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TENSILE STRENGTH OF NO-FINES RECYCLED AGGREGATE CONCRETE CYLINDERS

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ABSTRACT

In this research paper tensile strength of no-fines recycled aggregate concrete is investigated. Total of 42 standard size cylinders are prepared in seven batches. Two curing ages 7- and 28-day are considered with half of the specimen in for each. One batch is cast with all-conventional aggregates whereas in rest of six batches recycled aggregates are used from 20% to 70% in increment of 10%. To ensure well graded aggregates sieve analysis of both types of aggregates in performed. Split tensile test is conducted to determine the tensile strength of the specimens. Comparison of the results shows decrease in the parameter with increase in the quantity of recycled aggregates. Maximum loss of strength of proposed concrete in comparison to control concrete is observed equal to 33% at highest replacement level of the coarse aggregates. Comparison of the results with those reported in literature for 50% replacement level shows 9% reduction. Based on the obtained results 20% replacement level is considered suitable for production of no-fines recycled aggregate concrete.

KEYWORDS: No-fines recycled aggregate concrete, demolishing waste, tensile strength, green concrete.

1. INTRODUCTION

Concrete has proven itself as most widely used material in construction of almost all types of structures. It is in use since decades. However, in recent years rapid pace of infrastructure development around the world has increased the consumption of concrete ingredients at large scale. To meet the demand supply resources, have to either work for more time or increase the units, resulting in increase of the harmful effects of the processes on the environment and human life. The point is major concern of the concerned organizations around the globe. The second face of the rapid development is the generation of large quantum of the waste due to demolishing of the old and deteriorated structures. The same also happens due to unavailability of the space in the regions. Unavailability of space also aggravates the waste disposal problem. The issue thus either increase the financial burden of the project due to transportation of waste to far distances or disturb the environment, general appearance, and human life. Sometimes this waste is dumped in the outskirts of the city. In countries like Pakistan these areas are generally agricultural lands thus adds the problem by spoiling the valuable land which in turn is the backbone of the country. Therefore, to resolve both issues a possible solution is to make use of this waste in new concrete. The option is active area of research among scholars for sustainable development. To date many attempts have been made to utilize this waste in new concrete as one or other ingredient of it in fraction or in toto. However, deviation in the reported results require more work in the area to reach certain consensus.

At present the industry in using concrete in various forms from low strength to high strength concrete in aggressive environment. However, its weight is the serious issue and need proper attention in analysis and design. Also, the unavailability of good quality bricks for partition walls requires alternate light weight material to meet the needs. No-Fines concrete is one among the solutions. It is the type of concrete in which fine aggregates are omitted and only coarse aggregates are used. Originally no-fines or pervious concrete was developed to be used in pavements for quick drainage and recharge of the soil. But its use may be extended in buildings particularly in no or low load areas. Irrespective of the type of concrete used, it is mandatory to check its strength to ensure the durability.

Therefore, this research study proposes the use of demolishing waste in production of no-fines concrete and aims at investigating the tensile strength of the concrete.

2. LITERATURE REVIEW

Several attempts of the demolishing waste in new concrete are reported in literature. The authors in,[1] reviewed the recent developments on use of the demolishing waste in new concrete along with the problems associated with the old concrete, its processing in to aggregates etc. The conclusion of the research emphasis on the proper implementation of the relevant laws and regulation and if not available; as is the case in many countries; then preparation and implementation of the same. It is also highlighted that initially governments should encourage the use of the demolishing waste by giving incentives to streamline the matter. In another attempt Silva et. al.2 reviewed tensile strength of recycled aggregate concrete. The authors reviewed the state-of-art on the topic with reference to relationship between compressive and tensile strength of recycled aggregate concrete considering Euro-2 code. They observed similar relationship between two types of strengths as of conventional concrete irrespective of the dosage of recycled aggregates. The Concrete waste from tested laboratory cylinders3 has also been attempted in new concrete from 0% to 100% replacement of conventional coarse aggregates. The authors attempted both normal and high strength waste no effect on slump. About 10% reduction in compressive, tensile, and flexural strength was observed irrespective of the percentage replacement of conventional coarse aggregates. On the contrary Sagar and Memon[4] observed 5% reduction in tensile strength with 50% replacement of conventional coarse aggregates. In another attempt authors in[8] concluded that similar or higher strength of recycled aggregate normal strength concrete may be achieved if recycled aggregates from high strength concrete are used. Similar findings are shared by Gholampour, and Ozbakkaloglu9 for long-term properties of the concrete cured up to 90 days. Among various types of wastes used low grade recycled aggregates from granite in the dosage of 25%, 50%, and 100% have been used by Kou et. al.5 The authors used free water-cement ratio to observe tensile strength among other parameters and found decrease in strength with increase in dosage of the waste. Whereas Saifuddin et. al.7 observed no negative effect on tensile strength while using demolishing waste as coarse aggregates from 0% - 100%.

Conventional concrete and its behavior are well understood. Accordingly, numerical models are available to predict one parameter from others. But recycled aggregate concrete still need lot of work to understand its behavior very well. Therefore, in a research program by Khan et. al.[6] to check the validity of numerical equation of ACI to predict the tensile strength for recycled concrete, the authors observed that these equations are not valid for crushed brick

chips and recycled aggregates. Accordingly, the authors developed new set of equations to predict the tensile strength for above mentioned coarse aggregates from demolishing waste.

No-fines concrete is popular due to its higher porosity and light weight. The type of concrete was introduced with respect to surface drainage and subsequent recharge of soil water table particularly in heavy rains which otherwise either accumulates in the vicinity or put additional burden on existing drainage facilities. Therefore, it has been widely accepted to be used in pathways[10] road pavements11 and storm water management17 In an attempt, to check the effect of additives on strength properties of no-fines concrete Gaedicke et. al.12 used slag, different types of aggregate and cement paste and found that the type of aggregate affect the relationship between compressive and tensile strength. However, no effect on tensile strength is reported by varying content of cement paste and slag. The authors also developed numerical equation for prediction of tensile strength consistent with existing research. They also found that the ACI equations for the purpose also predict the tensile strength in good agreement for concrete having strength less than 20 MPa.

The study of the different properties of no-fines concrete is extended to vertical applications by Tittarelli et. al.[13] In their research program they used hydrophobic admixture to check, higher aggregate-cement ratio and lower water cement ratio. They found decreased durability due to introduction of the admixture and 50% increase in capillary water. Strength properties of no-fines concrete exposed to acidic liquids or environment have been studied by Ikbal et. al.14 using graded and single sized aggregates. For concrete cured up to 180 days and exposed to acidic solutions (pH=3.5) they found decrease in strength of the concrete. They also observed that 1:5 cement-aggregate ratio and graded aggregates perform well than other counterparts of the study. Cellulose fibres[15] have also been attempted in no-fines concrete for improvement of the strength. In another research study on the use of graded aggregates instead of uniform sized aggregates Tunio et. al.[18] observed betterment in strength properties and unit weight of no-fines concrete. Among different grading used in the study authors found 20 mm – 10 mm grading as good grading giving highest compressive strength equal to 15.7 MPa.

The use of no-fines concrete has also been extended to manufacture of masonry blocks[16] to replace the conventional clay bricks. To improve the strength properties of no-fines concrete different additives i.e. silica fume[19,24] fly ash,[22,25] non-standard sand,[20] roving fibres,21 lime stone dust23 among several others have been used. But still the strength of the concrete is

questionable and need improvement so that its used may be extended to other structural members than car parking and residential drives[19] pathways[10] road pavement with low load.[11]

It may be observed from the above discussion of state-of-art that very few attempts have been made to use the demolishing waste in no-fines concrete, particularly its tensile strength. Therefore, this research program aims at investigating the workability, unit-weight and tensile strength of no-fines concrete using demolishing waste as coarse aggregates. It is hoped that the effort will minimize the waste management issue to some extent and give understanding of the tensile strength of proposed concrete.

3. MATERIALS AND METHODS

To accomplish the objectives of proposed research work, large blocks of demolishing waste (Figure 1) of a slab of reinforced concrete building were brought to the laboratory. These blocks were hammered to obtain coarse aggregates of maximum size equal to 25mm. The material being waste contained debris. Also due to age of the structure or hammering several cracked particles were found present in the aggregates. Both unwanted objects were removed followed by washing of the aggregates with potable water. Washing of the conventional coarse aggregates were also done in same way but separately. Both aggregates were then allowed to dry in the laboratory (Figure 2).

Figure 1: Demolishing waste.

Figure 2: Drying of aggregates.

3.1 Gradation of coarse aggregates

Well graded aggregates are one of the parameters which contribute a lot towards the durability of the concrete. Therefore, to ensure well graded aggregates in no-fines concrete to be used in this research study, sieve analysis of both recycled and conventional aggregates is performed in standard manner. Percentage passing of different sized aggregates on standard sieves used for gradation of coarse aggregates is listed in Table 1. The last column of the

table gives the ASTM specified ranges. It may be observed that all sizes are in good agreement with the specified range.

Table 1: Sieve analysis of coarse aggregates.

#	Sieve	Passing (%)		Range (%)
		Conventional Aggregates	Recycled Aggregates	
1	1-inch	92.55	91.00	90 – 100
2	3/4-inch	41.59	40.32	40 – 85
3	1/2-inch	10.14	11.91	--
4	3/8-inch	1.95	3.41	0 – 15
5	#4	0	0	0 – 5

3.2 Cement and water

The cement used for this research work in ordinary Portland cement being sold in the market under brand name Pak Land. Water used fir mixing of concrete matrix and curing of the specimens was obtained from local water supply scheme. To ensure the suitability of the water pH value was determined and found equal to 6.7. The obtained pH value falls in the range of potable water.

3.3 Batch and mixing

As the no-fines concrete is to be developed, therefore, the concrete ingredients were batched in 1:4 ratio. First batch (B1) of the samples were prepared using all conventional aggregates. This batch was treated as the source to compare the results of the proposed concrete. In rest of six batches (B2 to B7) of the sample conventional coarse aggregates were replaced with recycled aggregates from 20% to 70% with increment of 10%. In all batches 0.5 water cement ratio was used. Traditionally 0.45 water cement ratio is used in 1:2:4 mix but considering the higher water absorption of the recycled aggregates,[1] above mentioned water cement ratio is adopted. For all batches, the concrete ingredients are batched using weight method. Standard one-bag concrete mixer is used for mixing the ingredients.

3.4 Preparation and curing of specimens

In each batch of concrete six standard size cylinders were prepared. The molds were oiled before filling followed by filling in three layers and compacting by table vibrator in standard fashion. Few de-molded specimens are shown in Figure 3. Rough surface of the specimens may be observed. It is due to the absence of the fine aggregates. After de-molding, the specimens were allowed to air dry for 24-hours at room temperature. There after the specimens were cured by fully immersing in potable water (Figure 4). Out of six specimens

in each batch three were cured for 7-days and rest of 50% were allowed to be cured for 28-days.

3.5 Testing of specimens

After completion of required curing age specimens were taken out of water and allowed to air dry for 24-hours. Then the specimens tested in universal testing machine under gradually increasing load for tensile strength. The standard procedure for the test is followed (Figure 5). The rupture load of each specimen is recorded. Standard formula for tensile strength is then used to evaluate the tensile strength.

Figure 3: Preparation of sample. Figure 4: Curing of specimens.

Figure 5: Specimen testing.

4. DISCUSSION OF RESULTS

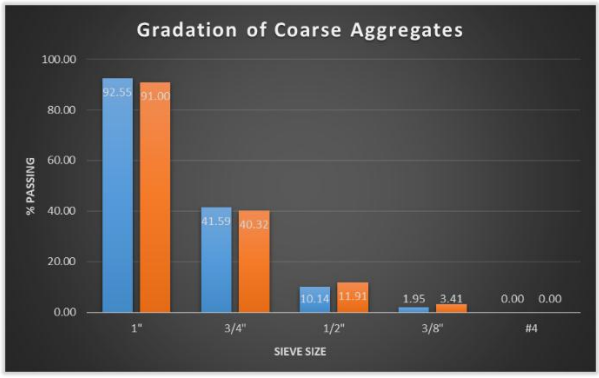
The gradation of both conventional and recycled coarse aggregates presented earlier is compared in Figure 6. It may be observed that both of the aggregates confirm the standard ranges for the purpose. Also, it may be observed that quantum of the different sizes of the aggregates is similar in both types. It ensures well graded aggregates in the proposed concrete, which in turn ensures proper strength of the hardened product. The load recorded in split tensile test of the specimens is then converted into tensile strength using standard formula. Average tensile strength of three samples in each batch for 7-day cured specimens is plotted in Figure 7. Figure 8 shows the same for 28-day cured specimens. From both of these

figures it is observed that increase in the dosage of recycled aggregates adversely affected the tensile strength of the specimens. With increase in the dosage of the recycled aggregates reduction in tensile strength is observed.

For conventional no-fines 7-day cured concrete the tensile strength recorded is equal to 2.13 MPa. It gradually decreased from 1.89 MPa (20% RCA) to 1.44 MPa (70%RCA). The percentage reduction in average tensile strength is shown in Figure 9. These samples observed strength reduction up to 33% with least reduction equal to 11% at 20% replacement level. At 50% replacement level the loss of strength is 21.42%. Tanwani and Memon,[4] based on their research reported tensile strength of recycled aggregate concrete equal to 2.36 MPa. At this replacement level for no-fines concrete used in this research work the tensile strength is observed equal to 1.68 MPa. The recorded value is about 29% less than that of normal recycled aggregate concrete.

On the other hand, the tensile strength for 28-day cured samples cast using all conventional aggregates is recorded equal to 2.6 MPa. The same for recycled aggregate no-fines concrete is observed equal to 2.39 MPa (20% RCA) to 1.39 (70% RCA). The percentage reduction of the property value in comparison to no-fines conventional concrete is shown in Figure 10. The samples observed reduction in the parameter up to 33%. Again, the least reduction in tensile strength is observed at 20% replacement level. At 50% replacement level the loss of the strength is about 20%; little less than 7-day cured samples at same replacement level. Tanwani and Memon,[4] reported tensile strength of recycled aggregate 1:2:4 concrete equal t 2.92 at 50% replacement level of conventional coarse aggregates. Their reported results are about 29% higher than the results observed in this research work. It is worth to note that irrespective of the curing age the difference between the tensile strength of recycled aggregate 1:2:4 concrete and recycled aggregate no-fines concrete is same. Therefore, it may be said that the loss of tensile strength of no-fines recycled aggregate concrete is due to the absence of fine aggregates. From the obtained results it may be concluded that the 20% dosage of recycled aggregates in no-fines recycled aggregate concrete is optimum as the loss of the strength at this replacement level is about 8% for 28-day cured specimens. It is further concluded that as the recycled aggregate concrete is less compressive strength also[1] therefore, proposed concrete may initially be used in footpaths, walkways, or similar components where load is not of prime importance. It is also anticipated that addition of

small quantity of the fine aggregates may improve the results therefore, it is proposed that the investigations may be undertaken to check the effect on tensile strength of the concrete.



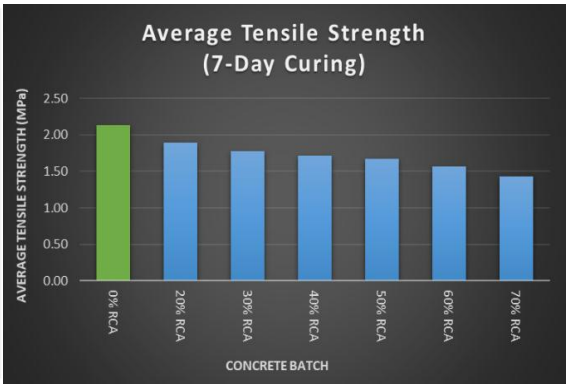
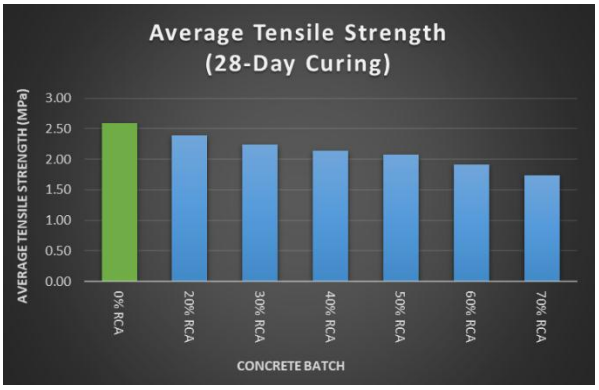


Figure 6: Sieve analysis of coarse aggregates. Figure 7: Average tensile strength (7-Day curing).



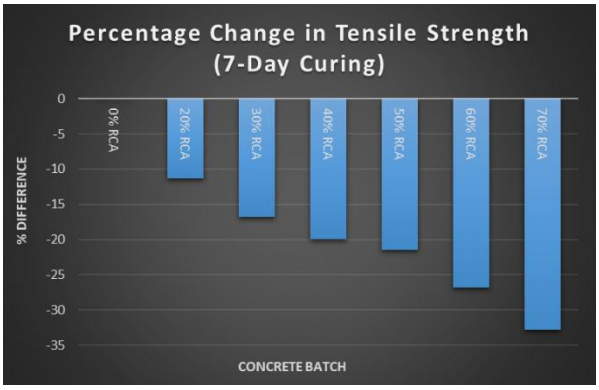


Figure 8: Average tensile strength (28-Day curing). Figure 9: Percentage reduction (7-Day curing).

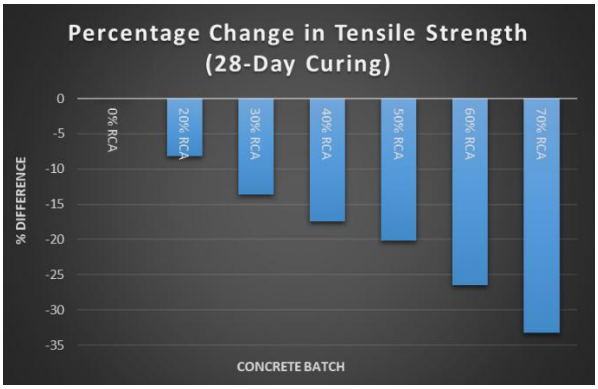


Figure 10: Percentage reduction (28-Day curing).

5. CONCLUSION

Based on the results of the research presented in this research paper following are concluded.

1. Demolishing waste may be used as recycled coarse aggregates in preparation of no-fines concrete; however, its tensile strength is less compared to no-fines concrete prepared with all-conventional aggregates.
2. Tensile strength reduces with increase in the replacement level of recycled aggregates.
3. Minimum loss of tensile strength is recorded equal to about 8% in 28-day cured samples at replacement level of 20%.
4. Maximum loss of tensile strength is recorded equal to about 33% in 28-day cured samples at replacement level of 70%.

Therefore, 20% replacement of the conventional aggregates with recycled aggregates from demolished concrete is concluded as optimum for preparation of no-fines recycled aggregate concrete.

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