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Effect of Bagasse Ash in Properties of Cement Paste and Mortar

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Abstract : Bagasse ash, the industrial by-product which harms the environment and causes disposal problems[2]. The incorporation of bagasse ash in cement mortar and concrete may give the satisfactory solution for environmental issues. The replacement of OPC with bagasse ash was made at 5, 10, 15, 20, 25 and 30%. The effect of bagasse ash on properties of cement mortar (1:3) was investigated experimentally. In this study, the test on cement for the control mix and the mix with bagasse ash was verified. The mechanical properties such as compressive strength, flexural strength were analysed experimentally.
Keywords: Bagasse ash, Cement mortar, Compressive strength and Flexural strength.

1.0 Introduction

The incorporation of pozzolanic material in Portland cement has been increasing day by day to reduce the environmental burden[6]. The concern in cement manufacturing industry is the production of greenhouse gases (co_2) and consumption of excessive energy. In order to reduce the consumption of cement, it can be partially replaced by natural admixtures or industrial by-product. The materials like fly ash, silica fume, slag, rice husk ash, metakaolin are used as a supplementary cementitious material. In addition to these, bagasse ash leads to be good choice for the partial replacement of cement[5]. Bagasse, the agro waste which forms the fuel for electricity generation and this process leads to by-product as bagasse ash. This industrial waste leads to environmental and health concern such as leaching out of chemicals to inhibit the plant growth and chronic lung condition. It has amorphous silica and displays good pozzolanic properties [1,2]. In a study by Ganesan et al, the replacement level at 20 % has a satisfactory performance than control mix [3]. India shows the second leading in the production of sugarcane and a larger amount of bagasse ash. The introduction of this residue ash as a blending material with cement offers a profitable and eco-friendly disposal of this hazardous material

Therefore, this investigation is made for the assurance of properties of bagasse ash blended cement mix. To estimate the replacement level, the experimental study is made at 5, 10, 15, 20, 25 and 30%.

2.0 Materials

2.1 Bagasse ash

Bagasse ash, the residual ash was collected from Bannari amman sugars limited, Tamil Nadu. The residual ash was ground using ball mill until the percentage of residue was less than 5% on sieving through 45µm sieve [2]. The product of burning process at incinerating temperature transforms silica into amorphous phase whose reactivity is proportional to the specific surface area [8]. The bagasse ash consists of ingredients such as SiO_2, CaO, Al_2O_3, Fe_2O_3.When partially replaced with cement, there was a lot of formation of complexes like calcium silicate hydrate (C-S-H) on hydrated. This C-S-H gel makes sound, strong and durable cementitious matter [1].The chemical composition of bagasse ash was shown in table 1 and the physical properties are shown in table 2.

2.2 Cement

Ordinary Portland Cement of 53 grade conforming to BIS:12269-1987 is supplied by Chettinadu groups of cements was used in this investigation. The chemical properties of the cement are shown in table 1 and the physical properties are shown in table 2.

Table 1. Chemical composition of Bagasse ash and Cement

S.No	Composition	Proportion	
		Bagasse ash	Cement
1	Silicon dioxide(SiO_2)	55.45	11.73
2	Alumina (Al_2O_3)	9.82	2.46
3	Calcium oxide(CaO)	8.95	70.85
4	Magnesium	7.90	0.80
5	Sodium oxide(Na_2O)	0.84	0.45
6	Potassium oxide(K_2O)	8.55	1.73
7	Ferrous oxide(FeO)	8.35	4.25

Table 2. Physical properties of Bagasse ash and Cement

S.No	Materials	Specific gravity	Mean grain size (µm)	Specific surface area (m^2/Kg)
1	Cement	3.15	22.75	328
2	Bagasse ash	2.20	5.45	853

2.3 Fine aggregate

The sand used for this experimental investigation was obtained from Ennore, Tamil Nadu. It must possess 100 percent pass through 2mm IS sieve and 100 percent retain on 90 µm IS sieve. The particle size distribution was obtained as follows: particle size corresponding 2mm to 1mm is 33.33%, a size corresponding 1mm to 500 µm is 33.33%, and size corresponding to 500 µm to 90 µm is 33.33%. The standard sand conforms to IS 650-1966.

3.0 Experimental program

3.1 Test on cement

3.1.1 Consistency test

The initial parameter which has to be determined for cement is consistency test. It is to estimate that the quantity of water required to produce a cement paste of standard consistency. The standard consistency of cement paste is defined as that consistency which will permit vicat plunger to penetrate to a point 5 to 7mm from the bottom of the mould. The apparatus required for the determination of consistency of standard cement paste is vicat apparatus, 10mm dia plunger, stopwatch and non-porous plate. A 300 gram of cement with weighed quantity of water is to be taken to prepare a cement paste and fill the vicat's mould with a gauging time neither less than 3 minutes nor greater than 5 minutes. After plunger contacts the surface of cement paste, allows a free fall of a plunger to sink into the paste. Trial pastes are made with varying percentage of water and the experiment was repeated for the plunger penetration of 5 to 7mm from the bottom of a mould. The percentage of water by weight to that of cement which gives the above consistency is called as standard consistency. The determination of standard consistency conforms to IS 4031(Part 4)-1988.

3.1.2 Initial and Final setting time

The initial setting time is the time elapsed between the hydration of cement and the paste starts losing its plasticity. The determination of initial setting time requires Vicat apparatus, Stop clock, Needle (1mm square cross section) and non-porous plate. The quantity of water to be taken is 0.85 % of standard consistency of cement paste. The experimental procedure remains same as for determination of consistency. The initial setting time is regarded as the time recorded from the instant of water added to the cement to the needle fails to pierce the paste for about 5mm measured from the bottom of a mould.

The final setting time is regarded as the time elapsed from the water added to the cement, to complete loss of its plasticity. The determination of final setting time requires Vicat apparatus, Stop clock, 1 mm square cross section needle with annular attachment. The experimental procedure remains same for the determination of initial setting time. It's the time required from the hydration of cement to the needle fails to make an impression on the cement surface. The determination of initial and final setting time conforms to IS 4031(Part 5)-1988.

As per BIS:12269-1987 specification, the initial setting time shall not be less than 30 minutes and the final setting time shall not be more than 600 minutes.

3.1.3 Soundness

The determination of soundness of the cement by the Le-chatelier method is to find the extent of free uncombined lime present in the cement. Lime causes a large change in volume after setting of concrete known as unsoundness. It is important to determine the soundness as its leads to crack, distortion and disintegration. The requirements are Le-chatelier mould, glass plate of 50mm square, a water bath is used. The Le-chatelier mould conforms to IS 5514-1996. The cement paste is prepared with 0.78 times the water required to give a standard consistency. The glass plate over which mould was placed, keeping the edge of mould gently together and cement paste was filled. Cover the mould with a glass plate over which small weight was placed. The whole assembly was kept submerged in water for 24 hours at a temperature of 27±2·C. The distance between the indicator points are measured as the initial distance and again submerged in boiling water bath for about 3 hours and allowed to cool. Measure the distance between the indicator points. The difference between these two measurements represents the expansion of cement. The determination of soundness of cement conforms to IS 4031(Part 3)-1988.

3.2 Mechanical properties

3.2.1 Compressive strength

The maximum compressive strength withstands by a solid material without fracture. In this investigation, the experimental analysis was made on 40 mm cube specimen. The specimen was cast to test at the age of 3, 7 and 28 days. The water cement ratio of 0.40 was adopted. The 40 mm specimen was investigated using compression frame jig assembly. The determination of compressive strength using compressive frame jig assembly conforms to IS 4031(Part 8)-1988. The ultimate compressive strength was given by eqn (4)

Ultimate compressive strength = Ultimate load/ loaded area of the specimen (4)

3.2.2 Flexural strength

Flexural strength is known as modulus of rupture defined as a material's ability to resist deformation under load. In this study, flexural strength of mortar has been determined using flexural jig assembly. The jig assembly consists of roller supports spaced 100 mm apart. The third roller is at equidistant from the two supports for transmitting the load P to the opposite face of the prism. The mortar prism of size 40*40*160 mm was cast and tested at the age of 3,7and 28 days of curing. The water cement ratio of 0.40 was adopted. The jig assembly is subjected to compressive load using a universal testing machine at the rate of 50±10 N/s. The determination of flexural strength conforms to IS 4031(Part 8)-1988. The breaking stress was calculated using eqn (5)

$R=6M/B^3$ (5)

Where M- Bending moment.

B – Side of square cross section.

4.0 Results and discussions

4.1 Consistency test

The water required for normal consistency was increasing with increase in bagasse ash content in the cement mortar. The porous nature of particle size and large surface area cause the increase in water demand of the mix [6]. The investigation shows that control specimen requires 30% water content, while 30% bagasse ash content in the mix requires 34% water content. The variation the consistency of cement with bagasse ash at different percentage are shown in Figure-1

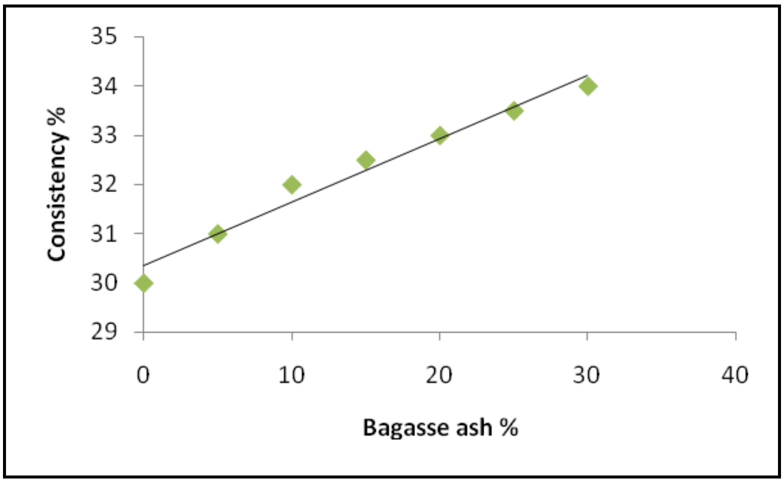

Figure-1 Variation of consistency of cement pastes with BA

4.2 Setting time

The setting time increases with increase in bagasse ash content in cement mortar. Figure-2 describes that initial setting time for control specimen was 60 min while for 30% replacement was 100 min. The final setting time for control specimen was 240 min and for 30% replacement was 310 min. It is inferred that change of state is prolonged due to large surface area and enhanced pozzolanic reactivity of bagasse ash.

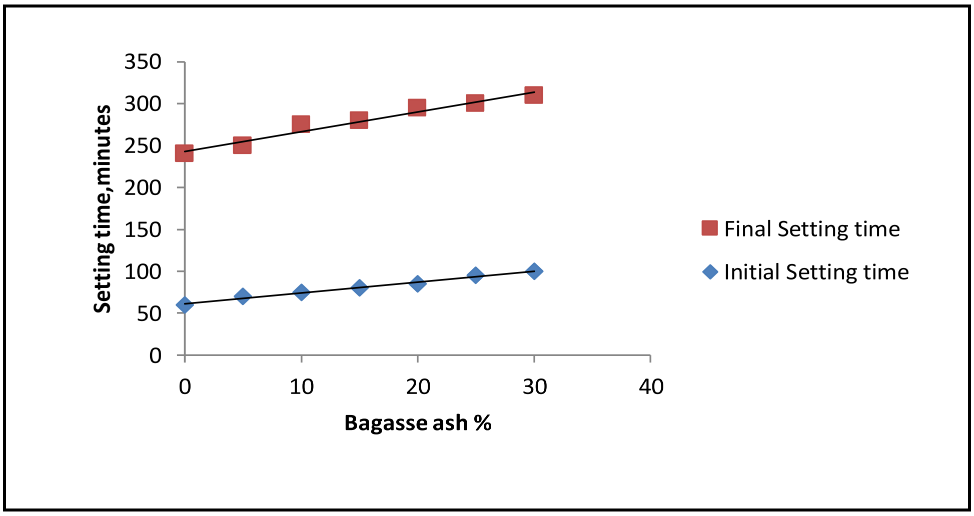

Figure-2 Variation of setting time of cement pastes with BA

4.3 Soundness

Lechatelier's expansion test to detect the change of volume caused by free lime. As bagasse ash consist 8.95% of calcium oxide, on treating with water responsible for the production of $Ca(OH)_2$. This cause unsoundness of the bagasse ash content mix. The results in figure-3 show that control mix has 1mm expansion, while 30% bagasse ash content mix has 2.6 mm expansion. Hence, the increase in expansion does not make an adverse effect since the results are within permissible limits 10mm specified by BIS.

Figure-3 Variation of soundness of cement pastes with BA

4.4 Mechanical properties

4.4.1 Compressive strength

The determination of compressive strength was made on 40mm cube specimen at the age 3,7and 28 days of curing. The increase in compressive strength was observed at 15% replacement level than the control mix as shown in figure-4. The factors responsible for the strength of the partial replacement of cement with ground bagasse ash is the pozzolanic reaction can be highly activated due to larger surface area and small particles of bagasse ash can fill the voids or air spaces in a mix.

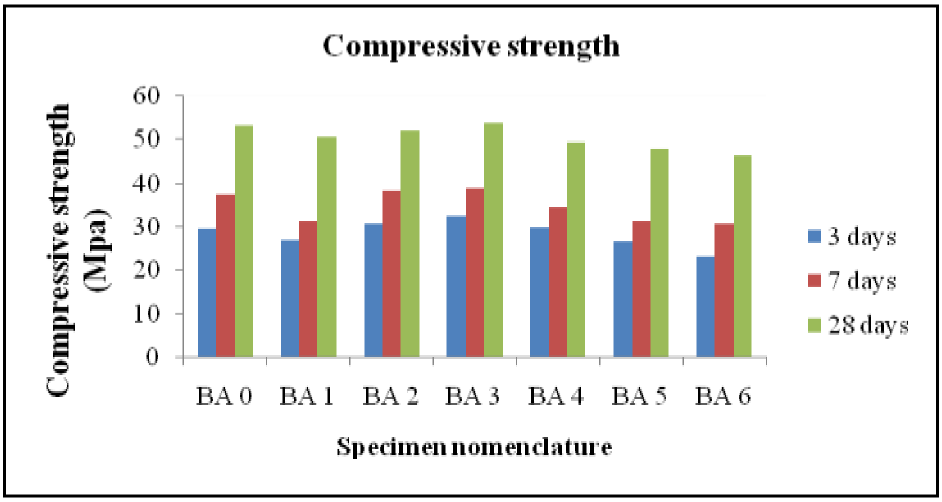

Figure-4. Compressive strength values for various proportions of Bagasse ash.

4.4.2 Flexural strength

Flexural strength was determined on prismatic specimen 40*40*160mm at the age of 3, 7 and 28 days of curing using flexural frame jig assembly. The control mix had a flexural strength of 13.26 Mpa at the age of 28 days. The mix containing 15% and 25% had a flexural strength of 14.27 Mpa and 15.271 Mpa or it attains 108% and 115% of control mix strength at the age 28 days respectively as shown in figure-5

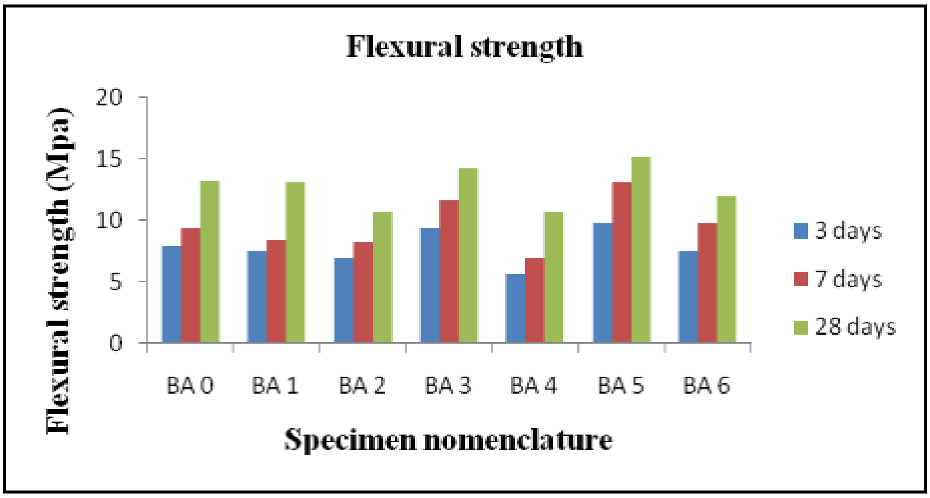

Figure-5. Flexural strength values in for various proportions of Bagasse ash.

5.0 Conclusions

Thus, this investigation is an evidence that environment can be protected from the disposal harms for the sugarcane bagasse ash and the use of raw materials , the production of green house gases (CO_2) during the manufacture of cement. This study makes the effective way of disposal of residual ash. Simultaneously, its the access for minimizing the use of natural resources and the production of CO_2 in the manufacture of cement. The results make the evident for replacement of cement with bagasse ash as follows

Test on cement were made for verifying the limits specified by the Indian standards at various proportions of bagasse ash such as 5, 10, 15, 20, 25 and 30%. At all replacement level,the satisfactory results were obtained within the permissible limits.

The pozzolanic reactivity were achieved 75% for a replacement level upto 30%. Therefore, Bagasse ash can be a supplementary cementitious material. It can be blended with cement upto 30%.

Compressive strength of cement with bagasse ash at 15 % mix achieved a greater strength than control mix. Flexural strength at 15 and 25 % replacement level with bagasse ash has shown a greater strength than ordinary Portland cement mix. These enhacement of mechanical properties is due to filler effect and dense mixes. Therefore 15 % will be optimum level of replacement of cement with bagasse ash.

6.0 References

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