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The Mechanical Properties of Concrete Incorporating Quarry Dust and Foundry Sand as Partial and Complete Replacement of Fine Aggregate

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***Abstract*— Concrete is the world's most consumable product next to water. Concrete is the most used construction material in the civil engineering. The quarry dust and foundry sand has been used as a partial replacement of the fine aggregate in the concrete. The quarry dust is obtained as a waste product in the quarry mines as a residue. The foundry sand is obtained as a waste from the metal foundries. By utilizing these two products as a partial replacement of fine aggregate in concrete. The concrete can be made more eco-friendly by reducing the use of natural sand. In the present work, fresh properties and hardened properties of control concrete are compared with the concrete made with quarry dust and foundry sand. To test the fresh properties, slump cone and compaction factor tests are conducted. To test the hardened properties compression test and split tensile tests are conducted for 7 days and 28 days. Control concrete of M30 grade is designed using 10262:2009 provision. Few regression models are also deduced to evaluate compressive and split tensile strengths.**

***Keywords*— Compressive Strength, Foundry Sand (FS), Quarry Dust (QD), Regression Model (RM), Split Tensile Strength.**

I. INTRODUCTION

Concrete is the most widely used composite material today. The constituents of concrete are coarse aggregate, fine aggregate, binding material and water. Rapid increase in construction activities leads to shortage of conventional construction materials. It is conventional that sand is being used as fine aggregate in concrete. For the past two years, the escalation in cost of sand due to administrative restrictions in India, demands comparatively greater cost at around two to three times the cost for crusher waste even in places where river sand is available nearby. The function of the fine aggregate is to assist in producing workability and uniformity in the mixture. The river deposits are the most common source of fine aggregate. Now-a-days the natural river sand has become scarce and very costly. Hence we are forced to think of alternative materials. River Sand is widely used for concrete as Fine Aggregate. No one can give assurance how far it can be available due to scarcity and cost of river sand. Engineering Research and Development department are amazing in the search of new material for replacement of fine aggregate.

Unlimited quarrying of sand are now available which are used as fine aggregate in the preparation of cement mortar resulted in lowering of water table, soil erosion etc. Cost of construction can be effectively reduced if quarry dust is available near the site. The Quarry dust may be used in the place of river sand fully or partly. Foundry sand is high quality silica sand with uniform physical characteristics. It is a by-product of ferrous and non-ferrous metal casting industries, where sand has been used for centuries as a material because of its thermal conductivity. It is a by-product from the production of both ferrous and non-ferrous metal castings. The physical and chemical characteristics of foundry sand will depend in great part on the type of casting process and the industry sector from which it originates. In modern foundry practice, sand is typically recycled and reused through many production cycles. The automotive industries and its parts are the major generators of foundry sand. Foundries purchase high quality size-specific silica sands for use in their moulding and casting operations. The foundry sand is normally of a higher quality than the typical bank run or natural sands used in fill construction sites. The sands form the outer shape of the mould cavity. In this study, an attempt has been made to find the suitability of quarry dust and foundry sand as fine aggregate.

II. STATEMENT OF PROBLEM

In the present work, an attempt has been made to use quarry dust and foundry sand as a supplementary material for fine aggregate. The main aim of this work is to study fresh and hardened properties of M30 grade control concrete and concrete made with quarry dust and foundry sand with different percentages as partial and complete replacement of fine aggregate.

III. OBJECTIVES OF THE STUDY

The following are the main objectives of the study

a) To evaluate the fresh properties of control concrete of M30 grade and concrete made with quarry dust and foundry sand as partial replacement and complete replacement of fine aggregate for fresh properties slump cone test, compaction factor tests are conducted.

b) To find out the compression strength of control concrete of M30 grade and concrete made with quarry dust and foundry sand as partial replacement and complete replacement of fine aggregate at 7 days and 28 days, tests are conducted.
c) To find out the split tensile strength of the control concrete of M30 grade and concrete made with quarry dust and foundry sand as partial replacement and complete replacement of fine aggregate at 7 days and 28 days, tests are conducted.
d) Statistical analysis has to be carried out to deduce regression models to evaluate compressive and split tensile strengths.

IV. Materials And Methodology

CEMENT:

In this present work Ultratech cement of 43grade ordinary Portland Cement (OPC) was used for casting cubes and cylinder for all concrete mixes. The cement was of uniform color i.e. Grey with a light greenish shade and was free from any hard lumps. The various tests conducted on cement are specific gravity, initial and final setting time and compressive strength. Testing on cement was done as per IS codes. The specific and composting limits of Portland cement are reported in below Table 1.

Table 1:
Physical properties of cement

Particulars	Experimental Results	As per standard IS 8112:2013
Specific gravity	3.15	---
Setting Time (minutes)		
Initial setting	125 minutes	30 minutes (Minimum)
Final setting	200minutes	600 minutes (Maximum)
Compressive strength (MPa)		
3 Days	24.10 MPa	23 MPa (Minimum)
7 Days	36.14 MPa	33 MPa (Minimum)
28 Days	44.20 MPa	43 MPa (Minimum)

Fine Aggregates:

Natural sand (NS): The sand used for this project was locally procured and conformed to grading zone II as per IS: 383-1970.

The specific gravity of natural sand was found to be 2.74. Fineness modulus is 2.57 and water absorption was found to be 1.3% and free moisture content was 0%.

Quarry Dust (QD): The quarry dust used for this project was procured from the crusher near Jagalur taluk. The specific gravity of quarry dust was found to be 2.46.

Foundary sand (FS): The foundry sand used for this project was procured from the A.N Foundries, Harihar. The specific gravity of Foundry Sand was found to be 2.31.

Coarse Aggregate:

Locally available coarse aggregate having the maximum size of 20mm were used in the present work. The specific gravity of coarse aggregate was found to be 2.71. Water absorption was found to be 0.3% and free moisture content was 0 %.

WATER:

Potable tap water was used for the preparation and curing of the specimens.

V. Mix-Design

The proportioning of the ingredients of concrete is an important phase of concrete technology as it ensures quality and economy. In pursuit of the goal of obtaining concrete with desired performance characteristics the selection of component materials is the first step, the next step is a process called mix design by which one arrives at the right combination of the ingredients. The mix design procedure adopted in the present work to obtain M30 grade concrete is in accordance with IS: 10262-2009. The specific gravities of the materials used are as tabulated in the below table 2. The different mix proportions can be viewed in APPENDIX.

Table 2:
Specific gravities of materials used

Materials	Specific gravity
Cement	3.15
Fine Aggregate	2.74
Coarse Aggregate	2.71

Table 3:
Mix proportions

W/C Ratio	Water (kg/m^3)	Cement (kg/m^3)	FA (kg/m^3)	CA (kg/m^3)
0.44	197	447.72	666.49	1132.10

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Table 4:
Concrete mix designation

Mix	Description
M0	CONTROL CONCRETE OF GRADE M30
M1	100% NATURAL SAND REPLACED WITH QUARRY DUST.
M2	100% NATURAL SAND REPLACED WITH FOUNDRY SAND.
M3	50% NS + 25% QD + 25% FS
M4	50% QD + 25% FS + 25% NS
M5	50% FS + 25% QD + 25% NS
M6	50% NS + 40% QD + 10% FS
M7	50% NS + 30% QD + 20% FS
M8	50% NS + 20% QD + 30% FS
M9	50% NS + 10% QD + 40% FS

VI. Casting Of Specimen And Testing Procedure

Cement, sand and Aggregate were taken in the mix proportion 1:1.48:2.52 which correspond to M30 grade concrete. The concrete was produced by mixing all the ingredients homogeneously. To this dry mix, required quantity of water was added (w/c ratio=0.44) and the entire mix was again homogeneously mixed. This wet concrete was poured into the moulds which was compacted both through hand compaction in three layers as well as through vibrator. After the compaction, the specimens were given smooth finish and taken out of the table vibrator. After 24 hours, the specimens were demoulded and transferred to curing tanks where they were allowed to cure for required number of days.

For evaluating the compressive strength, specimens of dimensions 150X150X150 mm were prepared. They were tested on 3000 KN capacity compression testing machine as per IS: 516-1999. The compressive strength is calculated by using the following equation,

$$f_{ck} = P/A$$

Where,
f_{ck}=Compressive strength of specimen (MPa)
P=Maximum load applied to the specimen (N)
A=Cross sectional area of the specimen (mm2)

For evaluating the split tensile strength, cylindrical specimen of diameter 150mm and length 300mm were prepared. Split tensile strength test was carried out on 3000KN capacity compression testing machine as per IS: 5816-1959. The split tensile strength is calculated by using the following equation,

$$f_{sp} = 2P/(\pi DL)$$

Where,
f_{sp}=Split tensile strength of specimen (MPa)
P=Load at failure (N)
L=Length of cylindrical specimen in mm
D=Diameter of cylindrical specimen in mm.

VII. Experimental Results

Fresh properties of concrete: - The test conducted on fresh properties of control concrete and concrete made with quarry dust and foundry sand with different percentages. The tests conducted for workability of concrete were slump test and compaction factor test, results are represented in Table 6 and Table 7 respectively.

Table 6:
Slump test values (mm)

Sl No	Mix	Slump (mm)
1	M0	118
2	M1	60
3	M2	0
4	M3	55
5	M4	50
6	M5	25
7	M6	40
8	M7	85
9	M8	45
10	M9	40

Table 7:
Compaction factor test values

Sl No	Mix	Compaction factor
1	M0	0.97
2	M1	0.91
3	M2	0.81
4	M3	0.90
5	M4	0.90
6	M5	0.87
7	M6	0.88
8	M7	0.94
9	M8	0.88
10	M9	0.88

Hardened properties of concrete

Compressive strength test results: - For each concrete mix, the compressive strength is determined on three 150X150X150mm cubes at 7 and 28 Days of curing. Following Table 8 gives the compressive strength test results of control concrete and concrete made with quarry dust and foundry sand with different percentages.

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Table 8:
Overall Results of Compressive Strength:

Mix	Compressive strength (N/mm^2)	
	7 Days	28 Days
M0	33.77	41.33
M1	32.88	41.50
M2	11.55	29.33
M3	36.44	43.11
M4	28.88	42.22
M5	24.88	34.22
M6	32.88	41.20
M7	39.55	47.55
M8	32.88	41.00
M9	31.00	40.88

Split tensile test results: The test has been conducted after 7 and 28 days of curing. Split tensile test conducted on 150mm diameter and 300mm length cylinder as per IS: 5186-1999. Following test results gives the split tensile test results of control concrete and concrete made with quarry dust and foundry sand with different percentages.

Table 9:
Overall Results of Split tensile Strength

Mix	Split tensile strength (N/mm^2)	
	7 Days	28 Days
M0	2.40	3.39
M1	2.38	3.37
M2	1.11	2.68
M3	2.90	3.53
M4	2.00	3.45
M5	1.78	3.04
M6	2.30	3.30
M7	3.11	4.03
M8	2.38	3.11
M9	2.34	3.10

VIII. Regression Models

A statistical regression is under taken to establish the empirical relationship between the compressive strength, % of quarry dust and % of foundry sand to evaluate compressive strength. Also, regression model is developed to evaluate the split tensile strength in terms of % of quarry dust and % of foundry sand. A linear regression model was developed, based on model the results are discussed here in:

f_{ck} = 39.5298 - (0.04964 X %QD) - (0.25232 X %FS) --------for *7 days*

f_{ck} = 45.169 - (0.01807 X %QD) - (0.14642 X %FS) --------for *28 days*

f_{sp} = 2.8739 - (0.0041 X %QD) - (0.01603 X %FS) ---------- for *7 days*

f_{sp} = 3.569 - (4.215E-4 X %QD) - (0.00855 X %FS) --------for *28 days*

Where,
f_{ck} = Characteristic compressive strength (N/mm^2)
f_{sp} = Split tensile strength (N/mm^2)
QD = Quarry dust
FS = Foundry sand

The performance of regression models (RM) on compressive and split tensile strength is as shown in the Table 10 to Table 13 also the variation between experimental and deduced regression model can be viewed in figure 1 to figure 4.

Table 10:
Performance of RM for 7 days compressive strength

Mix	EXP	RM	EXP/RM
M0	33.77	39.52	0.85
M1	32.88	34.56	0.95
M2	11.55	14.29	0.81
M3	36.44	31.98	1.14
M4	28.88	30.74	0.94
M5	24.88	25.67	0.97
M6	32.88	35.02	0.94
M7	39.55	32.99	1.20
M8	32.88	30.96	1.06
M9	31.00	28.94	1.07

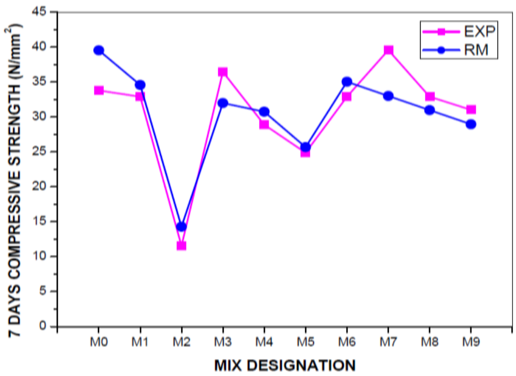

Fig 1: Performance of RM for Compressive strength at 7 days

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Table 11:
Performance of RM for 28 days compressive strength

Mix	EXP	RM	EXP/RM
M0	41.33	45.17	0.91
M1	41.5	43.36	0.96
M2	29.33	30.53	0.96
M3	43.11	41.06	1.05
M4	42.22	40.6	1.04
M5	34.22	37.39	0.92
M6	41.2	42.98	0.96
M7	47.55	41.69	1.14
M8	41.00	40.415	1.01
M9	40.88	39.13	1.04

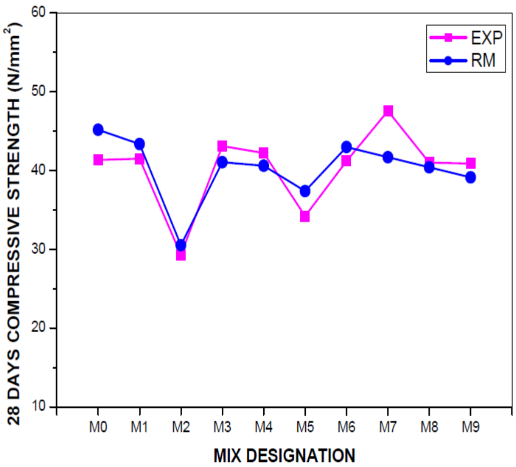

Fig 2: Performance of RM for Compressive strength at 28 days

Table 12:
Performance of RM for 7 days split tensile strength

Mix	EXP	RM	EXP/RM
M0	2.40	2.87	0.84
M1	2.38	2.46	0.97
M2	1.11	1.27	0.87
M3	2.90	2.37	1.22
M4	2.00	2.26	0.88
M5	1.78	1.97	0.90
M6	2.30	2.54	0.91
M7	3.11	2.43	1.28
M8	2.38	2.31	1.03
M9	2.34	2.2	1.06

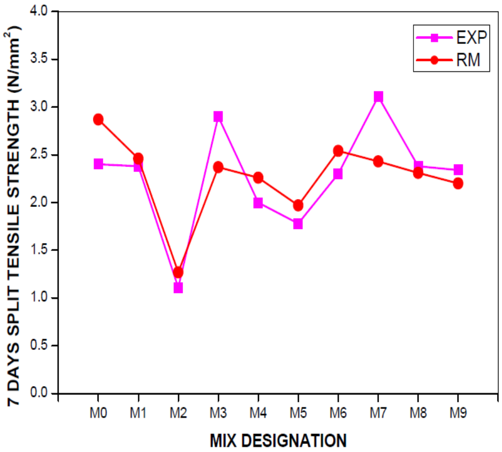

Fig 3: Performance of RM for Split tensile strength at 7 days

Table 13:
Performance of RM for 28 days split tensile strength

Mix	EXP	RM	EXP/RM
M0	3.39	3.57	0.95
M1	3.37	3.53	0.95
M2	2.68	2.71	0.99
M3	3.53	3.35	1.05
M4	3.45	3.34	1.03
M5	3.04	3.13	0.97
M6	3.3	3.47	0.95
M7	4.03	3.38	1.19
M8	3.11	3.3	0.94
M9	3.1	3.22	0.96

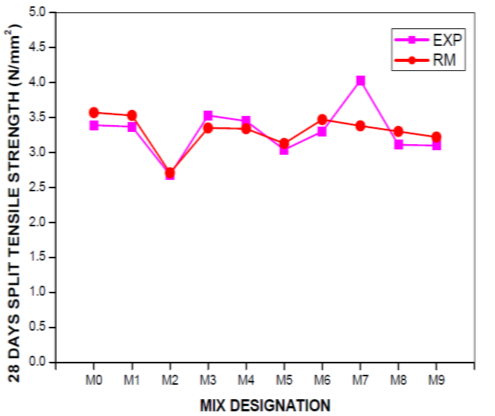

Fig 4: Performance of RM for Split tensile strength at 28 days

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IX. Observations And Discussions

In the present work, an attempt has been made to use quarry dust and foundry sand as a supplementary material for fine aggregate. The effect of quarry dust and foundry sand on cement concrete in fresh and hardened state is investigated and the following observations were made from the experiment conducted. To study the fresh properties of concrete, slump test and compaction factor test were conducted for control concrete and concrete made with quarry dust and foundry sand with different percentages.

1. From the results obtained from workability test it is clearly observed that addition of foundry sand and quarry dust decreases the workability. Between these two supplementary materials foundry sand having the major role in decreasing the workability because of its very fine nature.
2. At 7 days curing period the compressive strength of the mix M7 is higher than all mixes. The compressive strength of mix M1, M2, M4, M5, M6, M8, M9 is showing less compressive strength compared to control concrete by 2.63%, 65.79%, and 14.48%, 26.32%, 2.63%, 2.63% and 8.20% respectively. But M3 and M7 are showing good results compared to control concrete. The compressive strength is increased by 7.90% and 17.11% respectively.
3. At 28 days curing period M7 mix is showing better results compared to control concrete. The compressive strength of mix M1, M2, M5, M6, M8, M9 is showing less compressive strength compared to control concrete by 0.31%, 29.03%, 17.20%, 0.31%, 0.79%, and 1.08% respectively. But the compressive strength of mix M3, M4 and M_7 increased by 4.30%, 2.15% and 15.04% respectively compared to control concrete.
4. The splitting tensile strength results exhibits the same failure pattern at 7 days of curing period. The split tensile strength of mix M7 is showing better results compared to control concrete. The split tensile strength of mix M1, M2, M4, M5, M6, M8, M9 is showing less split tensile strength compared to control concrete by 0.83%, 53.75%, 16.67%, 25.83%, 4.16%, 0.83%, and 2.5% respectively. But M3 and M7 split tensile strength increases by 20.83% and 29.58% respectively compared to the control concrete.
5. At 28 days curing period M7 mix is showing better performance compared to all mix in split tensile strength. The split tensile strength of mix M1, M2, M5, M6, M8, M9 is showing less compressive strength compared to control concrete by 0.58%, 20.94%, 10.32%, 2.65%, 8.25%, and 8.55% respectively. But the split tensile strength of mix M3, M4 and M7increased by 4.12%, 1.76% and 18.87% respectively compared to control concrete.
6. From the observations made by the test results we can conclude that workability decreases by the addition of quarry dust and foundry sand. In mix M2 (100% replacement of natural sand with foundry sand) the mix is very harsh with zero slump. In Mix M3, M4 and M5 natural sand is replaced by the combination of quarry dust and foundry sand. Has the percentage of the combination of quarry dust and foundry sand increases workability decreases in these 3 mix M3, M4 and M5, Mix M5 is least workable because of high percentage of foundry sand (50% foundry sand + 25% quarry dust 25% natural sand).in mixes M6 to M9 mix M7is highly workable with combination of (50% natural sand +20% foundry sand + 30% quarry dust).
7. The results of compressive strength and split tensile strength clearly shows 100% replacement of natural sand to foundry sand is not feasible. But 100% replacement of natural sand to quarry dust is showing good results almost showing the same strength characteristics of control concrete. The effectiveness of these two supplementary materials works in combination with natural sand. Mix M3 and M7 show good results in both compressive and split tensile strength at both curing periods. The results clearly shows that quarry dust and foundry sand works well in combination with natural sand and forms a dense material due to the variation of fineness modulus of different materials when they work as a composite material making concrete a dense material.
8. From the deduced regression models, it is observed that the ratio EXP/RM is about 0.81 to 1.28. This indicates that the proposed models are suited to experimental values.

X. Conclusions

1. The incorporation of foundry sand in concrete causes systematic decrease in workability.
2. The incorporation of quarry dust in concrete causes systematic decrease in workability.
3. The combination of natural sand, foundry sand and quarry dust also results in decrease in workability compared to normal concrete made with natural sand.
4. Concrete acquires increase in compressive strength for mix M3 and M7 by 7.90%, 17.11% at 7 days and 4.30%, 15.04% at 28 days compared to control concrete.
5. Concrete acquires increase in split tensile strength for mix M3 and M7 by 20.83%, 29.88% at 7 days and 4.12%, 18.87% at 28 days compared to control concrete.
6. 100% replacement of natural sand with foundry sand is not feasible.

7. 100% replacement of natural sand with quarry dust can be done with slightest compromization of strength parameters.
8. Making concrete with the combination of natural sand, quarry dust and foundry sand with different percentage gives good results compared to control concrete. So the best way to use these materials is in combinations.
9. Non availability of Natural sand at reasonable cost led to the search of alternative materials. Quarry dust and foundry sand are the suitable alternative materials for natural sand at very low cost also solving the problem of waste disposal using these two materials in combination making concrete more eco-friendly.
10. Few regression models are deduced to evaluate the compressive and split tensile strengths interms of percentage of foundry sand and quarry dust for different days of curing

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IS CODES

1) IS 456:2000
2) IS 2386 (Part 3):1963
3) IS 383:1970
4) IS 516:1959
5) IS 5816:1999
6) IS 10262:2009

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APPENDIX

Quantity of different mixes used in casting for constant w/c ratio 0.44

Mix	Fineness Modulus	Water (kg/m^3)	Cement (kg/m^3)	Fine Aggregate			Coarse Aggregate (kg/m^3)
				Natural sand (kg/m^3)	Quarry dust (kg/m^3)	Foundry sand (kg/m^3)	
M0	2.75	197	447.42	666.49	-	-	1132.10
M1	2.32	197	447.42	-	666.49	-	1132.10
M2	1.65	197	447.42	-	-	666.49	1132.10
M3	2.28	197	447.42	333.24	166.62	166.62	1132.10
M4	2.10	197	447.42	166.62	333.24	166.62	1132.10
M5	2.19	197	447.42	166.62	166.62	333.24	1132.10
M6	2.40	197	447.42	333.24	266.59	66.54	1132.10
M7	2.24	197	447.42	333.24	199.94	133.29	1132.10
M8	2.37	197	447.42	333.24	133.29	199.94	1132.10
M9	2.35	197	447.42	333.24	66.54	266.59	1132.10