In search of future construction material - Recycled Aggregates for Concrete Production

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Abstract: Properties of the recycled aggregates and the suitability of the same in structural concrete were studied and compared with those of natural aggregates. The results showed that the particle size distribution of recycled aggregates is compatible with those of natural aggregates. The recycled aggregates had abrasive and impact values of 48.7% and 27.10%, respectively while those of the natural aggregates were 29.5% and 11.45, respectively. Bulk density of recycled aggregates was 1065 kg/m^3 with compared to 1296 kg/m^3 of Natural aggregates and the water absorption was 2.82% with compared to 1.22 of Natural aggregates. The mix design proposed for concrete was grade 30. Properties of concrete made fewer than three testing scenarios consisting different proportions of natural aggregate to recycle aggregate as 50% -50%, 25%-75%, and 0%-100% were compared with those of 100% natural aggregates. With increasing percentage of recycled aggregate content, compressive strength, flexural strength, tensile splitting strength and workability were decreased. According to the results, grade 30 concrete properties could be achieved with mix proportions of 50% natural aggregate and 50% recycled aggregate, without significantly affecting the concrete properties, indicating a 50% saving of natural aggregates thus reducing environmental impacts and enhancing sustainability.

Keywords: Water absorption, Compressive strength, Tensile splitting strength, Flexural strength, Workability.

1. Introduction

One of the most environmentally responsible ways of meeting the challenges in sustainability in construction is the use of recycled concrete or recycled aggregate in new constructions. Recycled materials are the materials for future due to heavy consumption of the natural resources by the community at present. Recycled aggregates can be defined as the aggregate resulting from the processing of inorganic material previously used in construction. Although research works in some countries had indicated that recycled aggregates could be used for production of concrete, it has not been researched enough in Sri Lanka to convince the Sri Lankan

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engineers. Hence the present study investigates the feasibility of using recycled aggregates as an alternative construction material.

2. Materials and Methods

2.1 Preparation of Samples

A bulk sample of demolished building waste collected from the COWAM centre site in Galle was used as the materials for testing.

2.2 Testing of Aggregates

Followings tests were carried out to test the aggregate properties of recycled aggregates and natural aggregates.

- Sieve Analysis test - (BS-812-103.1, 1985)
- Specific Gravity and Water Absorption test -(BS 812: Part II: 1975)
- Bulk Density test - (BS 812: Part II: 1975)
- LAAV test for crushing and impact value of aggregates- (ASTM C131)
- AIV test for impact value of aggregates - (IS: 2386 part IV)
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2.2 Testing of Concrete

To evaluate the properties of concrete made using recycled aggregates, the recycled aggregates were mixed with natural aggregates under three different scenarios.

Scenario No :	% of Recycled Aggregates	% of Natural Aggregates
1	50	50
2	75	25
3	100	0

Table 1 - Respective percentage of aggregates mixed for production of concrete

The properties of concrete made according to the mixed proportions given in table 1, were compared with the concrete made with 100% natural aggregates.

The measurements of the material quantities used to prepare the concrete were calculated according to the grade 30 mix design (BRE mix design method). The workability of each and every mix was tested prior to the making of concrete specimens. Curing was carried out as per the BS standards after the preparation of the concrete specimens. The testing of those specimens was done for 7 days, 14 days and 28 days.

Following tests were done to determine the concrete properties.

- Compressive strength of test cubes - (BS 1881-part 116 : 1983)
- Flexural strength - (BS 1881-part 118 : 1983)
- Tensile splitting strength- (BS 1881- part 117 : 1983)

3. Results and Discussion

Concrete is a mixture of compendious material, aggregate, and water. Aggregate is commonly considered as inert filler, which accounts for 60 to 80 percent of the volume and 70 to 85 percent of the weight of concrete. Aggregate is classified as course and fine. In the present study the coarse aggregates were varied while keeping the others as it is and the variation in the properties of concrete was studied.

3.1 Properties of recycled aggregates

There was no significant difference between the gradation curves of natural aggregates and. recycled aggregates. Gradation affects many properties such as bulk density, physical stability, permeability etc. According to the results, it shows a dense gradation such that approximately of equal amounts of various sizes of aggregates. It is favourable for engineering applications as the bulk density is relatively high, the physical stability is satisfactory, and the permeability is quite low, due to the well packing of particles and hence increasing of the unit weight (Parekh, 2011).

The average results of aggregate properties are given in table 2.

Aggregate Property	RA	NA
Specific Gravity	1.749	1.571
Water Absorption (%)	2.815	1.219
Bulk Density (kg/m^3)	1065.10	1296.15
LAAV (%)	48.70	29.50
AIV (%)	27.10	11.45

Table 2 – the results of aggregate properties of Recycled Aggregates (RA) vs. Natural Aggregates (NA)

The specific gravity of aggregate is considered to be admeasuring of strength or quality of the material in its (Yong, 2009).There is a reduction of 10% from natural aggregate to recycle aggregate with respect to table 2, hence the strength is reduced. This is because the recycle aggregate contains some amount of attached mortar and concrete paste.

The water absorption of recycled aggregates is 50% higher than that of natural aggregates probably due to the presence of abundant amount of voids due to attached mortar.

Aggregate density has an important influence on concrete density since aggregate occupy up to 75%-80% of the volume of concrete (Nelson, 2004). The bulk density of aggregates tends to decrease from NA to RA and hence the concrete density. This has an implication on the weight of the structure and the load it must carry, but it can be use

with thin section in high rise buildings.

When considering the LAAV and AIV values, there is a significant reduction in abrasion and impact resistance, so care should be taken when using them for pavements applications and should be verified with other properties

3.2 Property variation of concrete made using recycled aggregates.

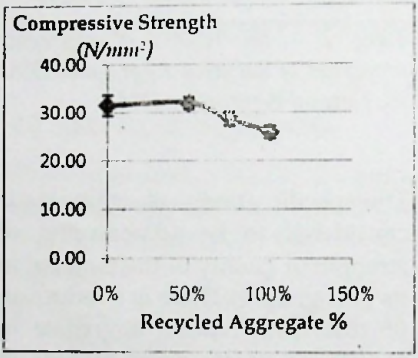

Figure 1 – Variation of compressive strength of concrete after 28 days

Figure 1, indicates that the concrete made even with 50% recycled aggregates achieves a strength required for grade 30 concrete, similar to that of 100% natural aggregates. This implies a 50% saving of virgin aggregate without affecting the concrete properties. Concrete made using 100% recycled aggregates also obtains a strength required for grade 25 concrete which is also satisfactory for various structural purposes.

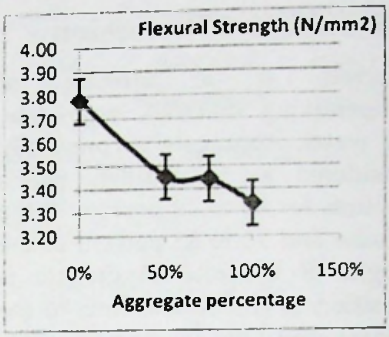

Figure 2 – Flexural Strength of concrete after 28 days

According to figure 3 there is a considerable difference in the flexural strength values of the concrete made by using 100% virgin aggregates and 50% recycled aggregates, but it should be shown that the difference between these two values is only 8.7%. The difference of the flexural strength values when using 100% virgin aggregates and 100% recycled aggregates is only around11.64%. This can be overcome when making the beams with reinforcement. The tensile splitting strength decreases from 2.63 to 2.42 N/mm2when increasing the proportion of RA been used. This is probably due to the better mechanical interlocking and interfacial bond due to the attached mortar paste in recycled aggregates.

However the workability of concrete decreases from 100mm to 55mm with increasing amount of recycled aggregates indicating more than 50% change probably due to the higher absorption of water by the pore spaces in mortar and attached concrete.

5. Conclusions

Mechanical properties of RA such as bulk density, water absorption, LAAV and AIV showed a relatively inferior quality when compared to that of natural aggregates. However, concrete made out of RA showed lesser impacts on the compressive strength and splitting tensile strength when compared to that made from 100% natural aggregates. The flexural strength of the concrete made by using RA shows a slight variation from that of NA, this can be overcome by adding steel reinforcement in to the concrete beams.

Concrete made using 50% RA and 50% NA was able to achieve the designed strength of grade 30 which indicates a possible replacement of 50% NA with recycled aggregates, indicating a 50% saving of NA, thus reducing the environmental impacts and enhancing sustainability.

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