Sawdust Ash (SDA) as Partial Replacement of Cement

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ABSTRACT

The possibility of using Sawdust Ash (SDA) as a construction material was experimentally investigated. Saw dust was burnt and the ash sieved using a 90 micron sieve. Three grades of ordinary Portland cement (OPC) namely; 33, 43 and 53 as classified by Bureau of Indian Standard (BIS) are commonly used in construction industry. A comparative study on effects of concrete properties when OPC of varying grades was partially replaced by SDA is discussed in this paper. Percentage replacement of OPC with SDA was 0, 10, 20, 30 and 40% respectively. Experimental investigations are carried out on mortar cubes, concrete cubes and beams specimens. The mix was designed for target cube strength of 30 MPa at 28 days with water-cement ratio of 0.38. The compressive strength, water absorption, shrinkage and durability of concrete were mainly studied. Test results shows that, inclusion of SDA cause little expansion due to low calcium content. Early strength development was observed to be about 50-60% of their 28 days strength. The study suggests the use of SDA as partial replacement of cement up to a maximum of 10% by volume in all grades of cement.

Keywords - Sawdust Ash, ordinary Portland cement (OPC), partial replacement.

1. INTRODUCTION

According to American Society for Testing Materials (ASTM, C-618-1978), pozzolana is a siliceous or a siliceous aluminous material which contains little or no cementitious value, but in finely divided form and in the presence of moisture or water, chemically reacts with calcium of moisture at ordinary temperature to form compound possessing cementitious properties. Such material commonly includes fly ash, calcined diamotaceous earth, rice husk ash and pulverized burnt clay. Many researchers are being done on the possible use of locally available materials to partially replace cement in concrete as cement is widely noted to be most expensive constituents of concrete.

Extensive research has shown the use of substitute's material, which possessing pozzolanic properties that it can produce concrete of better resistance to sulphate attack and reduce permeability. Mehta [1980] have shown that partial replacement of cement by fly ash can also reduce heat of hydration. Use of pozzolana can also reduce alkali aggregates reaction [Meland, 1986]. Cement according to Shetty [2005] is composed primarily of silica and lime, which form the essential cementing compounds tricalcium (C_3S) and dicalcium silicate (C_2S). Any alteration in silica content will invariably affect the strength characteristics of cement, which is expected when SDA is used to partially replace with any grades of cement for making concrete. The aimed of this study is at sourcing of locally available material for constructions in a bid to reduce the overall cost of construction. Therefore, the present study cannot be underscored.

2. SAWDUST ASH (SDA)

Sawdust is an organic waste resulting from the mechanical milling or processing of timber (wood) into various shapes and sizes. The dust is usually used as domestic fuel. The resulting ash known as saw-dust ash (SDA) is a form of pozzolana. Dry sawdust concrete weighs only 30% as much as normal weight concrete and its insulating properties approximate those of wood. With proper cement to sawdust ratios, it is not flammable. As a basic construction material, sawdust concrete does indeed have its functions. Sawdust is in abundance in North Eastern India (Meghalaya) and other parts of the world. Experimental study to evaluate the behaviour of concrete properties both in plastic and hardened states with the inclusion of various waste products such as fly ash [Naik and Ramme (1990), Gopalakrishna et al. (2001)], coconut ash [Oyelade and Akintoye (2011)], Rice hush ash [Nargale et al., 2012] are available in the technical literature. Sawdust has been used in concrete for at least 30 years, but not widely. Although seriously limited by its low compressive strength, sawdust concrete can be made to perform well in certain floor and wall applications.

Experimental investigation to evaluate the possibility of using Sawdust Ash (SDA) as a construction material has been reported by Sumaila and Job [1999], Udoeyo and Dashibil [2002]. Different grades of ordinary Portland cement (OPC) are available depending on the respective country codal classification. Bureau of Indian Standard (BIS) normally classify three grades of OPC namely: 33, 43 and 53, which are commonly used in construction industry. The possibility of using SDA as part replacement of OPC need to be investigate for confident used of these materials. The review of literature however, could not find any comparative study on the effect of concrete properties when cement of varying grades were partially replace by SDA are addressed together. Thus, in the present work a holistic approach was adopted to investigate the possibility of using SDA as a construction material. The contributions to strength gain, improvement in durability, water absorption and shrinkage are the main parameter of study.

3. EXPERIMENTAL PROGRAM

Sawdust collected from local saw mill was used in this study. The sawdust was openly heated to about the temperature of 600 ºC; the ash was then grounded after cooling and graded in accordance with BS-812 [1967]. Chemical properties of SDA and their comparison with OPC are presented in Table 1.

Coarse aggregate from crushed basalt rock was use. Flakiness and Elongation Index were maintained well below 15 %. River sand was used as fine aggregate. Material used have been tested as per relevant codal provision [IS 2386 (I, III), 1963]. The mix was designed for target cube strength of 30 MPa at 28 days with water-cement ratio of 0.38. A simple method of mix proportioning using SDA (i.e. SDA as part replacement of cement by weight) has been adopted. This was adopted due to remarkable difference in specific gravity of SDA and OPCs. (SDA= 2.15, 33 OPC=3.14, 43 OPC=3.15 and 53 OPC = 3.20)

Various grades of ordinary Portland cement (OPC) classified by BIS namely: 33, 43 and 53 conforming to standard codal provision [IS 269-1989, IS 8112-1989 and IS 12269-1987] were used. The cement by SDA are 0, 10, 20, 30 and 40% per each grades. Fly ash has been added as percentage by weight of total cementitious material replacing cement by various percentages. Table 2 illustrates the detail of various percentages chosen.

Eighteen cubes of sizes 150x150x150 mm were cast per variety of sample per each grades of cement for strength test and water absorption test. Cube strength was examined at different age's i.e. 7, 28, 56 and 90 days. However, water absorption test were examined at 56 and 90 days. For water absorption, the cubes were kept moist for the above test age in tap water and then heated for 24 hours at 110 ºC in an oven.

Two un-reinforced beams of sizes 150 x150x1000 mm per each grade of cement were cast to measure the shrinkage. Shrinkage test of beam after 28 days of curing were done by measuring the change in length of the specimen at 7 days interval.

Six mortar cubes of 50x50x50 mm were cast per variety of the sample and per each grades of cement for durability test (sulphate resistance). The resistance to sulphate attack were evaluated by immersion of well-cured specimens after 28 days of curing in a standard sodium sulphate solution (Na_2SO_4) having concentration of 16 gm/l [Buenfeld and Newman, 1984]. An enhanced sulphate salt concentration as high as eight times that of average salt concentration of sea water was considered. The specimens were alternately wetting and drying at 7 days intervals and then determining the strength loss as a result of sulphate exposure for 28 days.

Table 1: Physical and Chemical Properties of SDA and OPC

Elements	SDA % by weight	OPC % by weight
Specific gravity	2.51	3.14 (33 OPC) 3.15 (43 OPC) 3.20 (53 OPC)
Moisture contents (% by weight)	2.16	0.344
Loss on ignition (g/cm^3)	3.67	1.05
pH	11.12	12
SiO_2	50.20	20.70
AL_2O_3	1.02	5.75
Fe_2O_3	14.23	2.50
CaO	5.45	64.00
MgO	0.09	1.00
MnO	5.60	0.05
Na_2O	0.07	0.20
K_2O	9.57	0.60
P_2O_5	0.56	0.15
SO_3	0.58	2.75

Table 2 Details of proportions of cement and fly ash

Symbols	% of cement	% of SDA
C100	100	0
F10	90	10
F20	80	20
F30	70	30
F40	60	40

4. RESULTS AND DISCUSSION

Various parameters which significantly affect the properties of concrete (plastic and harden state) with the inclusion of SDA are discussed below.

4.1 Effect of SDA on cementitious properties

The physical and chemical properties of SDA used in this study are shown in Table 1. It is seen that the SDA proportion of silicon dioxide (SiO_2), aluminum oxide (Al_2O_3) and iron oxide (Fe_2O_3) when combined together was 65.45%, which slightly less than that specified by ASTM C 618[1978] for pozzolana but the average loss on ignition was 3.67 which satisfied the ASTM requirement. The specific gravity of SDA was found to be 2.51 which is about fourth-fifths that of cement (33 OPC=3.14, 43 OPC=3.15 and 53 OPC = 3.20). The pH value of SDA was evaluated as 11.12, which is alkaline in nature.

The main physical properties of SDA that influence the activity in gaining strength is its fineness. SDA required having equal or finer than OPC for its good cementing efficiency. The fineness of the 33, 43 and 53 cement grades OPC in this investigation are found to be 9, 8 and 6% residue on 90 micron sieve size respectively. Fineness of SDA is found to be 5%. This shows that SDA is of finer size as comparable to cement particles. Thus, it is expected to have appreciable influence on the strength development on concrete.

The variation of setting time [initial setting time (IST) and final setting time (FST)] and soundness of OPCs and SDA are furnished in Fig. 1 and 2 respectively. Fig. 1 shows that the setting time increased with increasing SDA content. This behavior may be due to the low rate of hydration in the paste containing SDA. Cement content is usually accompanied by high rate of hydration and it is usual that the reduction in cement content by replacing by SDA which is virtually inert at the early age would be accompanied by a low heat of hydration. 33 grades OPC takes longer time (both initial and final) as compared the other two grades. This same trend was also observed by Marthong [2002] when OPC of various grades were partially replaced by class-F fly ash. The soundness as shown in Fig. 2 slightly increased upon the inclusion of SDA. Soundness of 33 grades OPC was found to be slightly lower as compared to the other two grades of OPC. The obtained values of setting time and soundness was however, within the recommended range for all grades of OPC paste [IS 269-1989, IS 8112-1989 and IS 12269-1987].

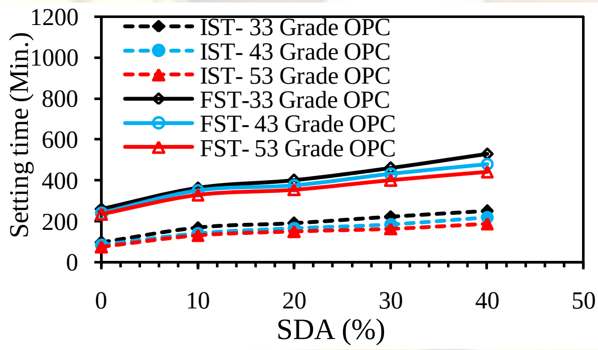

Fig. 1 Setting times with SDA content

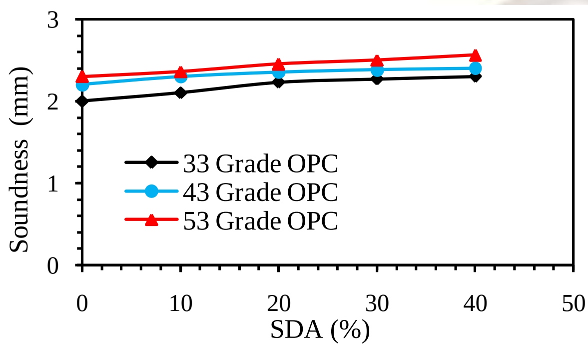

Fig. 2 Soundness with SDA content

The variation of normal consistency for different grades of OPC using different percentage SDA is shown in Fig. 3. The plot indicates that the water requirement for the paste increases approximately linearly for all grades of OPC. The normal consistency of 43 and 53 grades cement are higher by 7 and 10% as compared to that of 33 grade cement. Further, the cement of 53 grades is finer as compared to 33 grades OPC; hence more water is required for wetting the particles, as the total surface area of the particle is increases.

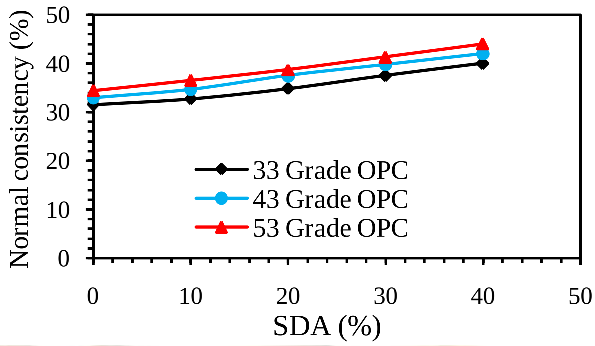

Fig. 3 Consistency with SDA content

4.2 Effect of SDA on concrete properties

4.2.1 Workability

It was observed from the slump and compacting factors test that the slump decreased upon the inclusion of SDA as partial replacement of OPC. Therefore, it can be inferred that to attain the required workability, mixes containing SDA will required higher water content than the corresponding conventional mixes. The workability (slump) of concrete for 33, 43 and 53 grades OPC varies from 23, 18 and 10 mm for concrete containing 40% SDA respectively. The higher value of slump is obtained for concrete with cement of 33 grades and least for 53 grades cement. This behaviour was as expected because higher the grade of cement the more fine it is. Finer cement requires more water to wet the surface particles.

4.2.2 Compressive strength

The Variation of cubes strength at different ages of 7, 28, 56 and 90 days with different grades of OPC and various percentage of SDA contents are shown in Fig. 4 to 6. The figure indicates that compressive strength of concrete in all grades of OPC at early age is significantly higher than that of concrete produced with SDA. It was also observed that compressive strength continued to increase with age but decreased with SDA contents in all grades of OPC. The reduction in strength at the initial stages of hydration may be because SDA acts as a retarder. The initial processes of hydration get retarded, which invariably may affect the initial process of strength development. The strength reduction was found to be lower for higher grade OPC. Comparison on the attaining of strength at 28 days it was observed SDA with 43 and 53 grades OPC attained about 60% of strength as compared to normal concrete, while SDA with 33 grades OPC could attain only 50% of its strength. This comparison shows that SDA 43 and 53 OPC with medium workability concrete compared favorably with OPC concrete in term of early strength development. In long term strength gain (at 90 days), SDA 43 and 53 grades OPC attained about 80% strength as compared to concrete with 0% SDA replacement, while SDA 33 grades OPC the strength gain was about 58% only. The comparison clearly shows that strength of SDA concrete slightly increase with age in all three grades of OPCs. Thus it indicate that replacement by SDA for 43 and 53 grades OPC is seems to be better in term of ultimate strength gain than that of 33 grades OPC. The same behavior was also observed by Marthong [2002] when OPC of various grades were partially replaced by class-F fly ash. However, the optimum strength of SDA concrete was observed to be 10% replacement in all the three grades of OPCs.

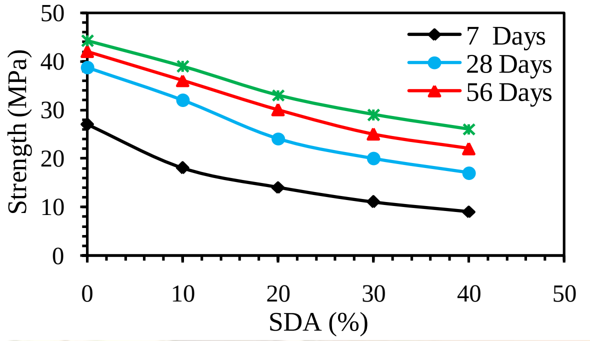

Fig. 4 Compressive strength of 33 grade OPC

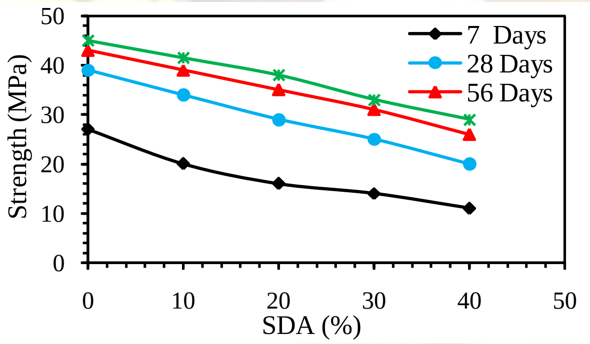

Fig. 5 Compressive strength of 43 grade OPC

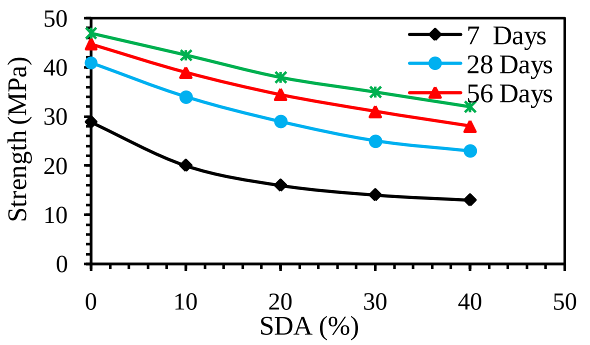

Fig. 6 Compressive strength of 53 grade OPC

4.2.3 Water absorption

The water absorption was calculated on the basis of initial soaked cube and then oven dried. Fig. 7 shows the variation in water absorption with SDA contents. The test results depict that water absorption up to 20% replacement decreased with the inclusion of SDA in all grades OPC as compared to pure cement and there after start increasing. The water absorption of 53 grade OPC concrete with SDA content is least than the other two and being maximum for 33 grades OPC concrete. This behaviour may be due to the fact that, 53 grade cement is finer and 33 grade OPC being coarser particles. Thus, permeability of paste with coarser cement particle is higher. The water absorption of SDA concrete also varies with age of concrete. The results also depict that water absorption too decreased with age. With age the water absorption decreased because gel gradually fills the original water filled spaces.

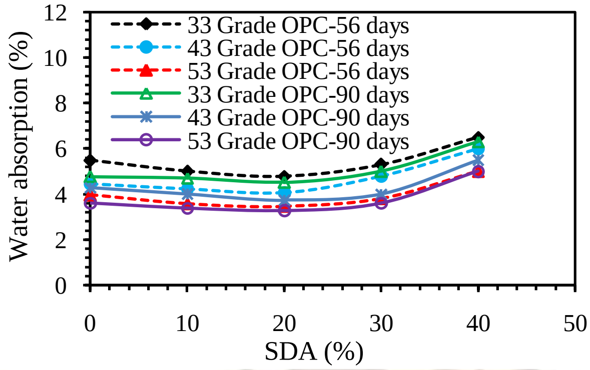

Fig. 7 Water absorption with SDA content

4.2.4 Shrinkage

It is well know that shrinkage directly relate to consistency. The consistency of SDA cementitious paste decreased as compared to OPC cement paste. This shows that shrinkage should decreased in SDA concrete due to the reduction in water demand and production of finer paste structure, which restrict the loss of pore water within the paste. However, in the present study it has been observed that the shrinkage of specimens with 40% SDA content measured at the age of 90 days found to be same for pure and SDA concrete at each proportion. This is in line with the observation by Marthong [2002] when OPC of various grades were partially replaced by class-F fly ash. Hence, it may be concluded that influence of SDA on shrinkage is negligible.

4.2.5 Durability

Variation in compressive strength with SDA content for 28 days exposed in sulphate solution and tap-water are shown in Fig. 8. The figure demonstrates that, for each grades of cement the strength of ordinary cube and that partially replaced by SDA immersed in sulphate solution have less compressive strength than the corresponding referral cubes immersed in tap-water. Strength decreases as SDA contents increases. The decreased in cube strength exposed in sulphate solution over that exposed in tap-water are about 8% for ordinary cubes and that of 40% SDA content are about 10-20% for all grades of OPC. Thus, inclusion of SDA as partial replacement of cement seems that it does not improve the durability when exposed to sulphate environment. Comparing all the three grades of OPC, the strength loss seem to be betters for 53 grade OPC as compared to the other two grades.

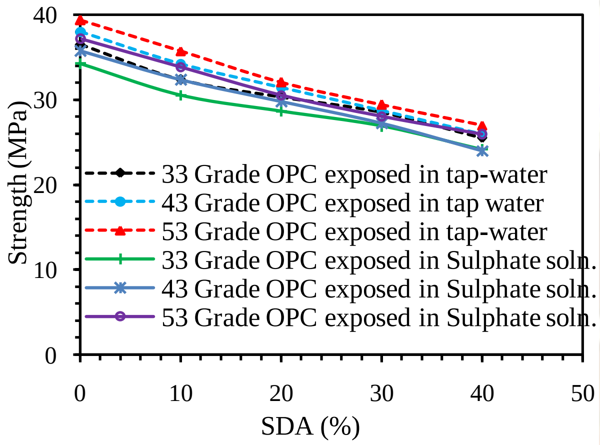

Fig. 8 Compressive strength under different environment

5. CONCLUSIONS

From the experimental work carried out and the analysis of the results following conclusions seem to be valid for possible use of SDA as partial replacement of cement.

1. Important oxides content was 65.45% by weight of SDA and has a pH value of 11.12, which shows that it's alkaline in nature. This shows that SDA has a significant physical and chemical property that encourages its uses as a pozzolanas.
2. Setting times increased in all grades of OPC upon the addition of SDA but are in the range recommended for pure cement.
3. Workability decreased upon the inclusion of SDA. Thus, mixes containing SDA will required higher water content than the corresponding conventional mixes.
4. Compressive strength of concrete increases with grade of cement. Early strength development was observed to be about 50-60% of their 28 days strength. Test results indicate that SDA concrete can attain the same order of strength as conventional concrete at longer curing periods. The rate of strength gain by SDA-33 grades OPC is lower as compared to 43 and 53 grades. However, study suggested the use of SDA as partial replacement of cement up to a maximum of 10% by volume in all grades of cement.
5. Water absorption of SDA concrete up to 20% replacement decreased with the increased in grades of OPC.
6. Shrinkage of SDA concrete is similar to the pure cement concrete in all grades of OPC.
7. Inclusion of SDA as partial replacement of cement does not improve the durability when exposed to sulphate environment. However, SDA with 53 grades OPC seems to be better.

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