

Effect of River Indus Sand and Recycled Concrete Aggregates as Fine and Coarse Replacement on Properties of Concrete

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Abstract—As the demand for concrete rises, the concrete materials demand increases. Aggregates occupy 75% of concrete. A vast amount of aggregates is utilized in concrete while aggregate natural resources are reducing. To overcome this problem, River Indus sand (RIS) and recycled concrete aggregate (RCA) were utilized as fine and coarse aggregate respectively. The aim of this experimental investigation is to evaluate the workability, and compressive and tensile strength of concrete utilizing RIS and RCA. Concrete samples of 1:2:4 proportions were cast, water cured for 7, 14, 21 and 28 days, and tested for compressive and tensile strength. The outcomes demonstrate that concrete possessed less workability when RIS and RCA were utilized. It was predicted that compressive strength of concrete would reduce up to 1.5% when 50% RIS and 50% RCA were utilized in concrete and 11.5% when natural aggregate was fully replaced by RIS and RCA, whereas the tensile strength decreased up to 1.60% when 50% by 12% respectively.

Keywords—compressive strength; split tensile strength; workability; River Indus sand (RIS); recycled concrete aggregates (RCA)

I. INTRODUCTION

Concrete is the one of the most utilizable products in construction manufacturing industry. Concrete has great durability, serviceability and availability compared to other building materials [1, 2]. Residential houses, skyscrapers, bridges, pavements and dams are mostly being constructed using concrete [3]. Nowadays it has become the major construction building material [4]. The main ingredients used to manufacture concrete are binder (cement), aggregates (coarse and fine), water and admixtures [5]. Aggregates are non-chemical reactive materials in concrete. They occupy 60-

75% of the concrete's total volume. Their texture, shape and sizes play a vital role in fresh and hardened concrete properties [6-7]. In construction industry, the aggregates are mostly obtained from natural resources [8]. High energy is used to obtain these aggregates and natural resources are utilized [9]. Gradual depletion of natural resources has forced construction industry to focus more on sustainability and utilization of waste materials [10]. In this study, RIS and demolished concrete waste, commonly known as recycled concrete aggregates (RCA), were utilized and partially and fully replaced fine aggregates and coarse aggregates respectively. Workability, compressive and tensile strength of concrete were analyzed in context of conventional concrete.

II. LITERATURE REVIEW

Though concrete is considered as the backbone of any country's infrastructure [11, 12], the use of natural resources in the manufacturing of concrete has raised environmental concerns. To overcome such concerns, the performance of concrete by replacing sand and coarse aggregate with other alternative sources has been examined. Authors in [13] analyzed the experimental performance of concrete by partially replacing sand with foundry sand with various proportions of fine aggregates (10%, 20%, 30%, 40% and 50% by mass) at various curing ages (7 days, 14 days and 28 days). The conclusion confirmed that 30% replacement was optimum. Compressive upsurges decline beyond that. Authors in [14] observed the slump flow and hardened state strength performance of concrete at 10%, 20%, 30%, 40%, and 50% partially replacement of foundry sand to natural sand. The results revealed that the slump flow of 30% replacement was satisfactory and the strength performance was boosted among

the other proportions. Authors in [15] experimentally examined the strength (compressive, split tensile strength and flexural strength) behavior of concrete while utilizing foundry sand as fine aggregate replacement. Foundry sand was replaced at various fractions 0, 15%, 25% and 35% with natural sand. The outcomes defined that the 25% replacement exhibited maximum strength among other percentages. RIS was used in [16] as fine aggregate replacement in concrete of various grades. Fine aggregates were fully replaced in M15, M20 and M25 grade concretes and their tensile strength was compared with concrete containing no replacement. It was determined that workability reduced significantly while the tensile strength was 1% to 2% lower than the conventional concrete's in all grades, suggesting that RIS would be utilized in order to conserve natural fine aggregates. Authors in [17] inspected the material and mechanical characteristics of concrete adding RCA as partially replacement of natural coarse aggregates at various fractions: 0%, 35%, 50% and 65%. The outcomes revealed that the RCA has less specific gravity and high water absorption in context to natural aggregates. Also, compressive and flexural behavior was analyzed. The compressive and flexural strength reduced up to 35% compared to conventional concrete.

Authors in [18] conducted an experimental study on concrete incorporating rice husk ash as cement and RCA as coarse replacement. Concrete with full coarse aggregate replacement with RCA and with full coarse aggregate replacement with RCA along with 10% RHA as cement replacement was analyzed and compared with control concrete. It was determined that the workability reduced with the use of RCA and further declined when RHA was used. It was further noticed that 100% RCA concrete showed significantly lower compressive and tensile strength compared to control concrete. Interestingly the 10% RHA + 100% RCA concrete showed increase in strength, suggesting that incorporation of RCA can be beneficial if it is used along with other materials. Authors in [19] analyzed experimentally the performance of concrete using RCA as coarse aggregate replacement at 20%, 40%, 60%, 80% and 100%. Mechanical and surface characteristics, permeability and greenhouse gases valuation were also evaluated at 7 and 28 days of curing. The results describe that by adopting RCA the mechanical performance was lower compared to conventional concrete's. Permeability was maximum when RCA was incorporated in concrete in terms of conventional concrete. Greenhouse gases investigation expressed that the CO₂ emission of this 100% RCA mix was 24% lesser than the control mix. Based on the above literature review, in this study RIS was utilized as fine aggregate replacement whereas RCA was adopted as coarse aggregates.

III. RESEARCH METHODOLOGY

A. Materials

Cement from the brand Lucky, an ordinary Portland cement CEM I 42.5N that obeys ASTM C0150-04AE01, was chosen for this study. In this research two types of aggregates (aggregates obtained from hill and RCA) were utilized. The material properties of aggregates obtained from hill were: the fines modulus of coarse aggregates was 3.18%, water absorption was 1.59%, and the specific gravity was 2.58

whereas the RCA had fines modulus 2.91%, water absorption 2.39% and specific gravity of 2.32. Hill sand possessed fines modulus of 3.10%, water absorption 1.2% and specific gravity of 2.46. And RSI had fines modulus 2.14%, water absorption 3.62 and specific gravity 2.46.

B. Experimental Procedure and Mix Proportions

The 1:2:4 mix design ratio for 3000 psi strength concrete was used for this study. Two different kinds of concrete mix were made, one was conventional concrete utilizing natural aggregates and the other was concrete incorporating RIS as fine aggregates and RCA as coarse aggregates. The aggregates were 50% partially and fully replaced with RIS and RCA as fine and coarse aggregates respectively. The concrete cubes were cast and tested for compressive strength at curing ages of 7, 14, 21 and 28 days and for the split tensile strength test the cylinders were cast for different curing ages 7, 14, 21 and 28 days. Concrete mixing was done by a semi-automatic rotary mixer. Slump flow of both concrete mixes was analyzed according to the method described in [20]. Compressive strength of both concretes was tested according to the overall method defined in [21] and split tensile strength was tested according to [22].

IV. RESULTS AND DISCUSSION

A. Workability

To check the workability of concrete, ASTM C 143 was followed. The workability outcomes of both concretes are given in Table I showing that workability declines along with RIS and RCA percentage.

TABLE I. WORKABILITY

Mixture	Slump Value (mm)
Conventional concrete	33.34
50% RIS and 50% RCA concrete	27.4
100% RIS and 100% RCA concrete	22.8

B. Compressive Strength

To check the compressive strength, ASTM C39 was followed. The compressive strength outcomes are shown in Table II and illustrated in Figure 1. The results demonstrate that by utilizing RIS and RCA the strength is reduced because the interlocking between the particles is not as strong and in utilizing RIS because a huge number of clay particles are present reducing the cement chemical hydration.

TABLE II. AVERAGE COMPRESSIVE STRENGTH

Mixture	Compressive Strength (MPa)			
	7 Days	14 Days	21 Days	28 Days
Conventional concrete	14.21	18.36	20.18	21.09
50% RIS and 50% RCA concrete	12.42	16.69	18.98	20.79
100% RIS and 100% RCA concrete	11.32	15.61	17.72	18.91

At 7 days water curing, the compressive strength of 50% RIS and 50% RCA concrete and RIS and RCA concrete, reduces by 14.41% and 25.53% respectively. At 14 days water curing, the compressive strength of 50% RIS and 50% RCA concrete and RIS and RCA concrete, reduces by 10% and 17.61% respectively. At 21 days water curing the compressive strength of 50% RIS and 50% RCA concrete and RIS and RCA

concrete, reduces by 6.32% and 13.88% respectively and at 28 days water curing the compressive strength of 50% RIS and 50% RCA concrete and RIS and RCA concrete, reduces up to 1.44% and 11.52% respectively.

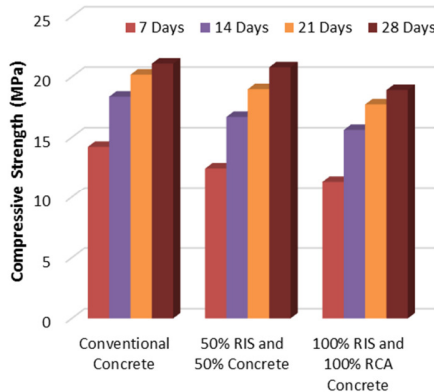


Fig. 1. Average compressive strength ss. curing age.

C. Split Tensile Strength

To check split tensile strength, ASTM C496 was followed. The split tensile strength test results are presented in Table III and illustrated in Figure 2. The outcomes describe that by adopting RIS and RCA the tensile strength is decreased because the RIS contains more clay particles causing the bonding between the particles to weaken while RCA are lighter than natural aggregates and the concrete becomes more brittle. Hence, while utilizing RIS and RCA, the split tensile strength is decreased.

TABLE III. AVERAGE SPLIT TENSILE STRENGTH

Mixture	Split Tensile Strength (MPa)			
	7 Days	14 Days	21 Days	28 Days
Conventional concrete	1.49	2.12	2.42	2.53
50% RIS and 50% RCA concrete	1.34	1.84	2.28	2.49
100% RIS and 100% RCA concrete	1.25	1.72	1.95	2.27

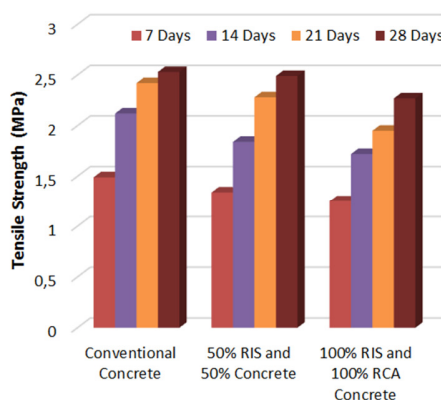


Fig. 2. Average tensile strength Vs. curing age.

At 7 days water curing, the tensile strength of 50% RIS and 50% RCA concrete and RIS and RCA concrete was reduced by 11.19% and 19.20% respectively, at 14 days curing it was

reduced by 13.20% and 23.26% respectively, at 21 days by 6.14% and 24.10% and at 28 days it was reduced by 1.60% and 11.45% respectively.

V. CONCLUSION

It can be concluded that when 50% RIS and 50% RCA were utilized in concrete the slump value was less than conventional concrete's whereas when RIS and RCA fully replaced natural aggregates the slump value was even lower. For improvement in slump flow, certain chemical admixtures should be utilized. From the mechanical properties results, compressive strength of 50% RIS and 50% RCA concrete decreased up to 1.5% compared to conventional concrete at 28 days of curing. Concrete compressive strength was reduced up to 11.5% when RIS and RCA fully replaced natural aggregates at 28 days curing. Tensile strength decreased up to 1.60% compared to conventional concrete when 50% RIS and 50% RCA were utilized at 28 days curing. The concrete tensile strength reduced up to 12% compared to conventional concrete when RIS and RCA fully replaced natural aggregates at 28 days of curing.

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