

# Water Penetration of Concrete made with Coarse Aggregates from Demolishing Waste

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**Abstract**-The results of laboratory investigations on water penetration in concrete made with coarse aggregates from demolishing waste are presented in this paper. Seven batches of standard size concrete cubes were cast with recycled aggregates from demolished concrete replacing coarse aggregates in percentages from 0% to 60%. The compressive strength of the samples was evaluated by non-destructive testing with the use of the Schimidz hammer. It was found that the strength reduces with an increase in recycled aggregate percentage. The maximum loss of strength due to the induction of recycled aggregates was 32% in the batch with 60% recycled aggregates. All samples were subject to constant water pressure of 5 bars for 72 hours. From the obtained results it was shown that the water penetration depth increases with increase in recycled aggregates rate. With 10% and 20% replacement the samples allowed less water to penetrate than conventional concrete samples, but 76% more penetration depth was recorded in samples with 60% replacement. Strength and water penetration results from dosages up to 20% show that the durability of the produced concrete allows it to be used in structural members with consideration of strength reduction in the design process. However, more water penetration with higher dosages of recycled aggregates needs proper care in design and usage of the concrete particularly for locations where concrete is exposed to water pressure.

**Keywords**-green concrete; recycled aggregates; demolishing waste; permeability; water penetration

## I. INTRODUCTION

Green concrete utilizes alternative concrete ingredients often involving waste generated from primary processes. Waste generated due to demolishing of old structures poses a serious problem. This waste to some extent is utilized as filling material and the remaining goes to landfills. In agriculture

dependent countries like Pakistan, the land near the cities is agricultural. Thus, dumping the waste in landfills will lead to adverse effects to the land and the environment. One of the options to minimize waste is by using it in new concrete as coarse aggregates. The green concrete developed by using the demolishing waste will not only reduce the waste amount to some extent, but will also reduce the negative impacts of quarrying for coarse aggregate production. However, the developed concrete should be checked for its properties with respect to conventional concrete to develop confidence in its use. Research on the use of demolishing concrete as coarse aggregates is active the last few decades. In this regard, authors in [1, 2] published review articles on the recent developments on the use of waste in fresh concrete with reference to recycling of aggregates, issues associated with the processes and its impact on the final strength of concrete.

Among various concrete properties, permeability is one of the most important. It controls the water infiltration in concrete, thus preventing the rusting of steel and strengthening the bond strength between steel and concrete. Also, it is the property which allows the flow of water through the concrete body if that is required, as in the case of thirsty concrete. In a research investigation, while checking the permeability of pavement concrete made with recycled aggregates and dolomite and marble waste, author in [3] observed the good permeability of the proposed material but noticed the decreased strength of recycled aggregate concrete in comparison with conventional concrete and concrete made with dolomite and marble waste. In another experimental study of the properties of pervious concrete, authors in [4] suggested 0.35 as water-binder ratio with enough strength of concrete to be used in sidewalks and civic paving projects. Permeability characteristics of fiber reinforced high performance concrete and fiber reinforced

concrete made with recycled aggregates as coarse and fine aggregates have been studied in [5, 6]. Based on the permeability results of the proposed concrete, the authors concluded that recycled aggregates partially replacing fine and coarse aggregates give almost similar properties as conventional concrete. The test results of concrete made with various alternative materials [7-17] regarding suitability [18], strength and durability [19], root cause of waste generation [20], sustained loading for 9 and 12 months [21, 22], fire resistance at 1000C for 18 and 24 hours [23, 24] show the promising effects of recycled aggregates as replacement materials suitable to be used in new concrete. Demolishing waste has also been tested as replacement of fine aggregates. To this end, authors in [25] replaced fine aggregates with demolishing waste by 10%, 30%, 50% and 100%. Laboratory tests of various properties of concrete showed results comparable to the conventional concrete's. Recycled aggregates with supplementary cementitious materials have been used in [26] to check the permeability of concrete at laboratory scale. The results revealed good resistance to water penetration in the proposed concrete. Authors in [27] performed laboratory investigations on six different concrete mixes with recycled aggregates in order to study the permeability characteristics under desiccation conditions. The study considered fresh concrete in ventilated tunnel and showed a reduction in the bleeding of the concrete with low water cement ratio. Liquid penetration depth and strength of concretes modified with polymer admixtures under the effect of crude-oil products was studied in [28].

Although a few attempts have been made to study the water penetration in concrete with demolishing waste in different conditions with and without other ingredients, the scattering of the results shows that more work is needed to develop the confidence in the use of this material. Therefore, this experimental study aims to evaluate the permeability of concrete made with coarse aggregates from demolishing waste at different percentages. It is hoped that the outcome will set a landmark for scholars and guidelines for relevant industry research.

## II. MATERIALS AND TESTING

### A. Concrete Ingredients

Demolished concrete was obtained from a 60 year old demolished reinforced concrete structure. The transformation of the material in coarse aggregates of maximum 25mm size was done manually by hammering. The obtained material was then sorted for debris and other unlikely materials followed by washing and drying in the laboratory. Same size conventional coarse aggregates were obtained from the local market. Sorting and washing of these aggregates were also done in similar fashion. These materials are shown in Figure 1. To prepare the proposed specimens, hill sand confirming the ASTM requirements was used as fine aggregates. Ordinary Portland cement under the brand name Pakland along with hill sand, obtained from the local market was used.

### B. Specimen Preparation

A total of seven concrete mixes were made. Among these mixes, one batch was prepared with only conventional coarse

aggregates, whereas in the rest six batches, conventional coarse aggregates were replaced with recycled aggregates from demolished concrete with percentages from 10% to 60%. In each batch, four cubical specimens of standard size were prepared using 1:2:4 mix and 0.5 water to cement ratio. Both parameters were selected due to their frequent occurrence in the construction industry. Water obtained from the city water supply line having pH value equal to 6.9 was used for the preparation of the mixes. Table I shows the details of the materials used in each batch. All the ingredients were mixed in a concrete mixer.



Fig. 1. Conventional and recycled aggregates.

TABLE I. MATERIALS

No	1	2	3	4	5	6	7
Batch	B1	B2	B3	B4	B5	B6	B7
RCA (%)	0	10	20	30	40	50	60
No. of cubes	4	4	4	4	4	4	4
Cement (kg)	6	6	6	6	6	6	6
Fine aggr. (kg)	12	12	12	12	12	12	12
Coarse aggr. (kg)	24.0	21.6	19.2	16.8	14.4	12.0	9.6
RCA (kg)	0.0	2.4	4.8	7.2	9.6	12.0	14.4
Water (kg)	3	3	3	3	3	3	3

Cube specimens were prepared by first oiling the inner surface of moulds, followed by filling with concrete in layers. A table vibrator was used to compact the concrete in the moulds. The specimens were de-moulded after 24h and left in the laboratory to air dry for next 24h. Curing of the specimens was done by fully immersing them in potable water for 28 days.

### C. Specimen Testing

After the curing period, the specimens were taken out of the water and were allowed to air dry for 24h. All the specimens were then tested for compressive strength with the Non-Destructive Testing (NDT) of the Schimidz hammer. The obtained results are listed in Table II. After the strength testing, the specimens were tested for water penetration in accordance with the procedure defined by ASTM C642 for the purpose [29] and were mounted on a water penetration test machine (Figure 2). The available machine tests six specimens at a time, therefore, the specimens were tested in turn. The specimens were mounted on the machine followed by filling of the cylinders with water. The water pressure was raised and kept equal to 5bars (5kg/cm<sup>2</sup>) for 72h. After the completion of this period, the specimens were un-mounted, and the surface water

was wiped off. The specimens were then split in to two parts in a universal testing machine (Figure 3). The internal structure of the specimens was found compacted without any visible voids. The saturated surface was marked and the depth of water at six different locations was recorded. The obtained results are listed in Table III.

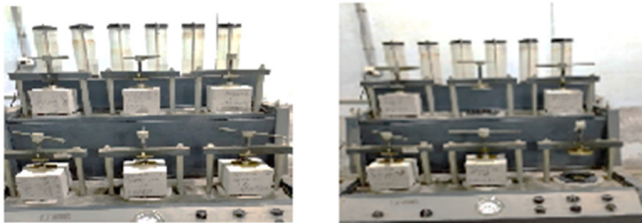


Fig. 2. Water penetration test.

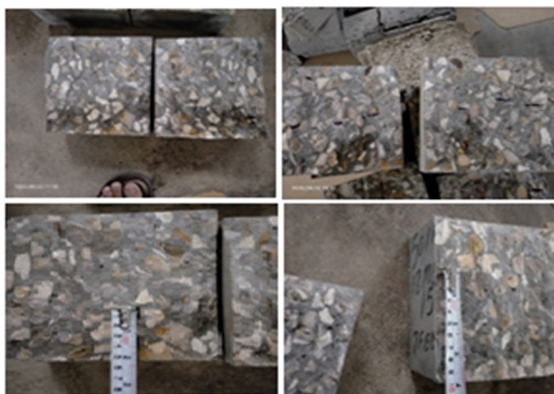


Fig. 3. Specimens after water penetration.

TABLE II. NDT COMPRESSIVE STRENGTH RESULTS

Batch	Sample No	RCA (%)	Compressive strength (psi)
B1	1	0	2892
	2		2953
	3		2881
	4		2853
B2	1	10	2567
	2		2681
	3		2645
	4		2581
B3	1	20	2281
	2		2181
	3		2367
	4		2367
B4	1	30	2119
	2		2260
	3		2119
	4		2253
B5	1	40	2053
	2		2045
	3		2053
	4		2181
B6	1	50	1912
	2		1918
	3		1881
	4		1912
B7	1	60	1753
	2		1767
	3		1667
	4		1781

III. RESULTS AND DISCUSSION

The compressive strength results of all specimens within a batch are averaged and plotted in Figure 4. The decreasing trend with increase in percentage of recycled aggregates can be observed. Maximum loss of strength is recorded with the highest replacement level. With 10% and 20% replacement levels, the loss of strength is about 10% and 23% respectively. The water penetration results for all samples of all batches are averaged in Table IV. It may be observed that the maximum and minimum depth of water penetration in conventional concrete is 70mm and 35mm, whereas for concrete with recycled aggregates they are 148mm and 10mm respectively. The minimum value is recorded in batch B1 (with 10% RCA) and the maximum value is observed in batch B4 (with 40% RCA), showing that the increase in the dose of recycled aggregates gave rise to water penetration.

TABLE III. WATER PENETRATION TEST RESULTS

Batch	Sample No	RCA (%)	Water penetration depth (mm)					
			1	2	3	4	5	6
B1	1	0	60	65	60	60	50	50
	2		40	55	52	56	35	50
	3		50	52	38	48	50	40
	4		42	48	49	70	52	60
B2	1	10	30	40	70	20	20	10
	2		56	55	70	42	35	56
	3		60	53	65	40	50	50
	4		62	62	45	60	60	74
B3	1	20	60	48	55	78	48	45
	2		44	54	52	45	52	70
	3		33	40	55	50	45	50
	4		45	45	55	35	50	52
B4	1	30	110	65	70	55	70	100
	2		95	64	60	50	70	110
	3		70	70	55	65	65	75
	4		100	100	74	70	70	66
B5	1	40	145	80	70	75	90	148
	2		60	40	75	55	62	60
	3		65	140	70	75	70	68
	4		45	70	57	54	50	65
B6	1	50	72	67	75	42	70	64
	2		130	88	50	70	50	128
	3		110	65	58	48	55	120
	4		98	50	90	60	106	100
B7	1	60	135	110	78	72	110	90
	2		60	80	80	80	82	65
	3		130	100	80	120	80	140
	4		85	90	92	80	70	60

TABLE IV. AVERAGE WATER PENETRATION DEPTH

RCA (%)	Average water depth (mm)				Average depth of batch (mm)
	1	2	3	4	
0	58	48	46	54	51
10	32	52	53	61	49
20	56	53	46	47	50
30	78	75	67	80	75
40	101	59	81	57	75
50	65	86	76	84	78
60	99	75	75	80	90

The average water penetration in conventional concrete is equal to 51mm. An increasing trend in the water penetration depth with increase in quantity of recycled aggregates is

observed. Water penetration depth of concrete with recycled aggregates is also compared with conventional concrete's in Figure 5. It may be observed that 30% and 40% replacement show identical values of penetration depths and very minor differences for 10% and 20% replacement of conventional coarse aggregates. The difference percentage of water penetration depth of concrete with recycled aggregates with respect to conventional concrete is shown in Figure 6.

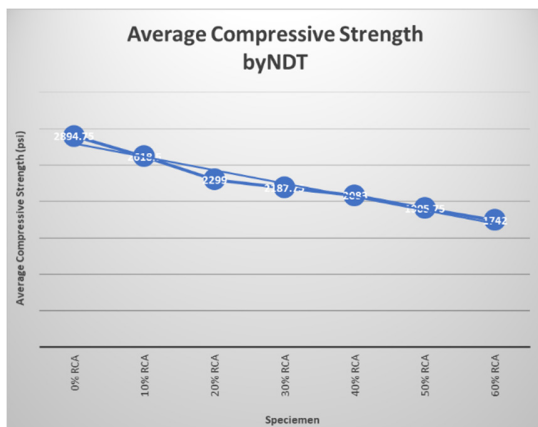


Fig. 4. Average compressive strength

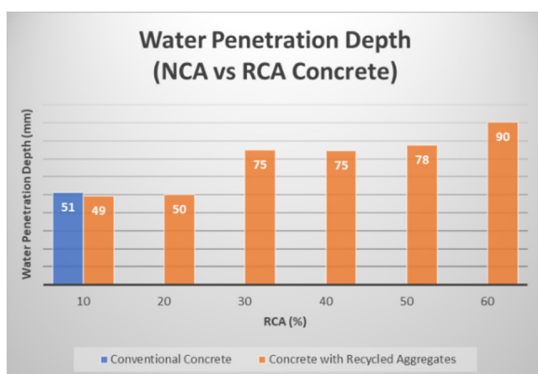


Fig. 5. Average water penetration depth.

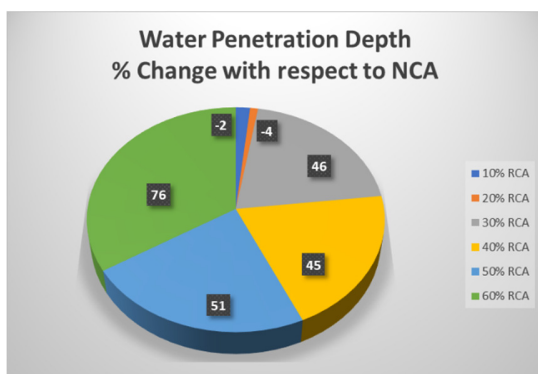


Fig. 6. The percentage change in penetration depth.

It may be observed that 60% dosage of recycled aggregates results in 76% higher values than conventional concrete. Lower dosages, i.e. 10% and 20%, show better performance of the

proposed concrete with 1% and 2% lesser water penetration than the conventional concrete. It may also be noted that the obtained results are better than the results published by authors in [30] for concrete made with brick aggregates. They reported water penetration depth in the range of 225%-550% in comparison with conventional concrete. The comparison of the acquired results with those published in [31] show that for 20% replacement, the water penetration level results of this work are 29% less whereas for 60% replacement are about 12% more. Although the internal structure of the specimens was observed good and similar to that of conventional concrete, yet an increase in water penetration is observed, probably due to the old mortar attached to the recycled aggregates which absorbs more water. Also, during the compaction of the specimens or even under the sustained pressure of water, this mortar disintegrates resulting in some voids which get filled when the concrete comes in contact of water.

IV. CONCLUSION

In this research work, the results of laboratory investigations on the evaluation of water penetration depth in concrete made with recycled aggregates are presented. Conventional concrete allowed the water to penetrate up to an average depth of 51 mm. Recycled aggregate concrete exhibited a slight resistance up to 2% with 10% and 20% replacement of conventional aggregates, but an increase up to 76% with increase in dosage of the recycled aggregates. The increased water penetration is mainly attributed to the old mortar attached to the recycled aggregates. Based on the findings of compressive strength and water penetration tests, it is concluded that 20% replacement of conventional coarse aggregates is in good agreement with conventional concrete's behavior. Replacement beyond this limit would require proper treatment of the concrete's surface exposed to water.

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