Everant Journals/ETJ
Research Article
Engineering and Technology Journal ISSN: 2456-3358
Impact Factor: 4.449

# Strengthening of Subgrade Soil by Using Crushed Concrete

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| ARTICLE INFO | ABSTRACT |
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| Corresponding Author: **Hitesh[1]** Post graduate student, Department of Civil Engineering ,GIET, Sonipat | Recycled aggregates consist of crushed, graded inorganic particles processed from the material that have been used in the constructions and demolition debris. The target of the present work is to determine the strength characteristic of recycled aggregates for the application in concrete pavement construction. The investigation was carried out by using workability test, compressive strength test, flexural strength test and sulphate resistance test. A total of five mixes with replacement of coarse aggregates with 0%, 10%, 20%, 30% and 40% recycled coarse aggregates were studied. The water cement ratio was kept constant at 0.38. It was observed that workability of concrete was decreased with the increase in recycled aggregates in 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 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).

Concrete structures that are designed to have service lives of at least 50 years have to be demolished after 20 or 30 years because of deterioration caused by many agents. Old buildings require maintenance for better and higher economics gains. The rate of demolition has increased

and there is a shortage in dumping space and also increase in cost of dumping. Instead of dumping this demolished concrete, use of demolished as recycled concrete would not only reduce the cost but also will conserve the non renewable energy sources. The use of demolished concrete will further result in reduction in use of natural aggregates.

## EXPERIMENTAL PROGRAMME

### General

Mix design is done to select the mix material and their required proportions. There are a lot of methods to determine the mix design. The methods used in India are in compliance with Bureau of Indian Standards (BIS). The motive of mix design is to determine the proportion in which concrete ingredients like cement, water, fine aggregates and coarse aggregates should be mixed to provide specified strength, workability, durability and other specified requirements as listed in standards such as IS: 456-2000. The designed concrete mix must define the material and strength, workability and durability to be attained. Concrete mix design guidelines are given in IS: 10262-1982. In the study, 5 batches of mixes were prepared. These batches were designated as m0, m1, m2, m3 and m4. Batch m0 was taken as control mix. The natural coarse aggregate was replaced by recycled aggregate in proportion of 0%, 10%, 20 %, 30% and 40% in m0, m1, m2, m3, and m4 respectively as given in table 1.

**Table 1 Proportions of Natural and Recycled Aggregates in Batches**

| Type of Mix Used | Recycled Aggregate (%) | Natural Aggregate (%) |
|---|---|---|
| m0 | 0 | 100 |
| m1 | 10 | 90 |
| m2 | 20 | 80 |
| m3 | 30 | 70 |
| m4 | 40 | 60 |

## MATERIAL PROPERTIES

The physical and mechanical properties of all ingredients like sand, natural coarse aggregates, cement and demolished coarse aggregates are per IS: 2386-1963 were determined.

### Cement

OPC (Ordinary Portland Cement) of grade 43 was used which conformed to IS: 8112-1989. Testing of cement was done as per IS: 4031-1968.

### Natural Fine Aggregates

Natural coarse sand was used as fine aggregate. The sand conformed to zone II as per IS: 383-1970.

### Natural Coarse Aggregates

Coarse aggregates of size 10mm and 20mm were used.

### Water

Properties of water used were as per clause no. 5.4 of IS 456-2000. It was free from deleterious materials. Water was used for mixing and curing of concrete. Portable water is generally taken for mixing and curing of concrete.

### Mix Proportion

As per design of concrete mix M40, the ratio of cement, fine aggregate and coarse aggregate was taken as 1:1.23:2.52 respectively.

### Sizes of Moulds

**Table 2**

| S.No. | Moulds | Size(mm×mm) | Specimen Casted |
|---|---|---|---|
| 1. | Cube | 150×150×150 | Compressive Strength |
| 2. | Beam | 100×100×500 | Flexural Strength |
| 3. | Cube | 150×150×150 | Sulfate Resistance |

### Number of Samples Casted

**Table 3**

| Type of Mix | For Compressive Strength | For Flexural Strength | For Sulphate Resistance | Total |
|---|---|---|---|---|
| m0 | 12 | 9 | 6 | 27 |
| m1 | 12 | 9 | 6 | 27 |
| m2 | 12 | 9 | 6 | 27 |
| m3 | 12 | 9 | 6 | 27 |
| m4 | 12 | 9 | 6 | 27 |
| Total | 60 | 45 | 30 | 135 |

## 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 done at 7, 28 and 56 days. In this chapter, results of these tests are discussed along with the results of workability.

### Workability

Workability varied with change in proportion of demolished aggregates. The slump values and compaction factor values did not show a uniform pattern as the percentage of demolished aggregates was uniformly varied. Figure 1 gives the variation of slump values versus type of mixes. Figure 2 gives the variation of compaction factor versus type of mixes.

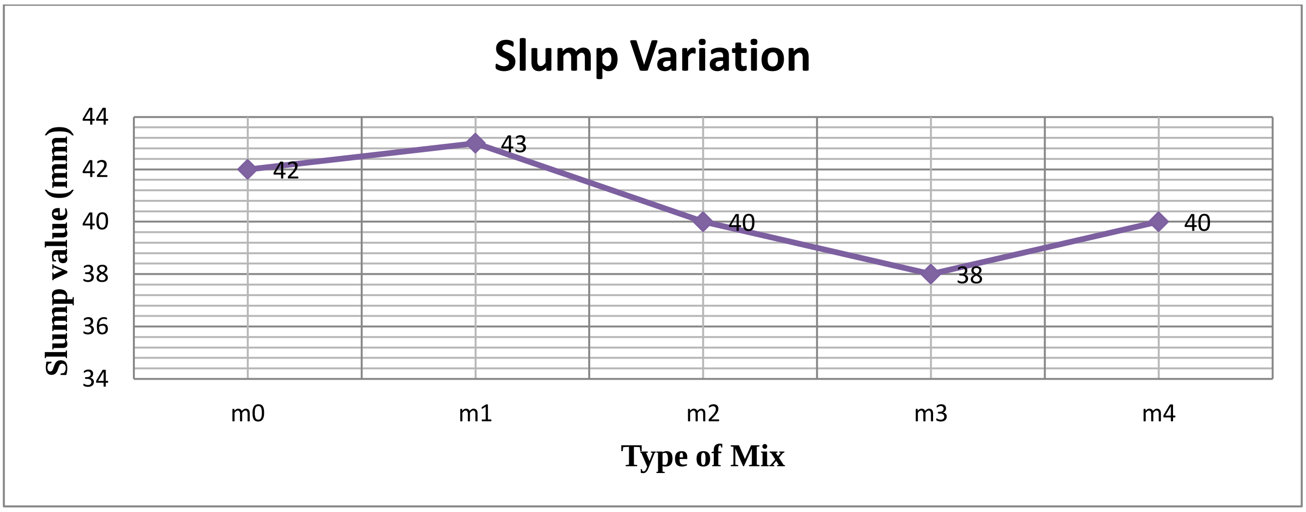


**Figure 1**. Variations of Slump Values with Type of Mix Used

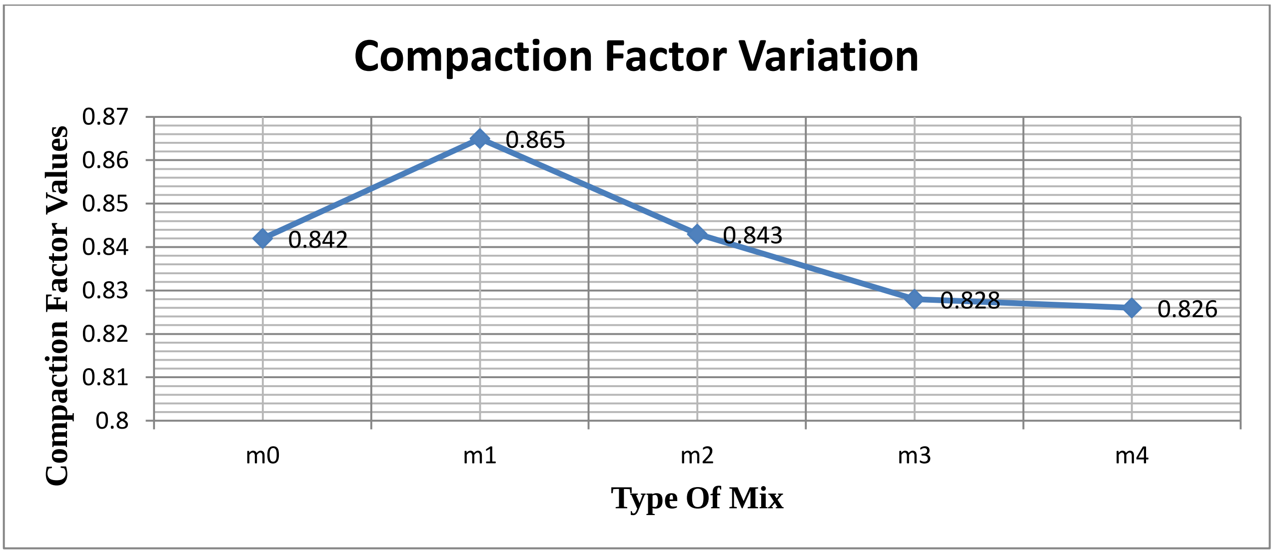


**Figure 2.** Variations of Compaction Factor Values with Type of Mix Used.

### Variation of Compressive Strength with Age

Table 4 gives the test 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 5 gives the percentage reduction in compressive strength for all mixes at different number of days.


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**Table 4. 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 5. 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 |

Figure 3 shows the comparison of compressive strength of different mixes at 7, 28, 56 and 90 days.

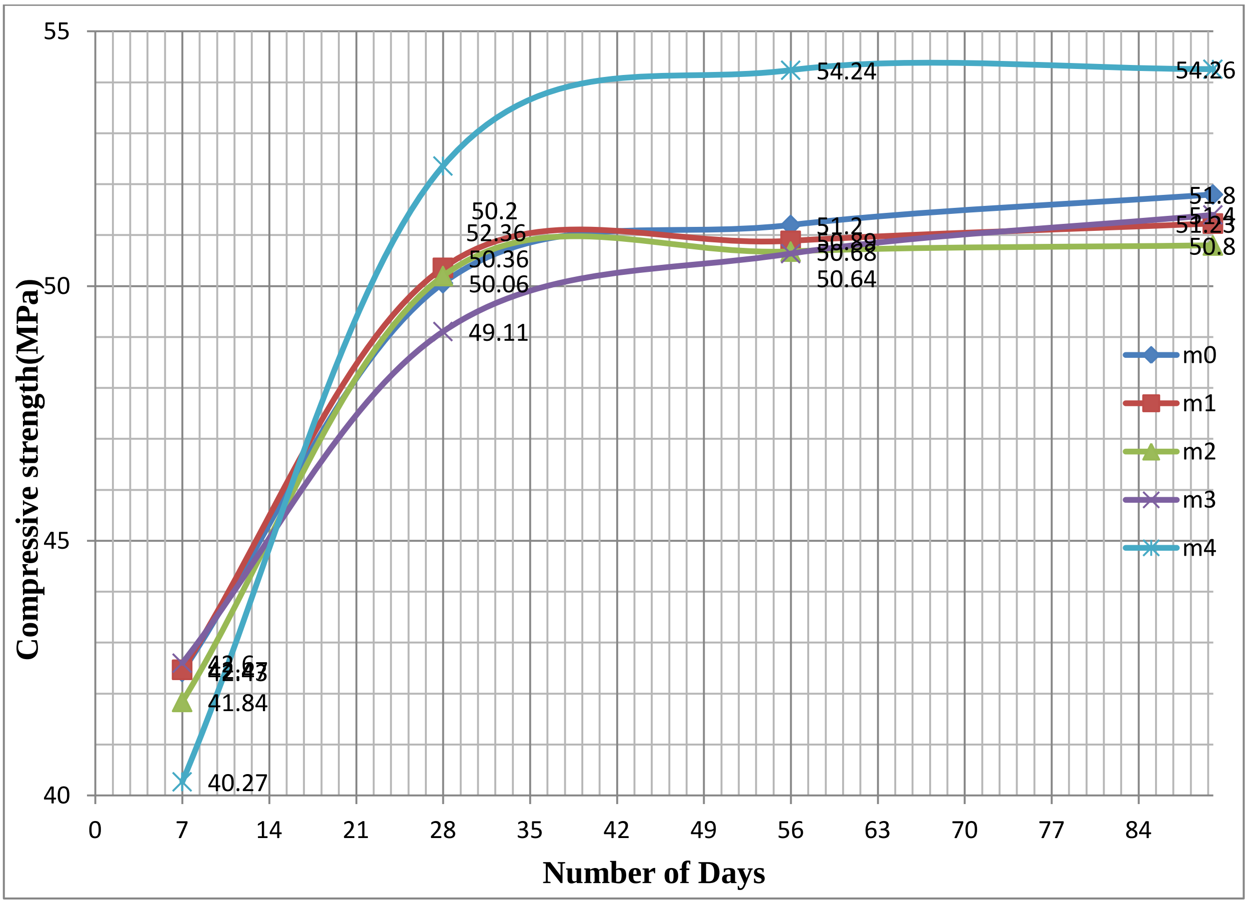


**Figure 3.** Comparison of Compressive Strength of all Five Mixes with Age of 7, 28, 56 and 90 Days.

Variation of Flexural Strength with Age

Table 6 gives the test results of flexural strength at 7, 28, and 90 days. The results of flexural strength are the average of 3 beams. Table 7 shows the percentage reduction in flexural strength for all mixes at different ages. Figure 4 shows the comparison of flexural strength at ages of 7,28 and 90 days.

**Table 6. Results of Flexural Strength**

| S.No. | Mix | W/C | Flexural strength (MPa) | | |
|---|---|---|---|---|---|
| | | | 7 Days | 28Days | 90 days |
| 1. | m0 | 0.38 | 4.20 | 5.32 | 5.64 |
| 2. | m1 | 0.38 | 4.31 | 5.60 | 5.67 |
| 3. | m2 | 0.38 | 4.10 | 5.40 | 5.8 |
| 4. | m3 | 0.38 | 4.12 | 5.38 | 5.62 |
| 5. | m4 | 0.38 | 4.22 | 5.40 | 5.58 |

**Table 7 Percentage Variation of Flexural Strength at Different Ages.**

| S.No. | Mix | Age (in Days) | % age Reduction in Flexural Strength | | | | |
|---|---|---|---|---|---|---|---|
| | | | m0 | m1 | m2 | m3 | m4 |
| 1 | 1:1.23:2.52 | 7 | - | 102.6 | 97.6 | 98.06 | 100.47 |
| 2. | 1:1.23:2.52 | 28 | - | 105.26 | 101.5 | 101 | 101.5 |
| 3. | 1:1.23:2.52 | 90 | - | 100.5 | 102.8 | 99.64 | 98.9 |

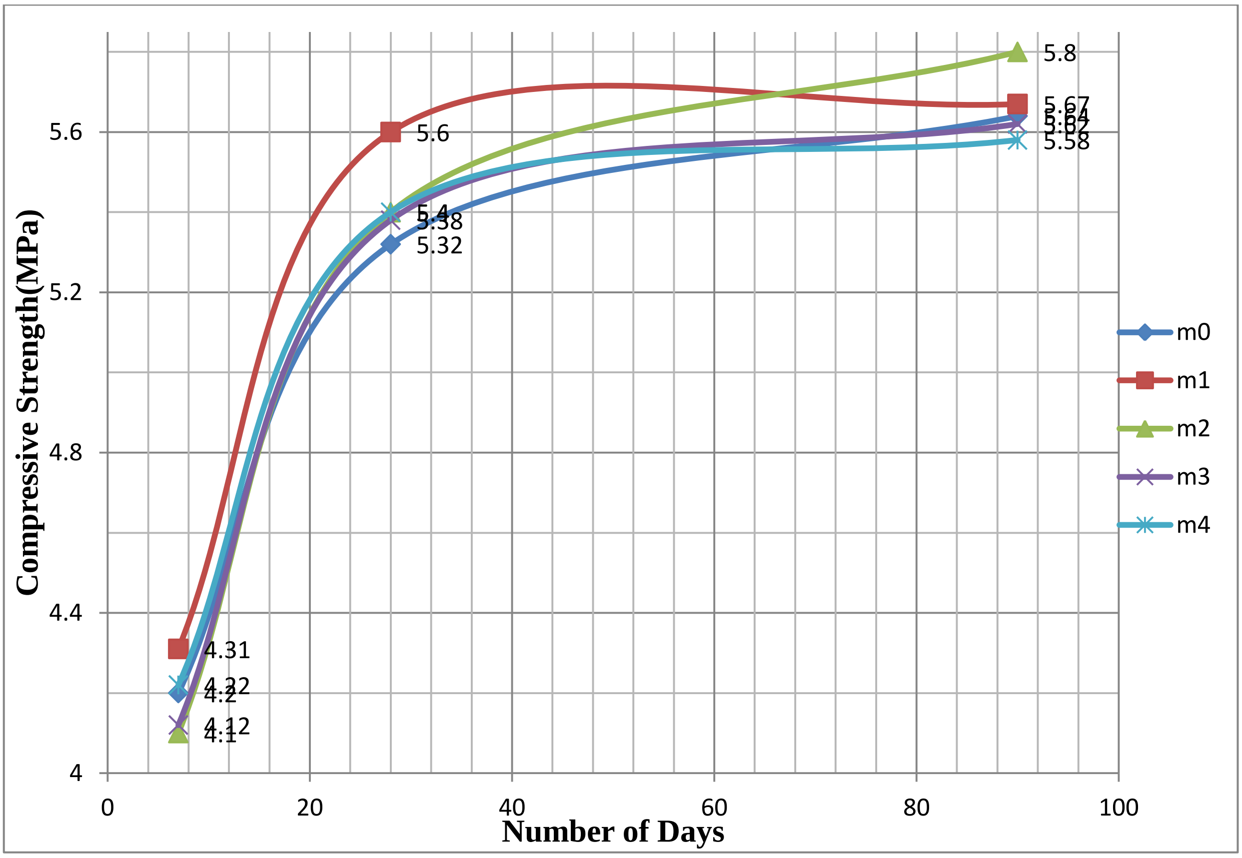


**Figure 4.** Comparison of Flexural Strength of all Mixes at 7, 28 and 90 days.

**Sulphate Resistance of RCA Concrete**

In this section of study, effect of sulphate solution on compressive strength of RCA concrete was investigated. Concrete cubes were kept in $MgSO_4$ (magnesium sulfate) solution for 7, 28 and 56


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days after normal curing for 28- days. Compressive strength of cubes was checked by using CTM. Table 8 gives the test results at age of specified number of days. Table 9 gives the details of percentage reduction in compressive strength at the age of specified number of days.

**Table 8 Test Results for Sulphate Resistance**

| S.No. | Mix | Type Of Solution | Compressive Strength(MPa) | | |
|---|---|---|---|---|---|
| | | | 7 Days | 28 Days | 56 Days |
| 1. | m0 | 5%of $MgSO_4$ | 41.75 | 48.74 | 48.3 |
| 2. | m1 | 5%of $MgSO_4$ | 41.79 | 49.05 | 49.23 |
| 3. | m2 | 5%of $MgSO_4$ | 38.8 | 48.26 | 47.62 |
| 4. | m3 | 5%of $MgSO_4$ | 41.8 | 45.6 | 49.03 |
| 5. | m4 | 5%of $MgSO_4$ | 39.53 | 50.73 | 49.38 |

**Table 9. Percentage Reduction of Compressive Strength Due To Sulphate Attack**

| S.No. | Mix | Type of solution | % age reduction in compressive strength | | |
|---|---|---|---|---|---|
| | | | 7 Days | 28 Days | 56 Days |
| 1. | m0 | 5%of $MgSO_4$ | 98.42 | 97.38 | 94.3 |
| 2. | m1 | 5%of $MgSO_4$ | 98.4 | 97.4 | 96.08 |
| 3. | m2 | 5%of $MgSO_4$ | 92.73 | 96.13 | 93.96 |
| 4. | m3 | 5%of $MgSO_4$ | 98.2 | 92.85 | 95.4 |
| 5. | m4 | 5%of $MgSO_4$ | 98.17 | 96.9 | 92.75 |

Figure 5 gives the comparison of compressive strength of all mixes kept in $MgSO_4$ solution at the age of 7,28 and 56 days.

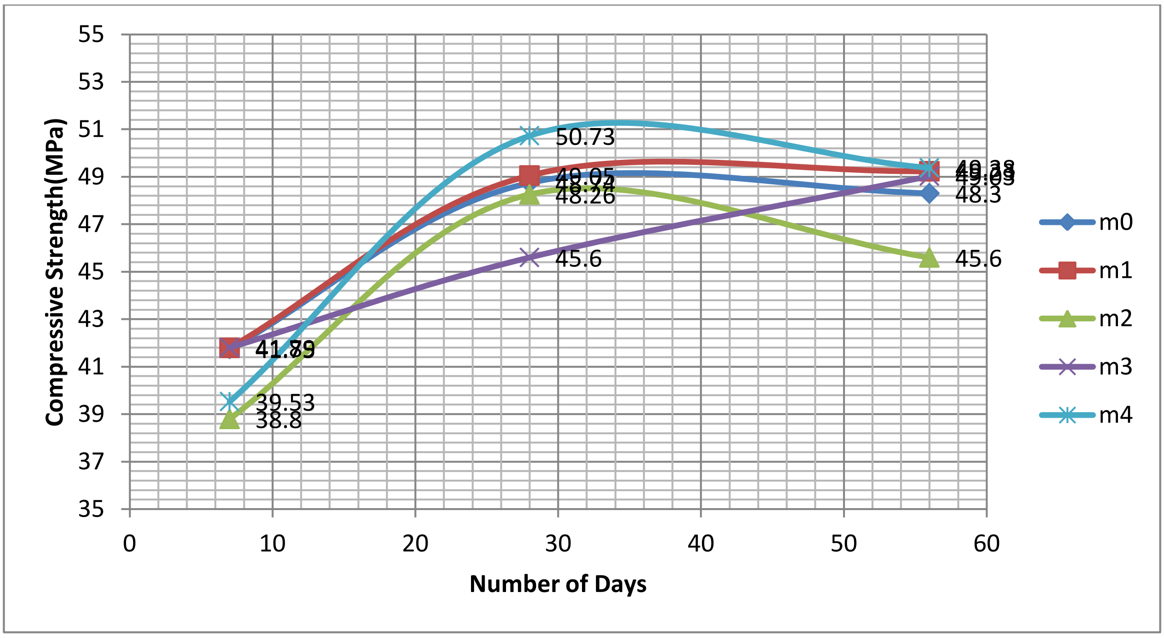


**Figure 5**. Comparison of Compressive Strength of all Mixes Kept in $Mgso_4$ Solution at the Age of 7, 28 And 56 Days.

## CONCLUSIONS

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

1. The compressive strength of all mixes exceeded at the age of 28 days. Compressive strength of control mix i.e. of


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DOI: 10.18535/etj/v2i12.04
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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.

2. 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.
3. 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.
4. 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.
5. 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.
6. 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.

From above conclusions it can be said that it is eco-friendly and creative to use demolished concrete in construction of concrete pavements.


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