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Effective Utilization of Crusher Dust in Concrete Using Portland Pozzolana Cement

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Abstract- The purpose for taking up this investigation owing to the fact that now a days natural sand confirming to Indian Standards is becoming scarcer and costlier due to its non availability in time because of Law of Land, illegal dredging by sand mafia, accessibility to the river source during rainy season, non confirming with IS 383-1970. Hence the present investigation was taken up with a view to verify the suitability, feasibility and potential use of crusher dust, a waste product from aggregate crushing plant in concrete mixes, in context of its compressive strength and workability and in terms of slump, compacting factor, flow table and modified flow respectively.

In view of above discussion, an attempt is made to replace the natural sand in concrete control mixes of M25 and M30 grades designed for 100 to 120mm slump at replacement levels of 30%, 40%, 50% and 60% using Portland Pozzolana Cement. There were in all 5 mixes in each grade of concrete including control mix and four mixes with crusher dust as a partial replacement of natural sand.

It was observed that with use of crusher dust at all replacement levels, the workability of concrete was reduced from 1-6%. From the test results, it was observed that the replacement of natural sand by crusher dust increased the compressive strength of concrete by 5-22%. It was also found that amongst all the mixes, the highest compressive strength was obtained for 40% replacement of sand by crusher dust. Hence it could be concluded and recommended that crusher dust could be effectively used in concrete of above grades for replacement levels of sand by 30-60% economically leading to sustainable development.

Index Terms- Crusher dust, sand, workability, strength.

I. Introduction

Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space among the aggregate particles and glues them together. The usage of concrete, worldwide, is twice as much as steel, wood, plastics, and aluminium combined. Concrete's use in the modern world is only exceeded by the usage of naturally occurring water. The economy, efficiency, durability, moldability and rigidity of reinforced concrete make it an attractive material for a wide range of structural applications.

Concrete is widely used for making architectural structures, foundations, brick/block walls, pavements, bridges/overpasses, motorways/roads, runways, parking structures, dams, pools/reservoirs, pipes, footings for gates, fences and poles and even boats. Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and makes it flow more freely.

Aggregate is one of the important constituents which has effect in strength development in the theory that the gaps of coarse aggregate is filled by the fine aggregate and the gaps of fine aggregate is filled by the binding materials. In addition the strength of concrete mainly depends on water/cement ratio, aggregate gradation, and aggregate size and shape, cement quality, mixing time, mixing ratios, curing etc. Concrete must be both strong and workable, a careful balance of the cement to water ratio is required when making concrete. Fine aggregate are basically sands won from the land or the marine environment. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. For concrete sand fineness modulus range is 2.3-3.1.

Among these ingredients river sand is commonly used as fine aggregate in concrete which is becoming scarce and hence expensive due to excessive cost of transportation from natural sources. The large scale depletion of these sources creates serious environmental problems. So Governments are restricting the collection of river sand from river bed. In such a situation the crusher dust can be an economical alternative to river sand. Crusher dust is a byproduct generated from quarrying activities involved in the production of crushed coarse aggregate. The residue from stone crusher is further washed with water to remove the excess fines so that the fraction confirming to the IS 383 – 1970 specifications can be extracted. It is possible to use such manufactured sand as fine aggregate in concrete which will reduce not only the demand for natural river sand but also the environmental burden.

All along India, we have been using natural sand. The volume of concrete manufactured in India has not been much, when compared to some advanced countries. The infrastructure development such as express highway projects, power projects and industrial developments have started now. Availability of natural sand is getting depleted and also it is becoming costly. Concrete industry now will have to go for crushed sand or what is called manufactured sand.

So far, crushed sand has not been used much in India for the reason that ordinarily crushed sand is flaky. Badly graded rough textured and hence result in production of harsh concrete for the given design parameters. We have been not using superplasticizer widely in our concreting operations to improve the workability of harsh mix. For the last about 4 to 5 years the old methods of manufacturing ordinary crushed sand have been replaced by modern crushers specially designed for producing, cubical, comparatively smooth textured, well graded sand, good enough to replace natural sand.

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II. Materials Used

PPC confirming to IS 1489-1991 part 1 was used in the experiment. Coarse aggregates of 10 mm and 20 mm size and natural sand confirming to zone III was used. Crusher dust confirming to zone I was also used as a partial replacement of natural sand at the replacement levels of 30%, 40%, 50% and 60%. The physical and chemical properties of all these materials were tested as per IS 383-1970.

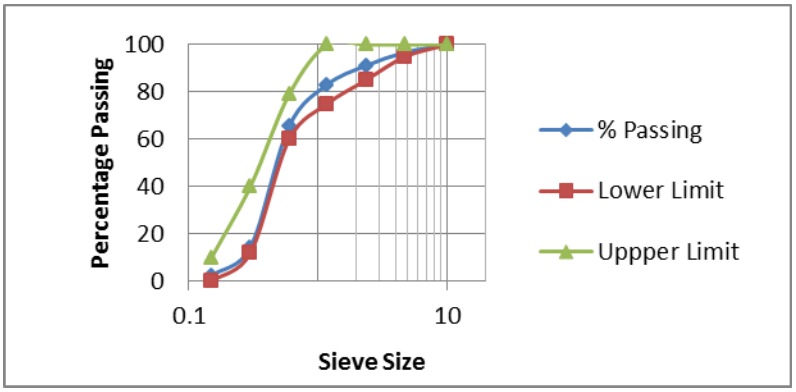
Table 1. Test Results on Cement

	Particulars	**Test Results**	**Requirements of IS:1489-1991 (Part 1)**
1.	Standard Consistency (%)	32	
2.	Setting Time (minutes) a. Initial b. Final	 240 335	 30 Min 600 Max
3.	Soundness a. Le-Chat Expansion (mm)	 1.0	 10.0 Max
4.	Compressive Strength (MPa) a. 72 +/- 1hr. (3 days) b. 168 +/- 2hr. (7 days) c. 672 +/- 4hr. (28 days)	 30.5 40.3 55.2	 16 Min 22 Min 33 Min
5.	Drying Shrinkage (%)	UT	0.15 Max
6.	% of Fly Ash addition	20.00	15.0 Min 35.0 Max

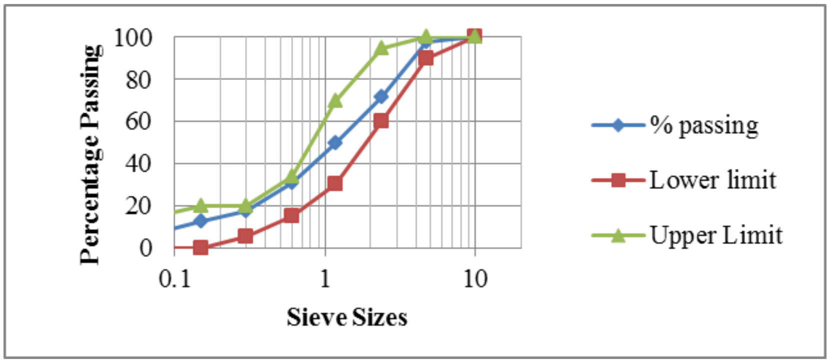
Table 2. Physical Properties of Aggregates

Particulars	**Specific Gravity**	**Water Absorption**
Coarse Aggregate (10 mm)	2.89	0.66 %
Coarse Aggregate (20 mm)	2.93	0.90 %
Sand	2.58	1.20%
Crusher Dust	2.65	0.84%

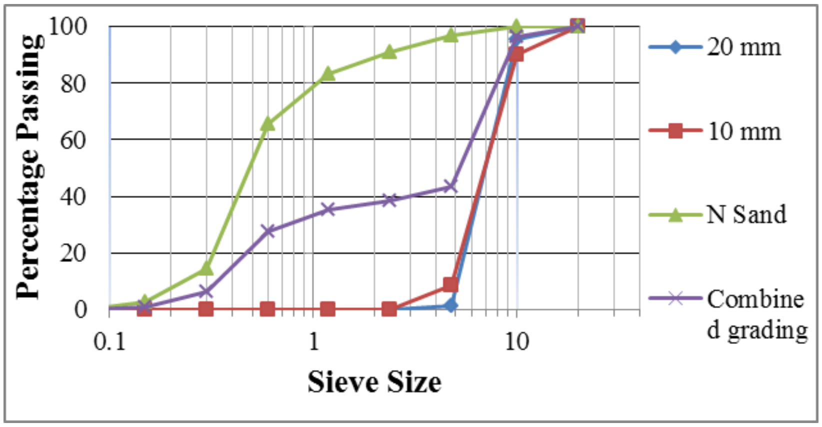
Graph 1. Grading Curve of Natural Sand.



Graph 2. Grading Curve for Crusher Dust.



Graph 3. Combined Grading Curve



Experimental Methodology:

Prior to starting the experimentation, mix design of M25 and M30 were carried out as per IS 10262-2009. The engineering properties of concrete mixes such as slump, flow table test, compacting factor test, modified flow test were carried out as per IS 1199-1959 and compressive strength test were carried out as per 516-1959.

A total of 120 specimens were cast and tested after 7 and 28 days of curing. The modified flow test apparatus is a patented apparatus developed by VNIT.

Table 3. Design Mixes (M25 Grade Concrete)

Mixes	Control Mix	70:30	60:40	50:50	40:60
w/c ratio	0.5	0.5	0.5	0.5	0.5
Cement (kg/m^{3})	440	440	440	440	440
Water (kg/m^{3})	220	220	220	220	220
Coarse Agg (kg/m^{3})	1206	1206	1206	1206	1206
Sand (kg/m^{3})	776	544	486	393	314
Crusher Dust (kg/m^{3})	00	240	340	420	494

Table 4. Design Mixes (M30 Grade Concrete)

Mixes	Control Mix	70:30	60:40	50:50	40:60
w/c ratio	0.45	0.45	0.45	0.45	0.45
Cement (kg/m^{3})	500	500	500	500	500
Water (kg/m^{3})	225	225	225	225	225
Coarse Agg (kg/m^{3})	1156	1156	1156	1156	1156
Sand (kg/m^{3})	731	519	464	336	303
Crusher Dust (kg/m^{3})	00	236	330	416	461

III. Results and Observations

Table 5. Compressive strength test results

SI. NO	CONCRETE MIX	CUBE COMPRESSIVE STRENGTH (150X150X150MM) MPa		CUBE COMPRESSIVE STRENGTH (100X100X100MM) MPa	
		7 DAYS	28 DAYS	7 DAYS	28 DAYS
1	M25 CONTROL MIX	21.13	31.84	25.5	35.2
2	M25 70 : 30 (C1)	21.65	34.47	25.7	41.2
3	M25 60 : 40 (C2)	22.47	38.96	28.3	43.7
4	M25 50 : 50 (C3)	21.32	37.74	28.1	42.9
5	M25 40 : 60 (C4)	21.64	33.4	26.3	41.4
6	M30 CONTROL MIX	27.86	39.84	29.8	41.5
7	M30 70 : 30 (C5)	27.92	41.93	29.1	45.1
8	M30 60 : 40 (C6)	28.19	46.19	30.4	48.7
9	M30 50 : 50 (C7)	27.6	44.81	29.8	46.2
10	M30 40 : 60 (C8)	27.89	43.26	29.5	43.3

Graph 4. Comparison of compressive strength of concrete

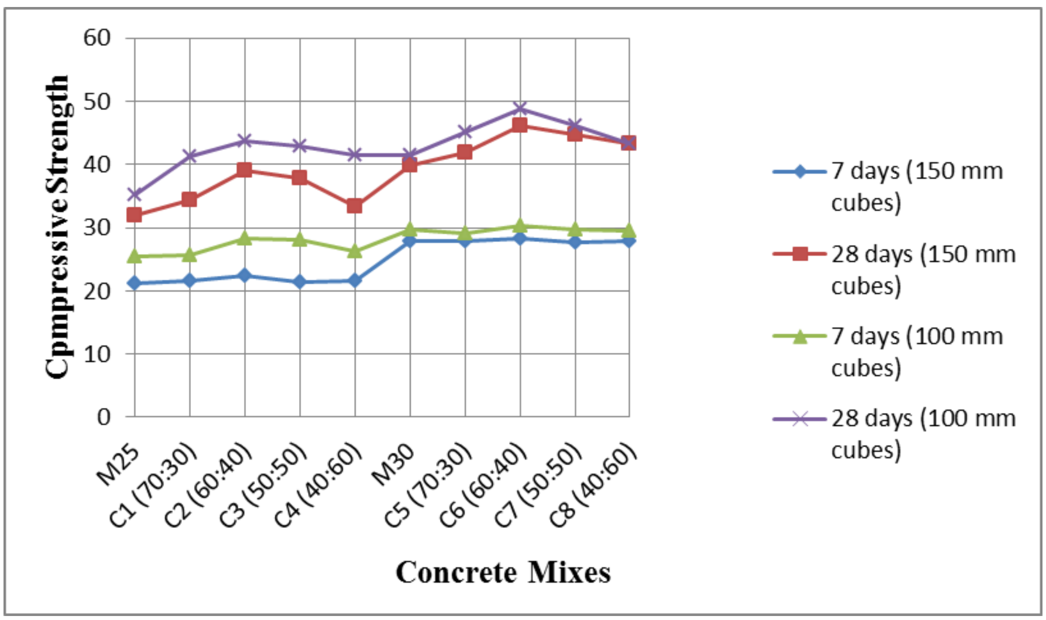
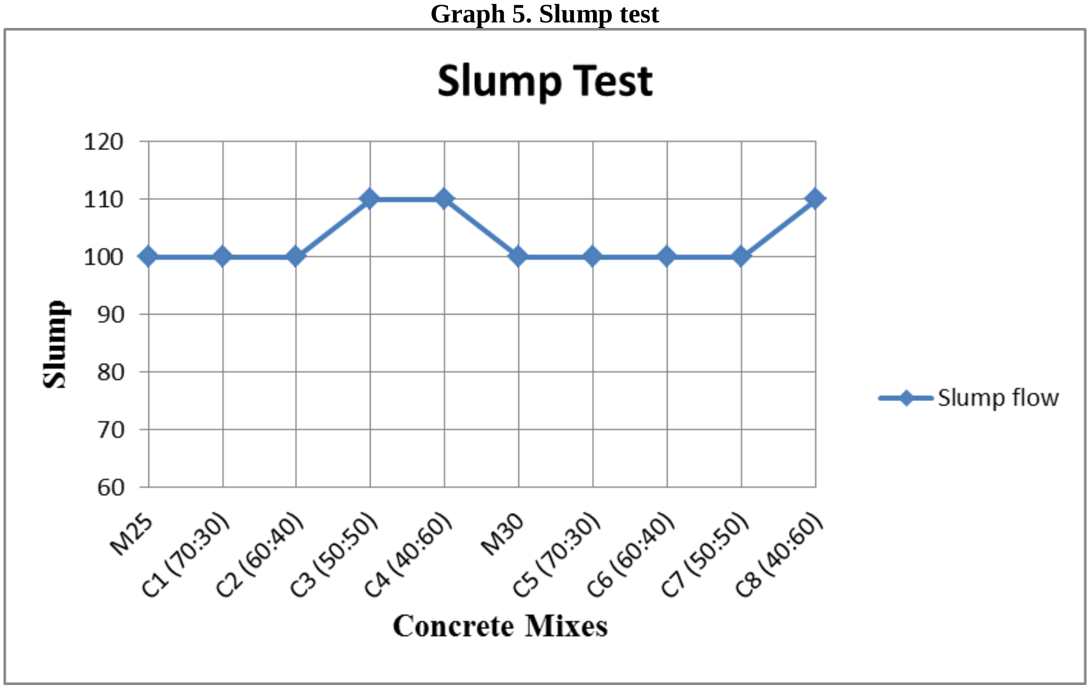


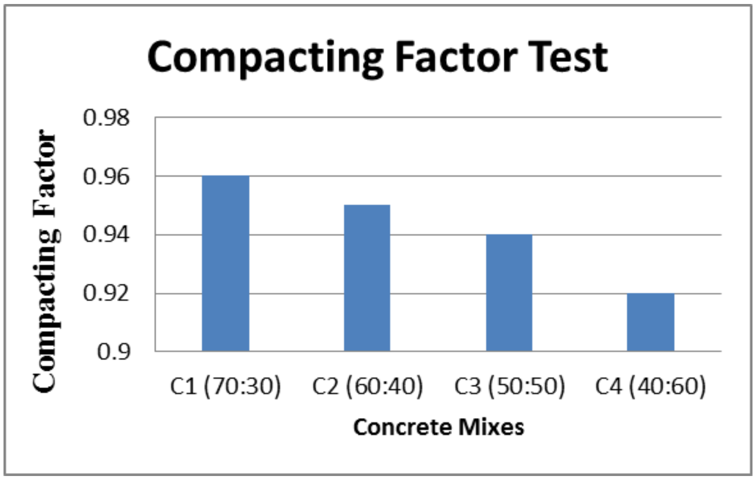
Table 6. Test results on the properties of fresh concrete

SI. NO	CONCRETE MIX	SLUMP FLOW (MM)	COMPACTING FACTOR TEST	FLOW TABLE TEST (%AGE)
1	M25 CONTROL MIX	100	0.98	18
2	M25 70 : 30 (C1)	100	0.97	16
3	M25 60 : 40 (C2)	100	0.96	20
4	M25 50 : 50 (C3)	110	0.95	18
5	M25 40 : 60 (C4)	110	0.93	18
6	M30 CONTROL MIX	100	0.98	18
7	M30 70 : 30 (C5)	100	0.96	18
8	M30 60 : 40 (C6)	100	0.95	20
9	M30 50 : 50 (C7)	100	0.94	18
10	M30 40 : 60 (C8)	110	0.92	18

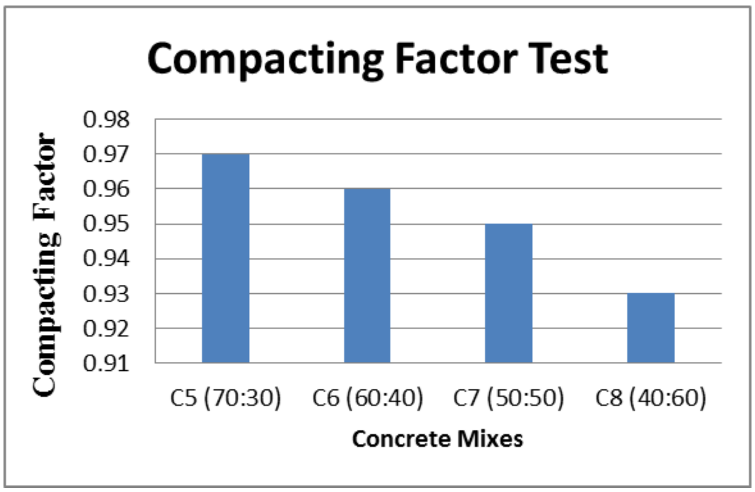
Graph 5. Slump test



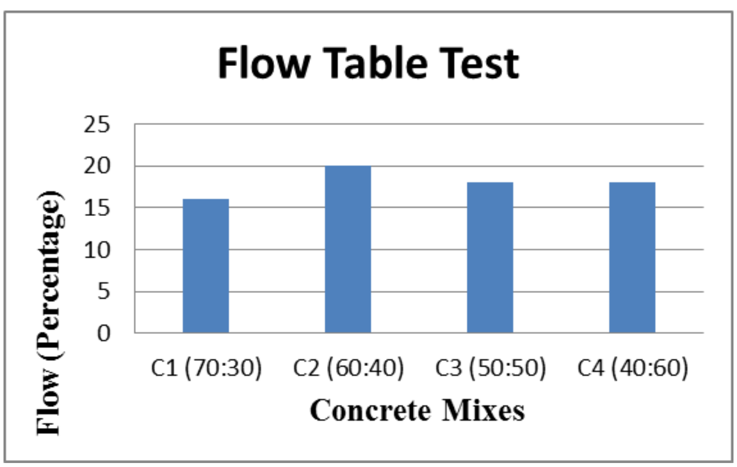
Graph 6 Comparison of compacting factor test on M25 grade concrete mixes



Graph 7 Comparison of compacting factor test on M30 grade concrete mixes



Graph 8 Comparison of flow table test on M25 grade concrete mixes



Graph 9. Comparison of flow table test on M30 grade concrete mixes

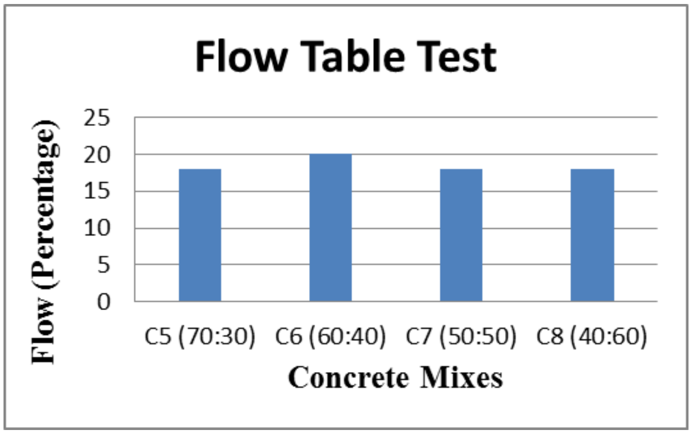
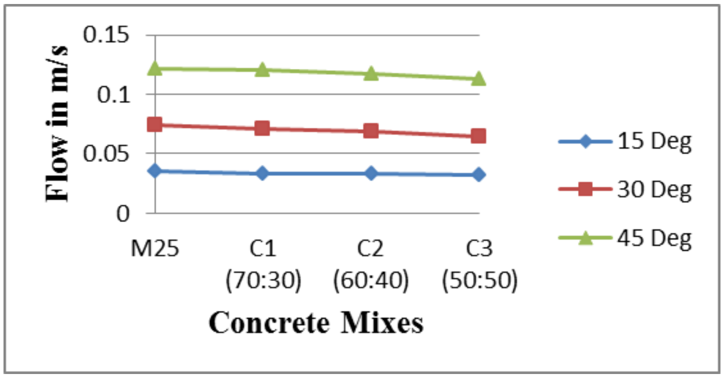


Table 7. Flow properties of concrete at different chute inclinations

SI. NO	CONCRETE MIX	FLOW AT DIFFERENT ANGLES (m/s)		
		15^0 Angle	30^0 Angle	45^0 Angle
1	M25			
2	M25 70 : 30 (C1)	0.035	0.074	0.122
3	M25 60 : 40 (C2)	0.033	0.071	0.121
4	M25 50 : 50 (C3)	0.033	0.069	0.117
5	M25 40 : 60 (C4)	0.032	0.064	0.113
6	M30			
7	M30 70 : 30 (C5)	0.034	0.072	0.121
8	M30 60 : 40 (C6)	0.032	0.069	0.118
9	M30 50 : 50 (C7)	0.031	0.066	0.115
10	M30 40 : 60 (C8)	0.029	0.063	0.11

Graph 10. Comparison of flow properties of M25 grade concrete mixes



Graph 11. Comparison of flow properties of M30 grade concrete mixes

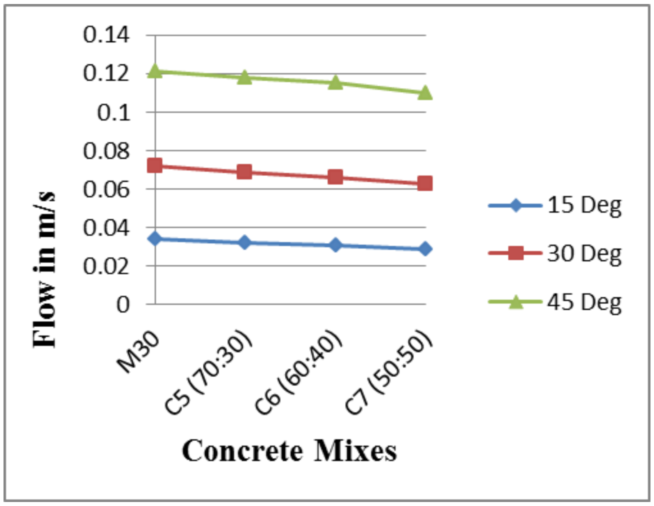
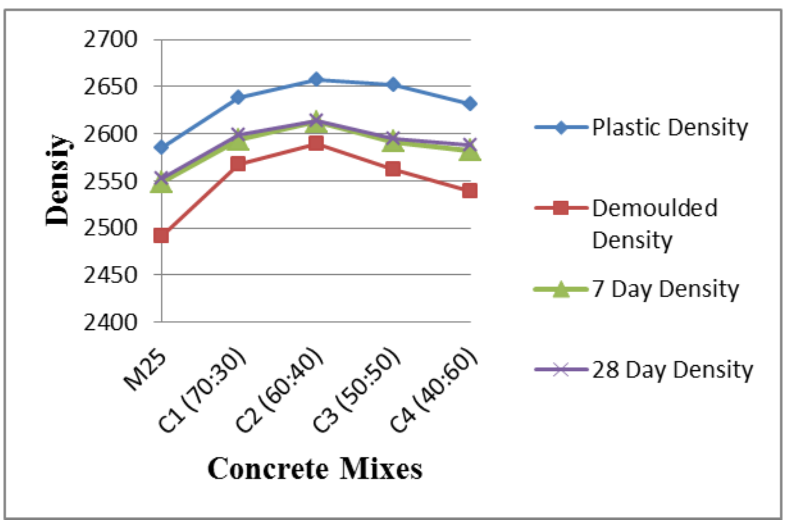


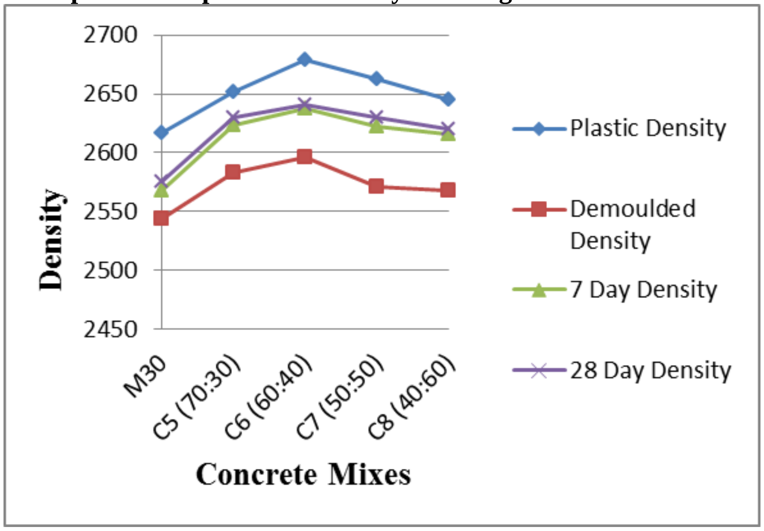
Table 8. Density of fresh and hardened concrete

SI. NO	CONCRETE MIX	PLASTIC DENSITY	DEMOULDED DENSITY	7 DAY DENSITY	28 DAY DENSITY
1	M25 CONTROL MIX	2585	2492	2549	2552
2	M25 70 : 30 (C1)	2638.5	2567.4	2593.9	2598.2
3	M25 60 : 40 (C2)	2656.8	2589.9	2613.1	2614.3
4	M25 50 : 50 (C3)	2652.3	2562.8	2591.5	2594.4
5	M25 40 : 60 (C4)	2632.1	2539.3	2582.1	2588.3
6	M30 CONTROL MIX	2616.3	2543.3	2568.2	2575.8
7	M30 70 : 30 (C5)	2651.4	2583.5	2623.2	2629.5
8	M30 60 : 40 (C6)	2678.6	2596.4	2637.2	2641.3
9	M30 50 : 50 (C7)	2663.1	2571.4	2622.4	2629.4
10	M30 40 : 60 (C8)	2645.2	2568.3	2615.8	2620.2

Graph 12. Comparison of density of M25 grade concrete mixes



Graph 13. Comparison of density of M30 grade concrete mixes



IV. CONCLUSION

Based on the results of the experimental investigation, following conclusions could be drawn as follows

The compressive strength of M25 concrete mix had increased by 22% with the use of crusher dust at 40% replacement of natural sand. The compressive strength of all mixes i.e., a partial replacement of natural sand with crusher dust at the levels of 30%, 40%, 50% and 60% showed an increase in compressive strength by 8.26%, 22.34%, 18.53% and 4.9% respectively.

The compressive strength of M30 concrete mix had increased by 16% with the use of 40% replacement of natural sand by crusher dust. The compressive strength of all mixes i.e., a partial replacement of natural sand with crusher dust at the levels of 30%, 40%, 50% and 60% showed an increase in compressive strength by 5.25%, 16%, 12.5% and 8.9% respectively.

Compacting factor test results show that there is a decrease in workability with the increase in quantity of crusher dust as a partial replacement of natural sand. The compacting factor test results for a partial replacement of natural sand by crusher dust at the levels of 30%, 40%, 50% and 60% was 0.97, 0.96, 0.95 and 0.93 respectively for M25 grade concrete mixes. Similarly, for M30 grade of concrete mixes, the compacting factor test results for a partial replacement of natural sand by crusher dust at the levels of 30%, 40%, 50% and 60% was 0.96, 0.95, 0.94 and 0.92 respectively. The workability can be increased by using plasticizers.

The round shape and smooth surface texture of natural sand reduces the inter particle friction in the fine aggregate component so that the workability is higher in natural sand. Manufactured sand particles are angular in shape and their rough surface texture improves the internal friction in the mix. Because of that the workability is reduced.

The maximum fresh and dry densities are maximum for concrete mixes containing 40% crusher dust as partial replacement of natural sand. The increase in density might also be increasing the compressive strength due to better particle packing.

The amount of fine particle present ensures effective packing and large dispersion of cement particles thus fomenting better hydration conditions moreover the dust particles completed the matrix interstices and reduce space for free water the combination of among the concrete components. This may achieved by adding plasticizers for workability by reducing the water cement ratio. With this we can achieve more workability, compaction and more strength. We can produce high performance concrete.

The modified flow test results indicate that as the crusher dust quantity increases, the velocity of the flow is also increased.

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