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Effect of Recycled Aggregates on Mechanical Properties of Concrete

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Abstract: Many structures that were constructed in India during the construction boom of the 1970s are now required of either major repairs or possible replacement. Also due to new construction for better economic growth, structures are turned into debris resulting from natural disasters like earthquake, cyclone and floods etc. Demolition or maintenance work on such structures results in large amount of concrete rubbles. The sustainable development concept, which apart from the sociological and economic aspects comprises energy saving, environment protection, and conservation of non-renewable natural resources. Use of Recycled concrete wastes can solve the problem of dumping of such wastes on valuable landfill and decreases the depletion of natural resources. In this research, the fresh and hardened properties of concrete using recycled concrete aggregate as coarse and fine aggregates were evaluated. Two series of RCA concrete aggregates were used. In series I the mixtures were prepared with 0, 20, 30, 40, 50, 60, 70 % Coarse RCA and in series II the mixtures were prepared with 0, 20, 30, 40, 50, 60, 70 % fine RCA. The results indicates, the strength of recycled concrete can be 10–25% lower than that of conventional concrete made with natural coarse aggregate. Target strength was achieved and the use of recycled aggregates up to 40% was beneficial with regards to strength and durability when compared with a normal concrete made from natural materials.

Index Terms: Compaction Factor, Curing, Demolition, Natural Coarse Aggregates, Moulding, Recycled Concrete aggregates, Split Tensile Strength,

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1. INTRODUCTION

Popularity of concrete is being translated into an annual worldwide production in the range of 12 billion tons, which accounts for about 1.7 billion tons of concrete per year per person living on this planet [1]. Many structures that were constructed in India during the construction boom of the 1970s are now required of either major repairs or possible replacement. This is because some of such structures are now reaching the end of their design life, may not have been constructed according to the specifications, or did not receive the required maintenance while in service. Also due to new construction for better economic growth, Structures are turned into debris resulting from natural disasters like earthquake, cyclone and floods etc, creation of building waste resulting from manmade disaster/war. The repair and replacement activities result in large quantities of construction waste that are usually dumped in the desert. They yields fragments in which the aggregate is contaminated with hydrated cement paste, gypsum, and minor quantities of other substances. Since aggregate makes up most of the concrete by volume, it makes sense to investigate the use of concrete waste as aggregate in new concrete. The size fraction that corresponds to coarse aggregate, although coated with cement paste, has been used successfully in many laboratory investigations and field studies[3].The use of old construction materials in new projects is not a new concept. Recycling construction waste and demolition debris dates back to the time of the Romans, who often reused stones from previous roads in rebuilding newer ones [2]. The sustainable development concept, which apart from the sociological and economic aspects comprises energy saving, environment protection, and conservation of non-renewable natural resources [13,14]. Shortage of natural aggregate in urban environment and the increased distance between the sources of natural aggregates and construction sites has constrained the contractors to consider RCA as an alternative of NCA [12]. Many authors from different countries study this problem. SolomonL. and Paulo H. (Brazil), and Poon C, Kou S. and Lam L. (China)in their research papers [10, 11] marked an aggregate which is got from demolished masonry and concrete structures as potentially good for use in new concrete [21,22]. The physical properties of recycled aggregates depend on both adhered mortar quality and the amount of adhered mortar. The adhered mortar is a porous material; its porosity depends upon the w/c ratio of the recycled concrete employed [4]. The density and absorption capacity of recycled aggregates are affected by adhered mortar and they must be known prior to the utilization of recycled aggregates [6, 7, 8]. Some researchers suggest a limit of 30% of recycled aggregate in order to maintain the standard requirements of

5% of absorption capacity of aggregates for structural concrete [5,16]. Concrete crushed by an impact crusher achieves a high percentage of recycled coarse aggregates without adhered mortar [5]. In order to achieve the results comparable to normal concrete, it is necessary to increase the quantity of water. The required quantity of water can be compensated either by measuring of water absorption of recycled aggregate in first 30 min or by its saturation via a prior immersion, or experimentally, until the same concrete consistency is achieved [23]. When natural fine aggregates in concrete were replaced by 0%, 25%, 50%, 75% and 100% fine recycled aggregates (<5 mm) and the free water/cement ratio was kept constant for all the mixes, the 28-day strength of the concrete developed at a slower rate [9]. The use of fine recycled concrete aggregates up to 30% replacement ratio would not affect the mechanical properties of concrete [10]. Use of fine CDW clearly reduces strength and durability of the produced concrete, which is mainly attributed to the constituents of CDW, which include considerable amounts of impurities such as brick and bitumen and account for its increased water absorption. Processing the CDW fine aggregate to reduce its water absorption as well as its impurities seems essential in order to improve strength and durability of the produced concrete [6].

RCA can be used in SCC as a replacement of NCA up to 50% by weight without affecting the key fresh properties such as filling ability, passing ability, and segregation resistance of concrete[11,15]. The permeability of RAC was significantly lower than the control mixture. The freeze–thaw durability of RAC was very low [17]. The new and old cement paste in recycled concrete can bind chlorides, RCA can contribute to chlorides binding, but the stability of this retention is very important, so a RCA of good quality must be used [18]. Otsuki found that chloride penetration in high strength RAC was slightly inferior to an equivalent concrete with NA, using a recycled aggregate with4.5% of water absorption [19]. The use of recycled aggregate might increase the chloride binding mechanism as it provides an extra quantity of CSH gel that helps the chloride absorption [11, 20]. The reclaimed concrete used to make recycled coarse aggregate may come from different sources of concrete elements of roads, bridges, buildings and other structures, or it can come from the residue of fresh and hardened rejected units in precast concrete plants. Variations between concrete types result from differences in aggregate quality, aggregate size and texture, concrete compressive strength, and uniformity [12]. It is desirable that the aggregate be made from the same grade of concrete so that to have the most consistent quality [23].

2.0 DETAILS OF EXPERIMENTS

2.1 Materials used in experiment

Ordinary Portland Cement (OPC) of 53grade confirming to Indian standard IS 12269-1987 was used. Fine aggregate (sand) used for this entire study or investigation for concrete was river sand confirming to zone-1 of IS: 383-1970. In this investigation, two types of coarse aggregates were used for preparation of concrete, Natural coarse aggregate (NCA) and recycled coarse aggregate (RCA). Crushed hard granite chips of maximum size 20mm were used in concrete mixes. The bulk density of aggregate was 1470 kg/m3 and specific gravity was found to be 2.87.

Recycled coarse Aggregate (RCA) was used from recycled aggregate plant at bavla near Ahmedabad. Maximum size of RCAthat has been produced was 20mm and minimum size was 4.75mm. Potable water confirming to IS: 456-2000 was used for casting and curing.

Table-1: Physical properties of NCA and RCA

Properties	NCA	RCA
Bulk Density(Kg/m^3)	1470	1451
Specific gravity	2.87	2.68
Water Absorption (%)	1.7	3.2
Fineness Modulus of coarse aggregates	7.8	6.9
Fineness Modulus fine aggregates	2.60	3.2

2.2 Mix design

Mix design was calculated using IS10262:2009 for different mixes using constant water to cement ratio of 0.50. The control mix was made with 100% natural coarse and fine aggregates (NAC). Series I was prepared with different levels of coarse RCA. Series II was prepared with different levels of fine RCA. Mixes M1, M2, M3, M4 ,M5 and M6 were prepared with 20%,30%, 40%, 50%, 60%, 70% replacement of Natural coarse aggregates by Coarse RCA. Mixes, M7, M8, M9 ,M10, M11and M12 were prepared with 20%,30%, 40%, 50%, 60%, 70% replacement of Natural River Sand by Fine RCA. Mixes were prepared with combination of natural coarse aggregates and recycled coarse aggregates as well as Natural River sand and Recycled Concrete Fine Aggregates as shown in Table-2.

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Table-2: Percentage Of Aggregate Used In Different Mixes

Series I		**Replacement of Natural Coarse Aggregates by Recycled Concrete Coarse Aggregates**						
Type of Mix	Control Mix Coarse Agg. (MCA)*	**M1**	M2	M3	M4	M5	M6	W/C Rat-io
NCA	100%	80 %	70 %	60 %	50 %	40 %	30 %	0.5
RCA (C.A)	00%	20 %	30 %	40 %	50 %	60 %	70 %	
Series II		**Replacement of River Sand by Recycled Concrete Fine Aggregates**						
Type of Mix	Control Mix Fine Agg. (MFA)*	M7	M8	M9	M10	M11	M12	W/C Rat-io
River Sand	100%	80 %	70 %	60 %	50 %	40 %	30 %	0.5
RCA (F.A)	00%	20 %	30 %	40 %	50 %	60 %	70 %	

MCA* = Mix with Natural CoarseAggregates, MFA* = Mix with Natural River (Fine) aggregates.
Weight of each ingredient used for cubes and cylinders were as shown in Table-3 and Table -4.

2.3 Specimen casting and Curing

Batching of Materials

A proper and good practice of mixing is required for better performance of concrete. A proper mix of concrete is essential for the strength of the concrete and better bonding of the cement and aggregate. All the mix materials were weighed as given in Table 3 and Table 4 and kept ready for concreting as per design mix proportions before concreting. Weigh batching was used. Drum type of mixture was used for mixing the concrete material.

Moulding: The specimens used in the compressive strength test were 150mm x 150mm x 150mm cubes. Specimen used in the Split tensile strength test was cylinder of 300 mm diameter and 150 mm height. Concrete moulds were oiled for easy stripping. The moulds for conducting tests on fresh concrete were made ready and inner surface were oiled.

Table 3: Weight Of Each Ingredient For Cubes In The Mixes.

Mix	W/C Ratio	Cement (Kg)	Natural Coarse Aggregates (Kg)	Recycled Concrete Coarse Aggregates (Kg)	River Sand (Kg)	Recycled Concrete Fine Aggregates (Kg)	Water Kg
MCA	0.5	8.77	26.29	0.0	14.60	0.0	4.39
M1	0.5	8.77	21.03	5.25	14.60	0.0	4.39
M2	0.5	8.77	18.4	7.89	14.60	0.0	4.39
M3	0.5	8.77	15.78	10.51	14.60	0.0	4.39
M4	0.5	8.77	13.14	13.14	14.60	0.0	4.39
M5	0.5	8.77	10.52	15.77	14.60	0.0	4.39
M6	0.5	8.77	7.89	18.4	14.60	0.0	4.39
MFA	0.5	8.77	26.29	0.0	14.60	0.0	4.39
M7	0.5	8.77	26.29	0.0	11.68	2.92	4.39
M8	0.5	8.77	26.29	0.0	10.22	4.38	4.39
M9	0.5	8.77	26.29	0.0	8.76	5.84	4.39
M10	0.5	8.77	26.29	0.0	7.3	7.3	4.39
M11	0.5	8.77	26.29	0.0	5.84	8.76	4.39
M12	0.5	8.77	26.29	0.0	4.38	10.22	4.39

Table 4: Weight Of Each Ingredient For Cylinder In The Mixes.

Mix	W/C Ratio	Ceme-nt (Kg)	Natural Coarse Aggreg ates (Kg)	Recycled Concrete Coarse Aggregat es (Kg)	River Sand (Kg)	Recyc-led Con. Fine Aggre-gates (Kg)	Water Kg
MCA	0.5	12.40	37.20	0.0	20.67	0.0	4.39
M1	0.5	12.40	29.75	7.45	20.67	0.0	4.39
M2	0.5	12.40	26.04	11.16	20.67	0.0	4.39
M3	0.5	12.40	22.32	14.88	20.67	0.0	4.39

M4	0.5	12.40	18.6	18.6	20.67	0.0	4.39
M5	0.5	12.40	14.88	22.32	20.67	0.0	4.39
M6	0.5	12.40	11.2	26.	20.67	0.0	4.39
MFA	0.5	12.40	37.20	0.0	20.67	0.0	4.39
M7	0.5	12.40	37.20	0.0	16.53	4.134	4.39
M8	0.5	12.40	37.20	0.0	14.46	6.20	4.39
M9	0.5	12.40	37.20	0.0	12.40	8.27	4.39
M10	0.5	12.40	37.20	0.0	10.33	10.33	4.39
M11	0.5	12.40	37.20	0.0	8.26	12.40	4.39
M12	0.5	12.40	37.20	0.0	6.20	14.46	4.39

Preparation of Concrete: Concrete was prepared in the mixer and dumped in iron tray placed on a flat surface. Again the concrete was manually mixed properly before placing in the moulds, the workability tests were conducted on fresh concrete. Workability affects the rate of placement and the degree of compaction of concrete. Slump test, compacting factor tests were conducted on fresh concrete. The vibration of the filled mould and cylinder is been used with vibrating machine for proper compacting. During the placing of fresh concrete into mould, proper care was taken to remove entrapped air by using a table vibrator to attain maximum strength. Vibrators were used after every 1/3 filling of material into the mould and the top surface was properly leveled at the end.

Curing: Curing of concrete is an important process to prevent the loss of moisture from concrete specimens while they are gaining their required strength. Inadequate curing is leading to unexpected cracks on the surface of concrete specimen. The test specimen should be stored in a place at a temperature of 27° +/- 2°C for 24 +/- 0.5 hrs. From the time addition of water to the dry ingredients. All concrete specimens were cured in water at room temperature for 7 and 28 days. After 7 an28 days curing, concrete specimens were removed from the curing tank to perform the tests on hardened concrete.

2.4 Test Methods

Slump Test: The concrete slump test is used for the measurement of a property of fresh concrete. The test is an empirical test that measures the workability of fresh concrete. A metallic mould in the form of a frustum of a cone was used to measures the slump value. The slump test result is a measure of the behavior of a compacted inverted cone of concrete under the action of gravity. It measures the consistency or the wetness of concrete.

Compaction Factor Test

The compacting factor test is designed primarily for use in the laboratory but it can also be used in the field. It is more precise and sensitive than the slump test and is particularly useful for concrete mixes of very low workability as are normally used when concrete is to be compacted by vibration. The compacting factor test has been developed at the Road Research Laboratory U.K. and it is claimed that it is one of the most efficient tests for measuring the workability of concrete. This test works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height. The degree of compaction, called the compacting factor is measured by the density ratio i.e., the ratio of the density actually achieved in the test to density of same concrete fully compacted.

Compressive strength Test

Compressive strength is defined as the maximum resistance of a concrete cube to axial loading. Three specimens of size 150 mm x 150 mm x 150 mm were used for compression testing for each batch of mix. Testing of specimens was carried out after curing at defined ages. Specimen dimensions were measured before testing. Clean the surfaces of cube and put in the test in machine. The platen was lowered and touched the top surface of the specimen. The load was applied at the gradually and maximum load at which specimen failed was recorded.

Split Tensile strength Test

Split tensile test was conducted on specimens of size150 mm diameter and 300 mm height. The testing of specimens should be carried out as soon as possible after curing. Specimen dimension were measured before the testing. Cleaned and cured specimens placed in the test in machine with longitudinal axis horizontal. The platen was lowered and was allowed totouch the top surface of the specimen. The force was applied and increases continuously. Maximum load atwhich the specimen failed was recorded.

3 ANALYSIS OF TEST RESULTS AND DISCUSSION

The results of Fresh and Hardened properties of different mixes of RAC using coarse and fine RCA are as shown in Table 5.

3.1 Fresh Properties

(i) Slump Test Result

The slump test indicates a decreasing trend of workability when the percentage of recycled aggregate increased. Table 5 shows the average slump recorded during the test. Figure 1shows a graphical representation of slump height. According to the result, the highest slump obtained was 70 mm and the lowest slump was 35mm. Target slump had been achieved, where the range is from 50mm to 100mm.The workability was good and can be satisfactorily handled for 0% recycled aggregate to 40% coarse RCA and up to 50% fine RCA. The slump from 0% RCA to 40% coarse RCA and up to50% fine RCA were considered moderate due to the drop in the range of 5mm to 10mm.There was no problem for the placement and compaction of fresh concrete. After 40% replacement of RCA, there was sharp decrease in slump value because of the high water absorption capacity of recycled aggregate. From the result obtained, it shows that the workability was getting lower when more recycled aggregate were used. Quantity of recycled aggregate affects water absorption, in the sense that the increase of the recycled aggregate quantity causes increase of the water absorption which is a consequence of increased porousness. Usage of 50-100% of coarse recycled aggregate increase the water absorption for 0.15-0.37% [24]. By submerging the RCA in water for 6to 7 hours before incorporating in to mix was decreased the absorption of water used in the mix, thus maintained the target slump values. As shown in Figure 1 Slump values of fine RAC mixes were more than coarse RAC mixes. Workability of mixes with fine RAC was higher than mixes with coarse RCA.

Table5: Test Results of Fresh and Hardened Concrete

Mix Type	**Slump Value**	**Compaction Factor Value**	**Compressive Strength**		**Split Tensile strength**	
Days of testing	(mm)	(mm)	7 (N/mm²)	28 (N/mm²)	7 (N/mm²)	28 (N/mm²)
MCA	70	0.870	29.20	39.78	3.11	5.23
M1	62	0.830	28.70	38.50	4.70	6.12
M2	58	0.810	26.25	37.00	3.10	5.27
M3	52	0.780	25.00	36.50	3.51	5.25
M4	45	0.770	17.30	34.20	3.77	5.0
M5	42	0.700	16.50	30.00	3.60	4.75
M6	35	0.610	15.10	28.20	3.55	4.5
MFA	70	0.870	29.20	39.78	3.11	5.23
M7	65	0.845	25.21	35.14	2.96	3.53
M8	60	0.830	25.04	33.81	2.28	3.46
M9	57	0.810	23.09	33.20	2.85	3.34
M10	55	0.800	22.69	32.80	2.45	3.22
M11	50	0.775	21.10	30.70	2.20	3.00
M12	40	0.765	19.85	29.10	2.12	2.77

(ii) Compaction Factor test result:

The Compaction Factor test results indicate a decreasing trend of workability when the percentage of RCA increased. Table 5 shows the values of Compaction Factor recorded during the test. Figure 2 shows a graphical representation of Compaction Factor values. According to the result, the highest value obtained was 0.870 and the lowest slump was 0.610. The workability was good and can be satisfactorily for 0% recycled aggregate to 40% coarse RCA and up to 50% fine RCA. After 40% replacement of RCA, there was sharp decrease in compaction factor value because of the high water absorption capacity of recycled aggregate. By submerging the RCA in water for 6to 7 hours before incorporating in to mix was decreased the absorption of water used in the mix, thus achieved the required compaction factor value.

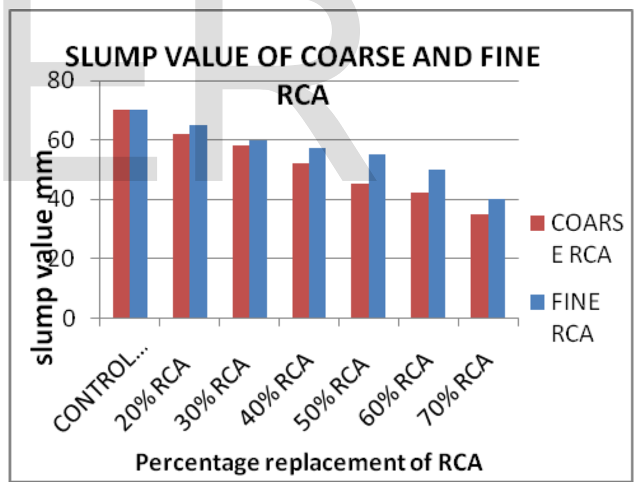

Figure 1: Slump value of coarse and fine RAC

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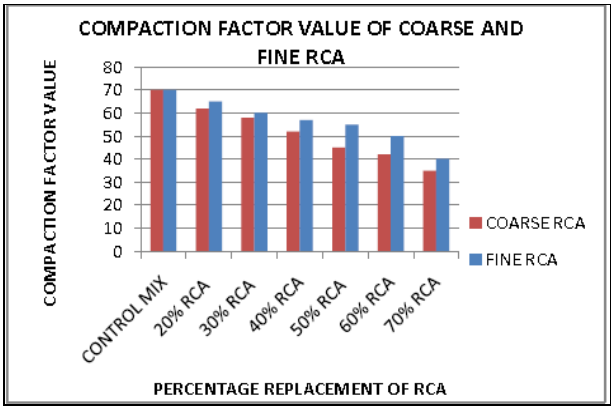

Figure 2: Compaction factor of coarse and fine RAC

3.2 Hardened Properties

(i) Compressive strength: The compression test indicates an increasing trend of compressive strength in the early age of the concrete specimens. However, it shows that the strength of recycled aggregate specimens is lower than natural aggregate specimens. Figure 3 shows a graphical representation of variation of compressive strength of coarse RAC. The target strength for this project is 31.0 N/mm². From the obtained result, the compressive strength of the control concrete mix was 39.78 MPa, which is more than target strength. It had shown that the Mixes M1, M2, M3, M4 met the target strength with replacement of 20%, 30%, 40%, 50% of RCA. The compressive strength for M5 and M6 is less than 31MPa.This shows that up to 30 to 50 % recycled aggregate replacement may achieve required strength. The results also shows that the concrete specimens with more replacement of recycled aggregate will get the lower strength when compared to the concrete specimens with less recycled aggregate. The compressive strength of 0% recycled aggregate was taken as the 100% compressive strength. From the result, the mix of 70% coarse recycled aggregate has the lowest compressive strength remained, which is only 70.88%.There was a drop of 29.11% when compared to 0% recycled aggregate. However the compressive strength remained for 40% recycled aggregate replacement was 91.75%. Hence the drop in compressive strength reduced to 8.24% only.From the obtained result, it is possible to use 30 to 40% coarse recycled concrete aggregate. Figure 4 shows a graphical representation of variation of compressive strength of fine RAC. It had shown that the Mixes M7, M8, M9, M10 met the target strength with replacement of 20%, 30%, 40%, 50% of RCA. The compressive strength for M11 and M12 is less than 31MPa.This shows that up to 40 to 50 % of fine recycled aggregate replacement may achieve required strength. The results also shows that the concrete mixes with more replacement of fine recycled aggregate will get the lower strength when compared to the concrete mixes with less recycled aggregate. The compressive strength of 0% recycled aggregate was taken as the 100% compressive strength. From the result, the mix of 70% fine recycled concrete aggregate has the lowest compressive strength remained, which is only 73.15%.There was a drop of 26.84% when compared to 0% recycled aggregate. However the compressive strength remained for 40% recycled aggregate replacement was 83.45%. Hence the drop in compressive strength is reduced to 16.54% only. From the obtained result, it is possible to use 30 to 40% fine recycled concrete aggregate.

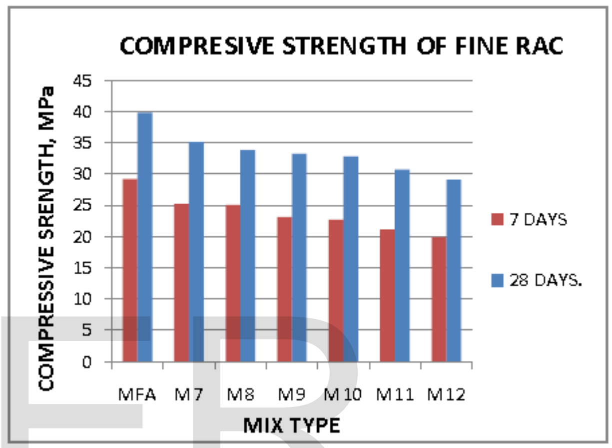

Figure 3: Compressive strength of coarse RAC

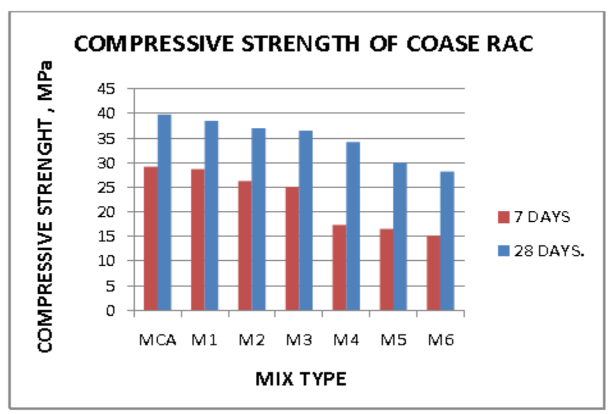

Figure 4: Compressive strength of fine RAC

(ii)Split Tensile Strength: The indirect split tensile test indicates a increasing trend of indirect tensile strength when the percentage of recycled aggregate increased. The tensile strength of recycled aggregate concrete can be higher than that of conventional concrete [5]. Figure 5 shows the percentage of tensile strength remained for the concrete specimens with the different percentage of fine recycled aggregate replacement. The result is almost same as the

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result of compressive strength. The concrete specimen of 70% coarse recycled aggregate has the lowest tensile strength remained, which is 86.04%. There is a drop of 13.95% when compared to 0% recycled aggregate. However, the concrete mix M3 with the 40% coarse recycled aggregate has the most tensile strength remained. It is 0.38% more than 0% recycled aggregates, which is still remained 100.38% when compared to 0% recycled aggregate concrete specimen. The split tensile strength of 20% coarse recycled aggregate mix M1 is more than 0% recycled aggregate, which is 117%. It is 17% more than control mix. The reason is because of the lower water cement ratio than other batches of concrete specimens.

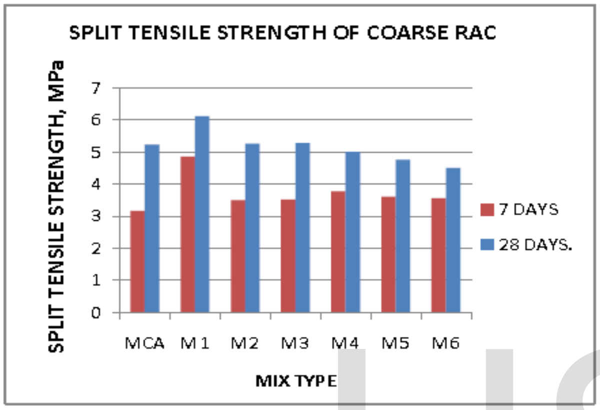

Figure 5: Split tensile strength of coarse RAC

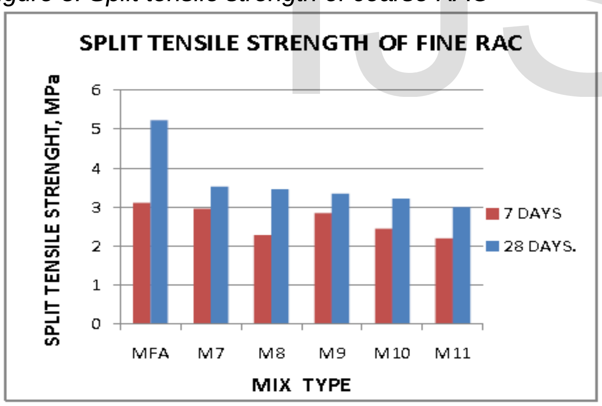

Figure 6: Split tensile strength of fine RAC

Figure 6 shows a graphical representation of variation of compressive strength of fine RAC. The concrete specimen of 70% fine recycled aggregate has the lowest tensile strength remained, which is 52.96% .There was a drop of 47.03% when compared to 0% recycled aggregate. However, the concrete mix M9 with the 40% fine RCA has the most tensile strength remained. It is 36.13% less than 0% recycled aggregates, which is still remained 63.86% when compared to 0% recycled aggregate concrete mix.For mix with fine RCA with increase in % of RCA, tensile strength decreased. Up to 40% replacement level split tensile strength is within permissible limit.

4 CONCLUSIONS

As per the results of experiment, following conclusions were derived:

(1) As per the result, both coarse and fine recycled aggregates can be used for low strength concrete.

(2) The slump flow and compaction factor of the RCA mixes decreased with increase in the RCA due to higher water absorption of RCA. Slump flow value of 20% replacement of RCA was 62 mm and 65 mm for coarse and fine RCA respectively. The values of compaction factor for 20% replacement of RCA were 0.830 and 0.835 for coarse and fine RCA respectively. For 40% replacement of RCA, the slump values were 50 mm and 57mm and compaction factor values were 0.780 and 0.810 for coarse and fine RCA respectively which were fulfill the design requirements. More than 40% replacement of RCA did not satisfy the required workability. By submerging the RCA in water for 6to 7 hours before incorporating in to mix was decreased the absorption of water used in the mix, thus maintained the target slump values.

(3) The 28 days compressive strength of mixes decreased with increase in percentage of RCA. 28 days Compressive strength of control mix was 39.78 N/mm², which decreased up to 34. 20 N/mm²for mix M4. These values were very near to target mean strength. 28 days Compressive strength of mix M7 was 532.14 N/mm², which decreased up to 32.80 N/mm² for mix M10. These values were very near to target mean strength.

(4) The 28 days split tensile strength of mixes M1, M2, M3 were 6.12 N/mm², 5.27 N/mm², 5.25 N/mm² respectively, which were more than strength of control mix of 5.23 N/mm². For mixes M4, M5 and M6 were 5.0 N/mm², 4.75 N/mm², and 4.5 N/mm² respectively. The split tensile strength of mixes M4, M5, M6 was less than strength of control mix. After replacement level of 40% RCA, split tensile strength decreased with increasing the percentage of RCA. The tensile strength of recycled aggregate concrete can be higher than that of conventional concrete.

(5) The 28 days split tensile strength of mixes M7, M8, M9, M10, M11, M12 were 3.53 N/mm², 3.46 N/mm², 3.34 N/mm² , 3.22 N/mm², 3.0 N/mm²,2.77 N/mm² respectively, which were less than strength of control mix of 5.23 N/mm2. The split tensile strength of mixes M4, M5, M6 was less than strength of control mix. Up to replacement level of 40% RCA, split tensile strength was comparable to requirement.

(6) The use of both coarse RCA as well as fine RCA up to 40% is beneficial in concrete industry as these recycled

concrete mixtures achieve similar properties when compared with a normal concrete.

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