STUDY OF RECYCLED AGGREGATE CONCRETE CONTAINING SILICA FUME AS PARTIAL REPLACEMENT FOR CEMENT

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ABSTRACT

Recycle Aggregate Concrete (RCA) is the concrete product produced with recycled aggregate to replace part or whole of natural aggregate. The purpose of this study is to find the properties of RCA and compare the same with the concrete produced with natural aggregates.

Recycle Concrete Aggregate has also been described as “the most revolutionary development in concrete construction for several decades”. It has proved to be beneficial from the point of economic, environmental benefits and Preservation of non renewable recourses

This thesis presents a study conducted on mechanical and durability properties of recycled aggregates concrete. The investigation covered concrete mixes at water cementitious material with ratio of 0.4. Ordinary Portland Cement of 43-grade was used in this study. The percentage of recycled aggregates that partially replaced natural aggregates by weight were 0%, 10%, 20%, 30%, 40% and 50%. Concrete cubes and cylinders were casted and tested in laboratories. The optimum proportion of replacement was found by conducting tests on mechanical properties like Compressive strength test and Split tensile strength test.

The results show that the optimum replacement of recycled aggregates with natural aggregates was 30%. Up to 30% replacement, it is possible to gain the same strength as conventional concrete. Beyond 30% replacement the strength results following decreasing trend.
INTRODUCTION

Now-a-days concrete industry is consuming lot of natural resources. This causes lot of damage to environment and mother earth. So, the less cement and natural aggregates that are used in concrete production, the lower the impact on environment. The increase in cost of landfill, scarcity of natural resources for aggregate, encourages the use of construction waste as a source of aggregate.

A sustainable construction has become a great concern over construction practice at the expense of the future of our planet. This is due to the fact that the construction industry is a massive consumer of natural resources and a huge waste producer as well. High value of raw material consumption in the construction industry becomes one of the main factors that cause environmental damage and pollution to our mother earth and the depletion of natural and mineral resources.

Every year, more than 165 million tones of natural aggregates are used in different civil and industrial constructions. Meanwhile, approximately 109 million tones of construction and demolition residues are generated in the UK; around 60 million tones of this are derived from concrete. The resources such as coarse aggregates, sands and cements will be at a disadvantaged position, as these resources are not able to cope with the high demand in the construction industry. Therefore, utilizing the recycled aggregate may be one of the significant efforts in achieving a sustainable construction.

As Recycled Aggregate (RA) begin to be acknowledged and accepted as a viable alternative to Natural Aggregates (NA), it is important to understand how Recycled Concrete Aggregate (RAC) performs compared with conventional concrete. A correct mix design and the introduction of differently shaped aggregates and different super plasticizers can influence structural concrete’s performance and provide it with strengths similar to the corresponding natural aggregates concrete (NAC), or even a possible enhancement, making it a feasible solution for the construction industry.

The major difference between natural aggregate and recycled coarse aggregate (RCA) is the adhered mortar at the surface of the RCA. It is a porous material, exhibits lower bulk density and saturated surface dry density, 1290–1470 kg/m$^3$ and 2310–2620 kg/m$^3$ respectively. The bulk density of the RCA is comparable to that of the lightweight aggregate. The higher porosity of the RCA is due to the higher content of adhered mortar responsible for its low resistance towards mechanical and chemical actions. Due to the presence of micro-cracks and residual cement paste bonded to the outer layer of recycled concrete debris, the increased porosity of aggregates generally results in a considerably higher water absorption which affects the „free” water – i.e., the water available for the chemical reactions and, consequently, the actual
water–cement ratio. Therefore, this higher porosity plays a key role on the concrete performances in both fresh and hardened states. Moreover, the mechanical properties of hardened RCA are affected by the weakness due to the higher porosity of recycled aggregates.

Generally, it is important that coarse aggregates have good strength, durability and weather resistance, that its surface be free from impurities such as loam, silt and organic matter, durable particle free from absorbed chemicals in permissible amount that will not affect hydration of cement and water, and bond of cement paste. Aggregates could be classified by their weight, rock type and their shape. The first and most important issue in choice of aggregate for concrete works is availability. Often the field engineers have to produce concrete from the aggregate generally available and close to the construction sites.

Why recycled aggregates from concrete wastes of material testing laboratories?

Concrete wastes of material testing laboratory was used as a coarse aggregates due to the following reasons:-

- Availability: Material testing laboratories, especially which specialized in testing concrete, produce large amount of hardened concrete as a results of testing. These wastes involved cylindrical, cubic and other varies of concrete specimens or elements.

- Cost of crushing: Actually, the concrete wastes obtained from materials laboratories had been crushed during testing. Specific crushing equipments are not needed for further crushing and manually operation seems

- Transportation cost: As well as most of the testing materials laboratories do exist within the city area, no extra cost is needed for long transportation from the source area to the production centers.

- Age of concrete wastes: Most of concrete wastes had small ages so that they can be easily treated and self healed by additional curing to improve their properties.

Types of Recycled Aggregates

Recycled Aggregate are of 8 types:-

- RCA (Recycled Concrete Aggregate)
- RCM (Recycled Concrete & Masonry)
- RA (Reclaimed Aggregate)
- RAP (Reclaimed Asphalt Pavement)
Recycled Concrete Aggregate

Recycled aggregate must confirm to certain standard for optimum engineering use; clean, hard, strong, durable particles free of tested in accordance with requirement set in BS 812 to investigate suitability of the Aggregate in new concrete.

LITERATURE REVIEW

Introduction

Literature review aims at collecting the important or useful data regarding the study from the previously published papers or journals.

Literature Review

Brito et al (2013) carried out the study on the mechanical properties of recycled concrete aggregates (RCA) and the influence of super plasticizers on RCA. The relative influence on the mechanical properties such as compressive strength, split tensile strength, and abrasion test of various incorporation rates of coarse aggregates (i.e., 25%, 50%, 100%) recycled from concrete waste, considering simultaneously the use of two types of super plasticizers (of average and high water reducing capacity). It was found to be that the increasing the RA in the mix reduce the concrete splitting tensile strength, but this can be overcome by introducing super plasticizers. It was found to be the super plasticizers has the capacity to slightly increase the tensile strength and the compressive strength and has the capacity to reduce the water in the mix.

Bhutta et al (2013) investigated the properties of porous concrete from waste crushed concrete (recycled aggregate). Porous concrete with acceptable permeability and strength using recycled aggregate from waste crushed concrete was developed. Tests carried out on porous concrete are void ratio, coefficient of permeability, compressive and flexural strengths. The effect of recycled aggregate on total void ratio, strength and permeability was mentioned. The total void ratio of porous concrete incorporating recycled aggregate was larger than that of porous concrete with normal aggregate. The addition of polymer modification resulted in a slight decrease in total void ratio regardless of type of aggregate. The compressive strengths of porous concretes using normal and recycled aggregates were significantly improved by 57% and 79% respectively, due to polymer modification. The use of recycled aggregate along with optimum content...
of polymer could produce acceptable porous concrete with both enough drainage and strength properties.

Kou et al (2012) carried out the feasibility study of using recycled fresh concrete waste (FCW) as coarse aggregates. The workability, compressive strength, split tensile strength, static modulus of elasticity, chloride ion penetration, and drying shrinkage of new concrete were determined. The compressive strength decreases with increase in FCW aggregate content. But the specified 28-day strength (32-44 MPa) could still be achieved with a replacement contents of < 30% wt. It was found that slump value increased with increase in FCW content. The water absorption capacity of concrete was increasing with increase in FCW content. Decrease in tensile splitting strength for the mix at all the curing ages was observed to be with 15% FCW. Elastic modulus and resistance to chloride ion penetration was decreases with increase in FCW. The utilization of FCW reduces the density, and increases the water absorption of the hardened concrete. It was observed that with no more than 30% replacement of granite by FCW and with a w/c of 0.35, it is still possible to produce concrete with a target 28-day compressive strength of 40 MPa.

RESULTS AND DISCUSSIONS

Introduction

This chapter aims at collecting the results of different tests performed on all the concrete mixes at different curing ages. This chapter is useful to examine the strength and durability properties of recycled aggregate concrete and to find out the optimum replacement levels of recycled aggregates. The results examined and discussed for the different tests conducted are listed as below.

1. Slump cone test of concrete mix
2. Compressive strength test of concrete
3. Split tensile strength test of concrete

Results

Slump test

Slump test is the most commonly used method of measuring consistency of concrete. Slump test was carried out on all the concrete mixes in the concrete laboratory. This test was very useful in detecting variation in the uniformity of a mix of given proportions. It also gives an idea of Water cement ratio to be used for different mixes. Fresh unsupported concrete flows to and sinking in the height takes place. This vertical settlement is known as Slump. Concrete is said to be workable if it can be easily mixed, compacted and easily finished. The results of all slump values of all mixes are shown in Table 4.2.

The internal surface of mould was cleaned thoroughly and free from moisture and any concrete before commencing the test. The mould was placed on rigid, horizontal and non-
absorbent surface. The mould filled in 4 layers, each approximately one quarter of height of the mould. Each layer shall be tampered with 25 strokes. After levelling the top, the mould was removed from concrete immediately by raising it slowly in a vertical direction. This allows the concrete to subside and slump shall be measured by measuring difference between the heights of mould and highest point of specimen being tested. If aggregate coated with cement paste residue and/or lumps of lean cement paste residue or natural aggregate. The term of recycled aggregate used in the project includes recycled concrete aggregate. Properties of recycled aggregate can be

Recycled concrete aggregate principally comprising crushed concrete consisting of natural
From Table 4.2, it can be seen that the slump value is decreasing with increase in the recycled concrete percentage in the mix. This is because the recycled aggregates absorbs more water than the normal aggregates because of the presence of dust and the mortar on the surface of recycled aggregates. All slump values were maintained in between 90-110mm by varying the dosage of super plasticizer.

**Compressive strength results**

Cubes of sizes 100 x 100 x 100 mm were cast for strength testing. These cubes were cured for 7, 14, 28, 56 and 90 days and tested in Compression testing machine having a The load was increased until the specimen fails. The maximum load taken by the specimen was noted. Experiment was repeated for two specimens of the same mix. The results of the strength tests conducted on concrete specimens of different mixes cured at different ages are presented and discussed in this section. The compressive strength Table 4.3.Compressive strength (MPa) values of all mixes at different curing ages

<table>
<thead>
<tr>
<th>Mix description</th>
<th>Slump (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1 0%RA +100%NA +10% SF</td>
<td>113</td>
</tr>
<tr>
<td>M2 10%RA +90%NA +10%SF</td>
<td>108</td>
</tr>
<tr>
<td>M3 20%RA +80%NA +10%SF</td>
<td>100</td>
</tr>
<tr>
<td>M4 30%RA +70%NA +10%SF</td>
<td>98</td>
</tr>
<tr>
<td>M5 40%RA +60%NA +10%SF</td>
<td>95</td>
</tr>
<tr>
<td>M6 50%RA +50%NA +10%SF</td>
<td>90</td>
</tr>
</tbody>
</table>

From the above test results and the graphical variation as shown in Fig 4.1, it was observed that the compressive strength results of the M2, M3 and M4 are comparable with the mix M1. This shows that the compressive strength of recycled aggregate concrete with up to 30% replacement of natural aggregates with recycled aggregates gives the same values as compared to the normal aggregates concrete or conventional concrete. The percentage loss in strength from 0%RA mix to 30%RA test results of all the mixes at different curing ages are shown in Table - 4.3. Variation of compressive strength of all the mixes with curing age is shown in Fig. - 4.1. The specimens were allowed to dry in sunlight for 1 day and are placed centrally in testing machine and load was applied continuously mix was 5.30% after 90 days, and at 28 days the loss of strength from M1 to M4 is 1.15%. After 30% replacement **Split Tensile Strength results**

Cubes of size 100×100×100mm were cast and cured for 7, 14, 28, 56 and 90 days. After curing age the cubes were allowed to dry in the sunlight for 1 day
and were tested under strength testing machine by placing the cubes diagonally in the centre. The load was increased until the specimen fails. The maximum load taken by the specimen was noted. Experiment was repeated for two specimens of the same mix and the average value was taken as final. The results of the strength tests conducted on concrete specimens of different mixes split tensile strength test results of all the mixes at different curing ages are shown in Table - 4.4. Variation of compressive strength of all the mixes with curing age is shown in Fig. - 4.2.

Table 4.4. Split tensile strength test (MPa) values of all mixes at different curing ages

<table>
<thead>
<tr>
<th>Mix Name</th>
<th>Description</th>
<th>Compressive Strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>7 days</td>
</tr>
<tr>
<td>M 1</td>
<td>0%RA+100%NA</td>
<td>31.1</td>
</tr>
<tr>
<td>M 2</td>
<td>10%RA+90%NA</td>
<td>30.0</td>
</tr>
<tr>
<td>M 3</td>
<td>20%RA+80%NA</td>
<td>29.6</td>
</tr>
<tr>
<td>M 4</td>
<td>30%RA+70%NA</td>
<td>30.8</td>
</tr>
<tr>
<td>M 5</td>
<td>40%RA+60%NA</td>
<td>26.3</td>
</tr>
<tr>
<td>M 6</td>
<td>50%RA+50%NA</td>
<td>25.9</td>
</tr>
</tbody>
</table>

i.e., 40% and 50% replacement of NA with RA shows the irregular behaviour in compressive strength values at both 28 days and 90 days. At early age of curing i.e. 28 days, the difference in compressive strength of M1, M2, M3 and M4 is very less, whereas at 90 days the difference in compressive strength of M1, M2, M3 and M4 is large. So it was observed that the optimum percentage of replacement of NA with RA is 30%. Beyond 30% replacement the results showing decreasing trend in terms of compressive strength at all curing ages.

From the above test results and the graphical variation as shown in Table 4.4 and Fig 4.2, it was observed that the split tensile strength results of the M2, M3 and M4 are comparable with the mix M1. This shows that the split tensile strength results of recycled aggregate concrete with 30% replacement of natural aggregates with recycled aggregates cured at different ages are presented and discussed in this section. The results showing decreasing trend in terms of compressive strength at all curing ages gives the same values as compared to the normal aggregates concrete or conventional concrete. After 30% replacement i.e., 40% and 50% replacement of NA with RA shows the irregular behaviour in split tensile strength values. The percentage loss in strength from 0%RA mix to 30%RA mix was 5.01%.
after 90 days, and at 28 days the loss of strength from M1 to M4 is 0.7%. So the optimum percentage of replacement of NA with RA is 30%. Beyond 30% replacement the results showing decreasing trend in terms of split tensile strength. The highest value of split tensile strength was observed for mix with 0% recycled aggregates at both initial stage and later stages of curing. The lowest value of split tensile strength was observed for mix with 50% recycled aggregates at both initial stage and later stage of curing. The decrease in the split tensile value of recycled aggregate concrete from one mix to other is high in the initial stages i.e. 7, 14, 28 days, whereas the decrease in split tensile value at 56, 90 days is uniform this can be clearly shown in the diagram. So, recycled aggregate concrete performed better with less than 30% replacement in the initial stages.

CONCLUSIONS

In this study, the mechanical and durability properties of concrete prepared with recycled aggregates were investigated. Based on the results of this experimental study, the following conclusions can be drawn.
Conclusions

1. The higher water absorption capacity of recycled aggregates has great influence on the water added to the mix, which can affect concrete’s workability. It is possible to gain the same compression and split tensile strength as conventional concrete up to 30% replacement of natural aggregate with recycled ones. But from the overall study, both the compression and split tensile strength values are decreasing with the increase in replacement levels.

REFERENCES

10. The increase of recycled aggregates content beyond 30% has negative effect on compressive strength of recycled aggregates concrete. The reduction in compressive strength after 28 days is about 10% when 50% recycled aggregates are used.
11. Split Tensile results also show down trend like compressive strength beyond 30% replacement of recycled aggregates.