrete for Sustainable Construction

concept of partial replacement of cement which is capable for sustainable development is characterized by application of industrial waste to reduce consumption of natural resources and energy and pollution of the environment. A presently large amount of ground granulated blast furnace slag is a by-product of manufacturing of pig iron with an important impact on environment and humans. This research work describes the feasibility of using the GGBS in self-compacting concrete production as partial replacement of cement. GGBS can be used as filler and help to reduce the total voids content in self-compacting concrete. Constant level of Fly ash is also used in all set of mix proportion to increase the powder content for achieving the Workability. The cement has been replaced by GGBS accordingly in the range of 0%, 25%, 30%, 35%, and 40% by weight of cement for M-30 mix.

After iterative trial mix the water/cement ratio (w/c) was selected as

0.40. Self-compacting Concrete mixtures produced, tested and compared in terms of compressive, split tensile strength and flexural strength with the conventional concrete for 7, 14, 28 days. When the percentage of GGBS replaced to cement with varying percentage from 25% to 40% the following results were drawn. With 25% of GGBS the compressive strength at the end of 7, 14 and 28 days 32.1, 39.94 and 47.56 N/mm² respectively. The compressive strength at the end of 28 days decreases when the GGBS percentage is increased beyond 40%. However the compressive strength of M30 concrete at the end of 28 days for 40% replacement of GGBS is 43.26 N/mm² as shown in Table -7. The compressive strength showed a steep decrease when the GGBS percentage is increased as shown in Chart -1. A similar increase in the split tensile strength was observed when the GGBS is increased 25% (5.55 N/mm² at the end of 28 days).

M. Verapathran and P. Murthi (2016) conducted to evaluate the effect of steel slag on acid resistance and rapid chloride permeability of high performance concrete (HPC). Effect of different aging periods (6, 12, 18, 24, 30, 36 AND 42 months) of steel slag aggregates (SSA) on acid resistance and rapid chloride permeability of concrete was studied. It was observed that the aging process of SSA improves the acid resistance and rapid chloride permeability of HPC made with SSA. A minimum of 30 to 36 months aging of SSA is required to achieve the acid resistance and rapid chloride permeability of HPC at par with conventional concrete. Steel slag aggregates have physical and mechanical properties similar to that of natural coarse aggregates. Hence, they can be utilized as alternative to natural coarse aggregates in concrete production. Workability of concrete decreases with increase in the aging period of steel slag aggregates. Dosage of super plasticizer may be increased to increase the workability. But in this work, it was kept constant for better comparison.

Sandeep Aghara and Prof. Tarak vora (2017) determine experimental and analytical study on torsion behaviour of RC beam strengthened with GFRP laminations. Fibre reinforced polymer (FRP) as an external reinforcement is used extensively to enhance the strength requirement related to flexure and shear in structural systems. But the strengthening of members subjected to torsion is yet to be explored as Torsion failure is a brittle form of failure. In present study experimental and analytical study on torsional strengthening of RC beam with GFRP lamination. Total six rectangular beams of size 180*230 and length 1500 mm are casted. Out of six beam one beam as

control beam and remaining five beams are GFRP wrapped beam at different configuration. Numerical work was carried out using non-linear finite element (FE). From experimental we conclude that wrapping pattern at 45° gives more torsional strength than wrapping at 90°.

Mithun R, et.al, (2018) evaluated the properties of concrete by replacing cement by GGBS at 30%, 40%, 50% and Fly ash at 15%, 25%, 35%. Different blends of fly ash and GGBS are tried according to Codal provisions for composite cements and M-sand as the replacements to fine aggregates keeping other constituents of concrete constant. These ternary mixes were tested for workability, strength and durability properties of concrete. The results were tested at 7 and 28 curing days. From test results, it is observed that workability of concrete surges with increase in Fly ash and GGBS content. Finally, from the experimental study we can conclude that composite cement with performance equivalent to control PPC or PSC can be prepared by using ternary mix of GGBS and Fly ash in the range of 30-50% and 15-35% respectively. The workability of concrete surges with increase in Fly ash and GGBS content. As the fly ash percentage increases in the ternary mix, the targeted mean strength decreases. Due to lag in gaining of compressive strength of the concrete, the de-shuttering time in site increases. The results of Modulus of elasticity of concrete replicates similar tendencies as cube compression strength of concrete. The partial replacement of cement with pozzolanic materials facilitates Environmental friendly disposal of the waste which is generated in enormous quantities. Composite cement is environmental friendly and recommended for gradual replacement of Ordinary Portland cement.

B K Varun and Harish B A (2018) attempted to use a fly ash and GGBS as a partial replacement of cement. The main aim of this work is to study the fresh and hardened properties of M-30 grade control concrete and concrete made with partial replacement of fly ash and GGBS with various percentages. To study the fresh properties slump test, compaction factor tests, Vee-bee consistometer tests are conducted. To study hardened properties compressive and splitting tensile strength tests are conducted. Making concrete with the combination of Fly ash and GGBS and cement with different percentages gives good results compared to control concrete. So the best way to use these materials is in combination. Due to environmental issues in the production of cement, industrial byproducts like fly ash and GGBS are used as supplementary materials in concrete and it saves cost of production of concrete, and makes it eco-friendly.

Azmat Ali Phul, et.al, (2019) investigated the incremental demand of cement in the construction field as a concern for environmental degradation, in this regard, replacement of cement is carried out with waste materials by using GGBS and Fly ash. On optimum level of GGBS and Fly ash was assessed with varied percentage from 0 to 30% for different curing periods. The workability of concrete tends to increase initially with increasing replacement percentage up to an optimum limit, but then decreases partially. GGBS and Fly ash content increases the workability reduces

at the same water containing and w/c. The optimum workability was observed at replacement percentage of 15% as compared to control one that achieved 30%. The outcomes indicated that the addition of GGBS and Fly ash enhances the workability and compressive strength which eventually improved the mechanical properties of concrete.

T.P. Meikandaan et al, (2019) investigated flexural behaviour of RC beam wrapped with GFRP sheets. Repair and strengthening of R.C beam is now becoming more and more important in the field of structural strengthening and retrofitting. The present paper reviews the study of Glass Fibre Reinforced Polymer (GFRP) flats under flexural behaviour in reinforced concrete beams. In this study, experimental investigation on the flexural behaviour of RC Beam has been studied by wrapping Glass Fibre Reinforced Polymer (GFRP) sheets. Reinforced Concrete Beam externally bonded with GFRP sheets were tested to failure using a symmetrical two point static loading system. Six Reinforced Concrete Beams have been cast for this experimental test. All cast beams are weak in flexure and having same reinforcement detailing. Three beams are used as control beams and three beams are strengthened using full bottom of glass fibre reinforced polymer (GFRP) sheets. The experimental result shows, that full bottom GFRP sheet wrapping in 70% preloaded beam can increase flexural capacity of the beam by 14% (on ultimate load) as compared to Controlled Beams. Initial flexural cracks appear at a higher load by strengthening the beam at soffit. The ultimate load carrying capacity of the strengthened beam is 14% more than the controlled beam.

Vinayak Awasare and Prof. M. V. Nagendra et.al, (2019) investigated Analysis of strength characteristics of GGBS concrete Today's construction industry, use of concrete is going on increasing rapidly. Cement is major constituent material of the concrete which produced by natural raw material like lime and silica. Once situation may occurs there will be no lime on earth for production of cement. This situation leads to think all people working in construction industry to do research work on cement replacing material and use of it. Industrial wastes like Ground Granulated Blast Furnace Slag (GGBS) show chemical properties similar to cement. Use of GGBS as cement replacement will simultaneously reduce cost of concrete and help to reduce rate of cement consumption.

S.V. Hema Shangari et.al, (2019) investigated An Analytical, Numerical and Experimental Investigation of Glass Fibre Sheet Wrapped Reinforced Concrete Beams in construction field maintenance, rehabilitation and strengthening of structural members are the major issue. The wrapping of RC beams with Glass Fibre Reinforced Polymer sheet increases the strength. A finite element reinforced concrete model has been analysed by using ANSYS finite element program for both unstrengthened and RC beams. In analytical investigation six beams were analysed using theoretical formulae. In experimental investigation six beams were casted and analysed under two point loading system in a loading frame. The retrofitting is attained with the adhesion of GFRP sheet to the total volume of the beams.

CHAPTER 3

METHODOLOGY AND

MATERIAL USED

COLLECTION OF MATERIALS



DESIGN MIX

CALCULATIONS MIXING
OF CONCRETE



ANALYSIS USING ANSYS
SOFTWARE



CASTING AND
DEMOULDING OF
CONCRETE SPECIMENS



CURING OF CONCRETE
SPECIMENS FOR 28
DAYS



TEST ON HARDENED
CONCRETE USING
STRENGTH PROPERTIES



DESIGN AND
ANALYSIS OF
REINFORCED CONCRETE
BEAMS RESULTS

3.1 CEMENT

Ordinary Portland cement is the most common type of cement in general use around the world as a basic ingredient of concrete, mortar, stucco, and most non-specialty grout. It developed from other types of hydraulic lime in England in the mid 19th century and usually originates from limestone. It is a fine powder produced by heating materials to form clinker.

After grinding the clinker we will add small amounts of remaining ingredients. Many types of cements are available in the market. When it comes to different grades of cement, the 53 Grade OPC Cement provides consistently higher strength compared to others. As per the Bureau of Indian Standards (BIS), the grade number of a cement highlights the minimum compressive strength that the cement is expected to attain within 28 days. For 53 Grade OPC Cement, the minimum compressive strength achieved by the cement at the end of the 28th day shouldn't be less than 53 MPa or 530 kg/cm².



FIG3.1: CEMENT

Table:3.1.1 properties of cement

S.no	Properties	Testresults
1	Normalconsistency	0.32
2	Initialsettingtime	50min
3	Finalsettingtime	320min
4	Specificgravity	3.14
5	Fineness	5%

The colour of OPC is grey colour and by eliminating ferrous oxide during manufacturing process of cement we will get white cement also. Ordinary Portland Cement of 53 Grade of brand name Ultra Tech Company, available in the local market was used for the investigation. Care has been taken to see that the procurement was made from single batching in airtight containers to prevent it from being effected by atmospheric conditions. The cement thus procured was tested for physical requirements in accordance with IS: 169-1989 and for chemical requirement in accordance IS:4032-1988.

3.2 FINE AGGREGATES

Sand is a natural granular material which is mainly composed of finely divided rocky material and mineral particles. The most common constituent of sand is silica (silicon dioxide, or SiO_2), usually in the form of quartz, because of its chemical inertness and considerable hardness, it is the most common weathering resistant mineral. Hence, it is used as fine aggregate in concrete. River sand locally available in the market was used in the investigation. The aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity in accordance with IS:2386-1963. The sand was surface dried before use.



Fig.3.2 FineAggregates

PROPERTIES	MAGNITUDE
Specific gravity	2.6
Bulk density ,kg/m ³	1830
Porosity,%	29.67
Grading zone	Zone II
Fineness modulus	3.13
Water absorption	1.02%

Table:3.2.1 PropertiesofFineAggregate

3.3 COARSE AGGREGATES

Crushed aggregates of less than 12.5mm size produced from local crushing plants were used. The aggregate exclusively passing through 12.5mm sieve size and retained on 10mm sieve is selected. The aggregates were tested for their physical requirements such as gradation, fineness modulus, specific gravity and bulk density in accordance with IS:2386-1963. The individual aggregates were mixed to induce the required combined grading. The particular specific gravity and water absorption of the mixture are given in table.3

PROPERTIES	COARSE AGGREGATE
Particle shape	Angular
Particle size	20mm
Specific gravity	2.75
Fineness modulus	4.18

Table:3.3.1 properties of coarse aggregate



Fig.3.3. COARSE AGGREGATE

3.4 WATER

Water plays a vital role in achieving the strength of concrete.

For complete Hydration it requires about 3/10th of its weight of water. It is practically proved that minimum water-cement ratio 0.35 is required for conventional concrete. Water participates in chemical reaction with cement and cement paste is formed and binds with coarse aggregate and fine aggregates. If more water is used, segregation and bleeding takes place, so that the concrete becomes weak, but most of the water will absorb. Hence it may avoid bleeding. If water content exceeds permissible limits it may cause bleeding. If less water is used, the required workability is not achieved. Potable water fit for drinking is required to be used in the concrete and it should have pH value ranges between 6 to 9.

S. No	Property	Value
1	PH	7.1
2	Taste	Agreeable
3	Appearance	Clear
4	Turbidity (NT units)	1.75

Table:3.4.1 Physical properties of water

3.5 GROUND GRANULATED BLAST FURNACE SLAG

Ground Granulated Blast furnace Slag (GGBS) is a by-product from the blast furnaces used to make iron. These operate at a temperature of about 1500 degrees centigrade and are fed with a carefully controlled mixture of iron ore, coke and limestone. The iron ore is reduced to iron and the remaining materials form a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching optimises the cementitious properties and produces granules similar to coarse sand. This granulated slag is then dried and ground to a fine powder.

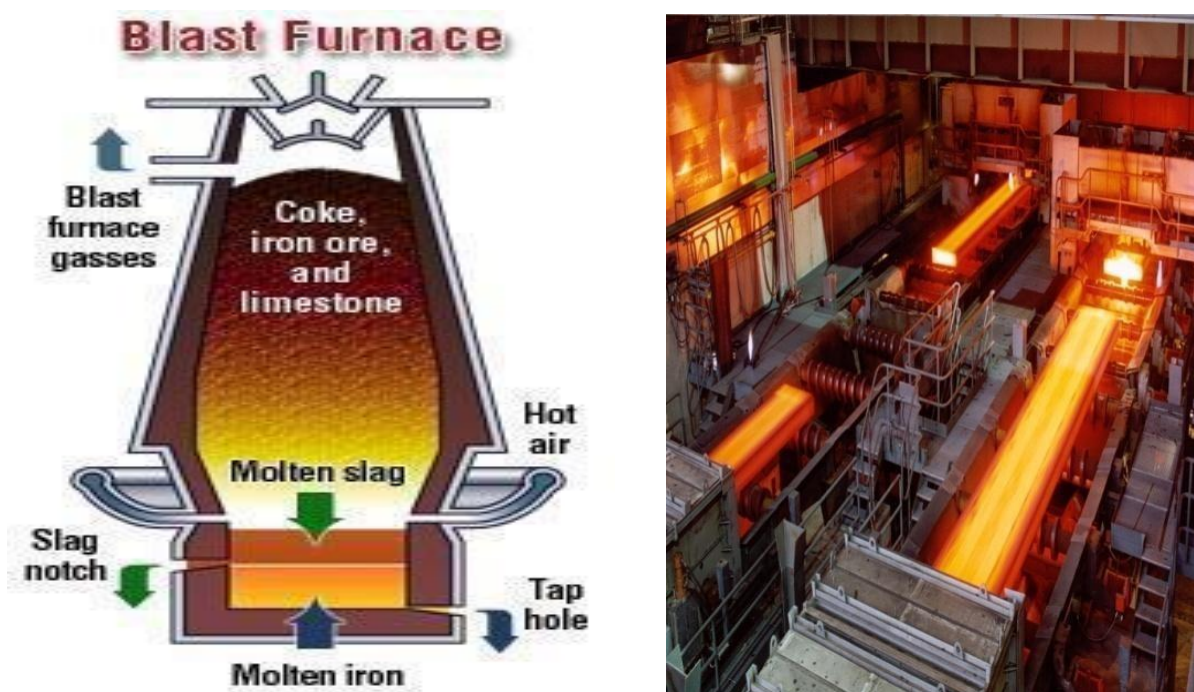


Fig.3.4: Sources of Ground Granulated Blast Slag

GGBS is used along with the ordinary Portland cement or other pozzolanic materials in concrete. Its use is increasing day by day because it improves the durability of concrete which essentially increases the lifespan of concrete structures from fifty to hundred years. GGBS has Good workability which helps in better placing and compaction and Due to the less heat of hydration the temperature rise will be less avoiding the risk of thermal cracking in large volume of concrete.

The main problem is the original conventional materials are depleting and we are in hunt for alternate building materials which lands us here on the purpose of GGBS. Being a by-product and waste using it effectively up to some extent serves as a step for a greener environment and at the same time keeping in mind that the strength of the concrete doesn't degrade by the usage of GGBS.

GGBS has similar or slightly improved consistency than ordinary Portland cement concrete. This makes the concrete very easy to place and compact. The setting time of concrete is mainly influenced by the temperature and water-cement ratio. Using of GGBS in concrete generally increases the setting time slightly up to 30 minutes. This has an advantage that this concrete mix can be workable for a longer time and the risk of developing cold joints will be lesser. This property is helpful in construction in warm weather. If GGBS is used in a concrete mix, it can develop almost same 28-day strength as ordinary Portland cement. At higher GGBS percentages the increased cementitious content may lead to achieve equivalent 28-day strength much faster. GGBS concrete gains strength more steadily than equivalent concrete made with Portland cement.

3.5.1 PROPERTIES OF GGBS

Ground Granulated Blast Furnace Slag which is a by-product of steel manufacturing industry is an accepted mineral admixture for use in concrete. This granulated material when further ground to less than 45 micron is called Ground Granulated Blast Furnace Slag (GGBFS).

S.NO	Property	Value
1	Normal consistency	30%
2	Initial setting time in min	55 minutes
3	Final setting time in min	9 hours
4	Specific gravity	2.98
5	Fineness of cement by sieve	8%

Table: 3.5.1.1 Physical Properties of GGBS

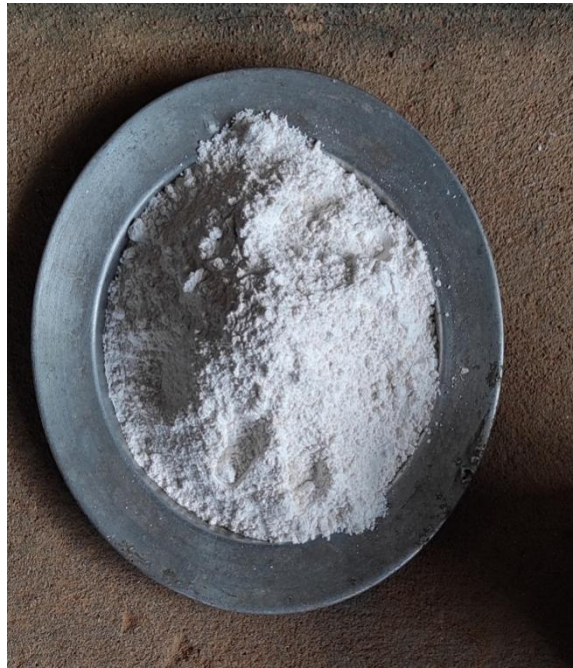


Fig.3.5:GGBS

Table:3.5.1.2 chemical properties of GGBS

Material	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	K ₂ O	Na ₂ O	LOI
GGBS	33.46	(SiO ₂ +Al ₂ O ₃ +Fe ₂ O ₃) =48.63		25.02	7.97	0.85	1.28	1.32	13.61

3.6.GLASSFIBREREINFORCEDPOLYMER

3.6.1. FIBREREINFORCEDCONCRETE

Fibres have been used as secondary reinforcements since ancient times. Historically, horsehair was used in mortar and straw in mud bricks. In the early 1900's, asbestos fibres were used in concrete and in the 1950's the concept of composite materials came into being and FRC was one of the topics of interest. There was a need to find a replacement for the asbestos used in concrete once the health risks associated with the substance were discovered. By the 1960s, steel, glass and synthetic fibres such as polypropylene (PP) fibres were used in concrete, and research into new FRC continues today.

Fibres are usually used in concrete to control the plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce the bleeding of concrete. Some types of fibres produce greater impact, abrasion resistance in concrete. There is considerable improvement in the post-cracking behaviour of concrete containing fibres. Although in the fibre-reinforced concrete the ultimate tensile strengths do not increase appreciably, the tensile strains at rupture do. Compared to plain concrete, fibre reinforced concrete is much tougher and more resistant to impact.

3.6.2.FIBREREINFORCEDPOLYMER(FRP)

Continuous fibre reinforced materials with polymeric matrix (FRP) can be considered as composite, heterogeneous, and anisotropic materials with a prevalent linear elastic behaviour up to failure. Normally, Glass and Carbon fibres are used as reinforcing material for FRP.

Epoxy is used as the binding material between fibre layers. For this study, GFRP sheet was used during the tests i.e., a bidirectional FRP with the fibre oriented in both longitudinal and transverse directions, due to the flexible nature and ease of handling and application, the FRP sheets are used for torsional strengthening. Throughout this study, E-glass was used manufactured by Owens Corning.

3.6.3 GLASS FIBRE

Glass fibre likewise called fibreglass. It is the material which is produced using amazingly fine strands of glass. Fibreglass is a lightweight, greatly solid, and strong material. In spite of the fact that quality properties are to some degree lower than carbon fibre and it is less solid, the material is ordinarily far less fragile, and the crude materials are substantially less costly. Its mass quality and weight properties are likewise extremely ideal when contrasted with metals, and it can be effectively framed utilizing shaping procedures. Glass is the most seasoned, and most natural, execution fibre. Filaments have been produced from glass since 1930s. Most broadly utilized class of strands in composites are those produced from E-glass.



Fig.3.6: Glass Fibre

E-glass is a low soluble base borosilicate glass initially created for electrical protection applications. It was initially delivered financially for composite produce in 1940's, and its utilization now approaches 2 MT for each year around the world. A wider range of nations produce E-glass and its correct arrangement fluctuates as per the accessibility and creation of the neighbourhood crude materials. It is made as consistent fibres in groups, or strands, each containing normally between 200 and 2000 singular fibres of 10-30 μm widths.

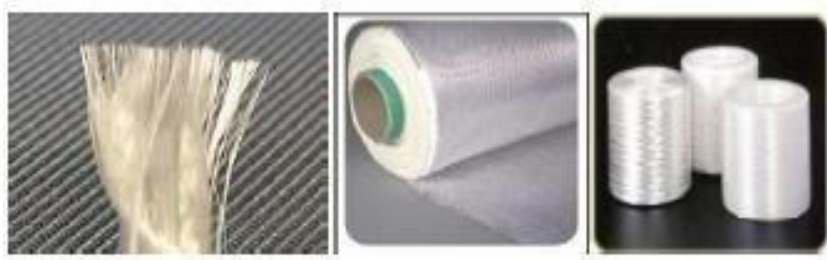


Fig.3.7: GFRP

Glass fibres are also available as thin sheets, called mats. A mat may be made of both long continuous and short fibres (e.g., discontinuous fibres with a typical length between 25 and 50 mm), randomly arranged and kept together by a chemical bond. The width of such mats is variable between 5 cm and 2 m, their density being roughly 0.5 kg/m^2 .

Glass fibres typically have a Young modulus of elasticity (70 GPa for E-glass) lower than carbon or aramid fibres and their abrasion resistance is relatively poor; therefore, caution in their manipulation is required. In addition, they are prone to creep and have low fatigue strength. To enhance the bond between fibres and matrix, as well as to protect the fibres itself against alkaline agents and moisture, fibres undergo sizing treatments acting as coupling agents. Such treatments are useful to enhance durability and fatigue performance (static and dynamic) of the composite material. FRP composites based on fibreglass are usually denoted as GFRP.

3.6.4. GLASS FIBRE REINFORCED POLYMER SHEET

Glass fibres are also available as thin sheets, called mats. A mat may be made of both long continuous and short fibres. To enhance the bond between fibres and matrix, as well as to protect the fibres itself against alkaline agents and moisture, fibres undergo sizing treatments acting as coupling agents. Such treatments are useful to enhance durability performance of the composite material. Glass fibres are the fibres commonly used in the naval and industrial fields to produce composites of medium-high performance. It possesses high strength. Glass is mainly made of silicon (SiO_2) with a tetrahedral structure (SiO_4).



Fig.3.8: Glass fibre reinforced polymer

FRP composites based on fibre glass are usually denoted as GFRP. The glass fibres available in the form of sheets called glass fibre reinforced polymer (GFRP) sheet. The fibres and matrix combine to form a GFRP sheet.

3.6.5 PROPERTIES OF GFRP MATERIALS

GFRP composites are a cutting-edge development material, another option to customary materials, for example, solid, steel and wood. Among numerous utilizations of FRP in common foundations, connect decks have got much consideration as a result of their lightweight, high quality-to-weight proportion, and consumption resistance.

Different points of interest of FRP extension decks are the lessening in scaffold deck development time and increment in administration life. The engaging quality of FRP composites as development materials gets from a set of points of interest gathered from the tailor capacity of this material class through the synergistic mix of strands in a polymeric pitch network, wherein the fibre fortifications convey stress in pre-designed bearings and the gap goes about as a medium to exchange stresses between abutting filaments through attachment and furthermore gives insurance to the filaments. The choice of framework and support for manufacture of any composite item predominantly relies on upon the properties of matrix and reinforcement.

3.6.6. APPLICATION OF GFRP OVERLAYS FOR STRENGTHENING OF RC BEAMS

Fibre reinforced polymer (FRP) composites are formed by embedding continuous fibres in a resin matrix that binds the fibres together.

3.6.6.1 Types of FRPs

Depending on the fibres used, FRP composites are classified into three types: Glass FRP composites (GFRP), Carbon FRP composites (CFRP) and Aramid FRP composites (AFRP). Although FRP composites are expensive and more susceptible to physical damage than steel, they have become an attractive substitute for steel in strengthening systems for concrete structures due to their many advantages, high strength to weight ratio, corrosion resistance, and high fatigue resistance, easy and reliable surface preparation.

3.6.6.2 FRP Composite

Fibre Reinforced Polymer composite is defined as a polymer (plastic) matrix, either thermo set or thermoplastic, that is reinforced (combined) with a fibre or other reinforcing material with a sufficient aspect ratio (length to thickness) to provide a discernable reinforcing function in one or more directions.

Application of GFRP overlays is the one of the simplest methods for wrapping the existing structures. GFRP has high strength ratio high stiffness to weight ratio, flexibility in design, non-corrosiveness, high ultimate strength and lower density.

3.6.7 ADVANTAGES AND LIMITATIONS OF GFRP OVERLAYS FOR STRENGTHENING OF BEAMS

Advantages

1. Low cost when compared to other FRPs
2. High strength to weight ratio
3. Corrosion resistance

3.6.8 APPLICATIONS

GFRP can be used for both interior and exterior fissures in a variety of shapes, styles and textures in new building or in retrofitting projects and also in domes, foundation, columns, balustrade, planters, panels, sculpture, entryways, modelling, facades, cornice, porticos, cupolas, signs, roofs.

3.7 EXPERIMENTAL WORK:

3.7.1 PRELIMINARY TEST:

Sieve Analysis for Fine Aggregate

The sieve analysis test for fine aggregate is described as follows. Take one kg of sand from the laboratory sample. Arrange the sieves in order of IS sieves nos. 480, 240, 120, 60, 30 and 15, keeping sieve no. 480 at the top and 15 at the bottom and cover the top. Keep the sample in the top sieve no. 480. Carry out the sieving in the set of sieves for not less than 10 minutes. Find the weight of the sample retained in each sieve.

Table:3.7.1.1 Sieve Analysis for Fine Aggregates

SIEVE ANALYSIS FOR FINE AGGREGATES					
S.No	Sieve size in (mm)	Weight Retained in (gms)	Percentage of weight Retained in (gms)	Percentage of weight Retained	Percentage of Passing
1	10	0	0	0	100
2	4.75	0	0	0	100
3	2.36	18	1.80	1.80	98.20
4	1.18	358	35.80	37.60	62.40
5	0.60	204	20.40	58.00	42.00
6	0.30	194	19.40	77.40	22.60
7	0.15	114	11.40	88.80	11.20
	Pan	112	11.20	100	0
	Total	1000		364	

Fineness modulus of heavy weight fine aggregate = Sum of Cumulative

% of retained / 100

Grading Zone: II F.M: $364/100 = 3.6$

Sieve Analysis for Coarse Aggregate

The sieve analysis test for fine aggregate is described as follows.

Take one kg of coarse aggregates. Arrange the sieves one over the other in relation to their size of opening. (25mm, 20mm, 12.5mm, 10mm, 4.75mm). Carry out the sieving for the specified time. Find the weight of aggregate retained on each sieve

SIEVE ANALYSIS FOR 20mm COARSE AGGREGATES					
Sl no	Sieves size in (mm)	Weight Retained in (gms)	weight Retained in (gms)	Percentage of weight Retained	Percentage of Passing
1	40	0	0	0	100
2	20	562	5.62	5.62	94.38
3	10	9390	93.90	99.52	0.48
4	4.75	26	0.26	99.78	0.22
5	Pan	22	0.22	100	0.00
	Total	10000	-	-	-

Table:3.7.1.2 Sieve Analysis for Coarse Aggregates

Specific Gravity Test

Table:3.7.1.3 Specific Gravity of Coarse Aggregates

Description	Notations	20mm in gms
Weight of empty Pycnometer	W_1	180
Weight of pycnometer + Water	W_2	466
Weight of pycnometer + Aggregate	W_3	260
Wt. of pycnometer + water + aggregate	W_4	514
$G = (W_3 - W_1) / (W_2 - W_1) - (W_4 - W_2)$		2.65

3.8 MIXDESIGN

3.8.1 DESIGNSTIPULATIONS

GradeDesignation	M-30
Typeofcement	O.P.C-53grade
FineAggregate	Zone-I
Sp.GravityCement	3.14
Sp.GravityFineAggregate	2.6
Sp.GravityCoarseAggregate	2.75

TARGETMEANSTRENGTH

$$f_{ck}=f_{ck}+(Sxt)$$
$$=30+(5 \times 1.65)=38.25\text{MPa}$$

SELECTIONOFWATERCEMENTRATIO

$$\text{Watercementratio} = 0.45(\text{for strength point of view})w/c$$
$$=0.50(\text{for durable point of view})$$

Adopt low value

$$w/c = 0.45$$

AIRCONTENT

$$\text{Air content} = 2\%$$

CALCULATEOFWATERCONTENT

$$\text{Water content} = 186 \text{ kg (As per Table No. 4, IS: 10262)}$$

$$\% \text{ of fine Agg} = 35\%$$

SANDCONTENT

Consider fine aggregate zone-

$$\text{ISand content} = 35 + 1.5\%$$
$$= 36.5\%$$

CALCULATE THE CEMENT CONTENT

$$\text{Cement content} = \text{water content} / w/c \text{ ratio}$$

$$= 186 / 0.45$$

$$= 425.73 \text{ kg/m}^3$$

CALCULATE C.A & F.A (AS PER IS: 10262, CI, NO. 3.5.1)

From Table-

3 volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate FOR Water-cement ratio of 0.50 = 0.60

We have a water-cement ratio is 0.45. Based on following condition volume of coarse aggregate is increased.

- i) As the water-cement ratio is lower by 0.10, the proportion of volume of coarse aggregate is increased 0.02.

$$\text{Volume of Coarse aggregate} = 0.61 \text{ Volume of}$$

$$\text{Fine aggregate} = 1 - 0.61$$

$$= 0.39$$

$$\text{Volume of Fine aggregate} =$$

0.39 Step:- 6 Mix Calculation

$$\text{Volume of concrete} = 1 \text{ m}^3 \text{ (a)}$$

$$\text{Volume of cement} = (\text{Mass of cement} / \text{Specific gravity of cement} * 1000) = (425.73 / 3.15 * 1000)$$

$$\text{Volume of cement} = 0.135 \text{ m}^3 \text{ (b)}$$

$$\text{Volume of water} = (\text{Mass of water} / \text{Specific gravity of water} * 1000)$$

$$= (191.58 / 1 * 1000)$$

$$\text{Volume of water} =$$

$$0.192 \text{ m}^3 \text{ (c) Volume of all aggregate} = a -$$

$$(b + c)$$

$$= 1 - (0.135 + 0.192)$$

$$\text{Volume of all aggregate (e)} = 0.673 \text{ m}^3$$

$$\text{Mass of Fine aggregate} = \{ (\text{volume of Fine aggregate}) *$$

$$(\text{specific gravity of}$$

$$\text{Fine aggregate}) * 1000 * e \}$$

$$= \{ 0.39 * 2.74 * 1000 * 0.673 \}$$

$$\text{Mass of Fine aggregate} = 719.17 \text{ kg}$$

$$\begin{aligned} \text{Mass of Coarse aggregate} &= \{(\text{volume of Coarse aggregate}) * (\text{specific gravity} \\ &\quad \text{Coarse aggregate}) * 1000 * e\} \\ &= \{0.61 * 2.74 * 1000 * 0.673\} \\ \text{Mass of Coarse aggregate} &= 1124.85 \text{ kg} \end{aligned}$$

MIX PROPORTION

Cement (kg)/m³	FA (kg)/m³	CA (kg)/m³	Water(l iter)/m³
425.73	719.17	1124.85	186

Table:3.8.1.1 Mix design of M30 grade concrete

3.8.3.REPLACINGMATERIALRATIO

CementReplacing20% ofGGBS

$$=425.73 \times (20/100) = 85.15$$

CementReplacing30 %ofGGBS

$$=425.73 \times (30/100) = 127.72$$

CementReplacing40 % ofGGBS

$$=425.73 \times (40/100) = 170.29$$

CementReplacing50 %ofGGBS

$$=425.73 \times (50/100) = 212.86$$

3.9 ANALYTICAL INVESTIGATION AND ANALYSIS

The analytical investigation is done using some theoretical formulas. For the wrapped section the ultimate moment and ultimate load is determined using the following formula.

STEP-1: FRP design material properties: Due to the long-term exposure to various type of environment can reduce the tensile properties, creep-rupture and fatigue endurance of laminates. So the material property used should be reduced based on environmental conditions.

$$f_{fu} = C_E f_{fu}$$

f_{fu} - Design ultimate strength of FRP
 C_E - Environmental Reduction Factor

$$\epsilon_{fu} = C_E \epsilon_{fu}^*$$

ϵ_{fu}^* - Design rupture strain of FRP

STEP-2: Existing Strain calculation: The only load acting on the beam at the time of GFRP installation is dead load. The existing strain value for the cracked section is given as

$$\epsilon_{bi} = \frac{M_{DL}(d_f - kd)}{I_{cr} E_c}$$

STEP-3: Design Strain of GFRP system To prevent an intermediate debonding failure mode, the effective strain for GFRP is calculated and it should be less than or equal to 0.9 times the design rupture strain of GFRP.

$$\epsilon_{fd} = 0.41 \sqrt{\frac{f_c'}{n E_f t_f}} \leq 0.9 \epsilon_{fu}$$

STEP-4: The effective level of strain in GFRP reinforcement:

$$\epsilon_{fe} = 0.003 \left\{ \frac{d_f - c}{c} \right\} - \epsilon_{bi} \leq \epsilon_{fd}$$

$$\epsilon_c = (\epsilon_{fe} + \epsilon_{bi}) \left\{ \frac{c}{d_f - c} \right\}$$

The maximum strain level in GFRP is governed by the strain level developed in GFRP at the point at which the concrete crushes, GFRP ruptures or debonds from the substrate.

STEP-5: Existing Strain in reinforcement Based on strain level in GFRP sheet, the existing strain in reinforcement is determined using the relation,

STEP-6: Stress level in reinforcement and GFRP

$$\varepsilon_s = (\varepsilon_{fe} + \varepsilon_{bi}) \left\{ \frac{d - c}{d_f - c} \right\}$$

The stress in steel is calculated

$$f_s = E_s \varepsilon_s \leq f_y$$

The stress in GFRP sheet is calculated

$$f_{fe} = E_f \varepsilon_{fe}$$

Concrete stress block factors are calculated based on the parabolic stress-strain relationship for concrete.

$$\beta_1 = \frac{4\varepsilon_{c'} - \varepsilon_c}{6\varepsilon_{c'} - 2\varepsilon_c}$$

STEP-7: Calculate Flexural strength components

Steel contribution to bending

$$M_{ns} = A_s \left\{ f_s d - \frac{\beta_1 c}{2} \right\}$$

FRP contribution to bending

$$M_{nf} = A_f \left\{ f_{fe} d_f - \frac{\beta_1 c}{2} \right\}$$

STEP-8: Calculate Flexural strength of section

The design flexural strength of the beam is calculated and it should be greater than the moment calculated for unwrapped beams.

$$\phi M_n = \phi (M_{ns} + \psi M_{nf}) \geq M_u$$

ANSYS ANALYSIS

ANSYS, Inc. is an American engineering software developer headquartered south of Pittsburgh in Cecil Township, Pennsylvania, and United States. Ansys publishes engineering analysis software across a range of disciplines including finite element analysis, structural analysis, computational fluid dynamics, explicit and implicit methods, and heat transfer.

3.9.1 HISTORY

The company was founded in 1970. By John A. Swanson as Swanson Analysis Systems, Inc (SASI). Its primary purpose was to develop and market finite element analysis software for structural physics that could simulate static (stationary), dynamic (moving) and thermal (heat transfer) problems. SASI developed its business in parallel with the growth in computer technology and engineering needs. The company grew by 10 percent to 20 percent each year, and in 1994 it was sold to TA Associates. The new owners took SASI's leading software, called ANSYS, as their flagship product and designated ANSYS, Inc. as the new company name.

Ansys was listed on the NASDAQ stock exchange in 1996. In 2011, Investor's Business Daily gave the firm a top score on its SmartSelect composite ratings. The organization claims to reinvest 15 percent of its revenue each year into research to continually refine the software.

3.9.2 ACQUISITIONS

Ansys has acquired a number of companies since 2000, including ICEM CFD Engineering, Space-claim, CADOE S.A., of Lyon, France, a company specializing in parametric analysis, and with numerous French clients, including Michelin, Renault, Airbus, Areva and EDF, [6] and CFX (2003); Century Dynamics, Harvard Thermal, and Fluent Inc. (2006).

Ansoft Corporation (2008); Apache Design Solutions (2011); Esterel Technologies (2012); [7] EVEN and Reaction Design (2013); Spaceclaim Corporation (2014) [8] and Numerical Technologies International (2015).

3.9.3 STRUCTURAL ANALYSIS

I) ANSYS AUTODYNE

ANSYS Autodyne is a computer simulation tool for simulating the response of materials to short duration severe loadings from impact, high pressure or explosions.

II) ANSYS MECHANICAL

ANSYS Mechanical is a finite element analysis tool for structural analysis, including linear, nonlinear and dynamic studies. ANSYS Mechanical also includes thermal analysis and coupled-physics capabilities involving acoustics, piezoelectric, thermal-structural and thermo-electric analysis.

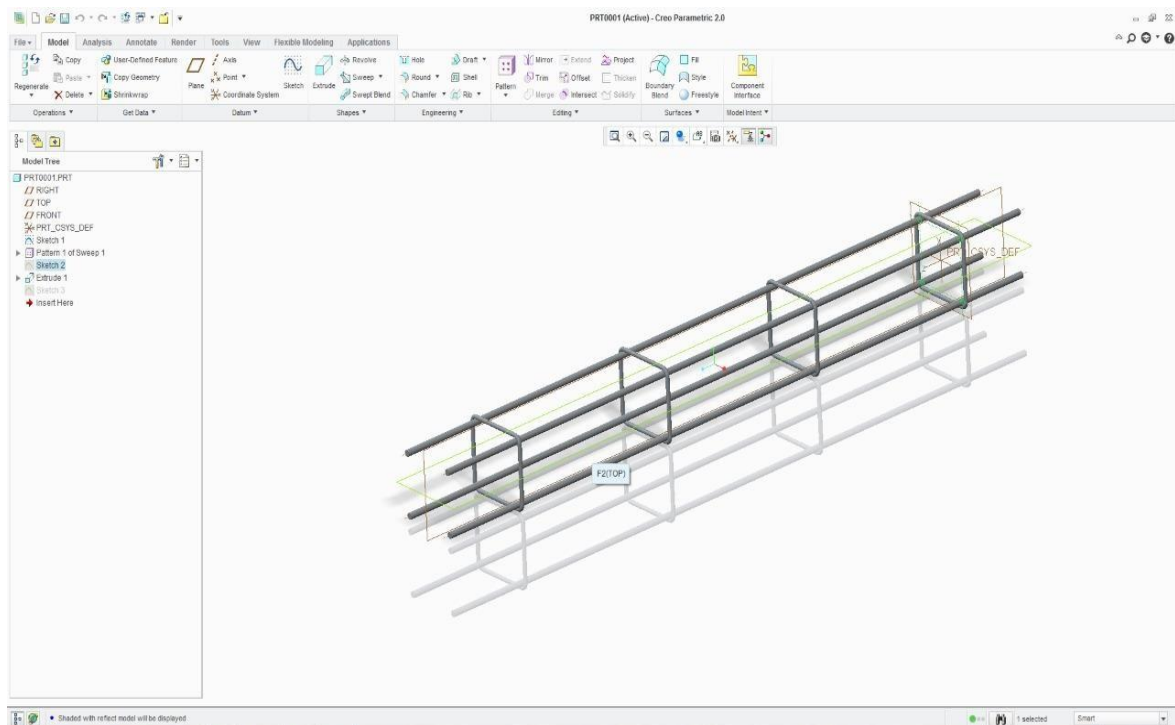


Fig:3.9 STEEL 3D MODEL IN ANSYS

3.10 ELECTRONICS

3.10.1 ANSYS HFSS

ANSYS HFSS is a Finite Element Analysis tool for simulating full-wave electromagnetic fields. HFSS incorporates finite element, integral equation, and hybrid methods to solve a wide range of microwave, RF and high-speed digital applications.

3.10.2 ANSYS MAXWELL

ANSYS Maxwell is a Finite Element Analysis tool for electromagnetic field simulation, primarily for engineers tasked with designing and analyzing electromagnetic and electromechanical devices, including motors, actuators, transformers, sensors and coils. ANSYS Maxwell incorporates finite element methods to solve static, frequency-domain, and time-varying electromagnetic and electric fields.

3.10.3 ANSYS SIWAVE

ANSYS SI wave is a specialized design platform for power integrity, signal integrity and Electromagnetic interference (EMI) analysis of electronic packages and PCBs.

SUITES

ANSYS Multi physics and ANSYS Workbench provide multiple ANSYS tools in a single package.

AVAILABILITY

A free student version is available for download, and supports up to 32,000 nodes/elements. SASI developed its business in parallel with the growth in computer technology and engineering needs. The company grew by 10 percent to 20 percent each year, and in 1994 it was sold to TA Associates.

3.11 BASIC STEPS INVOLVED IN ANSYS

3.11.1 PREPROCESSING

The major steps in pre-processing are (i) define key points/lines/areas/volumes (ii) Define element type and material/geometric properties and (iii) mesh Lines/areas/ volumes as required. The amount of detail required will depend on the dimensionality of the analysis i.e. 1D, 2D, axisymmetric and 3D (iv) To define contact pairing between the two surfaces if necessary (v) To define constraints (Translational and rotational) (vi) to define loads (point or pressure).

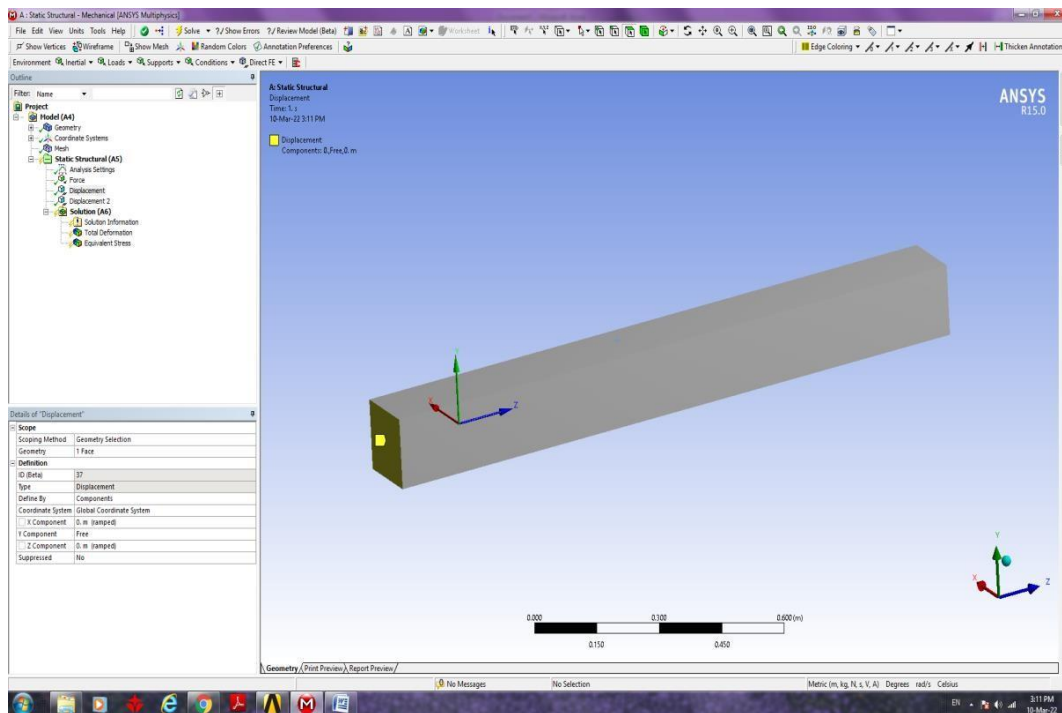


Fig:3.10 BEAM MODEL IMPORT IN ANSYS

3.11.2 SOLVER (SOLUTION)

Here the analysis type is defined like static, transient depending on model we are analysing. Next step is to set the solution using Solution Controls. Finally solving by incremental method using Newton Raphson solver.

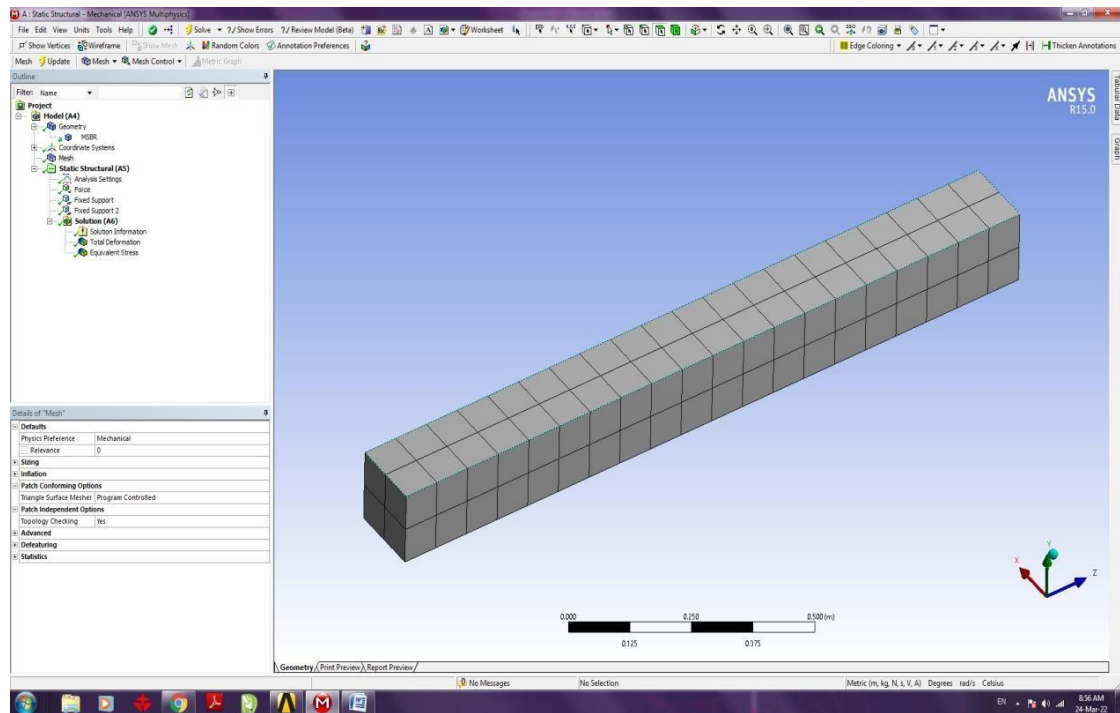


Fig:3.11 BEAMWITHGFRPMODELIMPORTINANSYS

3.11.3 POSTPROCESSING

In this step we can view the results (i) list of nodal displacements (ii) element forces and moments (iii) Deformed shape and (iv) Stress contour diagrams.

3.12 TESTPROCEDURE

3.12.1 CASTING AND CURING

The concrete cube specimens are casted by the consideration of the following steps

1. Cube Mould

The cube moulds of required size 150 x 150 x 150 mm for nominal size of aggregate not exceeding 38 mm. Cube moulds shall be provided with a base plate and they shall be as per IS:10086-1982.

2. Tamping Rod

As per IS:10086-1982, the tamping rod shall be 16 ± 0.5 mm dia and 600 ± 2 mm long with a rounded working end and shall be made of mild steel.

3. Casting Process

The cube mould plates should be removed, properly cleaned, assembled, and all the bolts should be fully tight. A thin layer of oil then shall be applied on all the faces of the mould. It is important that cube side faces must be parallel.

After taking concrete samples and mixing them, the cubes shall be cast as soon as possible. The concrete sample shall be filled into the cube moulds in layers approximately 5 cm deep.

In placing each scoopful of concrete, the scoop shall be moved around the top edge of the mould as the concrete slides from it, in order to ensure a symmetrical distribution of the concrete within the mould. Each layer shall be compacted either by hand or by vibration as described below.

4. CompactionByHand

Each layer of the concrete filled in the mould shall be compacted by not less than 35 strokes by tamping bar. The strokes shall be penetrate into the underlying layer and the bottom layer shall be rodded through its depth. Where voids are left by the tamping bar the sides of the mould shall be tapped to close the voids.



Fig:3.12 M30 Grade concrete mixing in partial replacement of GGBS by cement in 20%, 30%, 40% & 50%.



Fig:3.13 Casting the compression cubes



Fig:3.14 Aftercuredcompressioncubes

CastingofCylinders

The material properties of concrete can only be properly evaluated if test specimens are made and cured according to standards. Concrete cylinders are typically made to evaluate the compressive strength of the concrete as well as split tensile strength.

5. Cylinder Mould

Metal 100 x 200 mm or 150 x 300 mm cylinder moulds are used for casting concrete test specimens in the field. Before filling, they should be placed on a smooth, firm, level surface.

6. Tamping Rod

If 100 mm diameter moulds are used then it should be filled in 3 equal layers and each layer rodded uniformly 20 times with a 10 mm diameter x 450-600 mm long hemispherically tipped steel rod.

If 150 mm diameter moulds are used then it should be filled in 3 equal layers and each layer rodded uniformly 25 times with a 16 mm diameter x 450-600 mm long hemispherically tipped steel rod.

7. Casting Process

The strokes shall be distributed uniformly over the cross-section of the mould. The bottom layers shall be rodded throughout its depth. For each upper layer, the rod shall penetrate about 25 mm into the underlying layer. If voids are left by the rod, the sides of the mould should be tapped to close voids before adding the next layer of materials.



Fig : 3.15 Casted cylinder

Casting of Beams

According to standards, concrete beams are casted to evaluate the flexural strength of the concrete. The casting and testing procedure to be followed as Indian standard code IS 516:1959.

8. Cylinder Mould

The mould standard size will be 150 x 150 x 1500 made out of metal. The tamping bar shall be a steel bar weighing 2kg, 40 cm long and shall have a ramming face 25 mm square. The test specimen shall be made as soon as practicable after mixing and in such a way as to produce full compaction of concrete while neither segregation nor excessive laitance.



Fig :3.16 casting of beam

9. Casting Process

The compaction shall be distributed uniformly over the section of the mould. The bottom layer shall be rodded throughout its depth. For each upper layer, the rod shall penetrate about 25 mm into the underlying layer. If voids are left by the rod, the sides of the mould should be tapped to close voids before adding the next layer of material.



Fig:3.17 Compacting the concrete beams



Fig:3.18 Before curing the flexural beams

CURING

Curing plays a vital role concerning concrete strength development and Durability. Curing of Concrete is a method by which the concrete is protected against loss of moisture required for hydration and kept within the recommended temperature range. Curing will increase the strength and decrease the permeability of hardened concrete. Curing also helps in mitigating thermal and plastic cracks, which can severely impact the durability of structures.

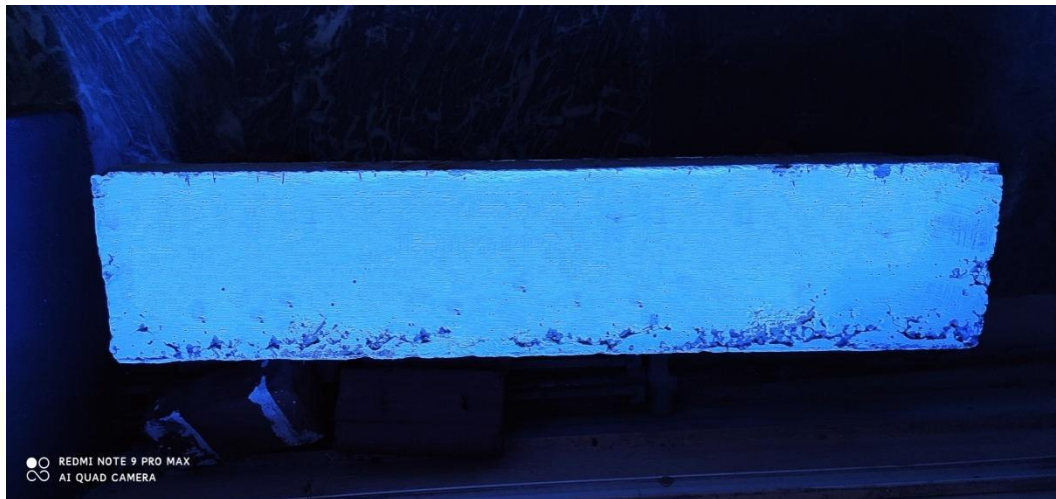


Fig: 3.19 curing of beam

Curing practice involves keeping the concrete damp or moist until the hydration of concrete is complete and strength is attained. Curing of concrete should begin soon after initial setting time of concrete.

As per IS 456— 2000 concrete should not be cured less than 7 days for

ordinary Portland Cement, and it must be at least 10 days for concrete with mineral admixtures or blended cement are used. In case of hot weather and very dry temperature conditions, the curing should not be less than 10 days for OPC and 14 days for concrete with blended cement & mineral admixtures.

3.12.2 TESTS ON HARDENED CONCRETE

The hardened concrete test consists of both the strength and durability properties of the concrete. The strength properties of concrete is carried out by compressive strength test, split tensile strength test, flexural strength test, cylindrical compression test, and young's modulus test and the durability properties of the concrete is carried out by Rapid chloride penetration test and sulphate attack test as follows.

3.12.2.1 Compressive Strength Test

This procedure is applicable for establishing testing method for the compressive strength of concrete specimens. Specimens stored in water shall be tested immediately on removal from the water and while they are still in the wet condition. Wet condition is also maintained by covering the specimens with wet burlap.

The bearing surfaces of the testing machine shall be wiped clean and dry loose sand or other material removed from the surfaces of the specimen which are to be in contact with the compression platens. In case of the cubes, the specimen is placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast that is, not to the top and bottom. The axis of the specimen shall be carefully aligned with the center of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine. The loading rate shall be set to 5.2 KN/sec for 15 cm cube, to uniformly load the specimen.

The load shall be applied without shock, and increased continuously until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall then be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.

$$\text{Compressive strength (N/mm}^2\text{)} = \frac{\text{Ultimate load in N}}{\text{Area of cross section (mm}^2\text{)}}$$

3.12.2.2 Split Tensile Test

This procedure is applicable for establishing testing method for the split tensile strength of concrete specimens.

Specimen when received dry shall be kept in water for 24 hours before they are taken for testing. Unless other conditions are required for specific laboratory investigation, specimen shall be tested immediately on removal from the water whilst they are still wet. Surface water and grit shall be wiped off the specimens and any projecting fins removed from the surfaces which are to be in contact with the packing strips. Marking - Diametral lines shall be drawn on the two ends of the specimen using any suitable procedure and device that will ensure that they are in the same axial plane. Placing of the specimen in the Testing Machine - The bearing surfaces of the testing machine and of the packing strips shall be wiped clean.

. Positioning — One of the plywood strips shall be centered along the centre of the lower platen. The specimen shall be placed on the plywood strip and aligned so that the lines marked on the ends of the specimen are vertical and centred over the plywood strip. These two plywood strips shall be placed lengthwise on the cylinder, centred on the lines marked on the ends of the cylinder. The assembly shall be positioned to ensure the following conditions:

- The lines marked on the ends of the specimen are vertical and that the projection of the plane of the two lines marked on the ends of the specimen intersects the centre of the platens, and
- The supplementary bearing bar or plate, when used, and the centre of the specimen are directly beneath the centre of thrust of the spherical bearing block.

Rate of Loading— The load shall be applied without shock and increased continuously at a rate to produce approximately a splitting tensile stress of approximately 14 to 21 kg/cm²/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. This rate of loading for 15 cm diameter and 30 cm length cylinder works out 1.62 kN/sec to 2.43 kN/sec. The maximum load applied to

the specimen shall then be recorded. The appearance of concrete and any unusual features in the type of failure shall also be noted.

The measured splitting tensile strength (T_{sp}) of the specimen shall be calculated to the nearest 0.01 N/mm^2 using the following formula

$$\text{Splitting strength (N/mm}^2\text{)} = \frac{2P}{l \cdot D}$$

Where,

P = maximum load in N applied to the specimen,
 d = measured diameter in mm of the specimen,
 l = measured length in mm of the specimen.

3.12.2.3 Flexural Strength test

This procedure is applicable for establishing testing method for the flexural strength of test specimens. Specimens stored in water at a temperature of 24°C to 30°C for 48 hours before testing shall be tested immediately on removal from the water whilst they are still in a wet condition. No preparation of the surface is required.

The bearing surfaces of the supporting and loading rollers shall be wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. The specimen shall then be placed in the machine in such a manner that the load shall be applied to the uppermost surface as cast in the mould, along two lines spaced 200 mm apart. The axis of the specimen shall be carefully aligned with the axis of the loading device. The bed of testing machine should be provided with two steel rollers 38 mm in diameter on which the specimen is to be supported, and these rollers should be placed at distance 600 mm c/c. No packing shall be used between the bearing surfaces of the specimen and the rollers.

The load shall be applied without shock and increasing continuously at a rate such that the extreme fibre stress increases at approximately 0.7 kg/sqcm/min, that is, at a rate of loading of 400 kg/min for the 150 mm specimens. The load shall be increased until the specimen fails, and the maximum load applied to the specimen during the test shall be recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure shall be noted.

The flexural strength of the specimens shall be expressed as the modulus of rupture shall be calculated to the nearest 0.05 N/mm² as follows:

$$\text{Flexural strength (N/mm}^2\text{)} = \frac{PL}{bD^2}$$

Where,

b = measured width in mm of the specimen,

h = measured depth in mm of the specimen at the point of failure,

l = length in mm of the span on which the specimen was supported,

and P = maximum load in N applied to the specimen.

3.13 WRAPPING OF GLASS FIBRE

Glass Fibre Wrapping can be used where concrete loses its capacity/design strength due to corrosion, change in use and the design code demands increases in load carrying capacity. It can also be used for restoration of the damaged RCC structures and to regain its design strength. Fibre wrapping is the latest strengthening/enhancement technology for reinforced concrete and masonry structural members.



Fig :3.20 Mixing of resin & hardener in 2:1 ratio

It is used for flexural, shear or confinement strengthening of structural members and ensure minimum disturbance to the structural members as compared to other conventional method. The above figure is the pictorial representation of glass fibre being used in this project work.

3.13.1 WRAPPING OF SPECIMEN WITH GFRP

Glass fibre reinforced polymer will be wrapped in bottom full layers at the length of the beam specimen.

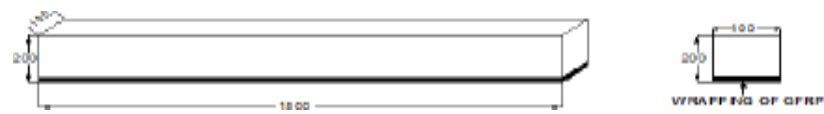


Fig:3.21 Wrapping of beam specimen

3.13.2 GFRP LAMINATE BONDING TECHNIQUE

Glass Fibre Reinforced Polymer (GFRP) laminates were used for strengthening the beams. The soffit of the beam was well cleaned with a wire brush and roughened with a surface-grinding machine.



Fig:3.22 GFRP wrapped 3 layers in RC beams

Two part epoxy adhesive consisting of epoxy resin and silica filler was used to bond the GFRP laminates. The adhesive was spread over the soffit. The GFRP laminate was applied gently by pressing the sheet from one end of the beam to the other along the length of beam.



Fig :3.23 After 24 hours the GFRP was fixed in the RC beam

CHAPTER 4

RESULTANDDISCUSSIONS

4.1.ANALYTICALINVESTICATIONS

4.1.1. BEAMDEFORMATIONANDSTRESSINANSYS

	NormalBeam		CompositeBeam	
Load (N)	DEFORMATION(m)	STRESS(Pa)	DEFORMATION(m)	STRESS(Pa)
500	3.80E-06	1.02E+05	4.30E-07	8.40E+04
1000	7.60E-06	2.05E+05	8.60E-07	1.60E+05
1500	1.15E-05	3.08E+05	1.20E-06	3.08E+05

Table:4.1.1 BEAMDEFORMATIONANDSTRESSINANSYS

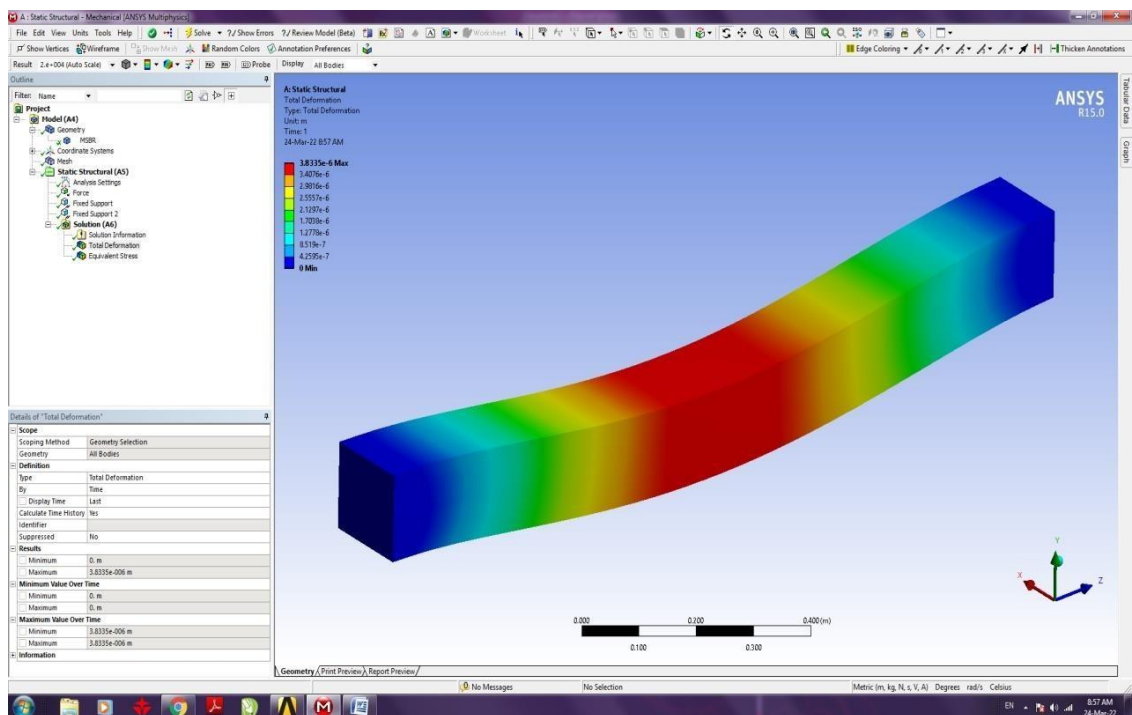


Fig.4.1:BEAMDEFORMATIONIN ANSYS

4.1.2.BEAMWITHGFRPMODELIMPORTINANSYS

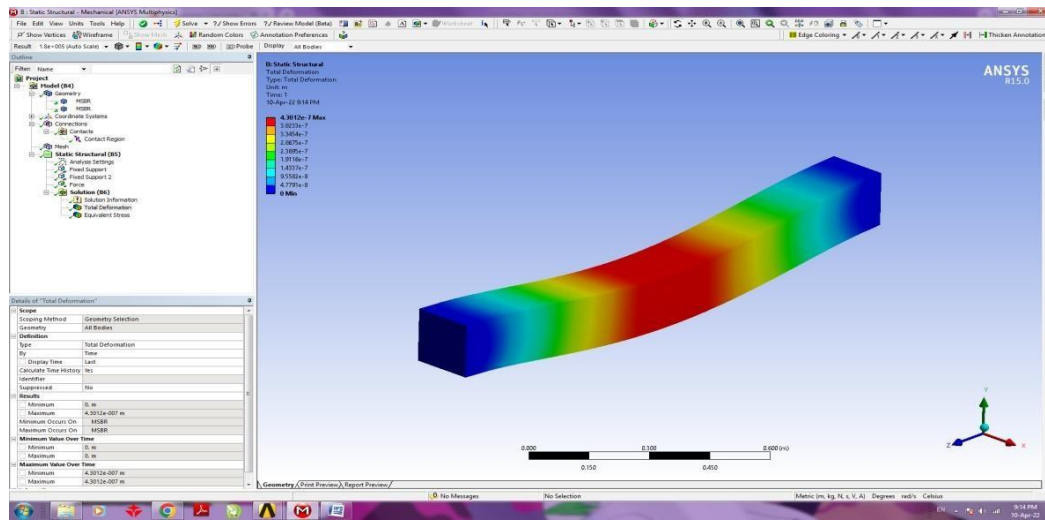


Fig.4.2:BEAMWITHGFRPMODEL IMPORT INANSYS

In the analytical investigation was processed in the ANSYS software. So first the input of normal RC beam was loaded in particular condition. It was having the maximum deformation of 0.4mm in the original dimensions of the beam. But second input was prepared in GFRP wrapped RC beam. It was carrying the same load to the first model, and give the deformation of 0.3mm in its original dimensions. So the GFRP wrapping process was increase the load carrying capacity of the element.

4.2 RATIOS FOR SPECIAL CONCRETE (EXTRA INGREDIENTS)

RATIOS OF GGBS ADDED IN CEMENT

Cement Replacing 20%, 30%, 40% & 50% of GGBS

GFRP 6mm thickness adding laying

4.3 COMPRESSIVE STRENGTH TEST

The compressive strength is usually obtained experimentally by means of a compressive test. In the study of strength of materials, the compressive strength is the capacity of a material or structure to withstand load tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine. Some materials fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load.



Fig.4.3: Preparation of testing of compression cubes



Fig.4.4: Testing of compression cubes in different ratios of GGBS
Compression strength test results

MIX DESIGN	% OF REPLACEMENT	COMPRESSIVE STRENGTH (N/mm ²)			
		7 DAYS	14 DAYS	21 DAYS	28 DAYS
M30	0	15.6	20.3	27.3	31.7
	20	16.2	22.4	27.5	32.6
	30	18.7	25.6	28.4	34.9
	40	15.8	23.4	27.5	33.2
	50	13.5	18.6	23.5	30.2

Table:4.3.1 Compressive Strength Test Result

MODEL CALCULATION

$$\begin{aligned}\text{STRENGTH} &= \frac{351000}{150 \times 150} \text{ N/mm}^2 \\ &= 15.6 \text{ N/mm}^2\end{aligned}$$

Fig.4.5: Compression Test Graph Result

If normally the conventional M30 grade concrete was produces the compressive strength after 28 days is above 30 N/mm². So the 20%, 30%, 40% & 50% partial replacement of GGBS concrete was produces the compressive strength of 32.6, 34.9, 33.2 & 30.2 N/mm². So results shows that the partial replaced concrete was give better strength while comparing to the conventional concrete.

4.4 Splittensilestrength

To determinethesplittensilestrength,cylindermouldsofdiameter150mm andlength300mmwerecasted.Totally,20 cylindricalspecimens werecastewithdifferent proportions of GGBS .

The split tensile strength of concrete is calculated by using the following

$$\text{formulaf}_{st}=2P/\pi ld$$

where

P-maximumloadatfailure

l-length ofcylindricalspecimen inmm

d-diameterofcylindricalspecimeninmm.

MIXDESIGN	% OF REPLACEMENT	SPLITTENSILESTRENGTHTEST (N/mm ²)			
		7DAYS	14DAYS	21DAYS	28DAYS
M30	0	2.3	4.3	5.25	7.65
	20	2.4	4.5	6.25	8.2
	30	2.5	4.6	6.54	8.73
	40	2.2	4.4	5.9	7.9
	50	2.1	4.1	5.12	7.32

Table:4.4.1 SplittensileTestResult

MODEL CALCULATION

$$f_{st}=2P/\pi ld$$

$$= 2 \times 700 / 3.14 \times 300 \times 150$$

$$= 2.3 \text{ N/mm}^2$$

Fig.4.6: Splittensile GraphResult

4.5 FLEXURALSTRENGTHTEST

Duringthetesting,thebeamspecimensofsize1500mmx150mmx150mm were used. Specimens were dried in open air after 7 daysofcuringandsubjectedtoflexuralstrengthtestunderflexuraltestingassembly.



Fig4.7: Testingofflexural beams overtheGFRPwrappingprocess

If the flexural strength test was giving the better results, comparing to the conventional concrete. Because of the flexural beams are wrapped in the GFRP sheets in 6mm thickness. It's also increase the load carrying capacity of the element were tabulated in table 4.4

S.NO	REPLACEMENTS OF GGBS	ULTIMA TELOAD IN (Tone)	FLEXURAL STRENGTH IN (N/mm ²)
1	0%	12	35.56
2	20%	16.57	47.28
3	30%	17.3	55.08
4	40%	17.84	41.96
5	50%	15	40.32

Table :4.5.1 Flexural Strength Test Result

CHAPTER 5

CONCLUSION

The shear behaviour of concrete beams reinforced with GFRP layer with 6mm thick shear reinforcement has been presented in our project.

- The compressive strength at 20%, 30%, 40% & 50% percentages GGBS was 32.6, 34.9, 33.2 & 30.2 N/mm². The increase percentage of strength at 30% percentage GGBS with 6mm thick GFRP layer over controlled concrete cube strength 28.3 N/mm² at 21 days.
- In 30% GGBS replaced Specimen's Flexural strength was 1.3% percentage increased (6.54 N/mm²) while compared to the conventional concrete specimen (5.25 N/mm²) in 21 days.
- From our experimental results 20%, 30%, 40% & 50% GGBS with 6mm thickened GFRP layer will gave better results compared to conventional concrete.
- In Analytical and experimental process of strength beam is comparatively increases in the addition of 30% GGBS and wrapped GFRP.
- In future GGBS is the good and also effective replacement of cement in the civil industries, and also GFRP is very much useful in retrofitting & rehabilitation process.
- Due to environmental issues in the production of cement industry by-product like GGBS as supply entry materials in concrete and it save cost of production of concrete and made it Eco friendly.
- The beams was designed under the reinforced section such that fails in flexural zone . The GFRP wrapped is higher strength when it compared with conventional concrete . GFRP materials can prevent the strength in future construction or repair work .

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