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Investigation of strength characteristics of cement bagasse ash mortars using full factorial approach

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ABSTRACT

The cement industry is one of the largest embodied energy consuming and CO_2 emitting industry. It is found that to produce one kg of cement, it requires 4.2MJ of energy and liberates about one kg of CO_2 which is one of the important greenhouse gases as the global warming reason. The partial replacement of ordinary Portland cement by agricultural waste is an alternative solution for decreasing the CO_2 emission and to minimize the embodied energy of cement. In this study, the effect of sugar cane bagasse ash from three different sources, i.e. from Pandavpura, Nanjangud and Kuntur were collected. The bagasse ashes were ground until the particles retained on a 150µm sieve.The physical and chemical properties of the samples were tested. The tests conducted on the cement mortar are the flow table test and compressive strength test at 0, 10, 15, 20 and 25% replacement of cement by weight with different water cement ratios of 0.3, 0.35 and 0.4. From the experimental results it was found that water demand for the mortar increases with increasing percentages of bagasse ash due to larger particle size and high porosity of bagasse ash. It was also observed that from all the sources an average strength of 100% 108%, 101%, 97% and 94% were attained for 0, 10, 15, 20 and 25% replacement of cement by bagasse ash at 28 days.

Keywords: *Bagasse ash, Compressive strength, Mortar, Workability.*

INTRODUCTION

Since many years, numbers of efforts have been made to reduce utilization of ordinary Portland cement because of its impact on environment during its production. Various alternative materials such as fly ash, ground granulated blast furnace slag, silica fume etc.. have been found to be satisfactory materials to produce various types of concrete with satisfactory strength and durability characteristics. In the present study, an effort has been made to utilize sugar cane bagasse ash which is a byproduct of sugar production industry. In India sugar cane is one of the major crop from which a large amount of sugar cane bagasse ash has been produced after processing, during production of sugar. With effective use of this byproduct as a partial replacement material for cement, an economical and environmental friendly concrete or mortar can be produced.

2. MATERIALS AND THEIR CHARACTERIZATION

CEMENT: Ordinary Portland Cement of 53-grade was used for the study. The cement was tested as per IS: 4031 and the properties obtained are given in Table 1 below.

Table 1: Test results on cement

Test	Result
Specific Gravity	3.15
Normal consistency (%)	30
Initial setting time(min)	140
Final setting time(min)	255

BAGASSE ASH: Bagasse ash samples from three different sources were collected for the study. The sources and properties of bagasse ash obtained for each samples are as shown in Table2.

Table 2: Test results on bagasse Ash

	Sources		
Test	**Nanjangud**	**Pandavpura**	**Kuntur**
Specific Gravity	2.15	1.88	2.07
Normal consistency (%)	37	39	35
Initial setting time(min)	125	131	135
Final setting time(min)	400	360	370

Table 3: chemical composition of the bagasse ash from the different sources

Chemical Composition	Kuntur	Nanjangud	Pandavapura
SiO_2 %	70.63	72.11	70.16
Al_2O_3 %	0.15	0.18	0.26
Fe_2O_3 %	5.97	7.03	6.67
CaO %	2.39	1.67	1.78
LOI %	14.35	15.15	11.25

SAND: Natural river sand of specific gravity 2.6 confirming to IS: 2386-1968 Part-III was used for the study. The properties of the Natural river sand is as shown in Table 3 below.

Table 4 : Test results on sand

Test	Result
Specific Gravity	2.6
Water absorption (%)	0.7
Bulk density(kg/m^3)	1440
Fineness modulus	2.9

3. EXPERIMENTAL PROGRAMME

The experimental programme includes flow table test and compressive stength tests. The flow table test was conducted to check water demand of the mortar mix. A total number of 312 standard mortar cubes of size 70.6mmX70.6mmX70.6mm were casted for differrent water cement ratios and different percentage replacement of bagasse ash for all three different sources. The compressive strength of specimens were tested for 7days and 28 days.

Table 5 : factors and levels considered

Factors	Levels				
W/C	0.3	0.35	0.4		
BA/C	0	0.10	0.15	0.20	0.25

FULL FACTORIAL APPROACH: A full factorial experiment is an experiment whose design consists of two or more factors, each with discrete possible values or "levels", and whose experimental units take on all possible combinations of these levels across all such factors.

Table 6 : Full factorial approach design of experiments

SL. No	W/C Ratio	BA/C Ratio
1	0.30	0
2	0.30	0.10
3	0.30	0.15
4	0.30	0.20
5	0.30	0.25
6	0.35	0

7	0.35	0.10
8	0.35	0.15
9	0.35	0.20
10	0.35	0.25
11	0.40	0
12	0.40	0.10
13	0.40	0.15
14	0.40	0.20
15	0.40	0.25

W/C: Water to cement ratio

BA/C: Bagasse ash to cement ratio

4. RESULTS AND DISCUSSIONS

4.1 Flow table test

The test has been conducted as per IS: 5512-1983 and water demand was measured for 100% slump with mix proportion 1:2 (cement sand ratio) with varying percentages of bagasse ash for all the sources. The test results shows that the water demand for a required workability varies with each sources depending upon the grain size distribution and specific gravity of the materials. This is due to larger particle size and higher porosity of Bagasse ash.

Table 7: Water Demand

Source	% Replacement	Water demand for 100% flow
Control mortar	0	0.40
Nanjangud	10	0.43
	15	0.44
	20	0.48
	25	0.49
Pandavpura	10	0.46
	15	0.48
	20	0.47
	25	0.52
Kuntur	10	0.45
	15	0.45
	20	0.46
	25	0.52

4.2. Compressive strength test:

From the experimental results it was observed that, both 7 days and 28 days compresive strengths were incresed at 10%,15%,repalcement and for 20%,25% replacement strength decreses due to greater porosity of the material as indicated by higher water requirement.it was also found that an average strength attainments of of 107%, 101%, 97% and 94% were achieved in relative to the normal concrete for 10, 15, 20 and 25% replacement of cement by bagasse ash at 28 days of curing.

Table 6: 7 days compressive strength

source	% replacement	7 days compressive strength (MPa)		
		for 0.3 W/C	for 0.35 W/C	for 0.4 W/C
100% OPC	0	32.21	28.42	25.06
Nanjangud	10	34.67	31.98	27.61
	15	32.94	29.37	25.69
	20	30.48	27.24	23.77
	25	29.47	25.42	20.59
Pandavpura	10	37.41	33.91	30.44
	15	35.88	32.46	28.24
	20	34.76	29.68	25.44
	25	30.66	27.39	22.48
Kuntur	10	38.15	34.17	31.64
	15	34.12	31.66	28.14
	20	31.28	27.44	24.36
	25	28.64	25.42	22.11

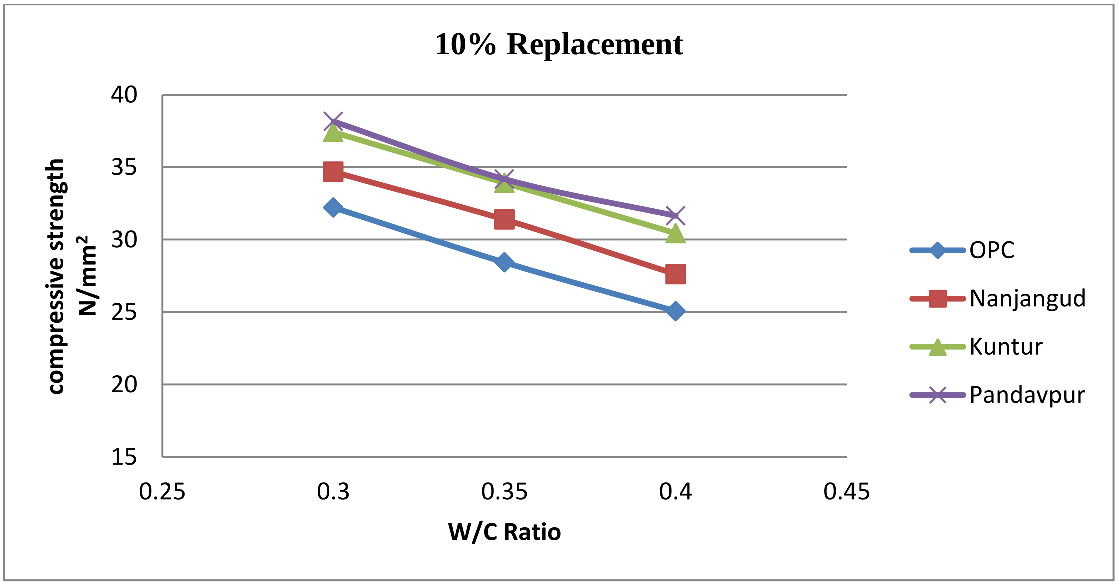

fig.1: 7 days compressive strength of 10% replacement

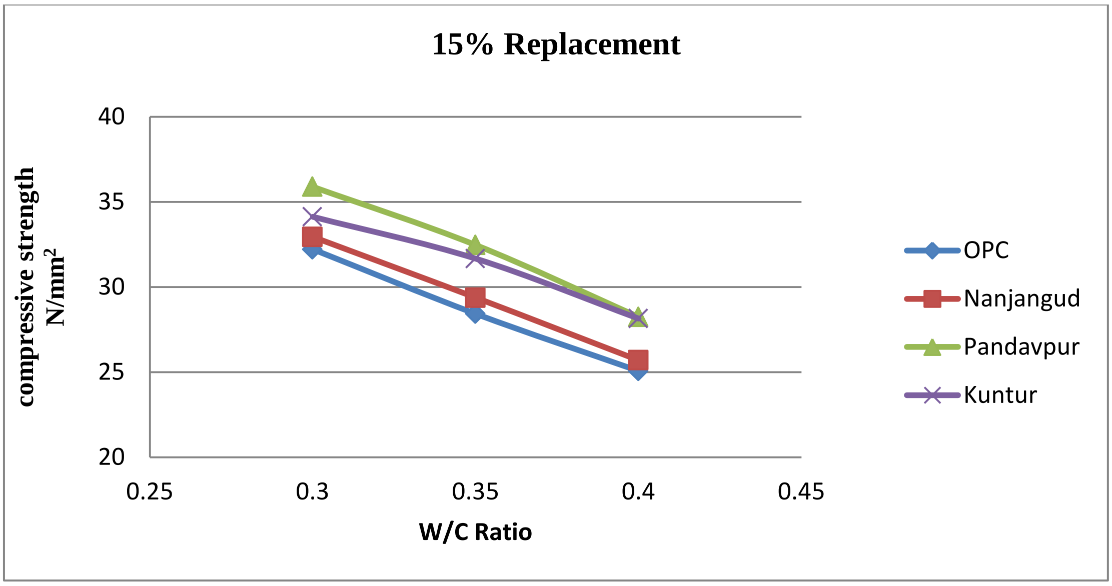

fig.2: 7 days compressive strength of 15% replacement

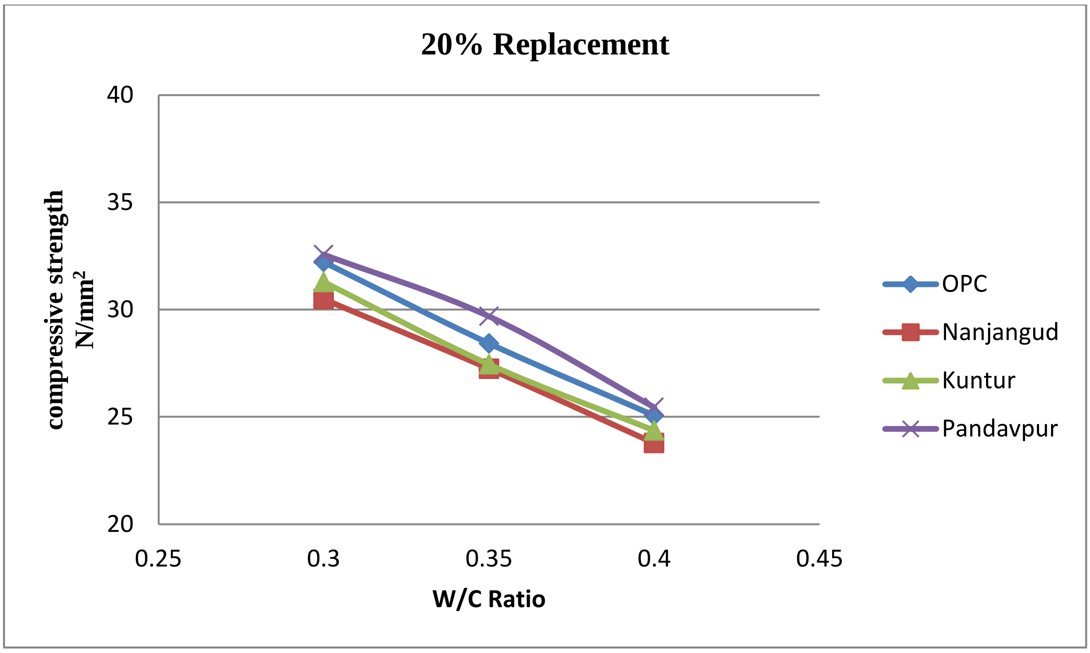

Figure .3: 7 days compressive strength of 20% replacement

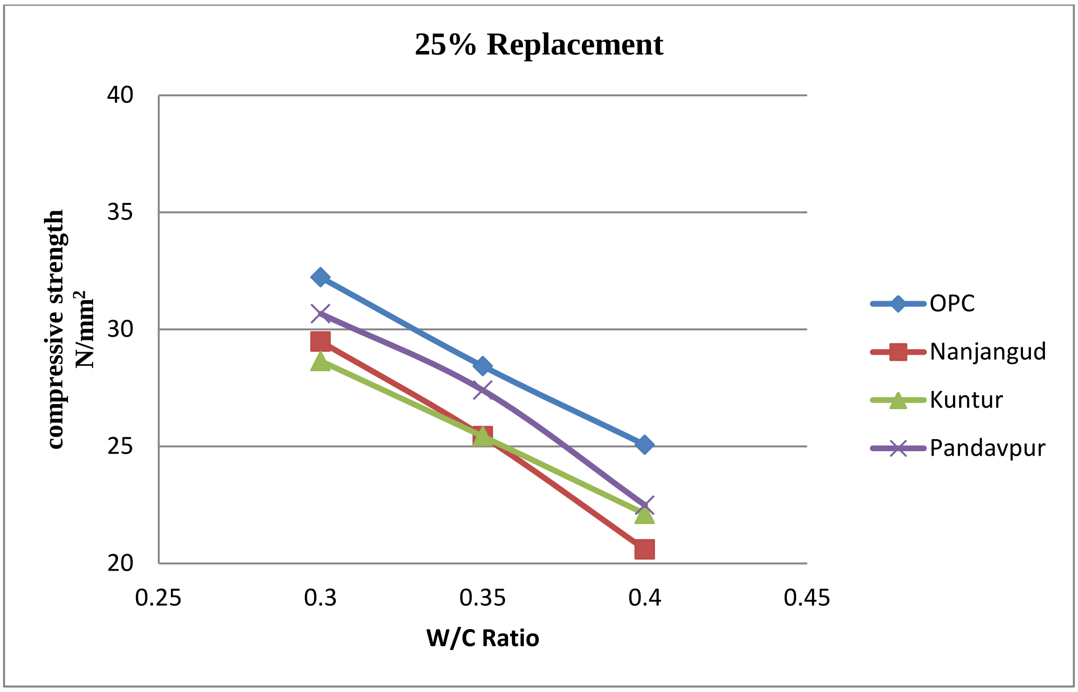

fig.4: 7 days compressive strength of 25% replacement

Table 7:28 days compressive strength

source	% replacement	28 days compressive strength (Mpa)		
		for 0.3 W/C	for 0.35 W/C	for 0.4 W/C
100% OPC	0	57.86	52.66	47.44
Nanjangud	10	59.2	54.84	50.08
	15	56.98	51.86	46.64
	20	52.24	46.48	42.45
	25	47.28	42.98	36.68
Pandavpura	10	62.66	57.48	51.12
	15	58.34	53.92	49.76
	20	55.94	49.96	45.9
	25	52.28	45.36	41.62
Kuntur	10	60.98	56.34	50.93
	15	58.98	52.98	48.12
	20	54.16	48.12	43.43
	25	50.68	44.28	40.96

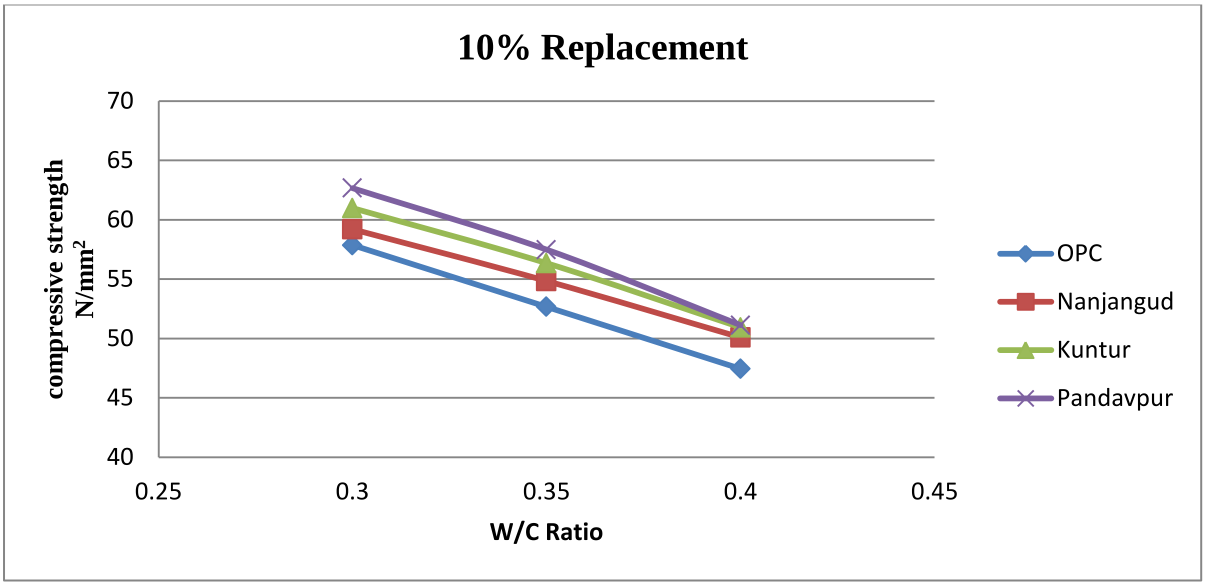

Figure .5: 28 days compressive strength of 10% replacement

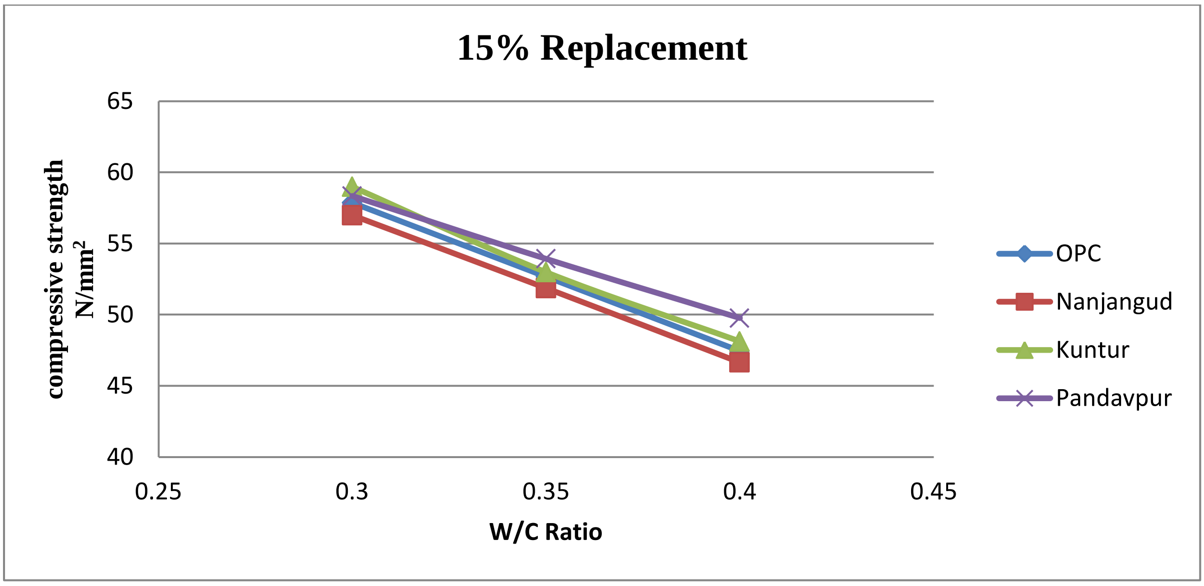

Figure 6: 28 days compressive strength of 15% replacement

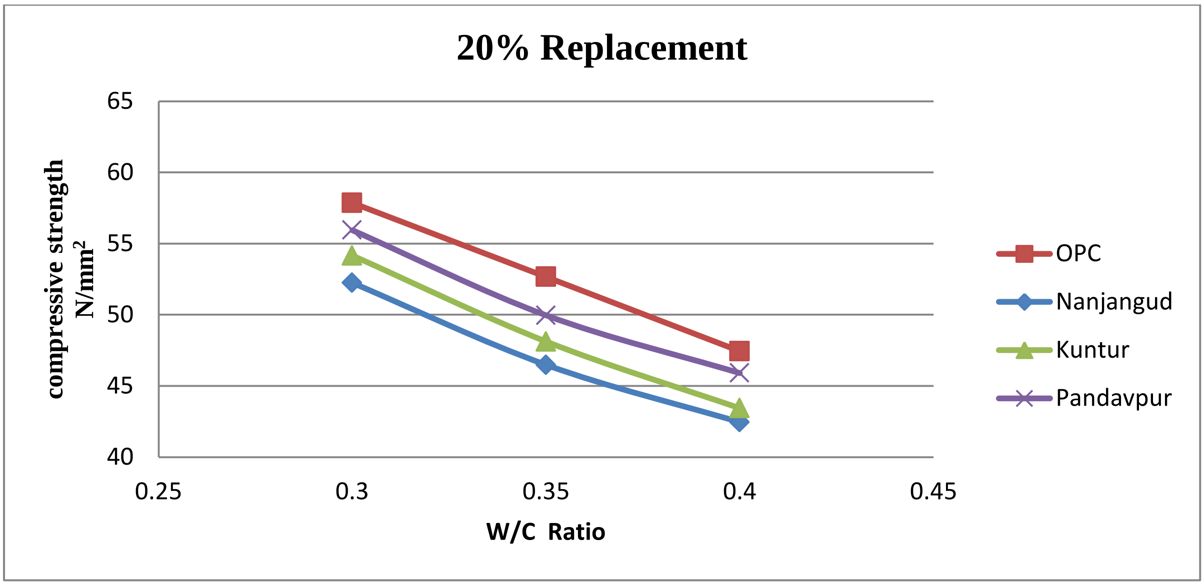

fig.7: 28 days compressive strength of 20% replacement

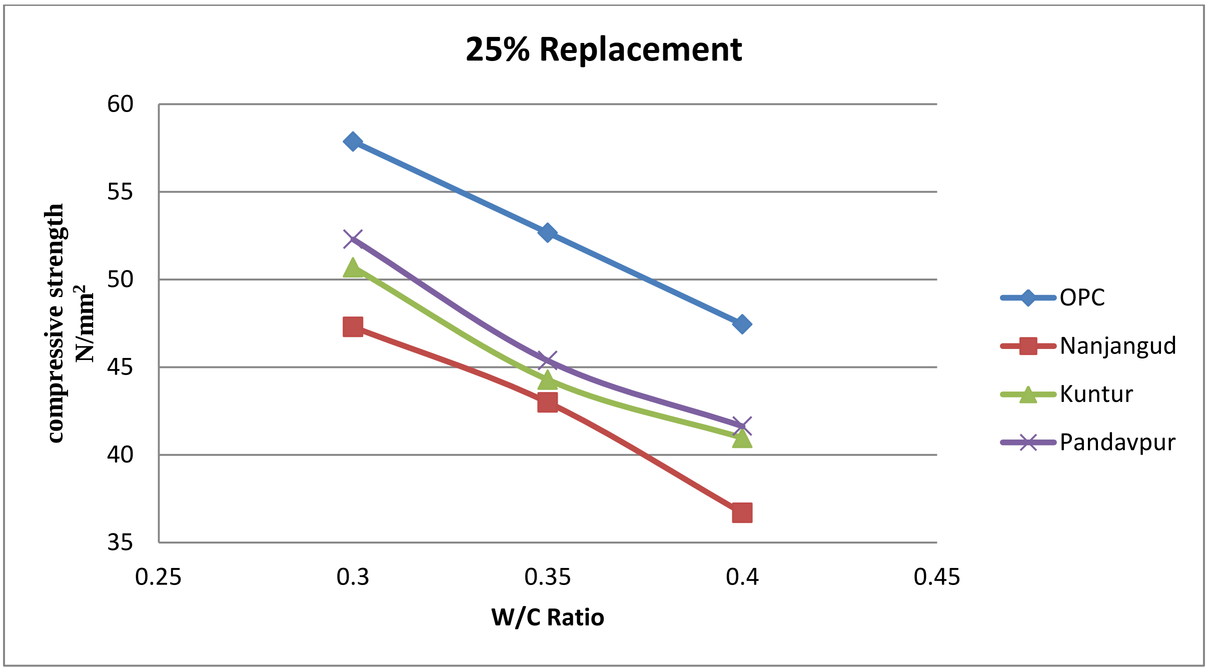

Figure .8: 28 days compressive strength of 10% replacement

5. CONCLUSIONS

Based on the study, following conclusions can be drawn.

- Water demand for a required workability increases as the percentage of bagasse ash replacement increases.
- The strength of the motar has decreased as the replacement of bagasse ash is increased due to higher porosity and water absorption of bagasse ash.

- At lower water cement ratios and lower replacement levels the percentage of strength attainment containing bagasse ash with respect to normal concrete is higher. And it decreases with the increase in replacement levels as well as water cement ratio.
- Fineness of bagasse ash is the important factor affecting the compressive strength of mortar. Mortar containing finer ash has a higher compressive strength than ash with a higher particle size ash.
- Based on the test results use of bagasse ash for 10 to 15% is preferred as the strength attainment of 107% and 101% were achieved for these replacements.

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