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Effect of Sugarcane Molasses on Compressive Strength and Workability of Fly Ash Mixed Concrete

Shantanu Bhide*[1], Jayesh Darshane[2], Darshana Shinde[3], Sudhanshu Dhokale[4], Prathamesh Deshmukh[5], Yashraj Desai[6], Pradeep Kodag[7]

*[1,2,3,4,5,6] UG Scholar, Department of Civil Engineering, Sinhgad College of Engineering, Pune, Maharashtra, India
[7]Assistant Professor, Department of Civil Engineering, Sinhgad College of Engineering, Pune, Maharashtra, India

ABSTRACT

Molasses, a by-product of sugar industry, is used as a water reducing, retarding admixture in fly ash mixed concrete. The positive effects of fly ash as a partial replacement of cement on the strength and durability of concrete are recognized through numerous researches. In this study, mechanical property such as compressive strength and workability of concrete adding fly ash and sugarcane molasses sourced from southern Maharashtra has been investigated. Effect of molasses with concentrations of 0.1%, 0.15%, 0.2% and 0.25% by weight of cement, cured at 7, 28 and 56 days were examined. The strength of concretes with various dosages of molasses showed slight increase at 7-day age against concrete without molasses. The compressive strength test results showed significant strength gain at all ages for 0.15% dosage molasses but peaks at 43.89% at 28 days. However, there was no significant increase in strength from 28 to 56 days which peaks 4.8% for 0.15% dosage. The slump values were observed to increase linearly with increase in dosage of molasses from 0.1% to 0.25% respectively.

Keywords : Admixture, Compressive Strength, Molasses, Retardation, Slump, Workability.

I. INTRODUCTION

Concrete is the most widely used construction material on this planet. In India, 68% of electricity is produced by the coal fired thermal power plant. Typically burning of 15–18.75 tons of coal generates 1 megawatt of electricity as well as 4.3–11 tons of fly ash. According to Central Electricity Authority of India, 182 million tons of fly ash is produced annually. Thus, the fundamental issue of dumping the enormous amount of fly ash produced arises due to its perilous effect.

Molasses has been used in numerous industries as raw material, like animal food industry, in production of alcohol, ferment and glycerine. In Maharashtra, there are 202 sugar factories, which process sugarcane to obtain sugar. At the end of various refining processes, a brown syrup, which is called molasses is obtained. During the past 5 years, the average amount of sugarcane crushed is 764 Lakh Million Tons (L.M.T) in the state of Maharashtra [28]. Approximately, 4% - 5% of crushed sugarcane remains as molasses after the process. The composition of molasses differs depending upon the source it has been obtained from.

Disposing of waste materials has adverse impact on environment. Thus, there has been developing pattern of using waste materials for various purposes. Therefore, waste materials like fly ash and molasses have been used as fractional replacement of cement, admixture respectively.

Molasses as an admixture can be used for preparation of concrete. This means of utilizing molasses instead of conventional admixture will not only cut down the production cost of concrete but it will also enhance its resistance to compressive strength [2]. It will also lead to the reduction in water utilization, expansion of setting time and likewise they improve the durability, workability and quality of concrete mixture

II. MATERIALS

A. Cement

53 grade ordinary Portland cement conforming to IS 12269 (1987) [21].

B. Fine Aggregates

Locally available crushed sand passing through 4.75 mm IS sieve was used. The specific gravity of the sand was found as 2.71 and confirming to zone II of table 4 of IS 383-1970 [17].

Table 1 shows the properties of fine aggregates used in the study.

TABLE 1.
PROPERTIES OF FINE AGGREGATES

Sr. No.	Name of the test	Result
1	Specific gravity	2.71
2	Water Adsorption	2.88%
3	Bulk Density	1.77 kg/lit
4	Fineness Modulus	2.99
5	Material Finer than 75 ų	19.79 %

C. Coarse Aggregates

Aggregates available from local sources have been used. The maximum size of coarse aggregate was 20mm and its specific gravity was 2.93.

Table 2 shows the properties of coarse aggregates used in the study.

TABLE 2
PROPERTIES OF COARSE AGGREGATES

Sr. No.	Name of the test	Result
1	Specific gravity	2.93
2	Water Adsorption	0.53 %
3	Flakiness index	10.99 %
4	Elongation index	17.10 %
5	Bulk Density	1.54 kg/lit
6	Aggregate Crushing Value	8.56%
7	Aggregate impact Value	4.79 %

D. Admixture

Molasses, a viscous form of brownish black colour, completely soluble in water was obtained from Loknete Balasaheb Desai Sugar Industry, Satara.

Table 3 shows the chemical analysis and contents of sugarcane molasses.

TABLE 3
CHEMICAL ANALYSIS OF MOLASSES

Sr. No.	Parameters	Results (%)
1	Total nitrogen	0.57
2	Sulphate as SO_4	2.40
3	Total Solids	77.0
4	Total Reducing Sugar	59.14
5	Apparent Purity	50.06
6	Water as moisture	23.00
7	Purity as sucrose	41.46
8	Inorganic constituent Ash	7.88
9	Chloride content	1.45

E. Fly Ash

Locally available fly ash, conforming to IS 3812: 1981 [22].

Table 4 shows the physical properties of fly ash.

TABLE 4
PHYSICAL PROPERTIES OF FLY ASH

Parameters	Fly Ash
Bulk Density (gm/cc)	0.9-1.3
Specific Gravity	1.6-2.6
Plasticity	Lower or non-plastic
Shrinkage Limit (Vol stability)	Higher
Grain size	Major fine sand / silt and small per cent of clay size particles
Clay (per cent)	Negligible
Free Swell Index	Very low
Classification (Texture)	Sandy silt to silty loam
Water Holding Capacity (WHC) (per cent)	40-60
Porosity (per cent)	30-65
Surface Area (m^2/ kg)	500-5000
Lime reactivity (MPa)	1-8

III. MIX PROPORTION

The cement dosage and W/C ratio were the same for all concrete mixtures as 340 kg/m^3 and 0.4, respectively. The weight ratios of cement/ fly ash/ fine aggregate/ coarse aggregate were 1: 0.42: 2.15: 3.23. The concrete was mixed in a pan mixer with a capacity of 0.035 m^3. The molasses was used as a superplasticizer.

IV. METHODOLOGY

Control mix design of concrete with 30% fly ash as partial replacement of cement was prepared as per the guidelines given in IS: 10262-2009 [23]. The fly ash content was decided as per IS: 1489 (Part 1): 1991 [24]. Four dosages of molasses as admixture were taken as 0.25%, 0.2%, 0.15%, 0.1% by weight of cement. The

control specimens were prepared without addition of admixture.

Mix designs with 0.5% & 1.5% molasses were also prepared and their specimens, cast and tested. The specimens were demolded after 96 hours and did not show sufficient strength on testing after 7 days. So, the study was narrowed down to minimal dosages of molasses i.e. 0.25%, 0.2%, 0.15%, 0.1% by weight of cement.

All the specimens were demolded after 24 hours whereas specimens with dosages of 0.25% and 0.2% of molasses were demolded after 48 hours. This delayed setting of concrete shows the retarding properties of molasses added concrete.

A. Workability

Workability of concrete has been measured by performing slump cone test. The test was carried out in accordance with IS: 1199: 1959 [25]. The slump values were measured at time intervals of 30, 45 and 60 minutes after preparation of the mix respectively. The ingredients of concrete were mixed properly on a water tight platform and the slump values were measured, record and tabulated properly.

B. Compressive Strength

Concrete cubes were prepared in accordance with the requirements of IS: 10086: 1982 [26]. Compressive strength tests were carried out on cubic specimens of 15x15x15 cm at the age of 7, 28 and 56 days respectively as per the specifications mentioned in IS: 516: 1959 [27]. The specimens were removed from the curing pond after period of 7,28,56 days and were allowed to dry in shade for a couple of hours. Each sample was weighed and the specimen was placed properly in 2000kN capacity Compressive Testing Machine. The surface of specimen was checked to be uniformly in contact with the upper arm of the CTM. Load was applied gradually and the ultimate load was recorded.

V. RESULTS AND DISCUSSION

A. The Slump Test

Workability of concrete has been measured by the slump cone test. It can be observed from Fig.1 that as the dosage of molasses decreases, the slump values also decrease. This effect can be attributed to the retarding property of molasses. The slump values were observed to be decreasing linearly over a span of 30, 45, and 60 minutes, respectively for all dosages of molasses.

For the same W/C ratio, the control mix shows slightly higher slump value than those of concrete with molasses. Nevertheless, the slumps remain in the ranges of 90-110 for admixture dosages of 0.15% and 0.2%. The slump results indicate that molasses can be used as an admixture effectively.

A graph of slump vs time was plotted for all the design mixes as shown in figure 1.

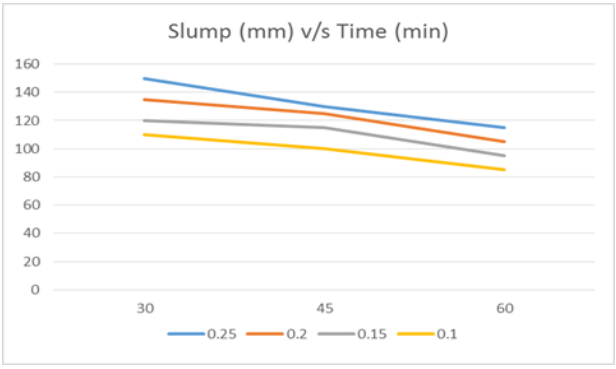

Figure 1. Slump vs Time

Figure 2 shows slump values recorded at 60 minutes for various dosages of molasses.

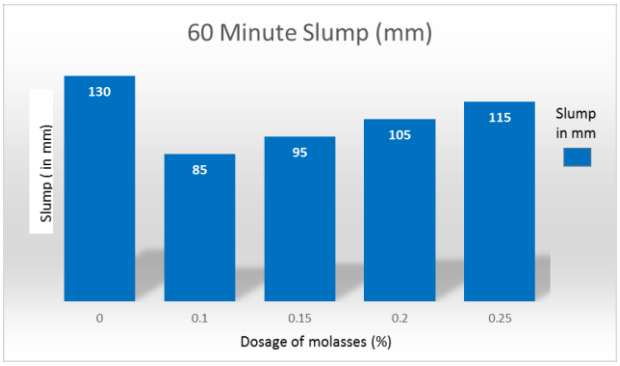

Figure 2. Slump values at 60 minutes

B. Compressive Strength

According to Table 1A, IS 9103: 1999 [20], the admixture used can be categorized as a water reducing admixture if the concrete prepared achieves 10% increase in compressive strength.

The compressive strength results of concrete cubes with different dosages of molasses are presented in Fig.3. The results reveal that, the compressive strength does not vary linearly with the dosage of molasses. Table 7 shows that, concretes with molasses give higher strength than those without molasses. For example, for 0.15% dosage, the compressive strength increased by 43.9% as compared to the concrete without molasses at 28-day age. Similarly, from Table. 6, compressive strength increased by 101.63% for 0.15% dosage as compared to 82% for 0% molasses.

All the concrete specimens having molasses as admixture have higher compressive strength than the control specimen.

The specimens with dosages of 0.25%, 0.2%, 0.15% and 0.1% molasses show an increase in compressive strength as 8.65%, 37.17%, 29.88% and 38.85%, respectively at 7 days age as compared to the control specimen containing no molasses.

The results of compressive strength test for all the specimens are comparatively shown in figure 3.

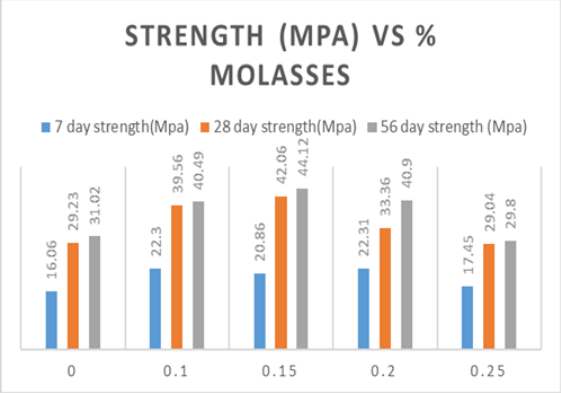

Figure 3. Compressive Strength results

The specimens with dosages of 0.25%, 0.2%, 0.15% and 0.1% molasses show an increase in compressive strength as -0.65%, 14.13%, 43.90% and 35.34% respectively at 28- day age as compared to the control specimen.

The specimens with dosages of 0.25%, 0.2%, 0.15% and 0.1% molasses show an increase in compressive strength as -3.93%, 31.85%, 42.23% and 30.53% respectively at 56- day age as compared to the control specimen.

From Table 6, it can be observed that significant increase in strength due to addition of molasses was only observed up to a period of 28 days. Beyond 28 days of age, no significant increase in strength was observed for all percentages of dosage.

From Fig. 2 and Fig. 3, 0.15% dosage of molasses is the optimum dosage considering the parameters of workability and compressive strength. Results of slump test and compressive strength test are tabulated in table 5.

TABLE 5
SLUMP AND COMPRESSIVE STRENGTH RESULTS

Type of Concrete	**60 Minute Slump (mm)**	**Compressive Strength (MPa)**		
		7 day	**28 day**	**56 day**
O.P.C	140	18.39	30.3	33.24
Fly Ash Concrete	130	16.06	29.23	31.02
0.25% Molasses	115	17.45	29.04	29.8
0.20% Molasses	105	22.03	33.36	40.9
0.15% Molasses	95	20.86	42.06	44.12
0.1% Molasses	85	22.3	39.56	40.49

Table 6 and Table 7 show the compressive strength increment with respect to age and dosages respectively.

TABLE 6
AGE WISE STRENGTH INCREMENT

Percentage Molasses	Percent Increase in Strength		
	7-28 day	28-56 day	7-56 day
0	82.00	6.12	93.15
0.1	77.40	2.35	81.57
0.15	**101.63**	4.90	**111.50**
0.2	49.53	22.60	83.33
0.25	66.42	2.62	70.78

TABLE 7
DOSAGE WISE STRENGTH INCREMENT

Percentage Molasses	Percent Increase in Strength		
	7 Days	28 Days	56 Days
0 – 0.1	38.85	35.34	30.53
0 – 0.15	29.89	**43.90**	**42.23**
0 – 0.2	38.92	14.13	31.85
0 – 0.25	8.65	-0.65	-3.93

VI.CONCLUSION

The following conclusions were drawn from the experimental study carried out using molasses as an admixture in preparation of concrete:

1. Usage of molasses as a plasticizer in concrete is satisfying IS 9103: 1999 [20] standard for water reduction criteria.
2. Molasses can be effectively used as a retarding and water reducing admixture in concrete.
3. As the dosage of molasses increases, the slump value increases which indicates higher workability.
4. The slump values after 60 minutes remain in the range of 90-110 mm for 0.15% and 0.20% admixture dosage. Therefore, molasses is useful to maintain the workability of concrete.
5. The concrete prepared with 0.15% dosage of molasses shows a maximum of 43.9% increase in compressive strength at 28 days.
6. Beyond 28 days age, a mere 2% - 5% increase in compressive strength can be observed for all specimens. Thus, the curing period can be limited to 28 days for molasses added concrete.
7. For 0.25% dosage beyond 28 days, the strength decreases by 3.93% up to 56 days age. Increase in dosage of molasses beyond 0.2% by weight of cement is not desirable.
8. Considering the parameters of workability and compressive strength, it can be concluded that 0.15% molasses is the optimum dosage.

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