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AN EXPERIMENTAL STUDY ON HIGH PERFORMANCE CONCRETE BY USING GGBS AND ROBO SAND

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ABSTRACT

In the engineering industry, the improvement of existing materials allow for technological advancement and the construction of more reliable structures without over design. A High performance concrete is somethingwhich demands much higher performance from concrete ascompared to performance expected from routing concrete.Use of chemical admixtures reduces the water content,thereby reducing the porosity within the hydrated cementpaste. Mineral admixtures also called as cement replacementmaterial (CRM) such as fly ash, rice husk ash, ground granulated blast furnace slag ,Met kaolin, silica fume are more commonly used in the development of Highperformance mixes, act as pozzolanic materials as well as finefillers, thereby the microstructure of hardened cement matrix becomes denser and strong. High performance concrete (HPC), a widely utilized material in heavy structural constructions. This paper gives the characteristics of HPC, the study of influence of water- binder ratio and the influence of strength. High performance concrete (HPC) is a concrete meeting special combinations of performance and uniformity and normal mixing. This leads to examine the admixtures to improve to improve the performance of the concrete. On the other side, cost of concrete is attributed to the cost of its ingredients which is scarce and expensive, this leading to usage of economically alternative materials in the production. This requirements is drawn the attention of investigators to explore new replacements of ingredients of concrete. This paper deals with the effective utilization of waste materialin concrete production as a partial replacement for Cement and sand. The cement has been replaced by GGBS in the range of30%, 40% and 50% by weight of cement, robo sand in the range of 5%, 15% and 25% by weight of cement for M40grademix.

I. INTRODUCTION

1.1 General

Concrete is considered as durable and strong material. Reinforced concrete is one of the most popular materials used for construction around the world. Reinforced concrete is exposed to deterioration in some regions especially in coastal regions. Therefore researchers around the world are directing their efforts towards developing a new material to overcome this problem. Invention of large construction plants and equipments around the world added to the increased of material. This scenario leads to the use of additive materials to improve the quality of concrete. As an outcome of the experiments and researches, cement based concrete which meets special performance with respect to workability, strength and durability known as “HIGH PERFORMANCE CONCRETE” was developed.

Concrete has been the major instrument for providing stable and reliable infrastructure since the days of Greek and roman civilization. The most important part of concrete is the cement. Use of cement alone as a binder material produces large heat of hydration. Since the production of this raw material produces lot of CO2 emission. The carbon dioxide emission from the cement raw material is very harmful to the environmental changes. Nowadays many researchers have been carried out to reduce the CO2. The effective way of reducing CO2 emission from the cement industry is to use the industrial by products or use of supplementary cementing material such as Ground Granulated Blast Furnace Slag (GGBS), Fly Ash(FA), Silica Fume (SF) and Metakaolin (MK). In this present experimental work an attempt is made to replace cement by GGBS to overcome these problems. River sand has been used as a major building material component. Its well- graded and that all sizes grains are well distributed in a given sample. River sand is mainly used for all kinds of civil engineering construction. River sand has been the most important choice for the fine aggregate River sand has been used as a major building material component. Its well-graded and that all sizes grains are well distributed in a given sample. River sand is mainly used for all kinds of civil engineering construction. River sand has been the most important choice for the fine aggregate component of concrete in the early periods. Overuse of the material have been led to environmental concerns, the depleting of securable river sand due to this the material cost also increases.

1.1 Historical Background

Although high strength concrete is often considered relatively new materials, its development has been gradual over many years. In USA, in the 1950’s concrete with a compressive strength of 34mpa was considered high strength, in the 1960’s, concrete with 41 to 52mpa compressive strength were used commercially.

In the early 1970’s, 62mpa concrete was being produced. In the world scenario, however, in the last 15 years, concrete of very high strength entered the field of construction, in particular constraint of high-rise buildings and long span bridges. According to code IS 456-2000 compressive strength over 110mpa has been considered for the applications in cast-in-place buildings and pre-stressed concrete members. But recently reactive concrete is a one which having nearly compressive strength of 50mpa. It is completely based on pozzolanic materials.

1.2 Definition of HPC

The performance requirements of concrete cannot be the same for different applications. Hence the specific definition of HPC required for each industrial application is likely to vary. The Strategic Highway Research Programme (SHRP) has defined HPC for highway application on the following strength, durability, and w/c ratio criteria.

(a) It should satisfy one of the following strength criteria:

4 hour strength _17.5 Mpa

24 hour strength _35.0 Mpa

i. ays strength _ 70.0 Mpa

(b) It should have a durability factor greater than 80% after 300 cycles of freezing and thawing.

(c) It should have a water-cement ratio of 0.35 or less.

In general, a “High performance Concrete” can be defined as that concrete which has the highest durability for any given strength class, and comparison between the concretes of different strength classes is not appropriate. This means that, with the available knowledge, one can always strive to achieve a better (most durable) concrete required for a particular

1.3 High Performance Concrete

High Performance Concrete (HPC) is that which is designed to give optimized performance characteristics for the given set of materials, usage and exposure conditions, consistent with requirement of cost, service life and durability.

The American Concrete Institute (ACI) defines HPC “As concrete which needs special combinations and uniformity requirements that cannot always be achieved routinely by using conventional materials and normal mixing, placing and curing practices”.

High performance in a broad manner can be related to any property of concrete. It can mean excellent workability in the fresh state like self leveling concrete or low heat of hydration in case of mass concrete, or very rigid setting and hardening of concrete in case of sprayed concrete or quick repair of roads and airfields, or low imperviousness of storage vessels, or very low leakage rates of encapsulation containments for contaminating material.

1.4 Need of High Performance Concrete

- To put the concrete into service at much earlier age, for example opening the pavement at 3-days.
- To build high-rise buildings by reducing column sizes and increasing available space.
- To build the super structure of long-term bridges and to enhance the durability of bridge decks.
- To satisfy the specific needs of special applications such as durability, modulus of elasticity, and flexural strength. Some of these applications include dams, grandstand roofs, marine foundations, parking garages, and heavy industrial floors.

Table 1.1: Performance characteristics of High Performance Concrete

Performance Characteristics	Requirements
Flow ability and workability	Easier
Bleeding	None or negligible
Ultimate strength	Higher
Durability	Very high especially after 3 months
Cost	Lower- initial cost of HPC is higher due to extra over head in quality control and processing, the benefit of extended service life, among many other benefits, exceed by far the high initial cost.

2. LITERATURE REVIEW

2.1 General:

This chapter presents a review of literature on subject of this thesis. The review covers the following aspects: i) Studies on High-Performance-Concrete over view on pozzolanas in concrete iii) Studies on Super plasticizers

2.2 Studies on High- Strength- Concrete (HSC):

P.L.Domone, and M.N.Soutsos, (1995) “The results show broadly similar effects to those in lower strength concrete, although of differing magnitude in some cases. Some potential advantages of ternary blends for optimization of properties have been demonstrated. Long- term strength of PFA and GGBS mixes may not reach those of 100% Portland cement mixes when the water-binder ratio is reduced to 0-26 and below, but micro silica can increase the strength of all mixes”.

R.Duval and E.H.Kadri (1998) “The results show that partial cement replacement up to10% silica fume does not reduce the concrete workability and propose a model to evaluate the compressive strength of silica fume concrete at any time. The increase of the compressive strength of SF concretes depends much more on the decrease of the water/cementitious materials ratio than on the replacement of silica fume with cement’.

ShreetiS. Mavinkurve, et al., (2003) “Present paper discusses the approach adopted to develop HPC mix by means of laboratory trials using HRM. The various properties of concrete, both in the fresh and hardened states are also highlighted .It can be concluded the high strength concrete up to compressive strength of 82.75 M pa, having quite low permeability and with reasonably high slump can be developed using Indian HRM and cement”.

Marta Kasior -Kazberuk and Malgorzata Lelusz (2006) “ Strength of concrete with different types of cement have been analyzed to evaluate the effect of addition content, the time of curing and the type of cement on the compressive strength changes. The pozzolanic and hydraulic activity of fly ash have mainly been pointed out as well as the possibility to use this addition as a concrete component

Eva Vejmelkova, et al., (2010). "High performance concrete with Czech metakaolin: Experimental analysis of strength, toughness and durability characteristics" Construction and Building Materials.

Pazhani.K.Jeyaraj.R (2010). "Study on durability of high performance concrete with industrial wastes." Applied Technologist and innovations

Vijaya Sekhar Reddy, et al., 2013 "Predicting the strength properties of high performance concrete using mineral and chemical admixtures", ARPN Journal of Science and Technology

2.3. Studies on Superplasticizers:

Super plasticizers are widely used in concrete processing to increase the rheological properties of hardened pastes. Super plasticizers are chemical admixtures which can maintain an adequate workability of fresh concrete at low water/cement ratio for a reasonable period of time, without affecting the setting and hardening behavior of the cementitious system. Super plasticizers are introduced in concrete. Like many other admixtures to perform a particular function, consequently they are frequently described according to their functional properties. Super plasticizers have been classified as high range water reducers (HRWR) to distinguish them from other categories of less effective water reducers.

Franklin (1976) stated that, super plasticizers are organic polyelectrolyte, which belong to the category of polymeric dispersants. The performance of super plasticizers in cementations system is known to depend on cement fineness, cement composition mode of introduction to the mixture etc., as well as on the chemical composition on super plasticizer. For many years, it was not possible to reduce water/cement ratio of concrete below 0.40 till the advent of super plasticizers. The super plasticizers were first used in concrete in 1960s and their introduction occurred simultaneously in Germany and Japan (Meyer and Hottori, 1981). At first, the super plasticizers were used as fluidizers than water reducing agents. By using large enough super plasticizer, it was possible to lower the water/binder ratio of concrete down to 0.30 and still get an initial slump of 200mm. Reducing the water/binder ratio below 0.30 was a taboo until.

Bache reported that using a very high dosage of super plasticizers and silica fume, water binder ratio can be reduced to 0.16 to reach a compressive strength of 280MPa (Bache, 1981).

Aitcin et al. (1991) reported, that by choosing carefully, the combination of Portland cement and super plasticizer, it was possible to make a 0.17 water/binder ratio concrete with 230mm slump after an hour of mixing which gave a compressive strength of 73.1MPa at 24 hours but failed to increase more than 125MPa after long term wet curing. During 1980s, by increasing the dosage of super plasticizers little by little over the range specified by the manufacturers, it is realized that super plasticizers can be used as high range water reducers (Ronneberg and Sandvik, 1990).

3MATERIALS USED IN PRESENT PROJECT AND THEIR METHODS

3.1 MATERIALS

In this present investigation the following materials were used.

3.1.1 Ordinary Portland cement (53 grade),
3.1.2 Fine Aggregate (<425μ),
3.1.3 Coarse Aggregates
3.1.4 Ground Granulated Blast Furnace Slag
3.1.5 Robo sand
3.1.6 Super plasticizer (Varaplast PC-432)

3.1.1 Ordinary Portland cement:

Portland cement is the most common type of cement in general use around the world, used as a basic ingredient of concrete, mortar, stucco, and most non-specialty grout. It usually originates from. It is a fine powder produced by grinding Portland cement clinker (more than 90%), a limited amount of calcium sulphate (which controls the set time) and up to 5% minor constituents as allowed by various standards. Portland cement clinker is a hydraulic material which shall consist of at least two-thirds by mass of calcium silicates (3CaOSiO2and2 CaO•SiO2), the remainder consisting of aluminum and iron-containing clinker phases and other compounds. The ratio of CaO to SiO2 shall not be less than 2.0. The magnesium oxide content (MgO) shall not exceed 5.0% by mass.

Table 3.1 Approximate Oxide Composition Limits of OPC

COMPOSIT0ION	PERCENTAGE (%)
CaO	60-67 %
SiO_2	17-25%
Al_2O_3	3.0-8.0 %
Fe_2O_3	0.5-6.0 %
MgO	0.1-4.0 %
Alkalies (Na_2O,K_2O)	0.4-1.3 %
SO_3	1.3-3.0 %

There are four major compounds in cement and these are known as C2S, C3S, C3A & C4AF, and their composition varies from cement to cement and plant to plant. In addition to the above, there are other minor compounds such as MgO, TiO2, Mn2O3, K2O and N2O.

They are in small quantity of these K2O and Na2O are found to react with some aggregates and the reaction is known as Alkali Silica Reaction (ASR) and causes disintegration in concrete at a later date. The silicates C3S and C2S are the most important compounds and are mainly responsible for the strength of the cement paste. They constitute the bulk of the composition. C3A and C4AF do not contribute much to the strength, but in the manufacturing process they facilitate combination of lime and silica, and act as a flux.

Table 3.2 : R.H. Bogue's Compounds

S. No	Compound	Name of compound	Formula	Composition as %
1	C_3S	Tricalcium silicate	$3\,CaO.SiO_2$	48-52 %
2	C_2S	Dicalcium silicate	$2\,CaO.SiO_2$	22-26 %
3	C_3A	Tricalcium aluminate	$3\,CaO.Al_2O_3$	6-10 %
4	C_4AF	Tetra calcium aluminoferrite	$4\,CaO.\,Al_2O_3.Fe_2O_3$	13-16 %

Table 3.3 Physical Properties of Zuari 53 grade cement based on IS: 12269-2013

Physical properties	Zuari 53 grade	IS: 12269-2013
Fineness		
Specific surface (m^2/kg)	290	>225
Soundness		
Le Chatelier Method(mm)	1.0	<10
Setting Time		
Initial (minutes)	160	>30
Final (minutes)	260	<600
Compressive Strength MPa		
3 days	39	>27
7 days	48	>37
28 days	60	>53

3.1.2 Fine Aggregate

The sand used for the experimental programmed was locally procured and conformed to Indian Standard Specifications IS: 383-1970. The sand was first sieved through 425µ sieve to remove any particles greater than 425µ and then was washed to remove the dust.

For the aggregate producer, the concrete aggregates are end products, while, for the concrete manufacturer, the aggregates are raw materials to be used for mix designs and successful concrete production. The aim of this study was to identify which fine aggregate characteristics are important, and additionally to relate the extent of the effect that the aggregate has on the concrete as compared against the effect of the changes in mix design. Fine aggregate is natural sand which has been washed and sieved to remove particles larger than 425µ. The fine and coarse aggregate are delivered separately. Because they have to be sieved, a prepared mixture of fine and coarse aggregate is more expensive than natural all-in aggregate. The reason for using a mixture of fine and coarse aggregate is that by combining them in the correct proportions, a concrete with very few voids or spaces in it can be made and this reduces the quantity of comparatively expensive cement required to produce a strong concrete.

A program for predicting the interaction between the fine aggregate and concrete was developed. The Bayesian method was used for statistical processing, and non-parametric non-linear Gaussian process models were applied for the interaction models. The program includes four concrete properties; flow value, air %, bleeding and compressive strength.

Table 3.4 : Physical Properties of FA

Aggregate Properties	FA
Specific gravity	2.62
Water absorption (%)	1.0
Bulk density (kg/m^3)	1460
Fineness modulus (%)	3.537
Moisture Content (%)	1.50

Set of Sieves for Fine Aggregate

3.1.3. Robo Sand (Crushed Rock Powder 425µ)

The Andhra Pradesh Government is seeking to encourage use of Robo sand, a natural sand substitute for use in the construction sector. This move comes in the backdrop of shortage of sand supply impacting the construction sector in the State. The Government is in the process of streamlining sand quarrying and prevents its indiscriminate use. Robo sand is sand manufactured in the stone quarries. It is a substitute for the river sand used in construction. Manufacturers claim it is better than the river sand. River sand, which is one of the constituents used in the production of concrete, has become expensive and scarce. So there is large demand for the alternative materials. The crusher dust produced from granite crushers is one of the alternative materials for river sand. The utilization if crusher dust which can be called as ROBO sand has been accepted as a building material in the western countries. Lot of research has been done regarding the crusher dust as alternative materials for river sand. They have used the crusher dust of size which has been passed through 75 micron. ROBO sand or crusher dust obtained from local granite crushers was used in concrete to cast the cubes and cylinders. The bulk density of ROBO sand IS 1768 kg/m3. The specific gravity of ROBO sand is 2.65.

The physical and chemical properties of Robo sand obtained by testing the samples as per Indian Standards are listed.

Table 3.6 : Physical properties ROBO SAND

Property	Robo Sand	Test method
Specific gravity	2.54-2.60	IS 2386 (Part III) 1963
Bulk Relative density(kg/m^3)	1720-1810	IS 2386 (Part III) 1963
Absorption (%)	1.20-1.50	IS 2386 (Part III) 1963
Moisture content (%)	Nil	IS 2386 (Part III) 1963
Fine particles less than 0.075mm (%)	12-15	IS 2386 (Part I) 1963
Sieve analysis	Zone II	IS 383 – 1970

3.1.4. Coarse Aggregate

According to IS: 383-1970, coarse aggregate most of which is retained on 4.75mm IS sieve. Coarse aggregate may be described as:

i. Uncrushed gravel or stone which results from natural disintegration of rock,
ii. Crushed gravel or stone when it results from crushing of gravel or

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hard stone, and

iii. Partially crushed gravel or stone when it is a product of the blending of (i) and (ii).

In this project, coarse aggregates are naturally occurring crushed stones. They are hard, strong, dense, durable, clear and free from veins and adherent coating, and free from injurious amounts of disintegrated pieces, alkali, vegetable matter and other deleterious substances. Also they are not flaky, scoriaceous and elongated pieces.

According to IS:456-2000, the nominal maximum size of coarse aggregate should be as large as possible within the limits specified but in no case greater than one-fourth of the minimum thickness of the member, provided that the concrete can be placed without difficulty so as to surround all reinforcement thoroughly and fill the corners of the form. For most work, 20 mm aggregate is suitable. Where there is no restriction to the flow of concrete into sections, 40 mm or larger size may be permitted. In concrete elements with thin sections, closely spaced reinforcement or small cover, consideration should be given to the use of 10 mm nominal maximum size.

Set of sieves for coarse aggregate

At a given water-cement ratio, rounded aggregates demands lower cement content because of its least surface area for a given volume which is called “specific surface area”. The higher cement demand in case of angular aggregates is offset to some extent by the higher strength and durability because of better interlocking. Flat surfaced particles such as “flaky” & “elongated “ones, having a larger specific surface area makes very poor concrete. Water demand and cement requirement for a given strength is higher for such particles.

Table 3.8 : Physical Properties of CA

Aggregate Properties	CA
Specific gravity	2.62
Water absorption (%)	1.32
Bulkdensity (kg/m^3)	1510
Fineness modulus (%)	6.59

3.2 Admixture

INTRODUCTION

Admixture is defined as a material, other than cement, water and aggregates that is used as ingredients of concrete and is added to the batch immediately before or during mixing. Additive is a material which is added at the time of grinding cement clinker at the cement factory. Admixtures are chemicals which are added to concrete at the mixing stage to modify some of the properties of the mix. Admixture should never be regarded as substitute for good mix design, good workmanship, are use of good materials.

These days concrete is being used for wide varieties of purpose to make it suitable in different conditions. In these conditions ordinary concrete may fail to exhibit the require quality performance or durability. In such cases, admixtures are used to modify the properties of ordinary concrete so as to make it more suitable for any situation.

Until about 1930 additives and admixture through used, were not considered as important part of concrete technology. Since then, there has been an increase in the use of admixtures. Though the use of admixtures and additive is being for frowned upon or scorned by some technologists, there are many on the contrary, who highly commend and foster the use and development of admixture as it imparts many desirable characteristics and effect economy in concrete construction. It should be remembered, however, that admixture are no substitute for good concreting practices.

The history of admixture is old as the history of concrete. It embraces a very vast field, but little type of admixture caller water reducers or high range water reducers, generally referred as plasticizers, are of recent interest. Plasticizers were not manufactured in India and them to be imported, and hence costly. Lack of education and awareness of the benefits occurred by the use of plasticizers, and we were used to making generally low strength concrete of the M15 to M30 which do not really need the use of plasticizers.

TYPES OF ADMIXTURES

1. CHEMICAL ADMIXTURE
2. MINERAL ADMIXTURE

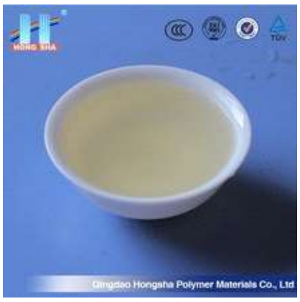
3.2.1. Chemical Admixture

CHEMICAL ADMIXTURES are added to concrete in very small amounts mainly for the entertainment of air, reduction of water or cement content, plasticization of fresh concrete mixtures, are control of setting time.

Seven types of chemical admixtures are specified in ASTM 494, and AASHTOM 194, depending on their purpose in PPC.

Table 3.8 : Physical and Chemical Properties of Superplasticizer

Characteristics	Superplasticizer
Calcium chloride Content	Nil
Specific gravity	1.08 at 20 °C
Air entrainment	Less than 1% additional air is Entrained.
Setting time	1 - 4 hours retardation depending on dosage and climatic conditions.
Chloride content	Nil to BS 5075



3.2.2. Mineral Admixtures Used:

GROUND GRANULATED BLAST FURNACE SLAG

Ground Granulated Blast Furnace is a byproduct from the Blast furnace slag is a solid waste discharged in large quantities by the iron and steel industry in India. These operate at a temperature of about 1500 degree centigrade and fed with a carefully controlled mixture of iron – ore, coke and limestone. The iron ore is reduced to iron and remaining materials from 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 been rapidly quenched in large volumes of water. The quenching optimizes the cementitious properties and produces granules similar to coarse sand. This granulated slag is then dried and to a fine powder. The re-cycling of these slag's will become an important measure for the environmental protection. Iron and steel are basic materials that underpin modern civilization, and due to many years of research the slag that is generated as a byproduct in iron and steel production is now in use as a material in its own right in various sectors. The primary constituents of slag are lime (CaO) and silica (SiO2). Portland cement also contains these constituents. The primary constituent of slag is soluble in water and exhibits an alkalinity like that of cement or concrete. Meanwhile, with the development of steel industry, the disposal of such a material as a waste is definitely a problem and it may cause severe environmental hazards.

Table-3.9 : Chemical Composition of GGBS

CHEMICAL PROPERTIES	GGBS
Fineness(m^2/kg)	276
Soundness(mm)	11
Initial setting time(min)	240
Insoluble residue	1.7%
Magnesia	15%
Sulphur	2.60%
Loss of ignition	3.5%
Manganese	3%
Chloride	0.2%
Moisture	1%
Glass	67%
Compressive strength at 7 days(MPa)	12
Compressive strength at 28 days	32.7
Specific gravity	2.89

6.TEST RESULTS AND DISCUSSIONS

The test data and results obtained from the tests conducted in the present investigations 40 concrete cubes have been presented in this chapter in which the tests are carried out, importance has been given to workability, ultimate compressive strength, cracking and durability. The results of high performance concrete are compared with individual percentage replacements and different combinations of admixtures for two types of concrete M40. Qualities such as workability, compressive strength, cracking have been observed and recorded.

6.1 Workability

Portland cement is in a form of agglomeration of particles held together by forces. During mixing process the agglomeration break down into fragments and hydration takes places at the surface of fragments. With the application of admixture the hydrating cement on the surface of fragments deflocculates each reduces the inter-particle fraction.

The effect reduced the relation of water between particles. More workable concrete can be obtained or less water required for a specified workability. As the inter-particle forces are reduced a more even dispersion of cement particles hence a more even hydration of cement can be achieved with an improvement to the density and strength of concrete may be designed to have proportion of fine aggregates with low flakiness index such as river sand.

With the presence of admixtures, the concrete can be flowable and pumpable. However, bleeding of concrete may occur and require attention. Also the presence of wet concrete on formwork is increased. Thus form work design should acknowledge the rate of concrete pour. The workable concrete will allow complete compaction without segregation.

Table 6.1: Slump Cone Test results

MIX PROPROTION	SLUMP
CM	100
30%GGBS	85
40%GGBS	110
50%GGBS	120
30%GGBS+5%RS	97
30%GGBS+15%RS	63
30%GGBS+25%RS	52
40%GGBS+5%RS	96
40%GGBS+15%RS	64
40%GGBS+25%RS	54
50%GGBS+5%RS	97
50%GGBS+15%RS	62
50%GGBS+25%RS	51

6.2 Compressive Strength

Compression test is the most common test conduct on hardened concrete, partly because easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitively relat6;ed to its compressive strength.

The cube specimen of 15cmx15cmx15cm was cast to test various concrete mixtures for compressive strength. The cubes after the moulding were stored in curing tanks and on removal of cubes from water at 7 days and 28 days the compressive strength was conducted. The water and grit on the cubes was removed before testing the cubes. The test was carried as per IS: 516-1959.

6.3 Crack Pattern

From the experiments it is observed

that as soon as crack propagates the sudden failure occurs in high performance concrete cubes is shown in figure

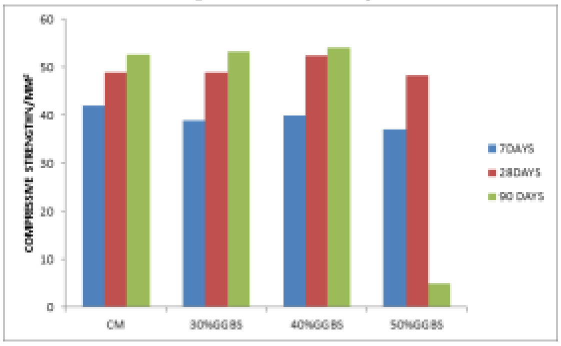
Table 6.2 : Compressive Strength Test Results

S.No.	Grade of Concrete	Compressive Strength of 7 Days (MPa)	Compressive Strength of 28 Days (MPa)	Compressive Strength of 90 Days (MPa)
1.	CM	42	49.5	52.6
2	30%GGBS	43.5	51	54.2
3	40%GGBS	44.2	53.5	55.8
4	50%GGBS	38.4	49.2	51.3
5	30%GGBS+5%RS	37	48	50.68
6	30%GGBS+15%RS	36.5	45.2	49.6
7	30%GGBS+25%RS	36	44.4	47.5
8	40%GGBS+5%RS	42.5	51.3	53.7
9	40%GGBS+15%RS	43.4	52.5	53.5
10	40%GGBS+25%RS	39.2	49.3	48.5
11	50%GGBS+5%RS	34.1	44	46.5
12	50%GGBS+15%RS	33.1	43.2	45.4
13	50%GGBS+25%RS	32.3	42.5	44.8

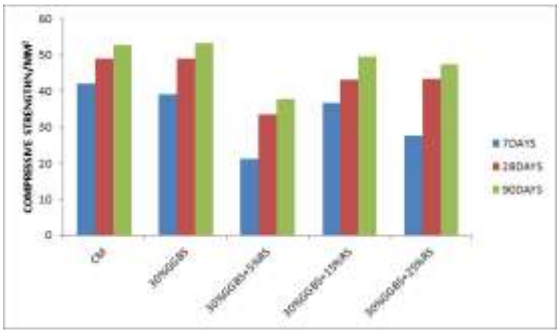
Table 6.3 : Split Tensile Strength Test Results

S.No	Grade of Concrete	7 Days Strength	28 Days Strength
1	CM	3.18	3.56
2	30%GGBS	3.37	3.85
3	40%GGBS	3.86	4.15
4	50%GGBS	3.7	3.65
5	30%GGBS+5%RS	3.17	3.45
6	30%GGBS+15%RS	3.27	3.56
7	30%GGBS+25%RS	3.22	3.63
8	40%GGBS+5%RS	3.34	3.78
9	40%GGBS+15%RS	3.85	4.13
10	40%GGBS+25%RS	3.28	3.82
11	50%GGBS+5%RS	3.16	3.56
12	50%GGBS+15%RS	3.06	3.79
13	50%GGBS+25%RS	3.12	3.62

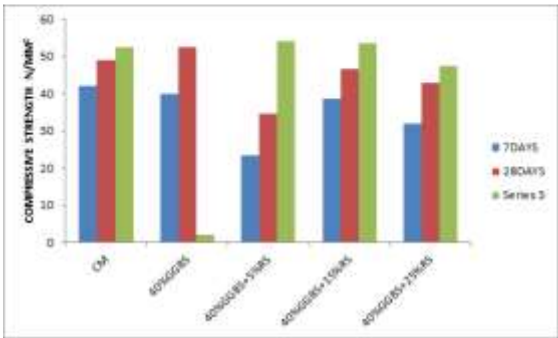
6.5 Graphical Representation of Compressive Strength

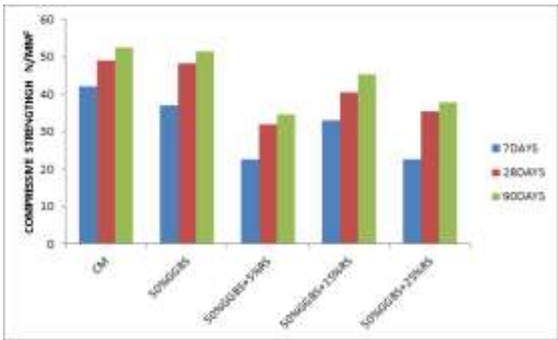


COMPRESSIVE STRENGTH OF GGBS MIXES:

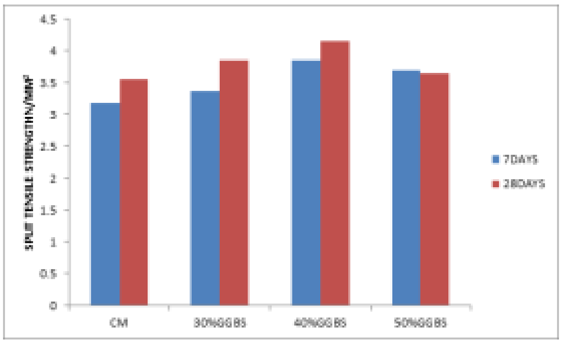


COMPRESSIVE STRENGTH OF GGBS WITH VARITIONS OF ROBO SAND





SPLIT TENSILE STRENGTH OF GGBS MIXES:



CONCLUSIONS:

- In high performance concrete mix design as water cement ratio adopted is low, super plasticizers are necessary to maintain required workability. As the percentage of mineral admixture is increased for through mixing and for obtaining the desired strength.
- The workability of concrete was found to be increases with the increase in GGBS in concrete. It further decreases as the percentage of Quarry Sand increases
- In M40 grade of concrete as the water-cement ratio of 0.36 is in sufficient to provide the good workability, hence super plasticizer are necessary for those grades of concrete.
- Maximum compressive and flexural strength has been obtained for replacement of cement by 40% GGBS.
- Compressive strength of concrete can be improved by using admixtures.
- From the graph it is proved that ROBO sand can be used as an alternative material for the fine aggregate.
- The compressive strength is increased as the percentage of ROBO sand is increased and further decreases.
- We observed that better results obtained when GGBS is replaced up to 40% and ROBO sand up to 15%.
- Maximum compressive strength obtained for replacement of cement by 40% GGBS and sand by 15% of robo sand
- Maximum split tensile strength obtained for replacement of cement by 40% GGBS and sand by 15% of robo sand,
- The scope of using high performance concrete in our constructional activities lies large, viz., precast, prestressed bridges, multi-storied buildings, bridges and structures on coastal areas and like. To affect this change, we will have to review the designing to structures by encouraging use of high performance concrete.

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