International Journal on Emerging Technologies **7**(1): 70-77(2016)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

Effect on Compressive Strength of Demolised Concete

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(Received 02 March, 2016 Accepted 12 April, 2016)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: The subject of concrete recycling is regarded as very important in the general attempt for sustainable development in our times. Experimental work was performed to determine the compressive, splitting tensile and flexural strength of recycled coarse aggregate concrete and to compare them with those of concrete made using natural crushed stone. The properties of the aggregates were also compared. The fine aggregate for recycled and conventional concrete was 100 percent natural sand. Test results indicates that the strength characteristic of recycled aggregates concrete are influenced by key factor such as the strength of the original concrete, the ratio of the coarse to fine aggregates in the original concrete, the ratio of the top size of aggregate in the original concrete to that of the recycled aggregate and the los angle abrasion loss and water absorption of recycled aggregate. These factor also influenced the effect of water cement ratio and dry mixing on the strength characters tics of recycled aggregates concrete. it also show that the relationship between splitting tensile , flexural, and compressive strength may have to be modified for recycled aggregate concrete. The final conclusion is that through proper measure s high quality concrete material can be produced using demolished concrete. For this purpose, it is determine the properties of the original concrete based on which real qualities can be targeted for demolished aggregate concrete.

I. INTRODUCTION

In the era of construction, concrete has been the leading building material since it was discovered and found viable for future due to its durability, easy maintenance, wide range of properties and adaptability to any shape and size. Concrete is the composite mix of cement, aggregates, sand and water. Concrete gets hardened like stone on mixing water with cement and aggregates. Concrete have two type ingredients namely active and inactive. The active group consists of water and cement. The inactive part consists of sand and coarse aggregates. Concrete have high compressive strength and low tensile strength. To overcome this shortcoming, steel reinforcements are used along with the concrete. This type of concrete is called reinforced cement concrete (RCC).

Developments. Earthquakes and bombarding in wars causes a lot of destruction of buildings and roads causing generation of a lot of concrete waste. In Second World War, bombardment caused demolition of buildings and roads. Transportations and reconstruction were the restrains in economy. At the same time, disposal of concrete waste was also a big problem. The idea of reusing demolished concrete as aggregates gave a solution to this problem and hence was justified as alternative material source in 1976.

Prospects in India. Indian economy is of developing nature. So the problem of demolished waste is not huge as in developed countries. But it is not far off when India may have to face this problem. In the down town areas of the metropolitan cities concrete towers are replacing the old buildings causing generation of demolished waste which needs to be transported and dumped. It is estimated that the construction industry in India generates about 10-12 million tons of waste annually. Projections for building material requirement of the housing sector indicate a shortage of aggregates to the extent of about 55,000million m^3 [chapter 4, *urbanindia.nic.in*].

Achieving Sustainability with Recycled Aggregate Concrete. Sustainability is defined as "Meeting the needs of the present without compromising the ability of the future generations to meet their own needs" (Naik 2005). The current usage of aggregate is not sustainable as demonstrated by the growing shortage of natural aggregates in urban area.

Recycling concrete, from deteriorated concrete structures, would reduce the negative impact on the environment and increase sustainability of aggregate resources (Oikonomou 2005, Hansen 1985). Use of RCA conserves virgin aggregate, decreases the impact on landfills and energy consumption, increases cost savings in the transportation of aggregate and waste products.

Barriers to Recycled Concrete Aggregate Use. There are several barriers in use of RCA in concrete. Cost of concrete crushers is very high which increases the initial cost for plant. In addition, maintenance cost of concrete crushers is also significant. Other barrier is related to quality of RCA. Highways require quality material that meets engineering, economic and environmental considerations (Turley 2003). However, where high performance concrete is not required, RCA can be used and thus, virgin aggregate can be conserved [Meyer 2008]. A lot of fine demolished concrete aggregate is created during the crushing process. This excess fine aggregate requires disposal or an alternate use. The absorption, strength, and impurities varies with the sources and type of RCA used. This means that it is unusable or that it might adversely impact the new pavement structure.

Objectives of the Study. The study on use of demolished concrete in pavement construction consists of conducting laboratory investigations on cement concrete prepared by using demolished concrete to estimate its suitability for pavement construction. The main objectives of study are:

i. To prepare mix design for M40 concrete with varying proportions of recycled aggregates.

ii. To determine the compressive strength of the samples at the end of 7, 28, 56 and 90 days.

iii. To determine the flexural strength of the samples at the end of 7, 28, and 90 days

iv. To determine the sulphate resistance strength of samples at the end of 7, 28 and 56 days.

The purpose of this research was to study the behavior of recycled coarse aggregates when it was included in Plain Cement Concrete. Slump test was performed on freshly mixed concrete, and compression test was performed on hardened concrete. 135 samples of concrete were prepared with RCA and natural aggregate, changing their mixture design parameters, including coarse aggregate proportion.

Compressive Strength. The ability to resist compression loads is called Compressive strength. It is found that the use of RCA in the concrete mix decreases compressive strength compared to natural aggregate. But it is also found that, at 28 days, all mix designs usually exceed 50MPa compressive strength (Shayan 2003). In one study it is found that the compressive strength of natural concrete was 58.6 MPa, and the RCA concrete ranged from 50.9 to 62.1 MPa. The compressive strength for 50% RCA concrete was higher than 100% RCA concrete (Poon 2002). In other study it is found that the loss of compressive strength is in the range of 30-40% for the concrete made with RCA at 28-days (Katz 2003). There was very less reduction in 28- and 56-day compressive strength when natural aggregate was partially replaced with RCA and a much greater reduction when RCA was used in full (Abou-Zeid 2005).

The compressive strength is most affected by the w/c ratio (Lin 2004). Other influential parameters include fine recycled aggregate content, cleanness of aggregate, interaction between fine recycled aggregate content and crushed brick content, and interaction between w/c ratio and coarse RCA content (Lin 2004). At a constant w/c ratio, air-dried RCA containing concrete had the highest compressive strength compared to oven-dried and saturated surface dry RCA (Poon 2003). Particularly at lower w/c ratios, unwashed RCA reduces compressive strength. Compressive strength is 60% of virgin concrete at 0.38 w/c and 75% at 0.6 w/c (Chen 2003).

In a study it is found that there is a strong interaction between maximum aggregate size and water-cement ratio when compared with compressive strength development (Tavakoli 1996a). Due to a lower w/c ratio Compressive strength may increase for RCA, 14% and 34% respectively in comparison of natural aggregates. However, compressive strength may decrease for RCA since it has a higher air entrainment, 25%, compared to virgin aggregate 23% (Salem 2003). The most of strength loss for RCA concrete can be caused by the presence of material smaller than 2 mm because natural sand has greater strength than RCA fines. It is recommended that RCA fines should not be more than 50% of the sand content (Shayan 2003). Bonding between the RCA and the cement can be affected by loose particles created during the crushing process. Treating the RCA by impregnation of silica fume resulted in an increase in compressive strength of approximately at 30% at 7-days and 15% at 28-days. If RCA is exposed to ultrasound then it results in a uniform increase of 7% compressive strength over time (Katz 2004). Compressive strength of the final concrete is affected by the age at which RCA has been crushed. For example, crushing concrete into RCA after three days compared to one day resulted in a seven percent increase in compressive strength of the new RCA concrete at 7 days. The difference in compressive strength of the new RCA concrete increased to 13% at the age of 90 days (Katz 2003). The compressive strength of the original crushed concrete affects the compressive strength of the RCA concrete (Tavakoli 1996a).

However, it is also found that RCA concrete can produce higher compressive strengths than the original concrete. For example, an 80 MPa concrete was produced from an original 60MPa concrete (Ajdukiewicz 2002). There was the same basic trend in all strength development when laboratory made RCA and field demolished RCA were compared (Tavakoli 1996a). Presence of admixtures in the original concrete had not much impact on the compressive strength of the new RCA concrete (Hansen 1984). Slag added RCA concrete develops strength over a longer period of time compared to normal concrete (Sagoe-Crentsil 2001). Some research showed that compressive strength is dependent on the amount of time the RCA spent in the stockpile after crushing (Rashwan 1997). For example, concrete made with RCA that was in the stockpile one day had a 25% higher compressive strength than concrete made with RCA that was in the stockpile 28 days. Concrete made with RCA that was in the stockpile seven days had 7% lower compressive strength than concrete that was in the stockpile 28 days (Rashwan 1997). If RCA concrete is exposed to $600^{\circ}C$ temperature then it showed good performance with a loss in compressive strength of 20-25% (Abou-Zeid 2005). In s study it is also found that RCA concrete fails due to passage of cracks through the RCA, however when virgin concrete fails it is usually due to bond failure at the aggregate-paste interface (Salem 2003

II. MATERIALS AND METHOD

The methodology of the present study follows Indian Standard code IS: 516- 1959. Testing of strengths of concrete was carried out as per this code. Concrete mix design guidelines were as per IS: 10262-2009.

Preparation of Material. All the materials should be taken at room temperature before going for batching and mixing. Materials are taken separately to ensure the avoiding the mixing of foreign material in them. Materials should be taken in such a way as to produce a mix of desired grading. Sieves should be used to separate the fine aggregates and coarse aggregates.

Proportioning. Proportioning of the material should be done as per design mix. Proportions of the materials were decided as per weight used in test cubes and unit weight of materials.

Mixing of Concrete. Mixing of concrete should be done either by hand mixing or by machine mixing. In the present study, machine mixing was used for mixing of concrete. Power driven mixer was used for mixing the materials. All the mixing water was added to mixing drum before introducing the solid materials. Half of the coarse aggregate was added to drum, then fine aggregate was added following the addition of cement and at the last remaining coarse aggregate was added to drum. Mixing time was not taken more than 2 minutes after adding the materials to drum and mixing is continued till uniform concrete was appeared.

Size of the Test Specimens. Moulds of cast iron were used to cast test samples, in shape of cube. Dimensions of cube were 150mm×150mm×150mm.

Casting of Specimens. Cubic moulds were well cleaned before pouring concrete in them. Mould oil was applied to inner sides of mould to avoid the sticking of concrete to sides of mould. Side plates were tightly assembled after application of mould oil between the joints. Concrete was poured in them and tamped with tamping rod.

Compacting of Concrete Samples. Compacting of concrete was done by table vibrator. Vibrating was done till desired compaction was reached

Compressive Strength. The dried cubes were tested at the age of 7, 28, 56 and 90 days. The cubes were tested on compression testing machine (CTM) after drying at room temperature as per IS: 516-1959. The load was applied at rate of 350MPa/minute in a uniform and continuous manner. Impacts were prevented during the application of load. Application of load was kept continued until the sample failed and maximum load carried by the sample was recorded. Three samples for each test reading were tested. Final value of test is taken as an average of three samples.

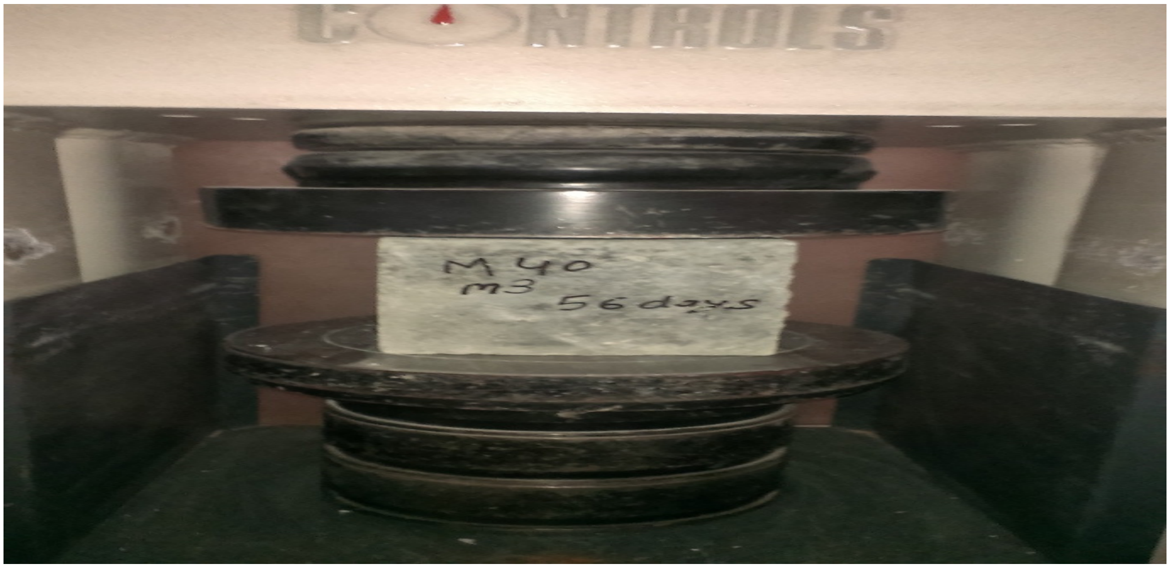

Fig. 1. Test for Compression Strength in CTM.

III. RESULTS AND DISCUSSION OF REULTS

Testing of sample was done at 7, 28, 56 and 90 days for compressive strength. For flexural strength testing of samples was done at 7, 28 and 90 days. Testing for sulphate resistance was
Table 1 gives the test done at 7, 28 and 56 days. In this chapter, results of these tests are discussed along with the results of workability

Variation of Compressive Strength with Age. Results of compressive strength at 7, 28, 56 and 90 days. Water cement ratio was kept as 0.38 for all mixes. Super plasticizer used was 0.6% of cement. Table 2 gives the percentage reduction in compressive strength for all mixes at different number of days.

Table 1: Test Results for Compressive Strength.

S.No.	Mix	W/C	Compressive strength (MPa)			
			7 Days	28Days	56 Days	90 Days
1.	m0	0.38	42.43	50.06	51.20	51.8
2.	m1	0.38	42.47	50.36	50.89	51.23
3.	m2	0.38	41.84	50.20	50.68	50.80
4.	m3	0.38	42.60	49.11	50.68	51.4
5.	m4	0.38	40.27	52.36	53.24	53.26

Table 2: Percentage Reduction in Compressive Strength at Different Ages.

S.No.	Mix	Age (in days)	%age Reduction in Compressive Strength				
			m0	m1	m2	m3	m4
1.	1:1.23:2.52	7	-	100.1	98.6	100.4	95
2.	1:1.23:2.52	28	-	100.5	100.3	98.1	104.5
3.	1:1.23:2.52	56	-	99.4	98.8	98.9	106
4.	1:1.23:2.52	90	-	98.8	98	99.2	104

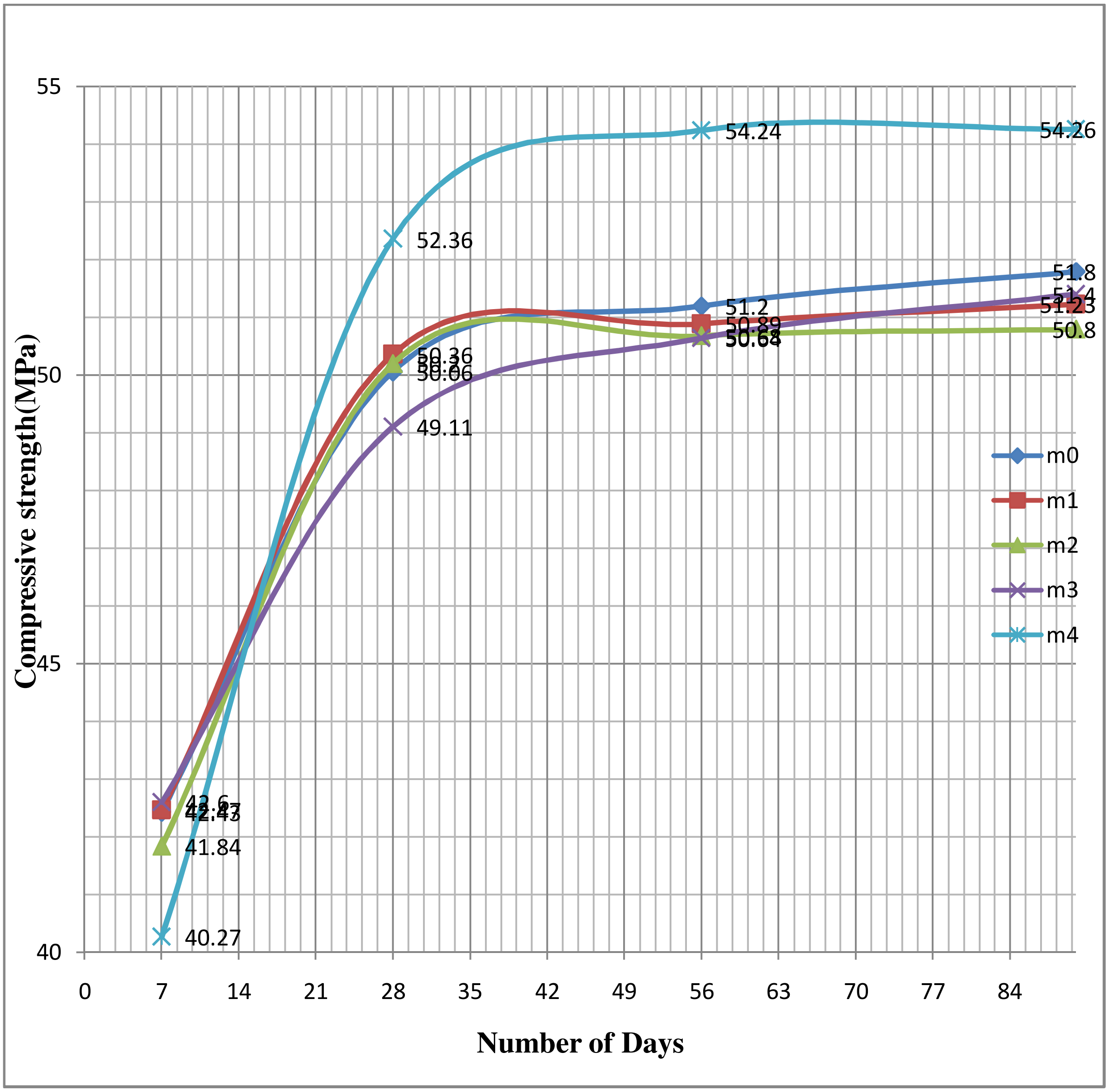

Fig. 2. Comparison of Compressive Strength of all Five Mixes with Age of 7, 28, 56 and 90 Days.

Fig. 2 shows the comparison of compressive strength of different mixes at 7, 28, 56 and 90 days.

Fig. 3 to Fig. 6 show the variation of compressive strength at 7days, 28 days, 56 days and 90 days with different mixes used in tests. The results showed fluctuations from mix to mix. In case of m4, it was observed that the compressive strength was suddenly increased as compared to other mixes.

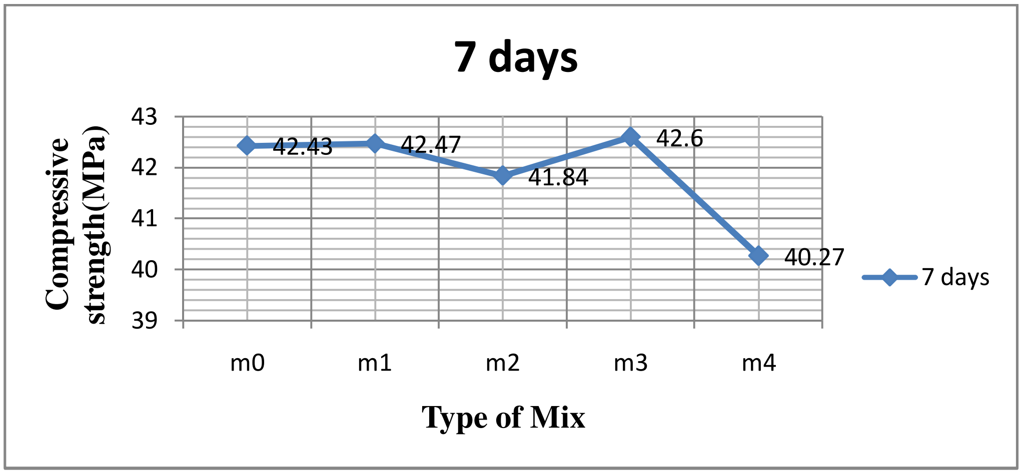

Fig. 3. Variation of Compressive Strength at 7days with Five Mix Used.

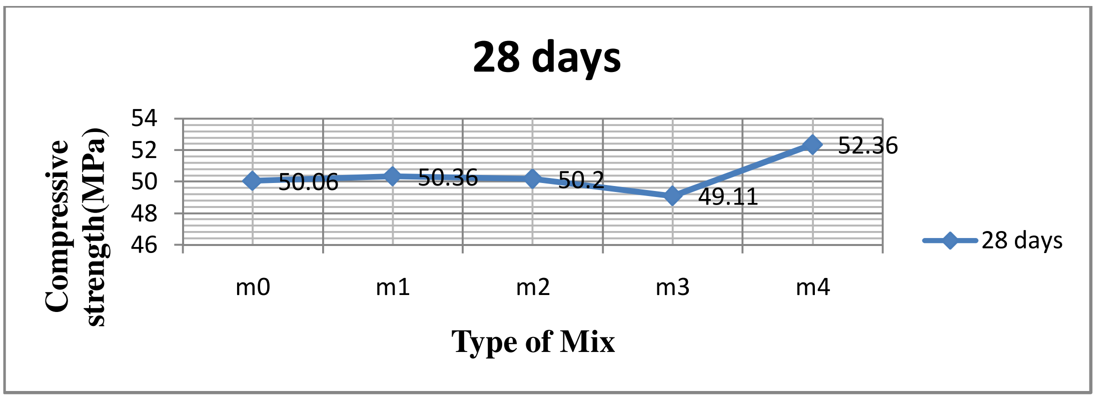

Fig. 4. Variation of Compressive Strength at 28 Days with Five Mix Used.

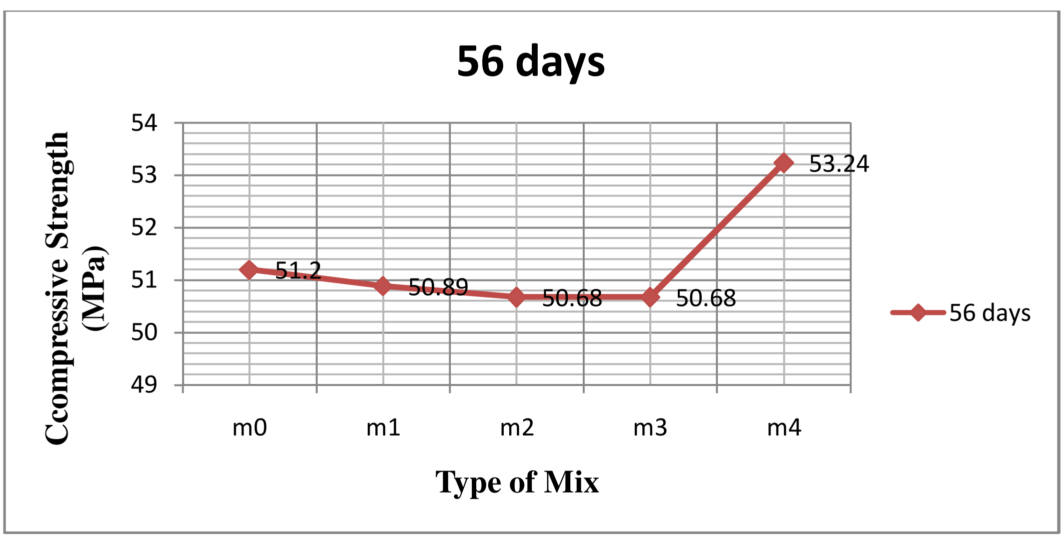

Fig. 5. Variation of Compressive Strength at 56 Days with Five Mix Used.

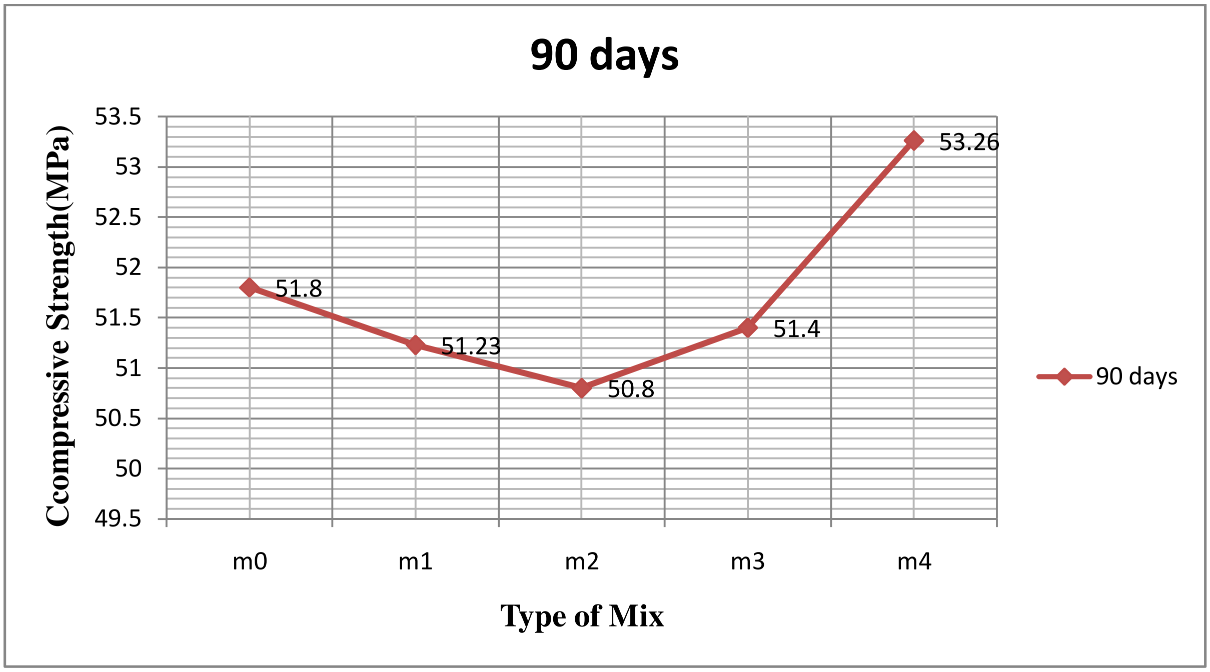

Fig. 6. Variation of Compressive Strength at 90 Days with Five Mix Used.

IV. CONCLUSIONS AND RECOMMENDATIONS

The research on usage of RCA in construction of pavement is very important because material waste is gradually increasing with the increase in urban development and increase in population. Recycled aggregates are easily available while natural aggregates need mining and their cost is much higher than the cost of natural aggregates. Recycled aggregates are cheaper than the virgin aggregates, so builders can easily afford these for construction purpose if their strength is equal or comparable to natural aggregates.

The study examines the properties of RCA when used with natural coarse aggregates. A lot of studies have been carried out on use of RCA concrete in construction. But in case of highway construction some more investigation is required. The main objective of the study was to investigate whether RCA can be used as material aggregates for concrete pavement construction. Compressive strength, flexural strength and sulfate resistance of RCA concrete is examined, where it was observed that mixing of RCA cause increased water absorption. To avoid this, super plasticizer is used to reduce the cement consumption. Concrete mix of M40 was designed as per properties of aggregates. The results of this study showed that RCA concrete gave comparable strength to conventional concrete. This indicated that RCA concrete can be viable source for construction of pavements. From the results, it is also found that workability of concrete is decreased due to higher water absorption. Whenever recycled aggregate is applied, water content is monitored carefully in concrete mix as water absorption is increased due to presence of porous mortar. In this study, super plasticizer (0.6% of cement) is used to overcome this problem.

Following conclusions can be drawn from results and discussion of results from the study:

i. The compressive strength of all mixes exceeded at the age of 28 days. Compressive strength of control mix i.e. of m0 is 50.05 MPa which is greater than the target strength of 48.25 for M40 concrete. Compressive strength of m1 is slightly increased to 50.36. So the compressive strength increases by 0.5%. For m2, compressive strength is increased to 50.20 MPa, it also showed an increase in compressive strength by 0.3%. Compressive strength of m3 is decreased to 49.11 MPa that showed a decrease in compressive strength by 1.9%. But in case of m4, there is sudden increase in compressive strength that raises the compressive strength to 52.36 MPa. Compressive strength is increased by 4.5%. So the results of test show that compressive strength does not follow a regular trend from m0 to m4. But from the results it is also concluded that compressive strength never went below the target strength for 28 days. This indicates that RCA can be used as replacement aggregates for compressive strength.

ii. Flexural strength also followed the same pattern as of compressive strength.

Flexural strength of control mix is 5.32MPa at age of 28 days. Flexural strength of mix m1 increased to 5.60 MPa.
It shows that the increase in flexural strength is 5% for m1. For m2 flexural strength at age of 28 days is 5.40MPa, which shows an increase in flexural strength by 1.5%. Flexural strength of mix m3 is 5.38 and the flexural strength increased by 1 %. For the mix m4, flexural strength is 5.40 MPa. It shows that the flexural strength increased by 1.5 % at the age of 28 days. From the results and discussion of the results it is found that the flexural strength of RCA concrete is comparable to the natural aggregate concrete which is a positive point. So the RCA concrete can be used for flexural strength by adjusting W/C ratio.
iii. Use of 5% of $MgSO_4$ solution caused the reduction in compressive strength. The compressive strength of RCA mixed concrete reduced upto 7%. Effect of sulphate solution increased when quantity of demolished concrete aggregate increased. This study showed that the strength of m4 at 56 days was most affected. So with increase in sulphate caused reduction in compressive strength of concrete.
iv. It was found that the RCA concrete have relatively lower bulk density, specific gravity and high water absorption as compared to natural concrete. This was due to the presence of mortar in present on recycled coarse aggregates.
v. In this study, trial castings were done to arrive at water content and desired workability. So it was advisable to carry out trial castings with demolished concrete aggregate proposed to be used in order to arrive at the water content and its proportion to match the workability levels and strengths requirements respectively.
vi. From this study it was observed that the demolished concrete was viable source for construction of concrete pavements. Economical and environmental pressures justify suitability of RCA concrete as alternative to the natural concrete. Where there is non-availability of natural aggregate from new rocks RCA can be a good or viable replacement option for natural coarse aggregate in pavement construction.

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