AN EXPERIMENTAL STUDY ON QUARRY DUST AS PARTIAL REPLACEMENT FOR SAND IN CONCRETE

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Abstract: Concrete plays the key role and a large quantum of concrete is being utilized in every construction practices. Quarry Dust which is a other non-voluble waste material after the extraction and processing of rocks to form fine particles less than 4.75mm.The Quarry dust can be an alternative to the river sand since river sand is expensive due to excessive cost of transportation from natural sources and also large scale depletion of these sources creates environmental problems .In this project work the usage of different quarry dusts by studying the physical and chemical properties, workability of the quarry dust concrete, with different ratios of 0%, 20%, 30%&40% for M20 grade of concrete behavior of quarry dust reinforced cement concrete beams, Sieve analysis was conducted for quarry dust and sand. Mix design has been developed using IS Mix Design for various proportion of four different quarry dust with river sand. Tests were conducted on cubes and cylinders to study the compressive and tensile strengths of concrete made of various proportion of quarry dust with river sand, optimum strength test values of various proportion of different quarry dust with river sand and the results were compared with naturalsand.

Key words: River Sand,Quarry dust, workability, compressive strength, tensile strength

INTRODUCTION

Concreteis an accumulation of cement,aggregateandwater. Intheproductionof concrete,granitestoneandriversandareusedascourse and fine aggregate,respectivelyalthoughthesematerialsareusuallyavailable,atsomeplaces it is economicaltosubstitutethesematerialsbylocallyavailable once.Atthesametimeincreasing quantityof Quarrydustis available from crushersaswaste. The disposal of this isamakessomeenvironmentalproblem. Ifitispossibletousethisquarrydustinmaking concrete by partial replacementof natural river sand,then this will not only save the cost of construction but at the same time it will solve the problem of disposal of this dust. On the other hand, the advantages of utilization of byproducts or aggregates obtained as waste materials are pronounced in the aspects of reduction in environmental load &waste management cost, reduction of production cost as well as improving the quality of concrete. Quarry dust has been used for different activities in the construction industry such as road construction and manufacture of building materials such as light weight aggregates, bricks and tiles. The use of quarry dust in concrete is desirable because of its benefits such as useful disposal of byproducts, reduction of river sand consumption aswell asincreasing the strengthand increasing the workability of concrete. Test have been madetoinvestigatesome property of quarry dust and thesuitability of those properties to enable quarry dust to be used as partial replacement material for sand in concrete.

The main objectives of the present study are to analyze the quarry dust from different quarries both unwashed and washed and ,to study the behavior of reinforced concrete beams for different ratios 0%, 20%, 30% & 40% for M20 grade of concrete and to determine the load carrying capacity of the beams, load deflection behavior.

MATERIALS

Cement:

Cement is the most important ingredient in concrete. One of the important criteria for the selection of cement is its ability to produce improved microstructure in concrete. Some of the important factors which play vital role in selection cement are compressive strength at various ages, fineness, heat of hydration, alkali content, tri calcium aluminate (C3A) content, tricalcium silicate (C3S) content, dicalcium silicate (C2S) content etc. it is also necessary to ensure compatibility of the chemical and mineral admixtures with cement. Ordinary Portland Cement (53 grade) with 30% normal consistency conforming to BIS: 12269-1987 was used in both of concrete and mortar.

Aggregate:

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. Aggregates occupy 70 to 80% of the volume of the concrete. The aggregates combine with the cement and water to produce concrete. Basically there are two types of aggregates, the fine aggregate and the coarse aggregate.

Fine Aggregate:

The sand obtained from river beds or quarry is used as fine aggregate. The fine aggregate along with the hydrated cement paste fill the space between the coarse aggregate.The important properties of aggregate are as follows:

1) Shape and texture.
2) Size gradation.
3) Moisture content.
4) Specific gravity.
5) Unit weight.
6) Durability and absence of deleterious materials.

River sand:

Properties of River Sand:

The physical properties of river sand was done according to IS 2386-1963. Fineness modulus: 2.39, Specific gravity: 2.56. Physical proportions envisaged in IS 383-1970 were carried out on sand sample. The gradations of the sand sample are as follows:

Table1: Sieve Analysis of Natural Sand

S.No.	Sieve Size	Wt. Retained (gms)	% Passing	Requirement as per zone III
1	4.75mm	0.019	98.1	90-100
2	2.36mm	0.113	86.8	85-100
3	1.18mm	0.088	78	75-100
4	600 micron	0.098	68.2	60-79
5	300 micron	0.214	46.8	12-40
6	150 micron	0.447	2.1	0-10
7	75 micron	0.021	0	-
8	pan	0	0	-

Quarry Dust:

Crushed sand less than 4.75mm is produced from hard granite rock using state of the art Crushing plants. Production of quarry fines (material < 4.75mm) is a consequence of extraction & processing in a quarry. The amount produced depends on the rock type, amount of fragmentation by blasting & type of crushing used.

The product is washed to remove excess fines using sand screw classifiers to get sand of excellent shape, gradation free from silt, clay and unwanted contamination. Quarries sand have been collected from two sites which are Cuddalore and Pondyin Cuddalore district of Tamilnadu in India.

Properties of Quarries Sand:

The physical properties of four different quarries sand were done according to IS 2386-1963.

Table 2:

Physical Properties.	Chennimalai quarry		Palladam quarry	
	Washed	Unwashed	Washed	Unwashed
Fineness modulus	2.61	2.34	2.65	2.35
Specific gravity	2.56	2.56	2.59	2.54

Table 3:

Typical chemical composition of quarrydust and natural sand. Constituent	Chennimalai Quarry rock dust (%)	Palladam Quarry rock dust (%)	Test method
SiO_2	65.21	63.29	IS: 4032-1968

CuO	0.12	0.092	
Fe_2O_3	10.52	9.68	
CaO	0.74	0.54	
MgO	4.27	3.07	

Sieve Analysis of Four Different Quarries Sand:

Physical proportions envisaged in IS 383-1970 were carried out on sand sample. The gradations of the sand sample are as follows:

Table 4:

Sieve analysis results of four different quarries sand					
IS sieve	**Percentage of passing**				**Requirement as per zone II(IS 383-1970)**
	Cuddalore quarry sand		**Pondyquarry sand**		
	Washed I	**Unwashed I**	**Washed II**	**Unwashed II**	
10mm	100	100	100	100	100
4.75mm	99	98.26	98.39	98.67	90-100
2.36mm	88.56	85.48	87.96	89.66	75-100
1.18mm	68.81	66.28	67.29	71.84	55-90
600 microns	53.82	55.58	49.57	54.60	35-59
300 microns	18.07	32.31	18.23	24.81	8-30
150 microns	5.08	19	6.93	13.14	0-10
75 microns	1.32	11.24	1.89	6.87	

For crushed sands, the permissible limit on 150 micron IS sieve is increased to 20%. The un-sieved quarry dust was used for concrete specimens.

Coarse aggregate Fineness modulus: 3.4775, Specific gravity : 2.7195 Sieve Analysis of Coarse Aggregate

The metal used confirms to the limits of 20mm graded aggregate as given in IS 383-1970.

Table 5:

Sieve analysis results of coarse aggregate					
IS sieve	**Percentage passing**				**% passing for single sized aggregate of nominal size(20 mm)**
	Trial I	**Trial II**	**Trial III**	**Average**	
40mm	100	100	100	100	100

20mm	88.73	93.47	88.26	90.15	85-100
16mm	43.93	47.8	46.46	45.79	-
12.5mm	9.13	13.8	11.87	11.60	-
10mm	2.53	6.13	5.66	4.77	0-20
4.75mm	0	0	0	0	0-5
2.36mm	0	0	0	0	-

Water:

Water is an important ingredient of concrete as it chemically participates in the reactions with cement to form the hydration product, C-S-H gel. The water used for making concrete should be free from the undesirable salts that may react with cement and reduce their efficiency. Silts and suspended particles are undesirable as they interfere with setting, hardening and bond characteristics. Algae in mixing water may cause a marked reduction in strength of concrete either by combining with cement to reduce the bond or by causing large amount of air entertainment in concrete.Water conforming to the requirements of BIS: 456-2000 is found to be suitable for making concrete. It is generally stated that water fit for drinking is fit for making concrete. For the present investigation, locally available potable water is used.

Steel:

SteelTMT (Thermo Mechanically Treated) Steel bars of size 10 mm, 8 mm have been used as main reinforcement and hanger bars respectively. 6 mm diameter bars have been used for shear reinforcement of beams.

Experimental Program:

This chapter presents the details of experimental investigations carried out on the test specimens to study the workability and strength-related properties of concrete using quarries sand and river sand. The steel and wooden moulds are used for all cubes, cylinders and beams. These moulds were cleaned and gaps were filled with plaster of Paris putty and oiled before casting. Here an attempt was made to study the strength development for four quarries sand and natural sand. The workability and the strength-related properties such as compressive strength, splitting tensile strength, flexural strength, young’s modulus were studied. Minimum of three specimens were tested for each mix for each test and the tests were conducted as per specifications.

Workabilityof Fresh Concrete:

On fresh concrete, the test related to workability measures like slump test and compaction factor test were carried out as per BIS specifications for four quarries sand and river sand.

Strength - Related Test for Concrete:

The specimens are tested for Cube compressive testCylinder splitting tensile strength test, Stress - Strain Curve and Elastic Modulus Flexural strength test

Cube Compressive Strength:

For cube compression testing of concrete and mortar, 150mm cubes and 70.6 mm cubes were used respectively. All the cubes were tested in saturated condition, after wiping out the surface moisture. Three cubes for each mix of four quarries sand with river sand were tested at the age of 7 days and 28 days of curing for concrete and 28th days of curing for mortar using compression testing machine of 2000 kN capacity.

Splitting Tensile Strength:

This is an indirect test to determine the tensile strength of cylindrical specimens. Splitting tensile strength tests were carried out on cylinder specimens of size 150 mm diameter and 300 mm length at the age of 28 days curing, using compression testing machine of 2000 kN capacity. To avoid the direct load on the specimen the cylindrical specimens were kept below the wooden strips. The load was applied gradually till the specimens split and readings were noted. The test set up for the splitting tensile strength on the cylinder specimen, with the wooden strips to avoid the direct load on the specimen is shown in Figure 7.2.

Stress - Strain Curve and Elastic Modulus:

Cylinder specimens of size 150 mm diameter and 300 mm height were used to determine the modulus of elasticity of concrete in compression at the age of 28 days curing. The test cylinder attached with a longitudinal compressometer to measure compressive strain on the 2/3 of the specimen from the center (gauge length = 200 mm) is shown in fig 7.3. Four cycles of loading and unloading was done, the cycles were continued till the percentage difference between two consecutive cycles becomes less than five percentage. The modulus of elasticity was found out by plotting the stress - strain curve. The modulus of elasticity was obtained with reference to tangent modulus

Flexural Strength Test:

Beam specimens of size 10x10x50 cm were used, casted and tested as shown in fig 7.3 to determine the flexural strength of concrete at the age of 28th days. The bearing surfaces of the supporting and loading rollers are wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. The specimen is then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould, along two lines spaced 13.3cm apart. The axis of the specimen is carefully aligned with the axis of the loading device. The load is applied without shock and increasing continuously at a rate such that the extreme fibre stress increases at approximately 0.7kg/sq.cm/min that is at a rate of 180kg/min. The load is increased until the specimen fails, and the maximum load applied to the specimen during the test is recorded.

Flow Table Test For Mortar:

The test is conducted on mortar samples using flow table with a flow of 105 to 115 %.The top of the flow table shall be carefully wiped clean, dried and the flow mould shall be placed at the centre. A layer of mortar about 25 mm in thickness shall be placed in the mould and tamped 20 times with the tamping rod. The tamping pressure shall be just sufficient to ensure uniform filling of the mould. The mould shall then be filled to overflow with mortar and tamped, as specified for the first layer. The mortar shall be cut off plane and level with the top of the mould by drawing the straight edge of a trowel (held perpendicular to the mould) with a sawing motion across the top of the mould. The top of the table shall be wiped clean and dried, taking care to remove any water from around the edge of the flow mould. The mould shall then be lifted away from the mortar and the flow table shall be immediately dropped through a height of 12.5 mm, 25 times in 15 seconds.Trial mortars shall be made with specified proportion of dry ingredients and adding different percentages of water until the specified flow is obtained. Each trial shall be made with fresh mortars.The flow is the resulting increase in average base diameter of the mortar mass, measured on at least four diameters at approximately equal intervals expressed as a percentage of the original base diameter.

Results& Discussion:

Workability Results:

Table 6: Slump test results of four different quarries sand for M_{20} grade.

Sand-Quarry mix Proportion		Slump value in mm for four quarries sand			
Sand %	Quarry sand%	Washed I	Washed II	Unwashed I	Unwashed II
100	0	0	0	0	0
90	10	5	5	4	4
80	20	11	9	9	10
70	30	22	18	14	16
40	40	30	28	27	25

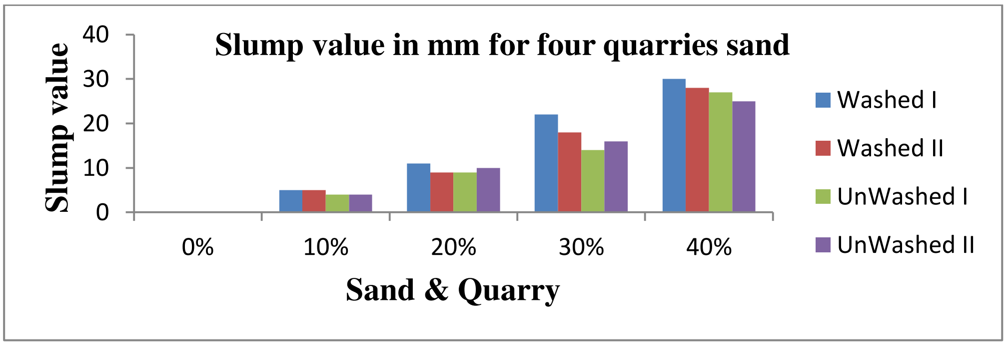

Fig. 1: Comparison of Slump value of Fresh Concrete of Four Quarries: river sand ratio for M20 grade

Table 7: Compaction factor of four quarries: river sand ratio for M_{20} grade

Sand-Quarry Mix Proportion		Compaction Factor For Four Quarries Sand			
Sand %	Quarry Sand%	Washed I	Washed II	Unwashed I	Unwashed II
100	0	0.92	0.92	0.92	0.92
90	10	0.80	0.77	0.78	0.79
80	20	0.79	0.81	0.80	0.81
70	30	0.83	0.82	0.85	0.84
40	40	0.87	0.88	0.86	0.86

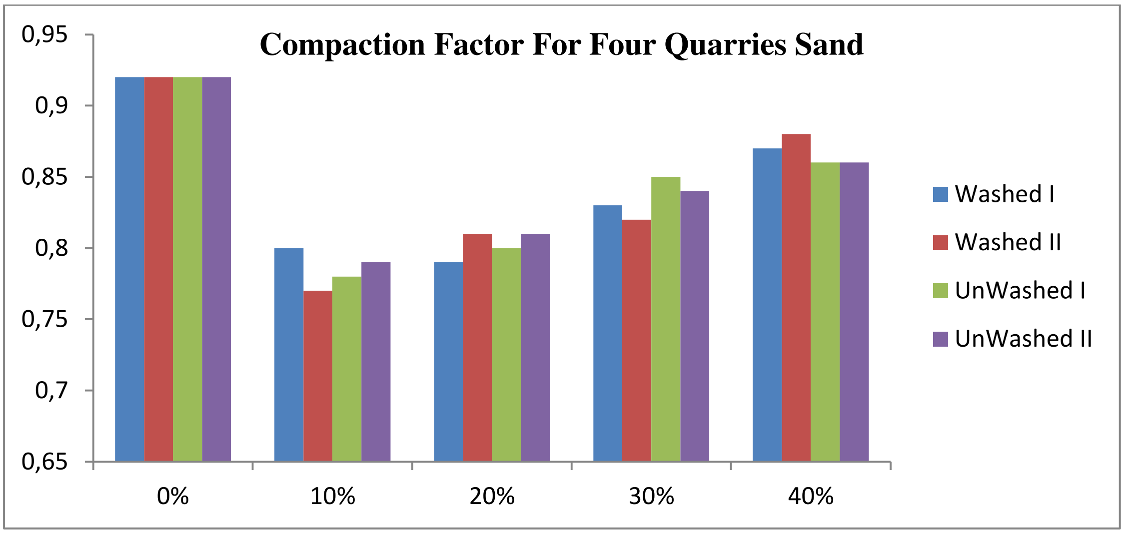

Fig. 2: Comparison of Compaction factor of Fresh Concrete of Four Quarries: river sand ratio for M20 grade

Strength-Related Test Results:

Compressive Strength Test Results:

Table 8: Compressive strength of M20 grade for Four Quarries: river sand ratio at 7th day

Sand-Quarry Mix Proportion		Compressive Strength Of 7th Day (N/Mm2) For Four Different Quarries Sand			
Sand %	Quarry Sand%	Washed I	Washed II	Unwashed I	Unwashed II
100	0	27.57	27.57	27.57	27.57
10	90	26.64	26.07	22.81	25.53
20	80	27.48	27.44	29.68	24.76
30	70	34.24	29.33	30.31	26.89
60	40	39.87	36.73	37.71	33.38

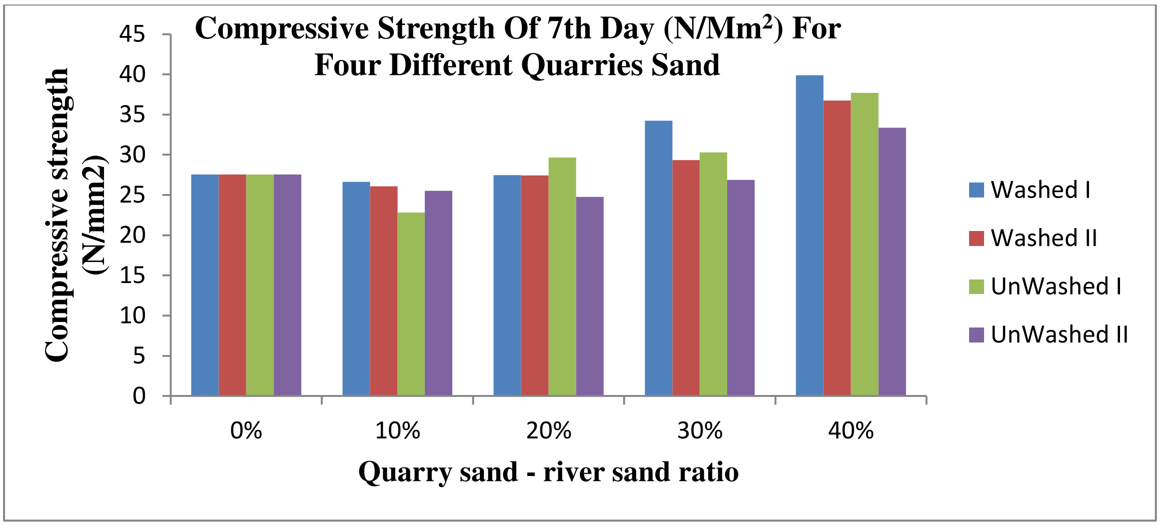

Fig. 3: Comparison of Compressive Strength of concrete of M20 gradefor Four Quarries: river sand ratio at 7th Day **Table 9:** Compressive strength of M20 grade for Quarrydust: River sand ratio at 28day

Sand-Quarry Mix Proportion		Compressive Strength Of 28th Days (N/Mm2) For Four Different Quarries Sand			
Sand %	Quarry Sand%	Washed I	Washed II	Unwashed I	Unwashed II
100	37.74	37.74	37.74	37.74	37.74
10	90	35.50	34.94	33.70	32.97
20	80	38.07	36.2	37.25	35.4
30	70	43.94	40.54	40.69	39.53
60	40	47.24	44.75	44.02	42.69

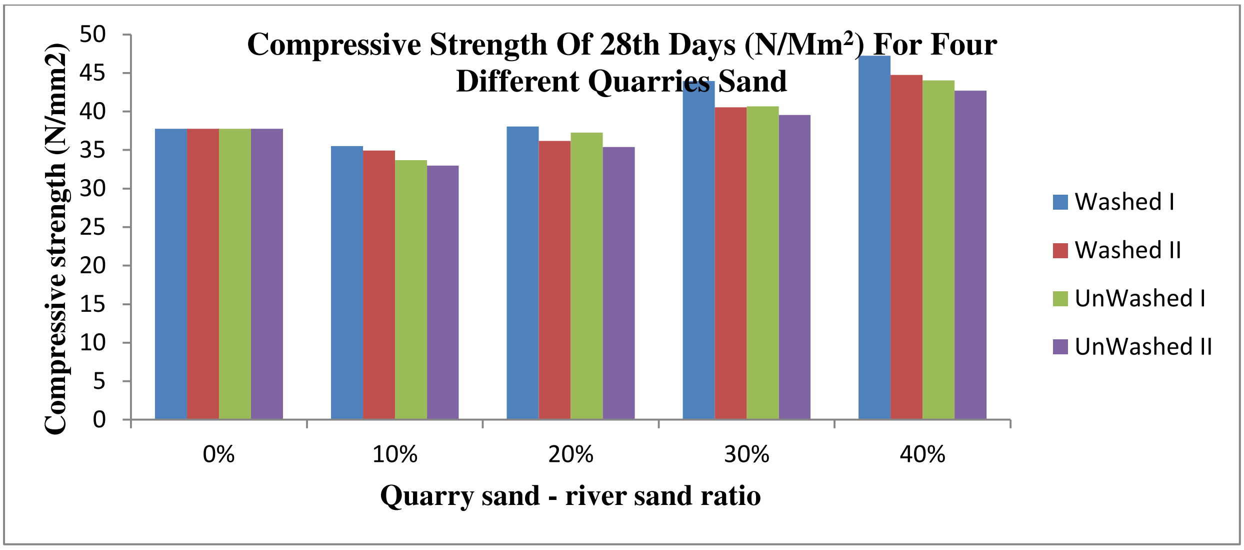

Fig 4: Comparison of Compressive strength of concrete of M20 grade for Four Quarries: river sand ratio at 28th day

Split Tensile Strength Test Results:

Table 10: Split tensile strength of M20 grade for Four Quarries: river sand ratio at 28thday

Sand-Quarry Mix Proportion		Split Tensile Strength Of 28th Days (N/Mm2) For Four Different Quarries Sand			
Sand %	Quarry Sand%	Washed I	Washed II	Unwashed I	Unwashed II
100	0	4.461	4.461	4.461	4.461
10	90	3.678	3.123	3.07	2.710
20	80	4.22	3.867	3.82	3.27
30	70	4.52	4.503	4.38	3.82
60	40	5.78	5.33	4.92	4.87

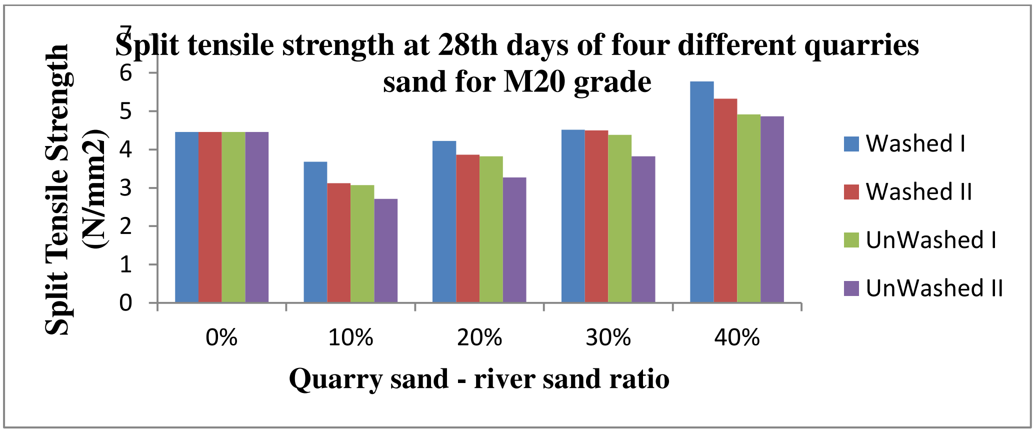

Fig 5: Comparison of Split Tensile Strength of concrete of M20 grade for Four Quarries: river sand ratio at 28th day

Flexural Strength Test Results:

Table 11: Flexural strength of M20 grade for Four Quarries: river sand ratio at 28thday

Sand-Quarry Mix Proportion		Flexural Strength Of 28th Days (N/Mm2)For Four Different Quarries Sand			
Sand %	Quarry Sand%	Washed I	Washed II	Unwashed I	Unwashed II
100	0	9.3	9.3	9.3	9.3
10	90	8.43	7.98	7.90	6.63
20	80	8.83	8.23	8.53	7.36
30	70	9.56	9.43	8.63	8.74
60	40	10.81	9.73	9.73	9.67

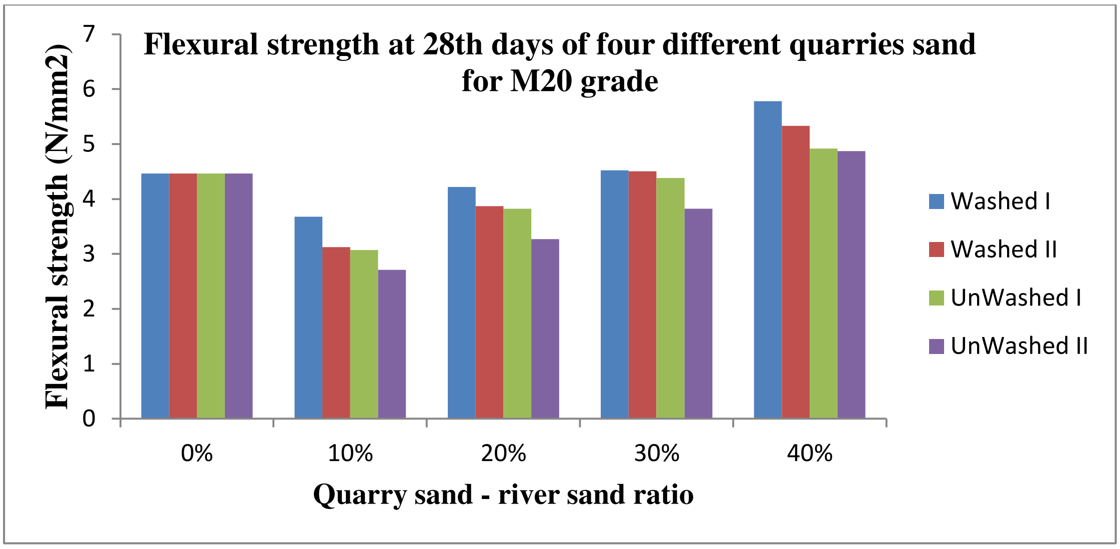

Fig 6: Comparison of Flexural Strength of concrete of M20 grade for Four Quarries: river sand ratio at 28th day

Young's Modulus Test Results:

Table 12: Young's modulus of M20 grade for Four Quarries: riversand ratio at 28day

Sand-Quarry Mix Proportion		Young's Modulus (N/mm2)For Four Different Quarries Sand X10^4			
Sand %	Quarry Sand%	Washed I	Washed II	Unwashed I	Unwashed II
100	0	2.68	2.68	2.68	2.68
10	90	2.29	2.23	1.98	1.97
20	80	2.83	2.79	2.62	2.67
30	70	3.57	3.61	3.42	3.50
60	40	3.97	3.93	3.78	3.67

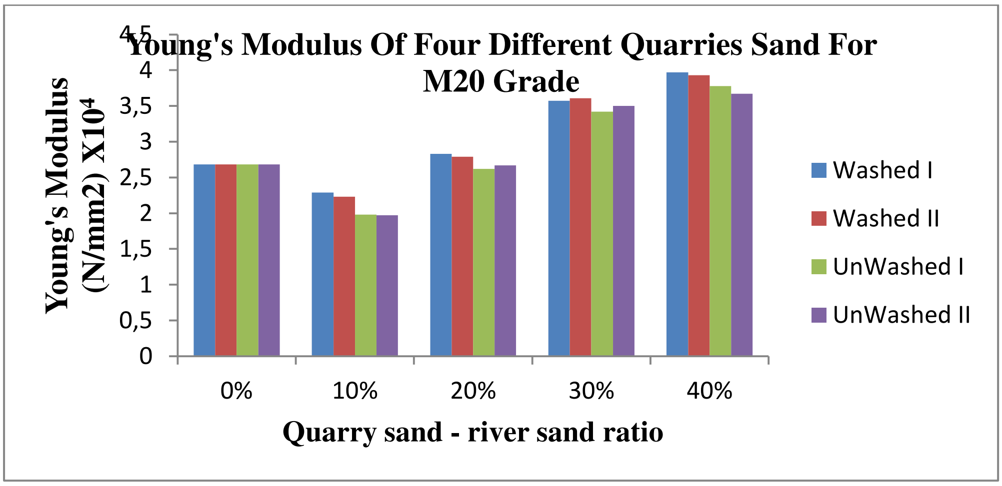

Fig 7: Comparison of Young's modulus of concrete of M20 grade for Four Quarries:river sand ratio at 28th

Discussion of Test Results:

Workabilityof Fresh Concrete:

The variation of workability of fresh concrete for various proportion mix of four different quarries sand with river sand is measured in terms of slump and compaction factor. Degree of workability for river sand and four different quarries sand were low and very low respectively as shown in table 1&2. While river sand proportion increased with four different quarries sand, the workability of slump value and compaction factor gradually increased. But, In 60:40 ratio (quarry sand: river sand) of concrete of four different quarries sand, the workability of slump and compaction were less compared to conventional concrete. The workability of washed quarry dust 1 is more comparing to quarry dust 2 because the finer particles present in quarry sand, so that the smaller the size of the aggregate, the high is the surface area and hence more amount of water is required for wetting the surface. Hence, unwashed sample is more influenced than washed sample. The workability of washed samples in fresh concrete is better than the that of unwashed samples, because the particles below 150 microns passed more than specified requirement percentage of passing (0-10%) as per zone II (IS 383-1970) in unwashed samples as shown in table 2. The workability results are plotted in the form of graph and are shown fig.1&2.

The quarry sand will almost have in angular shape, so contribution of good workability will be affected, because the frictional resistance between aggregates will be high. Thus the modern crushers are to be designed to yield well shaped and well graded aggregates.

Cube Compressive Strength of Concrete:

Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength.

The compressive strength of conventional concrete at 7th day is less compared to hundred percentage of four different quarries sand from the table. But the compressive strength of four different quarries sand as fully replaced at 28thdays are almost equal compared to conventional concrete.

The optimum ratio (quarry: river sand) of compressive strength of four different quarries sand at 28th days was found at 70:30 ratio. The overall strength at 70:30 ratio (quarry: river sand) reported 7.4 to 16 % increases compared to conventional concrete. The compressive strength of washed quarry dust of quarry1 is more than that of quarry 2.It was observed that the washed samples are high in strength compared to unwashed samples as shown in fig.3 and 4.

Split Tensile Strength Of Concrete:

The test results of split tensile strength for all sand are shown in table 10. The tensile strength of conventional concrete is high compared to that of four different quarries sand as fully replaced in concrete It is observed that the optimum replacement of river sand with quarries sand was observed to be 60:40 ratio (quarry: river sand). The results of tensile strength increased from 9.2% to 29.5% at 60:40 ratios in comparison with the conventional sand as shown in fig. 5.

Flexural Strength of Concrete:

From the test results as shown in table 11, the flexural strength of beams of four different quarries sand which were used as fully replaced in conjunction with cement , aggregate and water were less compared to that of river sand.

Flexural strength of washed samples was optimum at 70:30 ratio, but that of unwashed samples were less. At 60:40 ratio of four different quarries sand, the overall strength has increased as 4.3% to16 % of that of conventional concrete as shown in fig. 6.

Stress-Strain Curve and Young's Modulus of Concrete:

The stress- strain curve for all quarries sand and river were plotted in the form of graphs. The modulus of elasticity (Ec) for all sands were determined from the stress-strain curve and the results are presented in tables The variation of Ec at the age of 28 days with respect to ratio of quarry- river sand is shown in fig 7.

From the table 12, it is noted that the young's modulus (Ec) of concrete of four different quarries which were used as fully replaced were less in comparison with conventional concrete. The optimum ratio of young's modulus was obtained at 80:20(quarry: river sand) for washed samples, but for unwashed samples at 70:30 only. At 70:30 ratio for quarries sand with river sand, young's modulus of concrete is comparatively 27.6% to 34.7% more than that of similar mix of conventional concrete.

Conclusion:

The following conclusions are drawn from the present experimental investigation.

The workability of fresh concrete of four different quarries sand as fully or partially replaced with river sand which were low degree of workability were less compared to that of conventional concrete. But while percentage of river sand was increased with quarry sand, slump values and compaction factor gradually increased. The workability of washed quarry dust from quarry 1 gave better results than samples from other quarry

The compressive strength of the concrete increases with reduction in the quarry dust replacement .concrete Made of 20% replacementequals the compressive strength of concrete made of pure sand. The compressive strength of washed quarry dust from quarry 1 gave better results than samples from other quarry. Studies reported that At 70:30(quarry: river sand) ratio of four different quarries sand, the compressive strength, flexural strength, young's modulus of concrete and RC beams except the tensile strength of concrete have shown higher value than that of conventional concrete. But, at 60:40 ratio only, the tensile strengthachieved.

The Physical Properties of quarries sand have satisfied the requirements of code provision in properties studies.

It can be concluded that the replacement of natural sand with quarry dust, as partial replacement in concrete is possible Washed .Quarry dust from quarry1 has given better results due to the more SiO_2 and Fe_2O_3 and less amount of fines of size upto 150 microns. However, it is advisable to carry out trial casting with quarry sand proposed to be used, in order to arrive at the water content and mix proportion to suit the required workability levels and strength requirement. Also it is advisable to remove excess fines of size up to 150 microns by washing.

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