PERFORMANCE OF PLAIN, FLYASH AND GGBFS BASED MORTAR IN PLAIN AND BOILING WATER CURING

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF DEGREE
OF

MASTER OF TECHNOLOGY
IN
STRUCTURAL ENGINEERING

Submitted by:

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2K18/STE/08

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CANDIDATE'S DECLARATION

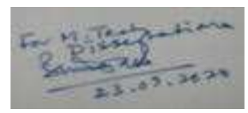
I, Lalit Kumar (2K18/STE/08), student of M.Tech (Structural Engineering), hereby declare that the project Dissertation titled **"PERFORMANCE OF PLAIN, FLYASH AND GGBFS BASED MORTAR IN PLAIN AND BOILING WATER CURING"** which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of and Degree, Diploma Associateship, Fellowship or other similar title or recognition.

Place: Delhi LALIT KUMAR

Date:23/09/2020

CERTIFICATE

I hereby certify that the Project Dissertation titled **"PERFORMANCE OF PLAIN, FLYASH AND GGBFS BASED MORTAR IN PLAIN AND BOILING WATER CURING"** which is submitted by Lalit Kumar (2K18/STE/08) to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.



Place: Delhi

Date:23/09/2020

Dr. ALOK VERMA

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ACKNOWLEDGEMENT

The success of a major ii project requires help and contribution from numerous individuals and the organisation. Writing the report of this project work gives me an opportunity to express my gratitude to everyone who has helped in shaping up the outcome of the project.

I express my heartfelt gratitude to my project guide **Dr.Alok Verma** for giving me an opportunity to do my Minor I project work under his guidance. His constant support and encouragement has made me realise that it is the process of learning which weighs more than the end result. I am highly indebted to the panel faculties during all the progress evaluations for their guidance, constant supervision and for motivating me to complete my work. They helped me throughout by giving new ideas, providing necessary information and pushing me forward to complete the work.

I also reveal my thanks to all my classmates and my family for constant support.

LALIT KUMAR

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Abstract

Fly ash and Ground Granulated Blast Furnace Slag are the waste obtained from industries and our concern to our surroundings. They have a negative impact on the environment and our daily life. Fly ash is obtained from thermal power plants and GGBFS is obtained from iron industries. As the industrialisation is increasing so rapidly world-wide and with increase in production waste generation is also increasing. And the problem rises with their dumping .

The utilisation of Fly ash and GGBFS in concrete as partial replacement of cement is seeking importance day by day. With some mechanical improvements in thermal power plant and iron industries operations as well as collection systems of fly ash and GGBFS has proved to enhance the quality of fly ash and GGBFS. To study the use of fly ash in mortar cement is replaced partially by fly ash and GGBFS with different percentages. In this experimental work mortar mix is prepared with replacement of fly ash and GGBFS by different compositions. Effect of fly ash and GGBFS on workability, setting time, compressive strength and water content are studied. To study the impact of partial replacement of cement by fly ash and GGBFS on the properties of mortar, experiments were conducted on mortar mixes.

The strength of mortar in construction works is determined at its 28 days Compressive strength. To find this Compressive strength, usually 28 days of moist curing is required. The 28 days of waiting time is too long a period for any corrective measure in case the strength is not desirable. That is after 28 days, by the time the quality of mortar is not found as required, the mortar would have hardened significantly and might be buried by subsequent construction. This makes the replacement of mortar mass of bad-quality very difficult, costly and time consuming. Suppose if the mortar of greater strength than required, the uneconomical mix is just a waste. These indicate a necessity for finding the 28 days characteristic strength for real good quality control. Hence, for better quality control, a rapid curing procedure is needed which facilitates identifying the 28 days strength in a day or so while the real mortar is still accessible and sufficiently soft to make its removal practicable. Hence, accelerated curing techniques are becoming important

In this project, Hot Water Curing Technique by which mortar will harden within a few hours and is expected to attain almost the same strength as a result which, it would have attained in 28 days by normal Curing Techniques.

Here, several tests like Compressive Strength Test, X-RAY Diffraction Test etc. on cubes of different mix will be performed and then the results of both the methods will be compared.

Chapter-1

Introduction

1.1 Mortar

Mortar is used in holding building materials like brick or stone together. It is a mixture of water, sand, and cement. The water in the mortar mix is used for hydrating the cement and holding the mix together. The water/cement ratio is more in mortar than that of in the concrete in order to form its bonding element. After mixing, the mortar mix is much thicker than concrete, making it suitable to use as a glue for building materials like brick. As mortar is replaced after every 25-50 years, So it can not be used in structural projects.

1.2 Concrete

Like Mortar, In Concrete there is a mixture of aggregates, cement, admixtures and water but it also contains rock chippings of gravel which makes it more strong and durable than mortar. As it requires a low water/cement ratio, it is more thin when mixed, which makes it very difficult to use as a bonding material. Concrete is used in structural projects and is reinforced with steel bars to maintain its structural integrity as the soil beneath settles. It is mostly used for support, such as beams, walls, or other building foundations.

1.3 Fly Ash

Fly Ash is also called as pulverized fuel ash. It is obtained from the coal combustion products. In Fly Ash there is a mixture of the fine particles which are brought out of the boiler with the flue gases. The Ash which falls in the lower portion of the boiler is named bottom ash. Electrostatic precipitators are used normally to capture the Fly Ash or some other particle filtration equipment are also used before the flue gases comes to the chimneys of coal fired power plants and alongside bottom ash faraway from rock bottom of the boiler is understood as coal ash. The variation of components of Fly Ash depends upon the source of coal from where it is found and properties and texture of the burned coal from which the ash would be obtained. All fly ash includes substantial amounts of silicon dioxide (sio2), aluminium oxide (Al_2O_3) and calcium oxide.

Chemical Composition

Component	Bituminous	Sub Bituminous	Lignite
SiO_2 (%)	20 – 60	40 – 60	15 – 45
Al_2O_3 (%)	5 – 35	20 – 30	20 – 25
Fe_2O_3 (%)	10 – 40	4 – 10	4 – 15
CaO (%)	1 – 12	5 – 30	15 – 40
LOI (%) Loss on Ignition	0 – 15	0 – 3	0 -5

TABLE-1.1

1.4 Ground Granulated Blast Furnace Slag

It is obtained from iron manufacturing industries. When added with concrete/mortar, it improves properties such as workability, strength, durability. It is produced by heating iron ore, limestone and coke at the temperature of 1500 degree Celsius. This process is completed inside the blast furnace.

The product obtained by this procedure is molten slag and iron. This molten slag contains silica, alumina and some amount of oxides. When this slag is passed through a water jet of very high pressure which produces the powder form of GGBFS.

Chemical Composition

MINERALS	AMOUNT(%)
CaO	30-50
SiO2	28-40
Al2O3	8-24
MgO	1-18

TABLE-1.2

Advantages

- Increase in sulphur attack resistance
- Penetration of chloride can be decreased
- Reduction of heat of hydration
- Reduction of voids in mortar
- The colour is more even and light

1.5 Curing

The process of curing is done to hydrate the cement under control temperature and control moisture movement from and into mortar. As continuous curing allows hydration of cement, continuous gain of strength also occurs and as hydration process stops, gain of strength also stops. Curing process is done under optimum moisture condition as the ratio within the capillaries goes down to 80%, the hydration process stops. If there will be lower water content, process will not occur properly and strength obtained will be lesser than desirable strength. The pores formed on and near the surface of mortar will allow the various hazardous agents to enter in it and will damage it and reduce its durability. And due to early dying of mortar there will be micro cracks and crack due to shrinkage on its surface. Evaporation of water from mortar occurs when it is exposed to open environment due to which water content will reduce hence loss of strength. Various physical factors like atmospheric pressure, temperature, moisture content and wind velocity and sort of the cement utilized in the combination has great impact on properties of mortar. If there is evaporation in initial time of curing then there will be plastic shrinkage and evaporation in last time of curing will lead to cracks due to shrinkage.

Temperature of curing is one of the most important factor that effect the rate of gain of strength of mortar. At higher temperature the cracks occur between two thermally incompatible components which are cement paste and sand, due to this strength of mortar decreases. When curing temperature of mortar is increased then mortar gains more early strength than that of at lower temperature, but later strength is gradually decreased. So, there must be uniform temperature throughout the curing process so that formation of cracks can be avoided. Many practical experiments has shown that strength of moist cured mortar is much higher than that of cured in dry environment.

Curing period is another factor that affects the strength of mortar, more is the time period of curing of mortar, the more will be the strength of mortar as hydration will go on.

Curing plays a vital role in deciding various properties of mortar, if curing is done properly with optimum moisture and temperature then mortar will posses higher durability, strength stability and more abrasion resistance.

1.6 Accelerated Curing

It takes around 28 days to gain mortar its 90% strength. If there is drying condition in this period then mortar does not attain full strength and cracks are formed. So, mortar is placed in moist condition during this period. The hydration rate increases with increase in temperature of curing and hence the rate of gain of strength. But at much higher temperature evaporation of starts to take place and loss of strength occurs. So, an optimal temperature lesser than temperature at which evaporation occurs is kept. The same technique is used in accelerated curing method and this technique is used in prefabrication industries. In situations like repairing a busy road bridge, this method is used which reduces its repairing time. The various methods of accelerated curing are curing with boiling water, curing in autoclave, curing with steam etc.

Generally, conductive heat is provided to cure the mortar either within the warm water curing or boiling water curing. This conductive heat enters from the surface of the cube to its core and hence creates temperature difference between both and hence thermal stresses. This issue can be solved by using autoclave method which provides uniform heat throughout mortar hence no thermal stress.

1.7 X-ray diffraction (XRD)

The principal of X-ray diffraction (XRD) is the twin wave/particle nature of X-rays to get information about the structure of crystalline materials. The main utilization of technology is that the identification and characterization of compounds on the basis of theirdiffraction pattern.

The main effect that starts to begin when a ray of beam of monochromatic X-rays interacts with an incident material is scattering of X-rays from atoms of the incident material. In materials with regular structure (i.e. crystalline), the scattered X-rays undergo constructive and destructive interference. This is known as of diffraction. This process of X-rays by crystals is explained by Bragg's Law, n(lambda) = 2d sin(theta). The shape and size of unit cell defines the possible direction of diffraction. The arrangement of atom and their type describes the intensities of diffracted waves. However, most of the materials aren't single crystals, but are made of the many small crystallites altogether with different possible orientations known as polycrystalline aggregate or powder. When a powder with irregular oriented crystallites is placed in an X-ray beam, the beam will see all possible interatomic planes. If the experimental angle is systematically changed, all possible diffraction peaks from the powder are going to be detected.

The parafocusing (or Bragg-Brentano) diffractometer is the commonest geometry for diffraction instruments.

Chapter -2

Review of Literature

2.1 GENERAL

The literature in the field of cementitious materials and fly ash and GGBFS utilization is vast and these literature analyze the influence of fly ash and GGBFS in cement by evaluating basic properties, strength characteristic, durability aspect and microstructural investigation. The extensive research is carried out by many researchers on the partial replacement of cement by secondary cementitious materials and also the use of ultrafine pozzolanic materials. However, the cement replacements with finer pozzolanic materials have shown better performance. But still, very limited research is on ultrafine fly ash and GGBFS with grinding aids. So, there is a high demand and research has to focus on the fly ash and GGBFS grinding process by using grinding aids in their effect on strength and durability point of view to identify the current research need

The present study is keen on the literature in various relevant sub areas such as,

- The ordinary Portland cement as binder materials
- The partial replacement of cement using pozzolanic materials
- The synthesis and characterization of fly ash
- The fly ash and ball milled fine fly ash effect on mechanical strength and durability aspects
- The consequence of fly ash and ball milled fly ash on masonry blocks
- Effect of boiling water curing on Fly Ash and GGBFS Mortar samples.

2.2 Studies on different methods of curing of mortars

Methods of curing for mortar having high cementious material This study is based on manufacturing and environment friendly construction material for precast industry. This study revealed that the physical and chemical properties of mortar like porosity, flexural strength, compressive strength and various others are different and under different curing methods. In this study cement was replaced by Rice Husk, GGBFS and Fly Ash up to 50% by mass. The cubes were cured under normal water (WC), air at room temperature (AC) and in hot water (HWC) at 60 degree celcius, under hot air (HAC). The study revealed that HAC method is most efficient method which gives high flexural and chemical strength and lower porosity for different mortar mixes. GGBFS based mortar show high early strength whereas Fly Ash and Rice Husk based mortars gave better quality at 24 hours boiling water curing.

M30 concrete cube curing under micro energy

This study revealed that with the help of radiation energy, accelerated curing could be provided with uniform temperature throughout. M-30 concrete cubes were prepared and were cured under micro energy at different time periods (6, 18 and 24 hours). Different microwave energy levels (360, 540, 720, 900Watt) and microwave curing time (20, 30, 40, 50minutes) were applied. In this study compressive strength obtained from micro energy curing method with 28 days normal curing compressive strength. The graphs were drawn to show the comparison of compressive strength of both the curing methods and results were found satisfactory.

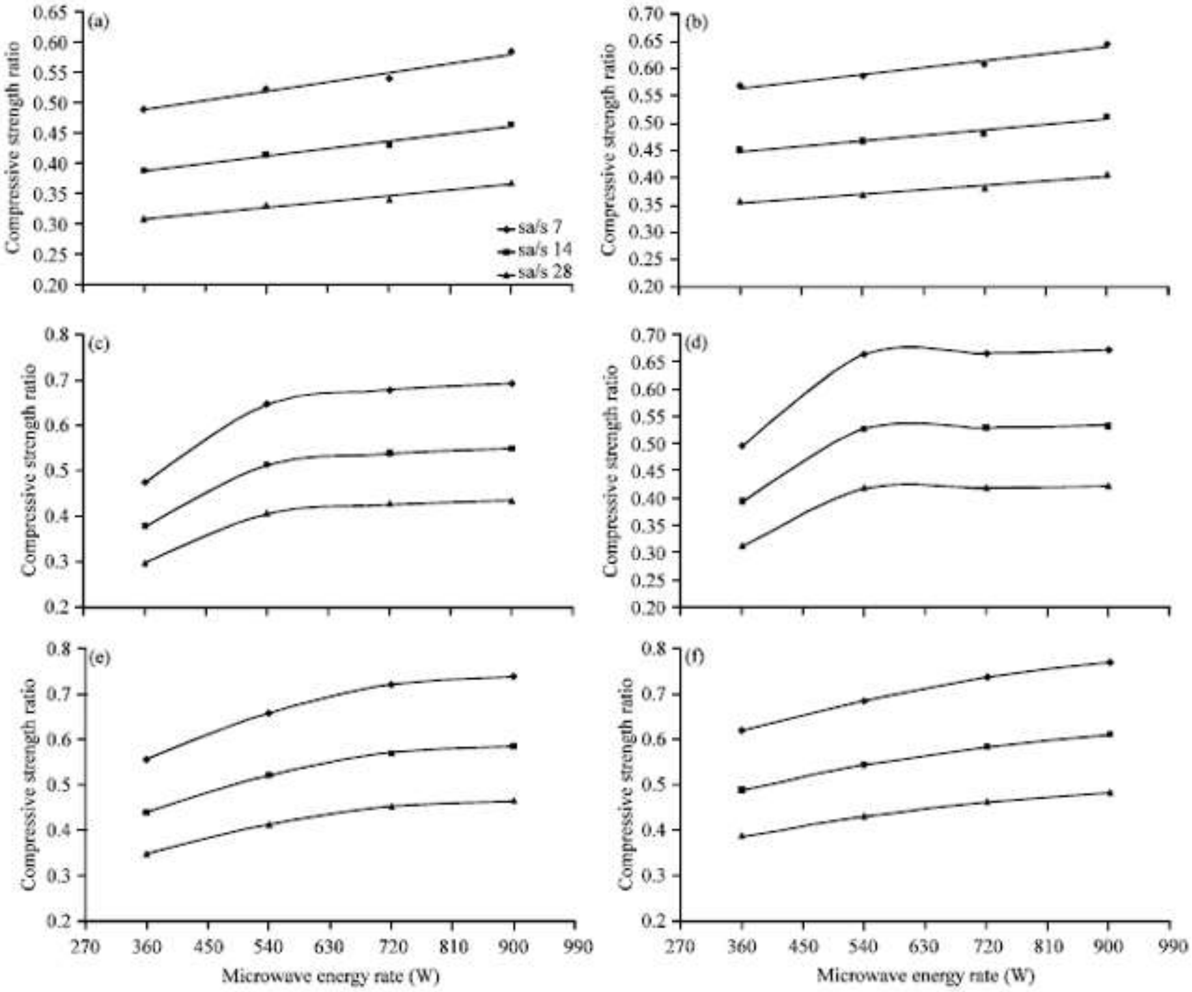


Fig 2.1

(Chithra S., 2014) Cement production is an intense energy consumptive activity which produces greenhouse gases and finding a suitable substitute is an important task in the present scenario. Temperature also plays a vital role in the rate of strength gain. Concrete specimens M20 i.e. compressive strength of 20 MPa were cast with 20%, 30% and 40% replacement of cement with GGBFS and were cured under different curing environments like hot water and hot air oven. The specimens were exposed to three different temperatures, namely 40℃, 50℃ and 60℃ for four hours in hot water curing. Compression test and split tensile test were done on concrete cubes and cylinders respectively. It resulted in the higher percentage replacement of cement with GGBFS yielded considerable increase in both tensile and compressive strength of the resulting concrete. It was found that replacement of cement with 40% of GGBFS under boiling water curing at 60℃ temperature has yielded maximum compressive and enduringness of concrete.

The experimental investigations dole out on control concrete and GGBFS admixed concrete to review the effect of thermal curing, following conclusions were drawn:

• Cement replacement with GGBFS yielded better results on compressive strength and enduringness regardless of its percentage to an extent of Sixteen Personality Factor Questionnaire and 54% respectively..

• Test results indicated that higher strength was obtained from few hours of thermal curing before normal curing in comparison with specimens subjected to only normal curing.

• Effect of thermal curing was simpler on enduringness than that of compressive strength of control concrete and GGBFS admixed concrete.

• Among two methods of thermal curing, it had been found that predicament curing was simpler than hot air oven curing.

• From the results it was found that, specimen with 40% percentage GGBFS under hot water curing at 60℃ has yielded maximum compressive strength and tensile strength.

• Another advantage of using GGBFS as a partial substitute was enough cost reduction of concrete.

With an optimum amount of GGBFS substitution; cost incurred for cement might be reduced to 10-15% of the initial cost. Furthermore, with the next reduction in use of cement, there'll be a discount within the amount of CO2 liberated into the atmosphere. Thus the optimum usage of GGBFS as a mineral admixture also reduces the environmental hazards.

(Prerna Tighare, May, 2017) Curing of concrete is the operation of maintaining humidity & temperature of freshly placed concrete during some definite period following placing, casting or finishing to assure satisfactory hydration of cement. When water is added to cement, sand & aggregate mix, the reaction between cement & water is exothermic. Hence lot of heat is evolved in reaction. This is known as heat of hydration. The heat of hydration results in evaporation of water from concrete that results in reduction of strength of concrete. Hence external application of water is required. This is 'curing'. Efficient uninterrupted curing is the key to quality concrete. Proper curing of concrete is crucial to obtain design strength. The curing period depends on the required properties of concrete. Curing is designed primarily to keep the concrete moist by preventing the loss of moisture from the concrete during the period in which it is gaining strength curing may be applied in number of ways & the most appropriate means of curing may be dictated by the site or the construction method. Various methods of curing are available. The existing study suggests that immersion curing is best suited for concrete but it involves more water as compared to other methods. However, if a combination of two or more methods is tried, the consumption of water can be reduced. The literature reviewed so far indicates that immersion method of curing concrete gives the best result as regards compressive strength. However, the basic limitation of immersion method is that it cannot be replicated on site. Hence the strength of concrete observed in laboratory is illusive & is not the real strength of concrete on site.

After going through the existing literature on Comparison of effect of Hot water curing, steam curing & Normal curing on strength of M-20 grade of concrete there is some shortcoming of immersion method & to overcome this shortcomings the present research effort aims at studying the combination of immersion method & other methods of curing like jute bag covering method & plastic membrane method. The effort shall be made to replicate the field conditions in the laboratory. The study seeks to assess the effect of different curing methods on compressive strength of concrete & concrete should be cured by best curing method to achieve a better compressive strength. The present study aims at combining immersion method with wet covering, with use of curing compound & plastic sheeting water requirement for 7 days, i.e. immersion curing combined with these is proposed to be calculated.

(Yash NAhata, 2013) Increase in technology in construction and industry has introduced various method of curing. A lot of research has been done to find effectiveness of various curing method and its effect on various properties of concrete. On the basis of literature review and practical investigations carried according to ASTM standards this paper examines the compressive strength of mortar cubes for 28 days, curing method effect on strength with the application of various curing compounds and structural grade methods with mortar mixes with cement: sand ratio 1:2.75 and ranging water/binder ratio between 0.45to 0.60, with use of field sand, ASTM graded sand and OPC, then comparison of strength of various curing methods. In this paper efficiencies of different curing method has been examined and compared with normal water curing. The paper revealed that 80-90% of efficiency can be obtained by providing membrane curing compounds as that of normal curing method.

It had found that ASTM standards are not suitable to use for Indian sand.From the experiments done in research of this paper it was revealed that ASTM standards are not suitable for almost every local raw material.

But at the same time in India we do not have any standard provisions for testing such curing compounds and testing of these compounds as per ASTM is very uncertain.

Mobasher et al. studied the effect of copper slag on the hydration of cement when upto 15% of Portland cement was replaced by copper slag. By X-Ray diffraction test was conducted and the reactions of porosity hydration were examined using mercury intrusion porosimetry and it was found that there was a significant increment in the compressive strength for upto 90 days of hydration.Reduction in capillary porosity measured using MIP indicated densification of the microstructure. Addition of copper slag decreased the Fracture and crack properties such as critical stress intensity factor and fracture toughness.

2.3 STUDIES ON STRENGTH BEHAVIOUR OF MORTAR USING VARIOUS MATERIALS AS PARTIAL REPLACEMENT OF CEMENT

Md. Moinul Islam In this paper, experiments were done to find out the impact on the strength of mortar of Fly Ash replacing cement at various percentages. With 6 different percentages of fly ash, cement is partially replaced. The standard mortar was taken which was Ordinary Portland cement (OPC) mortar . At 3, 7, 14, 28, 60 and 90 days both tensile and compressive strength was calculated and compared with standard mortar. (1) The rate of gain in strength of fly ash mortar specimens is observed to be lower than the corresponding OPC mortar.

(2) Fly ash mortar provides sufficient strength as compared with OPC mortar.

(3) Use of fly ash reduces the amount of cement content as well as heat of hydration in a mortar mix. Thus, this makes construction work environment friendly and economic.

S.No.	MORTAR MIX RATIO	% OF FLY ASH REPLACING CEMENT	7 DAYS STRENGTH (N/mm2)	28 DAYS STRENGTH (N/mm2)	RELATIVE STRENGTH (%)
1	1:3	0	29	42	100
2	1:3	10	26.8	40.8	97.14
3	1:3	30	25.5	36	85.7

TABLE-2.1.1

TREND LINE EQUATION FOR RELATIVE STRENGTH AT DIFFERENT %OF FLY ASH REPLACEMENT

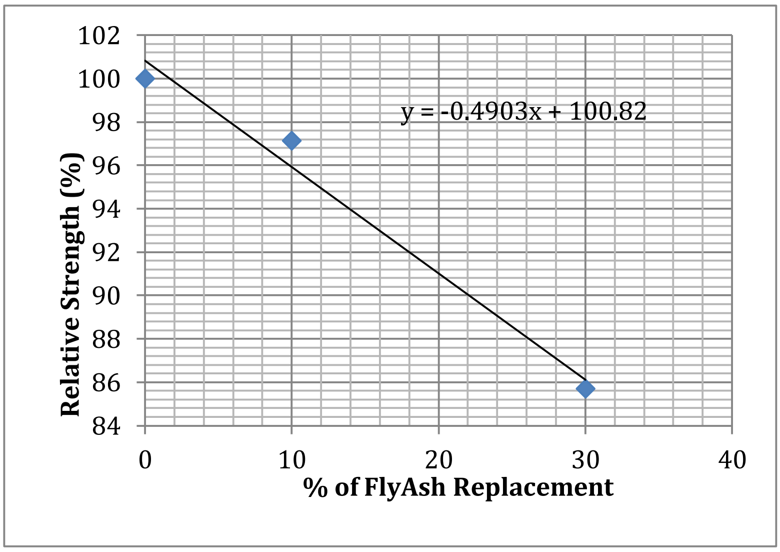


Figure- 2.2.1

Baboo Rai , Sanjay Kumar and Kumar Satish This paper presented results of compressive strength mortar in which quarry sand replaced natural sand and cement was replaced by Fly Ash (10%, 20% and 30%). The cube were tested for compressive strength at 3, 7 and 28 days. The experiment showed that use of quarry dust and Fly Ash together give a satisfactory result.

S.No.	MORTAR MIX RATIO	% OF FLY ASH REPLACING CEMENT	7 DAYS STRENGTH (N/mm2)	28 DAYS STRENGTH (N/mm2)	RELATIVE STRENGTH (%)
1	1:3	0	31.84	41.15	100
2	1:3	10	33.62	43.70	106.2
3	1:3	30	23.84	35.86	87

Table- 2.1.2

TREND LINE EQUATION FOR RELATIVE STRENGTH AT DIFFERENT %OF FLY ASH REPLACEMENT

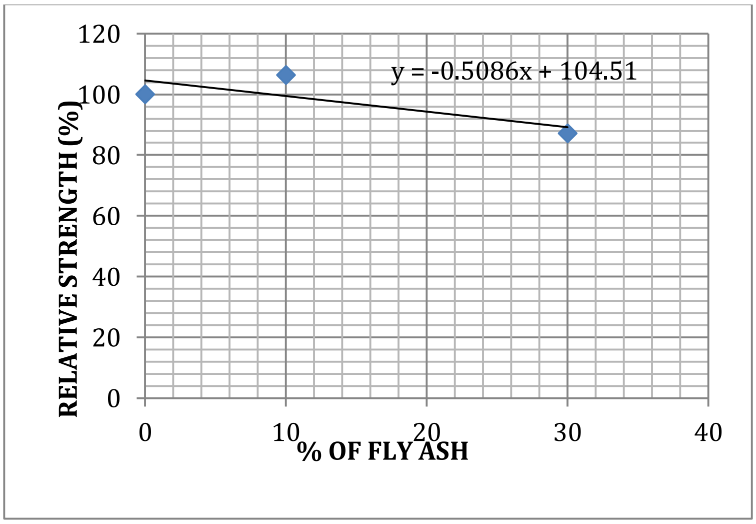


Figure- 2.2.2

AMARNATH YERRAMALA , Strength properties of **ash** mortars were evaluated through laboratory investigations. OPC of 53 grade replaced with class F fly ash with 5 – 30 % in the increments of 5 %. The results shown that at early age **in the least ash** replacements the strength decreased with **reference to** normal mortar. However, after 28 days and above the mortars made with **ash** replacement up **to fifteen** resulted higher strength than normal OPC mortar. Fly ash replacement of 20 and 30% always had lower strength than normal mortar. It was found that 10% **ash is that** optimum content for max strength.

S.No.	MORTAR MIX RATIO	% OF FLY ASH REPLACING CEMENT	7 DAYS STRENGTH (N/mm2)	28 DAYS STRENGTH (N/mm2)	RELATIVE STRENGTH (%)
1	1:2	0	17.6	24.8	100
2	1:2	10	14.2	25.8	104.03
3	1:2	30	10.4	19.60	79

Table 2.1.3

TREND LINE EQUATION FOR RELATIVE STRENGTH AT DIFFERENT %OF FLY ASH REPLACEMENT

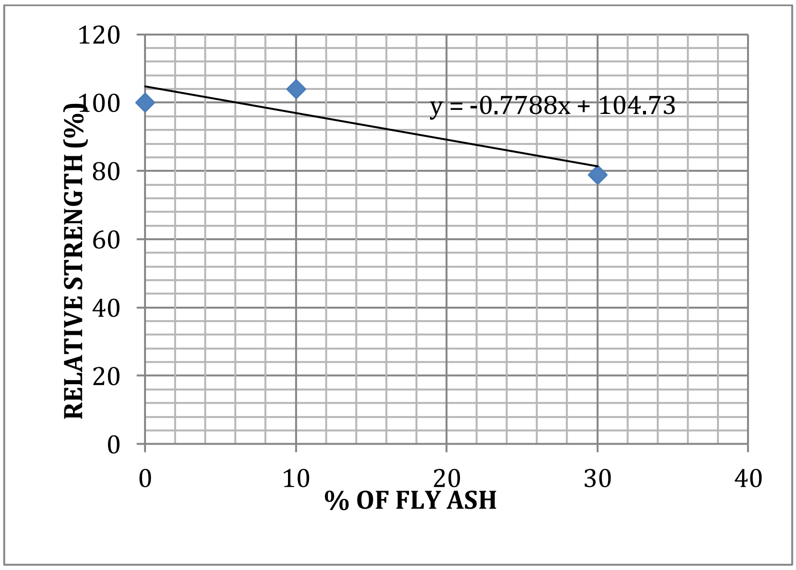


Figure-2.2.3

(**Alvin Harison**[*]**, Vikas Srivastava and Arpan Herbert Dept. of Civil Engineering, SHIATS, Allahabad-211007, U.P, India alvinjohnharison@gmail.com*;+91 8182820200)**

This investigation was a neighborhood of an experimental programme administered to review the use of non-conventional artifact (fly ash) for development of latest materials and technologies. it had been aimed toward materials which may fulfill the expectations of the development industry in several areas. during this study, cement was replaced by ash accordingly within the range of 0% (without fly ash), 10%, 20%, 30%, 40%, 50% and 60% by weight of cement for M-25 mix with 0.46 water cement ratio. Concrete mixtures were produced, tested and compared in terms of compressive strength. it had been observed that 20% replacement Portland Pozzolana Cement (PPC) by ash strength increased marginally (1.9% to 3.2%) at 28 and 56 d respectively. it had been also observed that up to 30% replacement of PPC by ash strength is nearly adequate to referral concrete after 56 d. PPC gained strength after the 56 d curing due to slow hydration process

S.No.	MORTAR MIX RATIO	% OF FLY ASH REPLACING CEMENT	7 DAYS STRENGTH (N/mm2)	28 DAYS STRENGTH (N/mm2)	RELATIVE STRENGTH (%)
1	1:3	0	23.4	31.6	100
2	1:3	10	19.2	32.4	102.5
3	1:3	20	20	33.2	105
4	1:3	30	17.2	25.4	80.3
5	1:3	40	12.4	19.8	62.6

Table- 2.1.4

At all levels compressive strength was measured. It was found that above up to 30% replacement level was more or equal to 30% replacement level on equal weight basis, surface referral concrete at 28 and 56 d. area of mix was increased due to addition of fly ash,

20% fly ash replacement was found to be optimum replacement.

TREND LINE EQUATION FOR RELATIVE STRENGTH AT DIFFERENT %OF FLY ASH REPLACEMENT

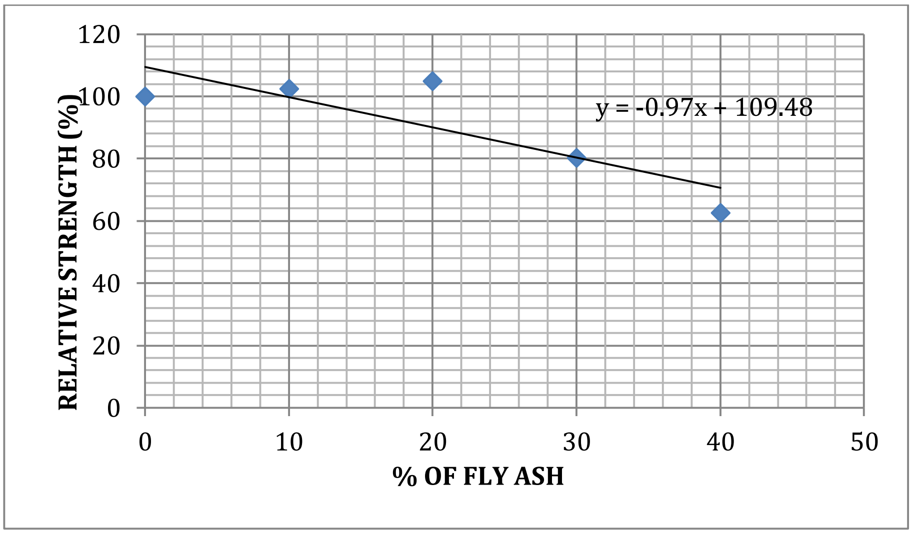


Figure- 2.2.4

Research on durability and strength properties Fibre Reinforced cement/ cementious composites

S.No.	MORTAR MIX RATIO	% OF FLY ASH REPLACING CEMENT	7 DAYS STRENGTH (N/mm2)	28 DAYS STRENGTH (N/mm2)	RELATIVE STRENGTH (%)
1	1:3	0	n/a	n/a	100
2	1:3	10	n/a	n/a	125
3	1:3	20	n/a	n/a	112

Table- 2.1.5

TREND LINE EQUATION FOR RELATIVE STRENGTH AT DIFFERENT %OF FLY ASH REPLACEMENT

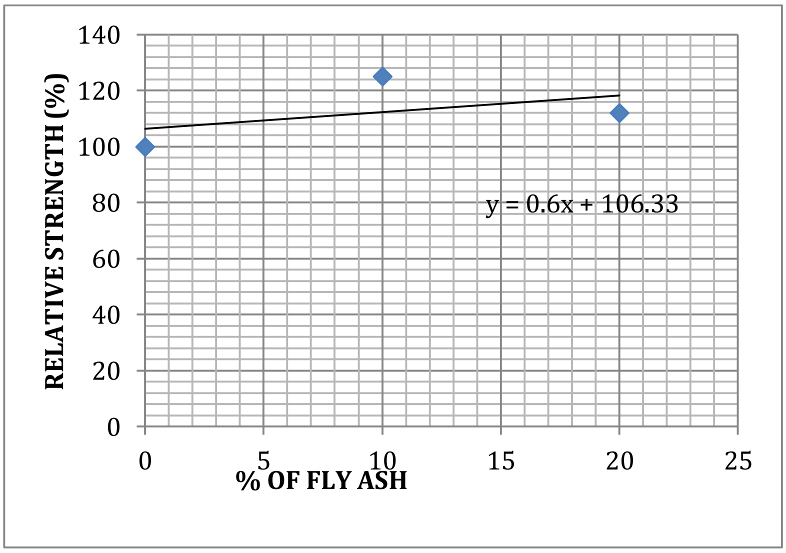


Figure- 2.2.5

Balamohan Balakrishnan1, In this study, mortar mixes were prepared by partially replacing the cement with up to 50% with fly ash at an incremental rate of 10%. Six mortar mixes with 1:4 \cement-to-aggregate ratios (by volume) using natural sand were prepared and examined for flow and compressive strength properties. It was found from the tests that the masonry mortars prepared with fly ash are better than that of prepared without any ash

S.No.	MORTAR MIX RATIO (BY VOL.)	% OF FLY ASH REPLACING CEMENT	7 DAYS STRENGTH (N/mm2)	28 DAYS STRENGTH (N/mm2)	RELATIVE STRENGTH (%)
1	1:4	0	n/a	12.2	100
2	1:4	10	n/a	13.2	108.2
3	1:4	20	n/a	12	99.8
4	1:4	30	n/a	11	90.16

Table-2.1.6

TREND LINE EQUATION FOR RELATIVE STRENGTH AT DIFFERENT %OF FLY ASH REPLACEMENT

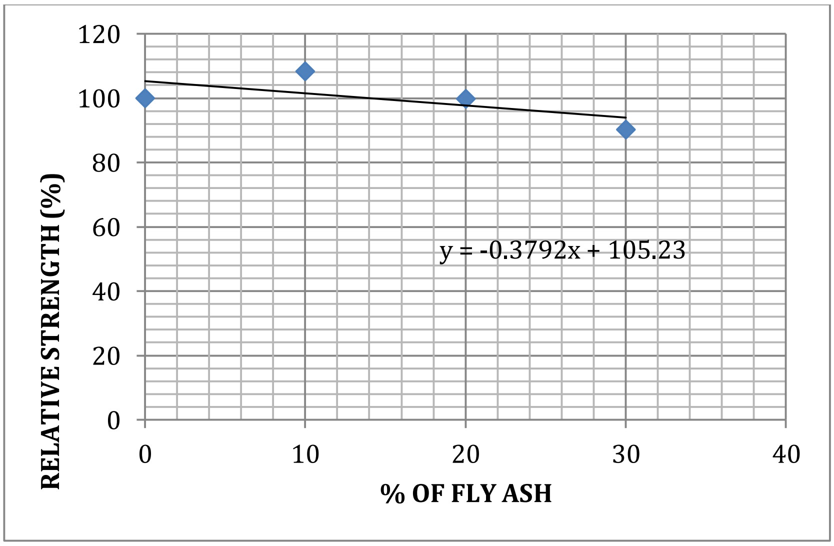


Figure- 2.2.6

Erion Luga Departmentof Civil Engineering, EPOKA University, Tirana, Albania)

In this study the performance of Portland cement with partial replacement with Kosovo fly ash in cement pastes and mortars was examined. Six different series of (0/100, 5/95,10/90,15/85.20/80 and 25/75) fly ash to cement ratios (FA/PC) were prepared and examined. Normal consistency, initial and final setting time of the cement pastes, and water absorption, flexural strength, compressive strength.Test result showed that Kosovo Fly Ash is good parameter that has improved the compressive strength of cement mortar by replacing upto 10%

It was found that with the increase in percentage of flyash, the water demand for normal consistency also increases,the initial and final setting time of cement pastes are delayed, and the water absorption capacity of the mortars icreases

S.No.	**MORTAR MIX RATIO (BY VOL.)**	**% OF FLY ASH REPLACING CEMENT**	**7 DAYS STRENGT H (N/mm2)**	**28 DAYS STRENGTH (N/mm2)**	**RELATIVE STRENGTH (%)**
1	1:3	0	n/a	49.1	100
2	1:3	5	n/a	57.2	116.5
3	1:3	10	n/a	48.4	98.57
4	1:3	15	n/a	45.4	92.46
5	1:3	20	n/a	36.3	73.9
6	1:3	25	n/a	31.5	64.15

Table- 2.1.7

TREND LINE EQUATION FOR RELATIVE STRENGTH AT DIFFERENT %OF FLY ASH REPLACEMENT

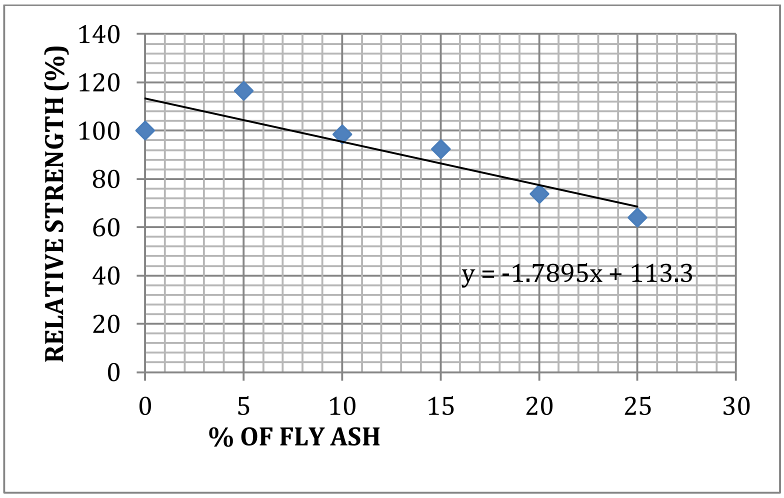


Figure- 2.2.7

Surajit Munshi, Gopinandan Dey, and Richi Prasad Sharma

In this study performance of mortar was examined with replacing cement partially with Rice Straw Ash. 3 mixes with 5%, 10% and 15% replacement with RSA were prepared. In this study, Rice Straw which is burnt under uncontrolled condition and converted in to ash is used. The setting times and compressive strength of that mortar mix using RSA at different percentage of cement replacement were examined and compared with the normal mortar. It was found that setting times are increased with increased percentage of RSA and there is increase in strength of mortar with certain quantity of replacement of cement with RSA which will lead economic construction.

S.No.	MORTAR MIX RATIO	% OF FLY ASH REPLACING CEMENT	7 DAYS STRENGTH (N/mm2)	28 DAYS STRENGTH (N/mm2)	RELATIVE STRENGTH (%)
1	1:3	0	13.04	28	100
2	1:3	5	12.6	29.8	106.4
3	1:3	10	12.6	32	114.3
4	1:3	15	11	26.8	95.7

Table- 2.1.8

TREND LINE EQUATION FOR RELATIVE STRENGTH AT DIFFERENT %OF FLY ASH REPLACEMENT

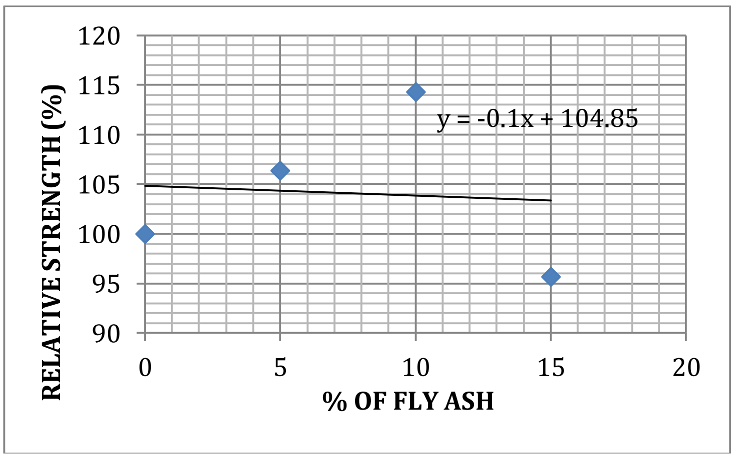


Figure- 2.2.8

TABLE FOR TREND LINE EQUATIONS FROM PREVIOUS RESEARCHES FOR CEMENT REPLACEMENT

S.No.	EQUATIONS (y=mx+C)	m	C
1	y=(-.49)x+100.8	(-.49)	110.8
2	y=(-.508)x+104.5	(-.508)	104.5
3	y=(-.778)x+104.7	(-.778)	104.7
4	y=(-.97)x+109.4	(-.97)	109.4
5	y=(.63)x+106.2	(.63)	106.2
6	y=(-.379)x+105.2	(-.379)	105.2
7	y=(-1.79)x+113.3	(-1.79)	113.3
8	y=(-.1)x+104.8	(-.1)	104.8

Table-2.2

GENERAL TREND LINE EQUATION FOR FLY ASH REPLACEMENT BY COMBINING OF ALL THE EQUATIONS

Y=(-0.548)X+106.1

CHAPTER-3

Methodology

Design for various Mortars

Before doing mix design following data is required-

1. Grade designation (1:3 by weight)
2. Type of cement (OPC 43 grade ultra tech is used)
3. Water-cement ratio (0.55)
4. Workability (slump 100mm)
5. Exposure condition (moderate)
6. Method of transporting (pump able)
7. Admixture used (NONE)

Apart from this data specific gravities of cement and fly ash used is to be found , for which test are done as per IS 2386-1963 PART 3.

3.1 Specific gravity of cement

Reference of IS 4031 part 11 is taken.

Apparatus- Le Chaterliers flask OR measuring cylinder, weighing balance.

Materials - kerosene (free from water) ,water and opc cement.

Procedure –

1. Dried the measuring cylinder carefully and filled with kerosene to a point on the stem at V1=150 ml.
2. Take 60 grams (w1) of opc cement and put it on paper and then carefully slide it to the cylinder. care being taken to avoid splashing and to see that cement does not adhere to the sides of the above the liquid .
3. After putting all the cement to the cylinder, roll the flask gently in an inclined position to expel air until no further air bubbles rises to the surface of the liquid.
4. Now read the new reading in the measuring cylinder as V2.

The specific gravity is given as = $\frac{W1}{V2 - V1}$.

FIG-3.1 -Specific Gravity of cement

(150ml KEROSENE OIL)

(60g CEMENT SAMPLE)

(INCREASE IN VOLUME)

Calculation

The specific gravity = $\dfrac{W1}{V2 - V1} = \dfrac{60}{169 - 150} = 3.1579 \approx 3.15$

Note: - as final reading is between 168ml and 170 ml ,it is taken 169 . but in actual fact it may be 169.1 or 168.9 ml. but this much smaller fraction cannot be read in the measuring cylinder as every small gap itself represents 2 ml . for which 0.1ml is very small. And if actual reading is 169.1 ,then specific gravity of cement will be 3.14 . but for all my calculations I have used 3.15 as standard value.

3.2 SPECIFIC GRAVITY OF FLY ASH

Apparatus- Le Chaterliers flask OR measuring cylinder, weighing balance.

Materials - kerosene (free from water) ,water and FLY ASH.

Procedure –

1. Dry and clean the flask carefully and fill 150ml Kerosene oil in it.
2. Take around 60 grams (w1) of fly ash and put it on paper and then carefully slide it to the cylinder. Care is taken to avoid splashing and to see that fly ash does not adhere to the sides of the above liquid .
3. After putting all the fly ash to the cylinder, roll the flask gently in an inclined position to expel air out until no further air bubbles rises to the surface of the liquid.
4. Now read the new reading in the measuring cylinder as V2.

The specific gravity is given as = $\frac{W1}{V2 - V1}$.

CALCULATION

The specific gravity is given as = $\frac{W1}{V2 - V1} = \frac{62}{178 - 150} = 2.2143 \approx 2.2$

Note :- Flash sample weight is 62g and The final reading is 178ml.

Fig 3.2 - Specific Gravity of Fly Ash

(150ml KEROSENE OIL)

(62g FLY ASH SAMPLE)

(INCREASE IN VOLUME)

3.3 Specific gravity test of Ground Granulated Blast Furnace Slag

Apparatus- Le Chaterliers flask OR measuring cylinder, weighing balance.

Materials - kerosene (free from water) ,water and GGBFS.

Procedure –

5. Dry and clean the flask carefully and fill 150ml Kerosene oil in it.
6. Take around 60 grams (w1) of GGBFS and put it on paper and then carefully slide it to the cylinder. Care being taken to avoid splashing and to see that GGBFS does not adhere to the sides of the above liquid .
7. After putting all the fly ash to the cylinder, roll the flask gently in an inclined position to expel air out until no further air bubbles rise to the surface of the liquid.
8. Now read the new reading in the measuring cylinder as V2.

Specific Gravity is given as = $\frac{W1}{V2 - V1}$.

Calculation

Specific Gravity = 61/20.8 = **2.93**

3.4 Specific gravity test of fine aggregates

Reference from IS 2386-1963 PART 3 is taken.

Apparatus - Pycnometer ,oven, enamel tray ,taping rod, filter paper funnel ,1000ml measuring cylinder etc.

Procedure-

1. A sample of about 500 g shall be placed in the tray and covered with distilled water at a temperature of 22 to 32°C. Soon after immersion, air entrapped in or bubbles on the surface of the aggregate shall be removed by gentle agitation with a rod. The sample shall remain immersed for 24 ± l/2 hours.

2. The water shall then be carefully drained from the sample, by decantation through a filter paper, any material retained being return & to the sample. The fine aggregate including any solid matter retained on the filter paper shall be exposed to a gentle current of warm air to evaporate surface moisture and the material just attains a ‗free-running' condition. The saturated and surface-dry sample shall be weighed (weight A).

3. The aggregate shall then be placed in the pycnometer which shall be filled with distilled water. Any trapped air shall be eliminated by rotating the pycnometer on its side, the hole in the apex of the cone being covered with a finger. The pycnometer shall be dried on the outside and weighed (weight B).

4. The contents of the pycnometer shall be emptied into the tray, care being taken to ensure that all the aggregate is transferred. The pycnometer shall be refilled with distilled water to the same level as before, dried on the outside and weighed (weight C).

5. The water shall then be carefully drained from the sample by decantation through a filter paper and any material retained returned to the sample. The sample shall be placed in the oven in the tray at a temperature of 100 to 110°C for 24 f l/2 hours, during which period it shall be stirred occasionally to facilitate drying. It shall be cooled in the air-tight container and weighed (weight D).

6. Calculations— Specific gravity, apparent specific gravity shall be calculated as follows-

$$\text{SPECIFIC GRAVITY} = \frac{D}{\{A - (B - C)\}}$$

HERE,

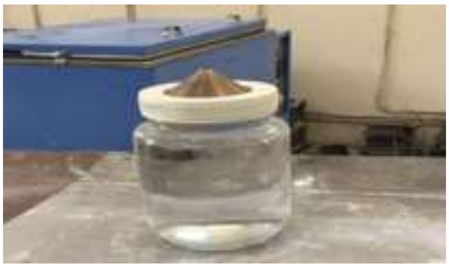
A= weight in g of saturated surface - dry sample,
B = weight in g of pycnometer containing sample and filled with distilled water,
C = weight in g of pycnometer filled with distilled water only, and
D = weight in g of oven - dried sample.

Fig 3.3 - Specific Gravity of Fine Aggregates

[Fine aggregate left for 24 hrs after step 1]

[sample ready for oven]

[sample placed in oven]



[pycnometer filled with water only]

[filtering of water from the sample]

[oven dried sample]

CALCULATIONS

Weight of saturated surface dry sample i.e. A = 500.9gram
Weight of pycnometer + water + fine aggregate i.e. B = 1866gram
Weight of pycnometer +water i.e. C = 1554gram
Weight of Oven dried sample i.e. D = 496gram

Now , specific gravity = $\frac{D}{\left[A-(B-C)\right]} = \frac{496}{\left[500.9-(1866-1554)\right]} = 2.626$

3.5 Design calculation for 0 % fly ash mortar or normal mortar

- Calculating dry volume of material required for 1cubic mt. volume of cement mortar.
- Now, I had assumed material consists of 33% voids. So, for 1cubic mt.of wet mortar, 1.33 cubic mt. material was required.
- I had taken mortar:cement(1:3)

CALCULATIONS

Let W be weight of cement

W/3.15 + 3W/2.63 + .52W/1 =1.33 *(wt. density of water)

16.388W / 8.2845 = 1330

W = 672.35 Kg

- Volume of one mortar cube = .0706 * .0706 * .0706
- Volume of mortar required for 12 cubes = 12 * (.0706)^3

  = 4.22 * 10^(-3) cubic mt.

Weight of cement required for 12 cubes = 672.35 * (volume of 12 cubes)

= 2.837 kg (2.9 Kg)

Weight of sand required for 12 cubes = 3 * (weight of cement)

= 8.7 Kg

Weight of water required for 12 cubes = 0.52 * (weight of cement)

= 1.51 Kg

3.6 Design for 10% Fly Ash Mortar

In this mortar 10% of cement was replaced by fly ash.

Calculations :

Calculating for 1cubic mt of dry mortar in similar way as done above-

0.9W/3.15 +3W/2.63 + 0.1W/2.2 + 0.52W = 1330

W = 667.5 Kg

Quantity of cement required for 1cubic mt. mortar =600.75 Kg

Now,

Quantity of cement required for 12 cubes = 2.54 Kg (2.6 Kg)

Quantity of sand required for 12 cubes = 3 * 2.82 =8.46 Kg

Quantity of fly ash required for 12 cubes = 0.283 Kg

Quantity of water required for 12 cubes = 1.48 Kg

3.7 Design for 30% Fly Ash Mortar

In this mortar 30% of cement was replaced by fly ash.

Calculations :

Calculating for 1cubic mt of dry mortar in similar way as done above-

0.7W/3.15 +3W/2.63 + 0..3W/2.2 + 0.52W = 1330

W = 658.77 Kg

Quantity of cement required for 1cubic mt. mortar = 658.77 * 0.7

= 461.139 Kg

Quantity of cement required for 12 cubes = 1.95 Kg

Quantity of sand required for 12 cubes = 8.33 Kg

Quantity of fly ash required for 12 cubes = 0.84 Kg

Quantity of water required for 12 cubes = 1.45 Kg

3.8 Design for 10 % GROUND GRANULATED BLAST FURNACE SLAG Mortar

In this mortar 10% of cement was replaced by GGBFS.

Calculations :

Calculating for 1cubic mt of dry mortar in similar way as done above-

0.9W/3.15 +3W/2.63 + 0.1W/2.93 + 0.52W = 1330

W = 671.54 Kg

Quantity of cement required for 1cubic mt. mortar = 671.54 * 0.9

= 604.4 Kg

Quantity of cement required for 12 cubes = 2.55 Kg

Quantity of sand required for 12 cubes = 8.5 Kg

Quantity of GGBFS required for 12 cubes = 0.284 Kg

Quantity of water required for 12 cubes = 1.47 Kg

3.9 Design for 30 % GROUND GRANULATED BLAST FURNACE SLAG Mortar

In this mortar 10% of cement was replaced by GGBFS.

Calculations :

Calculating for 1cubic mt of dry mortar in similar way as done above-

0.7W/3.15 +3W/2.63 + 0.3W/2.93 + 0.52W = 1330

W = 669.91 Kg

Quantity of cement required for 1cubic mt. mortar = 669.91 * 0.7

= 468.94 Kg

Quantity of cement required for 12 cubes = 1.98 Kg

Quantity of sand required for 12 cubes = 8.48 Kg

Quantity of GGBFS required for 12 cubes = 0.85 Kg

Quantity of water required for 12 cubes = 1.47 Kg

3.10 Cube Preparations

Step 1 : - Preparation of cubical moulds is done by proper cleaning them and then oil is applied at the jointed sections so that no concrete water leaves the cube and then proper tightening of the cubes is done after this a thin layer of oil as lubricant on all the faces of the cube.

Fig 3.4 - Cubicle moulds before and after tightening

Step 2 :- materials (except water) were weighed for 12 cubes accordingly from above calculations and mixed in dry state for 2 to 4 minutes.

FIG 3.5 - Mixture of cement and sand in dry state

Step 3 :- Water in the ratio of w:c = 0.52 was mixed in the mixture thoroughly for 2-3 minutes.

Fig 3.6 - Mixing of cement, sand and water manually

Step 4 :- Cubes were filled with the prepared mixture using Electric Mortar Mixer and shaken for 120 seconds for proper compaction.

Step 5 :- Filled cubes were covered with the plates and left for 24 hours in normal moisture condition.

Step 6 :- After 24 hours, cubes were put in the curing tank.

Fig 3.7 - Cubes in the curing tank

3.11 Boiling Water Curing

The boiling water curing tanks temperature was set to 100^{0}C and left for attaining the temperature . it took approx 2 hrs to reach the temperature to 100^{0}C.

When the temperature of the accelerated curing tank attained a value of 100^{0}C, the tank was opened carefully from the back side to ensure that no harm should be caused.

Fig 3.8 - Accelerated curing water Tank

Now placing the cubes along with the moulds was done very carefully so that no water splashes over us as it can cause severe burning of skin.

Fig 3.9 - Placing of mortar cubes in the tank

NOTE: Some points on boiling water curing as per IS 9013-1978

The temperature of water shall not drop more than 3^0C after the specimens are placed and shall return to boiling within 15 minutes.

Now at the completion of 2 hrs the cubes were taken out of the curing tank very carefully and cubes were taken out from the mould.

The cubes were then left for 15-20mins on the floor to get dry. The cubes were then ready for testing.

Similarly, after 3.5hrs, the remaining 3 cubes were lifted outside and dried in a similar manner.

Note :- Similarly 10% fly ash mortar cubes and 30% fly ash mortar cubes were prepared and tested.

3.12 Compression Strength Testing

Apparatus

Compression testing machine of suitable capacity

Fig 3.10- Compression Strength Testing Machine

Procedure

- At least 3 specimens from different mixes are to be tested and the average of three specimens is taken as compressive strength of the mix.
- The specimen must be surface dry only and not completely dry. If the cube is completely dry then it is soaked in water for 24 hrs before testing and then surface dried by keeping it in normal air for 15 to 20 minutes.
- At the time of testing the cubes surfaces are wiped out for any fine particles like sand or dust and the plate to be in contact with the machine is cleaned properly with the help of a dry cloth.
- Sides of the cubes are measured before testing to get the correct idea of area under compression.
- The placing of the mortar cube should be in such a way that load should pass through its centre i.e. no eccentricity is encountered.

Fig 3.11 - Placing of mortar cube in CTM

Fig 3.12 - Monitor showing applied load

3.13 Durability Tests

3.13.1 Acid Resistance Test

- The Acid resistance test is done on cubes of size 70.6 mm cube after immersing cube for 28 days in a curing tank.
- After 28 days cubes are weighted and then immersed in water diluted with one percent by weight of Sulphuric Acid for 28, 56, and 90 days.
- The cubes are taken out from the diluted acid water and then the surfaces of cube are cleaned by dry cloth.
- Weight and compressive strength of the cubes are taken and loss in percentage of compressive strength and weight is calculated.

3.13.2 Sulphate Resistance Test

- The Sulphate resistance test is done on cubes of size 70.6 mm cube after immersing cube for 28 days in a curing tank.
- After 28 days cubes are weighted and then immersed in 3% Sodium Sulphate Solution for 28, 56, and 90 days.
- The cubes are taken out from the Sodium Sulphate Solution and then the surfaces of cubes are cleaned by dry cloth.
- Weight and compressive strength of the cubes are taken and loss in percentage of compressive strength and weight is calculated.

CHAPTER - 4

Results

4.1 Compressive Strength Test Results

4.1.1 Compressive Strength Results for 0% Fly Ash Mortar

SNo.	Cube Name	Sample Number	LOAD(KN)	Compressive Strength (N/mm2)	Avg. Compressive Strength
1.	N(2HRS)	1	80.7	16.2	
		2	78.8	15.81	16.02
		3	80.1	16.07	
2.	NH(3.5HRS)	1	109	21.88	
		2	104	20.86	21.67
		3	111	22.27	
3.	N(7DAYS)	1	153.5	30.796	
		2	142.2	28.53	28.79
		3	134.9	27.06	
4.	N(28DAYS)	1	192.7	38.67	
		2	188.4	37.7	38.3
		3	202	40.5	

Table- 4.1.1

4.1.2 Compressive Strength Results for 10% Fly Ash Mortar

SNo	Cube Name	Sample Number	LOAD(KN)	Compressive Strength (N/mm2)	Avg. Compressive Strength (N/mm2)
1	F10(2HRS)	1	59.2	11.87	
		2	65.7	13.18	12.5
		3	62.1	12.46	
2	F10(3.5HRS)	1	108.6	21.78	
		2	115	23	22.41
		3	111.4	22.45	
3	F10(7DAYS)	1	151.6	30.415	
		2	165	33.1	30.73
		3	143	28.69	
4	F10(28DAYS)	1	208	41.7	
		2	211.6	42.4	42.46
		3	215.8	43.3	

Table- 4.1.2

4.1.3 Compressive Strength Results for 30% Fly Ash Mortar

SNo	Cube Name	Sample Number	LOAD (KN)	Compressive Strength (N/mm2)	Avg. Compressive Strength (KN/mm2)
1.	F30(2HRS)	1	42.3	8.43	
		2	45.8	9.18	9.31
		3	51.5	10.33	
2.	F30(3.5HRS)	1	79	15.85	
		2	82.5	16.55	16.456
		3	84.6	16.97	
3.	F30(7DAYS)	1	82.5	16.55	
		2	78.1	15.67	16.577
		3	87.3	17.51	
4.	F30(28DAYS)	1	157.5	31.6	
		2	172.9	32.4	30.91
		3	155.5	28.73	

Table- 4.1.3

4.1.4 Compressive Strength Results for 10% GGBFS Mortar

SNo.	Cube Name		LOAD(KN)	Compressive Strength (N/mm2)	Avg. Compressive Strength
1.	G10(2HRS)	1 2 3	99.1 95 98.6	19.88 19.06 19.782	19.574
2.	G10(3.5HRS)	1 2 3	118.4 111.4 113	23.754 22.35 22.671	22.925
3.	G10(7DAYS)	1 2 3	162.8 147.2 160.7	32.662 29.53 32.244	31.48
4.	G10(28DAYS)	1 2 3	230.8 226.3 202.3	46.3 45.4 40.6	44.1

Table- 4.1.4

4.1.5 Compressive Strength Results for 30% GGBFS Mortar

S No.	Cube Name		LOAD(KN)	Compressive Strength (N/mm2)	Avg. Compressive Strength
1.	G30(2HRS)	1	58.6	11.756	
		2	64.9	13.02	11.895
		3	54.4	10.91	
2.	G30(3.5HRS)	1	88.5	17.755	
		2	86.4	17.33	18.0
		3	94.1	18.88	
3.	G30(7DAYS)	1	93.4	18.74	
		2	98.6	19.782	19.67
		3	102.1	20.48	
4.	G30(28DAYS)	1	168.8	33.86	
		2	160.3	32.16	32.83
		3	161.8	32.46	

Table- 4.1.5

4.1.6 Combined table of Compressive Strength (N/mm2) of all mixes at different durations

MIXES	N(0%)	F10	G10	F30	G30
2HRS	16.02	12.5	19.574	9.31	11.895
3.5HRS	21.67	22.41	22.925	16.456	18
7DAYS	28.79	30.73	31.48	16.577	19.67
28DAYS	38.3	42.46	44.1	30.91	32.83

Table- 4.1.6

4.1.7 Combined Compressive Strength chart of all mixes

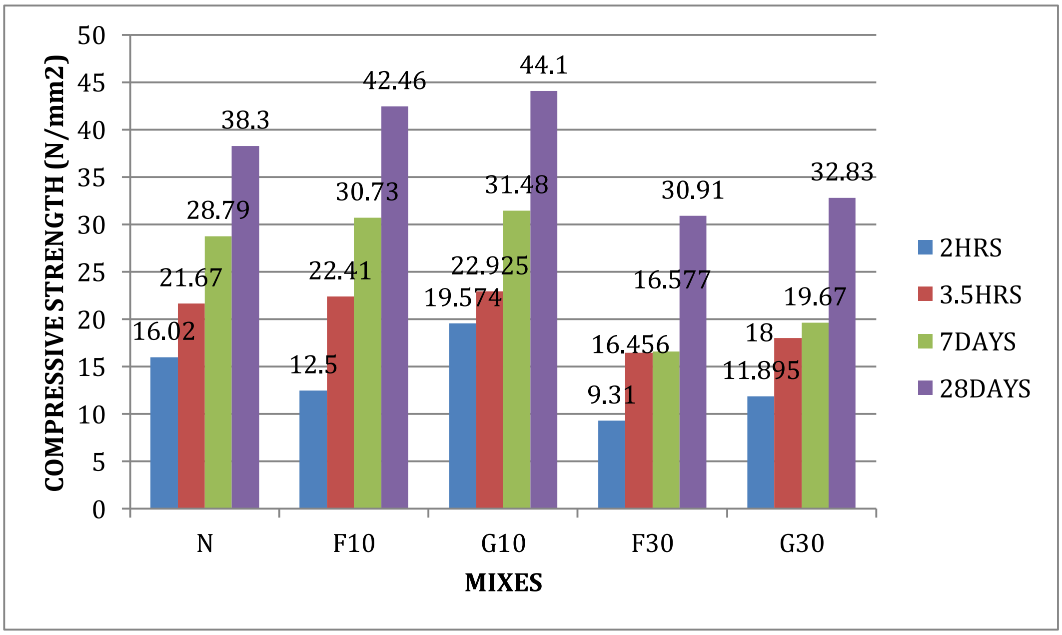


Fig - 4.1

4.2.1 TREND LINE EQUATION FOR COMPRESSIVE STRENGTH RESULTS AT DIFFERENT % OF FLY ASH

S.No.	MORTAR MIX RATIO	% OF FLY ASH REPLACING CEMENT	7 DAYS STRENGTH (N/mm2)	28 DAYS STRENGTH (N/mm2)	RELATIVE STRENGTH (%)
1	1:3	0	28.79	38.3	100
2	1:3	10	30.73	42.46	110.86
3	1:3	30	19.67	32.83	85.7

Table- 4.2.1

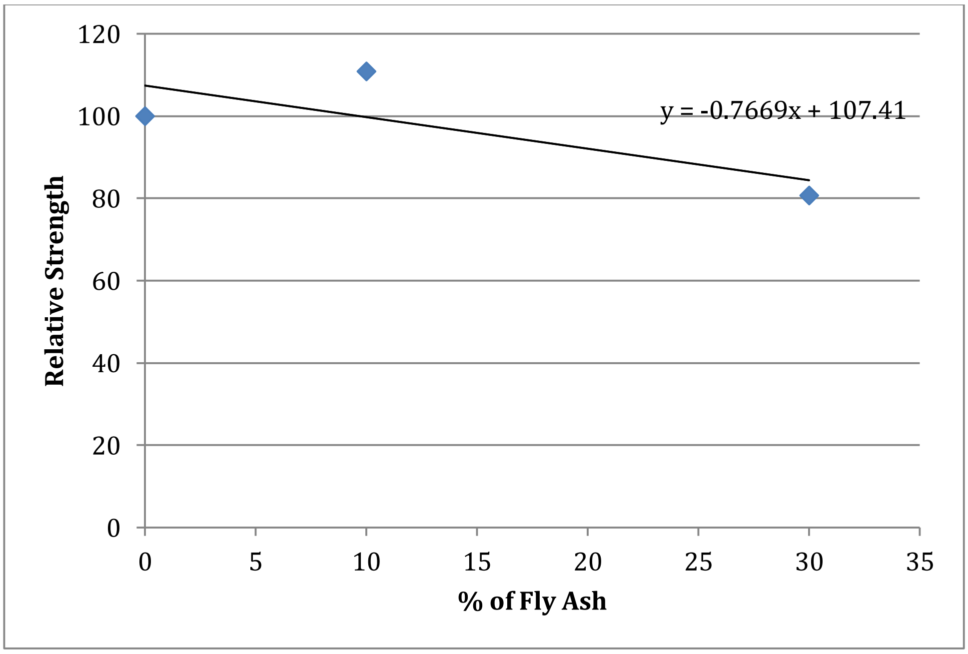


Figure- 4.2.1

4.2.2 TREND LINE EQUATION FOR COMPRESSIVE STRENGTH RESULTS AT DIFFERENT % OF GGBFS

S.No.	MORTAR MIX RATIO	% OF GGBFS REPLACING CEMENT	7 DAYS STRENGTH (N/mm2)	28 DAYS STRENGTH (N/mm2)	RELATIVE STRENGTH (%)
1	1:3	0	28.79	38.3	100
2	1:3	10	31.48	44.1	115.14
3	1:3	30	16.577	30.91	80.7

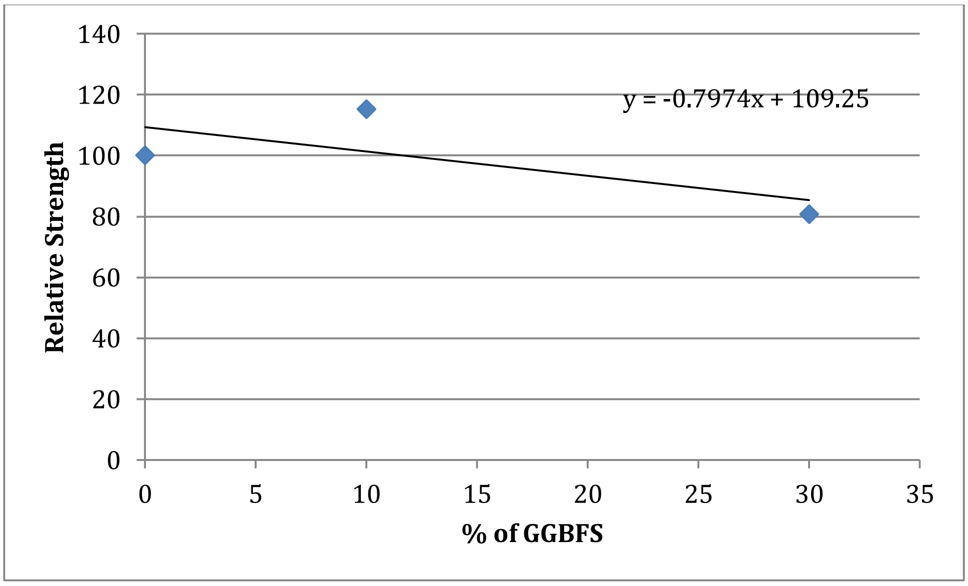


Figure- 4.2.2

4.3 Relationship between 3.5 hours mortar strength and 28 days mortar strength of different mortar mixes

4.3.1 For Normal Mortar

S.No.	3.5 Hours Strength	28 Days Strength
1	20.86	37.7
2	21.88	38.67
3	22.27	40.5

Table- 4.3.1

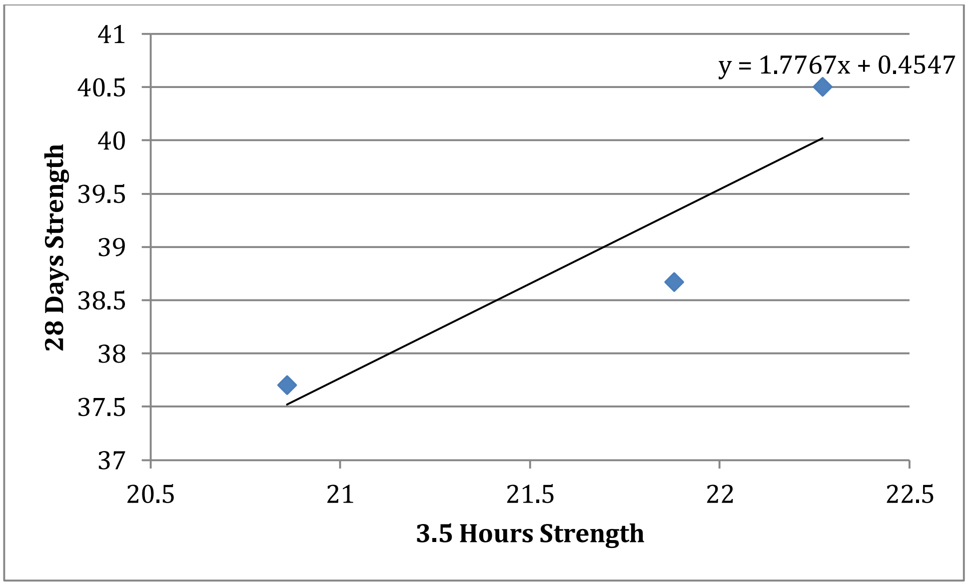


Figure- 4.3.1

Relationship between 3.5 Hours boiling water strength and 28 normal water curing for plain mortar is given as **y =1.776x + 0.454**

Where,

y - 28 days strength of mortar after normal water curing
x – 3.5 Hours strength of mortar after boiling water curing

4.3.2 For 10% Fly Ash based mortar

S.No.	3.5 Hours Strength	28 Days Strength
1	21.78	41.7
2	22.43	42.4
3	23	43.3

Table- 4.3.2

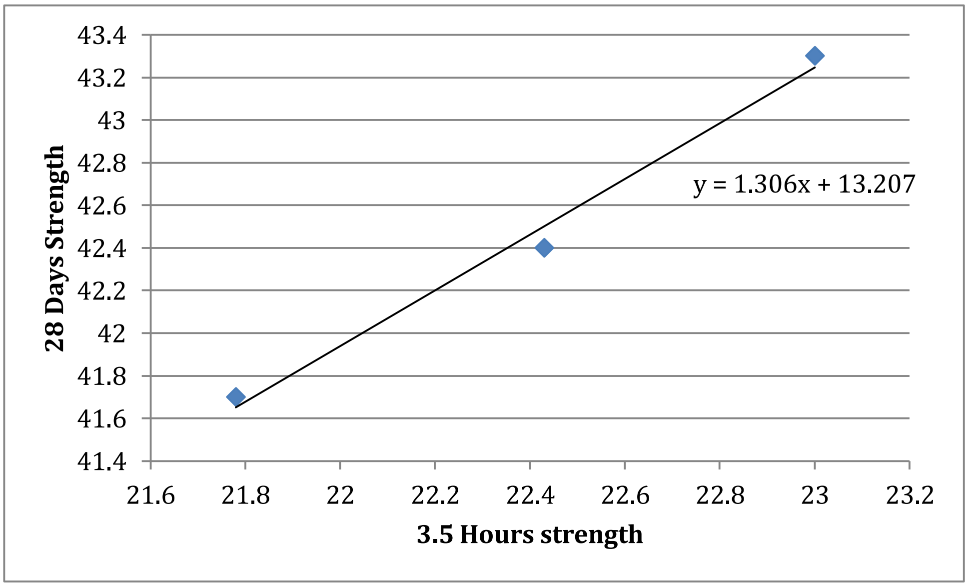


Figure- 4.3.2

Relationship between 3.5 Hours boiling water strength and 28 normal water curing for plain mortar is given as **y =1.306x + 13.20**

Where,

y - 28 days strength of mortar after normal water curing

x – 3.5 Hours strength of mortar after boiling water curing

4.3.3 For 30% Fly Ash based mortar

S.No.	3.5 Hours Strength	28 Days Strength
1	15.85	28.73
2	16.55	31.6
3	16.97	32.4

Table- 4.3.3

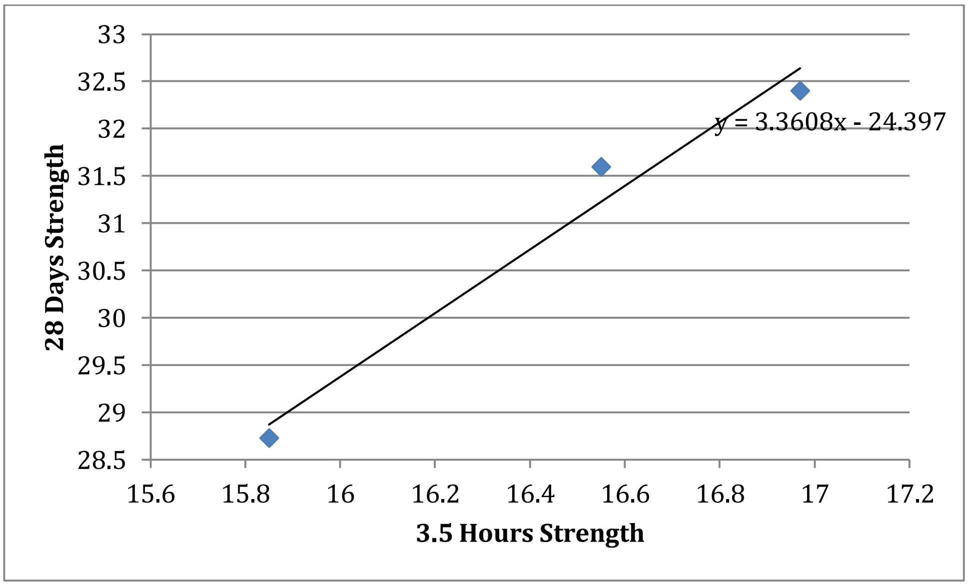


Figure 4.3.3

Relationship between 3.5 Hours boiling water strength and 28 normal water curing for plain mortar is given as **y = 3.360x - 24.39**

Where,

y - 28 days strength of mortar after normal water curing
x – 3.5 Hours strength of mortar after boiling water curing

4.3.4 For 10% GGBFS based mortar

S.No.	3.5 Hours Strength	28 Days Strength
1	22.35	40.6
2	22.671	45.4
3	23.754	46.3

Table- 4.3.4

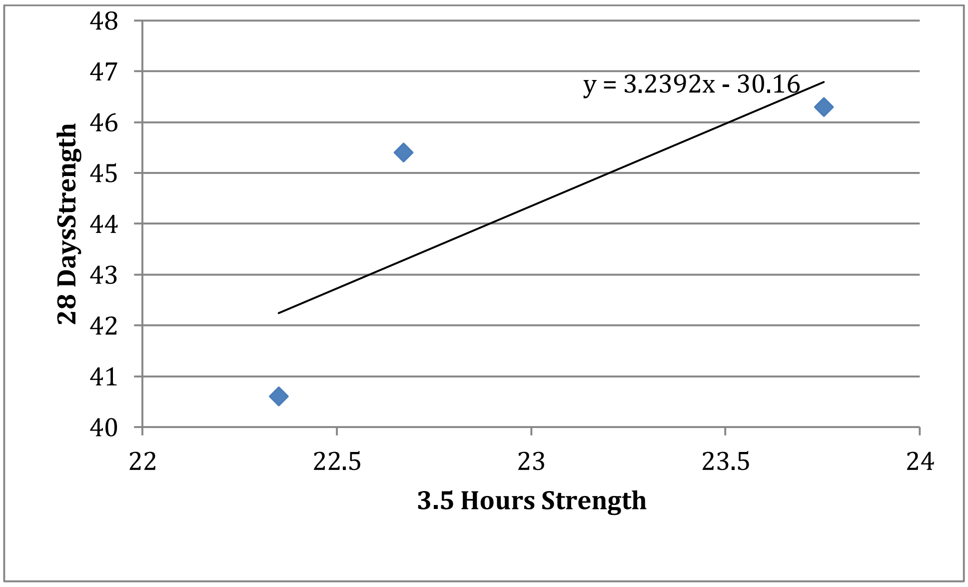


Figure- 4.3.4

Relationship between 3.5 Hours boiling water strength and 28 normal water curing for plain mortar is given as **y = 3.239x – 30.16**

Where,

y - 28 days strength of mortar after normal water curing

x – 3.5 Hours strength of mortar after boiling water curing

4.3.5 For 30% GGBFS based mortar

S.No.	3.5 Hours Strength	28 Days Strength
1	17.33	32.16
2	17.755	32.46
3	18.88	33.86

Table- 4.3.5

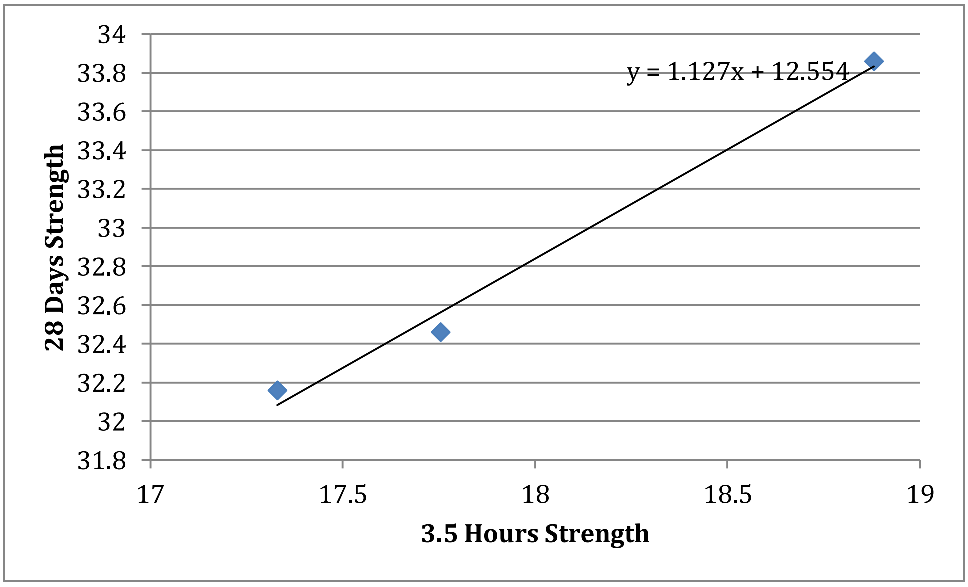


Figure- 4.3.5

Relationship between 3.5 Hours boiling water strength and 28 normal water curing for plain mortar is given as **y = 1.127x + 12.55**

Where,

y - 28 days strength of mortar after normal water curing
x – 3.5 Hours strength of mortar after boiling water curing

4.4 X-ray Diffraction Test Results

4.4.1 X-Ray Diffraction Test Result for plain Mortar

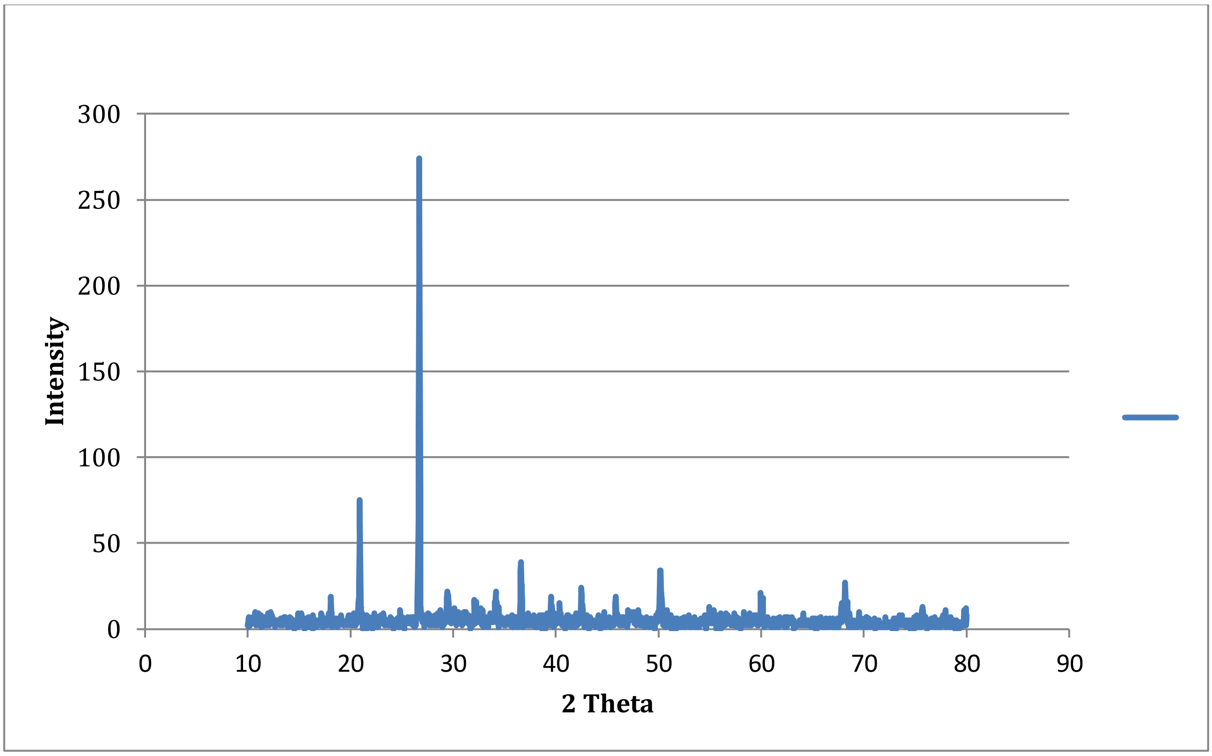


Figure- 4.4.1

X-Ray Diffraction test result is shown for plain mortar and the Graph Trend shows that the sample is of Crystalline nature.
Various peaks in the graph help to find out the composition of the sample as their respective 2 Theta value will show the presence of constituents.

- 2 Theta = 20.92 shows the presence of **Aluminate** (cubic).
- 2 Theta = 26.72 shows the presence of **Langbeinite** (95).
- 2 Theta = 29.4 shows the presence of **Alite**.
- 2 Theta = 34 shows the presence of **Ferrite**.

4.4.2 X-Ray Diffraction Test Result for Fly Ash based Mortar

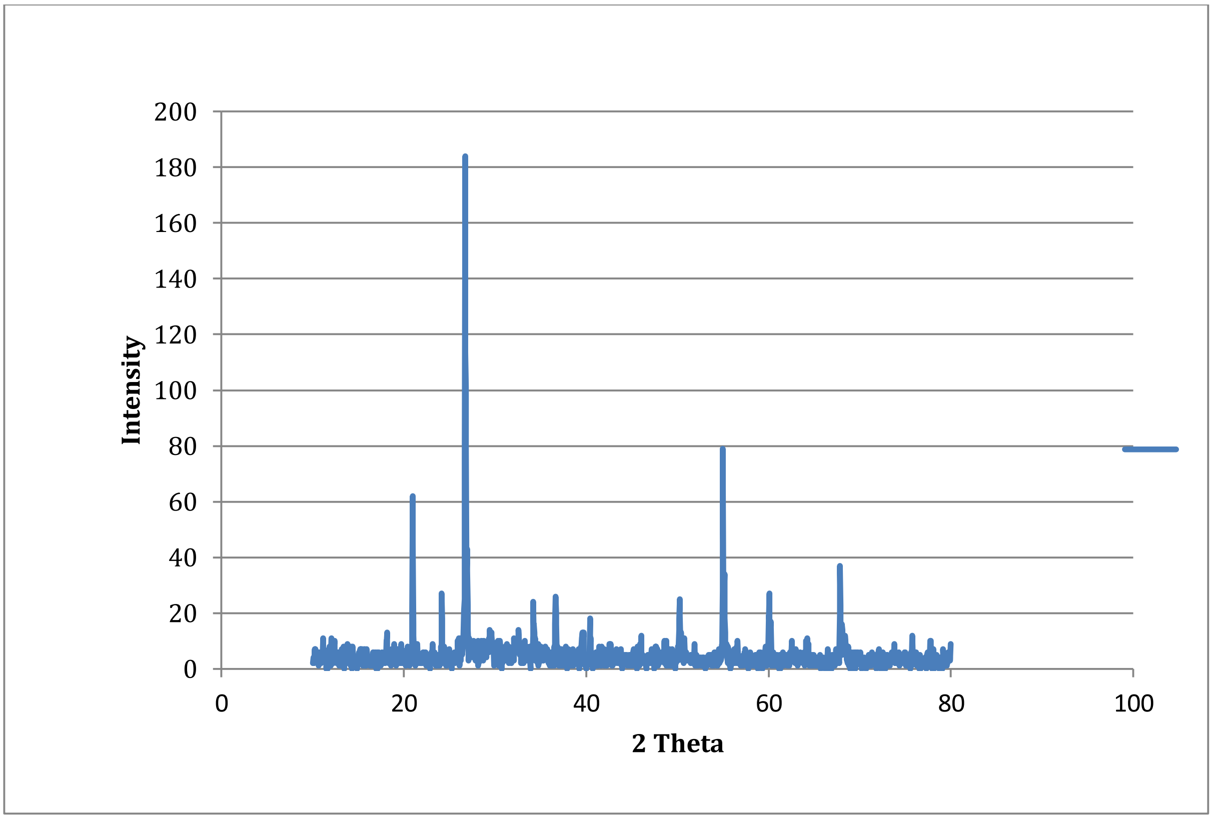


Figure- 4.4.2

X-Ray Diffraction test result is shown for Fly Ash based mortar and the Graph Trend shows that the sample is of Crystalline nature.
Various peaks in the graph help to find out the composition of the sample as their respective 2 Theta value will show the presence of constituents.

- 2 Theta = 18.08 shows the presence of **Portlandite** (74)
- 2 Theta = 20.96 shows the presence of **Aluminate** (cubic).
- 2 Theta = 24.16 shows the presence of **Ferrite** (16).
- 2 Theta = 26.72 shows the presence of **Langbeinite**.
- 2 Theta = 33.18 shows the presence of **Aluminate** (ortho rhombic)
- 2 Theta = 36.9 shows the presence of **Free Lime** (100).

4.4.3 X-Ray Diffraction Test Result for GGBFS based Mortar

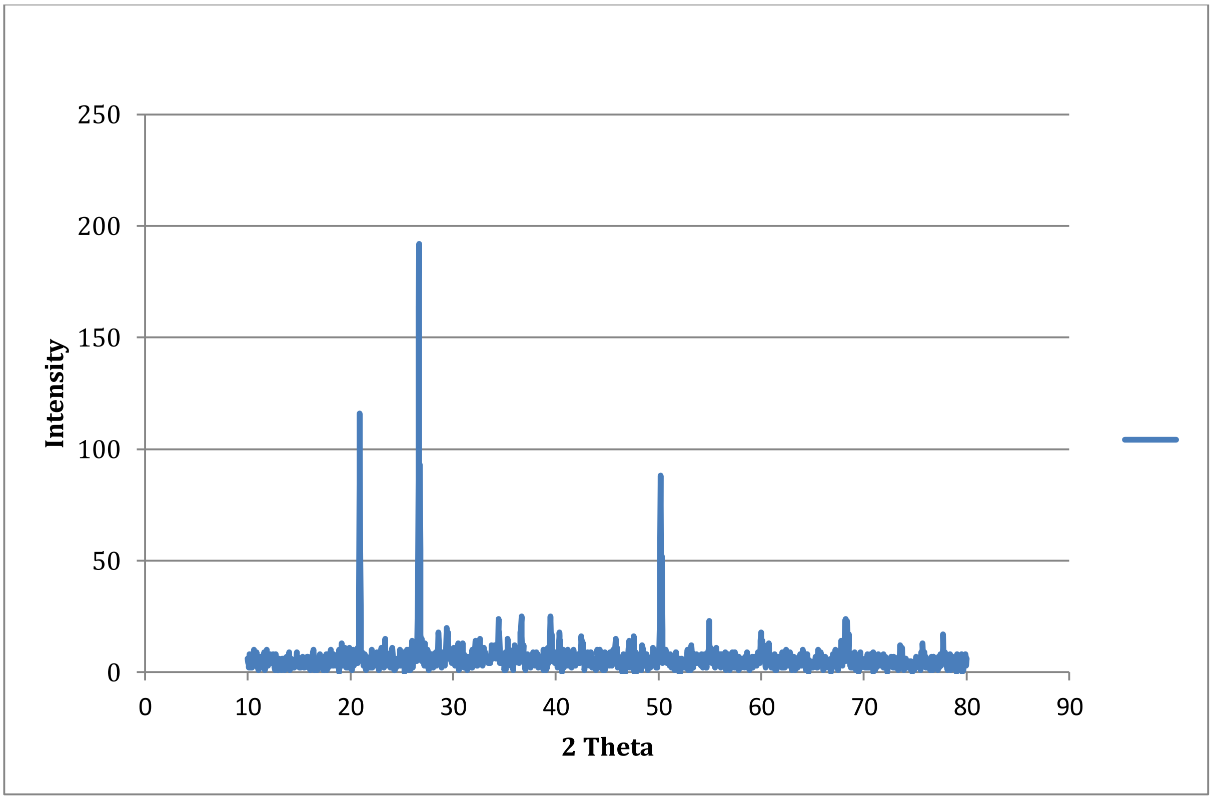


Figure- 4.4.3

X-Ray Diffraction test result is shown for GGBFS based mortar and the Graph Trend shows that the sample is of Crystalline nature.
Various peaks in the graph help to find out the composition of the sample as their respective 2 Theta value will show the presence of constituents.

- 2 Theta = 20.92 shows the presence of **Aluminate** (cubic).
- 2 Theta = 26.68 shows the presence of **Langbeinite** (95).
- 2 Theta = 28.56 shows the presence of **Gypsum** (75).
- 2 Theta = 33.4 shows the presence of **Aluminate** (cubic)
- 2 Theta = 36.9 shows the presence of **Free Lime** (100).
- 2 Theta = 42.33 shows the presence of **Periclase** (100).

Chapter – 5

Conclusion

- Use of hot water curing for predicting strength of Plain, Fly Ash and GGBFS cement mortar may be successfully made.
- Relationship between the strength of different type of mixes and curing durations in ordinary water as well as in hot water curing seem to be properly related.
- Graphs for Plain cement mortar and cement mortar with Fly Ash and GGBFS show various peaks, many of which are found to be at nearly same.
- Strength development as per as time duration both in curing as well as in hot water curing found on expected lines.
- It has been found that some Fly Ash mixes may give better strength at a particular time and in a particular curing environment. It seems to be due to pozzolanic action impacted by Fly Ash

References

Chithra S., D. G. (2014). *Effect of hot water curing and hot air oven curing on.*Thanjavar, India: Sphinx Knowledge House.

Evi Aprianti, P. S. (2015). *Introducing an effective curing method for mortar containing high volume cementitious materials.* University of Malaya.

Prerna Tighare, R. S. (May, 2017). *Comparison of Effect of Hot Water Curing, Steam.* Rungta, India: (IJRASET).

T.R. Neelakantan, S. R. (n.d.). *Accelerated curing of M30 Grade Concrete.* Asian Journal of Applied Sciences.

Yash NAhata, T. T. (2013). *Effect of Curing Methods on Efficiency of Curing of Cement.* Gandhinagar, India: ICBEE.

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IS-4031 CODE for testing Specific Gravity of Cement and Fly Ash

IS-2386(1963) for Specific Gravity of Fine Aggregates

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