RESOURCE SUSTAINABILITY INITIATIVE

(A study on usability of recycled coarse aggregate in concrete making)

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Abstract

This research targets at providing insights on how coarse aggregate prepared from recycled concrete differs from normal coarse aggregate. The recycled coarse aggregate in this context shall be considered only if it comes from demolished concrete waste and construction waste has been kept out of the scope of the study.

For this research the recycled coarse aggregate was collected from Pasakha, industrial dump yard and it was crushed to required size manually. The study is aimed at checking the feasibility of using recycled aggregate for concrete making. The aggregate test were conducted in the college laboratory firstly to check if the aggregate had the basic strength and qualities expected by standards. The aggregate test for natural or normal aggregate was conducted as a reference or control test.

On achieving satisfactory result for the test conducted for recycled coarse aggregate, the step was taken forward to conduct the test for concrete prepared out of both recycled coarse aggregate and normal aggregate using the same cement and fine aggregate. Workability test, shrinkage test and compressive strength were conducted and 46 specimens were prepared and compressive strength test and 6 for testing shrinkage. The paper also presents the stress-stress behavior and elastic modulus of both the concrete samples.

Key words: recycled coarse aggregate, natural or normal coarse aggregate, recycled aggregate concrete, normal aggregate concrete, workability, shrinkage, compressive strength, stress-strain curve, modulus of elasticity.

1. INTRODUCTION

The idea of concrete recycling prevailed since many decades but no precise finding has been published so far even though repeated research has been conducted in many parts of the world.

It has gained its importance since the volume of demolition concrete and concrete waste have increased by many times due to presence of many old buildings, bridges, concrete pavements and waste generated due to disasters and wars. Huge amount of concrete waste are generated when the structures are demolished after it has become obsolete and the natural disasters such as earthquake, cyclone, floods, etc. and war has turned good structures into debris.

Bhutan as of now seems to have no concern about the demolition waste generated as the amount of demolition waste generated is quite less owing to the fact that not much of the major infrastructure were present and very few of them were demolished, so the problem associated with demolished waste seems to be less alarming even if it is dumped simply near the their origin as it is present in very small quantity and its impacts are not so noticeable.

The countries such as UK, USA, France, Denmark, Germany and Japan have succeeded in developing suitable means of recycling and reusing the demolition waste up to 80- 90 percent while least effort has been made even in India (Job & Wilson, 2013).

The time has come where one needs to find the best solution to defend the crises associated with Demolition waste in Bhutan. Bhutan is a developing country, World Bank report 2015 has declared that Bhutan's economy has expanded at a robust pace due to development in hydropower sector. The Gross Domestic Product (GDP) growth was nearly 8% in 2011 and 2012 but in 2013 and 2015, GDP growth was found to be 12.5 % which is clear indication of rapid development in the country. So with development, there is always a parallel increase in number of large infrastructure, and the fact is that all the tall rise huge buildings are constructed using steels and concrete. Sooner or later the constructed civil engineering infrastructure need remodeling, demolishing, etc. yielding huge quantities of concrete waste.

The waste generated has to be handled properly so that it has least impact on the pristine environment. At the same time one can try using recycled concretes in construction to reduce the pressure on natural quarries.

2. LITERATURE REVIEW

Schoppe (2011) in the paper titled 'shrinkage and modulus of elasticity in concrete with recycled aggregate' pointed out that recycled aggregates are typically not used in concrete production due to its negative influence on the compressive strength, modulus of elasticity, shrinkage and creep. At the same time it was noted that the quality of old mortar adhered on the recycled greatly influence the performance of the aggregate which actually have a negative influence on pre-mentioned parameters.

Kou in 2006 in the research paper tilted 'Reusing Recycled aggregates in Structural Concrete' has concluded that there is no fundamental technical problem while using recycled aggregate but nevertheless it was proven that one of the practical way to use higher percentage of recycled aggregate in concrete is by precasting with initial steam curing step along with 25-35 percent of fly ash.

It was noted that as per the IS: 456-2000 prediction equation, concrete with high compressive is expected to yield high elastic modulus which exactly happened in the test and analysis conducted but it was later noted by the research conducted by Brown et al, (2005) that a concrete with a higher compressive strength does not always or necessarily give a higher elastic modulus than a concrete with a lower compressive strength.

The several past researchers have conducted study for determining compressive strength of RAC compared to NAC. The factors such as smoother texture, rounder shape of RA, and higher percentage of fine particles were the reasons RA had lower compressive strength than NA (Olorusongo, F.T., 1999).

3. METHODOLOGY

3.1 Methodology

The project basically aimed at comparing the behavior of normal concrete with recycled aggregate concrete. Literature reviewing was the start point for the project and it continued till the completion of the work. Through literature review, the appropriate approach that can be adopted was identified upon determining the aims and objectives of the project work. It then helped in figuring out the estimates of material required. Then the required materials were collect.

3.2 Material collection

Following were basic material used during the course of our project.

- Ordinary Portland cement, grade 43.
- Locally available fine aggregate.
- Locally available 20mm natural coarse aggregate.
- 20mm manually crushed recycled concrete aggregate.

The recyclable concrete was collected from dump yard at Pasakha, Phuntsholing while other materials were available in the college civil engineering laboratory.

3.3 Sample preparation.

On completing the material collection, sample preparation work started. For the aggregates test, aggregates were graded as required and put forward for testing. For the workability test, test samples were prepared in conjunction with the sample preparation for the shrinkage and compressive strength test. For the shrinkage and compressive strength test, cubes were casted and subjected to curing. For the cube test, M20 grade concrete was prepared. For nominal mix, one can adopt the mix ratio of 1:1.5:3 but for our research the mix design was performed and different mix ratios were adopted for different concrete type.

Table 1: Concrete mix ratios

	water	cement	fine aggregate	coarse aggregate
NAC	0.48	1.00	1.60	3.32
RAC	0.50	1.00	1.56	3.20

The mix ratios are:

For shrinkage test 3 samples for each concrete type was prepared, while 23 samples each were prepared for compressive strength test. In total 46 samples for compressive strength test and 6 for shrinkage test. Among 46 samples, 6 sample were tested after 7 days while 40 samples were tested after 28 days.

3.4 Testing

Four tests for the aggregates were conducted to check its toughness, strength, water adsorbing capacity and resistance against abrasion.

i. Impact value test-to find the toughness of the material to resist impact load and was carried out as per IS: 2386 (Part IV) – 1963. Higher the impact value, less tough the aggregate is.

ii. Abrasion test- test is conducted to determine the abrasion value of coarse aggregates as per IS: 2386 (Part IV) – 1963 and Angeles Abrasion Test was used. Higher the abrasion test value, the aggregate has less resistance against abrasion.

iii. Specific gravity test-The specific gravity of an aggregate is used to measure of strength or quality of the material. Stones having low specific gravity are generally weaker than those with higher specific gravity values.

iv. Water adsorption test- the test is used to calculate the change in the mass of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition. Higher the water absorption capacity of the aggregate, weaker the aggregates are as they have many voids in it.

Once the aggregates has shown a satisfactory result on conducting the aggregate test, it was then subjected to further testing. The aggregates were used for concrete making and tests for the concrete were conducted. Following are the test conducted for the concretes.

i. Workability test

The workability test was conducted using the slump and compacting factor test. Concrete is said to be workable if it is easily transported, placed, compacted and finished without any segregation. The slump test determines the consistency of concrete mix of given proportions while the compacting factor test determine the workability of concrete mix of given proportions in terms of compatibility and It is based upon the definition, that workability is that property of the concrete which determines the amount of work required to produce full compaction. The workable concrete has to be mixable, transportable, moldable and compactable.

ii. Shrinkage test

After casting the cube, it was cured for 7 days and decrease in the size of the cube was measured. The shrinkage was measured in terms of decrease in surface area. The change in size of the sample was measured to the precision of 0.02mm using Vernier caliper.

iii. Compressive strength test

The compressive strength of the concrete was tested mainly after 28 days. Upon completion of cube casting, the concrete cubes were cured for 28 days and was subjected to testing in a universal testing machine (UTM). The test was conducted after 7 days too but it has no significance at all as its values are not used in determining the ultimate strength of the concrete. It was conducted as a trial test.

4. TEST RESULTS

4.1 Aggregate test results.

Table 2: Impact value for aggregate

Type of aggregate	Impact value
Normal aggregate	17.2%
Recycled aggregate	20.4%

Table 3: Impact value for aggregate

Type of aggregate	Abrasion value
Normal aggregate	[illegible].45%
Recycled aggregate	37.62%

Table 4: Specific gravity value [illegible] aggregate

Type of aggregate	Specific gravity
Normal aggregate	2.62
Recycled aggregate	2.14

Table 5: Water adsorption value for aggregate

Type of aggregate	Water absorption value
Normal aggregate	0.35%
Recycled aggregate	0.44%

The plot below shows the test values obtained for different test conducted for the aggregate.

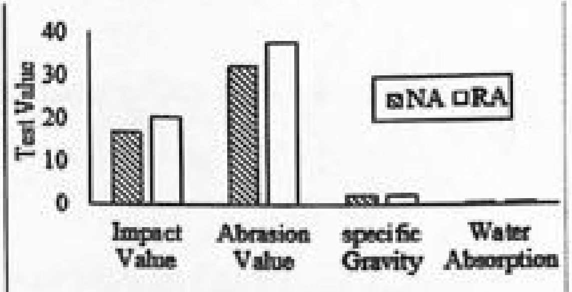

Fig. 1: Aggregate test values

Higher the impact value means less tough the aggregates are, while greater the specific gravity values means stronger the aggregates are. If the abrasion value is higher, it means that the aggregate is less resistance to abrasion and if the water absorption capacity is high, the aggregates are considered weak.

4.2 Concrete test results.

4.2.1 Workability test result

I. Slump test result.

Table 6: Slump test value

Type of concrete	Slump test
Normal concrete	85mm
Recycled concrete	76mm

II. Compacting factor test results.

Table 7: Compacting factor value

Type of concrete	Compaction factor
Normal concrete	0.89
Recycled concrete	0.78

According to IS 456-2000 slump value of 75-100 indicates it is medium workability.

The normal range of compacting factor of concrete should lie in the range of 0.8 to 0.92 therefore the concrete prepared are workable.

4.2.2 Shrinkage test result

The shrinkage of the sample was read after 12, 17, 22 and 28 days at an interval of 5 days and following test results are obtained.

Table 8: Test result for surface area shrinkage in %

time in days	Normal Aggregate Concrete	Recycled Aggregate Concrete
7	0	0
12	1.02	1.12
17	1.45	1.49
22	1.62	1.83
28	1.68	1.97

Based on above tabulated values, following graph is plotted.

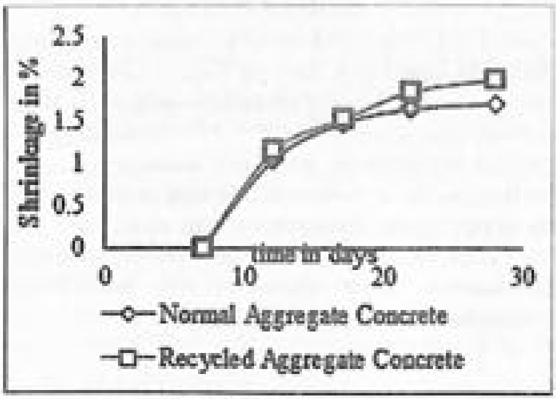

Fig. 2: Shrinkage curve

The maximum percentage of shrinkage in recycled aggregate concrete is 1.97 %. shrinkage strain produced by shrinkage is 0.0001(0.000087). Based on IS 1343, the shrinkage strain should not be more than 0.0005.

4.2.3 Compressive strength test result

The mean ultimate compressive strength of the concretes are as tabulated below.

Table 9: Mean ultimate compressive strength

Time	Sample	Compressive Strength in MPa
28 days	NAC	20.65
	RAC	20.44

Now the characteristic compressive strength of the concrete is computed using standard formula Characteristic Strength fck=fm-(1.64x σ ; Where f_m is the mean ultimate strength & σ is Standard Deviation.

Therefore characteristics compressive strength of a recycled concrete aggregate is 20.08MPa (>20MPa for M20).

4.2.3 Stress-Strain behavior

In conjunction with compressive strength test, the load-displacement relation was obtained, which was then used plot stress-strain curve as below.

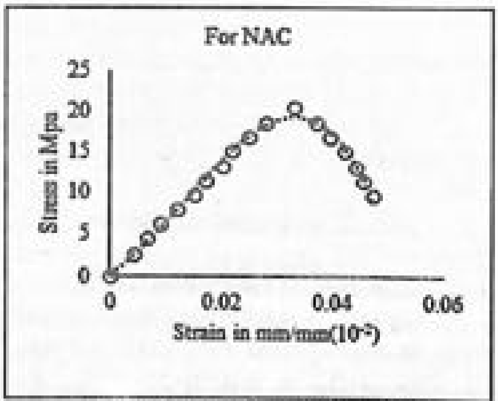

Fig. 3: Stress-Strain curve for NAC

Here the ultimate strength noted from the graph, fc'=20.65 MPa and Strain corresponding to the ultimate strength, Ɛo=0.00032

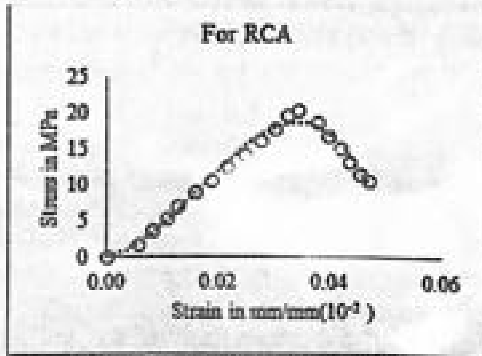

Fig. 4: Stress-Strain curve for RAC

Here the ultimate strength noted from the graph, fc'=20.44 MPa and Strain corresponding to the ultimate strength, Ɛo=0.00034.

Based on stress-strain relationship, the modulus of elasticity is computed as below.

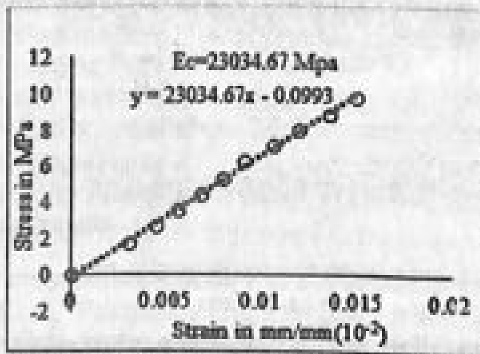

Fig. 5: Ec value for Normal aggregate concrete

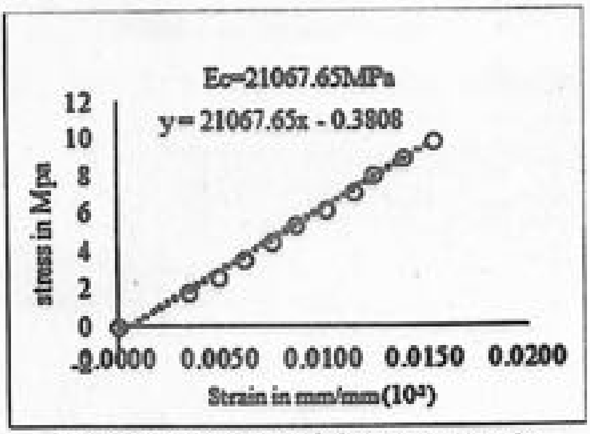

Fig. 6: Ec value for Recycled aggregate concrete

The elastic modulus can be predicted as per IS 456:2000

$Ec = 500\sqrt{fc0'}$

Where Ec=elastic modulus in MPa

fc'=compressive strength of concrete in MPa

The predicted value can have a tolerance limit of ± 20%

The predicted value of Ec for both the concrete type are as follows.

For Normal aggregate concrete:

$Ec = 5000\sqrt{fc'} = 5000\sqrt{20.65} = 22721.136$ MPa

For Recycled aggregate concrete:

$Ec = 5000\sqrt{fc'} = 5000\sqrt{20.44} = 22605.309$ MPa

In both the case Ec values obtained from the stress-strain curve lies within the tolerance limit.

RECOMMENDATIONS

5.1 Conclusion

Through the study conducted we could draw a conclusion that the recycled concrete in the form of a coarse aggregate can be used for concrete making for nonstructural elements, it won't lessen the quality of the concrete even if it was observed to have less strength compared to normal concrete.

It was also noted that for all the test we have conducted so far, recycled aggregate seemed to have perform good that gives the assurance that itz can be trusted and put forward for a use. The paper does not compels nor obligate one to use recycled aggregate for construction rather it tries to encourage individuals to adopt it after making all necessary analysis and decisive actions after considering environmental issues and non-renewability of natural aggregates.

Form the aggregate test conducted, it was observed that the all impact value, abrasion value, specific gravity value and water adsorption value were within permissible range confirming to be usable aggregate based on those parameters. From workability test, it was ascertained that we can prepare workable concrete mix that would prevent segregation and maintain homogeneous mix. The shrinkage test have concluded that shrinkage is within allowable range and the characteristic compressive strength obtained evidenced that the concrete prepared from recycled aggregate has enough compressive strength, and modulus of elasticity value within the permissible range. therefore recycled aggregate can be suggested for use if it could achieve minimum requirements on conducting other test for concr

5.2 Recommendations

The research here was conducted with limited scope due to time and resource constrain. Following test shall be recommended for further confirmation.

- Creep test.
- Freeze and thaw resistance test.
- Bond to reinforcement test.
- Resistance to aggressive chemical test, etc.

Apart from pre-listed test, we shall recommend to conduct the similar test with different grade of recycled concrete, with different age of recycled concrete and with Portland Pozzolana cement (PPC) to check the variations.

6. ACKNOWLEGEMENT

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