

Performance Evaluation of Recycled Aggregate Concrete

Sajjad Ali

*Lecturer, University of engineering and technology Peshawar campus-III, Bannu, Pakistan
Engr.Sajjad@yahoo.com*

Zia ur rahman

*Lecturer, University of engineering and technology Peshawar campus-III, Bannu, Pakistan
zia.ur2014@yahoo.com*

Qasim khan

*Lecturer, University of engineering and technology Peshawar campus-III, Bannu, Pakistan
Engr.qasim86@gmail.com*

Shah Room

*Lecturer, University of South Asia Lahore, Pakistan
Shahrome313@yahoo.com*

Ziad Khan

*Lecturer, UCEST Leads University Lahore, Pakistan
Ziaduet207@gmail.com*

Abstract

Recycled aggregates are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. The aim for this research was to determine the performance of recycled aggregate in the structural concrete giving a better understanding on the properties of concrete with recycled aggregates, as an alternative material to coarse aggregate in structural concrete. The investigation was carried out using workability test, compressive test and indirect tensile Test.

Test Samples were prepared from the virgin aggregate and workability test, compressive test and indirect tensile test were performed. After testing, samples were recycled to obtain recycled aggregate, a replica of demolished concrete structure in real life. The recycled aggregate samples were prepared in two batches. In the first batch the water cement ratio was kept same (0.55) as that in case of virgin concrete. In the second stage the water cement ratio was increased up to 0.60 to check the variation of concretes specimen in strength and workability.

It was found that at the same water / cement ratios, the workability of virgin concrete is higher than that of recycled concrete. Similarly at water / cement ratio of 0.55, the compressive strength and Tensile strength of recycled concrete is appreciably lower than that of virgin concrete. However, at higher w/c

ratio of 0.60, the compressive and tensile strength of recycled concrete is very close to that of virgin concrete. Unlike virgin concrete in which compressive strength decreases as water / cement ratio increases, in recycled concrete the contrary is the case, i.e. strength increases with increase in water / cement ratios.

Recycled aggregated can be used with confidence in construction works with increased water cement ratio. The environmental issue can be effectively addressed by avoiding the dumping of the demolished materials associated with the elimination costs pertaining to the disposing operations.

Keywords Virgin Aggregate, Recycled Aggregate, Workability

1. Introduction

Recycling is the method of processing the used material for use in creating new product. Recycled aggregate consist of crushed, graded inorganic particles obtained from the materials that have been used in the constructions and demolition debris. These materials are generally obtained from buildings, roads, bridges, and sometimes even from catastrophes, such as wars and earthquake

Concrete recycling has been identified throughout the world as part of the strategy on responsible management of Construction & Demolition materials. It is so because concrete recycling offers a number of benefits including keeping concrete debris out of landfills thereby conserving landfill space, reducing the amount of concrete aggregate required to be mined thereby conserving energy and resources, reduction of overall project cost by saving on the cost of concrete rubble disposal, and mitigating the pollution involved in trucking material over long distances.

In the past when structures made of concrete are demolished or renovated, the concrete debris was routinely trucked to landfills for disposal. In the present era of greater environmental consciousness, more environmental legislations, and the desire to reduce construction cost, recycling has become a more attractive option of dealing with the rubble.

The main aim of testing the recycled aggregate is to find the strength characteristics and to conduct analysis whether recycled aggregate is suitable to apply in the construction area. In previous studies, it was found that recycled aggregate concrete have lower compressive strength between 8% and 24% than corresponding concretes made with conventional aggregate(Ravindrajah and Tam,2005).There is significant difference in indirect tensile strength (split tensile strength) of conventional concrete and corresponding recycled aggregate concrete. Further it was noted that the flexural strength of recycled aggregate concrete is somewhere between 1/5 and 1/8 of its compressive strength, similar to what is the case for conventional concrete. However, no experimental data were presented (B. C. S. J., 2000)

It was found that recycled concrete aggregate had 7 to 9% lower relative density and 2 times higher water absorption than natural aggregate (Limbachiya and Leelawat, 2000). According to their test results, it shown that there was no effect with the replacement of 30% coarse recycled concrete aggregate used on the ceiling strength of concrete. In addition, recycled concrete aggregate could be used in high strength concrete mixes with the recycled concrete aggregate content in the concrete. There is no effect by using up to 30% of coarse recycled concrete aggregate on the standard 100mm concrete cube compressive strength. But when the percentage of recycled concrete aggregate used increased, the compressive strength was reducing (Limbachiya, 2004).

The strength characteristics of recycled aggregate concrete were influenced by the strength of the original concrete, the ratio of coarse aggregate to fine aggregate in the original concrete, and the ratio of top size

of the aggregate in the original concrete in the recycled aggregate (Tavakoli,1996). He also mentioned that water absorption and Los Angeles abrasion loss will influence the water cement ratio and top size ratio for the strength characteristic of recycled aggregate.

The adjustment of water/cement ratio when using recycled concrete aggregate during the concrete mixing can improved the strength of the recycled aggregate concrete specimens (Mandal *et al.*, 2002). From the results obtained, recycled aggregate concrete specimens had the same engineering and durability performance when compared to the concrete specimens made by natural aggregate within 28days design strength.

The aim of the present research is to determine the strength characteristic of recycled aggregate for application in the structural concrete, which will give a better understanding of the properties of concrete with recycled aggregate, a possible alternative to coarse aggregate in structural concrete.

2. Experimental Methodology and Results

It was planned to prepare cylindrical specimens of concrete with 6 inches diameter and 12 inches height using virgin aggregates obtained from local kurram crushing plant of district Bannu with a water/cement ratio of 0.55. After 28 days curing, Compression test was conducted on three cured samples according to ASTM C-39. Meanwhile the concrete cylinders were properly capped before testing and were placed in the direction of casting in UTM. Similarly three specimens were subjected to indirect tensile test following ASTM C-496 procedure and an average value was taken .The same process was repeated for concrete specimens constructed from recycled aggregates which were recovered by crushing the hardened concrete cylinders made of virgin aggregates using water/cement ratio of 0.55.However, in the second batch of sample preparation from recycled aggregate, water/cement ratio was increased to 0.60 and 28 days average strength was determined in term of compression and Indirect tensile strength. The results obtained are shown in the following table

Table 1: 28 Days Compressive and Indirect Tensile Strength of Virgin and Recycled Aggregate

Type of Aggregate	Compressive Strength	Indirect Tensile Strength
Virgin (0.55 W/C)	3897 psi	370 psi
Recycled(0.55 W/C)	3165 psi	310 psi
Recycled(0.60 W/C)	3821 psi	357 psi

Before conducting compression and indirect tensile tests on hardened concrete samples, important investigations were made both on virgin and recycled aggregates. It included specific gravity and water absorption, slump test and sieve analysis both for coarse and fine aggregates.

The specific gravity and water absorption capacity were determined using ASTM C 128-79 procedure and results are shown in the following table.

Table 2: Specific Gravity and Water absorption Capacity of Virgin and Recycled Aggregate

Material Property	Fine-Virgin	Coarse-Virgin	Recycled
Water Absorption capacity	1.56%	0.71%	2.6%
Specific gravity	2.62	2.7	2.5
Moisture content	0.2%	0.31%	0.43%

Sieve analysis of the sand was carried out according to ASTM C 136, fineness modulus of sand was 2.48 and the results are shown in the table below.

Table 3: Sieve Analysis of Fine Aggregate (Sand)

Sieve No	Weight Retained (grams)	% Weight Retained	Cumulative % Passing	ASTM Specification	Cumulative % Retained
#4	3	0.31	99.69	95-100	0.31
#8	31	3.16	96.53	80-100	3.47
#16	142	14.5	82.03	50-85	17.97
#30	285	29.08	52.95	25-40	47.05
#50	350	35.71	17.24	2-10	82.76
#100	136	13.88	3.36	--	96.64
#200	23	2.35	1.01	--	98.99
Pan Total	10980	1.02	0		100

The coarse aggregate was found to be well graded and it also met the requirements of ASTM C 33-09

Table 4: Sieve Analysis of Virgin Coarse Aggregate

Sieve size	Weight Retained(gm)	% weight Retained	% Passing	ASTM Range
2.5"	0	0	100	--
2"	0	0	100	--
1.5"	0	0	100	100
1"	0	0	100	90-100
¾"	3395	31.84	66.63	40-85
½"	4165	40.94	25.69	10-40
3/8"	1030	10.12	15.57	0-15
3/16"	964	9.47	6.1	0-5
Pan	620	6.09	0	--
Total	10174			

The details of Sieve Analysis of Recycled Aggregate are provided in the following table.

Table 5: Sieve Analysis of Recycled Aggregate

Sieve size	Wt .Retained(gm)	% Wt .Retained	% Passing	ASTM limits
1-1/2 "	0	0	100	100
1 "	209.5	6.98	93.02	90-100
3/4"	1497.2	44.9	50.1	40-85
1/2"	2419.3	80.64	19.36	10-40
3/8"	2791.4	93.04	6.46	0-15

Later on Slump test was used to determine the workability of fresh concrete made of virgin and recycled aggregate. The results obtained are shown in the following table.

Table 6: Slump Test for Virgin and Recycled Aggregate

Water/Cement Ratio	Slump Value(Virgin Aggregate)	Slump Value(Recycled Aggregate)
0.55	1.5 inches	zero
0.60	1.5 inches

3. Data Analysis

From Experimental investigation, it was observed that the specific gravity of recycled aggregate decreases as compared to virgin aggregate. However, the water absorption capacity of recycled aggregate is comparatively increased.

After Sieve analysis of the sand following ASTM C 136 procedure, fineness modulus of sand was recorded to be 2.48 which were under the standard limits. The virgin coarse aggregate obtained from kurram crushing plant was found to be well graded and it also met the requirements of ASTM C 33-09. Similarly results of recycled aggregate was also matching ASTM limits in this perspective.

To evaluate workability of recycled aggregate, the slump recorded was zero at 0.55 water cement ratio which is below the threshold slump value (less than 1 inch). However; this value was increased to 1.5 inches at a water cement ratio of 0.60.

It was noted that at water cement of 0.55, compressive and tensile strength of recycled aggregate was 3165 psi and 310 psi respectively. This value was increased to 3821 psi and 357 psi respectively when water cement ratio was increased to 0.60. However, even at increased water cement ratio of 0.60, the

strength of recycled aggregate concrete is still less than virgin aggregate concrete though very close to that of virgin aggregate concrete.

4. Conclusions

Based on the extensive laboratory investigation, it can be easily concluded that recycled aggregate is less workable as compared to virgin aggregate concrete at low water cement ratio. On the other hand, workability of recycled aggregate concrete increases with increase in the water cement ratio.

From the analysis of tests data, it is observed that strength characteristics (compressive and Tensile strength) of recycled aggregate concrete is mostly dependent on the amount of water used in the concrete mix, at higher water cement ratio; the strength is very close to that of conventional concrete.

At the same water cement ratio of 0.55, the compressive strength of recycled aggregate concrete is 18.78 % less than virgin aggregate concrete. However, this difference is limited to only 1.95 % when water cement ratio for recycled aggregate concrete was increased to 0.60. Similarly, this difference is only 3.51% regarding tensile strength with a water cement ratio of 0.60 in recycled aggregate concrete and keeping 0.55 water cement ratio in conventional concrete.

Although recycled aggregate can be applied in structure, but one issue must not be neglected as recycled aggregate with reduce water content would have low workability. Whenever recycled aggregate is applied, water content in the concrete mix has to be monitored carefully due to the higher water absorption capacity of recycled aggregate

Recycled Aggregate concrete can be used in all types of construction with confidence with slightly increased water content especially in case when required compressive strength is equal to or less than 3000 psi.

With the cheaper price of recycled aggregate compared to natural aggregate, the builders can carry out the construction task with lesser material costs.

To secure our environment and make it human friendly, the usage of recycled aggregate concrete become more important as the materials waste is gradually increasing with the increase of population and urban development.

6. References

- ASTM- American Society for Testing and Materials
B. C. S. J. (2000) "Study on Recycled Aggregate and Recycled Aggregate Concrete", Building Contractors Society of Japan, Committee on Disposal and Reuse of Conc Const Waste, Summary in Conc J, Japan – 16(7), pp 18 – 31.
Limbachiya M. C., Koulouris A, Roberts J. J. and Fried A. N. (2004) "Performance of Recycled Aggregate Concrete", Proc of RILEM Inter Sympo of Env – Conscious Mat and System for Sustainable Development, RILEM Publications: 127 – 136
Limbachiya M. C., Leelawat T. and Dhir R. K., 2000, *Use of recycled concrete aggregate in high-strength concrete*, Materials and Structures, Volume 33, November 2000, p574-580
Mandal, S., Chakraborty, S. and Gupta, A. (2002) Some studies on durability of recycled aggregate concrete. *Indian concrete journal*: 385-388

Sri Ravindrarajah R and Tam C. T. (2005) "Properties of Concrete made with Crushed Concrete as Coarse Aggregate", Magazine of Conc Research – 37(130), pp 29 – 38
Tavakoli, M. and Soroushian, P. (1996), "Drying Shrinkage Behavior of Recycled Aggregate Concrete," Concrete International, Vol. 18, No. 11, pp. 58-61

