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Novel Approach of Organic Admixture on the Properties of Concrete Interchanged In Hefty Measure with Fly Ash Blended Cement

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Abstract: **-- The goal of this paper is to provide a new look into the mechanism of jaggery replaced in large quantity into the concrete and to examine the impact on the physical behaviour of it. In this study, the Portland Pozzolana Cement (PPC) which is readily supplemented with fly ash was used as cement. The organic admixture (jaggery) rich in carbohydrate was supplemented with 0, 5, 10 and 15 % in place of cement by weight. The behaviour of cement paste and fresh properties of concrete was analysed using normal consistency, setting time, workability and compaction setup. Mechanical properties of concrete were checked with binary investigation i.e. with a non-destructive and destructive method. The results designates that the fresh behaviour of concrete was amended continuously with increased supplementation of admixture in concrete. In case of mechanical behaviour, the concrete was found with the varying output of strength when compared with non-destructive and destructive approaches. In both cases, the performance of concrete was found to be dwindled largely, with slight escalation at 15 % jaggery.**

***Keywords*: - Portland Pozzolana Cement (PPC), jaggery, non-destructive testing behaviour (NTB), destructive testing behaviour (DTB), and surface response model (SRM).**

I. INTRODUCTION

Cement production is a high energy consuming and heavy pollution creating process [1]. Each tonne of Ordinary Portland Cement (OPC) manufacturing releases almost similar quantity of CO2 in to the atmosphere, which makes approximately 6 % of complete man-made carbon emission [2]. Efforts are being made nowadays by the manufacturing companies to improve the formulation and the manufacturing process of cement to reduce the CO2 emission taking in to consideration financial aspects. In this regard efforts are made to use the waste materials arising from some industries to blend with OPC which will bring the reduction in the cost as well as CO2 emission. For example, fly ash, alkofine; silica fumes and blast furnace slag etc. are most common and currently being used in fields [2]. Apart from the fundamental mineral admixture replacement, chemical admixtures are found to be in need for sustainable development, from ecological and economical point of view [3]. Physical and mechanical characteristics of concretes and mortars can be achieved in a better manner by using different chemical additives such as antifreezes, super plasticizers, acryl, polypropylene, glass and other fibres and polystyrene beads [4]. Usually these compounds are composed of variety of different molecules and also the formulae used are also unknown due to some protected proprietary reasons [4]. The use of such variances affects the human health due to presence of toxic pollutants in it [5]. The changes occurring day-by-day articulates that, the chemicals to which the building inhabitants are exposed today are very different as compare to that which was experienced 50 years back. In case of ancient construction techniques, the materials used were cow dung, jaggery, mud, eggs, sugar, clay, burnt coconut shell, wood, surkhi, etc.[6], which was found to be less polluting and eco-friendly source as compared to that of modern techniques. Among that jaggery, sugar, eggs etc. were the main products which were used for binding the materials. Many researchers have made attempts to use ancient admixture in to the modern practices for obtaining the better outputs. Yonghe Xu et al. (2011) investigated the effect of sucrose on cement hydration and temperature when added at the dosage level of 0.08-0.2 %. The strength variation was analysed with respect to that of temperature variation [7]. LI Weifeng et al. (2014) studied the influence of sugarcane molasses on the normal consistency and setting time of cement. In this analysis, the compressive strength of concrete and the changes occurring in the fluidity of cement

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mortars was also studied [8]. Garci Juenger and Jennings (2002) reported that, the use of 1 % sucrose in cement paste can shorten the delay period at high curing temperature. It was also observed that the addition of sucrose increases the surface area of cement pastes and also alters the pore size distribution and micro-structure of C-S-H gel [9]. Marta Bermudez (2007) studied the effect of use of sugar on to the thickening time of cement slurries. The sugar added in this study was in varying quantities so as to examine the aspects such as strength, thickening time and slurry volume [10]. Many researchers have also given their efforts in different related investigations to examine the variations occurring in properties of concrete [11-16]. From the literature it is observed that, most of the efforts were taken towards the study of sugar, sucrose, molasses etc. based on their quantity, curing temperature, pore size distribution and strength. However, no much effort was taken for investigation of reaction of jaggery, when it is used in concrete with some supplementary cementitious materials. Therefore, in this paper an attempt is made to evaluate the changes that are occurring in the physical properties of concrete. The observations were made on both states i.e. the fresh and hardened state of concrete to evaluate the changes that are occurring in both phases with increased supplementation of jaggery.

II. EXPERIMENTAL PROGRAMME

2.1 Materials

The cement used in the investigation was Portland Pozzolana Cement (PPC) conforming I.S. 1489:1991 (part-I) [17], which is blended with approximately 15-30 % fly ash. The physical and chemical properties of PPC cement is presented in Table 1 and 2 [17, 18]. The fine aggregates used in the investigation was of well distributed sizes taken from the river of nearby area of Rasayani (Raighad, Maharashtra). The coarse aggregates used were made available from the nearby quarry with standard size. The water used was normal tap water. The admixture (jaggery) used was ordinary jaggery, with slight dark brown colour. The general composition of jaggery is given in Table 3 [19].

Table 1

Physical properties of PPC cement

Physical properties	PPC cement
Specific gravity	3.0
Fineness (m^2/kg)	300
Initial setting time (minutes)	30
Final setting time (minutes)	600
Soundness Le-chat (max) (mm)	10
Soundness Autoclave (max) (%)	0.8

Source: IS: 1489:1991 (Part-I)

Table 2

Chemical properties of PPC cement

Chemical composition	PPC (%)
SiO_2	28-32
Al_2O_3	7.0-10.0
Fe_2O_3	4.9-6.0
CaO	41-43
MgO	1.0-2.0
SO_3	2.4-2.8

Source: S. Muralidharan et.al. (2004).

2.2 Mix proportions for concrete

In this study concrete mix was prepared as per the mix design, with the specification of designing mentioned in I.S. 10262:2009 and I.S. 456:2000 [20, 21].

Table 3

General composition of Indian jaggery

Content	Value range (%)
Carbohydrate	83.5–95.0
Sucrose	72.8–80.3
Reducing sugar	6.8–14.2
Minerals	0.6–2.6
Calcium	0.2–0.36
Chloride	0.2–0.34
Phosphorus	0.03–0.22
Potassium	0.10–0.16
Sodium	0.006–0.025
Iron	0.005–0.020
Magnesium	0.008–0.105
Copper	0.007–0.010
Cobalt, nickel and molybdenum	0.001–0.008
Protein	0.35–0.40
Non-protein nitrogen (mg/100 g)	19.6–42.9
Protein nitrogen (mg/100 g)	13.7–17.6
Vitamins, mg/100 g	
Thiamine	0.018–0.030
Riboflavin	0.042–0.046
Nicotinic acid	3.92–4.50
Vitamin C	5.20– 30.00
Carotene, mg/100g	155.0–168.0
Phenolic, mg/100g	280.0–320.0
Fat, wax pectin and organic acid	0.10–0.60
Moisture	3.9–7.2

Source: Sahu and Saxena (1994).

2.3 Tests on specimens

In this investigation, various tests to examine the performance of cement and concrete using jaggery were done. The influence of jaggery on consistency and setting time of cement was examined with the help of vicat apparatus. The fresh behaviour of concrete was examined with the help of slump cone test and compaction factor test. For the investigation of hardened properties, the rebound hammer test and uniaxial compression test was performed.

2.2.1 Cement behavior

The investigation for behaviour of cement with respect to proportion of jaggery was analysed using vicat apparatus. The consistency test for cement was performed as per the guidelines of I.S. 4031(Part 4)-1988 [22]. In case of setting time, the investigation was done to analyse the variation in initial and final setting time of cement with increased replacement of jaggery. The test conducted was on same apparatus i.e. vicat, but the variation is found with the quantity of water used for it. The specification of I.S. 4031 (Part-5)-1988 followed for the setting time implies that the water used for the test is 85 % of the water found in the consistency test [22].

2.2.2 Fresh properties

The fresh properties of concrete were examined for all the four mixes prepared with proportion of jaggery i.e. 0, 5, 10 and 15 %. In order to investigate workability, the slump cone apparatus was used. The viscous behaviour of concrete was examined using the arrangement specified in the test as per I.S. 7320-1974 specification [23]. In case of compaction factor apparatus, the assembly was provided with two hopper and cylinder at bottom. The procedure for conduction test was adopted as per the specification of I.S. 5515-1983 [24]. The partially and fully compacted concrete was analysed and the changes were evaluated.

2.2.3 Mechanical properties

In order to evaluate the mechanical behaviour of concrete, methods used were destructive and non-destructive. The non-destructive testing was performed with the help of rebound hammer apparatus following I.S. 13311(Part 2):1992 specification [25]; similarly in case of destructive apparatus uniaxial-compression testing machine was used as per the given specifications of I.S. 516-1959 [26].

III. RESULTS AND DISCUSSIONS

3.1 Behaviour of cement

In this investigation, the cement paste evaluated for its performance was found with impulsive behaviour. The normal consistency test conducted on the cement paste, prepared with all the specified dosages. The results of consistency implies that the consistency of cement paste was found to be admired using less water as compare to that of normal paste. It was observed that the consistency value of cement paste was reduced continuously with increased replacement of admixture, which was further found to be falling nearly by 50 % at 15 % of jaggery. The Table 4 presents the value of consistency and setting time at all the dosage level of jaggery.

3.2 Fresh concrete

The results of the slump cone and compaction factor test are presented in Table 5. The output of the slump cone test

Table 4

Normal consistency and setting time output

Sr. no.	Percentage of jaggery	Normal consistency	Setting time (minutes)	
			Initial	Final
1	0	33	30	602
2	5	21	49	678
3	10	18	46	653
4	15	16	39	648

implies that the workability of the concrete which was observed to be 182 mm at normal state was found to be increased continuously with supplementation of jaggery. The result shows that the workability of concrete was increased nearly by 18 % when compared with normal concrete. Similar type of enhanced flow was also observed by Marta Bermudez (2007) in cement slurry with increased quantity of sugar in it [10]. In case of compaction factor test, the compaction level which was 0.99 at normal state was found to be improved with increased quantity of jaggery as shown in Table 5. The compaction value which was 0.99 at normal condition was found to be further improved and finally found to be 0.93 at 15 % jaggery. The result shows that the compaction was increased by 0.04.

Table 5

Slump cone and compaction factor results

Sr. no.	Percentage of jaggery (%)	Slump cone value (mm)	Compaction factor value
1	0	182	0.99
2	5	198	0.97
3	10	207	0.94
4	15	213	0.93

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3.3 Mechanical behaviour of concrete

3.3.1 Destructive and non-destructive methods

The results of mechanical behaviour of concrete are presented in Table 6 and 7. In case of non-destructive testing technique, the compressive strength was found after 3, 7, 14 and 28 days which are shown in Table 6. The result implies that the strength of concrete was falling largely at 5 and 10 % replacement of jaggery at all the curing periods. It was observed that the strength of concrete was better improved with 15 % jaggery, as compared to that of 5 and 10 % jaggery, but however it was less as compared to that of normal concrete. The strength parameters are also graphically represented in Figure 1, which can be seen with both destructive and non-destructive results. In case of destructive testing, the concrete was obtained with more failure condition. Similar behaviour was observed for destructive method, but the values obtained were much lower as compared to non-destructive method. The results of destructive methods by uniaxial compression testing machine are presented in Table 7, which indicates the strength with all curing periods used in the investigation. The results of 5% and 10 % jaggery was found to be largely falling at all the adopted curing periods, similar to that of non-destructive test results. In this case, it was observed that the strength of concrete with 15 % was more as compare to that of 5% and 10 % jaggery, but when compared with normal concrete it was still lagging with a considerable score of strength.

Table 6

Compressive strength with non-destructive technique

Sr. no.	Percentage of jaggery (%)	Compressive strength (N/mm^2)			
		3 days	7 days	14 days	28 days
1	0	6.66	10.33	19.00	24.33
2	5	00.00	00.00	09.00	11.66
3	10	00.00	08.00	10.66	12.33
4	15	09.66	11.00	12.33	18.33

Table 7

Compressive strength with uniaxial compression testing

Sr. no.	Percentage of jaggery (%)	Compressive strength (N/mm^2)			
		3 days	7 days	14 days	28 days
1	0	5.22	9.63	16.71	23.27
2	5	1.65	1.73	2.83	3.09
3	10	2.29	2.33	3.49	5.07
4	15	4.21	5.13	7.11	8.89

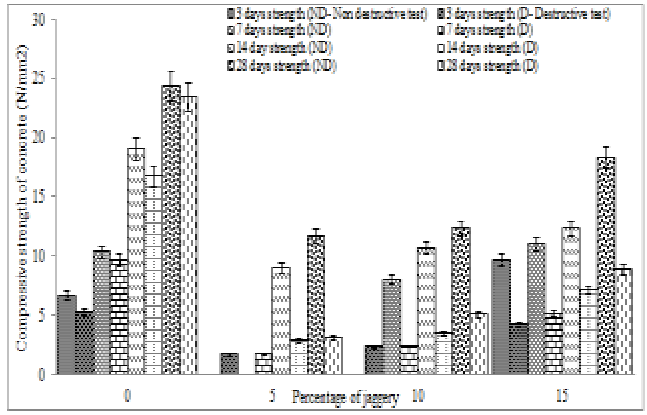


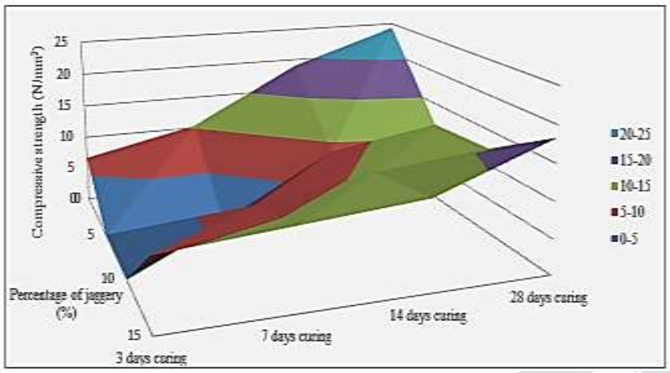
Figure 1 Compressive strength of concrete with non-destructive and destructive method

3.3.2 Analysis using surface response model

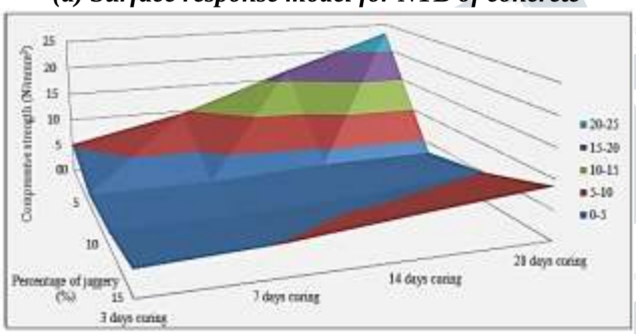
In both the cases i.e. non-destructive and destructive testing, the behaviour of compressive strength was analysed at all the adopted curing period. In order to have a better analysis of compressive strength, surface response model (SRM) was prepared for both the cases i.e. non-destructive testing behaviour (NTB) and destructive testing behaviour (DTB) as shown in Figure 2 (a) and (b). The orientation of model was presented with X-axis at 70o and Y-axis at 15o, with perspective at 15o. The position of the surface represents the performance of concrete in compressive strength which was found with respect to percentage of jaggery and curing period. It is observed from Figure 2 (a) and (b) that the surface response for normal concrete was well defined at all the adopted curing periods, as compare to other mixes. In case of NTB with 15 % jaggery, the SRM was found to be with lower elevations at all position when compared with normal concrete. When the SRM of DTB was compared with NTB, the positions of surface were found to be largely falling at all the sections. In case of NTB with 5 and 10 % jaggery, it was found that the position of surface was almost zero after 3 days curing, which was further found to be with rising gradient, but the analysis of surface nature in DTB was found to be almost flat at all the positions.

IV. CONCLUSION

The investigation deliberates an empirical effort done to examine the variation in the properties of concrete with replacement of organic admixture i.e. jaggery. The results indicate that the normal consistency and setting time of cement improves with increased replacement of jaggery. It is observed that, addition of jaggery reduces the amount of water added to achieve the normal consistency and at 15 % of jaggery the amount of water reduction observed is 50%. The workability and compaction factor values were found to be enhanced with replacement of jaggery. At 15% jaggery, the workability was found to be 30% more than the normal concrete. The compressive strength was found to be extremely low with 5% and 10% jaggery, but found with improvement at 15%.



(a) Surface response model for NTB of concrete



(b) Surface response model for DTB of concrete

Figure 2 Surface response models for (a) NTB and (b) DTB

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