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EVALUATION OF HIGH STRENGTH CONCRETE USING HOSPITAL WASTE ASH AND SILICA SAND IN CONCRETE

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Abstract

Concrete is a material constituted of cement, Sand, Coarse aggregates, and water. Cement is the predominant component of both conventional and Replacement concrete. Cement processing emits massive concentrations of Carbon-dioxide throughout the environment. To reduce the concentration, cement is substitute by any local available cementitious material. Nowadays, due to the carbon dioxide and global warming, several investigations are undergoing replacement cement. Several new products are used as an effluent substitute medium for cement, like rice husk ash, eggshell residue, baggage ash, etc. Hospital waste management is a huge problem in our society. The annual production of medical waste produced from health care facilities, is around 250,000 tons. The purpose of this study is to determine the feasibility of using hospital waste ash produced from a health care facility as a partial replacement for cement. The quantity of hospital Plastic waste ash (5, 10, 15, and 20% by weight of cement) is the major variable in this study, whereas the amount of cementitious material, water to cementitious material ratio, fine and coarse aggregate content are all constant. Nowadays, there is a need a realistic material like natural sand. Despite the fact that M-sand is used as a substitute for River sand, it comes with a number of drawbacks due to its angular size and inability to fill pore spaces. Silica sand is a silica-containing material that efficiently covers pores in concrete. The primary objective of this research is to partially replace M-Sand with Silica Sand in order to enhance concrete properties. Silica sand is combined with M-Sand in various proportions of 5%, 10%, 15%, and 20%. The tests on fresh and hardened concrete are now complete. The findings show that Silica Sand can be used as a partial substitute for M-Sand.M30 and M45 mix design concrete is used for the experimental investigation. The main important parameters are strength, durability and workability of concrete. The study clearly reveals the investigation into numerous substitutions of cement with hospital plastic waste ash in the mix proportion, 5 % to 20% of its cement weight. The trial mix proportion is carried out for the different properties of workability, durability and strength achieves the optimal level of cement substitution with hospital plastic waste ash.

Keywords: Cement, M-30and M-45 grade, Hospital Plastic Waste Ash (HPWA), Silica Sand.

1. INTRODUCTION

Cement is most utilizing material in the construction field and it leads to enormous carbon pollution into the environment. Over the last decades, there has been an increasing trend on blending ordinary Portland cement with locally sourced raw materials like industrial, agricultural or domestic waste. Alternative ingredients for cement manufacture have already been investigated and employed, including fly ash, silica fume, rice husk, coconut shell, eggshell, and sugarcane fiber.

The search for a new and viable alternative is important for conservation of natural resources and also reduction in manufacturing cost. Hospital waste ash used as unutilized supplementary cementious material until now and silica sand as partial replacement for M-sand. According to the Ministry of Environment and Forestry, India produces 4,05,702 kg of biomedical waste per day. Approximately 72% of the total is discarded. On the other hand, more than 28% of biological waste is left neglected. The most frequent method of disposing of biological waste is incinerating it in specially designed biomedical waste incinerators.

The ash generated from the burning of biomedical waste is used to create a landfill. On the other hand, these wastes may be successfully employed in concrete manufacture, decreasing the requirement for land for biomedical waste ash disposal on the one hand, and saving the environment by reducing cement consumption and production on the other.

The angularity of M-sand, which is produced by crushing aggregates, is lost. The strength of the mortar is primarily determined by one of these two types of fine aggregates. The mechanical and rheological properties of cement mortars are affected by aggregates. Physical characteristics, form, particle-size distribution, and surface all have an effect on various properties of mortar in the new state.

The substitution of M-sand with Silica sand was the focus of a considerable portion of the exploration studies. It's worth noting that there haven't been many studies done on replacing fine aggregates in mortar with eco-sand. Silica Sand is actually a granular material which contains quartz and minute amounts of coal, clay. Because silica is a key component in the production of artificial glass, ceramics, and concrete, it has a wide range of applications. Silicon dioxide, often known as silica, is a chemical substance found as a primary ingredient in this sand.

When used for this purpose, silica sand (also known as industrial sand) is the principal structural component in a variety of building products. Silica is used to increase the durability and structural integrity of flooring, mortars, cement, roofing shingles, asphalt, and other industrial products.

Because silica is weather, wear, and corrosion resistant, it is frequently used as a caulk or sealer. For the first time, tests were conducted to assess this bio-waste as a supplemental cementious material and silica sand for M-sand.

2. MATERIALS

2.1 Cement

In this project, OPC 53 cement grade was used. Cement is tested according to Indian standard IS 4031-1988. Tables 1 show the parameters of cement.

Fig 1: Cement

Tables 1: Parameters of Cement

Sl.No.	Characteristics of Cement	Results Obtained	As per IS 12269:2013
1	Specific Gravity	3.15	3.1 - 3.15
2	Fineness	3%	≤ 10%
3	Consistency	30%	30 - 35
4	Initial Setting Time	180 (min)	≥ 30
5	Final Setting Time	250 (min)	< 600
6	Specific Surface Area	294 m^2/kg	≥ 225

2.2 Sand

For experimental research, river sand is used as a fine aggregate. Sieve analysis and zone II are used to determine the quality of fine sand aggregate. In IS 2386-1963, river sand was given specific physical qualities, as shown in Table 2.

Fig 2: M-Sand

Table 2: Properties of Fine Aggregate

Sl.No.	Physical characteristics of Fine Aggregate	Values	IS 2720-III
1	Specific gravity	2.60	2.53-2.67
2	Fineness Modulus	2.90	
3	Water Absorption	1%	<2%
4	Bulk Density (kg/m^3)	1765	

2.3 Coarse Aggregate:

For our research, we used granite crushed stone with a diameter of 20 mm. Local quarries are a good source of it. In Table 3, the characteristics of crushed stone were examined and tabulated**.**

Fig 3: Coarse Aggregates

Tables 3: Properties of Coarse Aggregate

Sl.No	Physical Characteristics of Coarse Aggregate	Values
1	Specific gravity	2.74
2	Fineness Modulus	5.53
3	Water Absorption	0.5%
4	Aggregate Impact Value (%)	21.5%
5	Aggregate Crushing Value (%)	21.4%

2.4 Silica Sand

Silica sand is a silica-containing material that efficiently covers pores in concrete. In Table 4, the characteristics of silica sand were examined and tabulated

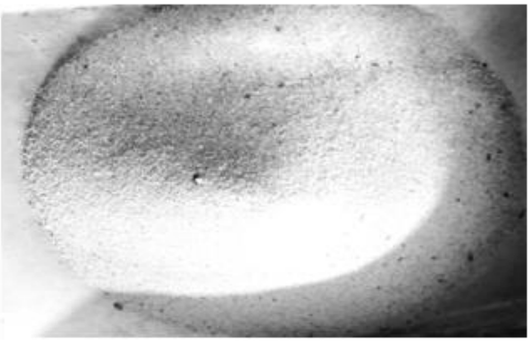


Fig 4: Slica Sand

Table 4: Properties of Silica Sand

Sl.No	Basic Properties of Silica Sand	
1	Specific gravity	2.60
2	Fineness Modulus	2.56
3	Moisture Content	1.4 %
4	Bulk Density	1565 kg/m^3

2.5 HPWA

The ash are burnt from hospital waste syringe and the properties are characterized below in the table 5.

Fig 5: HPWA

Table 5: Properties of HPWA

Sl.No	Basic Properties of HPWA	
1	Sp. Gravity of HPWA	2.70
2	Fineness	4%
3	Consistency	35 %
4	Soundness	1 cm
5	Specific Surface	471.6 m^2/kg
6	Moisture Content	8.5 %

3. EXPERIMENTAL PROGRAM

3.1 Testing to Determine Mechanical Properties

3.1.1 Preparation of Concrete Mixtures

The OPC, fine aggregates (natural river sand), coarse aggregates (crushed stones), fly ash, GSWs and SAPs were used to prepare the concrete mixtures. In total, thirty-three mix proportions were prepared, one of which was a control mix, which had no replacement of cement and the remaining thirty-two were GSW-concrete mixtures with different percentages of the GSWs as 5%, 10%, 15%and 20%. The control mixture was cured naturally, while the remaining thirty-two GSW-concrete mixtures were cured using the different percentages of self-curing agent (SAPs)as 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, 0.6%, 0.8% and 1.0%. The various mix proportions are shown in Table 7. These mix proportions were designed such that they satisfy the performance criteria of the concrete mixtures, both for the fresh and hardened concrete. The aggregates were weighted in dry condition for all concrete mixtures. The materials were mixed using the tilting drum mixer machine. The required materials were mixed properly to maintain the uniformity of the mixture and water was added with a constant water cement ratio of 0.45. After the GSW-concrete mixtures were prepared, they were casted in standard moulds as per the IS 10262-2009 [19]. All the moulds were oiled properly before casting the specimens. In total, 627 specimens were tested, of those 198 cubes were prepared for compression tests, 198 cylinders were prepared for split tensile tests, 33 cylinders were prepared for modulus of elasticity tests, and the remaining 198 beams were prepared for flexural tests.

Before casting the specimens in moulds, workability of the fresh GSW-concrete mixtures was determined using the slump test, compacting factor test, Vee-Bee consistometer test, and flow table apparatus. After 24-hours, the specimens were demoulded and maintained at room temperature and tested after7 and 28 days for hardened properties. For compression and splitting tensile strength of concrete, 150 mm ×150 mm ×150 mm cubes and 150 mm×300 mm cylinders were prepared, respectively. For each mix proportions, six cubes were prepared for compression tests, six cylinders were prepared for 7 and 28 days split tensile test and one cylinder was prepared for 28 days' modulus of elasticity test for GSW-concrete mixtures. In addition, six concrete beams were casted to determine the flexural strength after 7 and 28 days of self-curing. All these six beams had a size of 500 mm x 100 mm x 100 mm. The compressive strength of the cubes, split tensile strength and modulus of elasticity of the cylinders were measured by the compression testing machine (CTM) which has a capacity of 2000kN.The flexural strength of the concrete beams was measured using the Universal Testing Machine (UTM)after7 and 28 days of self-curing.

Modulus of rupture test was carried out for the specimens which had dimensions of 100 mm x 100 mm x 500 mm, using the Universal Testing Machine (UTM). The UTM has the capacity of 400 kN. Two-point loading method was adopted to determine the modulus of rupture as per the IS: 516-1959 [20]. For each mix, three identical specimens were tested at the age of 7 and 28 days and the mean values are reported. A total of 198 specimens were tested for modulus of rupture test.

3.2 Labelling of Test Specimens

Among the thirty-three mixtures, thirty-two mixtures were GSW-concrete mixtures with addition of SAP and the remaining one was the control mixture. To identify the concrete mixtures, the specimens were labelled properly. Fig. 6shows an example of the labelling used in the experimental program. As shown in the label, SCC-C70-FA25-GSW05-SAP0.1 is explained as follows:

- "SCC-C70" indicates the self-curing concrete with cement content of 70%.
- "FA25" indicates the percentage of fly ash used in the mixture is 25%.
- "GSW05" means the percentage of granite saw waste used in the mixture is 5%.
- "SAP0.1" indicates the percentage of super absorbent polymer used in the concrete mixture is 0.1%.

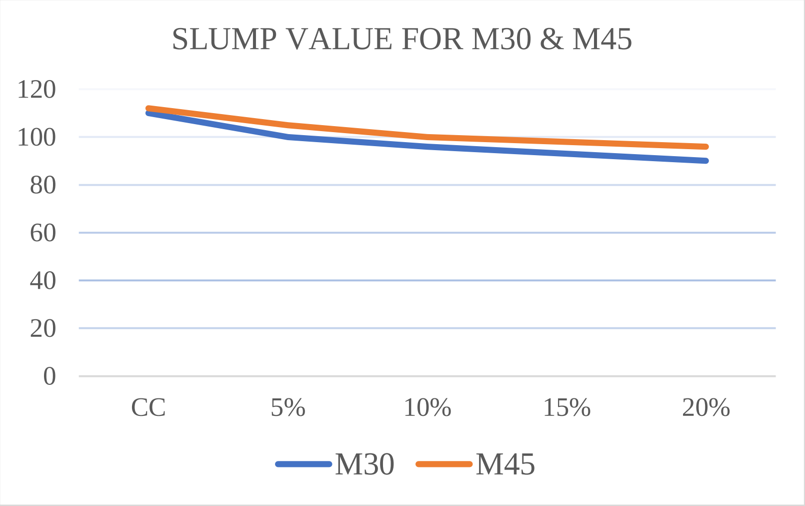
4. SLUMP VALUE

The device is in the shape of a Frustum cone, with a height of 300mm, a depth of 200mm, and a height of 100mm. M30 concrete has been dumped and is layered well. A trowel is used to level the top layer. Raise the cement-filled cone at this time. Calculate the variance between the sample peak and bottom, as shown in fig 6**.**

Fig 6: Slump Test

Table 6: Slump Test

	SPECIMEN	**SLUMP VALUE (mm)**	
		M30	**M45**
C1	(100% +0%+100%+0%)	110	112
C2	**(**95+5% c ,95%+5% s)	100	105
C3	(90+10% c ,90%+10% s)	96	100
C4	(85+15% c , 85+15% s)	93	98
C5	(80+20% c , 80+20% s)	90	96



The findings show that as the substitution standard increased, the workability of concrete reduced. This may be attributed to the fact that ash is lighter than cement. In an equivalent weight basis, hospital waste ash and silica sand occupy more volume than cement, requiring more water for concrete workability.

4.1 Density of Concrete

Quantity mass per volume is the definition of density. M30 & M45 blend design is used to set up new cement. Using a gauging scale, the concrete was measured. Concrete is poured, and it is allowed to dry for four weeks. Finally, the dried samples were taken out of the tank and exposed to the air.

Fig 7: Density of Concrete

Table 7: Density of Concrete

	SPECIMEN	**DENSITY OF CONCRETE**	
		M30	**M45**
C1	(100% +0%+100%+0%)	2562	2580
C2	(95+5% c ,95%+5% s)	2554	2572
C3	(90+10% c ,90%+10% s)	2548	2564
C4	(85+15% c , 85+15% s)	2534	2552
C5	(80+20% c , 80+20% s)	2522	2548

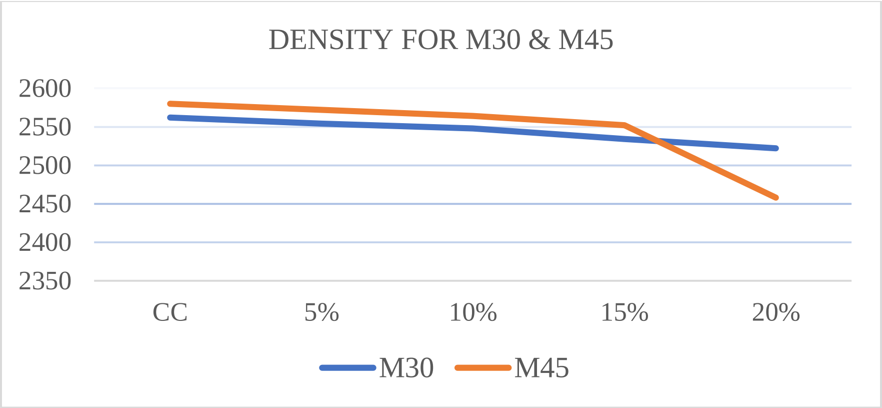


Fig 7: Density of concrete

The results states that the Workability of concrete declined as replacement level increased, as seen in the table. However, there was no discernible difference in density.

4.2 Compaction Factor

The research is used to properly determine the compaction element's workability quality. The ratio of uncompacted to totally compacted concrete weights is known as the compact element. The compaction factor test is used for concrete that has a limited workability and cannot be tested using the slump test. The contraption is made up of three layers: upper, middle, and bottom. The top layer of M30 concrete has been poured and smoothed. The snare entrance is used to stream the Concrete in the middle layer, followed by the base round and hollow layer. Clean up the concrete pours on the chamber's exterior and level it**.**

Fig 8: Compaction Factor

Table 8: Compaction factor Test

	SPECIMEN	**COMPACTION FACTOR**	
		M30	**M45**
C1	(100% +0%+100%+0%)	0.90	0.90
C2	**(**95+5% c ,95%+5% s)	0.87	0.88
C3	(90+10% c ,90%+10% s)	0.85	0.86
C4	(85+15% c , 85+15% s)	0.82	0.85
C5	(80+20% c , 80+20% s)	0.80	0.83

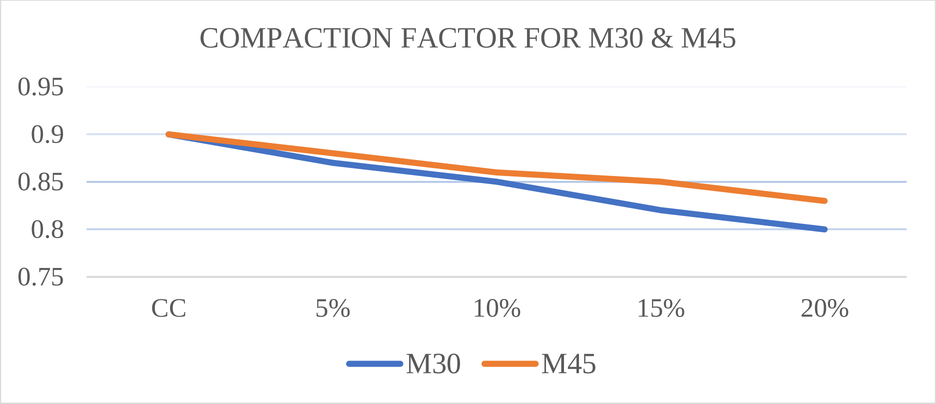


Fig 8: Compaction Factor Test chart

As per IS1199, The compaction factor range in between 0.7-0.95; the degree of workability is medium. The findings show that as the substitution standard increased, the workability of concrete reduced. This may be attributed to the fact that ash is lighter than cement. In an equivalent weight basis, hospital waste ash and silica sand occupy more volume than cement, requiring more water for concrete workability.

4.3. Compressive Strength - M30

Cubes with concrete mix design ratios of 0.150 x 0.150 x 0.150 m are cast and cured for 28 days in 0.150 x 0.150 x 0.150 m size moulds. 45 cube numbers are partially or completely cast in concrete with or without WHA. After 1,2, and 4 weeks in the treatment tank, the sample was removed and dried. Cubes are tested at the CTM of 1T capacity, as shown in Fig. 4.8, and the test results were completed in accordance with IS 516. The burden is gradually increased until the test is no longer effective. Before failure, the sample's peak load and accompanying loads are stated. The ratio between maximal load and c / s can be used to calculate sample strength**.**

Fig 9: Compressive Strength Test

Table 9: Compression Test (M30)

SPECIMEN	COMPRESSIVE STRENGTH - M30(N/MM^2)		
	7 Days	14 Days	28 Days
CC	19.51	26.80	33.25
95(C)+5%(ASH)+95(S)+5(SS)	20.01	26.90	34.01
90(C)+10%(ASH)+90(S)+10(SS)	20.21	27.01	35.25
85(C)+15%(ASH)+85(S)+15(SS)	19.67	26.47	33.95
80(C)+20%(ASH)+80(S)+20(SS)	18.47	25.15	32.80

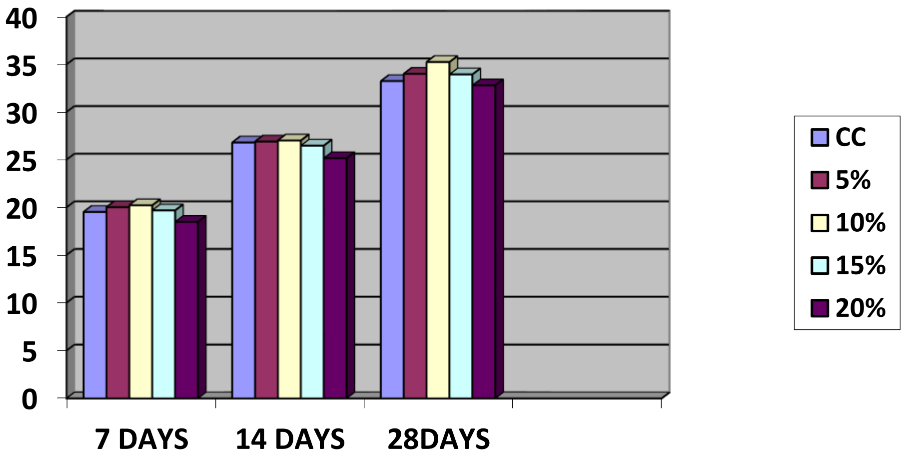


Fig 9: Compression Test (M30) chart

At 28 days the compressive strength for 5%, and 10% attains 2.28%, 6.01% more than conventional concrete. The strength of 15% and 20% attains 2.10%, 1.35% which is less than conventional concrete. From the above results states that optimum replacement of hospital waste and silica sand in cement and M-sand is 10%.

4.6. Compressive Strength - M45

Table 10: Compression Test (M45)

SPECIMEN	COMPRESSIVE STRENGTH - M45 (N/MM2)		
	7 Days	14 Days	28 Days
CC	29.52	39.3	43.10
95(C)+5%(ASH)+95(S)+5(SS)	29.91	39.75	47.48
90(C)+10%(ASH)+90(S)+10(SS)	30.47	40.6	50.10
85(C)+15%(ASH)+85(S)+15(SS)	29.69	39.5	46.90
80(C)+20%(ASH)+80(S)+20(SS)	28.88	38.45	42.85

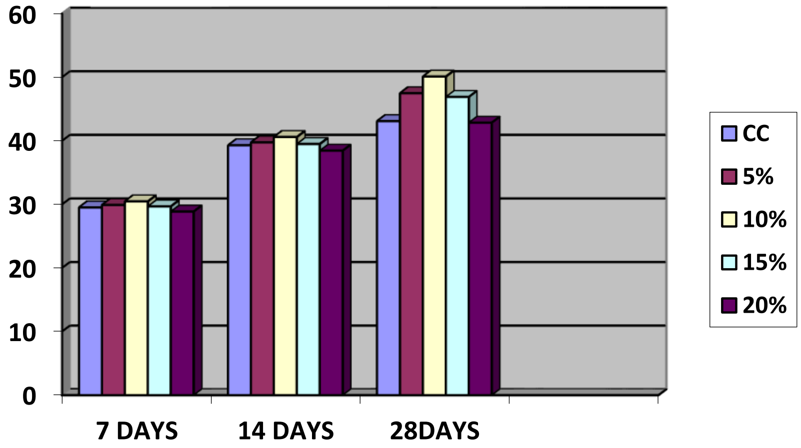


Fig 10: Compression Test (M45) chart

At 28 days the compressive strength for 5%, and 10% attains 10.16%, 16.24% more than conventional concrete. The strength of 15% and 20% concrete is 8.81 percent, which is lower than that of normal concrete. According to the foregoing findings, a 10% replacement of hospital waste and silica sand in cement and M-sand is optimal.

4.7 Split Tensile Strength - M30

It's used to determine how potent a sample is. The cylinders are horizontally positioned between the loading surfaces in the indirect technique. The test can be carried out in accordance with IS 5816: 1999. The weight is gradually increased along the length of the sample in fig. 4.9. When the load is applied horizontally to the specimen, tensile failure occurs. Finally, the specimens' breaking loads are recorded.

Fig 11: Split Tensile Test

Table 11: Split Tensile Test (M30)

SPECIMEN	SPLIT TENSILE STRENGTH-M30(N/MM2)	
	7 DAYS	28 DAYS
CC	2.26	3.95
95(C)+5%(ASH)+95(S)+5(SS)	2.34	4.02
90(C)+10%(ASH)+90(S)+10(SS)	2.49	4.15
85(C)+15%(ASH)+85(S)+15(SS)	2.31	3.96
80(C)+20%(ASH)+80(S)+20(SS)	2.24	3.88

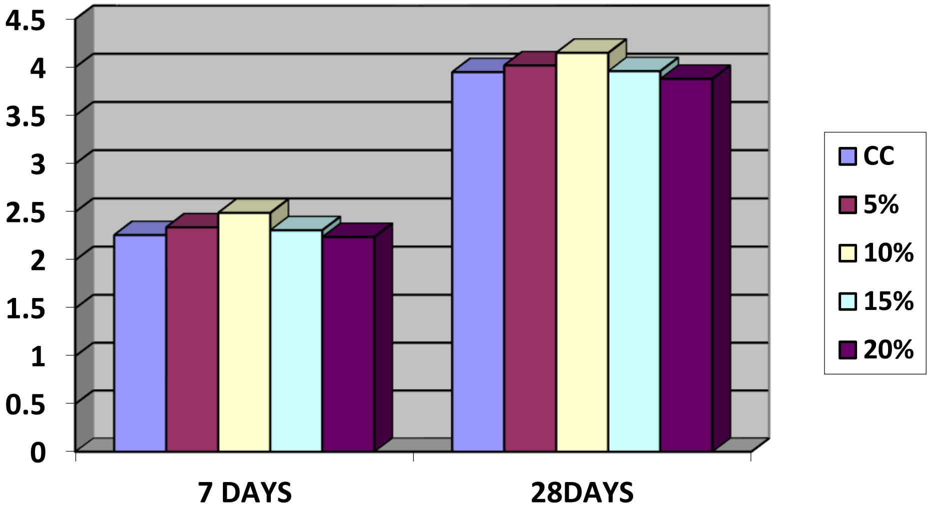


Fig 11: Split Tensile Test(M30) chart

At 28 days the split tensile strength for 5%, and 10% attains 1.74%, 3.29% more than conventional concrete. The strength of 15% and 20% attains 0.25%, decrease by 1.77% which is less than conventional concrete. From the above results states that optimum replacement of hospital waste and silica sand in cement and M-sand is 10%.

4.8 Split Tensile Strength - M45

Table 12: Split Tensile Test (M45)

SPECIMEN	SPLIT TENSILE STRENGTH-M45(N/MM2)	
	7 DAYS	28 DAYS
CC	2.43	4.21
95(C)+5%(ASH)+95(S)+5(SS)	2.91	4.46
90(C)+10%(ASH)+90(S)+10(SS)	3.03	4.82
85(C)+15%(ASH)+85(S)+15(SS)	2.61	4.22
80(C)+20%(ASH)+80(S)+20(SS)	2.38	4.16

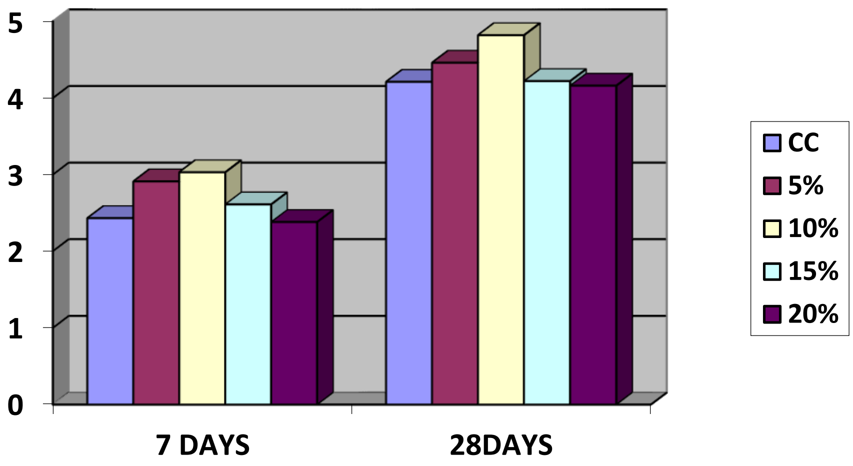


Fig 12: Split Tensile Test (M45) chart

At 28 days the split tensile strength for 5%, and 10% attains 5.93%, 8.55% more than conventional concrete. The strength of 15% and 20% attains 0.23%, decrease by1.18% which is less than conventional concrete. From the above results states that optimum replacement of hospital waste and silica sand in cement and M-sand is 10%.

4.9 Flexural Strength - M30 & M45

Prism can be cast without the use of cement and with the use of WHA as a cement substitute at a mixed ratio (0 percent, to 20 percent). The Two-point loading method was used to study a prism that was cast with dimensions of 100 x 100 x 500 mm. The experiment is set up using a UTM with two supports on either side of the specimen and two loading setups. The two supports appear to be assembled in a simple supported condition. The force is gradually increased to a two-point load in the sample's center. The LVDT is positioned in the center of the specimen to monitor the load and deflection of the specimen until the last load is attained, as shown in Fig.

Fig 13: Flexural Strength Test

Table 13: Flexural Strength Test

SPECIMEN	FLEXURAL STRENGTH-M 30 &M45(N/MM2)	
	M30	M45
CC	3.72	4.94
95(C)+5%(ASH)+95(S)+5(SS)	3.85	5.08
90(C)+10%(ASH)+90(S)+10(SS)	4.01	5.15
85(C)+15%(ASH)+85(S)+15(SS)	3.80	4.96
80(C)+20%(ASH)+80(S)+20(SS)	3.65	4.58

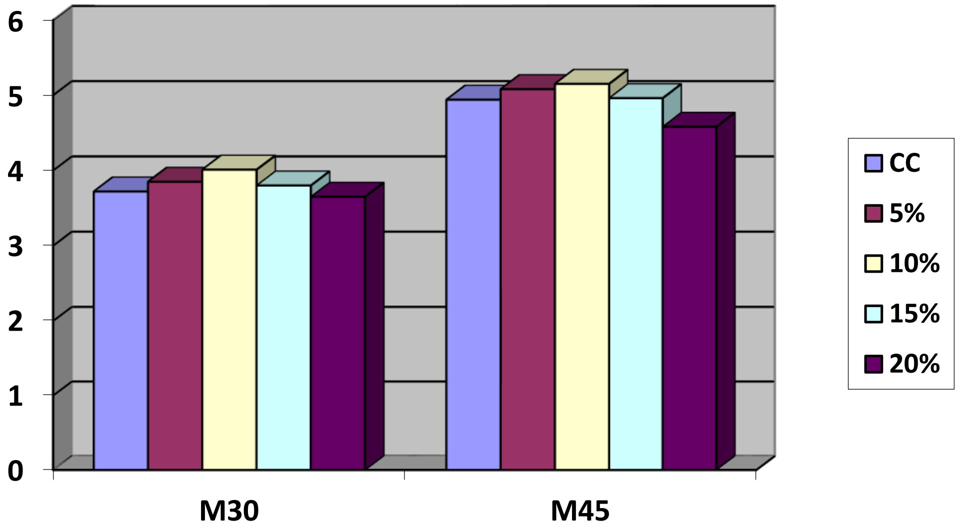


Fig 13: Flexural Test chart

At 28 days the flexural strength for 5%, and 10% attains 2.83%, 4.25% more than conventional concrete. The strength of 15% and 20% attains 0.40%, decrease by 7.3% which is less than conventional concrete. From the above results states that optimum replacement of hospital waste and silica sand in cement and M-sand is 10%.

CONCLUSION

- The working capacity of the concrete is decreased according to the Hospital Waste Ash substitution percentage. In an equivalent weight basis, hospital waste ash and silica sand occupy more volume than cement, requiring more water for concrete workability.
- In addition to 10 percent substitution of cement with Hospital Waste Ash, the setting time increases
- The findings show that as the substitution standard increased, the workability of concrete reduced. This may be attributed to the fact that ash is lighter than cement. In an equivalent weight basis, hospital waste ash and silica sand occupy more volume than cement, requiring more water for concrete workability.

- ➢ The mechanical performance of a blended concrete shows high compression, tensile and flexural strength at 10% partly replaced cement by HWA than conventional concrete and other proportions.
- ➢ For M30-At 28 days the compressive strength for 5%, and 10% attains 2.28%, 6.01% more than conventional concrete. The strength of 15% and 20% attains 2.10%, 1.35% which is less than conventional concrete.
- ➢ For M45-At 28 days the compressive strength for 5%, and 10% attains 10.16%, 16.24% more than conventional concrete. The strength of 15% and 20% attains 8.81%, which is less than conventional concrete.
- ➢ For M30-At 28 days the split tensile strength for 5%, and 10% attains 1.74%, 3.29% more than conventional concrete. The strength of 15% and 20% attains 0.25%, decrease by 1.77% which is less than conventional concrete.
- ➢ For M45-At 28 days the split tensile strength for 5%, and 10% attains 5.93%, 8.55% more than conventional concrete. The strength of 15% and 20% attains 0.23%, decrease by1.18% which is less than conventional concrete.
- ➢ For M30- At 28 days the Flexural strength for 5%, and 10% attains 3.49%, 7.79% more than conventional concrete. The strength of 15% and 20% attains 2.13%, decrease by 1.88% which is less than conventional concrete.
- ➢ For M45- At 28 days the Flexural strength for 5%, and 10% attains 2.83%, 4.25% more than conventional concrete. The strength of 15% and 20% attains 0.40%, decrease by 7.28% which is less than conventional concrete.
- ➢ Beyond 10% blended cement, the results show a reduction rate in strength aspects. Results show that 10% of HWA can be used as supporting material in concrete.
- ➢ When Hospital Waste Ash increases, concrete density decreases. The density of 10 % replacement concrete is decreased by 0.85% than conventional concrete and 20% replacement concrete is decreased by 1.99% than conventional concrete. it concludes that the density of concrete is slightly variable while adding Hospital Waste Ash.

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