EXPERIMENTAL STUDY ON STRENGTH AND DURABILITY PROPERTIES OF GGBS BASED CONCRETE IN SEA WATER.

P.Malliga[1], Dr.B.Vidivelli[2]
[1]Associate Professor, Department of Civil Engineering, E.G.S.Pillay Engineering college, Tamil Nadu, India
[2] Professor, Department of Civil &Structural Engineering , Annamalai University, Chidambaram. Tamil Nadu, India

Abstract:*Concrete made with Portland cement has been a popular construction material in the world for the past 170 years or more .The major causes in our construction industry is emission of carbon dioxide during cement manufacture and solid waste disposal problem. However, reduction of cement consumption by partial replacement of ordinary Portland cement by industrial wastes or by-products. Ground granulated blast furnace slag is by-product and is obtained by quenching molten iron slag from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. These materials called pozzalonas) when combined with calcium hydroxide, exhibits cementitious properties. The study has been made to evaluate the effect on mechanical and durability properties of M20 grade concrete made with replacement of cement with ground granulated blast furnace slag(GGBS),(20%,40%and60%) by weight.For each set of GGBS, mechanical properties were studied by performing compression test for cubes, Flexure test for beams and split tensile test for cylinders and durability properties were studied by performing sulphate attack and seawater test cube .*

Keywords: *Ground granulated blast furnace slag (GGBS),sea water ,sulphate attack,durability.*

1.Introduction

Concrete is one of the important construction material used in the world in all engineering works including the infrastructure development at all stages. 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. One tonne of carbon dioxide is estimated to be released to the atmosphere when one tonne of ordinary Portland cement is manufactured. The use of waste material having cementitious properties as a replacement of cement in concrete .The main focus now a days is on search of waste material or by product from manufacturing processes, which can be used as partial replacement of cement in concrete, without compromising on its desired strength. Ground Granulated Blast Furnace Slag has been constantly in use as cementations replacement for sustainable infrastructure. Ground-granulated blast-furnace slag (GGBS or GGBFS) is a by-product of iron manufacturing industry. Iron ore, coke and limestone are fed into the furnace, and the resulting molten slag floats above the molten iron at a temperature of about 1500 ˚C to 1600 ˚C. The molten slag has a composition of 30% to 40% silicon dioxide (SiO2) and approximately 40% CaO, which is close to the chemical composition of Portland cement. After the molten iron is tapped off, the remaining molten slag, which mainly consists of siliceous and aluminous residues, is then rapidly water-quenched, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size which is known as ground granulated blast furnace slag (GGBS). The production of GGBS requires little additional energy compared with the energy required for the production of Portland cement. The replacement of Portland cement with GGBS will lead to a significant reduction of carbon dioxide gas emission. GGBS is therefore an environmentally friendly construction material. It can be used to replace as much as 80% of the Portland cement when used in concrete. GGBS concrete has better water impermeability.

2. literature review

A. Syed Asif Ali[1]**"Experimental study on partial replacement of cement by fly ash and GGBS "** .The partial replacement of cement by 9% of ground granulated blast furnace slag and 40% fly ash will improve the compressive strength, split tensile strength and flexural strength. Mix proportion of M25 grade was found to be 1:1.36:2.71.the compressive strength was found to be in 7 days and 28 days of curing are 31.59N/mm^2 and 45.47 N/mm^2 respectively. The split tensile strength was found to be 12.78 N/mm^2 at 28 days of curing. The flexural strength was found to be 8.81N/mm^2 at 28 days of curing.***B.Yogendra O.Patil [2]*****"GGBS as partial replacement of OPC in cement concrete- An experimental study"**. This paper presents an experimental study of compressive and flexural strength of concrete prepared with ordinary Portland. Cement, partially replaced by ground granulated blast furnace slag in different proportions varying from 0% to 40%.It is observed from the investigation that the strength of concrete is inversely proportional to the % of replacement of cement with ground granulated blast furnace slag. It is concluded that the 20% replacement of cement is possible without compromising the strength with 90 days curing. The replacement of ordinary Portland cement by GGBS up to 20%shows the marginal reduction of 4% to 6 % in compressive and flexural strength for 90 days curing, however beyond 20% replacement by GGBS the reduction in strength is substantial. The reduction in the cost of concrete at the current market rate is 14%, in the case of GGBS as replacement of ordinary Portland

cement by 20%. The partial replacement of ordinary Portland cement by GGBS, not only provides the economy in the construction but it also facilities environmental friendly disposal of waste slag.***C. Swaroop*** *[3]* **"Durability studies on concrete with fly ash & GGBS".** Study is mainly confined to evaluation of changes in both compressive strength and weight reduction in five different mixes of M30 grade namely conventional aggregate concrete(CAC), concrete made by replacing 20% of cement by fly ash (FAC_1), concrete made by replacing 40% of cement by fly ash (FAC_2), concrete made by replacing 20% replacement of cement by GGBS (GAC_1) and concrete made by replacing 40% replacement of cement by GGBS (GAC_2). ***D. Tanveer Asif zerdi****[4]* **"Suitability & Performance of concrete with the addition of GGBS as partial replacement of cement"** .This article represents an study of compressive strength of concrete prepared with ordinary Portland cement 53 grade, partially replaced by GGBS in different proportions varying from 0%, 10%, 20% and 30%. The increase in percentage of GGBS results in decrease in strength of concrete. But at 20% GGBS the compressive strength is nearer to plain concrete mix, at the age of 28 days curing. The reduction in the cost of concrete at the current market rate is 14% in the case of GGBS as replacement of ordinary Portland cement by 30%.***E. Suresh****[5]***"Ground granulated blast slag (GGBS) in concrete- a review"** .The present technical report focuses on investigating characteristics of concrete with partial replacement of cement with ground granulated blast furnace slag (GGBS). The topic deals with the usage of GGBS and advantages as well as disadvantages in using it in concrete. This usage of GGBS serves as replacement to already depleting conventional building materials and the recent years and also as being a byproduct it serves as an eco friendly way of utilizing the product without dumping it on ground. The movement of moisture of GGBS mixes, probably due to the dense and strong microstructure of the interfacial aggregate/binder transition zone are probably responsible for the high resistance of GGBS mixes to attack in aggressive environments such as silage pits. The mineral composition cement paste of GGBS probably contributes to this resistance. ***F. Amit gavali****[6]***"Experimental study on ground granulated blast furnace slag in concrete"** .Use of GGBS improves the quality of concrete. GGBS concrete is characterized by high strength, lower heat of hydration, and resistance to chemical corrosion. In recent years GGBS when replaced with cement has emerged as a major alternative to conventional concrete and has rapidly drawn the concrete industry attention due to its cement savings, energy savings, and cost savings, environmental and socio-economic benefits. The optimum GGBS replacement as cementitious material is characterized by high compressive strength, low heat of hydration, resistance to chemical attack, better workability, and good durability and cost effective. The flexural strength was maximum at 40% replacement of GGBS. To increase in the GGBS replacement level workability of concrete increase. Use M40 grade of concrete the compressive strength increase when the cement is replaced by GGBS. At 40% replacement of cement by GGBS the concrete attained maximum compressive strength. ***G. Mohd majiduddin****[7]***"Experimental investigation on the effect of physical, chemical and mechanical properties of fly ash and ground granulated blast furnace slag (GGBS) on concrete"** .This experiment study aimed to investigate the physical, chemical and mechanical property of fly ash and blast furnace slag cement concrete. Compressive strength of fly ash obtained for 5% replacement of cement has shown significant improvement in various properties at the age of 28 days indicated by 13% increase in compressive strength and in GGBS, 40% replacements shown significant improvement in various properties at the age of 28 days indicated by 85% increase in compressive strength. Highest flexural strength in fly ash is obtained for 20% replacement and strength is $5.43N/mm^2$ and in GGBS 30% replacements have got highest flexural strength and the strength is $3.54N/mm^2$. The advantage of the use of fly ash and GGBS in concrete is the flexibility that it allows with the selection of the mixture proportions. The sub grade of the road infrastructures can consume the slag produced or stored with significant quantities. Slag is an insensitive material with water, quality which is suitable for the use of sub-grade. The insensitivity is due primarily to its cleanliness and its small percentage of slag is at lower than 80µm. this slag has a very tight grain-size distribution, which decreases the aptitude for the compaction, and this will be necessary thus to carry out a correction with other material. ***H. Yasutaka sagawa****[8]***" Properties of concrete with GGBS and its applications for bridge superstructures"** .This paper deals with the chloride diffusion coefficient of the concrete mixed with ground granulated blast furnace slag was investigated. As the results, GGBS reduced the effective diffusion coefficient of chloride ion by from 1/5 to 1/10. Also, GGBS with specific surface area of 6000 cm^2/g improved the chloride resistance of concrete when water to binder ratio (W/B) was smaller than 45%. In addition, GGBS with specific surface area of $6000cm^2/g$ was applied to prestressed concrete bridge. The effective diffusion coefficient of the concrete used for bridge superstructure showed the lower value. As the results of simple simulation by using fick's second law, it is expected that steel bars in concrete will not occur corrosion for 100 years.***I. Sonali****[9]***"To study the partial replacement of cement by GGBS & RHA and natural sand by quarry sand in concrete"**. Good compressive strength is obtained when 22.5%GGBS+7.5% Rice husk ash is replaced with cement and natural sand is replaced by 60% quarry sand for M40 grade of concrete. Permeable voids are decreases with the age of curing and the combination of ground granulated blast furnace slag and rice husk ash and quarry sand will be more durable.***J. Vignesh****[10]* **"An experimental investigation on strength parameters of fly ash based geo polymer concrete with GGBS"** .In this paper an attempt is made to study strength properties of geo polymer concrete using low calcium fly ash replacing with slag in 5 different percentages. Sodium silicate ($103 kg/m^3$) and sodium hydroxide of 8 molarities ($41 kg/m^3$) solutions were used as alkaline solution in all 5 different mixes. Fly ash is replaced by GGBS for reducing green house gases and emission of co_2. Water absorption property is lesser than the normal concrete. The optimum replacement level of fly ash by GGBS in geo polymer concrete will achieve more strength in short time (i.e., 70% of the compressive strength in first 4 hours of setting).***K. Santosh Kumar karri****[11]***"Strength and Durability studies on GGBS concrete"** .The present paper focuses on investigating characteristics of M20 and M40 grade concrete with partial replacement of cement with ground granulated blast furnace slag by replacing cement via 30%, 40%, 50%. Workability of concrete increases with the

increase percentage of GGBS. The compressive strength values of acid effected concrete decreases than normal concrete but effect of acid on concrete decreases with increase of percentage of GGBS. The effect of Hcl on strength of concrete is lower than the effect of H_2SO_4 on strength of concrete.

3.MATERIAL & ITS PROPERTY

A.Cement

Cement in general can be defined as a material which possesses very good adhesive and cohesive properties which make it possible to bond with other materials to form compact mass. Ordinary Portland cement of43 grade (SUPER) was usedin this investigation. The physical properties of the cement tested according to Indian standards procedure confirms to the requirements of IS 10262- 2009 and the physical properties are given in table1.

PROPERTIES	RESULT OBTAINED
Specific gravity	3.12
Soundness	8
fineness	8%
Initial setting time	34mins
Final setting time	540mins
consistency	31%

Table.1 properties of cement

B. Fine Aggregate

The fine aggregate used in the project was locally supplied and conformed to grading zone II as per IS: 383:1970. It was first sieved through 4.75mm sieve to remove any particles greater than 4.75mm. Properties of the fine aggregate are tabulated below in Table 2.

PROPERTIES	RESULT OBTAINED
Specific gravity	2.64
Bulk density	1668 kg/m^3
Fineness modulus	2.75
Grading zone	Zone II
Water absorption ratio	1%

Table 2 Properties of Fine Aggregate

C. Coarse Aggregate

Locally available coarse aggregate having the maximum size of (10 - 20mm) were used in this project. Coarse aggregate confirming to IS 383:1970. Properties of the coarse aggregate are tabulated in Table 3.

PROPERTIES	RESULT OBTAINED
Specific gravity	2.84
Bulk density	1765 kg/m^3
Fineness modulus	6.45
Maximum size	20mm
Water absorption ratio	0.5%

Table 3 properties of coarse aggregate

D. Ground Granulated Blast Furnace Slag

Ground-granulated blast-furnace slag (GGBS) is a by-product of iron manufacturing industry. Iron ore, coke and limestone are fed into the furnace, and the resulting molten slag floats above the molten iron at a temperature of about 1500 ˚C to 1600 ˚C. The molten slag has a composition of 30% to 40% silicon dioxide (SiO2) and approximately 40% CaO, which is close to the chemical composition of Portland cement. After the molten iron is tapped off, the remaining molten slag, which mainly consists of siliceous and aluminous residues, is then rapidly water- quenched, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size which is known as ground granulated blast furnace slag (GGBS).. The results furnished by the manufacturer are presented in Table 4.

CHEMICAL COMPOSITION		PHYSICAL PROPERTIES	
Calcium oxide	33.2%	colour	Off-white
silica	34.4%	Specific gravity	2.9
alumina	21.5%	Bulk density	1200 kg/m^3
magnesia	9.5%	fineness	>350 m^2/kg
Iron oxide	0.2%	Particle size	40 microns

Table 4 properties of GGBS

E. Potable Water

Potable Water used for mixing and curing is clean and free from injurious amount of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete. Potable water is used for mixing concrete. The pH value of water lies between 6 and 8 that indicate the water is free from organic matters.

F. sea water

Sea water used for curing the concrete cubes and cylinder for 7 days, 14 days, 28 days and 60 days for identifying alkali aggregate expansion. PH value of sea water lies between 7.5 to 8.4, the average value in equilibrium with the atmospheric CO_2 being 8.2.

G. H_2SO_4 acid solution:

Concrete cubes are cured in H_2SO_4 acid for 7 days, 14 days, 28 days, 60 days in 5ml H_2SO_4 acid of 1 litre of potable water for studying durability properties of concrete. Most soils contain some sulphate in the form of calcium, sodium, potassium and magnesium. They occur in soil or ground water. Because of solubility of calcium sulphate is low; ground waters contain more of other sulphates and less of calcium sulphate. Ammonium sulphate is frequently present in agricultural soil and water from the use of fertilizers of from sewage and industrial effluents. Decay of organic matters in marshy land, shallow lakes often leads to the formation of H_2S,in which can be transformed in to

sulphuric acid by bacterial actioncharacteristics whitish appearance is the indication of sulphate attack.

4.RESULTS

a. Compressive strength test results

SI. NO	% OF GGBS	COMPRESSIVE STRENGTH			
		7 days	14 days	28 days	60 days
1	0	13.33	20.84	28.35	37.30
2	20	13.25	21.13	30.98	38.54
3	40	14.34	21.95	32.70	39.31
4	60	14.17	20.99	31.42	38.36

Table5 comparison of compressive strengths of various cubes cured in potable water

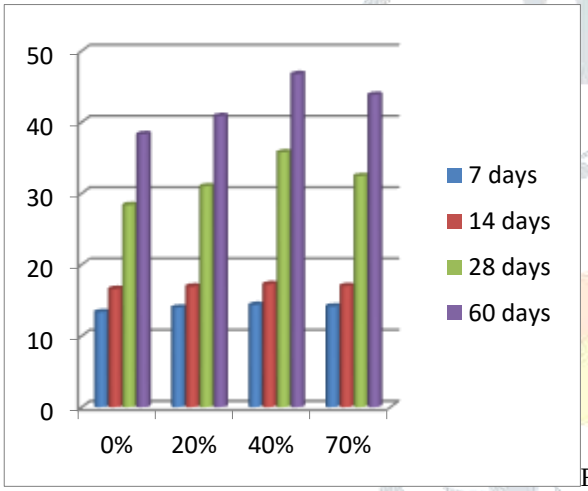

Figure1 comparison of compressive strengths of various cubes cured in potable water

SI. NO	% OF GGBS	COMPRESSIVE STRENGTH			
		7 days	14 days	28 days	60 days
1	0	11.80	16.96	21.92	32.25
2	20	12.31	17.23	22.56	33.81
3	40	12.43	17.88	23.24	34.13
4	60	13.75	17.67	23.15	33.58

Table 6 comparison of compressive strengths of various cubes cured in sea water

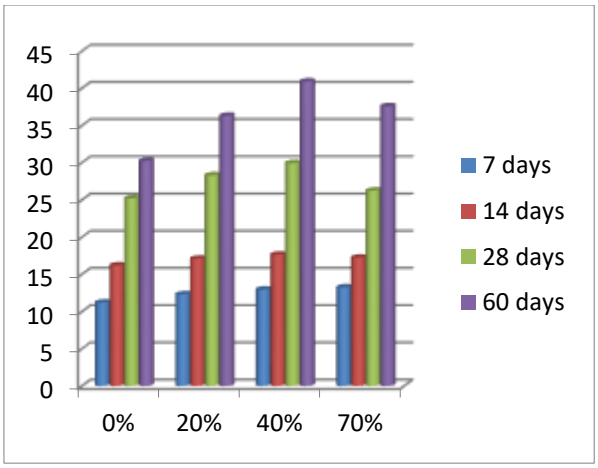

Figure 2 comparison of compressive strengths of various cubes cured in sea water

SI. NO	% OF GGBS	COMPRESSIVE STRENGTH			
		7 days	14 days	28 days	60 days
1	0	9.90	14.02	19.83	30.60
2	20	10.28	14.63	19.98	31.08
3	40	10.64	14.79	20.12	31.65
4	60	10.91	15.02	20.53	32.04

Table 7 comparison of compressive strengths of various cubes cured in H_2SO_4 acid solution

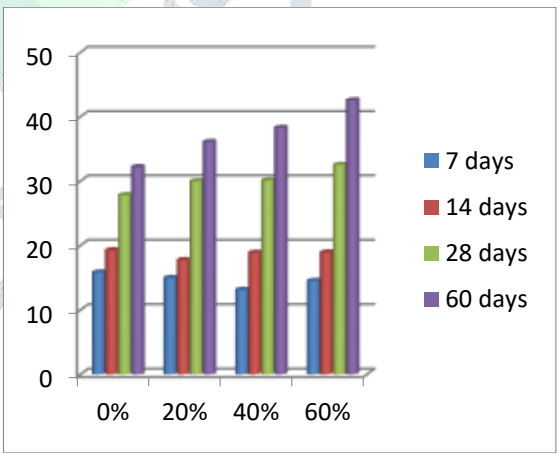

Figure3 comparison of compressive strengths of various cubes cured in H_2SO_4 acid solution

b.split tensile strength test results

SI. NO	% OF GGBS	SPLIT TENSILE STRENGTH		
		7 days	14 days	28 days
1	0	0.89	1.79	2.69
2	20	0.95	1.9	2.85
3	40	1.06	2.13	3.20
4	60	0.90	1.81	2.72

Table 8 split tensile strength test results

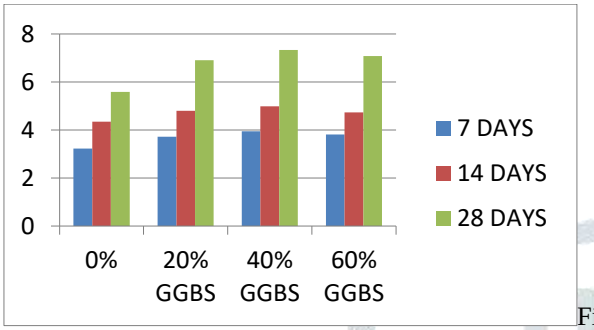

Figure 4 split tensile strength test results

c.flexural strength test result

SI.NO	% OF GGBS	FLEXURAL STRENGTH in 28 days N/mm^2
1.	0%GGBS	3.21
2.	20% GGBS	3.33
	40%GGBS	3.54
	60%GGBS	3.30

Table9 flexural strength test result

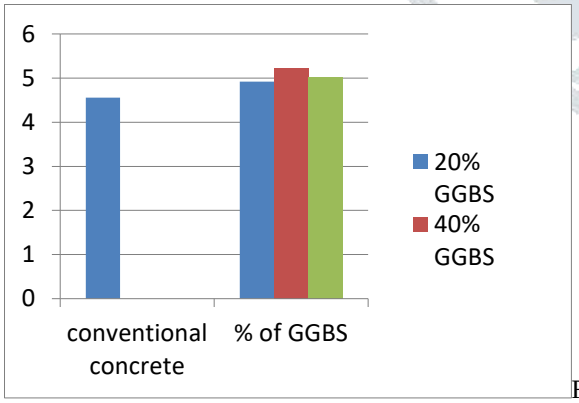

Figure 5 flexural strength test result

5. CONCLUSION

- The maximum compressive strength of 38.54 Mpa , 39.31 Mpa and 38.86 Mpa is achieved at 20%, 40% and 60% replacement of GGBS respectively as compare to 37.30 Mpa of strength of conventional concrete for 60 days curing in potable water. Thus maximum strength is achieved in 40 % of GGBS replacement than other replacement levels.
- The maximum compressive strength of 34.13 Mpa is achieved at 40% replacement of GGBS as compare to 32.25 Mpa of strength of conventional concrete for 60 days curing in sea water.
- The maximum compressive strength of 32.04 Mpa is achieved at 60% replacement of GGBS as compare to 30.60 Mpa of strength of conventional concrete for 60 days curing in H_2SO_4.
- 40% replacement of GGBS has the equal weight of plain cement concrete (8.42 kg) , when cured in sea water.
- Using GGBS instead of cement , not only provides the economy in the construction but it also facilitates environmental friendly disposal of the waste slag which is generated in huge quantities from the steel industries.
- Hopefully one day in the future GGBS will replace ordinary Portland cement as the most abundant man-made material in construction field.

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