

Mechanical properties of Quarry Dust and Rice Husk Ash in Recycled Aggregate Concrete

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ABSTRACT

The properties of concrete made from partial replacement of sand with quarry dust and rice husk ash to cement and 100% replacement of recycled concrete aggregate to coarse aggregate studied experimentally in laboratory conditions in an attempt to propose an eco-friendly material concrete. The M25 grade (IS code 456-2000) of concrete considered as reference mix and suggested design mixes are obtaining from the partial replacement of its cement, sand and coarse aggregate proportions. The test specimens made from the proposed design mixes are of 150 mm x 150 mm x 150 mm cube for the compression, 100 mm x 300 mm cylinder for the tension, and 500 mm x 150 mm x 150 mm size of the beam for the flexural test prepared as per standards for the experimental study. The workability of the trial mixes also studied due to the addition of fine particles such as quarry dust and rice husk ash. The results revealed that the strength increased significantly in compression, tension and flexure at an optimum mix proportion (M-15).

Keywords: Recycled Aggregate, Quarry Dust, Rice Husk Ash, Mechanical properties

1 INTRODUCTION

1.1 Recycled concrete aggregate

The limited availability of natural aggregates such as gravel and river sand in the concrete production poses a great concern in the construction industry. It tends to find alternate materials and increased need to reduce, reuse and recycle the concrete. The old and deteriorated concrete structures needed to demolished by time to time, which results in huge amounts of construction waste that becoming a problem to environment pollution [1]. The depletion of natural raw materials poses the severe question of concrete production [2]. It is vital to find alternate construction materials to overcome the above-stated problem. The alternatives materials suggested should be cost-effective, and their use in concrete production should reduce their disposal problem simultaneously. The majority of concrete is made of aggregates, so the utilization of 'recycled concrete aggregates' (RCA) as a replacement to the natural coarse aggregate is extremely encouraging [1]. An alternative aggregate for structural concrete made up of recycled demolished concrete is a viable solution to the problems as mentioned earlier [1]. The demolition building sites are causing large quantities of crushed concrete waste, which are presently representing a significant issue of discarding them in urban regions [3]; without much

of a stretch be reused as aggregate and utilized as a part of the concrete. The quest for the possible alternative material is inevitable to avoid increased construction cost and the decrease in usage of natural materials. It, therefore, requires the study in the connection between crushing strength; splitting strength and modulus of rupture to achieve the optimal mix proportioning for the effective use of aggregates from the recycled concrete [4].

1.2 Quarry Dust (QD) and Rice Husk Ash (RHA)

Stone quarry dust is a waste from quarries and used as an alternative to river sand and the environmental impact also cut back by using it [5]. Pozzolanic materials used as a replacement for cement in varying proportions. Industrial wastes like Rice husk ash, fly ash, and silica fume all have the combined benefit of being pozzolanic that would otherwise destined as landfill. RHA is accountable for its high pozzolanic reactivity because of the non-crystalline silica and high specific plane area. The experimental work for this study includes the analyze the properties of materials used, mix proportion for the concrete, fresh concrete properties, and hardened concrete properties. Concrete properties investigated with the replacement of natural-fine aggregate with quarry dust partially and cement with rice husk ash, along with ‘recycled concrete aggregate.’ In this study, cement replaced with RHA in 5%, 10%, 15%, 20% and the ‘fine aggregate’ was replaced with quarry dust at 10% to 50%. The ‘compressive strength’ was recorded at 7, 14 and 28 days and the tensile strength defined only at 28th day.

2 MATERIALS USED

‘OPC’ of 53 grade and natural river sand of specific gravity 3.15 and 2.54 used respectively for the experiment. RCA obtained from crushed concrete from the demolition waste of a building in the nearby locality used. The water absorption property of ‘recycled concrete aggregate’ is high so that it is necessary to saturate it to attain required workability in case if no water reducing agent is added [1]. In this investigation, recycled aggregates are saturated in water for 12 hours and kept in surface dry condition before using it in the concrete to avoid the adding excess quantity of water, since its water absorption is 5%. Use of ‘recycled aggregates’ in SSD condition gives good workability [7]. Quarry dust procured, and the specific gravity, bulk density, water absorption values inspected and for the experiment.

2.1 Properties of materials used

The specific gravity of cement and aggregate tested, according to IS 4031(Part 11):1988 and IS 2386(Part 3):1963 respectively. The mortar content adhered with the recycled aggregate makes it porous, non-homogeneous and loss in density [8,9,10,11]. Depending on the size of the recycled

aggregate the residuals of mortar adhered varies from twenty-five to sixty percent [12]. Poon et al. [13] examined that recycle aggregate consists of the natural coarse and fine aggregate of 60-65% and 30-35% of cement by volume. The mortar adhered is attributed to high water absorption [14,15,16], and also the pores in RA soak up more water [17]. The water absorption may range up to 12% that is 2 to 3 times higher than the natural aggregate. [9,10,13,18]. The absorption of water limit over 7% and 13% of coarse RA and fine aggregate respectively are not desirable to be used the mechanical properties compared to natural aggregate [20,21,22,23] are substandard. The properties of the various material's specific gravity, bulk density, and water absorption values tabulated in table 1. The residue percent from aggregate crushing strength test value should not exceed 45% according to Indian standard codes for the concrete production. In this study, residue percentage of 18.63% for natural coarse aggregate and 25% for RCA used.

Table-1: Properties of Material

SL.NO	MATERIAL	SPECIFIC GRAVITY	BULK DENSITY (Kg/m ³)	WATER ABSORPTION (%)
1	NCA	2.62	1510	1%
2	RCA	2.56	1451	5%
3	Sand	2.54	1460	1%
4	Quarry dust	2.52	1720	4%
5	Cement	3.15	-	-
6	Rice husk ash	2.06	-	-

*(NCA-Natural coarse aggregate, RCA-Recycled concrete aggregate)

Rice Husk is the waste product generated from the rice mills, and that husk can be burnt to produce rice husk ash. The roots, anchored the rice plant in the soil and absorbed silica from it and assimilates to its structure of the plant during the growth [24]. RHA is available as a waste material in the developing countries and it is composed of nanocrystalline silicon dioxide (SiO₂) with the high specific surface area and high pozzolanic reactivity [25]. Commercially available rice husk ash and its physical and chemical properties listed in table 2.

Table-2: Physical and Chemical properties of RHA

SL.NO	PARAMETERS	VALUES
1	Fineness passing 45 micron	96%

2	Specific gravity	2.06
3	Silicon dioxide (SiO ₂)	80.20%
4	Aluminum oxide (AlO)	7.15%
5	Ferric oxide (Fe ₂ O ₃)	0.16%
6	Calcium oxide (CaO)	0.55%
7	Magnesium oxide (MgO)	0.35%
8	Sulphur trioxide (SO ₃)	0.24%
9	Pozzolanic activity	84%

3. METHODOLOGY

The concrete mix design calculations proposed in (IS-10262:2009) referred to design the concrete mixes using quarry dust and rice husk ash for all the replacement levels. The reference mix prepared for the M25 grade with 'OPC 53' cement, natural fine aggregates and coarse aggregates (20mm size). The mix design proportion is 1:1.53:2.47 and having, 433 kg/m³ cement, 186 kg/m³ water as 0.43 water-cement ratio, 663 kg/m³ natural fine aggregate and 1070 kg/m³ coarse aggregate. The various replacement levels for other mixes made by replacing sand with quarry dust from 10-50% and cement with rice husk ash from 5-20% along with 100% completely replacing the 'natural coarse aggregate' with 'recycled concrete aggregates' in SSD condition. Cube and cylinder specimens casted for the M25 grade with natural coarse aggregate, sand, and cement, and named as reference mix. Recycled aggregate, which is collected from a demolished building, used as coarse aggregate for the entire experiment in SSD condition. The following specimens were casted in 21 different mixes, namely M1-M21 and are tabulated in table 3, for each mix 6 cubes of 150 mm size were tested for crushing strength, 3 cylinders of size 150 mm x 300 mm were tested for splitting strength and 3 beams of size 500 mm x 100 mm x 100 mm were tested for flexure. The cubes tested at every 7th day, 14th day and 28th day for compressive strength test and the average value of the specimens were considered. The tensile strength test carried out for three cylinders of each type of mix after the 28th day, and the average value has determined as its tensile strength. Ironically flexural strength test carried out only for three beams of one particular mix type, which it has gained maximum compression value.

Table-3: Mix proportions

Mix ID	NCA	RCA	FINE AGGREGATE	QUARRY DUST	CEMENT	RHA	CUBES	CYLINDER S
M1	100	-	100	-	100	-	6	3
M2		100	90	10	95	5	6	3
M3		100	80	20	95	5	6	3
M4		100	70	30	95	5	6	3
M5		100	60	40	95	5	6	3
M6		100	50	50	95	5	6	3
M7		100	40	60	95	5	6	3
M8		100	90	10	90	10	6	3
M9		100	80	20	90	10	6	3
M10		100	70	30	90	10	6	3
M11		100	60	40	90	10	6	3
M12		100	50	50	90	10	6	3
M13		100	40	60	90	10	6	3
M14		100	90	10	85	15	6	3
M15		100	80	20	85	15	6	3
M16		100	70	30	85	15	6	3
M17		100	60	40	85	15	6	3
M18		100	50	50	85	15	6	3
M19		100	40	60	85	15	6	3
M20		100	90	10	80	20	6	3
M21		100	80	20	80	20	6	3

4. RESULTS AND DISCUSSIONS

4.1 Workability

Slump test (IS: 1199 - 1959) properties of the fresh concrete influenced by water-cement ratio, constituent materials of concrete, type, size, shape, texture and water absorption of aggregate. Due to porous nature of recycled aggregate, more water needed to obtain the desired workability [28]. Pre-soaked aggregates are used to balance the low water-cement ratio [29]. The slump test

values of 21 trial mix are tabulated in table 4. Workability of concrete reduces accordingly when the replacement level of quarry dust and RHA increases. When workability of concrete becomes too low, concrete becomes difficult to compact, and there is no sufficient water for the process of hydration.

Table-4: Slump test values of M1-M21 mixes

SL.NO	TYPE OF MIX	SLUMP(mm)
1	M1	21
2	M2	21
3	M3	18
4	M4	15
5	M5	10
6	M6	5
7	M7	21
8	M8	17
9	M9	13
10	M10	10
11	M11	4
12	M12	18
13	M13	14
14	M14	10
15	M15	7
16	M16	0
17	M17	15
18	M18	11
19	M19	7
20	M20	4
21	M21	0

4.2 Compressive strength

The specimens were tested at every 7th, 14th, and 28th days. The compressive strength results of this study are depicted in figures 1, 2 & 3 respectively. The increase in replacement of RA with

same w/c ratio greatly influences the compressive strength of concrete [33,34]. It is observed that when 40% of fine aggregate is replaced with quarry dust, there is an increase in compressive strength compared to other mixes. Various experiments reported that the compressive strength is reduced up to 30% when replacing 100% of natural aggregates with 'RA' [12,14,35,32,36,37]. There were no such prominent changes in compressive strength when replacement took place up to 30%. [34,37,39]. In another study, it was accounted that the crushing property of RAC changes due to the bond of cement in the recycled aggregate [38].

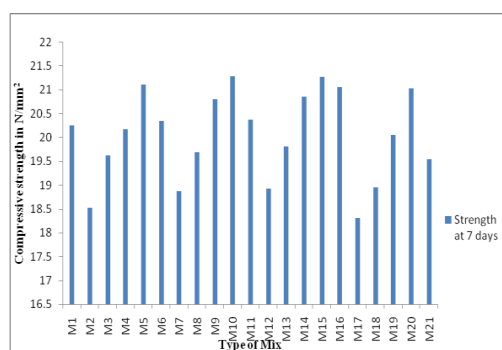


Fig.-1

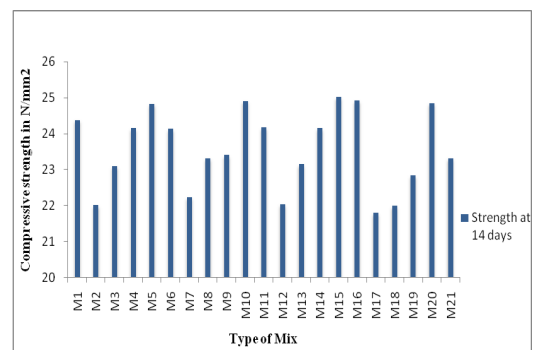
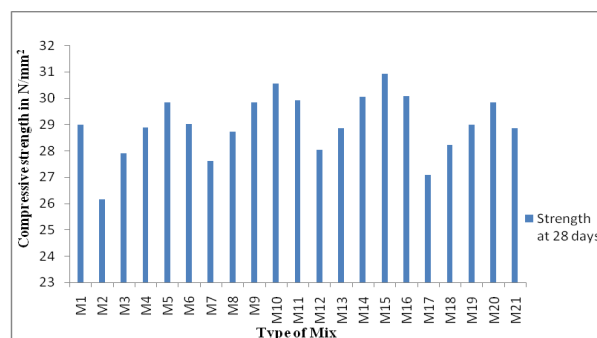


Fig-2

Compressive strength of all mixes at 7th day

Compressive strength of all mixes at 14th day

Fig.-3 Compressive strength of all mixes at 28th day

Hence samples M5, M10, M15 and M20 shows higher compressive strength after 7, 14 and 28 days compressive strength test. As the percentage of quarry dust increases up to 40% the strength increases for all replacement levels of RHA (5%, 10%, 15%, 20%). Also, it is noted that as the percentage of RHA increases up to 15% the strength also increases. The increase in

strength is due to the reduction in workability of concrete and accordingly the replacement level of quarry dust and RHA increases. The fineness of RHA is a valuable property for the strength of blended concrete. The fine particle size of RHA mixed with concrete produces higher strength than that of control mix. At 50% replacement level of quarry dust, and at 20% replacement level of RHA the strength started decreasing, the reduction in strength is due to the workability of concrete becomes too low.

4.3 Tensile strength

The replacement level of recycled aggregates influences the tensile strength [40,41]. The change in tensile strength due to uneven surface of recycled aggregates which offers the bonding [42]. The graph shows the results of tensile strength of trial mixes at 28th day in figure 4. It is found that there is a remarkable variation in the tensile strength of samples of mixes - M5, M10, M15, and M20 where the increased percentage fine aggregate is replaced with quarry dust.

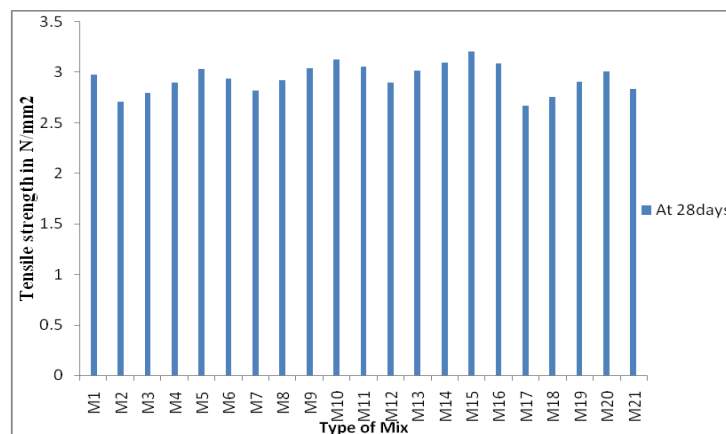


Fig.-4 Tensile strength of all mixes at 28th day

4.4 Flexural strength

Flexural strength (IS 516 – 1959) is a measure of resistance of a concrete beam or slab without any reinforcement. The maximum strength is obtained from the mix ratio M1, M5, M10, M15, and M20 and these mix ratios are considered as the optimum mixes and these mix ratios are taken for the casting of flexural strength specimens. The bar chart showing the flexural strength of trial mixes at 28th day is depicted in figure 5.

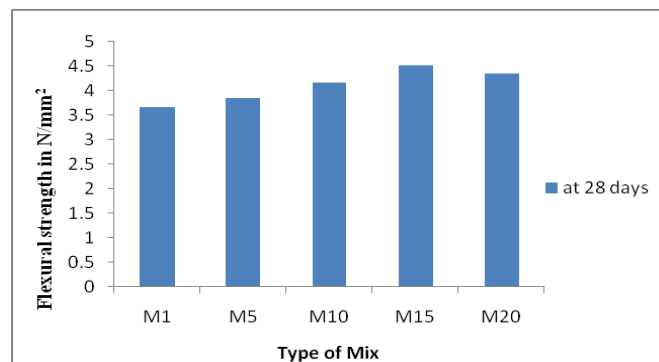


Fig. 5: Flexural strength at 28th day

4.5 Comparison of compressive strength results

The increase or decrease in percentage of compressive strength of M2-M21 to Mix M1 is compared in table 5. It is observed that amongst all the highest positive increment variation can be seen in M10 and M15.

Table-5: Percentage increase/decrease in compressive strength after 28 days

Nominal Mix	Other mixes	Increase/Decrease in strength (%)
Mix M1	M2	-9.76
	M3	-3.75
	M4	-0.31
	M5	+3
	M6	+0.1
	M7	-4.72
	M8	-0.89
	M9	+3.55
	M10	+5.45
	M11	+3.2
	M12	-3.27
	M13	-0.37
	M14	+3.65
	M15	+6.76
	M16	+3.82

	M17	-6.51
	M18	-2.65
	M19	+0.03
	M20	+3
	M21	-0.37

4.6 Comparison of tensile strength results

The table 6 shows the percentage of increase or decrease in tensile strength of the mixes after 28days of curing with respect to Mix M1. By comparing all the mixes Mix M10 shows that the percentage increment in tensile strength is about 5%, whereas M15 shows the astounding percentage of increment in tensile strength which is 7% when contrasted to conventional concrete strength M1.

Table-6: Percentage increase/decrease in tensile strength after 28 days

Nominal Mix	Other mixes	Increase/Decrease in strength (%)
Mix M1	M2	-9.06
	M3	-6.04
	M4	-2.34
	M5	+1.67
	M6	-1.34
	M7	-5.36
	M8	-2.01
	M9	+2.01
	M10	+5.03
	M11	+2.68
	M12	-0.26
	M13	+1.34
	M14	+4.02
	M15	+7.71
	M16	+3.69

	M17	-10.4
	M18	-7.38
	M19	-2.34
	M20	+1.00
	M21	-4.69

4.3 Comparison of flexural strength results

The table 7 shows the percentage increase or decrease in tensile strength of the mixes after 28days of curing with respect to Mix M1. By comparing the results of flexural strength M15 shows the highest percentage of increase in strength when compared to conventional concrete strength (M1).

Table-7: Percentage increase/decrease in tensile strength after 28 days

Nominal Mix	Other mixes	Increase/Decrease in strength (%)
Mix M1	M5	+4.64
	M10	+13.66
	M15	+22.95
	M20	+18.30

5 CONCLUSIONS

The experimental study shows that,

- The workability of fresh concrete decreases as the percentage of replacement of quarry dust and rice husk ash increases due to changes in the fineness properties of the aggregates.
- Mix15 shows the highest compressive, tensile and flexural strength as considered as the optimum proportion of this study.
- The compressive strength of reference mix, M1 is 28.99 N/mm^2 , whereas the strength of Mix 15 is 30.95 N/mm^2 , which is 6.76% more than the conventional concrete strength.
- The tensile strength of reference mix, M1 is 2.98 N/mm^2 , whereas the tensile strength of

M15 is 3.22 N/mm², which is 7.71% more than the conventional concrete.

- The flexural strength of the mix M15 is 22.95% more than the conventional concrete strength.
- The optimum percentage of quarry dust and rice husk ash is 20% and 15% respectively.
- The cost of quarry dust is much cheaper than the sand and recycled aggregates are readily available in India. This leads to considerable savings in cost of construction and considering RHA as a partial replacement of cement reduces the consumption of cement and CO₂ emissions and gives environmental benefits.

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