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Effect of Fine Aggregate Type on Workability and Compressive Strength of Recycled Aggregate Concrete

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ABSTRACT

The ever-increasing need of infrastructure around the globe gave rise to consumption of concrete ingredients at faster pace and generates huge quantum of the construction and demolishing waste. Both factors are serious problem to environment and waste management. Therefore, this research article presents the laboratory investigation on the effect of type of fine aggregates in recycled aggregate concrete prepared with recycled aggregates from demolished concrete. It will not only reduce the waste management to some extent, help in preserving the environment, avoid health problems of inhabitants, but also help in preserving the conventional sources of aggregates. Three types of fine aggregates, i.e. river sand, pit sand and hill sand are used. The concrete using 1:2:4 mix and 0.5 water cement ratio is designed in two groups. First group used only conventional aggregates whereas, in second group 50% recycled aggregates from demolished concrete are used. In each group three batches using river sand, pit sand and hill sand are used. Slump test of each batch is conducted. In each batch 5 cylinders of standard size are prepared, cured for 28-days and tested for compressive strength. Obtained results showed better performance of conventional concrete with river sand but the induction of recycled aggregates affected both workability and compressive strength. The workability of recycled aggregate concrete with river sand was better (-14%) compared to concrete with hill sand (-20%). However, slump values for all batches remained within limits specified for normal concrete. Use of hill sand in recycled aggregate concrete showed better performance in terms of compressive strength as the residual compressive strength was recorded equal to 86% in comparison to conventional concrete with river sand.

Keywords: Recycled aggregate concrete, workability, compressive strength, type of sand, fine aggregates, demolishing waste, green concrete.

1. INTRODUCTION

With time humans have witnessed drastic changes in residential and associated infrastructures from caves to sky scrappers. Modern day development has contributed a lot towards the socioeconomic development of the regions but few drawbacks are also augmented with it. Out of which consumption of conventional sources, running of industries to meet the requirement and waste generation are only few among the long list. Waste generation due to infrastructure development is mainly due to non-availability of space which force the industry to demolish in old deteriorated or short height structures to make room for new vertically tall structures. This waste was dumped in landfills earlier but the space problem has now made it a serious problem around the globe. Proper disposal of it requires additional measures resulting in financial burden on the project. Therefore, reuse of it in new concrete has got wide acceptance of the concerned around the globe and the research on the topic is active area among the scholars. The concrete utilizing this waste in one or other form is termed as green concrete and contribute towards the eco-friendly sustainable development. As coarse aggregates occupy maximum volume of the body of concrete therefore, most of attempts of reuse of the demolishing waste are in the form of coarse aggregates as partial or full replacement of conventional coarse aggregates.

Among the main ingredients of concrete fine aggregates play an important role as filler between the gaps of coarse aggregates. Three conventional forms of it are widely used. Also, various forms of recycled waste have been attempted in concrete. No matter it is conventional concrete or concrete made by using other ingredients its workability and strength are the key parameters to be ensured for proper durability and serviceability. Properties of aggregates and methods of proportioning affect both of these parameters. Another issue in the field is the availability of good quality fine aggregates in the vicinity of the project. In many cases it is observed that agreed upon / recommended type of fine aggregate need to be transported from far distances resulting in additional financial burden on the project. Whereas, other type of fine aggregate may be available in the region. Commonly used fine aggregates are hill sand, river sand and pit sand. Each type has different effect on the workability and final strength of conventional concrete. If used in recycled aggregate concrete definitely different type of fine aggregate will have different effect on the parameters. Therefore, this experimental study proposes to check the effect of type of fine aggregates on workability and strength of concrete utilizing demolishing waste as coarse aggregates. The associated properties of fine and recycled aggregates will also be evaluated before evaluating workability and strength. It is anticipated that the outcome of the work will give clear understanding of the behavior of recycled aggregate concrete using different types of fine aggregates.

2. LITERATURE REVIEW

The reuse of demolishing waste in new concrete has got attention of the scholars since couple of decades. Good number of researches focusing the issues associated with the aggregates, their impact on fresh and hardened properties of concrete have been published around the world. Yet the confidence level of the concerned industries is not the mark where the matter may be streamlined. Similar argument is made in a review paper[1] published on the topic. The research on recent developments on the use of the waste highlights the issues associated with the aggregates and their impact. It concludes with the argument that proper implementation of rules and regulation in processing and reuse of the aggregates is highly important to streamline the matter at mass scale. The replacement of conventional aggregates with quartzite, granite and river gravel along with pit sand have also been attempted. The workability of normal concrete mix showed better results for river gravel whereas, the quartzite remained better than granite aggregates. On the other hand, compressive strength of cubes cured at various curing agrees showed highest results with quartzite aggregates. The river gravel was last in the series of aggregates[2.] Towards the durability of recycled aggregates concrete Ismail and Ramili3 investigated the effect of single and hybrid fiber system. The authors also used treated recycled aggregates. The treatment of aggregates by soaking them in hydrochloric acid followed by impregnation in wollastonite solution showed improved results towards energy absorption and impact resistance. The authors also recorded adaptive increase due to the use of fibers. It has been evident from the literature that dosage of recycled aggregate has significant impact on the strength of final product. To this end Naouaoui et. al.4 reports 50% replacement level as optimum and more better if 20% pozzolana is used as cement replacement. In another attempt Ogar5 suggest 100% replacement but if early strength of the concrete is desired. On the same issue Kim et. al.6 suggest use of recycled aggregates from prestressed concrete waste for better compressive strength. This clearly demonstrates that the non-uniformity of the findings is one of the hurdles in broader use of the material.

Waste materials are not only used as coarse aggregates but have also been attempted as fine aggregates. Use of marble dust is reported effective for improvement of the compressive strength of concrete cured up to 90 days7. Using coarse grained fine aggregates up to 5 mm with dolomite and steel fibers can improves the strength of concrete up to 150MPa for 56 day cured specimens[8]. Ismail et. al.9 through their research program also report that proper gradation of sand can improve the compressive strength to much extent. The authors through their research findings argue that increase in fineness modulus improves the compressive strength. In another attempt of studying compressive strength of concrete with light weight aggregates from bottom ash Islam et. al.[10] observed that density is the key parameter to ensure proper compressive strength. It is mainly attributed with effect of sand content.

Workability of concrete play important role in strength of concrete. Among several factors water-cement ratio is one of the parameters which affect the workability. On the contrary higher water absorption of the aggregates disturb the water cement ratio. The effect should be addressed properly in concrete mix design to avoid degradation of the workability. Silt, clay, organic impurities[9] and sand fines[12] are the factors which disturbs the water-cement ratio of the mix. Yalley and Sam[12] based on their research findings reports that increase in sand fines reduces the workability of concrete. They found 4% sand fines a limit beyond which workability of concrete get affected. Reduction in workability and strength with increase in recycled fine aggregates is also reported by Kumar et. al.[13] however, the authors suggest improvement by using metakaolin upto 13%. Sand to aggregate ratio is another parameter which influence the workability of concrete therefore based on the research findings Simarso et. al.14 developed set of coefficients to address the issue with respect to workability of concrete.

Several other studies report use of waste products as replacement of the ingredients of concrete for example demolishing waste as replacement of fine and coarse aggregates[15], local sand[16], metallurgical sludge waste as coarse aggregates[17], improved recycled aggregates by removing impurities using air blower[18]. From the above discussion it may be observed that either the literature is silent or least work is devoted on studying the effect of type of sand on workability and compressive strength of concrete made with recycled aggregates from demolishing waste. This motivates the proposed research. It will not only use the demolishing waste in new concrete but also provide clear understanding on the use of different types of fine aggregates. Thus will provide an option for the user to opt the type of sand available in the region.

3. MATERIAL AND TESTING

This section briefly describes the materials used for the proposed work along with the tests conducted for the materials and concrete produced using the materials.

3.1 Cement

In this research work ordinary Portland cement being sold under brand name Lucky cement is used. It was obtained from local market (Figure 1). It was grey in color. The basic properties of the cement were evaluated in accordance with relevant ASTM standards. The obtained results are listed in Table 1.

Table 1: Properties of cement

#	Property	Value
1	Fineness (%)	97
2	Specific gravity (g/cm^3)	3.11
3	Initial setting time (min)	62
4	Final setting time (min)	282
5	Consistency (%)	31
6	Loss on ignition (%)	0.9

3.2 Fine aggregates

The fine aggregates in concrete matrix plays important role of filling the voids between coarse aggregates. It also contributes towards the strength of the product. Type, size, and quality of the aggregates thus plays vital role towards the durability and serviceability of the concrete. The main aim of this research work is to check the effect of different types of fine aggregates on the workability and compressive strength of recycled aggregates concrete. Therefore, three different types of fine aggregates, i.e. river sand, pit sand, and hill sand are used in this work. All three types of the aggregates were obtained from the locality (Figure 2). Basic properties of the aggregates were evaluated following the relevant ASTM standards. Sieve analysis of the aggregates was also done. The obtained results for the properties of the aggregates are listed in Table 2, whereas the percentage passing of the aggregates on various sieves during sieve analysis are tabulated in Table 3.

Table 2: Properties of fine aggregates

#	Property	River sand	Pit sand	Hill sand
1	Water absorption (%)	1.34	1.72	1.01
2	Specific gravity (g/cm^3)	2.63	2.61	2.64
3	Bulk density (kg/m^3)	1592	1871	1905
4	Moisture content (%)	16.3	11.5	5.2
5	Fineness modulus	2.26	2.38	3.41

Table 3: Properties of fine aggregates

Sieve	Opening (mm)	% Passing			ASTM Range
		River Sand	Pit Sand	Hill Sand	
#4	4.75	100.00	100.00	100.00	95 – 100
#8	2.36	96.47	95.93	97.73	80 – 100
#16	1.18	88.10	83.13	81.65	50 – 85
#30	0.6	58.90	56.57	54.30	25 – 60
#50	0.297	24.33	19.13	19.73	10 – 30
#100	0.149	5.97	6.93	5.70	5 – 30
#200	0.075	0.33	0.13	0.10	0 – 10

Figure 1: Cement

Figure 2: Fine aggregates

3.3 Coarse aggregates

In this experimental program conventional coarse aggregates used were obtained from local market. The maximum size of the aggregates was 1-inch (25 mm). For recycled aggregates, old demolished concrete in shape of large blocks (Figure 3) was obtained from demolishing of reinforced concrete building in the vicinity. The large blocks were brought to the laboratory. There, the blocks were reduced by hammering to maximum of same size as of conventional coarse aggregate (Figure 4). The obtained aggregates were then sorted for unwanted substance, impurities, and cracked particles. Thereafter, the aggregates (conventional and recycled) were washed with potable water and left to air dry in laboratory. Basic properties of the aggregates, viz. water absorption, specific gravity, density, surface texture, angularity, soundness, impact value, crushing value, and loss on ignition were determined in accordance with the relevant ASTM standards. Obtained results of the properties are listed in Table 4.

The aggregates were also sieved to make sure that well graded aggregates are used in concrete. This is typically necessary from strength and durability point of view. The passing percentage of the aggregates is listed in table 5. The fineness modulus of the conventional and recycled aggregates was evaluated equal to 5.25 and 6.93 respectively.

Table 4: Properties of coarse aggregates

#	Property	Conventional Aggregates	Recycled Aggregates	% change
1	Water absorption (%)	1.03	3.12	+202.91
2	Specific gravity (g/cm^3)	2.61	2.17	-16.86
3	Density (kg/m^3)	2110	1562	-25.97
4	Surface texture	Fairly smooth	Rough	-
5	Angularity	Angular	Angular	-
6	Soundness	3.92	7.28	+85.71
7	Impact value	12.6	31.7	+151.59
8	Crushing value	22.1	34.6	+56.56
9	Loss on ignition	0.92	3.15	+242.39
10	Fineness modulus	5.25	6.93	+32.00

Table 5: Sieve analysis of coarse aggregates

Sieve (mm)	Sieve	Passing (%)	
		CA	RCA
37.50	1 1/2in	100.00	100.00
25.00	1in	97.83	96.94
19.00	3/4in	49.32	52.47
12.50	1/2in	21.45	22.47
9.50	3/8in	5.49	2.00
4.75	# 4	0.81	0.21
2.36	# 8	0.34	0.21
Pan		0.00	0.00

Figure 3: Demolished waste

Figure 4: Recycled coarse aggregates

3.5 Concrete mix

To accomplish the proposed work concrete mix is designed using six batches in two groups. In first group all conventional aggregates are employed in the concrete whereas, in second group equal dosage of conventional and recycled aggregates (50% each) is used. The dosage of recycled aggregates is adopted following the recommendations of Oad and Memon [19]. In three batches of both groups' river sand, pit sand and hill sand are used in turn. Table 6 gives details of all the batches adopted in this work. 1:2:4 ratio of concrete ingredients with water cement ratio of 0.5 is adopted for all mixes. The mix ratio is selected due to its maximum used in the construction industry. Normally 0.45 w/c ratio is adopted for concrete mix adopted but this work adopted 0.5 as water cement ratio considering the higher water requirement of the recycled aggregates. Batching of the ingredients is done by weight batching followed by the mixing of the ingredients in concrete mix till uniform paste is made.

Table 6: Details of concrete mixes

#	Batch	Cement	Fine aggregates	CA (%)	RCA (%)	Mix ratio	w/c ratio	Number of cylinders
1	B1	OPC	Hill sand	100	0	1:2:4	0.5	5
2	B2		River sand	100	0			5
3	B3		Pit sand	100	0			5
4	B4		Hill sand	50	50			5
5	B5		River sand	50	50			5
6	B6		Pit sand	50	50			5

3.6 Slump test

Workability of each mix in turn was determined by slump test. The filling, removal and measurement of the cone was done in standard way. Selected test is shown in figure 5. Obtained results of slump are listed in Table 7.

Table 7: Slump values

#	Group	RCA (%)	River sand (mm)	Pit sand (mm)	Hill sand (mm)
1	G1	0	49	46	44
2	G2	50	42	37	35

Figure 5: Slump test

Figure 6: Concrete specimens

3.7 Compressive strength

For determination of compressive strength altogether 30 concrete cylinders of standard size (6"/12") were cast by first oiling the inner surface of the molds then filling of concrete was done in three layers. The compaction of the specimens was done by table vibrator in standard fashion. The specimens of all six batches in two groups were prepared as per details mentioned earlier. After a day the specimens were demoulded (Figure 6) and left to air dry for 24-hours. There after all the specimens were fully immersed in potable water for curing (Figure 7) of 28-days.

At the completion of curing age, specimens were taken out of water, wiped with clean cloth and allowed to air dry in laboratory for 24-hours. Then, in turn all the specimens were tested in universal load testing machine for crushing load. The load was applied on the specimens gradually at the rate of 500 N/sec. Crushing load was recorded and converted in compressive strength using usual notation given by ASTM C39 [20]. Obtained results of compressive strength of all specimens is listed in Table 8.

Figure 7: Curing

Figure 8: Specimen testing

Table 8: Compressive strength

Group	RCA (%)	Specimen Number	Concrete with River sand (MPa)	Concrete with Pit sand (MPa)	Concrete with Hill sand (MPa)
G1	0	1	24.25	21.17	23.24
		2	24.73	21.53	22.95
		3	25.12	20.36	23.41
		4	24.18	21.78	23.52
		5	24.82	21.56	22.82
G2	50	1	19.84	17.13	19.75
		2	19.93	17.52	20.11
		3	19.22	17.36	19.94
		4	18.71	18.11	19.85
		5	19.65	17.33	20.22

4. RESULTS AND DISCUSSION

4.1 Basic properties and sieve analysis

From the basic properties of the ingredients of concrete evaluated and presented earlier it may be observed that the cement confirms to the requirement of relevant ASTM standard. The properties of fine aggregates show minor deviation with each other. Considering river sand as control aggregates, water absorption of pit and hill sand was +24% and -25% respectively. In need it is due to the water wash of the river sand in water bed, whereas pit sand is exposed to environment thus the water absorption capacity of it observed high whereas, hill sand being coarse sand absorbs less water than river sand. Similarly, specific gravity of pit sand may be observed 1% less and for hill sand 1% more than river sand. Bulk density of both pit and hill sand are observed higher compared to the river sand. Moisture content of pit sand remained 30% less, whereas, the same for hill sand was only 32% of that of river sand. Fineness modulus of all three types of fine aggregates remained within the specified range for the parameter. Hence it may be observed that river sand is better compared to pit and hill sand in terms of basic properties. The gradation of all three types of aggregates was done in standard fashion. Percentage passing vs particle size is shown in Figure 9. It may be observed that all three types of aggregates are in good agreement with each other. Also, the percentage passing of the aggregates on various sieves in with in the specified limits of relevant ASTM standards.

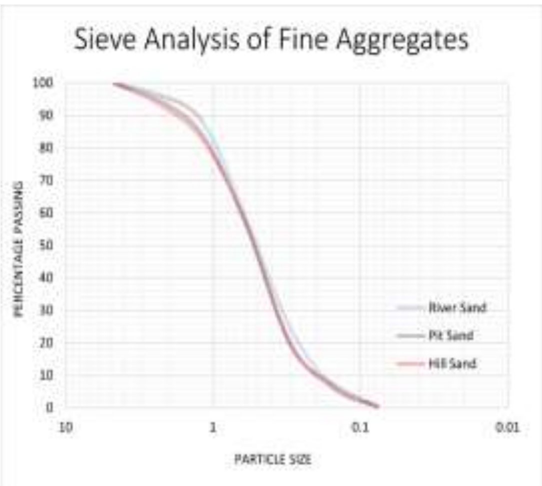

Figure 9: Sieve analysis of FA

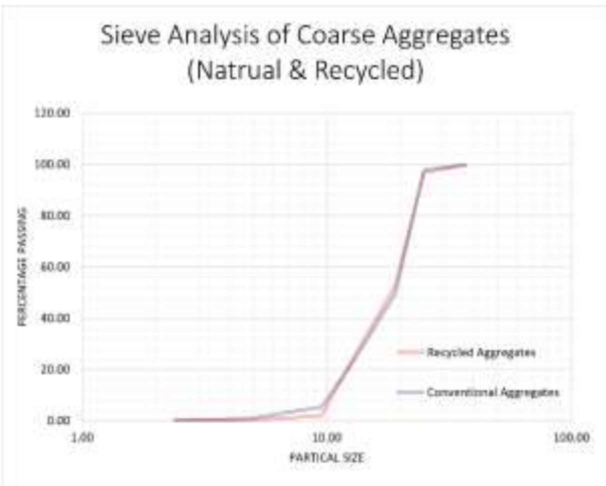

Figure 10: Sieve analysis of CA

Analogous to fine aggregates, the basic properties of coarse aggregates were also evaluated. Angularity of both types of aggregates is same where is surface texture of the recycled aggregates is coarser than conventional aggregates. Among other properties, water absorption, soundness, impact and crushing values and loss on ignition may be observed far higher than those of conventional aggregates. On other hand specific gravity and density are less compared to those of conventional aggregates. This variation of the properties confirms with the findings already presented in literature but differ in percentile values. In deed it is due to the age of the concrete in which it was exposed to different environmental and weather effects. Also, the old mortar attached with the aggregates plays role in deviation of the properties. Sieve analysis results of both aggregates presented earlier are plotted for percentage passing vs particle size in Figure 10. It may be observed that particle size of both aggregates is in good agreement with each other, however, the fines modulus of recycled aggregates remained 32% higher than that of conventional aggregates. It is because of manual processing of the waste into aggregates and could be overcome if the aggregate processing is done with crushing plant.

4.2 Slump test

The results of sump test presented earlier are plotted as bar graph (Figure 11) for concrete with 0% recycled aggregate and concrete with 50% recycled aggregates for all three types of fine aggregates used. From Figure 11 comparison of the slump value of individual batches may also be made. It may be observed that induction of recycled aggregates adversely affected the slump value. Also, the slump value of concrete with river sand remained higher compared to other types of fine aggregates. It is due to the fineness of the material. Slump values of concrete with pit sand remained higher than the sump value of concrete with hill sand with or without recycled aggregates. It is attributed to the coarser nature of the material. The percentile deviation of slump value of all five batches versus concrete with no recycled aggregates and river sand is shown in Figure 12. It may also be observed from this figure that least slump value is recorded for concrete with hill sand and recycled aggregates. However, all slump values remained within the range of normal concrete.

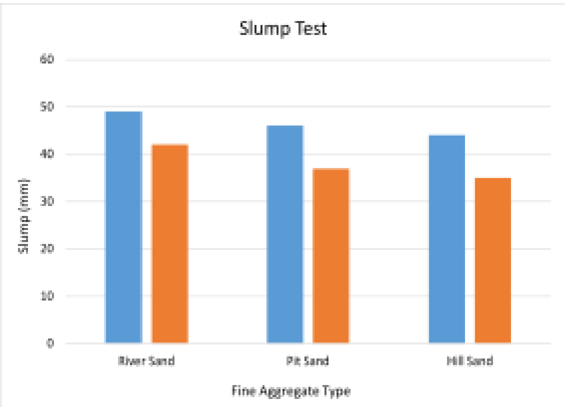

Figure 11: Slump values

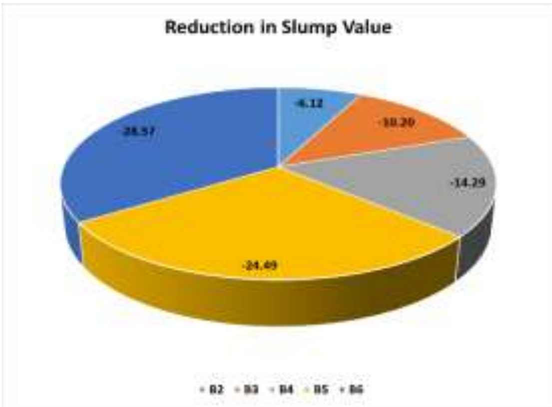

Figure 12: Percentage change in slump values

4.3 Compressive strength

The compressive strength results of all specimens of all batches presented earlier in tabular form are plotted as bar graph in Figure 13. It may be observed from the figure that the compressive strength of the specimens within the batch is close to each other. For all batches the standard deviation of compressive strength of individual samples remained less than 1%. For further comparison average compressive strength of individual samples in every batch is evaluated and plotted in Figure 14. It may be observed that the compressive strength of concrete with recycled aggregates got adversely affected for all types of fine aggregates used. In conventional concrete river sand samples gave better average compressive strength than pit and hill sand concrete, with least values recorded for concrete with pit sand. Unlike to it, for concrete with recycled aggregates, concrete with hill sand showed better results than pit and river sand concretes. Considering concrete with river sand and no recycled aggregates, percentage change of the compressive strength of all other batches is shown in Figure 15. Whereas, the same for conventional and recycled aggregate concrete for each type of fine aggregates is shown in Figure 16. It may be observed from Figure 15 also, that the conventional concrete with hill sand observed least reduction equal to 6% and 19% for recycled aggregate concrete with same fine aggregates. Checking the effect of type of fine aggregates, it is observed that recycled aggregates concrete with river sand observed 21% reduction in compressive , whereas 18% and 14% reduction was recorded for recycled aggregate concrete with pit sand and hill sand.

It is thus evident that although river sand in conventional concrete shows better performance in terms of workability and compressive strength but its performance is not that prominent in recycled aggregate concrete due to inferior properties of recycled aggregates. The negative effect of it is compensated to some extent with strength of hill sand. Hence, the performance of hill sand in recycled aggregate concrete is better compared to pit and river sand with least loss of compressive strength.

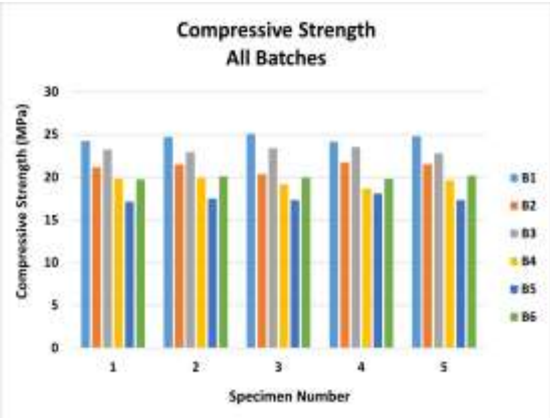

Figure 13: Compressive strength

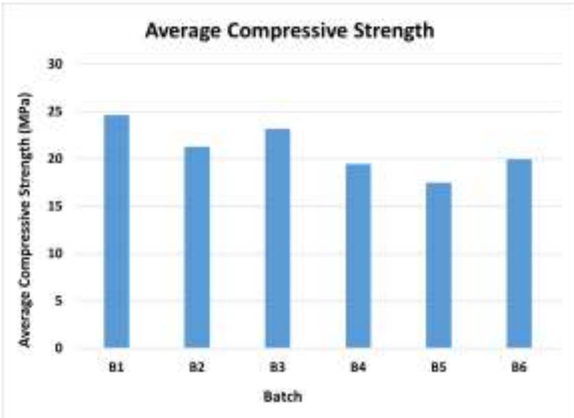

Figure 14: Average compressive strength

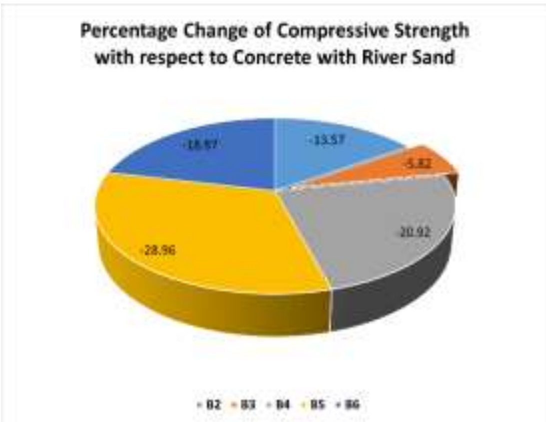

Figure 15: CS deviation (all batches)

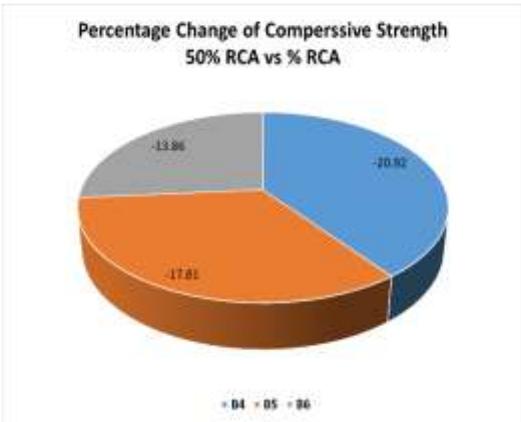

Figure 16: CS deviation (0% and 50% RCA)

5. CONCLUSION

Based on the outcome of laboratory investigations on the effect of type of aggregates on workability and compressive strength of recycled aggregate concrete it is concluded that although the performance of river sand is better in conventional concrete but its performance is not that good in recycled aggregate concrete. Whereas, the hill sand showed minor loss (20%) of workability in comparison to conventional concrete with hill sand. However, compressive strength of recycled aggregate concrete with hill and remained better with 86% residual strength. Therefore, for recycled aggregate concrete made with recycled aggregates from demolished waste of concrete, hill sand is better compared to pit and river sand.

Declaration by Authors

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