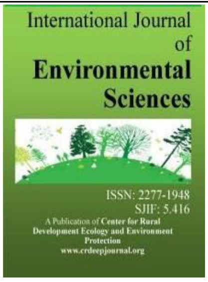
Vol. 9. No.2. 2020

Contents available at:

www.crdeepjournal.org

International Journal of Environmental Sciences (ISSN: 2277-1948)



Full Length Research Article

Optimization of Cement content in Concrete using Additives

P. Sai Kumar, V.Srikanth, Y.Sandhya Rani, V.Anil, K.Praveena and V.R.Uma

Department of Civil Engineering, Sanskrithi School of Engineering, Puttapathi-515134, India.

ARTICLE INFORMATION

Corresponding Author:
P. Sai Kumar

Article history:
Received: 23-04-2020
Revised: 27-04-2020
Accepted: 22-05-2020
Published: 21-06-2020

Key words:
Fly ash, GGBS, Mix-Design, Slump Cone, Compaction Factor, and Split Tensile.

ABSTRACT

This work was carried out to optimize the cement content in concrete using pozzolanic materials as reduction of CO_2 released during the production of cement is major issues of construction industry. Concrete is the most used construction material in the civil engineering. Concrete is the world's most consumable product next to water. The fly ash and GGBS has been used as partial replacement of cement in the concrete. The fly ash is obtained as combustion of pulverized coal and collected by mechanical dust collector or electro static precipitator. The GGBS is a by-product of iron and steel making industry, obtained by quenching of 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. By utilizing these two products as a partial replacement of cement in concrete, the concrete can be made more eco-friendly by reducing the use of cement. In the present work, an attempt has been made 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 tests and compaction factor tests are conducted. To study hardened properties compressive and splitting tensile strength tests are conducted and comparison study will be done.

Introduction

The present study attempts to optimize the cement content in concrete mixes using pozzolanic materials, without sacrificing the strength and workability of concrete. In an engineering domain, an optimization plays an important role in designing of the concrete mixes, and their process improvement. Attempts have been made by many researchers in the past to make use of optimization techniques to obtain optimum content of mix proportions to achieve maximum strength for a given set of materials and exposure conditions. Concrete mixture optimization involves the adaptation of available resources to meet varying engineering demands, construction industry requirements, and economic needs. However, it is very difficult to design concrete mix proportions so as to maximize economical efficiency as well as is the concrete performance by traditional methods. So, the optimization technique is primarily required to improve possible combinations of material components, maximize the economical efficiency and also to improve the performance of concrete and reduces the variability among the construction material proportions. Concrete is the most widely used construction material in the world and it has played a major part in shaping civilization. The Romans were the first at using concrete but it was also known to the Egyptians and in a primitive form to Neolithic civilizations. The main difference between the concrete found in these classical civilizations and modern ready mixed concrete is the binding agent. The Egyptians used crushed gypsum, the Romans knew that how to make lime by burning crushed limestone and they even discovered that adding volcanic ash or old bricks and tiles improved the setting characteristic of their cement. Modern concrete was developed after the discovery of Portland cement. First patented in 1824 but not developed in its present form until 1845 when higher kiln temperatures were achieved, Portland cement made knew forms of construction possible. Despite these advances attempts to supply the building trade with ready mixed concrete on site foundered until the late 1920's when delivery trucks were fitted with a drum that agitated the concrete while on the move. In the UK, the first ready mixed operation was set up in 1930 and by the 1960's a successful national network of concrete plants was firmly established. Today, Ready mix concrete comprises a mix of aggregates, cement, water and a variety of admixture. Understanding these individual ingredients in a little more detail provides an insight into ways of obtaining the best results for different types of project. Concrete is the product of mixing, aggregate, cement and water. The setting time of concrete is chemical reaction between the cement and water, not a drying process. This reaction is called hydration, the reaction liberates a considerable quantity of heat this liberation of heat is called heat of hydration. There is an initial set when the concrete will cease to be liquid but have little strength, thereafter the concrete will gradually gain strength over a time until it achieves the strength required.

In the present work, an attempt has been made to use fly ash and GGBS as a supplementary binding material for cement.

The main aim of this work is to study fresh and hardened properties of M-30 grade control concrete and concrete made with fly ash and ground granulated blast furnace slag as a partial replacement of cement.

The following are the main objectives of the study
(1) To evaluate the fresh properties of control concrete of M-30 grade and concrete made with partial replacement of cement by fly ash and ground granulated blast furnace slag for fresh properties, slump cone test, compaction factor test are conducted.
(2) To find out the compressive strength of control concrete of M-30 grade and concrete made with fly ash and ground granulated blast furnace slag as a partial replacement of cement at 28 days tests are conducted.
(3) To find out the split tensile strength of control concrete of M-30 grade and concrete made with fly-ash and ground granulated blast furnace slag as a partial replacement of cement at 28 days tests are conducted.

The use of fly ash and GGBS as a replacement of cement not only extends technical advantages to the properties of concrete but also contributes to the environmental pollution control. The fly ash is obtained from the thermal power plant, by burning the coal. The GGBS is obtained as a by-product from iron and steel making industry. By using these we can reduce the disposal problem of fly ash and GGBS.

Literture review

Experimental investigations on partial replacement of cement with fly ash in design mix concrete by Prof. Jayeshkumar Pitroda, Dr. L. B. Zala, and Dr. F.S. Umrigar. (Oct-Dec, 2012) This research work describes the feasibility of using the thermal industry waste in concrete production as partial replacement of cement. The use of fly ash in concrete formulations as a supplementary cementatious material was tested as an alternative to traditional concrete. The cement has been replaced by fly ash accordingly in the range of 0% (without fly ash), 10%, 20%, 30% & 40% by weight of cement for M-25 and M-40 mix. Concrete mixtures were produced, tested and compared in terms of compressive and split strength with the conventional concrete. These tests were carried out to evaluate the mechanical properties for the test results for compressive strength up to 28 days and split strength for 56 days are taken.In this research paper they concluded that, compressive strength reduces when cement replaced fly ash. As fly ash percentage increases compressive strength and split strength decreases. Use of fly ash in concrete can save the coal & thermal industry disposal costs and produce a 'greener' concrete for construction. The cost analysis indicates that percent cement reduction decreases cost of concrete, but at the same time strength also decreases. This research concludes that fly ash can be innovative supplementary cementatious Construction material but judicious decisions are to be taken byengineers.

Durability studies on concrete with fly ash and ggbs by A.H.L. Swaroop, K. Venkateswararao, and Prof P. Kodandaramarao (Jul-Aug, 2013) In this paper they mainly concentrated on 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 (FAC1), concrete made by replacing 40% of cement by Fly Ash (FAC2), concrete made by replacing 20% replacement of cement by GGBS (GAC1) and concrete made by replacing 40% replacement of cement by GGBS (GAC2). The effect of 1% of H_2SO_4 and sea water on these concrete mixes are determined by immersing those cubes for 7days, 28days, and 60days in above solutions. They observed the respective changes in both compressive strength and weight reduction. From the study they concluded that, the early strength is compared to less in fly ash and GGBS concretes than conventional aggregate concrete. The results of fly ash and GGBS concretes when replaced with 20% of cement are more than compared to CAC at the end of 28 days and 60 days for normal water curing. In sea water curing the GGBS when they replaced with 20% of cement shows good response for durability criteria. In H_2SO_4 solution curing the Fly Ash when replaced with 20% of cement shows good response for durability criteria. In case of weight loss GGBS offer more resistance than fly ash. They concluded that, the strength of fly ash concrete when replaced with 20% cement is increased and the strength of fly ash concrete when replaced with 40% cement is decreased, they recommend that the use of fly ash between 20- 40% replacement with cement for better results.

Partial replacement of cement by ground granulated blast furnace slag in concrete by Reshma Rughooputh and Jaylina Rana (2014) In this paper the main aim of the work was to investigate the effects of partially replaced Ordinary Portland Cement (OPC) by ground granulated blast furnace slag (GGBS) on the properties of concrete including compressive strength, tensile splitting strength, flexure, modulus of elasticity, drying shrinkage and initial surface absorption. Results showed that the compressive and tensile splitting strengths, flexure and modulus of elastic increased as the GGBS content increased. The percentage drying shrinkage showed a slight increment with the partial replacement of OPC with GGBS. However, concrete containing GGBS failed the initial surface absorption test confirming that GGBS decreases the permeability of concrete. From the study they concluded that, the partial replacement of OPC with GGBS improves the workability but causes a decrease in the plastic density of the concrete. The compressive and tensile splitting strengths, flexure and modulus of elasticity increases with increasing GGBS content. The drying shrinkage shows a slight increment with GGBS. GGBS fails the initial surface absorption test confirming that the surfaces of their concrete mixes were practically impermeable. Based on the results, the optimum mix is the one with 50% OPC and 50% GGBS.

Triple blending of cement concrete with fly ash and ground granulated blast furnace slag by K.V. Pratap,M. Bhasker, and P.S.S.R.Teja (Jan-Jun, 2014)
In this paper they mainly concentrated on compressive strength, split tensile strength and flexural strength of concrete mix of M-60 grade, with partial replacement of cement with Ground Granulated Blast furnace Slag and FLY-ASH. They use the concept of triple blending of cement with GGBS and FLY-ASH, this triple blend cement exploits the beneficial characteristics of both pozzolanic materials in producing a better concrete. They concluded that, the compressive strength, flexural strength and split tensile strength of concrete are improved with the addition of fly ash and GGBS as partial replacement to cement. The compressive strength of concrete is increased by a maximum of 11.13 % at 28days with (4+16) % replacement. The flexural strength of concrete is increased by a maximum of 11.74% at 28days with (4+16) % replacement. The split tensile strength of concrete is increased by a maximum of 23.01% at 28 days with (4+16) % replacement.

Fly ash as a partial replacement of cement in concrete and durability study of fly ash in acidic (H_2SO_4) environment by

T.G.S Kiran, and M.K.M.V Ratnam (December, 2014) In this project report the results of the tests carried out on sulphate attack on concrete cubes in water curing along with H_2SO_4 solution. Also, aiming the use of fly-ash as cement replacement. The present experimental investigation were carried on fly ash and has been chemically and physically characterized, and partially replaced in the ratio of 0%, 5%, 10%, 15%, 20% by weight of cement in concrete. Fresh concrete tests like compaction factor test was hardened concrete tests like compressive Strength at the age of 28 days, 60 days, 90 days was obtained and also durability aspect of fly ash concrete for sulphate attack was tested. The result indicates that fly ash improves concrete durability. From the study they concluded that the compressive strengths of concrete (with 0%, 5%, 10%, 15% and 20%, weight replacement of cement with FA) cured in Normal water for 28, 60 and 90 days have reached the target mean strength. The compressive strengths of concrete (with 0%, 5%, 10%, 15% and 20%, weight replacement of cement with FA) cured in different concentrations of (1%, 3%, and 5%) Sulphuric acid solution for 28, 60 and 90 days indicate that at 10% replacement there is increase in strength and beyond that the strengths decreased. The strength decreases in acidic environment with age of concrete. In concrete cement can be replaced with 10% FA with maximum increase in strength beyond starts decreases. Due to slow pozzolanic reaction the FA concrete achieves significant improvement in its mechanical properties at later ages.

Materials and methodology

Cement: - In this present work ultratech cement of 43 grade ordinary Portland cement (OPC) is used for casting cubes for all concrete mixes. The cement is of uniform color i.e. Grey with light greenish shade and is free from any hard lumps. The various tests conducted on cement are specific gravity, initial and final setting time and compressive strength. Testing on cement is done as per IS codes. The properties of Portland cement are reported in below table 1.

Table 1: Physical properties of cement

Particulars	Experimental Results	IS Limits (IS:8112-1989)
Specific Gravity	3.15	-
Initial setting	125 minutes	Not less than 30 min
Final setting	210 minutes	Not more than 600 min
	Compressive strength (MPa)	
3 Days	24.10	16 MPa (minimum)
7 Days	38.14	22 MPa (minimum)
28 Days	48.20	43 MPa (minimum)

Fine Aggregate (FA):- The sand used for this project was locally procured. The specific gravity of natural sand is found to be 2.6. Fineness modulus is 2.57, water absorption is found to be 0.5% and free moisture content is 0%. The physical properties of fine aggregate are mention in Table 2

Table 2: Physical properties of Fine Aggregate

Property of FA	Result
Specific gravity	2.6
Fineness modulus	2.57
Water Absorption	0.5%

Coarse Aggregate (CA):- Locally available coarse aggregate having the maximum size of 20mm is used in the present work. The specific gravity of coarse aggregate is found to be 2.67. Water absorption is found to be 1% and free moisture content is 0%. The physical properties of fine aggregate are mention in Table 3

Table 3: Physical properties of Coarse Aggregate

Property of CA	Result
Specific Gravity	2.67
Water Absorption	1%

Fly ash: - In present work the fly ash is procured from Bellary thermal power station and it is located in Kudatini village, Bellary.

GGBS: - In the present work GGBS is procured from cement factory in Tadipatri.

Water: - Potable tap water is used for the preparation of specimens and for curing specimens.

Mix design

The mix design procedure adopted in the present work to obtain M-30 grade concrete is in accordance with IS: 10262-2009 and IS: 456-2000.Mix design values are as formulated below in table 4. The following all the notations used for varying different percentages of fly ash, GGBS and cement.

Table 4: Mix Designation

Mix designation	Description
M0	100% cement + 0% fly ash + 0% ggbs
M1	60% cement + 10% fly ash +30% ggbs
M2	60% cement + 20% fly ash +20% ggbs
M3	60% cement + 30% fly ash +10% ggbs
M4	40% cement + 10% fly ash +50% ggbs
M5	40% cement + 20% fly ash +40% ggbs
M6	40% cement + 30% fly ash +30% ggbs
M7	40% cement + 40% fly ash +20% ggbs
M8	40% cement + 50% fly ash 10% ggbs
M9	50% cement +25 % fly ash +25% ggbs

Casting and testing of concrete specimens

Casting of specimen

Cement, sand and aggregate were taken in the proportion 1:1.41:2.49.which is corresponding to M-30 grade concrete. The concrete was produced by mixing all the ingredients homogeneously. To this dry mix, required quantity of water was added (w/c=0.44) and the entire mass was again homogeneously mixed. This wet concrete was poured into the moulds which was compacted both through hand compaction in three layers as well as through vibrator after the compaction, the specimens were given smooth finish and taken out of table vibrator. After 24 hours the specimens were demoulded and transferred to curing tanks where they were allow to cure for required number of days. For evaluating compressive strength, specimens of dimensions 150x150x150 mm were prepared. They were tested on 3000kN capacity compressing testing machine as per IS: 516-1999. For evaluating the split tensile strength, cylindrical specimen of diameter 150mm and length 300mm were prepared. Split tensile strength test was carried out on 3000kN capacity compression testing machine as per IS: 5816-1959.

Test on fresh concrete

The test conducted on fresh properties of control concrete and concrete made with fly ash and GGBS as partial replacement of cement. The tests conducted for workability of concrete are slump test and compaction factor test. The variation of slump values and compaction factor values are presented in the form of graph as shown in the figure 1 to figure 3.

Test on harden concrete

Compressive Strength Test

For each concrete mix, the compressive strength is determined on three 150x150x150 mm cubes at 28 days of curing. Following table gives the compressive strength test results of control concrete and concrete made with fly ash and GGBS as partial replacement of cement.

Split Tensile Strength Experiment

The test has been conducted after 28 days of curing. Split tensile test conducted on 150mm diameter and 300mm length cylinder as
per IS: 5186-1999.

Results and discussions

Results of workability of concrete

Workability of the concrete are found by Slump cone and compaction factor test. The results obtained for different mix proportions of partial replacement of cement by GGBS and Fly ash as mentioned below in table 6.

Table 6: Slump and compaction factor values for concrete made with fly ash and GGBS as partial replacement of cement

Mix	Slump (mm)	Compaction factor values
M0	95	0.91
M1	105	0.91
M2	170	0.95
M3	160	0.95
M4	70	0.89
M5	150	0.94
M6	155	0.96
M7	160	0.96
M8	130	0.94
M9	155	0.95

The values of slump test and compaction factor test are presented in figure 1 and figure 2 as below.

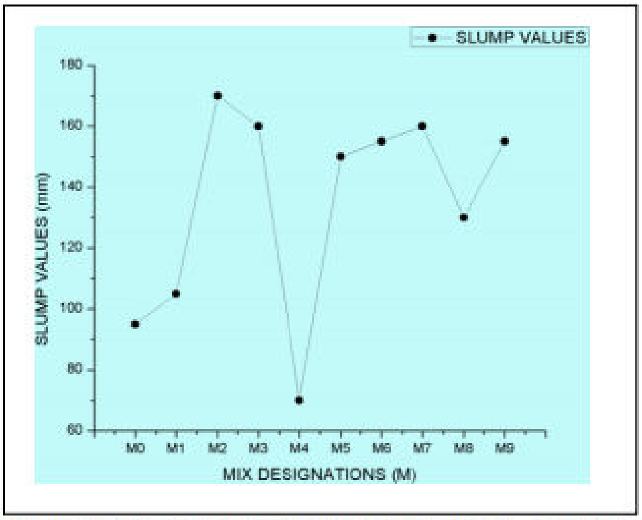


Fig 1: Graph shows slump values for normal concrete and concrete made with fly ash and GGBS as partial replacement of cement

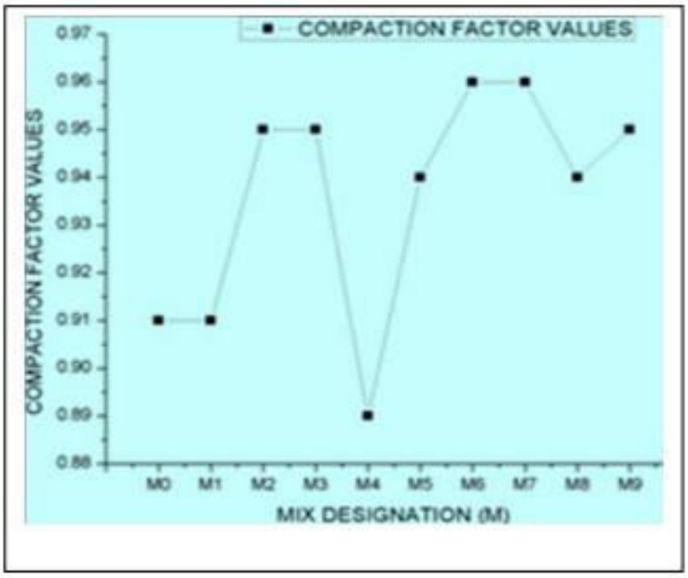


Fig 2: Graph shows compaction factor values for normal concrete and concrete made with fly ash and GGBS as partial replacement of cement

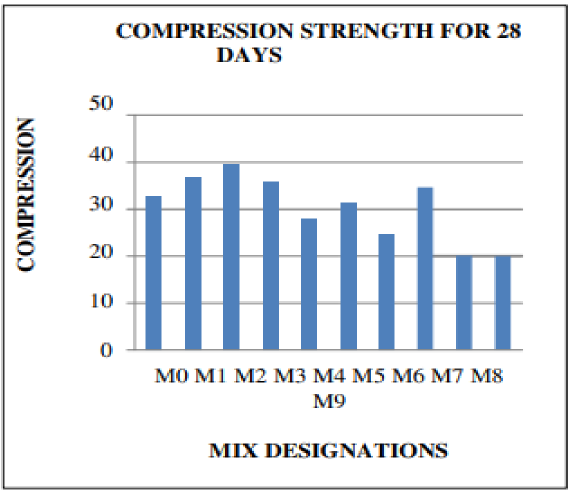


Fig 3: Graph shows 28 days compressive strength of normal concrete and concrete made with partial replacement of cement with fly ash and GGBS.

Results of Split tensile strength of concrete

The table below shows the overall results of split tensile strengths of control concrete and concrete made with fly ash and GGBS as a partial replacement of cement. The variation of split tensile strength in the form of graph is as shown in the figure 5.

Table 7: Results of split tensile strength

MIX DESIGNATION	SPLIT TENSILE STRENGTH (N/mm^2) for 28 days
M0	3.23
M1	3.25
M2	3.35
M3	2.60
M4	2.97
M5	3.18
M6	2.83
M7	3.25
M8	2.57
M9	2.69

Results of compressive strength of concrete

The table below shows the overall results of compressive strengths of control concrete and concrete made with fly ash and GGBS as a partial replacement of cement. The variation of compressive strength in the form of graph is as shown in the figure 4.

Table 8: Results of compressive strength

MIX DESIGNATION	COMPRESSIVE STRENGTH (N/mm^2) for 28 days
M0	32.81
M1	36.85
M2	39.70
M3	35.85
M4	28.00
M5	31.26
M6	24.67
M7	34.67
M8	20.15
M9	20.01

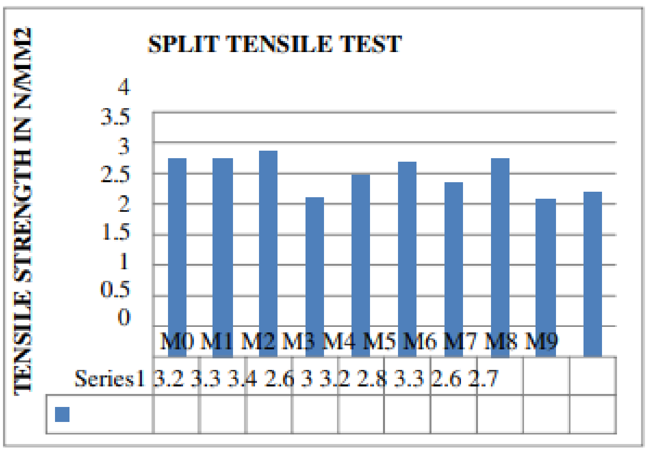


Fig 4: Graph shows 28 days of split tensile strength for normal concrete and concrete made with fly ash and GGBS as partial replacement of cement

Summary of results

From the results obtained from workability test, it is clearly observed that increasing in fly ash and decrease in the GGBS content leads to the increase in workability. The study is carried out under three sub heading mix M1, M2, M3 are the mixes where the replacement level is kept below 50%. The total blending is 40% (fly ash and GGBS) and 60% cement. The mix M4, M5, M6, M7, M8 is the mixes with high volume replacement 60% (fly ash and GGBS) and 40% cement. The mix M9 is the only mix where blending materials and cement are in equal proportions 50% (fly ash and GGBS) and 50% cement. The mix M2 (20% Flyash+20%GGBS+60%OPC) is giving good result in all ages of curing and it is compared in low volume replacement category. Mix M2 is having higher compressive strength than M1 & M3.The mix M7 (40%Flyash+20%GGBS+40%OPC) is giving good result in all the ages of curing and it is compared in high volume replacement category. Mix M7 is having higher compressive strength than all other mixes that is M4, M5, M6 and M8. M2 (20% Flyash+20%GGBS+60%OPC) is giving good results in all ages of curing when it is compared with low volume replacement category. Mix M2 is having higher split tensile strength than mix M1 & M3. The mix M7 (40%Flyash+20%GGBS+40%OPC) is giving good result in all the ages of curing and it is compared in high volume replacement category. Mix M7 is having higher split tensile strength than all other mixes in high volume replacement category that is M4, M5, M6, & M8. From the study conducted on hardened properties of concrete at various ages of curing period it is evident that concrete made with fly ash and GGBS as a partial replacement of cement is performing well compared to control concrete at all ages of curing. Several mixes M1, M2, M5 have showed better results than the control concrete. But mixes M3, M4, M6, M8 and M9 have not showed the result better than the control concrete. The study also reveals that the best mix in low volume replacement category is M2 & high volume replacement category is M7. But when the performance of these two mixes is compared M2 is performing well in both compression & split tensile strength at all ages of curing. The percentage increase in compressive strength of M2 compared to M7 is 14.50% at 28 days of curing

Conculsion

Incorporation of Fly ash and GGBS as a partial replacement of cement in concrete gives good results in both fresh and hardened state. In low volume replacement Mix M2 (20%Fly ash +20%GGBS+60%OPC) gives good workability and strength. In high volume replacement Mix M7 (40%Fly ash+20%GGBS+40%OPC) gives good workability and strength. The study reveals that low volume replacement mix M2 (20% Flyash+20% GGBS+60% OPC) is giving good result than high volume replacement Mix M7 (40%Flyash+20% GGBS+40% OPC) at all ages of curing. 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 by products 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.

Acknowledgement

This work is carried out as a part of B.Tech course, work as a group of five students under the supervision of V.R.Uma,

Assistant professor in Department of Civil Engineering, Sanskrithi School of Engineering, Puttapathi.

References

Reshma Rughooputh and Jaylina Rana (2014) “Partial Replacement of Cement by Ground Granulated Blast furnace Slag In Concrete”

K.V.Pratap, M.Bhasker, P.S.S.R.Teja (Jan-Jun, 2014). “Triple Blending of Cement Concrete with Fly Ash and Ground Granulated Blast Furnace Slag”

T.G.S Kiran, M.K.M.V Ratnam (December-2014). “Fly Ash as a Partial Replacement of Cement in Concrete and Durability Study of Fly Ash in Acidic (H2SO4) Environment”

Mohd Majiduddin (Asst prof), Md Muzzaffar Khan (Asst prof), Omer Zaheer Ahmed, Md. Hashmath. (March -2015) “Experimental investigation on the effect of physical, chemical And mechanical properties of fly ash and ground granulated blast furnace slag (GGBS) on concrete”

T. Subramani, and K.S. Ramesh (May-2015) “Experimental Study On Partial Replacement of Cement with fly-ash and complete replacement of sand with M sand”

Rajith M, Amritha E K (June-2015) “Performance of Concrete with Partial Replacement of Cement and Fine Aggregate by GGBS and GBS”

Vinit Kumar Singh , Vikas Srivastava , V.C Agarwal , Alvinharison (July-2015)
“Effect of fly ash as partial replacement of cement in PPC concrete”

Santosh Kumar Karri, G.V. Rama Rao, P. Markandeya Raju. (Oct-2015). “Strength and durability studies on GGBS concrete”

Mr. S Praveen, Mr. S S Janagan (Nov-2015) “Partial replacement of cement with nano fly ash (class c) and nano GGBS”

R. D. Padhye, N. S. Deo (8 & 9 Jan 2016). “Cement replacement by fly ash inconcrete”