P.E.S. COLLEGE OF ENGINEERING MANDYA

(An Autonomous Institution under VTU, Belagavi)

A Dissertation on

"EXPERIMENTAL CHARACTERIZATION OF MORTAR USING BAGASSE ASH AND FLY ASH HYBRIDIZATION"

Submitted in fulfillment for the award of the degree of

MASTER OF TECHNOLOGY

IN

COMPUTER AIDED DESIGN OF STRUCTURES

Submitted by

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MTech. (CADS)

<u>CERTIFICATE</u>

This is to certify that **ROHITH.R** bearing USN: **4PS21CCS08** have satisfactorily completed the dissertation work entitled **"EXPERIMENTAL CHARACTERIZATION OF MORTAR USING BAGASSE ASH AND FLY ASH HYBRIDIZATION"** in fulfillment of requirements for award of degree of **Master of Technology** in **Computer Aided Design of Structures** by **P.E.S College of Engineering**, Mandya, an Autonomous institution Affiliated to **Visvesvaraya Technological University**, Belagavi during the year 2022-2023. The Project has been approved as it satisfies the academic requirements in respect of the project work prescribed for the Degree in Master of Technology.

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DECLARATION

I, **ROHITH.R (4PS21CCS08)**, Student of final semester **Master of Technology** in **Computer Aided Design of Structures** by **P.E.S College of Engineering**, **Mandya**, hereby declare that the dissertation entitled **"EXPERIMENTAL CHARACTERIZATION OF MORTAR USING BAGASSE ASH AND FLY ASH HYBRIDIZATION"** has been independently carried out by me at Department of Civil Engineering, P.E.S.C.E ,Mandya under the guidance of **LAKSHMI P.S**, Assistant Professor, Department of Civil Engineering, Mandya , in fulfillment for the award of **Master of Technology** in **Computer Aided Design of Structures** by the P.E.S College of Engineering, Mandya under VTU Belagavi during the academic year 2022-2023. Further, the matter embodied in this dissertation has not been submitted previously by anybody for the award of any Degree or Diploma to any other University.

Place: Mandya

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ABSTRACT

The limestone reserves are getting depleted in the next few years which is one the basic ingredient in the manufacture of cement, so we have to find an alternative material as admixture for cement replacement. In this study we have carried out mechanical and durability property tests by partially replacing cement with bagasse ash and fly ash at 10%, 20%, 30%, 40% and 50% at equal proportion in mortar of grade 1:4 and 1:6, the results were assessed for 7 and 28 days and 56 days. The mechanical properties assessed are compression and flexural strength using 50 mm cube specimens and 160x40x40 mm prism specimens respectively, and the durability properties assessed are water absorption test, acid and sulphate attack test and sorptivity test which is done for 28 days water cured 50 mm and 70.6 mm cube specimens. The results have concluded that there is no early strength gain in compression and flexure for 7 days but there is increase in strength at the later stages for 28 days due to delayed hydration and there is no much difference in strength of 56 days cured specimens due to 80%-90% hydration within 28 days. The water absorption results have shown less than 15% of water absorption which is in the acceptable limit 15% [6]. The acid and sulphate attack results have shown percentage loss within 15% and 10% respectively. The sorptivity test shows the saturation level within 2 hours of test due to complete capillary suction of water throughout all the specimens.

Keywords: Bagasse ash, Fly ash, Mortar, Cement, Admixture.

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LIST OF ABBREVIATION

SI.No	Short form	Description
1	SCBA	Sugarcane bagasse ash
2	FA	Fly ash
3	SSA	Sewage sludge ash
4	GBS	Granulated blast furnace slag
5	Sc	Compressive strength
6	NS	Nano silica
7	PPC	Portland pozzolana cement
8	OPC	Ordinary Portland cement
9	PSC	Portland slag cement
10	DSF	Densified silica fume
11	SCMs	Supplementary cementitious material
12	UPV	Ultrasonic pulse velocity
13	RHA	Rice husk ash
14	POFA	Palm oil fuel ash
15	M-sand	Manufactured sand
16	LOI	Loss on ignition

CHAPTER - 1

INTRODUCTION

1.1 GENERAL

Cement is a vital construction material that plays a fundamental role in the creation of buildings, infrastructure, and various structures. It is a fine powder composed primarily of limestone, clay, and other materials that are heated to a high temperature in a kiln and then ground to produce a fine powder. This powder, when mixed with water, forms a paste that hardens over time, resulting in a strong material. Another important characteristic of cement is its durability. When properly cured and maintained, cement-based structures can withstand considerable loads, resist weathering, and have a long lifespan. This durability makes cement a preferred choice for a wide range of construction projects, including buildings, bridges, dams, roads, and many other infrastructure developments.

However, it's important to note that cement production has environmental implications. The process of manufacturing cement involves the release of carbon dioxide (CO_2) emissions, contributing to climate change. Efforts are being made within the industry to reduce these emissions through technological advancements and the adoption of more sustainable practices. Several benefits will be attained regarding greenhouse gas emissions resulting from the use of mineral admixtures as cement replacement, since their use allows reducing cement production.

Most of the supplementary cementitious materials including bagasse ash are industrial by-products and cannot be used directly as pozzolanic material in concrete. .Various processing methods have been used in previous research studies to evaluate their effects on the pozzolanic activity of different supplementary cementitious materials including fly ash, silica fume, slag, rice husk ash, and metakaolin etc. Only a few industrial operations are required to transform some of the cited industrial by-products into pozzolan. These operations typically correspond to grinding and classification, which are responsible for the controlled reduction in particle size and increase in specific surface area. Such increase in specific surface area is directly responsible for the kinetics of their pozzolanic reactions, which can be limited in the case of poorly reactive.

Sugarcane, scientifically known as Saccharum officinarum, is a vital crop grown for its sweet juice, which is extracted and used to produce sugar, ethanol, and a variety of other products. Sugarcane is primarily cultivated in tropical and subtropical regions due to its requirement for a warm and humid climate. It thrives in areas with well-drained, fertile soil and an abundance of rainfall.

The value of the Indian sugar industry (including sugar and its byproducts) is greater than Rs.80,000 cr. Five crore sugarcane farmers are supported by the Indian sugar sector, which is hence of great political significance. The ISMA website contains key statistics regarding the Indian sugar business. There were 732 sugar mills in India as of July 31, 2017, with a total capacity of 34 million tonnes of sugar. About half of the mills are privately owned. India needs about 25 million tonnes of sugar. India consumed 18.8 kg of sugar per person in 2016, compared to the global average of 23 kg. India has a total area of 47 lakh hectares. Following are the sugarcane crop acres for each state [30].

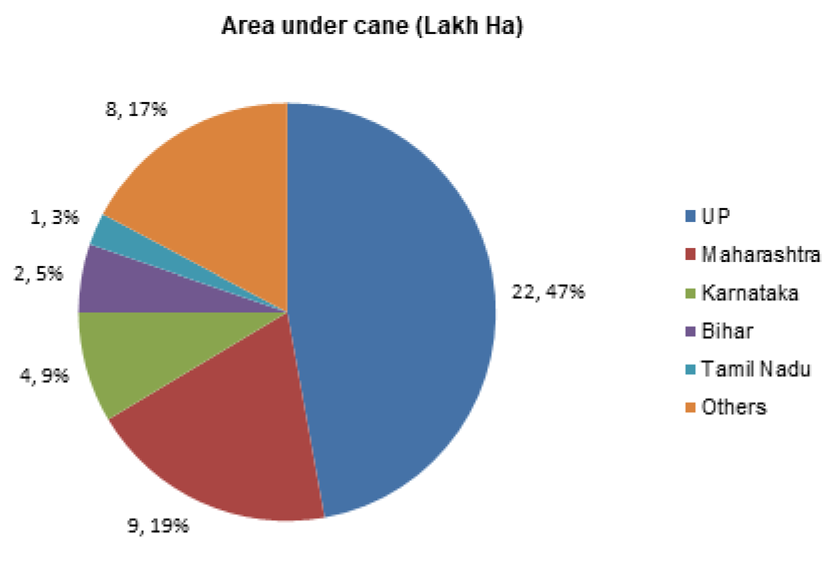

Fig 1.1 State wise sugarcane bagasse ash generation [30]

The primary component is the boiler, where coal is burned to produce high-pressure steam. The combustion of coal releases various pollutants into the atmosphere, including sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter, and greenhouse gases such as carbon dioxide (CO_2). These emissions have been associated with air pollution, climate change, and adverse health effects. To mitigate these environmental concerns, modern coal-fired plants often employ advanced technologies such as electrostatic precipitators and scrubbers to reduce emissions. These technologies help capture and remove particulate matter and certain gases before they are released into the atmosphere.

Fly ash is a byproduct of coal combustion .One of the significant uses of fly ash is in the construction industry. Due to its pozzolanic properties, fly ash can be used as a supplementary cementitious material in the production of concrete and cement-based products.

India used about 214.91 million tonnes (mt) of the 232 mt of fly ash produced in 2020–21. In other words, in 2020–21, 92.41 percent of the fly ash was used. Furthermore, by recycling fly ash from the previous year, 60 out of 202 power utilities were able to use more than 100% of the fly ash. Additionally, 118 power plants out of the 202 that provided data have managed to use fly ash at a rate of between 90% and 100%.[31]

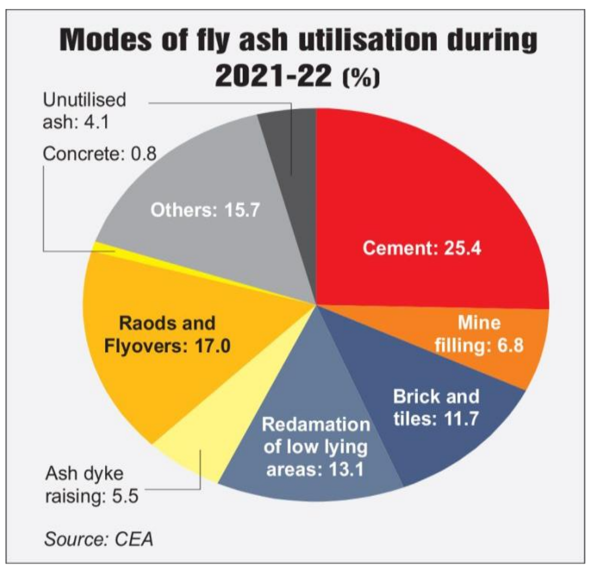

Fig 1.2 Utilization of fly ash by various industries [31]

CHAPTER – 2

LITERATURE REVIEW

2.1 LITERATURE REVIEW

Yun -Feng Li et al. [4]: cement mortar with different steel slag kinds and different dosage of admixtures are studied. Experiments results show the effect of steel slag powder on performance of cement mortar and concrete. When compound mineral admixtures with steel slag powder and blast-furnace slag powder are mixed into, the performance of cement mortar and concrete can be improved further due to the synergistic effect and activation each other. The mineral admixture will be a perfect component of green concrete and its utilization will be a valuable resource for recycling. Compressive and flexural strength of concrete with steel slag powder tend to decrease as the content of steel slag increases. Properties of concrete will be greatly enhanced when compound mineral admixture of steel slag powder and blast furnace slag is mixed into concrete

Yen li et al. [7]: Waste materials with pozzolanic characteristics, such as sewage sludge ash (SSA), coal combustion fly ash (FA), and granulated blast furnace slag (GBS), were reused as partial cement replacements for making cement mortar in this study. Experimental results revealed that with dual replacement of cement by SSA and GBS and triple replacement by SSA, FA, and GBS at 50% of total cement replacement, the compressive strength (Sc) of the blended cement mortars at 56 days was 93.7% and 92.9% of the control cement mortar, respectively. GBS had the highest strength activity index value and could produce large amounts of CaO to enhance the pozzolanic activity of SSA/FA and form calcium silicate hydrate gels to fill the capillary pores of the cement mortar. Consequently, the Sc (compressive strength) development of cement mortar with GBS replacement was better than that without GBS, and the total pore volume of blended cement mortars with GBS/SSA replacement was less than that with FA/SSA replacement. In the cement mortar with modified SSA and GBS at 70% of total cement replacement, Sc at 56 days was 92.4% of the control mortar. Modifying the content of calcium in SSA also increased its pozzolanic reaction. $CaCl_2$ accelerated the pozzolanic activity of SSA better than lime did. Moreover, blending cement mortars with GBS/SSA replacement could generate more monosulfoaluminate to fill capillary pores.

Jorge I tobon et al. [1]: In this paper the effects of Nano silica (NS) on porosity, capillary suction (UNE 8398:2008), compressive strength (ASTM C 349), and sulfate resistance (ASTM C 1012) were evaluated for mortars made with Portland cement (control) and partially replaced with a commercial NS suspension, in percentages by weight of 0%, 1%, 3%, 5%, and 10%. Mortars with a water/binder (w/b) ratio of 0.55 and addition of superplasticizer, for flow correction, were prepared. The improvement of compressive strength is significantly higher in samples with 10 wt. % of NS, after 1 curing day they achieve an increase near to 120% in comparison to the control sample and at other curing ages the increment is close to 80%. In the assessment of sulfate resistance, it was found that, mortars with 5 and 10 wt. % NS decreased expansion by 90% and 95%, respectively after 2 years of immersion.

Abhish m et al. [18]: The paper presents the laboratory investigations carried out on Portland pozzolana cement (PPC) & Portland slag cement (PSC) both are blended cement (factory blended), 53 grade OPC concrete. Here physical properties of ingredient materials were determined in accordance with IS specifications. The investigation is carried out for M30 grade of concrete mix with W/C ratio of 0.43, 0.41, and 0.41 respectively. The design of concrete mix is carried out according to IS method. Tests are carried out for fresh concrete and hardened concrete according to IS code. It has been observed from experimental data that, the blended cement concrete is performing well when compared to conventional concrete. This is due to the fact that the effective diffusion coefficient of various cement particles. However study is to be Carried out longer term to ascertain the strength behavior of concrete.

B. T Naveen Kumar et al. [19]: In this paper the Ordinary Portland cement containing fly ash is used as blended cement to prepare the concrete mix. M 30 grade concrete with water cement of 0.45 is used for the study. The project work involves casting of cubes (150mm x 150mm x 150mm), cylinders (150mm diameter and 300mm height) and prism (100mm x 100mm x

500mm). The concrete specimens are cured under water for 28 days and expose to 400°C, 600°C, and 800°C for 1 hour. The compressive strength, spilt tensile strength and flexure strength are measured for these specimens and compared with the strength of conventional concrete. The strength of each mix is found to increase compared to conventional concrete and a greater increase in strength is observed in mix with partial replacement with nano-metakaolin. The strength is found to increase up to 600°C and showed to decrease at 800°C.

P. M bobby et al. [20]: This paper aims to consolidate the studies conducted on the performance of blended concrete in Marine environment and compare with an experimental analysis. The studies conducted by the researchers all over the world have already derived the applicability of blended concrete in most aggressive environment like marine applications. The main impact of supplementary cementing material is the reduced chloride intrusion thereby reduction in reinforced corrosion. An experimental study was also conducted to analyze the performance of multi blended cement concrete in marine environment. The ternary blended concrete exhibits very good corrosion resistance properties with a nominal reduction in compressive and split tensile strength. And the very good flexural strength in marine environment.

Chow Wee Kang et al. [21]: The main purpose of this study is to investigate the effects of different combinations of ternary blended mortars incorporating supplementary cementitious materials such as Ground Granulated Blast Furnace Slag (GGBS) and Densified Silica Fume (DSF). In this study, mortars were prepared with 100% quarry dust and GGBS was replaced with DSF at 2% step increments up to 16% at a w/b ratio of 0.24. At the same time OPC content was fixed at 50%. The compressive and flexural strength, drying shrinkage, and porosity of mortars were all tested. The results indicated that the increasing DSF content increases; GGBS reduces the superplasticizer dosage for the desired workability of the mortar. The utilization GGBS and DSF has improved the performances ternary blended mortar incorporating quarry dust as a fine aggregate in terms of mechanical strength, drying shrinkage and total porosity tested. The high strength ternary blended mortar incorporating GGBS and DSF exhibited optimum mechanical and durability performance at the OPC: GGBS: DSF ratio of 50:38:12**.**

Sheba babu et al. [22]: The aim of this experimental study was to investigate the durability aspects in terms of the changes in mechanical properties of cement mortar specimens made with OPC and different combinations of various Supplementary Cementitious Materials (SCMs) exposed to ammonium based salt solution prepared using chemical grade ammonium chloride (NH_4Cl). The mortar specimens were exposed to ammonium chloride solution in two different concentrations (1.25 M and 2.5 M) for a maximum exposure duration of two and half months**.** The changes in the mechanical properties were evaluated on the basis of visual assessment, depth of penetration, changes in the compressive strength, changes in Ultrasonic Pulse Velocity (UPV) and relative dynamic modulus of elasticity. From all the test results, it can be concluded that the ternary blended mix with OPC, GGBS and Silica fume (OPC-GGBS-SF) has higher resistance to ammonium chloride attack. The results stress the need to include SCMs and the importance to tailor make the concrete for structures exposed to aggressive environment like ammonium chloride**. .** The SCMs used for the study include Class F Fly ash (FA), Ground Granulated Blast Furnace Slag (GGBS).

J.Ponniah et al. [2]: In this paper a detailed review about the utilization Natural admixture Egg as an admixture and cement is partially replaced by Fly ash and Silica fume. Since Egg is rich in its calcium content the mechanical properties of mortar can be influenced to great extent. Results have concluded that the porosity and permeability for the mortar specimens were found to be highest in increase in percentages of Fly ash and Silica fume. The Percentage of water absorption was found to be minimum in the mix proportion with 15 percentage of fly ash and silica fume as partial replacement to cement and the admixture with 0.75%. The tensile and flexural strength of the mortar specimens were found to be same compared to that of the compression strength, i.e., the strength value was higher for the mix proportions of Fly ash and Silica fume at 15% and natural admixture egg at 0.75%. The values of compression strength of mortar specimens cured under acid curing were found to be lower than that of the water cured specimens.

Dodda Srinivas et al. [23]: This paper represents a study on the strength, durability, and corrosion resistance of quaternary blended mortar made with Portland pozzolana cement (PPC), ground granulated blast furnace slag (GGBS) and rice husk ash (RHA) exposed to marine environment. Binary blended concrete mix using GGBS and RHA as partial replacement for cement is already well established. The optimized quaternary blended mortar specimen's show improved mechanical strengths, both compressive and flexural. These specimens also exhibit enhanced resistance to chloride penetration, corrosion, and water absorption compared to the control mix after 28 days of water curing. A quaternary blended mortar mix prepared with 70% PPC, 20% GGBS, and 10% RHA exhibits the maximum mechanical strength, resistance to chloride penetration, and corrosion, mass loss and water absorption upon exposure to marine environment up to a period of 180 days.

Chandrasekhar Reddy K et al. [24] : In this paper two distinct waste materials, such as palm oil fuel ash (POFA) and sugar cane bagasse ash (SCBA), are used as basic materials in this research, with weight fractions of 0%, 5.0%, 10.0%, 15.0%, 20.0%, and 25.0%, respectively, to substitute for grade 50 MPa concrete. Mechanical properties such as flexural strength, tensile and compressive strength of hybrid reinforced blended concrete were examined in the primary phase at 28 days of age. From the experimental investigation, mechanical properties are enhanced, and higher compressive and flexural strength are achieved as 64 MPa and 7.93 MPa in addition to 20% POFA and SCBA particles. The durable properties of quaternary blended concrete are enhanced properties due to the addition of hybrid materials.

2.1 SUMMARY OF LITERATURE SURVEY

- From the review of journal it is observed that as the steel slag increases the compressive strength and flexural strength is decreases and other durability properties can be improved.
- Adding GGBS as ternary blended material with FA and SSA which produces silica gel and produce a very good durability properties especially in terms of porosity.
- Fly ash can be used pozzolon because of it high density and less loss of weight at high temperature.
- And also since untreated SCBA can't be used for the study a high amount of energy is required to get a treated bagasse ash so we are carrying out study for untreated sample.
- When compared with OPC the blended cement performs well at different water cement ratios and shows good resistance to marine applications with resist to chloride attacks.
- Ternary blended mix with OPC, GGBS and Silica fume (OPC-GGBS-SF) has higher resistance to ammonium chloride attack and. A quaternary blended mortar mix prepared with 70% PPC, 20% GGBS, and 10% RHA exhibits the maximum mechanical strength, resistance to chloride penetration, and corrosion, mass loss and water absorption.
- There is research gap in hybridization of SCBA and fly ash which has to be worked out.

2.3 OBJECTIVES OF PROPOSED WORK

The objective of above titled work includes

- To study the mechanical properties of mortar with partial replacement of cement by SCBA and FA.
- To study the durable properties of mortar with partial replacement of cement by SCBA and FA.
- To find the optimum percentage of replacement which results in good mechanical and durable properties of mortar.

CHAPTER - 3

METHODOLOGY

The methodology to be followed in the project work is explained by the flow chart below

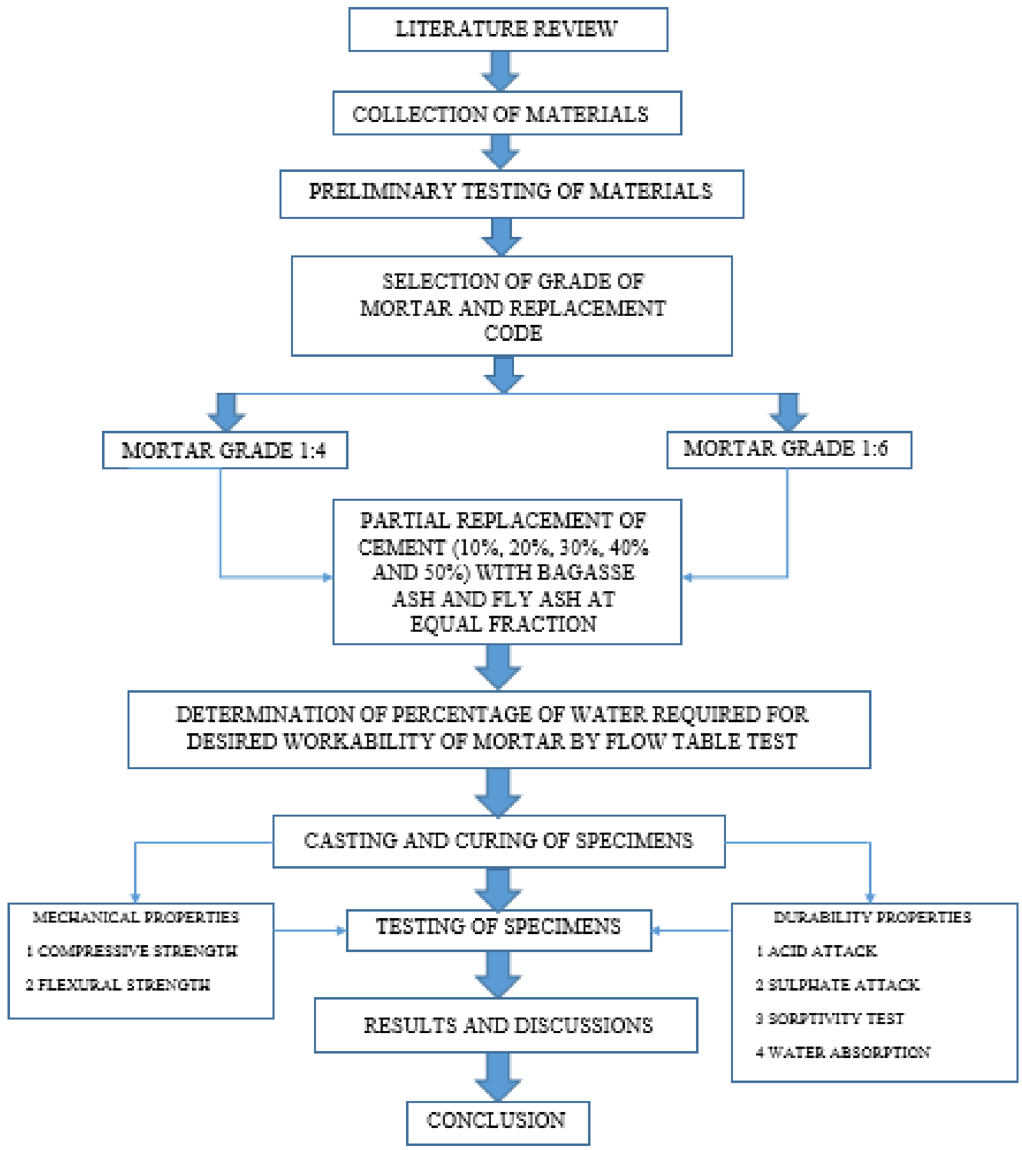

Fig 3.1: Flow chart for the methodology to be followed in the project work

CHAPTER - 4

COLLECTION AND PRELIMINARY TESTING OF MATERIALS

4.1 COLLECTION OF MATERIALS

As the first part of this experimental work, the materials that are selected should conform to IS codes and tests are conducted on the materials as per IS codes.

MATERIAL USED

The materials that are used in the preparation of specimen is having the effect on the strength and durability properties of the mortars. So the materials used in the casting the specimen are

- OPC 43 grade cement
- Manufactured sand
- Sugar cane bagasse ash
- Fly ash
- Water

4.1.1 CEMENT

Ordinary Portland Cement (OPC) is one of the most widely used types of cement in construction. OPC is known for its excellent strength and durability, OPC is primarily composed of calcium, silicon, aluminum, and iron, along with other minor ingredients. It is fundamental ingredient of mortar. In this experiment OPC 43 grade cement was used.

4.1.2 WATER

Portable water was used in the experiment. Contaminated water can cause problems when setting or causes premature failure of the structure. The water used in this experiment is a tap water.

4.1.3 FINE AGGREGATES

Fine aggregate is one of the main constituents of the masonry mortars, M-sand is used as fine aggregate in this experiment. High-quality hard rocks or quarry stones are selected as the raw materials for producing M-sand. And undergo screening process for different size of particles, washed and graded as a build materials. The size of the M-sand ranges from 150 microns to 4.75 mm. Fig 4.1 shows the M-sand used in project work. The factors which affecting the quality of the M-sand are

- Grading
- Particle size
- Particle shape
- Texture
- Fineness modulus

Table 4.1: The physical properties of fine aggregate (Manufacturing sand)

SI.No	Particulars	Results
1	Zone	II
2	Bulk density	1630 kg/m^3
3	specific gravity	2.75

Fig 4.1: Manufactured sand (M-sand) used in the project work

4.1.4 SUGARCANE BAGASSE ASH

Sugar cane bagasse ash, the residual ash is collected from NSL sugars limited which is located at Koppa village, Maddur Taluk, Mandya district. It is dried for 2-3 days so that there is no moisture content in it and sieving is one in order to reduce the particle size of r using it as cement replacement material. Table 4.2 shows physical properties of sugarcane bagasse ash.

Table 4.2: Physical properties of sugar cane bagasse ash

SI.No	Particulars	Results
1	Specific gravity	1.971
2	Fineness	2.62%
3	Color	Black
4	Particle size	150 µ

4.1.5 FLY ASH

Fly ash used in this experiment is collected from the fly ash bricks manufacturing industries in nayandalli Bengluru. C-Type fly ash is collected which is already dried and stored in 25 kg bags. Particle size used for this experiment is 150µm, so as to get the nominal passing of material. Table 4.3 shows physical properties of fly ash.

Table 4.3: Physical properties of fly ash

SI.No	Particulars	Results
1	Specific gravity	2.275
2	Fineness	25.53%
3	Color	White grey
4	Particle size	150 µm

4.2 PRELIMINARY TESTING OF MATERIALS

4.2.1 TESTS ON CEMENT

The following tests are conducted on the cement

4.2.1.1 SPECIFIC GRAVITY OF CEMENT

The specific gravity of cement refers to the ratio of the mass of given volume of sample to mass of equal volume of water at the same temperature, Fig 4.2. Shows specific gravity bottle of 50 ml capacity. The procedure is followed as per IS: 4031-1988 [26]

Fig 4.2: Specific gravity bottle

Table 4.4: The specific gravity test for the cement

SI.No	Observation	Values
1	weight of cement ,W5	50g
2	weight of empty density bottle,W1	65 g
3	Weight of density bottle + distilled water, W2	170g
4	Weight of density bottle + kerosene, W3	151 g
5	Weight of density bottle + cement + kerosene, W4	188 g
6	Specific gravity of kerosene = (W3-W1)/ (W2- W1)	0.82
7	Specific gravity cement = (W5*(W3-W1)/ ((W5 + W3-W4) (W2 -W1))	3.14

4.2.1.2 STANDARD CONSISTENCY

The standard consistency test for cement is a procedure used to determine the amount of water required to produce a cement paste of standard consistency. It helps in assessing the workability and setting characteristics of cement. It is the quantity of water required to be mixed in cement before performing other cement tests. The percentage of water corresponding to 33 to 35mm depth of penetration gives the standard consistency. The procedure is followed as per IS: 4031(PART4)-1988 [26]. Table 4.5 standard consistency test for cement and Fig 4.3 shows Vicat apparatus for consistency test.

Fig 4.3: Vicat Apparatus

Table 4.5: Stand consistency test for cement

SI.No	Description	Trial-1	Trial-2	Trial-3	Trial-4	Trial-5
1	Percentage of water added	25	27	29	30	33
2	Initial reading, mm	42	42	42	42	42
3	Final reading, mm	41	38	25	15	5
4	Height penetrated, mm	1	4	17	27	37

Standard consistency of cement is 33%

4.2.1.3 INITIAL AND FINAL SETTING TIME

The initial and final setting time of cement are essential properties that determine its workability, handling time, and strength development. It is very important to know the initial setting time of cement so that we can assess the time available for concrete to place in the position and it the stage in the hardening process that may result in crack that will not re-unite., Final setting time helps to decide the time required to use the structure as soon as possible. Fig 4.4 shows initial and final setting time test and Table 4.6 shows Initial and Final setting time test .Procedure is in accordance with IS 4031(PART5)-1988 [27].

Fig 4.4: Initial setting time and final setting time conducted

Weight of given sample of cement = 400 gm

The normal consistency of a given cement sample = 33 %

Table 4.6: Initial and Final setting time test

SI.No	Setting Time (min)	Penetration (mm)
1	5	0
2	10	1
3	15	2
4	20	3
5	25	4
6	30	5
7	35	6
8	420	0

INITIAL SETTING TIME	35 min
FINAL SETTING TIME	420 min

4.2.2 TESTS ON FINE AGGREGATE

The following tests were conducted on fine aggregates

4.2.2.1 WATER ABSORPTION AND SPECIFIC GRAVITY OF FINE AGGREGATE

In summary, the specific gravity of sand holds significant importance in concrete mix design, workability, water-cement ratio, porosity, water absorption, grading, filtration applications, and quality control.

The water absorption of fine aggregate significantly impacts the workability, concrete mix design, durability, moisture content control, volume stability, and overall quality of concrete. Fig 4.5 shows the Pycnometer apparatus for specific gravity test and Table 4.7 shows specific gravity and water absorption test for fine aggregate. The water absorption and specific gravity test is conducted as per IS 2386 (PART 3) [28].

Fig 4.5: Pycnometer

Table 4.7: Specific gravity and water absorption test

SI.No	Observation	Values
1	Weight of pycnometer + water + sand, A	1868 g
2	Weight of pycnometer + water, B	1554 g
3	Weight of sample, c	500 g
4	Weight of oven dried sample, D	495 g
5	Specific gravity = D/(C-(A-B))	2.66
6	Apparent specific gravity = D/(D-(A-B))	2.73
7	Water absorption (C-D)/D*100	1

4.2.2.2 SIEVE ANALYSIS ON FINE AGGREGATE

Sieve analysis is a technique used in civil engineering and materials testing to determine the particle size distribution of a granular material. It involves separating the material into different size fractions using a series of standard sieves with varying mesh sizes which is called gradation. The results of sieve analysis are typically presented in the form of a sieve analysis graph or table. The fineness module is a numerical index of fineness, Fig 4.6 shows sieve and sieve shaker used for sieve analysis and Fig 4.7 particle size distribution. The Table 4.8 shows sieve analysis test for fine aggregate. The sieve analysis of performed as IS 2386 part-1 [29]

Fig 4.6: Sieve and Sieve shaker

Table 4.8: Sieve analysis test

IS sieve size	Wt. retained in each sieve (gm)	Percentage Retained	Cumulative Percentage Retained (F)	Percentage passing
4.75 mm	0	0	0	100
2.36 mm	126.93	12.69	12.69	87.30
1.18 mm	294.9	29.49	42.18	57.81
600 µm	146.98	14.69	56.88	43.11
300 µm	145.55	14.55	71.43	28.56
150 µm	178.94	17.89	89.33	10.67
Pan	106.7	10.67	100	0

Weight of sample taken: 1000g

Fineness Modulus = $\frac{\sum F}{100} = \frac{272.52}{100}$ = 2.72 (medium sand)

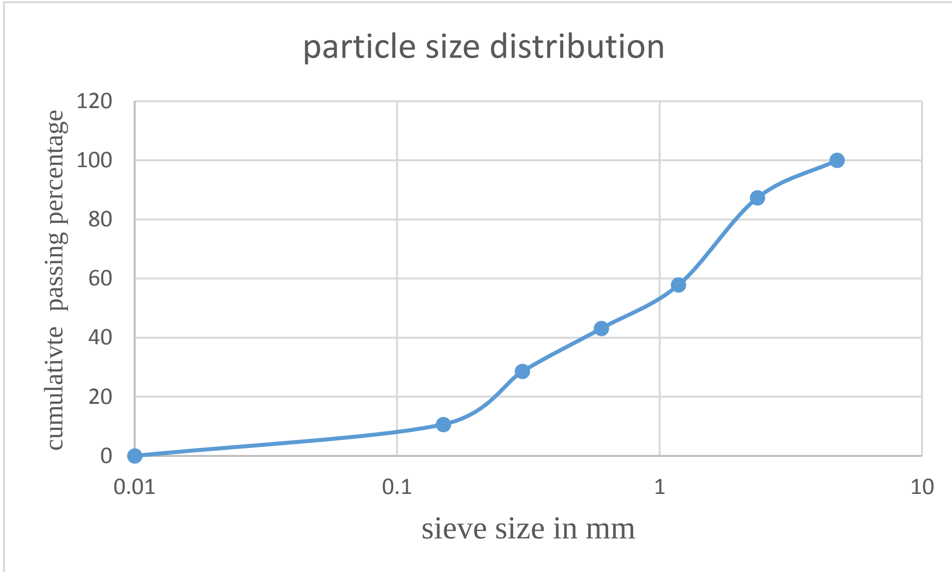

Fig 4.7: Particle distribution graph

4.2.3 TESTS ON BAGASSE ASH AND FLY ASH

4.2.3.1 LOSS ON IGINITION TEST

Loss on ignition = $\frac{W2-W3}{W2-W1}$ X 100

Where

W1 = weight of empty crucible

W2 = Weight of the crucible and the sample

W3 = Weight of crucible and the sample after heating at 900℃ for 1 hour

Fig4.8: Fly ash sample for test and testing of fly ash sample in muffle furnace

Table 4.9: LoI values for Bagasse ash sample

SI.No	Sample type	W1 (gm)	W2 (gm)	W3 (gm)	LoI value (%)
1	Sample sieved through 300 micron	35	52	47.4	27.05
2	Sample sieved through 150 micron	35	50	46.4	24
3	Sample sieved through 90 micron	35	50	49	6.67
4	Sample sieved through 75 micron	35	50	49	6.67

Table 4.10: LoI values for Fly ash sample

SI.No	Sample type	W1 (gm)	W2 (gm)	W3 (gm)	LoI value (%)
1	Sample sieved through 300 micron	36	51.6	51.33	1.73
2	Sample sieved through 150 micron	38	53.6	53.21	2.5
3	Sample sieved through 90 micron	35	46.2	45.57	5.625
4	Sample sieved through 75 micron	35.4	50.9	50.26	4.12

4.2.3.2 CONDUCTOMETERIC METHOD FOR BAGASSE ASH AND FLY ASH

Calculations for bagasse ash:

1. Sample taken =2.5 gms
2. Calcium hydroxide solution taken = 100 ml
3. Initial conductivity value = 4.35 mS
4. Final conductivity value (after 2 mins) = 3.56 mS

The $\Delta\sigma$ 2min value is greater than 0.4 hence the bagasse ash exhibits variable pozzolonicity

Calculations for fly ash:

1. Sample taken = 2.5 gms
2. Calcium hydroxide solution taken = 100 ml
3. Initial conductivity value = 6mS
4. Final conductivity value(after 2 mins) = 4.6 mS

The $\Delta\sigma$ 2min value is greater than 1.4 hence the fly ash exhibits good pozzolonicity

Fig 4.9: Conductometer Apparatus

4.2.4 BAGASSE ASH SIEVING AND FLY ASH

a. Bagasse ash Sample taken for each sieve = 250 grams

Table 4.11: Percentage of bagasse ash passing through each sieve size

SI.No	Sieve size	Passing (gm)	Percentage of passing (%)
1	300	224	89.6
2	150	101.8	40.72
3	90	38	15.2
4	75	5	2

b. Fly ash Sample taken for each sieve = 250 grams

Table 4.12: Percentage of fly ash passing through each sieve size

SI.No	Sieve size	Passing (gm)	Percentage of passing (%)
1	300	223	89.2
2	150	201	80.4
3	90	121.3	48.52
4	75	23	9.2

From the above results it is clear that as fineness of the material increases the strength of the mortar increases, but the sample chosen here is 150 micron over 90 micron because very less particle passes through the 90 micron sieve and also poses difficulty in sieving.

4.2.5 DRY SIEVING OF BAGASSE ASH AND WET SIEVING OF FLY ASH (AS PER IS 1727:1967) [8]

Table 4.13: Dry sieving analysis test

I.S Sieve size	Retained(gm)	Percentage Retained (%)	Cumulative Percentage Retained (F)	Percentage Passing (%)
300	20.1	8.04	8.04	91.96
150	166.9	66.76	74.8	25.2
Pan	63	25.2	100	0

Weight of bagasse ash sample taken = 250gms

Fineness modulus = $\frac{\sum F}{100} = \frac{182.84}{100}$ = 1.82%

4.2.5.1 WET SIEVING OF FLY ASH IN 45 MICRON SIEVE SIZE

Weight of sample takin = 100 grams

Weight of fly ash retained in 45 micron sieve after oven drying at 100℃ for 24 hours = 27.6 grams

Percentage of fly ash retained is $\frac{27.6}{100}$ x 100 = 27.6%

Note: As per IS 2386 Part 1, the allowable range is from 22% to 34%, so it is satisfied.

4.2.6 SPECIFIC GRAVITY OF BAGASSE ASH AND FLY ASH

Table 4.14: Specific gravity of bagasse ash and fly ash

SI.No	Sample size	Specific gravity
1	Sample of bagasse ash passing through 150 micron sieve	1.971
2	Sample of fly ash passing through 150 micron sieve	2.275

4.2.7 TESTS ON BLENDED CEMENT

Standard consistency and initial and final setting time tests are conducted on blended cement replaced up to 50 %(bagasse ash + fly ash) as per IS 4031(PART -4, 5)-1988 [26, 27]. Table 4.15 shows the comparison of cement with blended cements for standard consistency, Initial setting time and final setting time.

Table 4.15: Comparison between cement and blended cements for standard Consistency, Initial setting time and Final setting time

SI. No	Tests	Cement	10% replace ment (5% bagasse ash 5% + fly ash)	20% replace ment (10% bagasse ash + 10% fly ash)	30% replacem ent (15% bagasse ash + 15% fly ash)	40% replacem ent (20% bagasse ash + 20% fly ash)	50% replacem ent (25% bagasse ash + 25% fly ash)
1	Standard consistency	33%	39%	52%	61%	69%	78%
2	Initial setting time	35 min	145 min	245 min	300 min	360 min	400 min
3	Final setting time	420	600	720	815	940	1200

CHAPTER - 5

SELECTION AND TESTING OF MORTARS GRADES WITH REPLACEMENT CODE

The specimens that are taken for study is cube of 50 mm and 70.6 mm in size for compressive strength test and durability tests like sulphate attack, acid attack, water absorption test and sorptivity test. Table 5.1 shows details of test used in the project.

Table 5.1: Details of test samples

Type of sample mould	Type of test	Size (mm)
Cube mould	Compressive strength	50x50x50 mm 70.6x70.6x70.6 mm
Prism mould	Flexural strength	160x40x40 mm

The Grade of mortar used in the project is MM 3 and MM 7.5 from IS 2250:1981 code and replacement code given are A1, B1, C1, D1, E1 and F1 for 1:4 grade mortar and A2, B2, C2, D2, E2, F2, for 1:6 grade mortar with 10%, 20%, 30%, 40% and 50% replacement with equal proportion of bagasse ash and fly ash respectively. Table 5.2 and Table 5.3 shows details of mortar mix identity and water cement ratio for both the grade of mortar.

Table5.2: Replacement proportions of cement by fly ash and Bagasse ash for MM 7.5 Grade mortar

SI.No	Mortar mix identity	Mortar mix (MM7.5 Grade)	W/c ratio
1	A1	1Cement (100%):4 sand	0.77
2	B1	1Cement (90% Cement+5% fly ash+5% bagasse ash):4 Sand	1.02

3	C1	1 Cement (80% Cement+10% flyash+10% Bagasse ash):4 Sand	1.04
4	D1	1 Cement (70% Cement+15% flyash+15% bagasse ash):4 Sand	1.06
5	E1	1 Cement (60%Cement+20% flyash+20% bagasse ash):4 Sand	1.11
6	F1	1 Cement (50% Cement+25% flyash+25% bagasse ash):4 Sand	1.12

Table 5.3: Replacement proportions of cement by fly ash and bagasse ash for MM 3 Grade mortar

SI.No	Mortar mix identity	Mortar mix (MM 3 Grade)	W/c ratio
1	A2	1Cement (100%):6 sand	0.81
2	B2	1Cement (90% Cement+5% fly ash+5% bagasse ash):6 Sand	1.09
3	C2	1 Cement (80% Cement+10% flyash+10% Bagasse ash):6 Sand	1.23
4	D2	1 Cement (70% Cement+15% flyash+15% bagasse ash):6 Sand	1.28
5	E2	1 Cement (60%Cement+20% flyash+20% bagasse ash):6 Sand	1.38
6	F2	1 Cement (50% Cement+25% flyash+25% bagasse ash):6 Sand	1.7

5.1 TESTS ON FRESH MORTAR

FLOW TABLE TEST

Place the mould in the Centre after thoroughly cleaning and drying the flow-table top. Apply grease lightly for smooth flow and Place a layer of mixed mortar about 25 mm thick and tamper it for 20 times with tampering rod, the tamping pressure must be precisely right to guarantee that the mould is filled evenly. After that, add mortar to the mould and compact it according to the first layer's instructions. Cut the surplus mortar to a plane that is flush with the top of the mould by sawing across the top of the mould with the straight edge of a trowel that is held almost perpendicular to the mould. Cleanse and dry the table, taking special care to remove any debris or water from the area at the edge of the flow mould. The mould should be lifted after this and immediately drop the table through a height of 12.5 mm, 25 times in 15Sec. Fig 5.1 shows the flow table apparatus for flow table test. The average base diameter of the mortar mass is measured on at least four diameters at roughly equal intervals and expressed as a percentage of the initial base diameter is the flow percentage

Fig 5.1: Flow table apparatus

5.2 TEST ON HARDENED MORTAR

5.2.1 MECHANICAL PROPERTIES

1. Compressive strength Test [11]: The specimen must be analyzed as soon as it is taken out of the curing water it was stored in and while it is still wet. Before testing, the specimen's dimensions must be recorded. The specimen must be inserted into the testing device with the bearing surfaces of the device thoroughly cleaned and dried, with the load applied to the opposing sides of the cast cube and not on the top and bottom. The load shall be applied at the rate140 kg/cm^2 per minute with any shock or sudden impact load then the maximum load at which the specimen breaks shall be noted in kN and later to MPa. The compressive strength is Maximum load at failure to that of cross sectional area of the specimen. Always consider the average of the three values for the corresponding mix. Fig 5.2 shows load application and failure pattern of specimens

Compressive strength = P/A in MPa

Where,

P = maximum load at failure

A = cross section area of the specimen

Fig 5.2: Load application from UTM and failure pattern observed in specimen

2. Flexure strength test for the mortar cubes [25]: The strength in bending of mortar beams is measured as flexural strength (160 x 40 x 40 mm)**.** Before testing, ensure that the surfaces of the mortar beams are clean and free from any irregularities. If necessary, lightly sand the surfaces to ensure uniform contact with the loading points. The commonly used span length for mortar beams is 120 mm. Ensure that the supports are level and parallel. Apply the load at the center of the beam using the flexural testing machine. Gradually increase the load at a constant rate until failure occurs or the desired maximum load is reached. The recommended rate of loading is 10 N/mm² per minute. Record the maximum load and corresponding deflection at failure or the desired maximum load. And the flexural strength is calculated from the formula. Fig 5.3 shows the failure pattern of prism after load application.

$$\text{Flexural strength } (f_b) = \frac{3Pxa}{2xbxd^2} \text{ in MPa}$$

Where,

P = Breaking load, KN

a = Length between the two roller support in mm

b = Mortar beam’s breadth

d = Mortar beam’s depth

Fig 5.3: Failure pattern observed after testing the flexural strength of prism

5.2.2 DURABILITY PROPERTIES

1. Acid attack test [14]: This test is performed to assess the effect of acid on hardened mortar cubes after 28 days curing. The specimen is takin out after curing and dried for 24 hours, to perform this test 5% hydrochloric acid was taken to the weight of water required to immerse all the cubes and make sure that the container used for the test is non-reactive to the acid. Then measure the initial weight of the sample cubes and immerse the cubes in the acid solution and measure the loss in weight of the specimen for every week up to two weeks, care should be taken that the solution must be verified once a week to maintain same concentration.

2. Sulphate attack [13]: This test is performed to assess the resistance of mortar cubes which is immersed in sulphate solution after 28 days of curing. The specimen is taken out after curing and dried for 24 hours and to prepare the solution we need 50 g of sodium sulphate or magnesium sulphate for every 900 ml of water and solution is prepared. Make sure that the container used for immersion should be non-reactive. Firstly measure the initial weight of the cubes, then immerse the mortar cubes in sulphate solution and measure the loss of weight of the specimen for every week up to 2 weeks, Fig: 5.4 sample immersed in HCl and sodium sulphate for durability test. Finally measure the loss of compressive strength after 21 days of immersion and compare the values of normal water cured cubes.

Fig 5.4: Mortar cubes immersed in HCL and sodium sulphate for durability test

3. Water absorption test [15]: First cure the **s**pecimen as per the requirement of your work say 28 days. Then keep the specimen in air 48 hours then place the specimen in the oven at 100 to105℃ for 24 hours and then take the specimen out of oven after a while and allow it to cool down to room temperature and then take the oven dry weight of the specimen as A and immerse the specimen in the fresh water for 24 hours and then take out the specimen and wipe with cloth to surface dry it and take the surface dry weight as B and express the result as percentage of water absorption. Fig: 5.5 shows oven dry sample immersed in water.

Percentage of water absorption = $\frac{B-A}{A} X\ 100$ Where,

A = Initial weight of 28 days cured and oven dried sample

B = Final weight of surface dried sample after 24 hours immersion in water

Fig 5.5: Sample immersed for 24 hours in the free water

4. Sorptivity test for mortar [12]: This test method is used determine that rate of water absorption when only one surface of the specimen is made to come in contact with water (sorptivity). The procedure for this test is first take out the sample from water which is cured for 28 days and oven dry it for 24 hours at 100 to 105 °C, then wrap the specimen at all three sides out of four with electric insulation tap and place it on the non-water absorbing support which is placed 2 to 3 mm below water level so that when the specimen is placed on the support 2 to 3 mm of water is contact with specimen and before immersing measure the initial weight of the sample and also exposed area of the specimen in mm^2 and take the reading as per the table given below and finally the sorptivity is measured from the formula below. Table 5.4 shows sorptivity test table for sample.

Table 5.4: Sorptivity test conduction table for time interval and tolerance

time	60S	5 min	10 min	20 min	30 min	60 min	Every hour up to 6h	once a day unto 3 days	day 4 to 7,3 measurement 24 hours apart
tolerance	2S	10S	2min	2min	2min	2min	5min	2h	2h

$$I = \frac{m_t}{a \times d} \; in\ mm/s^{\frac{1}{2}}$$

Where

I = water absorption

m_t = change in specimen mass in grams

a = area of specimen in contact in mm^2

d = density of water in g/mm^3

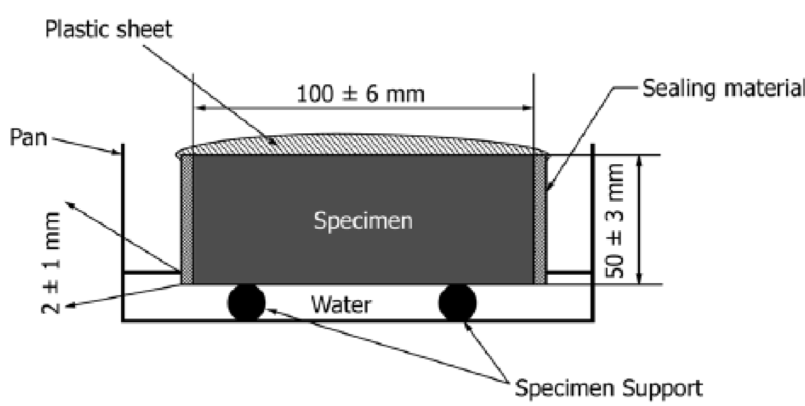

Fig 5.6: Sorptivity test setup

5.3 FLOW TABLE TEST

5.3.1 FLOW TABLE TEST FOR CONVENTION MORTAR 1:4

(VOLUME CALCULATIONS AS PER APPENDIX A1)

Mould dimensions:

Top diameter of the mould = 7 cm

Bottom diameter of the mould = 10 cm

Average diameter of the mould = 8.5 cm

Flow percentage = $\frac{Average\ flow\ dia - Average\ dia\ of\ mould}{Average\ dia\ of\ mould}$ x 100

Fig 5.7

Fig 5.8

Fig 5.9

Fig 5.7, 5.8 and 5.9: Flow table test conducted for blended cement mortars of different proportions

The flow table test is conducted for conventional mortar of grade 1:4 (A1) and the water percentage recorded for 85% flow rate is 77.5% and Table 5.5 shows the percentage of water added to that of corresponding flowrate for the above mentioned mortar mix and Fig 5.10 shows the water percentage versus flow percentage for above mentioned mortar mix.

Table 5.5: Percentage of the water added and flow percentage for the conventional mortar 1:4

Percentage of water added (%)	Flow percentage (%)
75	68
80	103
85	137
90	172

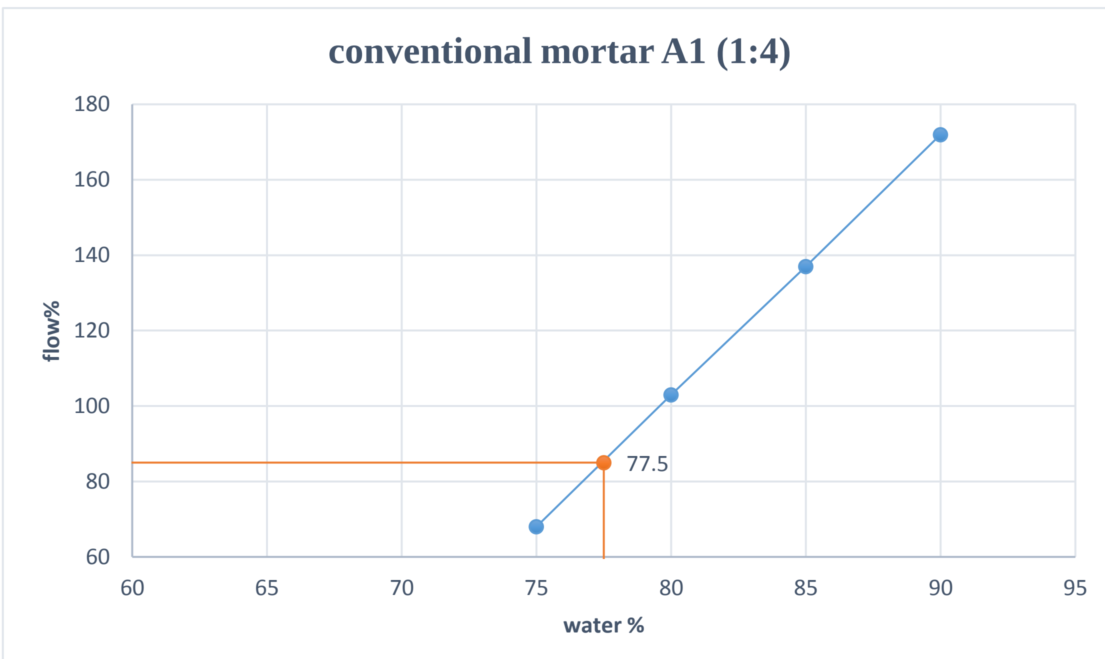

Fig 5.10 Flow percentage versus water percentage for conventional mortar 1:4

5.3.2 FLOW TABLE TEST FOR CONVENTION MORTAR 1:6

(VOLUME CALCULATIONS AS PER APPENDIX A2)

The flow table test is conducted for conventional mortar of grade 1:6 (A2) and the water percentage recorded for 85% flow rate is 81% and Table 5.6 shows the percentage of water added to that of corresponding flow rate for the above mentioned mortar mix and Fig 5.11 shows the water percentage versus flow percentage for above mentioned mortar mix.

Table 5.6: Percentage of the water added and flow percentage for the conventional mortar 1:6

Percentage of water added (%)	Flow percentage (%)
75	74
80	84
85	93
90	102
95	111

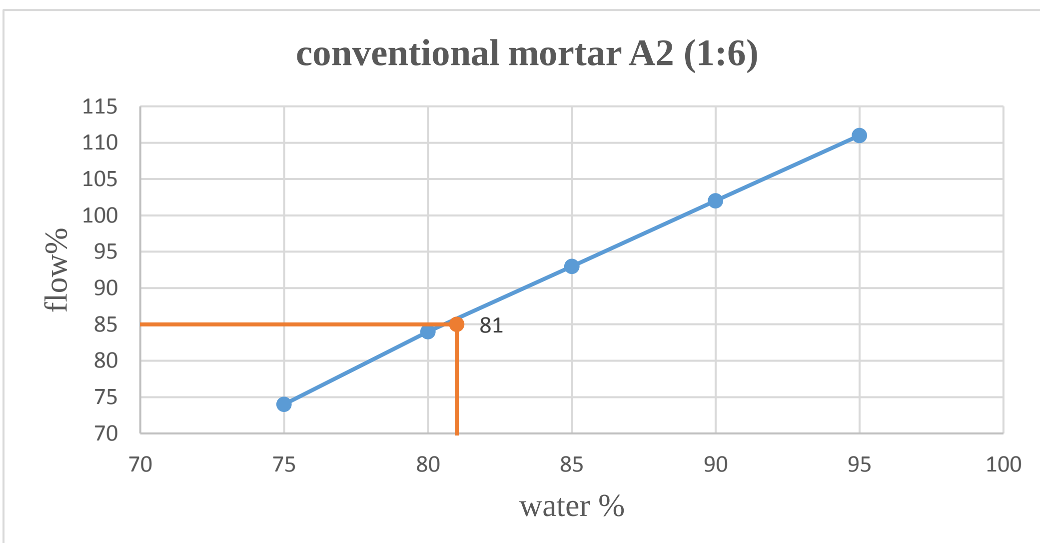

Fig 5.11: Flow percentage versus water percentage for conventional mortar 1:6

5.3.3 FLOW TABLE TEST FOR CEMENT REPLACEMENT 10% (1:4 ratio)

(VOLUME CALCULATIONS AS PER APPENDIX B1)

The flow table test is conducted for conventional mortar of grade 1:4 (B1) and the water percentage recorded for 85% flow rate is 101% and Table 5.7 shows the percentage of water added to that of corresponding flow rate for the above mentioned mortar mix and Fig 5.12 shows the water percentage versus flow percentage for above mentioned mortar mix.

Table 5.7: Percentage of the water added and flow percentage for the 10% cement replacement (5% bagasse ash + 5% fly ash) mortar 1:4 ratio

Percentage of water added (%)	Flow percentage (%)
80	60
85	70
90	80
100	84
105	89

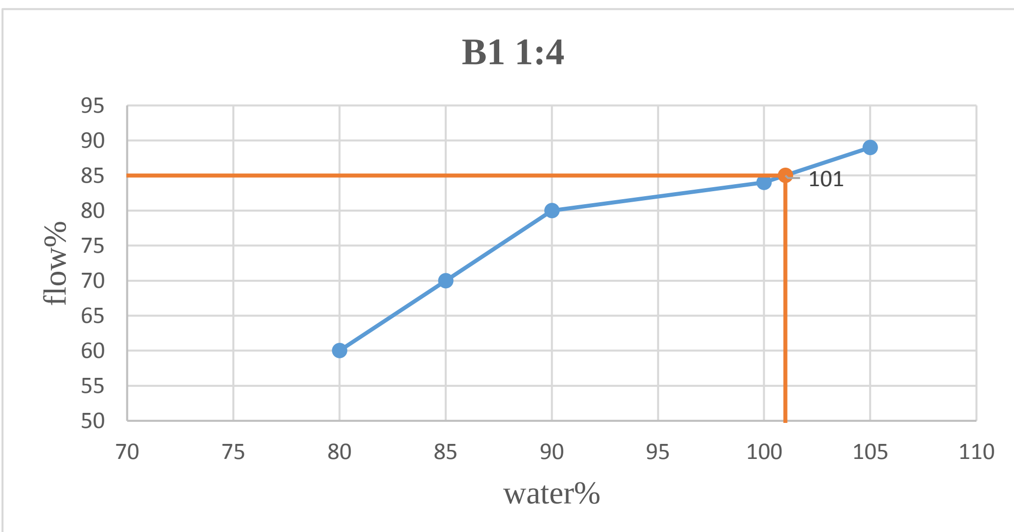

Fig. 5.12: Flow percentage versus water percentage for 10% replacement cement (5% bagasse ash + 5% fly ash) mortar (1:4 ratio)

5.3.4 FLOW TABLE TEST FOR CEMENT REPLACEMENT 10% (1:6 ratio)

(VOLUME CALCULATIONS AS PER APPENDIX B2)

The flow table test is conducted for conventional mortar of grade 1:6 (B2) and the water percentage recorded for 85% flow rate is 110% and Table 5.8 shows the percentage of water added to that of corresponding flow rate for the above mentioned mortar mix and Fig 5.13 shows the water percentage versus flow percentage for above mentioned mortar mix.

Table 5.8: Percentage of the water added and flow percentage for the 10% cement replacement (5% bagasse ash + 5% fly ash) mortar 1:6 ratio

Percentage of water added (%)	Flow percentage (%)
90	59
100	79
110	85
120	92

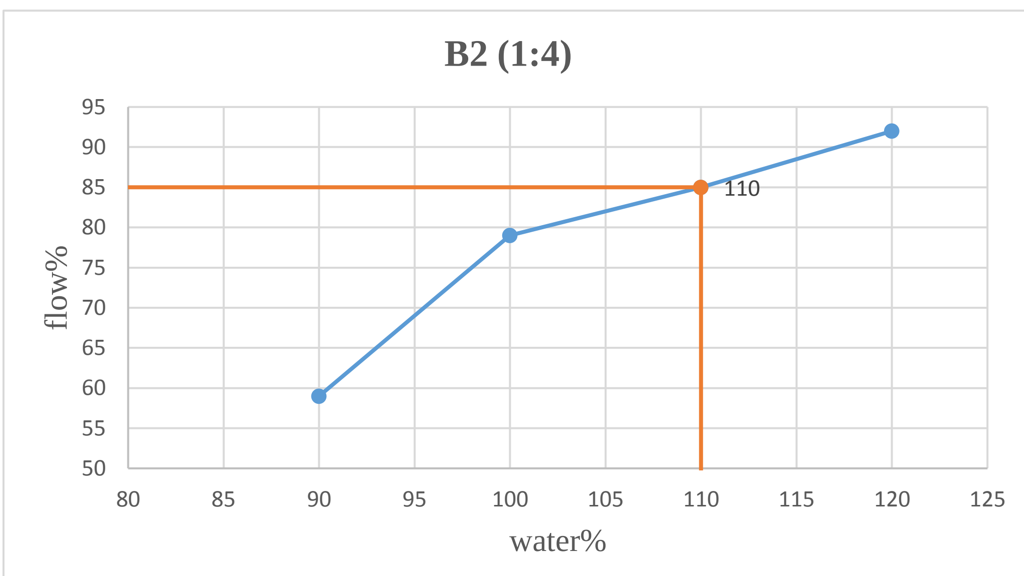

Fig 5.13: Flow percentage versus water percentage for 10% replacement cement (5% bagasse ash + 5% fly ash) mortar (1:6 ratio)

5.3.5 FLOW TABLE TEST FOR CEMENT REPLACEMENT 20% (1:4 ratio)

(VOLUME CALCULATIONS AS PER APPENDIX C1)

The flow table test is conducted for conventional mortar of grade 1:4 (C1) and the water percentage recorded for 85% flow rate is 104% and table 5.9 shows the percentage of water added to that of corresponding flow rate for the above mentioned mortar mix and fig 5.14 shows the water percentage versus flow percentage for above mentioned mortar mix.

Table 5.9: Percentage of the water added and flow percentage for the 20% cement replacement (10% bagasse ash + 10% fly ash) mortar 1:4 ratio

Percentage of water added (%)	Flow percentage (%)
95	38
100	65
105	92
110	119

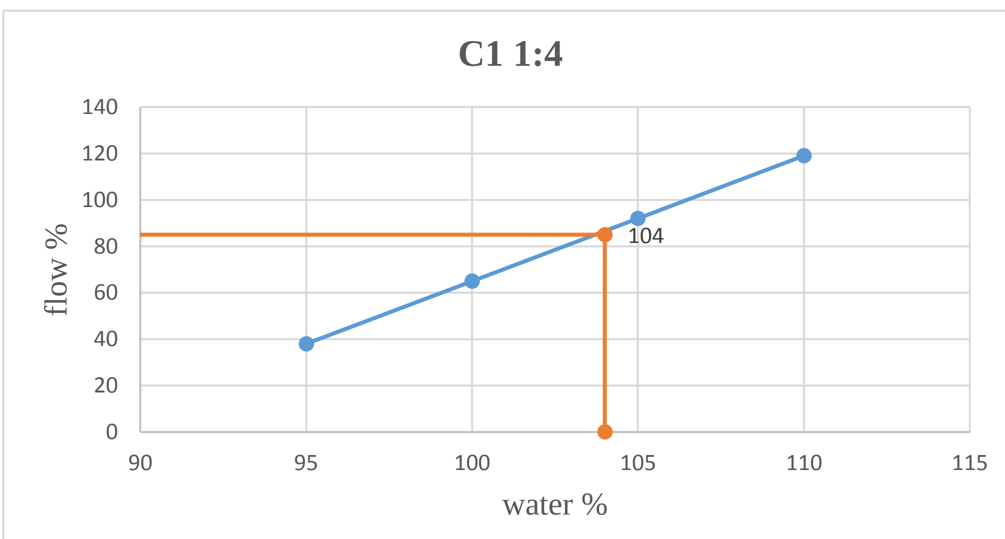

Fig 5.14: Flow percentage versus water percentage for 20% replacement cement (10% bagasse ash + 10% fly ash) mortar (1:4 ratio)

5.3.6 FLOW TABLE TEST FOR CEMENT REPLACEMENT 20% (1:6 ratio)

(VOLUME CALCULATIONS AS PER APPENDIX C2)

The flow table test is conducted for conventional mortar of grade 1:6 (C2) and the water percentage recorded for 85% flow rate is 121.2% and table 5.10 shows the percentage of water added to that of corresponding flow rate for the above mentioned mortar mix and fig 5.15 shows the water percentage versus flow percentage for above mentioned mortar mix.

Table 5.10: Percentage of the water added and flow percentage for the 20% cement replacement (10% bagasse ash + 10% fly ash) mortar 1:6 ratio

Percentage of water added (%)	Flow percentage (%)
110	63
115	72
120	80
125	101.5

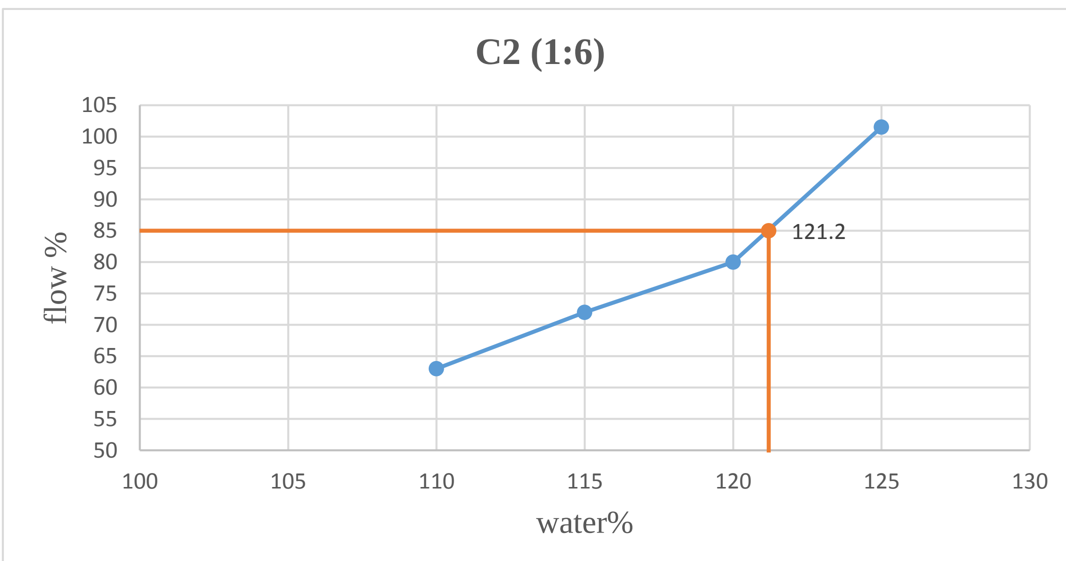

Fig 5.15: Flow percentage versus water percentage for 20% replacement cement (10% bagasse ash + 10% fly ash) mortar (1:6 ratio)

5.3.7 FLOW TABLE TEST FOR CEMENT REPLACEMENT 30% (1:4 ratio)

(VOLUME CALCULATIONS AS PER APPENDIX D1)

The flow table test is conducted for conventional mortar of grade 1:4 (D1) and the water percentage recorded for 85% flow rate is 106% and table 5.11 shows the percentage of water added to that of corresponding flow rate for the above mentioned mortar mix and fig 5.16 shows the water percentage versus flow percentage for above mentioned mortar mix.

Table 5.11: Percentage of the water added and flow percentage for the 30% cement replacement (15% bagasse ash + 15% fly ash) mortar 1:4 ratio

Percentage of water added (%)	Flow percentage (%)
100	58
105	81
110	106
115	118

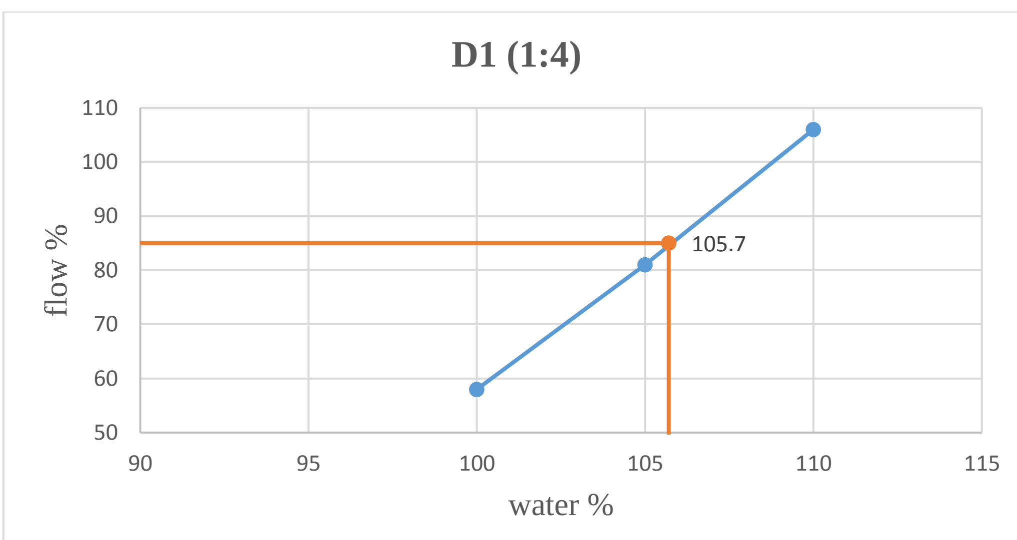

Fig 5.16: Flow percentage versus water percentage for 30% replacement cement (15% bagasse ash + 15% fly ash) mortar (1:4 ratio)

5.3.8 FLOW TABLE TEST FOR CEMENT REPLACEMENT 30% (1:6 ratio)

(VOLUME CALCULATIONS AS PER APPENDIX D2)

The flow table test is conducted for conventional mortar of grade 1:6 (D2) and the water percentage recorded for 85% flow rate is 127.5% and Table 5.12 shows the percentage of water added to that of corresponding flow rate for the above mentioned mortar mix and fig 5.17 shows the water percentage versus flow percentage for above mentioned mortar mix.

Table 5.12: Percentage of the water added and flow percentage for the 30% cement replacement (15% bagasse ash + 15% fly ash) mortar 1:6 ratio

Percentage of water added (%)	Flow percentage (%)
115	61
120	74
125	81.5
130	89

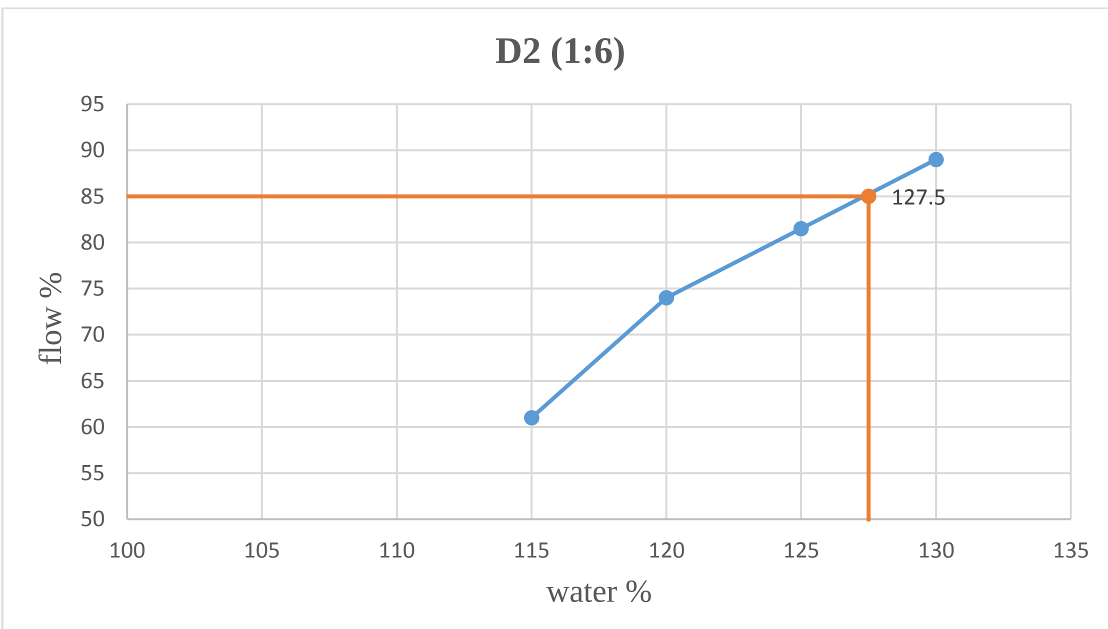

Fig 5.17: Flow percentage versus water percentage for 30% replacement cement (15% bagasse ash + 15% fly ash) mortar (1:6 ratio)

5.3.9 FLOW TABLE TEST FOR CEMENT REPLACEMENT 40% (1:4 ratio)

(VOLUME CALCULATIONS AS PER APPENDIX E1)

The flow table test is conducted for conventional mortar of grade 1:4 (E1) and the water percentage recorded for 85% flow rate is 116% and Table 5.13 shows the percentage of water added to that of corresponding flow rate for the above mentioned mortar mix and Fig 5.18 shows the water percentage versus flow percentage for above mentioned mortar mix.

Table 5.13: Percentage of the water added and flow percentage for the 40% cement replacement (20% bagasse ash + 20% fly ash) mortar 1:4 ratio

Percentage of water added (%)	Flow percentage (%)
105	72
110	79
115	84
120	90

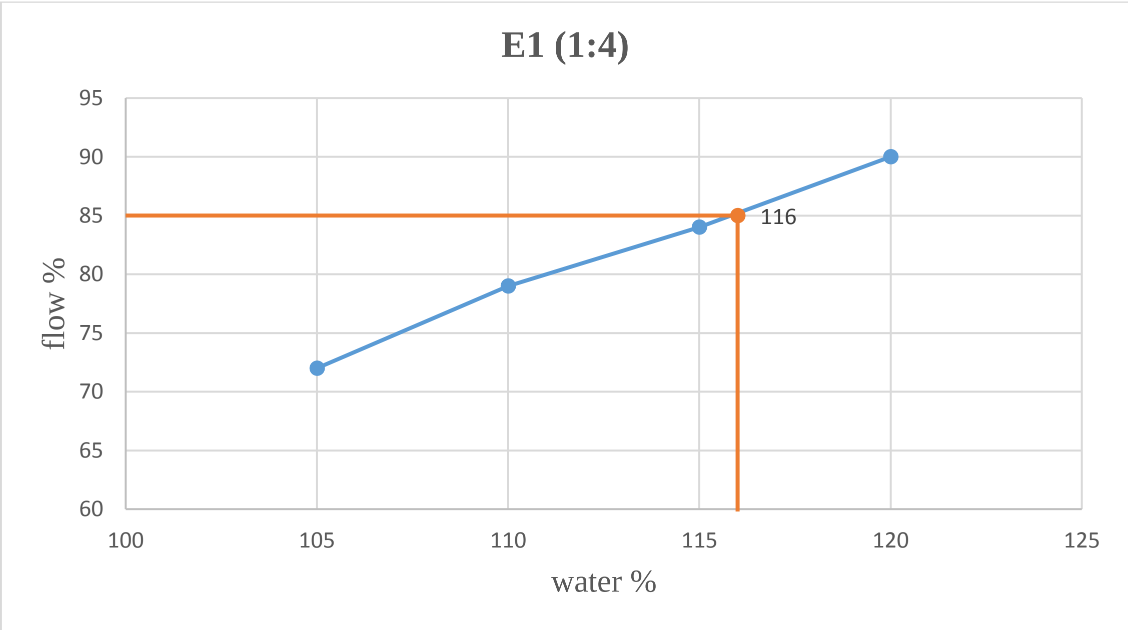

Fig 5.18: Flow percentage versus water percentage for 40% replacement cement (20% bagasse ash + 20% fly ash) mortar (1:4 ratio)

5.3.10 FLOW TABLE TEST FOR CEMENT REPLACEMENT 40% (1:6 ratio)

(VOLUME CALCULATIONS AS PER APPENDIX E2)

The flow table test is conducted for conventional mortar of grade 1:6 (E2) and the water percentage recorded for 85% flow rate is 134.5% and Table 5.14 shows the percentage of water added to that of corresponding flow rate for the above mentioned mortar mix and Fig 5.19 shows the water percentage versus flow percentage for above mentioned mortar mix.

Table 5.14: Percentage of the water added and flow percentage for the 40% cement replacement (20% bagasse ash + 20% fly ash) mortar 1:6 ratio

Percentage of water added (%)	Flow percentage (%)
125	65.6
130	76
135	86.2
140	96.5

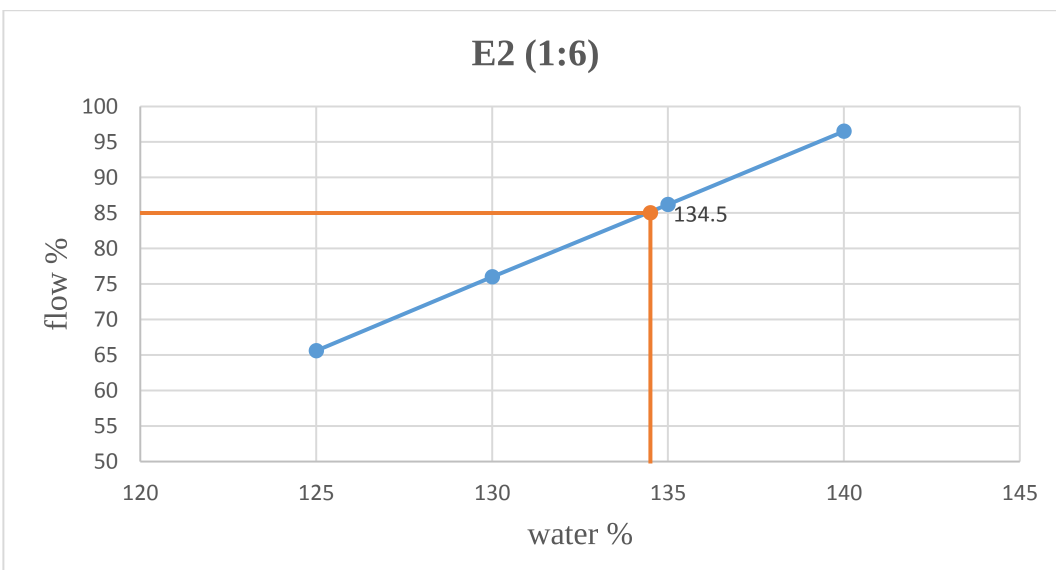

Fig 5.19: Flow percentage versus water percentage for 40% replacement cement (20% bagasse ash + 20% fly ash) mortar (1:6 ratio)

5.3.11 FLOW TABLE TEST FOR CEMENT REPLACEMENT 50% (1:4 ratio)

(VOLUME CALCULATIONS AS PER APPENDIX F1)

The flow table test is conducted for conventional mortar of grade 1:4 (F1) and the water percentage recorded for 85% flow rate is 121.7% and Table 5.15 shows the percentage of water added to that of corresponding flow rate for the above mentioned mortar mix and Fig 5.20 shows the water percentage versus flow percentage for above mentioned mortar mix.

Table 5.15: Percentage of the water added and flow percentage for the 50% cement replacement (25% bagasse ash + 25% fly ash) mortar 1:4 ratio

Percentage of water added (%)	Flow percentage (%)
115	53
120	76
125	102
130	128

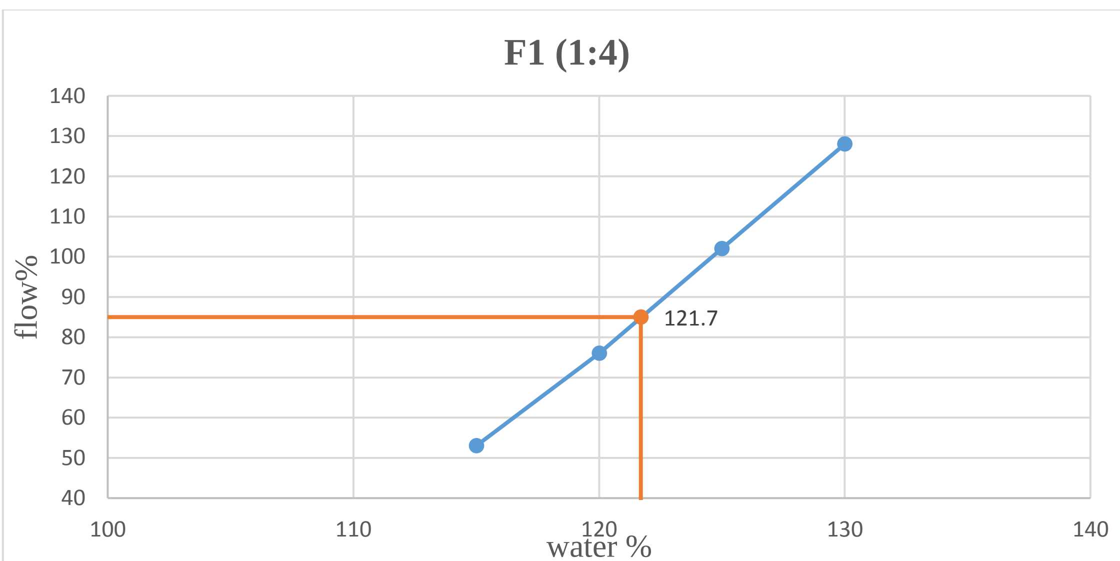

Fig 5.20: Flow percentage versus water percentage for 50% replacement cement (25% bagasse ash + 25% fly ash) mortar (1:4 ratio)

5.3.12 FLOW TABLE TEST FOR CEMENT REPLACEMENT 50% (1:6 ratio)

(VOLUME CALCULATIONS AS PER APPENDIX F2)

The flow table test is conducted for conventional mortar of grade 1:6 (F2) and the water percentage recorded for 85% flow rate is 176.6 % and Table 5.16 shows the percentage of water added to that of corresponding flow rate for the above mentioned mortar mix and Fig 5.21 shows the water percentage versus flow percentage for above mentioned mortar mix.

Table 5.16: Percentage of the water added and flow percentage for the 50% cement replacement (25% bagasse ash + 25% fly ash) mortar 1:6 ratio

Percentage of water added (%)	Flow percentage (%)
150	68.66
160	75.32
170	82
180	86
190	93

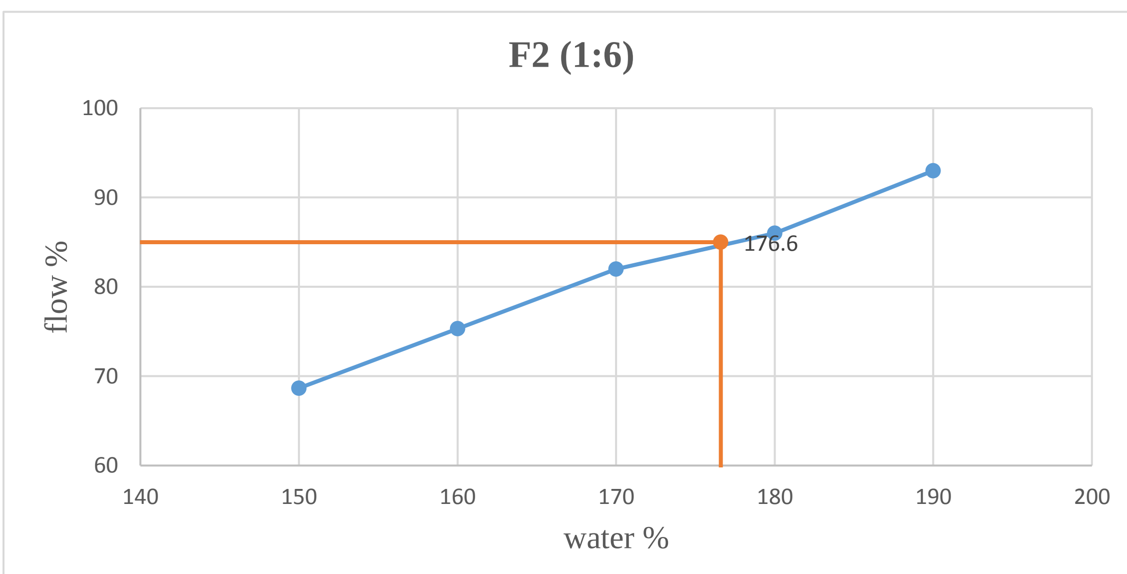

Fig 5.21: Flow percentage versus water percentage for 50% replacement cement (25% bagasse ash + 25% fly ash) mortar (1:6 ratio)

5.4 CASTING AND CURING OF TEST SPECIMENS

5.4.1 MIXING:

Mixing of mortar is carried out in the following steps:-

- Collect all the required materials for mixing mortar, including cement, sand, water, and any additives or admixtures as specified by the project requirements.
- Refer to the project specifications or relevant standards to determine the proper ratio of cement to sand for the desired mortar strength and consistency.
- Ensure that the mixing area is clean and free from debris. Use a clean and sturdy mixing container, such as a wheelbarrow or mortar mixing box.
- Mix the mortar until it reaches the desired consistency, Inspect the mortar mixture for uniform color and consistency. Make sure there are no clumps or dry spots in the mixture.
- Water is finally added and mixing is done until the mortar seems to be homogenous and of the desired consistency.
- When the cement is replaced with the bagasse ash and fly ash in the mortar mix, the amount of bagasse ash and fly ash to replace cement in the mix is carefully measured and then thoroughly mix them as the above steps.

Fig 5.22: Mixing of mortar

5.4.2 CASTING OF SPECIMENS:

Mould of sizes 50 x 50x 50 mm, 70.6 x 70.6 x 70.6 mm and prism mould of 40 x 40 x 160 mm are used in this experimental work.

Following are the steps are carried out while casting mortar in the cub moulds

- Ensure that the cube molds are clean and free from any debris or previous residue. The mould internal faces should be correct and precise. All the angles to adjacent face will be at right angles.
- Apply a thin layer of mold release agent or oil to the interior surfaces of the molds to facilitate easy removal of the hardened mortar cubes.
- The mortar should be filled in three layers
- Each layer should be compacted with 35 strokes per layer and finally kept on vibrating machine for final compaction
- Use a straight edge or trowel to strike off the excess mortar from the top surface of the molds. Ensure that the mortar surface is level and flush with the top edges of the molds.

Fig 5.23: Casting of test specimens

5.4.3 CURING:

After casting the specimens are kept for 24 hours in mould for final set. And then the specimen are removed from mould. To identify the specimen, marking should be done. The curing duration for mortar cubes may vary depending on factors such as cement type, mix design, and project specifications. Generally, curing periods can range from 7 to 56 days. The cubes should be cured in the fresh water, due to exothermic setting of specimen, care should be taken to avoid freezing or overheating. Improper curing may result in scaling, reduced strength, whereas proper curing results in good strength. Fig 5.24 shows the curing of specimens in plastic tub

Fig 5.24: Curing of specimens

5.5 TESTING OF SPECIMENS

5.5.1 COMPRESSION TEST RESULTS AT 7 DAYS

The compression test was conducted for the 50 mm cube specimens which is cured for 7 days, 28 days and 56 days for two grades of mortar (1:4, 1:6) which is partial replaced by bagasse ash and fly ash from 10% to 50% at equal proportion and the results are taken below in Table No 5.17, 5.18, 5.19, 5.20, 5.21 and 5.22.

Table 5.17: Compression test results for 1:4 proportion mortar for7 days

Mould size	Mortar mix identity	Sample	Load in kN	Stress in MPa	Average stress value in MPa	Compliance status (as per IS 2250:1981)
50x50x50 mm	A1	cube 1	26	10.4	10.66	MM 7.5 complied
		cube 2	27	10.8		
		cube 3	27	10.8		
	B1	cube 1	17.5	7	7.16	MM 7.5 complied
		cube 2	18	7.2		
		cube 3	18.2	7.28		
	C1	cube 1	13.2	5.28	5.3	MM 7.5 complied
		cube 2	13	5.2		
		cube 3	13.6	5.44		
	D1	cube 1	7.4	2.96	3	MM 7.5 complied
		cube 2	7.4	2.96		
		cube 3	7.8	3.12		
	E1	cube 1	9.2	3.68	3.72	MM 7.5 complied
		cube 2	9.6	3.84		
		cube 3	9.1	3.64		
	F1	cube 1	6.2	2.48	2.41	MM 7.5 complied
		cube 2	6	2.4		
		cube 3	5.9	2.36		

5.5.1 COMPRESSION TEST RESULTS AT 7 DAYS

Table 5.18: Compression test results for 1:6 proportion mortar for 7 days

Mould size	Mortar mix identity	Sample	Load in kN	Stress in MPa	Average stress value in MPa	Compliance status (as per IS 2250:1981)
50x50x50 mm	A2	cube 1	11.4	4.56	4.48	MM 3 complied
		cube 2	11	4.4		
		cube 3	11.2	4.48		
	B2	cube 1	10.8	4.32	4.18	MM 3 complied
		cube 2	10.4	4.16		
		cube 3	10.2	4.08		
	C2	cube 1	10.2	4.08	4.04	MM 3 complied
		cube 2	10	4		
		cube 3	10.1	4.04		
	D2	cube 1	7.3	2.92	3.04	MM 3 complied
		cube 2	7.6	3.04		
		cube 3	7.9	3.16		
	E2	cube 1	6.4	2.56	2.6	MM 3 complied
		cube 2	6.8	2.72		
		cube 3	6.3	2.52		
	F2	cube 1	3	1.2	1.29	MM 3 complied
		cube 2	3.5	1.4		
		cube 3	3.2	1.28		

5.5.2 COMPRESSION TEST RESULTS AT 28 DAYS

Table 5.19: Compression test results for 1:4 proportion mortar for 28 days

Mould size	Mortar mix identity	Sample	Load in kN	Stress in MPa	Average stress value in MPa	Compliance status (as per IS 2250:1981)
50x50x50 mm	A1	cube 1	42	16.8	16.7	MM 7.5 complied
		cube 2	41.5	16.6		
		cube 3	41.8	16.72		
	B1	cube 1	35.5	14.2	13.9	MM 7.5 complied
		cube 2	34.9	13.96		
		cube 3	34.1	13.64		
	C1	cube 1	33	13.2	13.2	MM 7.5 complied
		cube 2	32.8	13.12		
		cube 3	33.1	13.24		
	D1	cube 1	16	6.4	6.5	MM 7.5 complied
		cube 2	16.6	6.64		
		cube 3	16.52	6.608		
	E1	cube 1	16	6.4	6.4	MM 7.5 complied
		cube 2	16	6.4		
		cube 3	16.1	6.44		
	F1	cube 1	10.2	4.08	4.1	MM 7.5 complied
		cube 2	10.4	4.16		
		cube 3	10.1	4.04		

5.5.2 COMPRESSION TEST RESULTS AT 28 DAYS

Table: 5.20: Compression test results For 1:6 proportion mortar for 28 days

Mould size	Mortar mix identity	Sample	Load in kN	Stress in MPa	Average stress value in MPa	Compliance status (as per IS 2250:1981)
50x50x50 mm	A2	cube 1	32	12.8	12.8	MM 3 complied
		cube 2	32.1	12.84		
		cube 3	31.9	12.76		
	B2	cube 1	22	8.8	8.88	MM 3 complied
		cube 2	22.4	8.96		
		cube 3	22.2	8.88		
	C2	cube 1	16	6.4	6.54	MM 3 complied
		cube 2	16.9	6.76		
		cube 3	16.2	6.48		
	D2	cube 1	16	6.4	6.4	MM 3 complied
		cube 2	16	6.4		
		cube 3	16	6.4		
	E2	cube 1	11.6	4.64	4.56	MM 3 complied
		cube 2	11.2	4.48		
		cube 3	11.4	4.56		
	F2	cube 1	8.4	3.36	3.37	MM 3 complied
		cube 2	8.8	3.52		
		cube 3	8.1	3.24		

5.5.3 COMPRESSION TEST RESULTS AT 56 DAYS

Table 5.21: Compressive strength results for 1:4 proportion mortar for 56 days

Mould size	Mortar mix identity	Sample	Load in kN	Stress in MPa	Average stress value in MPa	Compliance status (as per IS 2250:1981)
50x50x50 mm	A1	cube 1	47.1	18.8	18.79	MM 7.5 complied
		cube 2	46.8	18.7		
		cube 3	47	18.8		
	B1	cube 1	34	13.6	13.60	MM 7.5 complied
		cube 2	33.7	13.5		
		cube 3	34.3	13.7		
	C1	cube 1	29	11.6	11.63	MM 7.5 complied
		cube 2	28.9	11.6		
		cube 3	29.3	11.7		
	D1	cube 1	21	8.4	8.4	MM 7.5 complied
		cube 2	21	8.4		
		cube 3	21	8.4		
	E1	cube 1	19	7.6	7.51	MM 7.5 complied
		cube 2	18.4	7.4		
		cube 3	18.9	7.6		
	F1	cube 1	15.2	6.1	6.12	MM 7.5 complied
		cube 2	15.4	6.2		
		cube 3	15.3	6.1		

5.5.3 COMPRESSION TEST RESULTS AT 56 DAYS

Table 5.22: Compression strength results for 1:6 proportion mortar for 56 days

Mould size	Mortar mix identity	Sample	Load in kN	Stress in MPa	Average stress value in MPa	Compliance status (as per IS 2250:1981)
50x50x50 mm	A2	cube 1	35.9	14.4	14.39	MM 3 complied
		cube 2	36	14.4		
		cube 3	36	14.4		
	B2	cube 1	25	10.0	10	MM 3 complied
		cube 2	24.8	9.9		
		cube 3	25.2	10.1		
	C2	cube 1	22	8.8	8.84	MM 3 complied
		cube 2	22	8.8		
		cube 3	22.3	8.9		
	D2	cube 1	17	6.8	6.85	MM 3 complied
		cube 2	17.1	6.8		
		cube 3	17.3	6.9		
	E2	cube 1	13	5.2	5.2	MM 3 complied
		cube 2	12.9	5.2		
		cube 3	13.1	5.2		
	F2	cube 1	10.2	4.1	4.08	MM 3 complied
		cube 2	10	4.0		
		cube 3	10.4	4.2		

5.5.4 FLEXURAL TEST RESULTS AT 7 DAYS

The flexural strength test was conducted for the prism (40x40x160) specimens which is cured for 7 days, 28 days and 56 days for two grades of mortar (1:4, 1:6) which is partial replaced by bagasse ash and fly ash from 10% to 50% at equal proportion and the results are taken below in Table No 5.23, 5.24, 5.25, 5.26, 5.27 and 5.28.

Table 5.23: Flexure Strength test results For 1:4 proportion mortar for 7 days

Mould size	Mortar mix identity	Sample	Breaking load in kN	Bending strength in MPa	Average strength value in MPa
160x40x40 mm	A1	cube 1	2.8	3.5	3.3
		cube 2	2.6	3.2	
		cube 3	2.65	3.3	
	B1	cube 1	1.8	2.2	2.2
		cube 2	1.78	2.2	
		cube 3	1.72	2.1	
	C1	cube 1	1.2	1.5	1.5
		cube 2	1.28	1.6	
		cube 3	1.22	1.5	
	D1	cube 1	1	1.2	1.2
		cube 2	1	1.2	
		cube 3	0.95	1.2	
	E1	cube 1	0.7	0.9	0.9
		cube 2	0.75	0.9	
		cube 3	0.69	0.9	
	F1	cube 1	0.6	0.7	0.7
		cube 2	0.59	0.7	
		cube 3	0.61	0.8	

5.5.4 FLEXURAL TEST RESULTS AT 7 DAYS

Table 5.24: Flexure Strength test results For 1:6 proportion mortar for 7 days

Mould size	Mortar mix identity	Sample	Breaking load in kN	Bending strength in MPa	Average strength value in MPa
160x40x40 mm	A2	cube 1	2.2	2.7	2.6
		cube 2	2.17	2.7	
		cube 3	2	2.5	
	B2	cube 1	1.4	1.7	1.7
		cube 2	1.38	1.7	
		cube 3	1.41	1.8	
	C2	cube 1	1	1.2	1.2
		cube 2	1	1.2	
		cube 3	1	1.2	
	D2	cube 1	0.8	1.0	1.0
		cube 2	0.74	0.9	
		cube 3	0.79	1.0	
	E2	cube 1	0.4	0.5	0.5
		cube 2	0.42	0.5	
		cube 3	0.38	0.5	
	F2	cube 1	0.3	0.4	0.4
		cube 2	0.32	0.4	
		cube 3	0.3	0.4	

5.5.5 FLEXURAL TEST RESULTS AT 28 DAYS

Table 5.25: Flexure Strength test results for 1:4 proportion mortar for 28 days

Mould size	Mortar mix identity	Sample	Breaking load in kN	Bending strength in MPa	Average strength value in MPa
160x40x40 mm	A1	cube 1	3.6	4.5	4.4
		cube 2	3.52	4.4	
		cube 3	3.58	4.4	
	B1	cube 1	2.5	3.1	3.1
		cube 2	2.52	3.1	
		cube 3	2.51	3.1	
	C1	cube 1	2.15	2.7	2.7
		cube 2	2.2	2.7	
		cube 3	2.2	2.7	
	D1	cube 1	2	2.5	2.5
		cube 2	2	2.5	
		cube 3	2	2.5	
	E1	cube 1	0.7	0.9	0.9
		cube 2	0.69	0.9	
		cube 3	0.68	0.8	
	F1	cube 1	0.6	0.7	0.7
		cube 2	0.58	0.7	
		cube 3	0.61	0.8	

5.5.5 FLEXURAL TEST RESULTS AT 28 DAYS

Table5.26: Flexure Strength test results for 1:6 proportion mortar for 28 days					
Mould size	Mortar mix identity	Sample	Breaking load in kN	Bending strength in MPa	Average strength value in MPa
160x40x40 mm	A2	cube 1	2.7	3.4	3.3
		cube 2	2.71	3.4	
		cube 3	2.68	3.3	
	B2	cube 1	1.8	2.2	2.3
		cube 2	1.9	2.4	
		cube 3	1.78	2.2	
	C2	cube 1	1.9	2.4	2.4
		cube 2	1.9	2.4	
		cube 3	1.9	2.4	
	D2	cube 1	1	1.2	1.2
		cube 2	1	1.2	
		cube 3	1	1.2	
	E2	cube 1	0.6	0.7	0.8
		cube 2	0.61	0.8	
		cube 3	0.62	0.8	
	F2	cube 1	0.55	0.7	0.6
		cube 2	0.5	0.6	
		cube 3	0.5	0.	

5.5.6 FLEXURAL TEST RESULTS AT 56 DAYS

Table 5.27: Flexure Strength test results for 1:4 proportion mortar for 56 days

Mould size	Mortar mix identity	Sample	Breaking load in kN	Bending strength in MPa	Average strength value in MPa
160x40x40 mm	A1	cube 1	4	5.0	5.0
		cube 2	3.9	4.8	
		cube 3	4.1	5.1	
	B1	cube 1	2.8	3.5	3.4
		cube 2	2.8	3.5	
		cube 3	2.7	3.4	
	C1	cube 1	2.6	3.2	3.1
		cube 2	2.44	3.0	
		cube 3	2.52	3.1	
	D1	cube 1	2.3	2.9	2.9
		cube 2	2.3	2.9	
		cube 3	2.3	2.9	
	E1	cube 1	1.4	1.7	1.7
		cube 2	1.4	1.7	
		cube 3	1.4	1.7	
	F1	cube 1	1	1.2	1.2
		cube 2	1	1.2	
		cube 3	1	1.2	

5.5.6 FLEXURAL TEST RESULTS AT 56 DAYS

Table 5.28: Flexure Strength test results for 1:6 proportion mortar for 56 days

Mould size	Mortar mix identity	Sample	Breaking load in kN	Bending strength in MPa	Average strength value in MPa
160x40x40 mm	A2	cube 1	2.9	3.6	3.6
		cube 2	2.92	3.6	
		cube 3	2.9	3.6	
	B2	cube 1	2.1	2.6	2.7
		cube 2	2.1	2.6	
		cube 3	2.2	2.7	
	C2	cube 1	2.3	2.9	2.9
		cube 2	2.3	2.9	
		cube 3	2.3	2.9	
	D2	cube 1	1.2	1.5	1.6
		cube 2	1.4	1.7	
		cube 3	1.2	1.5	
	E2	cube 1	1	1.2	1.2
		cube 2	1	1.2	
		cube 3	1	1.2	
	F2	cube 1	0.8	1.0	1.0
		cube 2	0.85	1.1	
		cube 3	0.8	1.0	

5.5 ACID ATTACK TEST RESULTS FOR 7 AND 14 DAYS

Acid attack is conducted as per ASTM C267 for 50 mm cube specimens which is cured for 28 days in water and then immersed in 5% HCL to that of total water added and final loss of weight is taken for 7 and 14 days, Table 5.29,5.30 shows acid attack results 7, 14 days.

Table 5.29: Acid attack results for 7 days

SI.No	Mix design code	Size of specimen	Initial weight of the sample (average of three) in gms	Loss of weight the sample after 7 days immersion in HCL (average of three) in gms	Percentage loss after 7 days (%)
1	A1	50x50 mm	259	255	1.67
2	A2		236	232	1.41
3	B1		268	261	2.49
4	B2		250	245	2.13
5	C1		259	252	2.83
6	C2		258	248	3.88
7	D1		254	240	5.38
8	D2		253	235	6.99
9	E1		256	241	5.86
10	E2		250	235	5.87
11	F1		254	236	6.96
12	F2		254	241	5.87

Table 5.30: Acid attack results for 14 days

SI.No	Mix design code	Size of specimen	Initial weight of the sample (average of three) in gms	Loss of weight the sample after 14 days immersion in HCL (average of three) in gms	Percentage loss after 14 days (%)
1	A1	50x50 mm	259	251	3.09
2	A2		236	228	3.39
3	B1		268	254	5.22
4	B2		250	234	6.40
5	C1		259	236	8.88
6	C2		258	241	6.59
7	D1		254	236	7.09
8	D2		253	223	11.86
9	E1		256	226	11.72
10	E2		250	231	7.60
11	F1		254	230	9.45
12	F2		254	238	6.30

5.6 SULPHATE ATTACK TEST RESULTS FOR 7 AND 14 DAYS

Sulphate attack is conducted as per ASTM C1012-4 for 50 mm cube specimens which is cured for 28 days in water and then immersed in 5% NaSO_4 to that of total water added and final loss of weight is taken for 7 and 14 days, Table 5.31, 5.32 shows sulphate attack results for 7, 14 days.

Table 5.31: Sulphate attack results for 7 days

SI.No	Mix design code	Size of specimen	Initial weight of the sample (average of three) in gms	Loss of weight the sample after 7 days immersion in NaSO_4 (average of three) in gms	Percentage loss after 7 days (%)
1	A1	50x50mm	262	255	2.7
2	A2		243	239	1.6
3	B1		260	256	1.5
4	B2		259	254	1.9
5	C1		257	251	2.3
6	C2		261	256	1.9
7	D1		253	246	2.8
8	D2		263	257	2.3
9	E1		262	252	3.8
10	E2		256	250	2.3
11	F1		256	248	3.1
12	F2		250	246	1.6

Table 5.32: Sulphate attack results for 14 days

SI.No	Mix design code	Size of specimen	Initial weight of the sample (average of three) in gms	Loss of weight the sample after 14 days immersion in NaSo4 (average of three) in gms	Percentage loss after 14 days (%)
1	A1	50x50mm	262	250	4.6
2	A2		243	228	6.2
3	B1		260	241	7.3
4	B2		259	246	5.0
5	C1		257	239	7.0
6	C2		261	242	7.3
7	D1		253	238	5.9
8	D2		263	244	7.2
9	E1		262	240	8.4
10	E2		256	234	8.6
11	F1		256	231	9.8
12	F2		250	228	8.8

5.7 WATER ABSORPTION TEST CONDUCTED FOR 28 DAYS CURED SPECIMENS

Water absorption test is conducted as per [15] for 50 mm cube specimens which is cured for 28 days in water and oven dried for 24 hours and then immersed in portable water for 24 hours and final weight is taken and water absorption value is calculated, Table 5.32 shows water absorption test results.

Table 5.32: Water absorption test

SI.No	Mix design code	Size of specimen	sample number	Initial weight of 28 days cured oven dried sample (A)	Final weight of 24 hours soaked surface dried sample (B)	Percentage of water absorption (%)
1	A1	50 x 50 x 50 mm	1	242	259	7.02
			2	243	263	8.23
			3	246	262	6.50
2	A2	50 x 50 x 50 mm	1	214	240	12.15
			2	218	237	8.72
		70.6 x 70.6 x 70.6 mm	3	639	717	12.21
3	B1	50 x 50 x 50 mm	1	264	287	8.71
			2	249	272	9.24
			3	246	270	9.76
4	B2	50 x 50 x 50 mm	1	248	269	8.47
			2	242	260	7.44
		70.6 x 70.6 x 70.6 mm	3	674	737	9.35
5	C1	50 x 50 x 50 mm	1	257	282	9.73
			2	238	262	10.08
			3	234	257	9.83
6	C2	50 x 50 x 50 mm	1	223	246	10.31
			2	219	242	10.50
		70.6 x 70.6 x 70.6 mm	3	686	753	9.77
7	D1	50 x 50 x 50 mm	1	242	270	11.57
			2	248	263	6.05
			3	236	254	7.63

8	D2	50 x 50 x 50 mm	1	236	263	11.44
			2	232	259	11.64
		70.6 x 70.6 x 70.6 mm	3	724	795	9.81
9	E1	50 x 50 x 50 mm	1	238	264	10.92
			2	223	249	11.66
			3	217	237	9.22
10	E2	50 x 50 x 50 mm	1	244	269	10.25
			2	241	266	10.37
		70.6 x 70.6 x 70.6 mm	3	678	753	11.06
11	F1	50 x 50 x 50 mm	1	219	246	12.33
			2	217	247	13.82
			3	221	251	13.57
12	F2	50 x 50 x 50 mm	1	231	256	10.82
			2	238	264	10.92
		70.6 x 70.6 x 70.6 mm	3	694	773	11.38

Fig 5.25: Oven dried sample immersed in water for 24 hours

5.8 SORPTIVITY TEST CONDUCTED FOR 28 DAYS CURED SPECIMENS

Sorptivity test is conducted as per [12] for 50 mm cube specimens which is cured for 28 days in water and oven dried for 24 hours and the results were drawn. Table 5.33 shows the sorptivity test results.

Table 5.33: Sorptivity test for mortar

Sorptivity value I in mm/$s^{\frac{1}{2}}$ for different duration								
SI.No	Mortar mix identity	60s	5 min	10 min	20 min	30 min	60 min	Every hour upto 6h
1	A1	1.6	2.4	2.8	3.6	4	5.2	6.8
2	A2	0.8	1.2	2	2.4	3.2	3.2	3.2
3	B1	0.8	1.6	2	3.2	3.6	4.8	7.2
4	B2	1.2	2.8	3.2	4.8	6	7.6	8.8
5	C1	0.8	1.2	2	2.4	3.2	4	6.8
6	C2	3.2	5.2	6	7.2	8	8.4	9.2
7	D1	0.4	1.6	2.4	4	5.6	7.6	10
8	D2	0.4	1.6	1.2	2.8	4	5.6	8.4
9	E1	0.4	1.2	2	3.2	4.4	6.4	9.6
10	E2	2.8	5.6	6.8	8.8	10	10.4	10.8
11	F1	1.2	3.6	4.8	7.2	8.8	10.8	12
12	F2	1.2	3.6	5.6	8.8	10.4	11.2	11.2

Fig 5.26

Fig 5.27

Fig 5.26, 5.27: Sorptivity samples before and after reaching saturation level respectively

CHAPTER – 6

RESULTS AND DISCUSSIONS

6.1 FRESH PROPERTIES OF THE MORTAR

The fresh property of mortar is determined using the flow table test, the Table 6.1, 6.2 below shows the percentage of water required for the conventional mortar and the mortar prepared by replacing the cement by varying percentage of bagasse ash and fly ash in two ratio 1:4 and 1:6. The water – cement ratio calculated for a flow percentage of 85%.

Table 6.1: Results of the flow table test for 1:4 grade mortars

SI.No	percentage of bagasse ash and fly ash replacement in equal proportion for 1:4	Water percentage (%)
1	0%	77.5
2	10%	101
3	20%	104
4	30%	105.7
5	40%	116
6	50%	121.7

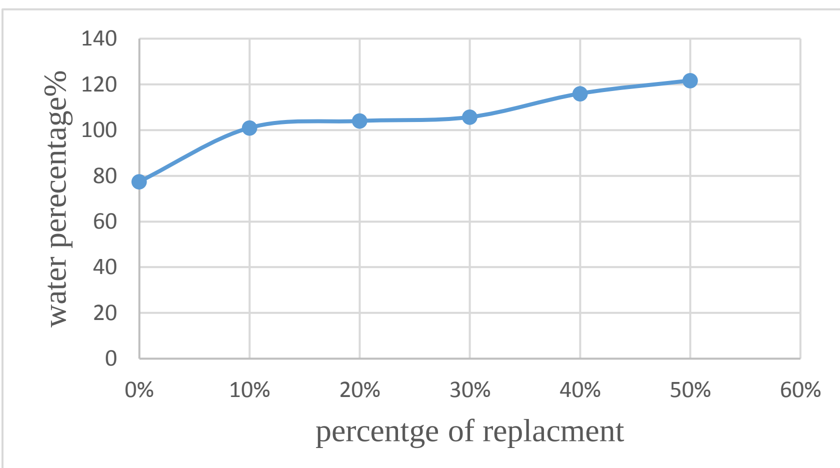

Fig 6.1: Graph showing variation of the water percentage for varying percentage of bagasse ash and fly ash replacement (1:4)

Table 6.2: Results of the flow table test for 1:6 grade mortars

SI.No	percentage of bagasse ash and fly ash replacement in equal proportion for 1:6	Water percentage (%)
1	0%	81
2	10%	110
3	20%	121.2
4	30%	127.5
5	40%	134.5
6	50%	176.6

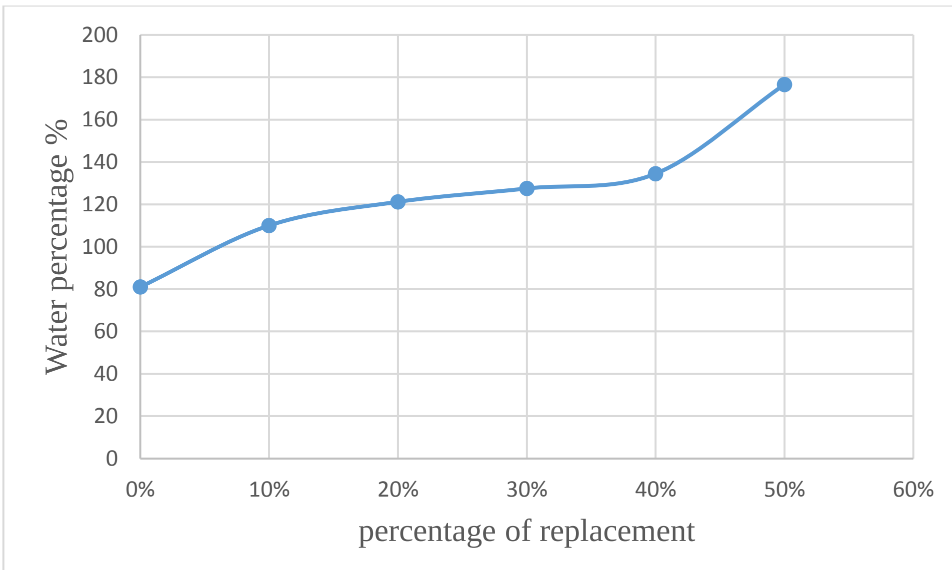

Fig 6.2: Graph showing variation of the water percentage for varying percentage of bagasse ash and fly ash replacement (1:6)

Discussions:

It can be observed that the water percentage required for achieving the given flow rate 85%. As the replacement percentage of bagasse ash and fly ash increases the water percentage required to achieve the flow increases due to higher surface area of pozzolan.

6.2 HARDENED PROPERTIES OF MORTAR

The compressive strength was conducted as per [11] for both the grade of mortar and the findings of the results was compared in the below Fig 6.3, 6.4.

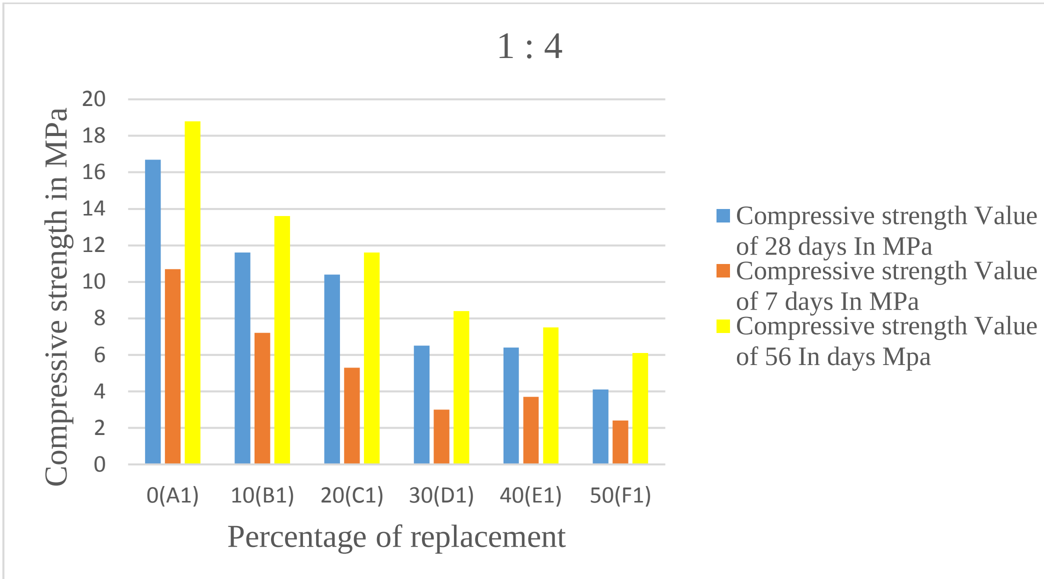

Fig 6.3: Comparison of compressive strength of 50 mm cube specimens at 7 days, 28 days and 56 days for 1:4 grade mortar

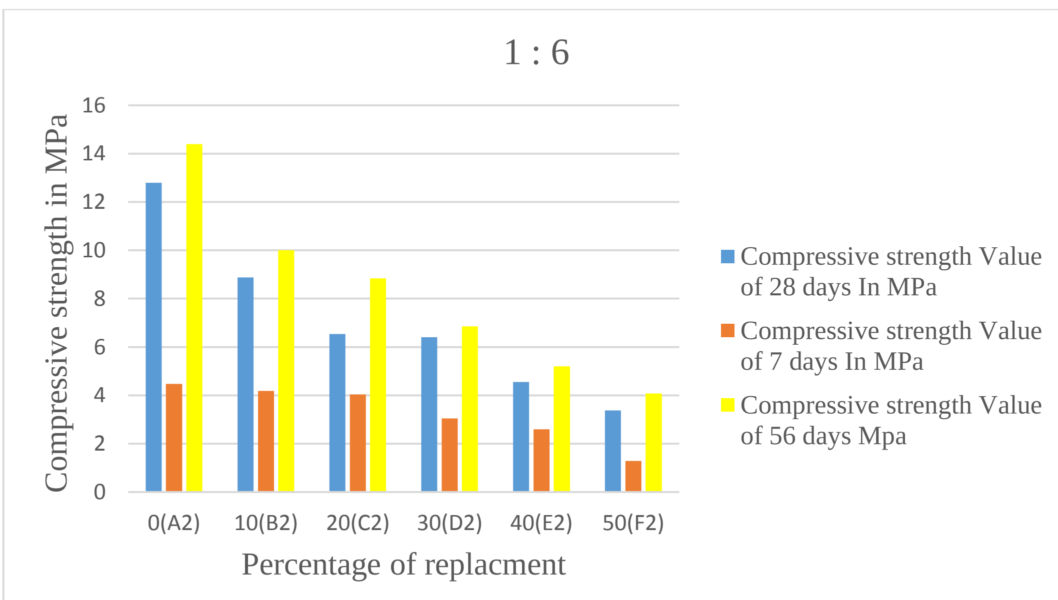

Fig 6.4: Comparison of compressive strength of 50 mm cube specimens at 7 days, 28 days and 56 days for 1:6 grade mortar

The flexural strength was conducted as per [25] for both the grade of mortar and the findings of the results was compared in the below Fig 6.5, 6.6.

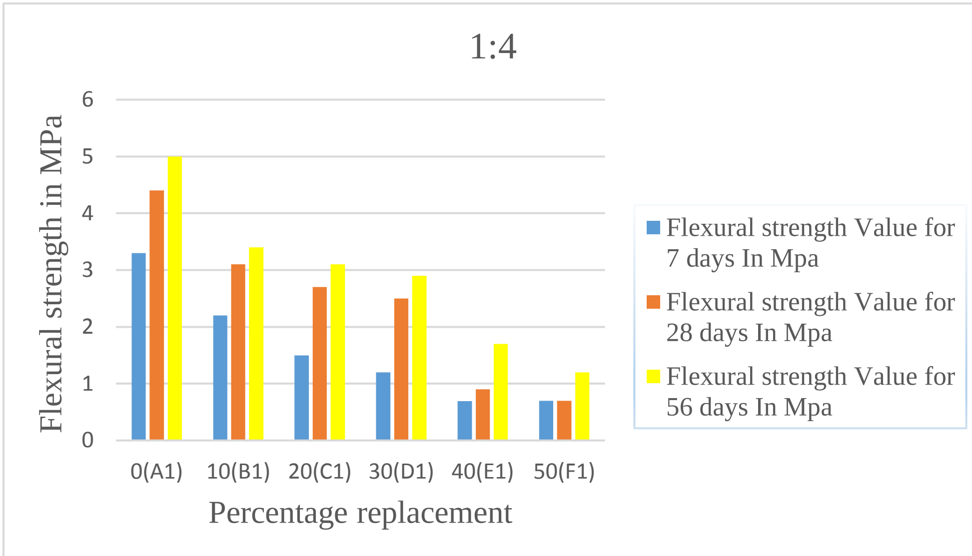

Fig 6.5: Comparison of flexural strength of prism specimens at 7 days, 28 days and 56 days for 1:4 grade mortar

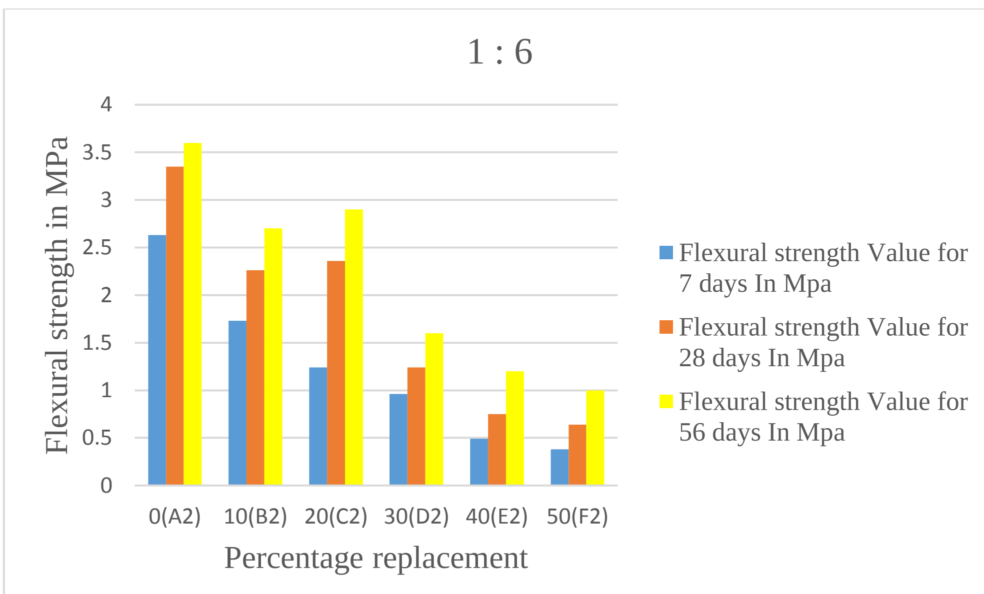

Fig 6.6: Comparison of flexural strength of prism specimens at 7 days, 28 days and 56 days for 1:6 grade mortar

Discussions:

Compression strength

1. It is observed the compressive strength of conventional mortar is greater than mortar replaced by bagasse ash and fly ash replaced for both the grades and lowest of 1.29 for 7 days (1:6) and highest of 18.8 for 56 days (1:4)
2. For all the cubes specimen the minimum strength of MM3 and MM 7.5 is achieved as per IS 2250:1981

Flexural strength

1. It is notice that the flexural strength of the conventional mortar is considerably high compared to that of the mortar in which cement is replaced in varying percentage of bagasse ash and fly ash.
2. The flexural strength of the mortar for mix proportion 1:6 ratio is very low and the highest achieved was 3.6 MPa for 56 days.

6.3 DURABILITY TEST ON HARDENED MORTAR

1. ACID ATTACK

Acid attack is conducted as per [14] and the findings are shown in the Fig 6.7 below.

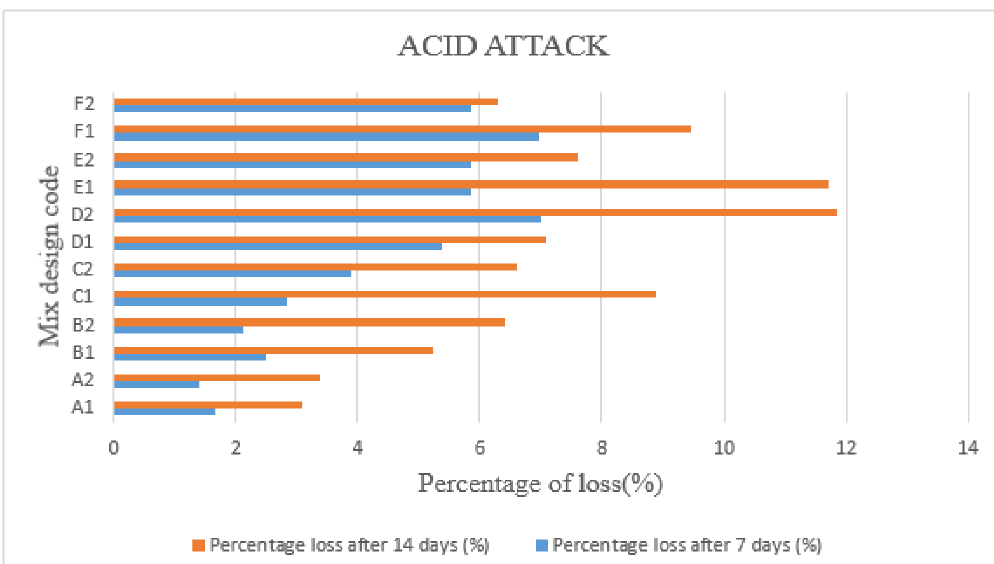

Fig: 6.7: Acid attack results comparison for 7 and 14 days

Fig: 6.8: Acid attack samples after 14 days

Discussions: From the above figure it is observed that after 1 week the deterioration for mortar cubes immersed in 5% HCL is less than 10% for all mortar cubes and after 2 weeks is less than 15% for all mortar cubes which well within the limit 15% [4].

2. SULPHATE ATTACK

Sulphate attack is conducted as per [13] and the findings are shown in the Fig 6.8 below

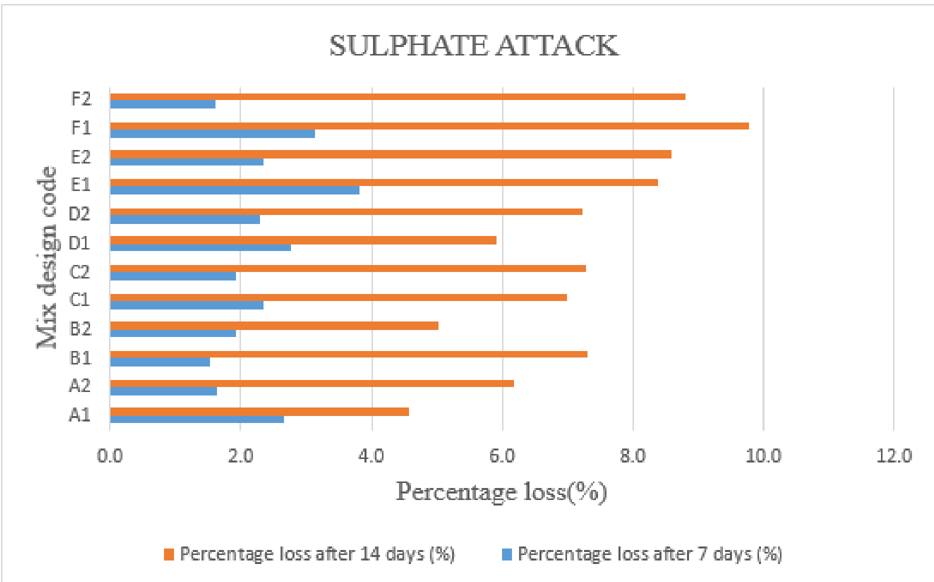

Fig: 6.8: Sulphate attack results comparison for 7 and 14 days

Fig 6.9: Sulphate attack samples after 7days of immersion

Discussions: From the above figure it is observed that after 1 week the loss of weight for mortar cubes immersed in 5% sodium sulphate is less than 3% for all mortar and after 2 weeks the loss of weight is less than 10% for all the specimens.

3. WATER ABSORPTION TEST

Water absorption test is conducted as per [15] and the findings are shown in the Fig 6.10 below

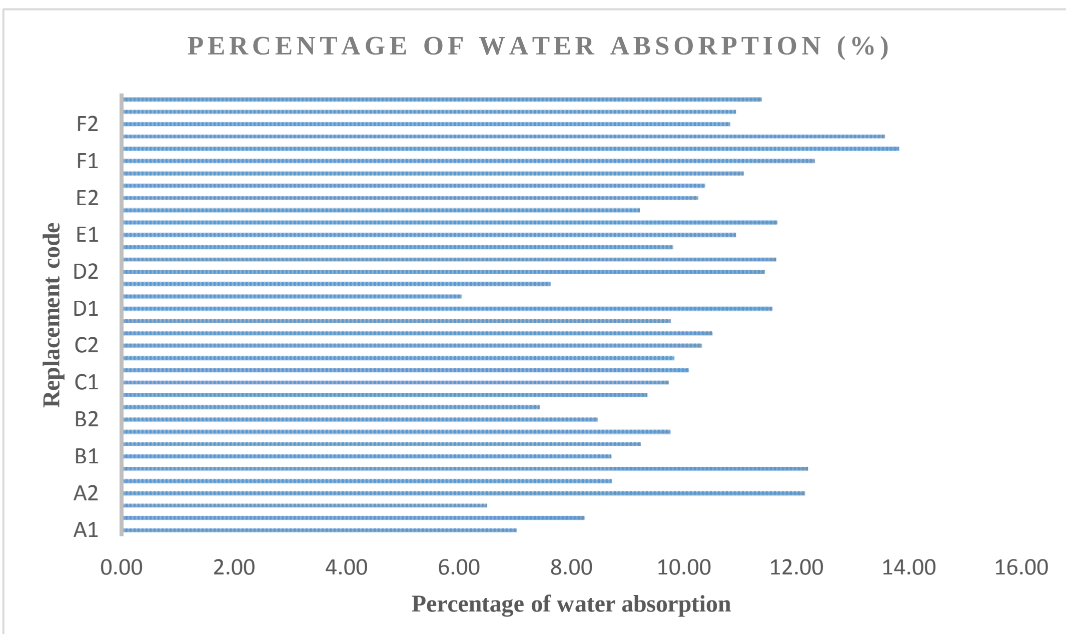

Fig 6.10: Comparison water absorption test

Discussions: From the above figure it is observed the % of water absorption of oven dry sample is less 15 % which within the acceptable limit 15% [15].

4. SORPTIVITY TEST

Sorptivity test is conducted as per [12] and the findings are shown in the Fig 6.11 below.

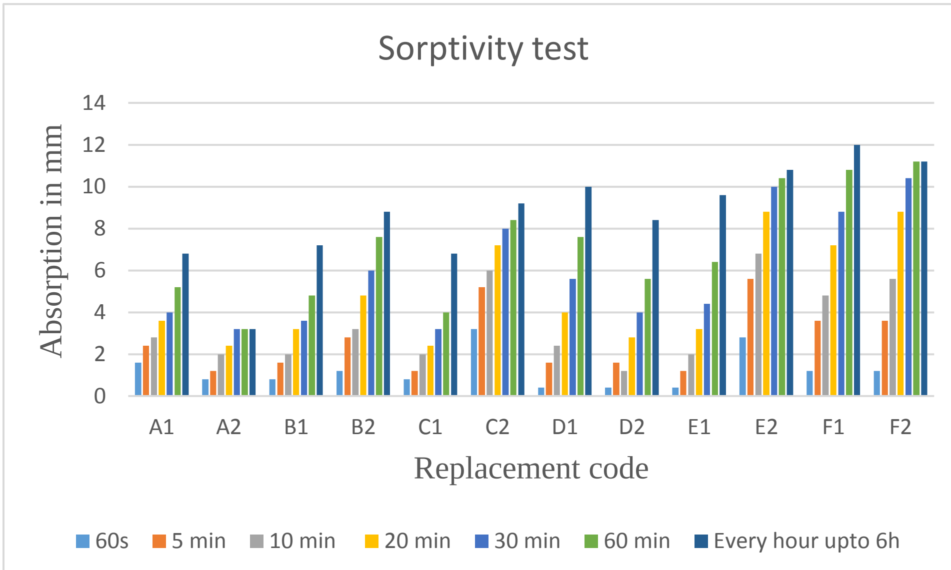

Fig 6.11: Comparison of absorption (I) values for different duration

Discussions: The sorptivity test is conducted for both mortar grades after 28 days of curing and oven drying for 24 hours and it has observed that capillary rise in water reached the saturation level within two hours of test due to complete filling of pores in mortar.

CHAPTER – 7

CONCLUSION

At the end of the study the following conclusions are drawn:

1. The compressive strength results have concluded that the initial gain in strength (7 days) was less and there is very large increase in strength for 28 days cured specimen due to increase in hydration rate after 7 days.
2. There is not much increase in strength for 56 days specimens due to early hydration within 28 days.
3. The flexural strength results have concluded that the initial gain in strength (7 days) was less and there is very large increase in strength for 28 days cured specimen.
4. It is notice that the flexural strength of the conventional mortar is considerably high compared to that of the mortar in which cement is replaced in varying percentage of bagasse ash and fly ash.
5. The flexural strength of the mortar for mix proportion 1:6 ratio is very low and the highest achieved was 3.6 MPa for 56 days.
6. The nominal Compressive and flexural strength is observed at 20 % replacement when compared to conventional mortar.
7. Minimum strength in compression for MM3 and MM7.5 mortar is achieved as per IS 2250:1981[11].
8. The sorptivity test is conducted for both mortar grades after 28 days of curing specimens and it has observed that capillary rise in water reached the saturation level within two hours of test due to complete filling of pores in mortar.
9. It observed the % of water absorption of oven dry sample is less 15 % which within the acceptable limit of 15%[15].
10. The sulphate attack and acid attack results have concluded that the percentage loss is 15% and 10% respectively.

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APPENDIX- 1

A1: Conventional mortar 1:4

Volume of mould = $\frac{\pi\ x\ h\ x\ (R^2+r^2+Rr)}{3}$

$= \frac{\pi\ x\ 5\ x\ (5^2+3.5^2+5\ x\ 3.5)}{3}$

$= 2.866 \times 10^{-4}$

Dry volume of mortar = 1.35 x 2.866 x 10-^{4} = 3.86 x 10^{-4}

Quantity of cement = dry volume x cement proportion x density of cement/sum of Proportion

$= 3.86\ x 10^{-4}\ x\ \frac{1}{5}\ x\ 1440 = 112$ grams

Quantity of sand = dry volume x sand proportion x density of sand/sum of Proportion

$= 3.86\ x 10^{-4}\ x\ \frac{4}{5}\ x\ 1630 = 506$ grams

A2: Conventional mortar 1:6

Volume of mould = $\frac{\pi\ x\ h\ x\ (R^2+r^2+Rr)}{3}$

$= \frac{\pi\ x\ 5\ x\ (5^2+3.5^2+5\ x\ 3.5)}{3}$

$= 2.866 \times 10^{-4}$

Dry volume of mortar = 1.35 x 2.866 x 10^{-4} = 3.86 x 10^{-4}

Quantity of cement = dry volume x cement proportion x density of cement/sum of Proportion

$= 3.86\ x 10^{-4}\ x\ \frac{1}{7}\ x\ 1440 = 80$ grams

Quantity of sand = dry volume x sand proportion x density of sand/sum of Proportion

$= 3.86\ x 10^{-4}\ x\ \frac{6}{7}\ x\ 1630 = 542$ grams.

B1: 10% replacement of cement (1:4)

Quantity of cement to be taken = 0.9 x 112 = 101 grams

Quantity of fly ash = $\frac{5}{100}$ x 112 x 0.81 = 4.53 grams

Quantity of bagasse ash = $\frac{5}{100}$ x 112 x 0.625 = 3.5 grams

Total cementitious material = 109.03 grams

B2: 10% replacement of cement (1:6)

Quantity of cement to be taken = 0.9 x 80 = 71.82 grams

Quantity of fly ash = $\frac{5}{100}$ x 80 x 0.81 = 3.23 grams

Quantity of bagasse ash = $\frac{5}{100}$ x 80 x 0.625 = 2.5 grams

Total cementitious material = 77.33 grams

C1: 20% replacement of cement (1:4)

Quantity of cement to be taken = 0.8 x 112 = 89.6 grams

Quantity of fly ash = $\frac{10}{100}$ x 112 x 0.81 = 9 grams

Quantity of bagasse ash = $\frac{10}{100}$ x 112 x 0.625 = 7 grams

Total cementitious material = 105.67grams

C2: 20% replacement of cement (1:6)

Quantity of cement to be taken = 0.8 x 80 = 60 grams

Quantity of fly ash = $\frac{10}{100}$ x 80 x 0.81 = 6.48 grams

Quantity of bagasse ash = $\frac{10}{100}$ x 80 x 0.625 = 5 grams

Total cementitious material = 75.48grams

D1: 30% replacement of cement (1:4)

Quantity of cement to be taken = 0.7 x 112 = 79 grams

Quantity of fly ash = $\frac{15}{100}$ x 112 x 0.81 = 13.6 grams

Quantity of bagasse ash = $\frac{15}{100}$ x 112 x 0.625 = 11 grams

Total cementitious material = 104grams

D2: 30% replacement of cement (1:6)

Quantity of cement to be taken = 0.7 x 80 = 56 grams

Quantity of fly ash = $\frac{15}{100}$ x 80 x 0.81 = 9.72 grams

Quantity of bagasse ash = $\frac{15}{100}$ x 80 x 0.625 =7.5 grams

Total cementitious material = 73 grams

E1: 40% replacement of cement (1:4)

Quantity of cement to be taken = 0.6 x 112 = 67.2 grams

Quantity of fly ash = $\frac{20}{100}$ x 112 x 0.81 = 18.144 grams

Quantity of bagasse ash = $\frac{20}{100}$ x 112 x 0.625 = 14 grams

Total cementitious material = 99.344 grams

E2: 40% replacement of cement (1:6)

Quantity of cement to be taken = 0.6 x 80 = 48 grams

Quantity of fly ash = $\frac{20}{100}$ x 80 x 0.81 = 12.96 grams

Quantity of bagasse ash = $\frac{20}{100}$ x 80 x 0.625 = 10 grams

Total cementitious material = 71 grams

F1: 50% replacement of cement (1:4)

Quantity of cement to be taken = 0.5 x 112 = 56 grams

Quantity of fly ash = $\frac{25}{100}$ x 112 x 0.81 = 23 grams

Quantity of bagasse ash = $\frac{25}{100}$ x 112 x 0.625 = 17.5 grams

Total cementitious material = 97 grams

F2: 50% replacement of cement (1:6)

Quantity of cement to be taken = 0.5 x 80 =40 grams,

Quantity of fly ash = $\frac{25}{100}$ x 80 x 0.81 = 16.2 grams, Quantity of bagasse ash = $\frac{25}{100}$ x 80 x 0.625 = 12.5 grams,

Total cementitious material = 68.7 grams

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