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Determination of Compressive Strength of Concrete Made With Natural Aggregates and Varying Percentages of Demolished Waste Concrete Aggregates

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Abstract– *Basic mechanical property of concrete is its compressive strength and is one of the indicators to determine the performance of concrete. In this paper, the effects of various percentages (0%, 50%, 100%) of Recycled Aggregate (RA) i.e demolished concrete waste aggregate on compressive strength of Recycled Aggregate Concrete (RAC) were investigated. Natural aggregate (NA) is replaced by recycled aggregate (RA) as coarse aggregate in different concrete mixes. This research also covered RAC mixtures at different water-cement ratio 0.45, 0.50, concrete grades taken is M20, M25 respectively. It was found that RAC had lower compressive strength compared to Natural Aggregate Concrete (NAC). At the age of 28 days, RAC with water-cement ratio 0.45, 0.50, and M20, M25 respectively had the highest strength.*

Key Words **- compressive *strength, concrete grades.***

I. INTRODUCTION

Demolished waste concrete is concrete that is being used as recycled aggregate (RA) as partially or fully replacement in coarse and fine aggregate. It is believed RA have been used from 1945 in concrete production and started when World War II damaged a large quantity of concrete structures and thus increased high demand of aggregates to rebuild the structures (Kheder and Al-Windawi, 2005).Engineers recognized the factors like depletion of natural aggregates, tightly environmental law and waste disposal problems which influenced the application of demolished waste concrete aggregates.

Demolished waste concrete aggregates (RA) had such a possible application in certain area and Masood et. al. (2002) have summarized it. They have conducted some experimental investigations and found that RA had a potential functioning as aggregate that can be applied in concrete roads, drainage work, shallow storage tanks, culverts, low cost housing structures and sewage or treatment plants. Now depletion of natural aggregate sources are the main factor why RA is not been using. But according to Masood et. al. (2002), Asian countries should think seriously about the application of RA due to the increasing of discharge concrete for each year. Hong Kong, Japan and China have become pioneer counties in Asia which are actively conducting study on RA application in construction industry. It can be seen in some research by Poon and Chan, (2006), Eguchi et. al., (2006) and Huang et. al.,(2002). Poon and Chan, (2006) has reported the application of 14,300 m^3 RA for Hong Kong Wetland Park construction. Meanwhile in Taiwan, the Construction and Demolition (C&D) waste is handling properly since 1999 (Huang et. al, 2002) and Japan have committed in application of RA by publishing 'Standard for Usage of Concrete with Recycled Aggregate' in 1996 (Eguchi et. al., 2006).

United Kingdom is one good example of western countries which practicing demolished waste concrete aggregates in its construction industry. In DOE 1996, the '1995 UK Government White Paper Making Waste Work' had targets to increase the use of waste and recycled materials as aggregates to 30 million tones per year by 2006. In UK, Construction and Demolition (C&D) waste has been identified were had value in engineering materials for construction industry (Lawson et. al., 2001). Lawson et. al. (2001) also reported that 51.1% or 27.4 million tonnes of (C&D) waste were disposed directly to landfill, 39.6 % or 21.2 million tonnes were excepting from licensed disposal and were primarily used for land modeling during the construction projects and 9.2 % or 5 million tonnes were either crushed to produce a graded product or directly recovered. Recycling and reuse (C&D) waste and produced as RA is expected to improve on supplying of construction material and also can solve the disposal of waste construction material (Masood et. al., 2001).

RAC has attracted many researchers to study its performance. Previous researchers have conducted study on application of RA and found that RAC have lower compressive strength compared to Natural Aggregate Concrete (NAC), (Ismail, Suraya and Mia, 2007).

II- EXPERIMENTAL WORK

2.1 Materials

The materials used in this experiment were:

1. Ultra-Tech PSC-53 Grade Cement was used.
2. Sand (fine aggregates)
3. Natural gravel with maximum size 20 mm (NA) .
4. Demolished waste concrete (RA) - used as coarse aggregate .

The demolished waste concrete coarse aggregates were obtained by crushing the waste concrete from old demolished structures that were dismantled due to completion of their life span. Compressive strength of concrete was tested in Marshal Geo Test Concrete Technology Laboratory , Raipur , Chhattisgarh , India. Demolished concrete was obtained from demoliseds old concrete structures in Bhilai that had compressive strength between 20 to 22 N/mm^2. These waste concrete demolished concrete was broken into smaller pieces and crushed using hammers. Then the RA produced is sieved with max size 20 mm. Table 1 showed the physical properties of NA and RA.

Table 1 Physical Properties of Aggregate

S.No	Type of Properties	Normal Aggregate	Recycled Aggregate
1	Abarasion value(%)	20.45	27.7
2	Aggregate Impact Value (%)	17.7	36.2
3	Aggregate Crushing Value (%)	17.28	35.86
4	Absorption (%)	0.625	0.712

2.2 Concrete mixes

Two groups of concrete mixes, NAC and RAC were produced using natural sand as fine aggregate. NAC mixes were used fully Natural Aggregate as coarse aggregate in concrete mix. Meanwhile RAC mixes were used demolished waste concrete aggregate as partially or fully replacement of Natural Aggregate as coarse aggregate. These mixes were designed according to concrete mix design IS 10262-2009 . The concrete mixtures were prepared with a water-cement (w/c) ratio 0.45 and 0.50. The slump target is between 70mm to 190mm for NAC and RAC mixes. The combination in concrete mixes after this will be called as RA00, RA50 and RA100. Table 2.2 showed the details of concrete mixes.

Table 2 Series of mix proportion

Series	Natural Aggregate (%)	Recycled Aggregate (%)
RA00	100	00
RA50	50	50
RA100	00	100

2.3 Testing of Concrete

Slump and compressive test was conducted to determine concrete's workability and compression strength. Slump test is conducted following ASTM C 143-90a. Compressive test is conducted by following BS 1881: Part 108:1983 and three cubes of 150mm x 150mm x 150mm were tested at 7, 14 and 28 days.

III- RESULTS AND DISCUSSION

3.1 Slump Test Result

The slump results are presented in Table 3.1. It can be observed in Figure 3.1 that concrete mixes at 0.45 had a lower slump compared to 0.50 and 0.55 concrete mixes. On the other hand, when replacement of RA is increased in concrete mixes, the slump of concrete mixes is decreased. It was expected because recycled aggregate is high in water absorption. Poon C.S. et. al. (2006) revealed that mortar over RA is lead to low slump of RAC .

Table 3- Slump for Different w/c Ratio Concrete Mixes

Series	W/C Ratio	Slump (mm)
RA00	0.45 0.50	130 170
RA50	0.45 0.50	85 163
RA100	0.45 0.50	45 150

3.2 Compressive Strength Test Of Concrete

The compressive strength results are presented in Table 4. Each presented value is the average of three measurements. It is shown in Fig. 1 & 2, that compressive strength of Demolished Waste Concrete (RAC) is lowered compared to Natural Aggregate Concrete (NAC). For w/c ratio 0.45 and 0.50, the concrete mixtures prepared with 0% , 50% and 100 % replacement of demolished concrete waste, it has been found that M20 grade of concrete with 0.45 w/c gave 18.99 N/mm^2 at 7 days as compared to M25 w/c 0.50 gave 18.12 N/mm^2 ,similarly in case of 14 days M20 gave better results as compared to M25 , similarly 28th day results of M20 grade concrete was 32.57 N/mm^2 as compared to M25 27.89 N/mm^2. Normally as RA replacement increased, compressive strength will decrease (Topcu and Sengel (2004) and Kou, Poon and Chan (2007)). The higher compressive strength may be attributed to the greater bonding force and strength when same type of aggregates was used. Otherwise, RAC still obtained lower compressive strength compared to NAC.

Table 4 Compressive Strength Of Concrete With Different Mixes

Series	Grade of Concrete	W/C Ratio	7- days	14- days	28- days
RA 00	M 20	0.45	18.99	22.37	32.57

	M 25	0.50	18.12	20.28	27.89
RA 50	M 20	0.45	15.26	20.91	24.99
	M 25	0.50	13.98	19.71	23.28
RA 100	M 20	0.45	12.40	17.36	22.08
	M 25	0.50	15.02	17.16	21.69

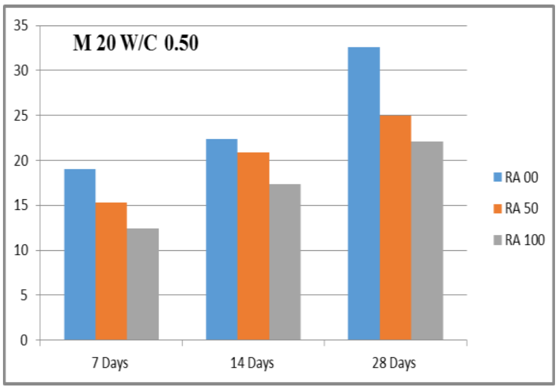

Figure 1 Compressive Strength Of M20 W/C 0.5 With Different Coarse Aggregate Proportions

Again the results were better for M20 grade of concrete when 50% of demolished waste concrete was used to make fresh concrete , the compressive strength results showed 7days , 14 days , 28 days results were better as compared to M25 grade concrete with 0,50 w/c ratio. We have seen that when water cement ratio is higher there is decrease in strength of concrete with ages, might be possibility of segregation and 50% demolished waste concrete used , which has already completed its service period , and not capable of bearing heavy loads.

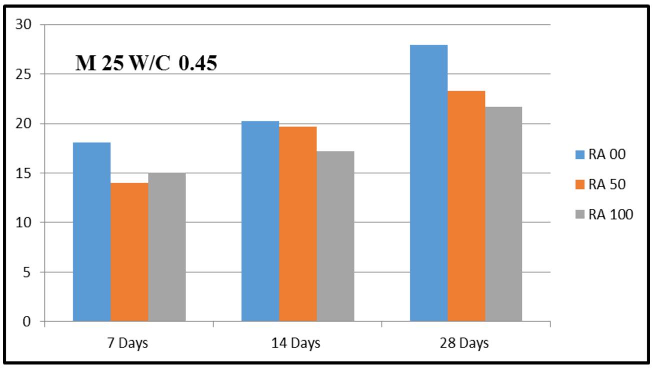

Figure 2 Compressive Strength Of M25 W/C 0.45 With Different Coarse Aggregate Proportions

The results obtained of concrete made with 100% demolished waste concrete as aggregates were inferior in case of both M20 and M25 grades of concrete as demolished waste concrete has less bearing capacity to bear vertical loads, also bonding between the particles weakens. Hence the compressive bearing strength in case of concrete made of 100% demolished concrete waste is less as compared to concrete made with fresh broken stone coarse aggregates.

From the results figure 3 we can compare M20 grade of concrete with 0% demolished concrete waste at 7th day RA 50% is 19.64% weaker and RA 100% is 33.43% weaker of concrete made with natural aggregate.

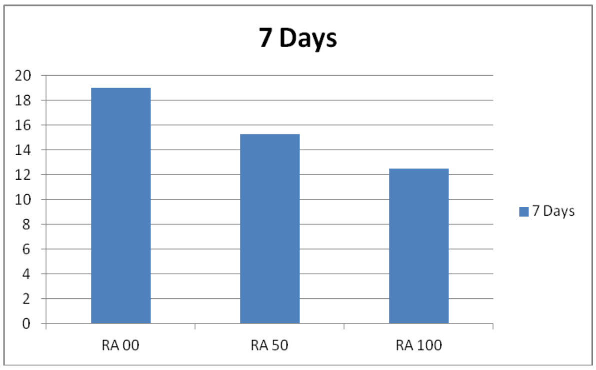

Figure 3 Compressive Strength Of M20 With Different Coarse Aggregate Proportions At 7th Day

Also from figure 4 M20 grade of concrete with 0% demolished concrete waste at 14th day RA 50% is 6.52% weaker and RA 100% is 22.39% weaker of concrete made with natural aggregate.

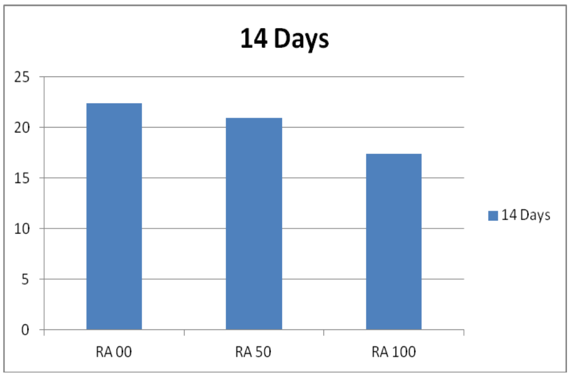

Figure 4 Compressive Strength Of M20 With Different Coarse Aggregate Proportions At 14th Day

Also from figure 5 for M20 grade of concrete with 0% demolished concrete waste at 28th day RA 50% is 23.27% weaker and RA 100% is 32.20% weaker of concrete made with natural aggregate.

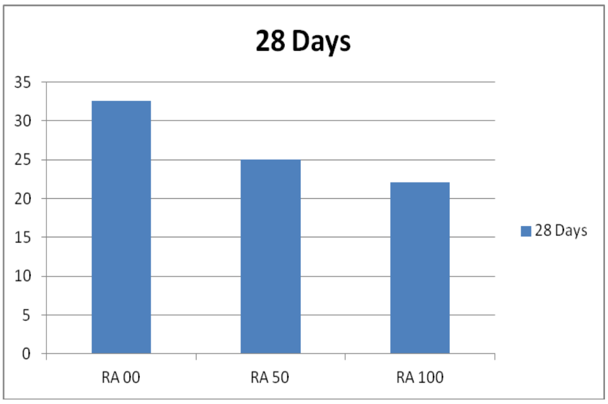

Figure 5 Compressive Strength Of M20 With Different Coarse Aggregate Proportions At 28th Day

From the results in figure 6 we can compare M25 grade of concrete with 0% demolished concrete waste at 7th day RA 50% is 17.35% weaker and RA 100% is 17.10% weaker of concrete made with natural aggregate.

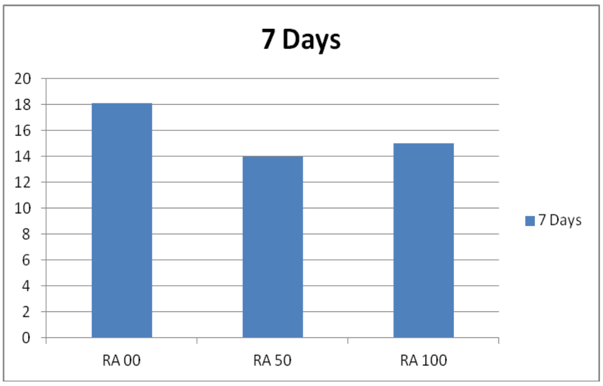

Figure 6 Compressive Strength Of M25 With Different Coarse Aggregate Proportions At 7th Day

Also M25 grade of concrete in figure 7 with 0% demolished concrete waste at 14th day RA 50% is 2.81% weaker and RA 100% is 15.38% weaker of concrete made with natural aggregate.

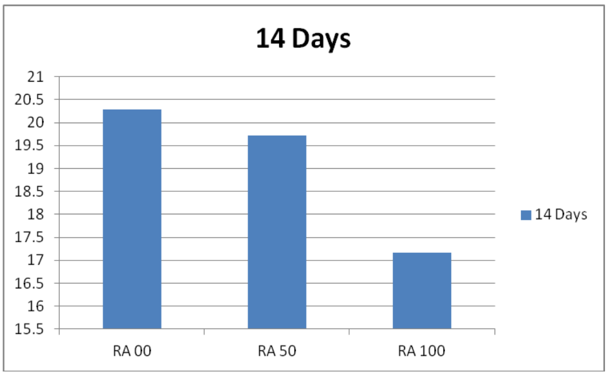

Figure 7 Compressive Strength Of M25 With Different Coarse Aggregate Proportions At 14th Day

Also M25 grade of concrete in figure 8 with 0% demolished concrete waste at 28th day RA 50% is 16.52% weaker and RA 100% is 22.23% weaker of concrete made with natural aggregate.

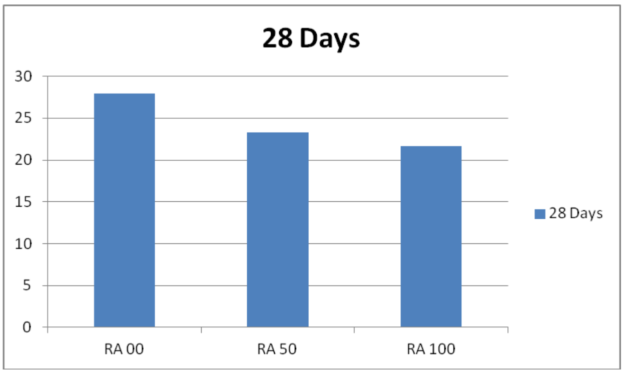

Figure 8 Compressive Strength Of M25 With Different Coarse Aggregate Proportions At 28th Day

CONCLUSION

The following conclusions have been made based on the results of this study:

1. With the same w/c ratio, the slump value decreases if percentage of RA is increased.
2. The compressive strength of Recycled Aggregate Concrete was lower than that of Natural Aggregate Concrete.
3. Lower water-cement ratio of Recycled Aggregate Concrete lead to higher in compressive strength. RAC could increase its compressive strength by reducing the water-cement ratio of concrete.
4. The relationship of w/c ratio and compressive strength of RAC is inversely proportional.
5. Recycled concrete can be effectively used in low cost housing where slab load is not high , it can also be used in the construction of boundary wall columns and for other construction where compressive load is not too much .
6. By using recycled aggregates in concrete problem of dumping demolished waste can be minimized .
7. Using of recycled aggregates in concrete also reduces environmental pollution , which would otherwise would have been produced during crushing of gravels as coarse aggregate for concrete .
8. As industrialization is growing day by day hence the waste from industries in the form of ashes and dust is becoming a hectic problem to solve, and also we are seeing many of the rural people are migrating from rural area to urban area in search of job, education, improved life style , large amount of infrastructure construction is going on and much of infrastructure will be needed in future too, hence new technologies can be adopted in which these waste from industries in form of ashes and dust can be used in construction of different members of buildings, in that way large amount of land can be saved which was to be used for land fill, also under ground water can also be saved from polluting, which was many times affected by leachate problem, hence saving many people lives, hence making healthy citizens of country, and helping in economic development.

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