# Strength & Durability Parameter of Recycled Concrete Aggregate

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## Abstract

In this research the strength and durability parameters of recycled aggregates are studied to determine the optimum quantity of recycled aggregates that can be used as substitute for natural aggregates without affecting the strength of concrete. Compression test, Water penetration Test and Rapid Chloride penetration test were conducted on specimens of Grade M40, M50 and M60 with 0, 40, 60 and 80 % of replaced aggregates. For compression test the cube was cured for 28, 56 and 90 days, and for durability test (Water penetration Test and Rapid Chloride penetration test) cube was cured for 28 days. The result is obtained and compared with that of natural coarse aggregate. It is found that use of recycled aggregates does not decrease the strength of concrete substantially.
**Keywords: Recycled Aggregate, Durability Parameters of Recycle Concrete, Compressive Strength of Recycle Concrete, Water Penetration, RCPT**

## I. INTRODUCTION

The construction industry is one among the greatest and most energetic sectors in world. The weight of this activity is indicated on the environment. The construction sector consumes a lot of raw materials and strength than the other economic activity and create the waste fraction among the planet. Every year approximately billion tons of wastes are manufactured in the world.

Therefore, recycling this waste is fundamental to reduce the volume of dumped waste. On the other side, recycling has another environmental advantage that become less the consumption of resources from the earth. Construction and demolition waste (CDW) recycling plants have been proved to be economically practical as well as having a good environmental effect. However, for that to be true it is necessary that the production from the plants can be taken in by the market. IN other words, there is a strong need to expand the industrial applications of Construction and demolition waste (CDW). Many research studies are execute on the use of RA in concrete in an attempt to realize the properties of RA concrete; however, most of the studies are concentrated on the mechanical properties of the resulting concrete. Finite work is carried out on the understanding of the durability aspects of the emerging construction material as is most likely with concrete that is built with natural aggregate. Hence, in this research while carried out the design of replaced RA with natural aggregate with different proportion 0% to 80% replacement of RA with NA. After replacing the sample, place the sample for curing for 28 days, 56 days and 90 days absolute care was taken and cured with fresh water. After curing determine the durability parameter by different test given experimental work. From experimental conclusions, determine the best durability of appropriate replacement proportion and construct precast structural element of that proportion.

### A. *Recycled Concrete Aggregate*

Recycled aggregate is manufactured by crushing concrete, and once in time asphalt, to recover the aggregate. Recycled aggregate can be used for numerous intend.

### B. *Need Have Recycled Aggregate*

Urbanization growth rate in India is huge due to industrialization. Fast infrastructure development need a huge amount of construction materials, land requirements & the site. For large construction, concrete is promote as it has longer life, less service cost & more desirable execution. Safety of environment is a fundamental element which is immediately attached with the continuity of the human race. Variable like surrounding awareness, safety of resources from earth, defensible evaluation, compet in a major role in fashionable necessity of construction works. Because of deviation, demolished materials are disposed on earth surface & not handed down for any reason. Such case impact the productiveness of surface of the land. As per report of Central Pollution Control Board (CPCB) Delhi, in India, 48million tons solid waste is bring out of which 14.5-million-ton waste is created from the construction waste sector, out of which only 3% waste is handed down for embankment. Out of the total construction demolition waste, 40% is of concrete, 30% ceramics, 5% plastics, 10% wood, 5%metal, & 10% other mixtures. As described by global awareness, development in global construction sector speculate and become greater in construction exhaust of 4800 billion US dollars in 2013. These amount shows a huge growth in the construction sector, almost 1.5 times in 5 Years. For creation of concrete, 70-75% aggregates are essential. Out of this 60-67% is of course aggregate & 33-40% is of fine aggregate. As per latest investigation by the Fredonia group, it is estimate that the overall requirement for construction aggregates may exceed 26 billion tons by 2012. Guiding this requirement is the maximum user China 25%, Europe 12% & USA 10%, India is also in top 10 users. From environmental opinion, for manufacturing of natural aggregates of 1 ton, emissions of 0.0046 million ton of carbon exist whereas for 1ton recycled aggregate created only 0.0024-million-ton carbon is created. Bearing in mind the global utilization of 10 billion tons/year of aggregate for concrete production, the carbon footprint can be intent for the natural aggregate as well as for the recycled aggregate.

### C. *Economical & Environmental Impact*

The opinion in the construction industry suggest definite involvement concerning about possibility of natural aggregate resources, as they are being very quickly consumed. Current data exhibit the growing claim of construction aggregate to power 48.3 billion metric tons by the year 2015 with the top most utilization being in Asia. This growing demand is guide by a huge of construction waste. For example, construction waste from European Union countries express about 31% of the total waste generation per year. Similarly, in Hong Kong, the waste production was nearly 20 million tons in the year 2011, which established about 50 % of the global waste generation. Dumping in landfills is the common simple method to conduct the construction waste, which create huge deposits of construction and demolition waste sites. creation to limit this practice and to stimulate spiritualy recycling of construction and demolition waste in many other construction applications manage to exploite up to 10 % of the recycled aggregate in many other construction applications. Therefore, recycling has the implied to decrease the quantity of waste materials disposed of in dumping ground sand to protect resources from earth.

## II. OBJECTIVES

- To study the effect of recycled concrete aggregate (RCA) on properties of concrete by experiment.
- Application of recycled concrete aggregate (RCA) in precast structural component is a new technology.
- By conducting different laboratory tests on prepared specimens, it is intended to analyze the result.
- To construct precast structural element on the basics of durability parameter by replacing natural aggregate (NA) with recycled aggregate (RA).
- Therefore, it is an aim of this study to introduce an environmental friendly technology, which can be beneficial to the society and to the nation.

## III. METHODOLOGY

Data required for the casting of specimens and mix designs were collected. Mix designs prepared using IS 10262-2009 and on the basis of trials final mix designs were formulated. Procured materials were tested for different properties. Cubes were casted for different grades of mix (i.e. M40, M50, M60) and they were immersed in curing tank for 28,56,90 days for compression test and 28 days for water penetration test, RCPT. After completion of curing period cubes were removed from curing tank and were left there to dry. Compressive testing was done on these cubes to determine the compressive strength. In same manner the cubes casted for durability test were removed from the curing tank and were tested for water penetration test and rapid chloride penetration test. i.e. for durability test. After testing compressive strength of natural concrete and recycle concrete were compared.

### A. *Procedure of Tests*

#### 1) *Compression Test*

All the materials were obtained on site. The proportion of materials to be used was calculated as per the concrete mix design for M40, M50 & M60 grade. Recycled concrete aggregate replacement was done by various percentage by weight of coarse aggregate 20 mm and 10 mm in respective proportions. Used concrete blocks were obtained from MIT collage pune. Then crushing and sieving were done on site. Crushed sand was used as a fine aggregate. The percentage of admixture were decided as per trial and error basis and final percentage of admixture was 0.02% by weight of water. Firstly dry mixing of aggregates, cement and sand is done. Water was added during the process of mixing. After adding 80% water, Admixture was added gradually and after that remaining 20% water were added. Mixing process was done within 1 minute. After mixing slump cone test on fresh concrete were taken. Then concrete was poured in 3 layers in well-greased moulds. Hand tamping was adopted as per specifications in the IS code for proper compaction. After 25 blows on each layer moulds were kept on vibrating table to avoid voids. Three specimen of cubes of different replacement levels for different tests were casted.

After 24 hours, the demoulding is done and the cube is kept in water tank for 28 days,56 days and 90days for curing. With proper curing of 28 days,56 days and 90 days the composite was taken for testing. The various test carried out on hardened concrete were compressive strength test and durability tests such as water penetration test and rapid chloride penetration test.

Before testing, weights of all composites were noted. Cube moulds were of size 150mm conforming to IS: 10086-1982. Cubes were tested on a Digital Compression Testing machine. Gradual load was applied and readings were noted at failure. Testing of 28 days, 56days and 90 days curing were carried out for different replacement levels 0%, 40%, 60%, 80%. The durability tests of concrete cubes are pending and should be conduct afterward.

Fig. 1: Water Curing of Samples


Fig. 2: Compressive Strength Test

### *B. Water Permeability Test*

Basic procedure of such a test is to apply water under pressure to one surface of the specimen for a specific time and then split the specimen perpendicular to the injected face and determine visually the depth of penetration. The test is carried out according to German standard DIN 1048 on concrete specimens of size 150x150x150 mm, at an age of 28 days. The test cell assembly being used had the provision for testing three cubes at a time. Once the specimens were assembled in the test cells, a water pressure of 500 KPa (5 bar) was applied for 72 hours. Water pressure is applied by means of an arrangement consisting of a water tank connected to an air compressor through a valve, to adjust the pressure.

Permeability apparatus is used for determining the permeability of cement mortar and concrete specimens of 15cm cubes cast in the laboratory. Three pressure gauges for indicating pressure in each cell are applied apart from the main pressure gauge which indicates pressure in chamber. Compressor with pressure gauge 0-20 $kg/cm^2$ with automatic pressure valve and pressure rubber hose. Suitable for 440 volts A.C. three phases.

Fig. 3: Water Permeability Apparatus

### *C. Rapid Chloride Penetration Test*

This test method was originally developed by the Portland Cement Association, under a research program paid for by the Federal Highway Administration (FHWA). The original test method may be found in FHWA/RD-8l/l19, Rapid Determination of the Chloride Permeability of Concrete. “Since the test method was developed, it has been modified and adapted by various agencies and standard’s organizations. These include:

1) AASHTO T277, “Standard Method of Test for Rapid Determination of the Chloride Permeability of Concrete”
2) ASTM C1202, “Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration”

### *D. Specifications of Test*

The diameter of the specimen is 100 mm having length 50 mm and specimen is cured for 28 days. The Testing period for this test is 28 days.

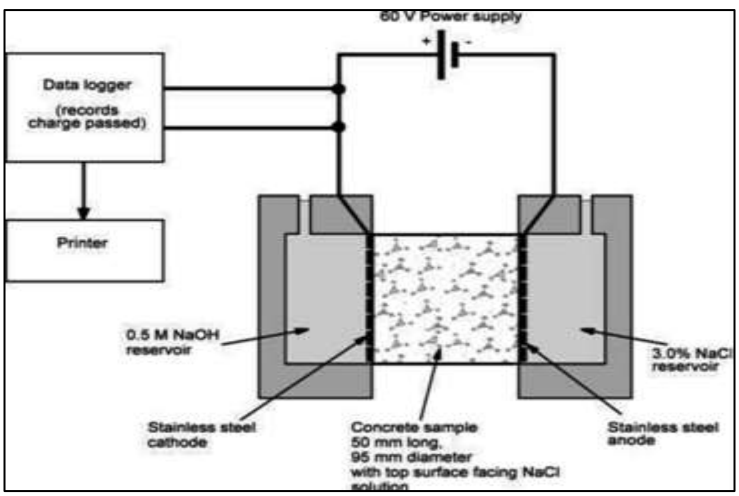


Fig. 4: AASHTO T277 (ASTM 1202) Test Setup

1) The test method involves obtaining a 100 mm (4 in.) diameter core or cylinder sample from the concrete being tested.
2) A 50 mm (2 in.) specimen is cut from the sample.
3) The side of the cylindrical specimen is coated with epoxy, and after the epoxy is dried well, it is put into a vacuum chamber for 3 hours.
4) The specimen is vacuum saturated for 1 hour and allowed to soak for 18 hours.
5) It is then placed in the test device (see test method for schematic of device.
6) The left-hand side (-) of the test cell is filled with a 3% NaCl solution.
7) The right-hand side (+) of the test cell is filled with 0.3N NaOH solution.
8) The system is then connected and a 60-volt potential is applied for 6 hours.
9) Readings are taken every 30 minutes.
10) At the end of 6 hours the sample is removed from the cell and the total amount of coulombs that is passed through the specimen is calculated.

## IV. RESULTS

### *A. Results for Compressive Strength Test*

Table – 1
M40 Compressive Test of Concrete (28 Days)

| Sr. No. | Weight of Cement Cube (kg) | Average Weight (kg) | Compressive Strength (MPa) | Average Compressive Strength (MPa) |
|---|---|---|---|---|
| 0% Replacement | | | | |
| 1 | 8.716 | 8.8 | 45.32 | 51.23 |
| 2 | 8.849 | | 53.68 | |
| 3 | 8.840 | | 54.69 | |
| 40% Replacement | | | | |
| 1 | 8.890 | 8.9 | 48.59 | 46.73 |
| 2 | 8.850 | | 53.07 | |
| 3 | 8.970 | | 38.53 | |
| 60% Replacement | | | | |
| 1 | 8.940 | 9.00 | 44.99 | 42.79 |
| 2 | 9.110 | | 39.82 | |
| 3 | 8.970 | | 43.56 | |
| 80% Replacement | | | | |
| 1 | 8.845 | 8.92 | 34.44 | 39.41 |
| 2 | 8.960 | | 38.97 | |
| 3 | 8.940 | | 44.82 | |

Table – 2
M40 Compressive Test of Concrete (56 Days)

| Sr. No. | Weight of Cement Cube (kg) | Average Weight (kg) | Compressive Strength (MPa) | Average Compressive Strength (MPa) |
|---|---|---|---|---|
| 0% Replacement | | | | |
| 1 | 8.890 | 8.87 | 54.66 | 53.77 |
| 2 | 8.840 | | 52.88 | |
| 3 | 8.880 | | 53.78 | |
| 40% Replacement | | | | |
| 1 | 8.834 | 8.873 | 50.66 | 49.29 |
| 2 | 8.845 | | 48.33 | |
| 3 | 8.940 | | 48.89 | |
| 60% Replacement | | | | |
| 1 | 9.101 | 8.904 | 48.63 | 45.72 |
| 2 | 8.901 | | 40.82 | |
| 3 | 8.710 | | 47.71 | |
| 80% Replacement | | | | |
| 1 | 8.810 | 8.72 | 40.88 | 40.25 |
| 2 | 8.790 | | 40.44 | |
| 3 | 8.560 | | 39.44 | |

Table – 3
M40 Compressive Test of Concrete (90 Days)

| Sr. No. | Weight of Cement Cube (kg) | Average Weight (kg) | Compressive Strength (MPa) | Average Compressive Strength (MPa) |
|---|---|---|---|---|
| 0% Replacement | | | | |
| 1 | 8.831 | 8.838 | 51.65 | 54.89 |
| 2 | 8.891 | | 57.34 | |
| 3 | 8.793 | | 55.68 | |
| 40% Replacement | | | | |
| 1 | 8.84 | 8.91 | 41.89 | 48.03 |
| 2 | 8.93 | | 49.63 | |
| 3 | 8.96 | | 52.57 | |
| 60% Replacement | | | | |
| 1 | 8.73 | 8.537 | 48.25 | 45.63 |
| 2 | 8.34 | | 39.21 | |

| | | | | |
|---|---|---|---|---|
| *3* | *8.54* | | *49.43* | |
| *80% Replacement* | | | | |
| *1* | *8.73* | *8.687* | *40.88* | *41.43* |
| *2* | *8.68* | | *42.88* | |
| *3* | *8.65* | | *40.53* | |

Table – 4
M50 Compressive Test of Concrete (28 Days)

| *Sr. No.* | *Weight of Cement Cube (kg)* | *Average Weight (kg)* | *Compressive Strength (MPa)* | *Average Compressive Strength (MPa)* |
|---|---|---|---|---|
| *0% Replacement* | | | | |
| *1* | *8.870* | *8.88* | *54.22* | *56.15* |
| *2* | *8.840* | | *59.11* | |
| *3* | *8.940* | | *55.11* | |
| *40% Replacement* | | | | |
| *1* | *8.910* | *8.996* | *52.16* | *49.63* |
| *2* | *9.120* | | *40.21* | |
| *3* | *8.960* | | *56.52* | |
| *60% Replacement* | | | | |
| *1* | *8.321* | *8.689* | *47.33* | *47.33* |
| *2* | *8.913* | | *45.78* | |
| *3* | *8.834* | | *48.88* | |
| *80% Replacement* | | | | |
| *1* | *8.840* | *8.873* | *38.16* | *42.67* |
| *2* | *8.860* | | *44.52* | |
| *3* | *8.920* | | *45.33* | |

Table – 5
M50 Compressive Test of Concrete (56 Days)

| *Sr. No.* | *Weight of Cement Cube (kg)* | *Average Weight (kg)* | *Compressive Strength (MPa)* | *Average Compressive Strength (MPa)* |
|---|---|---|---|---|
| *0% Replacement* | | | | |
| *1* | *8.856* | *8.556* | *54.68* | *57.89* |
| *2* | *8.354* | | *56.77* | |
| *3* | *8.458* | | *62.22* | |
| *40% Replacement* | | | | |
| *1* | *8.870* | *8.867* | *52.63* | *51.59* |
| *2* | *8.910* | | *46.85* | |
| *3* | *8.800* | | *55.29* | |
| *60% Replacement* | | | | |
| *1* | *8.910* | *8.86* | *49.18* | *47.58* |
| *2* | *8.880* | | *46.25* | |
| *3* | *8.790* | | *47.31* | |
| *80% Replacement* | | | | |
| *1* | *8.810* | *8.817* | *46.66* | *45.62* |
| *2* | *8.910* | | *47.28* | |
| *3* | *8.730* | | *48.94* | |

Table – 6
M50 Compressive Test of Concrete (90 Days)

| *Sr. No.* | *Weight of Cement Cube (kg)* | *Average Weight (kg)* | *Compressive Strength (MPa)* | *Average Compressive Strength (MPa)* |
|---|---|---|---|---|
| *0% Replacement* | | | | |
| *1* | *8.530* | *8.570* | *52.69* | *58.26* |
| *2* | *8.340* | | *59.27* | |
| *3* | *8.840* | | *62.82* | |
| *40% Replacement* | | | | |
| *1* | *8.940* | *8.573* | *62.42* | *52.18* |
| *2* | *8.340* | | *49.59* | |
| *3* | *8.440* | | *44.53* | |
| *60% Replacement* | | | | |
| *1* | *8.360* | *8.667* | *43.56* | *48.39* |

| | | | | |
|---|---|---|---|---|
| *2* | *8.730* | | *47.61* | |
| *3* | *8.91* | | *54.00* | |
| *80% Replacement* | | | | |
| *1* | *8.830* | *8.887* | *39.38* | *45.91* |
| *2* | *8.900* | | *48.89* | |
| *3* | *8.930* | | *49.46* | |

Table – 7
M60 Compressive Test of Concrete (28 Days)

| *Sr. No.* | *Weight of Cement Cube (kg)* | *Average Weight (kg)* | *Compressive Strength (MPa)* | *Average Compressive Strength (MPa)* |
|---|---|---|---|---|
| *0% Replacement* | | | | |
| *1* | *8.890* | *8.880* | *64.44* | *64.59* |
| *2* | *8.860* | | *62.66* | |
| *3* | *8.890* | | *66.67* | |
| *40% Replacement* | | | | |
| *1* | *8.790* | *8.826* | *59.11* | *58.93* |
| *2* | *8.840* | | *57.33* | |
| *3* | *8.850* | | *60.35* | |
| *60% Replacement* | | | | |
| *1* | *8.910* | *8.877* | *55.34* | *52.80* |
| *2* | *8.830* | | *49.38* | |
| *3* | *8.890* | | *53.68* | |
| *80% Replacement* | | | | |
| *1* | *8.920* | *8.920* | *43.59* | *48.36* |
| *2* | *8.910* | | *52.96* | |
| *3* | *8.930* | | *48.53* | |

Table – 8
M60 Compressive Test of Concrete (56 Days)

| *Sr. No.* | *Weight of Cement Cube (kg)* | *Average Weight (kg)* | *Compressive Strength (MPa)* | *Average Compressive Strength (MPa)* |
|---|---|---|---|---|
| *0% Replacement* | | | | |
| *1* | *8.501* | *8.688* | *63.43* | *65.02* |
| *2* | *8.760* | | *66.23* | |
| *3* | *8.743* | | *65.41* | |
| *40% Replacement* | | | | |
| *1* | *8.910* | *8.803* | *61.64* | *57.21* |
| *2* | *8.810* | | *58.39* | |
| *3* | *8.690* | | *51.60* | |
| *60% Replacement* | | | | |
| *1* | *8.730* | *8.557* | *53.97* | *55.64* |
| *2* | *8.300* | | *58.06* | |
| *3* | *8.640* | | *54.89* | |
| *80% Replacement* | | | | |
| *1* | *8.710* | *8.619* | *45.63* | *49.41* |
| *2* | *8.345* | | *48.26* | |
| *3* | *8.801* | | *54.34* | |

Table – 9
M60 Compressive Test of Concrete (90 Days)

| *Sr. No.* | *Weight of Cement Cube (kg)* | *Average Weight (kg)* | *Compressive Strength (MPa)* | *Average Compressive Strength (MPa)* |
|---|---|---|---|---|
| *0% Replacement* | | | | |
| *1* | *8.930* | *8.610* | *65.45* | *65.87* |
| *2* | *8.340* | | *70.06* | |
| *3* | *8.560* | | *68.89* | |
| *40% Replacement* | | | | |
| *1* | *8.900* | *8.920* | *56.73* | *59.84* |
| *2* | *8.930* | | *62.12* | |
| *3* | *8.930* | | *60.67* | |
| *60% Replacement* | | | | |

 

| | | | | |
|---|---|---|---|---|
| 1 | 8.940 | 8.853 | 48.89 | 53.28 |
| 2 | 8.910 | | 45.39 | |
| 3 | 8.710 | | 65.56 | |
| 80% Replacement | | | | |
| 1 | 8.810 | 8.817 | 56.12 | 49.93 |
| 2 | 8.910 | | 41.02 | |
| 3 | 8.730 | | 52.65 | |

### B. Results for RCPT

Table – 10
Chloride Permeability based on Charge Passed

| Charge Passed (Coulombs) | Chloride Permeability |
|---|---|
| >4,000 | High |
| 2,000–4,000 | Moderate |
| 1,000–2,000 | Low |
| 100–1,000 | Very Low |
| <100 | Negligible |

Table – 11
RCPT Results (M40)

| Grade | percentage | Total charged passed in coulombs |
|---|---|---|
| M40 | 0% | 1997 |
| | 40% | 1990 |
| | 60% | 2011 |
| | 80% | 2166 |

Table – 12
RCPT Results (M50)

| Grade | percentage | Total charged passed in coulombs |
|---|---|---|
| M50 | 0% | 2016 |
| | 40% | 2016.9 |
| | 60% | 2076.4 |
| | 80% | 2133.9 |

Table – 13
RCPT Results (M60)

| Grade | percentage | Total charged passed in coulombs |
|---|---|---|
| M60 | 0% | 1994 |
| | 40% | 2030.2 |
| | 60% | 2068.8 |
| | 80% | 2139.1 |

### C. Results for Water Permeability Test

Table – 14
Water Permeability Test Results (M40)

| Grade | percentage | Avg. depth of penetration (mm) |
|---|---|---|
| M40 | 0% | 32 |
| | 40% | 35 |
| | 60% | 39 |
| | 80% | 43 |

Table – 15
Water Permeability Test Results (M50)

| Grade | percentage | Avg. depth of penetration (mm) |
|---|---|---|
| M50 | 0% | 29 |
| | 40% | 33 |
| | 60% | 35 |
| | 80% | 40 |

Table – 16
Water Permeability Test Results (M60)

| Grade | percentage | Avg. depth of penetration (mm) |
|---|---|---|
| M60 | 0% | 26 |
| | 40% | 31 |
| | 60% | 33 |
| | 80% | 38 |

## V. Conclusion & Future Scope of Study

### A. *Conclusion*

- For M40, M50, M60 grade of concrete compressive strength decreases with increases recycled aggregate. There is only small decrease in compression strength (appro.10%) when nearly half of the natural aggregate replaced by recycled aggregate.
- For M40, M50, M60 grade of concrete durability decreases with increases in recycled aggregate.
- More than 70% replacement of recycled aggregates is not recommended for high strength structures.
- Concrete with up to 20% replaced aggregate can be used in coastal region.
- w/c ratio has to be increased for recycled aggregate hence use of admixture like pc based is recommended.
- The water penetration level was found to be within low and medium permeability for M60 and M40, M50 grade concrete respectively. The water permeability decreases with increase in the grade of concrete. In general, recycled aggregates increases the water penetration level. But the study found out that the water penetration has not increased significantly, making the recycled aggregate a viable option.
- From RCPT, the chloride permeability level was found to be in medium level. The medium permeability level does not affect the strength of the concrete to a great extent. With proper recycling and treatment process the chloride penetration level can be even reduced.
- It can be concluded from the three tests that the Recycled aggregate can be used as an alternative for natural aggregate up to 40 to 45% without considerable decrease in the strength and durability
- This can be a good option for sustainable and eco-friendly recycling technique for utilizing demolition waste into construction project again, while further studies should be conducted to improve performance of recycled aggregate.

### B. *Future Scope of Study*

- To increase the strength of the concrete various types of fibers can be used.
- To reduce the water content for high strength structures, the various admixtures can be use.
- We can study other durability parameters such as acid attack test, water sorptivity test, chloride attack test, water absorption test etc.
- We can minimize the waste of the concrete by increasing percentage replacement with conventional concrete.
- Using well graded angular aggregates. (Stronger the course aggregate, better) the strength can be increase.
- Now a day use of plastic waste as a construction material is been studied. Shredded plastics could also be a good recycled aggregate.
- Better cost-effective methods for recycling, cleaning and treating the aggregates has to be studied.

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