EXPERIMENTAL STUDY ON ENGINEERING PERFORMANCE OF RECYCLED AGGREGATE IN NEW CONCRETE MIX

Sanjay Singh Raghav

1M.Tech Student, Department of Civil Engineering, Patel Institute of Technology, Bhopal.

ABSTRACT
Recycled aggregates consists of crushed concrete, inorganic particles processed from the materials that have been already used in the structural constructions and demolition debris. The aim of this project is to determine the strength characteristics of recycled aggregates for application in high strength structural concrete, which will give a better understanding on the properties of concrete with recycled aggregates as an alternative material to coarse aggregate in structural concrete. The aim of this thesis is to determine and compare the strength of concrete by using different percentage of recycled aggregates. Recycled aggregate is also the type of artificial aggregate, which is obtained from construction and demolition wastes. Constructions and demolitions are processes that go one after the other. The demolished building aggregate in India generally goes to waste in landfill operation. Recycling of these waste materials from building demolition can provide a solution to this problem. The investigation was carried out using sieve analysis test, Specific gravity test, Water absorption test, Impact test, Crushing value test, Workability test and Compressive strength test. There were total of five batches of concrete mixes consisting of every 25% increment of recycled aggregate replacement from 0% to 100%.

KEYWORDS
Aggregate, Concrete, Compressive Strength, Structural Concrete.


1: INTRODUCTION OF RECYCLED AGGREGATE
Construction and demolition are processes that go one after the other. The demolished building material and aggregate in India is generally used as a filler material. After few years of construction and demolition waste will be more than half of the National total waste in most countries of the world, so recycling of these concrete waste materials can provide an effective solution to this problem. Spaces for landfill are becoming very difficult to find. These are found to be either too far from the demolition site or too costly to maintain. At the same time sources of transport of suitable aggregate for making concrete are continuously being exhausted. The recycling of building demolition waste materials into new buildings can provide a solution to these problems. Grinding reinforced concrete buildings can reduce the volume of land filled debris by roughly 70%.

While volume reduction itself is advantageous, recycling of the waste material creates a product that can be sold or used for filling, soil stabilization, road metal and for other purposes, thereby reducing further environmental loads by substituting recycled aggregates for natural virgin aggregates. Recycling is the act of processing the used material for use in producing new product. The use of naturally available aggregate is getting more and more intense with the advanced development in infrastructure area. In order to reduce the usage of natural aggregate, recycled concrete aggregate can be used as the replacement materials. Recycled concrete aggregate consists of crushed concrete, masonry waste, asphalt waste and inorganic particles processed from the materials that have been already used in the structural constructions and demolition debris.

2: METHODOLOGY
Various test specimens were prepared to determine the compressive strength, water absorption and other properties of the concrete mix. The data is the reference of study experiment that has to be done. Experiments needed to be done to achieve the objectives given are sieve analysis, specific gravity, water absorption, impact and crushing strength of aggregates.

2.1: MATERIALS AND THEIR TESTING METHODS
2.1.1: Materials Used
Materials Ordinary Portland cement, fine aggregate and coarse aggregate. Recycled Concrete Aggregate. The main source of recycled concrete aggregate was demolished structures waste concrete mainly the slabs, columns and beams which were free from any reinforcement or other contaminants, cubes from this material were casted and tested in the laboratory. The local crushing plants were not able to crush the concrete waste and thus the crushing and sieving had to be done manually. The demolished waste concrete (Fig. 3.1) were broken initially manually and then sieving was done using IS sieves.
The process produced, recycled concrete aggregate of sizes 10mm and recycled concrete aggregate 20mm size. The concrete was crushed manually and then used for testing.

3: TESTING METHODS

A: Sieve Analysis Test
Fineness modulus (FM) of aggregate is an index number, which gives an idea about the coarseness of an aggregate. Fineness modulus of an aggregate is approximate proportion of the average size of particles in the aggregate. Fineness modulus is determined by adding the cumulative percentage of material retained on each sieve and dividing the sum of cumulative percentage of material retained on each sieve by 100. In this method, the fineness modulus of coarse and fine aggregate are determined separately. Specific values of FM are higher for coarse aggregate and it is as follows:
- For 20mm size = 6 to 6.9.
- 40mm size = 6.9 to 7.5.
- For 20mm size = 4.8 to 5.1.
- 25mm size = 5.1 to 5.5.

Apparatus and Test Procedure for Sieve Analysis Test.
Set of Sieves with Pan, Electronic Balance and Tray.
1. Take a suitable sample of aggregate with known weight.
2. Put the aggregate on the top most sieve.
3. Sieve it for 15 minutes.
4. Find out wt. retained on each sieve.
5. From that cumulative percentage of weight retained on each sieve was calculated.

B: Specific Gravity Test
Specific gravity is the ratio of the weight of given volume of dry aggregate to the weight of equal volume of distilled water.

Apparatus and Test Procedure for Specific Gravity Test
Pycnometer, Electronic Balance, Aggregate.
1. Make the Pycnometer dry and clean, then weigh it with its cap and ring.
2. Unscrew the cap and put 200gms. of aggregate and weigh it.
3. Add water to the top of brass cap. Remove all the trapped air by pouring additional water.
4. Dry the Pycnometer and fill it to the top and weigh it.
5. Find the average specific gravity by using formula.
   a) Wt. of empty Pycnometer = W1.
   b) Wt. of Pycnometer + aggregates/sand = W2.
   c) Wt. of Pycnometer + aggregates + Water = W3.
   d) Wt. of Pycnometer + Water = W4.
   e) Specific Gravity = (W2-W1)/(W2-W1)-(W3-W4).

C: Water Absorption Test
Stones having higher water absorption values are porous and hence weak. They are generally unsuitable unless found acceptable based on crushing and grinding. The sample is weighed on water and the buoyant weight is found. The aggregate is taken out and weighed after the surface is dried. The specific gravity can be calculated by dividing dry weight of aggregate by weight of equal volume of water. The water absorption is expressed as percentage water absorption in terms of oven dried weight of aggregate. The specific gravity of rock varies from 2.6 to 2.9. Rock specimen having more than 0.6 percent of water absorption is considered unsatisfactory.

Apparatus and Test Procedure for Water absorption.
Electronic Balance, Oven Wire Basket and Water Tank.
1. About 2Kg of dry aggregate sample is placed in wire basket and immersed in water for 24hrs.
2. The weight of the sample is taken, after it is surface dried.
3. The aggregate sample is placed in oven (100-108 C) for 24Hrs.
4. After complete drying dry weight of the sample is taken.
5. Percentage of water absorption is calculated.

D: Impact Test
The property of a material to resist impact is known as toughness. Due to movement of vehicles on the road the aggregates are subjected to impact resulting in their breaking down into smaller pieces. The aggregates should therefore have sufficient toughness to resist their disintegration due to impact. This characteristic is measured by impact value test. The aggregate impact value is a measure of resistance to sudden impact or shock, which differs from its resistance to gradually applied compressive load.

Apparatus and Test Procedure of Impact Test.
The Test Procedure Adopted was according to the IS: 2386 (Part IV)–1963 as given below:
1. The test sample consists of aggregates sized 10.0mm 12.5mm. Aggregates may be dried by heating at 100-110 C for a period of 4 hours and cooled.
2. Sieve the material through 12.5mm and 10.0mm IS sieves. The aggregates passing through 12.5mm sieve and retained on 10.0mm sieve comprises the test material.
3. Pour the aggregates to fill about just 1/3rd depth of measuring cylinder.
4. Compact the material by giving 25 gentle blows with the rounded end of the tamping rod.
5. Add two more layers in similar manner, so that cylinder is full.
6. Strike off the surplus aggregates.
7. Determine the net weight of the aggregates to the nearest gram (W).
8. Bring the impact machine to rest without wedging or packing up on the level plate, block or floor, so that it is rigid and the hammer guide columns are vertical.
9. Fix the cup firmly in position on the base of machine and place whole of the test sample in it and compact by giving 25 gentle strokes with tamping rod.
10. Raise the hammer until its lower face is 380mm above the surface of aggregate sample in the cup and allow it to fall freely on the aggregate sample. Give 15 such blows at an interval of not less than one second between successive falls.
11. Remove the crushed aggregate from the cup and sieve it through 2.36mm IS sieves until no further significant amount passes in one minute. Weigh the fraction passing the sieve to an accuracy of 1gm. Also, weigh the fraction retained in the sieve.
12. Compute the aggregate impact value.
   a) Total wt. of aggregates sample filling the cylindrical measure = W1.
   b) Wt. of aggregates passing 2.36mm sieve after the test = W2.
c) Wt. of aggregates retained on 2.36mm sieve after the test = W3.
d) Aggregate impact value = (W2/W1)*100.

The mean of two observations, rounded to nearest whole number is reported as the Aggregate Impact Value.

E: Crushing Value Test
The strength of coarse aggregate may be determined by aggregate crushing strength test. The aggregate crushing value gives a relative measure of the resistance of an aggregate sample to crushing under gradually applied compressive load.

Apparatus and Test Procedure of Crushing Value Test.
Steel cylinder of internal diameter 150mm diameter and 180mm height with a base plate and a plunger compression testing machine, sieves, aggregate, etc.;
1. Dry aggregate passing through 12.5mm sieve and retained on 10mm sieve is filled in the cylinder in three layers.
2. Each layer being compacted by 25 blows of tamping rod of diameter 16mm.
3. Then the plunger is placed on the top of the specimen and a load of 40 tones is applied by the compression testing machine.
4. The crushed aggregate are removed and sieved through 2.36mm sieve.
5. The material which passes through this sieve is weighed (Ws).

F: Workability Test of Fresh Concrete
According to Cement Manufacturer’s Association India, a good concrete must have workability in the fresh state and also develop sufficient strength. It also mentioned that there are four factors that can affect the workability. They are as below:
- Consistency: The degree of consistency is dependent on the nature of works and type of compaction.
- Water/Cement Ratio: Water/cement ratio is the ratio of water in a mix to the weight of cement. The quantity of water required for a mix depend on the mix proportions, types and grading of aggregate.
- Grading of Aggregate: The smooth and rounded aggregate will produce a more workable concrete than the sharp angular aggregate.
- Cement Content: The greater workability can be obtained with the higher cement content.

G: Slump Cone Test
Slump cone test is performed to determine the workability of fresh cement concrete. The test is simple and cheap. It is suitable to use in the laboratory and also at site. Although the test is simple, but the testing has to be done carefully. A huge slump may be obtained if there is any disturbance in the process. The slump test will give a reasonable indication of how easily a mix can be placed, although it does not directly measure the work needed to compact the concrete. It also mentioned that a slump less than 25mm will indicate a very stiff concrete and a slump more than 125mm will indicate a very runny concrete.

Apparatus Required and Test Procedure for Slump Cone Test.
The following Apparatus and Equipments were used complying with IS 7320–1974:
1. Mould: A hollow frustum of a cone that made from galvanized steel sheet. The thickness is between 1.5mm to 2mm. The mould has a foot piece and handles on outer surface and smooth internal surface. The bottom diameter of the mould is 200mm, the top diameter of the mould is 100mm and height of the mould is 300mm.
2. Rod: A metal rod of 16mm diameter; 600mm long and having a length of 25mm in spherical shape, one end with a radius of 8mm.
3. Base Plate: A 3mm thick smooth, rigid and non-absorbent material metallic base plate.
4. Scoop: A suitable size to carry the aggregate of concrete.
5. Ruler: A suitable steel ruler to measure the height of slump.

The Test Procedure was according to the IS 7320 – 1974. The Procedures were as below:
1. Before the test, the internal surface of the mould was cleaned and wetted.
2. The mould was placed on a smooth and horizontal surface, free from vibrations or shock. While the mould was being filled, it was held firmly by standing on the foot pieces.
3. The mould was filled in three layers. Each layer was around one-third of the height of the mould. Each layer was being rodded with 25 strokes of rounded end of the rod. Strokes of rod were made in a uniform manner at the cross-section of the mould.
4. The surface concrete was rolled off after the top layer has been rod. Then, remove the mould immediately by raising it slowly and carefully in the vertical direction.
5. Measured the height of slump immediately. It was determined between the height of the mould and the average height of the top surface of the concrete.

4: TEST RESULTS AND ANALYSIS
Series of tests were carried out on materials, fresh and hardened concrete to obtain the strength characteristics of recycled aggregate for potential application as a structural concrete. The results for material test like water absorption, specific gravity, aggregate crushing value and aggregate impact value test are given in Table 1. Test results on fresh concrete are arranged in Table 2. Compressive strength of hardened concrete is presented in Table.

FINAL RESULT OF ALL TESTS ON MATERIALS

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Particulars</th>
<th>Natural Aggregate</th>
<th>Recycled Aggregate</th>
<th>Sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water Absorption</td>
<td>1.83%</td>
<td>5%</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Specific Gravity</td>
<td>2.75</td>
<td>2.85</td>
<td>2.65</td>
</tr>
<tr>
<td>3</td>
<td>Agg Crushing Value</td>
<td>20.02%</td>
<td>22.50%</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Agg Impact Value</td>
<td>7.91%</td>
<td>11.99%</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1: Slump Cone Test Result

The slump test indicates a decreasing trend of workability when the percentage of recycled aggregate increased. Below shows the average slump recorded during the test.
According to the result, the highest slump obtained was 65 mm and the lowest slump was 20 mm. From the result it indicates that the workability was tending to harshness with increase in replacement with recycled aggregate because recycled aggregate are more porous as compared to conventional or natural aggregate.

**COMPRESSION TEST RESULT AND ANALYSIS**

The compression test by CTM (Compressive Testing machine) indicates an increasing trend of compressive strength with age of the concrete specimens. However, it shows that the strength of recycled aggregate specimens is lower than natural aggregate specimens. Table 3 shows the increase of compressive strength with age recorded during the test.

<table>
<thead>
<tr>
<th>% of RAC</th>
<th>0 %</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Days</td>
<td>160 kg/cm²</td>
<td>145 kg/cm²</td>
<td>135 kg/cm²</td>
<td>120 kg/cm²</td>
<td>110 kg/cm²</td>
</tr>
<tr>
<td>28 Days</td>
<td>250 kg/cm²</td>
<td>235 kg/cm²</td>
<td>225 kg/cm²</td>
<td>205 kg/cm²</td>
<td>195 kg/cm²</td>
</tr>
</tbody>
</table>

Compressive Strength for 0% Recycled Aggregate

Graph 1: Sup Test Result with different %

Graph 2: Compressive Strength for 25% Recycled Aggregate

Graph 3: Compressive Strength for 50% Recycled Aggregate

Graph 4: Compressive Strength for 75% Recycled Aggregate

Graph 5: Compressive Strength for 100% Recycled Aggregate
CONCLUSION
The experimental results show that increasing the percentage of recycled aggregate influence adversely the properties of fresh and hardened concrete. As the percentage of the recycled aggregate increased, the workability and compressive strength of the concrete decreased.

These results indicate that as the percentage of Natural Aggregate decreases by replacing the Recycled Aggregate, the corresponding strength goes on decreasing; however, up to 50% replacement it reduces less compressive strength. Hence, for structural concrete natural aggregate can be replaced by the recycled aggregate up to 50% limit. The other property like workability of concrete considerably reduces as the amount of recycled aggregate increases. This thesis is aimed to determine the strength characteristics of recycled aggregate concrete for potential application in the structural concrete.

One thing should always keep in mind while using recycled aggregate that water content in the concrete mix has to be monitored carefully, because recycled aggregate absorb more water than natural aggregate.

REFERENCES