# Effect of Sulphate Solution on Recycled Aggregate Concrete

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***Abstract*--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. Natural aggregate used in concrete, is being used faster than it is being produced, creating a shortage in the future. Despite this, the demand of demolished concrete for use as recycled coarse aggregate (RCA) in concrete is increasing. Using this demolished waste concrete as recycled coarse aggregate conserves natural aggregate, reduces the effect on landfills, lowers energy consumption and save cost. However, there are still many doubts on the use of RCA in concrete pavements. This research shows the effects of sulphate solution ($MgSO_4$) on concrete made with recycled coarse aggregate. Five mixes were prepared using the various proportions of recycled coarse aggregates i.e. 0%, 10%, 20%, 30%, 40%., keeping the other ingredients constant. Super plasticizer (0.6% of cement) [3] is used to reduce water cement ratio to 0.38. At 28-days, all of the five mixes exceed the 48 MPa design compressive strength. Testing showed that the mixes containing RCA showed similar or improved performance when compared to the conventional concrete for sulphate attack.**

***KEY WORDS: RCA, MPa***

## 1. INTRODUCTION

There is a shortage of natural aggregate and an increment of demolished concrete. The current usage of concrete is not sustainable due to the increased shortage of natural aggregates in urban area. 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 $m^3$ [4]. An additional 750 million $m^3$ aggregates would be required for achieving the targets of the road sector. Recycling of aggregate material from construction and demolition waste may reduce the demand-supply gap in both these sectors. 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 early deterioration. The cost of quality aggregate has increased above the inflation rate and it is projected that this trend will continue as further restrictions are placed on this resource in the future. Not only is there the environmental impact of transporting the waste concrete but the waste concrete also fills up valuable space in landfills. Due to ill effects of waste concrete with space and cost, traditional disposal of concrete in landfills is no longer an acceptable choice. Use of RCA, saves the cost in the transportation of aggregate and waste products, and in waste disposal. There are some barriers also in using RCA. Highways require quality material that meets engineering, economic and environmental considerations. However, where high-performance concrete is not required, RCA can be used and virgin aggregate conserved. The use of material specifications are a barrier to the use of RCA concrete. A performance-based or end result specification would allow more RCA use. However, specific standards on how to use RCA in new concrete are not currently available



## 2. OBJECTIVES OF THE STUDY

The present study involves laboratory investigations on use of demolished concrete in construction. The main objectives of study are:

1. To highlight the current issues associated with using RCA.
2. To determine the compressive strength of RCA concrete at the age of 7,28 and 56 days.
3. To determine the effect of $MgSO_4$ solution on compressive strength of recycled aggregate concrete.
4. To demonstrate advantages of using a performance based specification as compared to a prescriptive specification for both the conventional concrete and the concrete with recycled concrete aggregates.

## 3. METHODOLOGY

A concrete mix M40 was designed as per the physical properties of aggregates. Physical properties of aggregates are given in table 1.

Table 1: Physical properties of aggregates

| Properties | Natural aggregates | | Recycled aggregates |
|---|---|---|---|
| | Coarse | Fine | Coarse |
| Shape and texture | 100% crushed faces | 100% crushed faces | 100 % crushed faces |
| Specific gravity | 2.68 | 2.65 | 2.5 |
| Water absorption | 0.9 | 1.85 | 1.5 |
| Fineness modulus | 7.3 | 3.1 | 6.8 |

Using these physical properties of aggregates M40 mix was designed as per IS 10262-2009[2]. Water cement ratio is 0.38 with super plasticizer (0.6% of cement).

The mix design ratio comes out to be 1:1.23:2.52 for cement, fine aggregates and coarse aggregates respectively.

## 4. EXPERIMENTAL

Before going to compressive strength, workability of concrete was checked by slump test and compaction factor test. Workability was decreased as proportion of RCA is increased. Slump value and compaction factor

After this five batches were prepared with varying proportion of recycled coarse aggregates with increasing amount of 10% in each batch. They were designated as m0, m1, m2, m3 and m4 with RCA proportion of 0%, 10%, 20%, 30% and 40% respectively. All other ingredients of concrete were kept constant in each batch.

value were decreased due to higher water absorption [1] in case of RCA concrete. Table 2 gives the detailed comparison of slump values and compaction factor values.



Table 2: Slump value and Compaction factor

| Mix | W/C | Super Plasticizer (% of Cement) | Slump Value(Mm) | Compaction Factor |
|---|---|---|---|---|
| mo | 0.38 | 0.6 | 42 | 0.842 |
| m1 | 0.38 | 0.6 | 43 | 0.865 |
| m2 | 0.38 | 0.6 | 40 | 0.843 |
| m3 | 0.38 | 0.6 | 38 | 0.828 |
| m4 | 0.38 | 0.6 | 40 | 0.826 |

Compressive strength: Compressive strength of concrete was checked at age of 7,28 and 56 days. Concrete cubes of 150*150*150 $mm^3$ were prepared and compressive strength was determined after keeping the cubes in sulphate solution for 28 days.

The strength of recycled aggregate concrete was compared with strengths of natural aggregates concrete.

## 5. RESULTS

Effect of sulphate solution on compressive strength of RCA concrete was investigated. Compressive strength of concrete made with recycled concrete aggregate was determined. After this concrete cubes were kept in $MgSO_4$ (magnesium sulfate) solution for 7, 28 and 56 days after normal curing for 28- days. Compressive strength of cubes was determined by using compression testing machine (CTM). Table 3 gives the results for compressive strength for recycled concrete aggregates. Table 4 gives the test results of compressive strength after curing in sulphate

solution. Table 5 gives the details of percentage reduction in compressive strength at the age of specified number of days.

Table 3 Results for Compressive Strength of RCA Concrete

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

Table 4 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 5 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 1 gives the comparison of compressive strength of all mixes kept in $MgSO_4$ solution at the age of 7, 28 and 56 days.

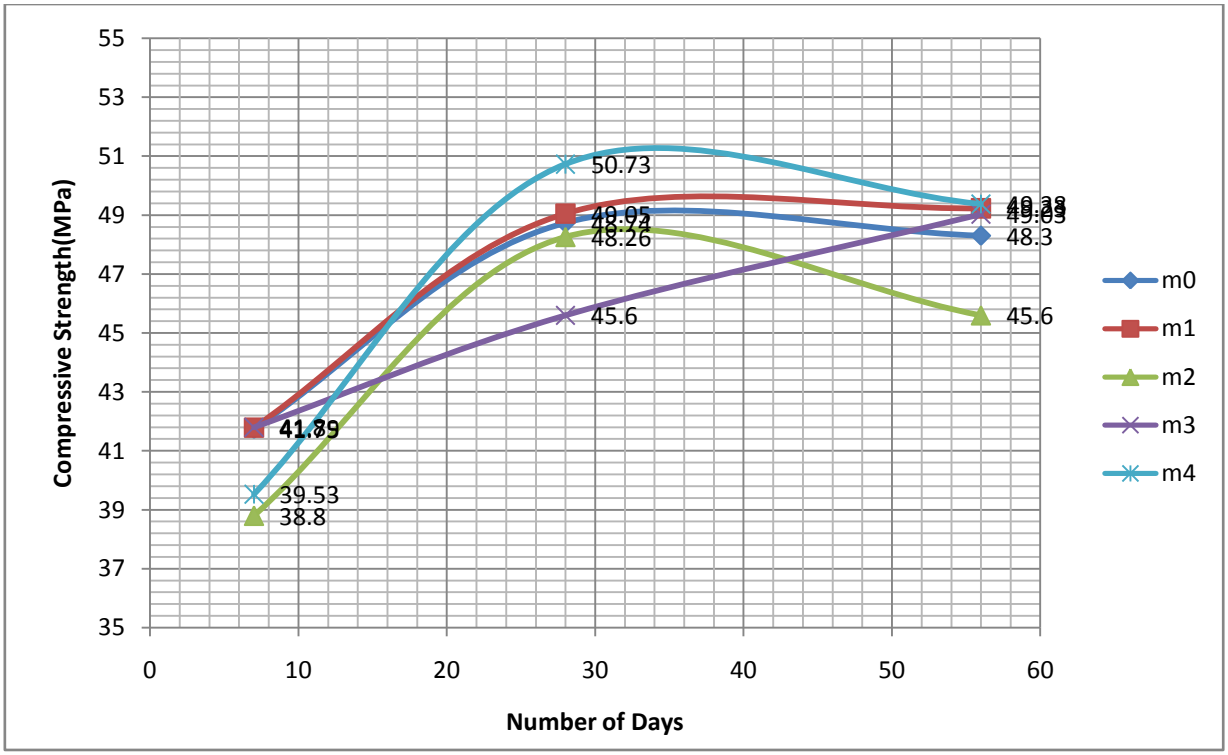


Figure 1 Comparison of Compressive Strength of All Mixes Kept in $Mgso_4$ Solution at the Age of 7, 28 and 56 Days

The results for sulphate resistance of concrete showed that the compressive strength of concrete was decreased by 3% in case of control mix and 3-7% in case of RCA concrete. At the age of 56 days, compressive strength of m4 was reduced to 92.75%.

## 6 CONCLUSIONS

1. This study examined the compressive and flexural strengths of RCA concrete at 7 and 28 days and compared the strength with control mix with natural aggregates.
2. The strengths showed a very less fluctuation between the mixes.
3. 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.
4. 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.
5. From this study it was observed that the demolished concrete was viable source for concrete constructions. 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 concrete constructions.

## 7. REFERENCES

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