Reuse of Waste Polyethylene Coated Recycled Concrete Aggregate with Improved Strength and Durability in Concrete

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INTRODUCTION

Utilization of municipal solid waste (MSW) is becoming a global practice in the struggle to control the ever-increasing environmental pollution. Among all the constituents of the MSW produced in Pakistan, demolition and construction (D&C) waste and plastics contributes about 8% each (Pak-EPA, 2017) [1]. Recycled Concrete Aggregate (RCA) is a component of D&C waste that has poor structural performance [2]. It can be concluded that plastic coated aggregates result in durable and long life asphalt concrete [3]. This leads us to conclude that coating the aggregate will result in better durable long life asphalt concrete. This research is based on the idea to enhance the strength of RCA for structural application by using another waste material (polyethylene plastic bags). This study has investigated different techniques of coating RCA with shredded waste plastic bags (melting point of plastic is from 200-250°C), which can be melt using solar ovens (up to 315°C) [4], to improve the mechanical and durability properties of RCAs in concrete.

OBJECTIVES

- To produce cost effective sustainable construction materials
- To reuse waste plastic and demolition waste materials in construction industry.
- To have cleaner environment by finding useful application of waste material.
- To produce load bearing concrete using recycled concrete and waste plastic.

METHODS

Different stages followed in this research work are shown in the flowchart in **Figure 1**

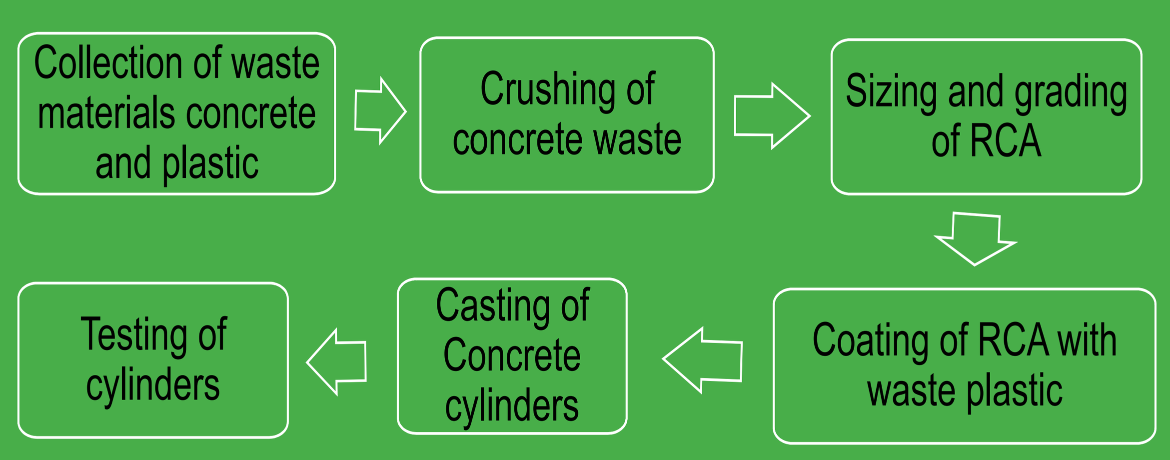

Figure 1. Hierarchy of different stages of research

Material Collection

In this research, concrete waste was crushed to obtained RCAs. These RCAs were coated with locally available waste plastic to enhance its properties. Two different approaches were tested to produce plastic coated RCAs.

- **Method 1**
  RCAs were heated to a temperature beyond the softening point of poly-ethylene plastic i-e 200°C to 250°C (achievable with solar oven, up to 315°C [4]).
  At that point, plastic waste was added to it and manually mixed with RCAs. The mixture is left for cooling for about 15 minutes. The cooled mixture is known as PCRCAs shown in **Figure 2. (a)**
- **Method 2**
  The shredded plastics are heated in a closed container for about 10-15 min--utes at 250°C to get liquified plastic. RCAs were mixed with liquified plastic to obtain PCRCAs. shown in **Figure 2.(b)**

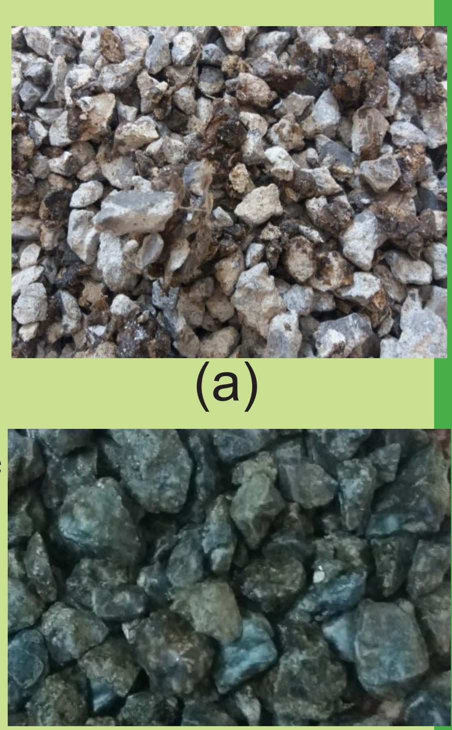

Figure 2. Aggregates coated with waste plastic

Two different percentage of RCAs were coated
1- Partially coated (about 40-50% of surface area)
2- Fully coated (about 95-100% of surface area)

In order to get the required standards sieve analysis (AASHTO T27), water absorption and specific gravity(ASTM C127), soundness test(ASTM C88), Loss angeles abrasion test(AASHTO T96-87) were conducted on natural aggregates, uncoated RCAs, partially coated RCAs and fully coated RCAs. Slump test(ASTM C143), compressive and tensile strength test (ASM C39) were performed on natural aggregate concrete (NAC), partially coated RAC and fully coated RAC.

RESULTS

Overall, an enhancement in durability and workability of concrete with slight decrease in strength but within the acceptable range for concrete has been observed. **Table 1** shows that water absorption of RCA has significantly decreased with coating and has less specific gravity.

Sieve Analysis

Sieve analysis test was performed to make sure that the both RCA and natural aggregate are well graded.

Table 1. Water absorption and specific gravity of NA and RCA.

Types of aggregates	Water Absorption (%)	Specific gravity
Natural Aggregate	1.3	2.76
Fully coated RCA	2.5	2.51
Partially Coated RCA	4.4	2.39
Uncoated RCA	6.4	2.35

Durability Properties of Aggregates

The overall mechanical properties of aggregates were improved. The hardness of aggregates increased with coating and in full coated samples, the hardness was double as compare to un-coated RCAs. Aggregate soundness tests were performed using sodium sulphate solution of 25% saturated for 6 cycles. **Table 2** shows soundness test results. The results shows exceptionally well soundness with negligible loss in weight of aggregates after sulphate attack. After soundness test the detached particles of old cement matrix in un-coated RCA is shown in **Figure 3a**, no deterioration was observed in coated RCA as shown in **Figure 3b**. **Figure 4** shows the abraded RCA after Los Angeles Abrassion test.

Figure 3. Uncoated and coated aggregate after sulfate soundness test

Figure 4. RCA after LA abrasion test

Table 2. Los Angeles abrasion and soundness test results

Type of Aggregates	Abrasion (%)	Soundness
Natural aggregate	16.7	1.63
Fully coated RCA	20	5.5
Partially Coated RCA	31	
Uncoated RCA	42.5	65.7

Slump

Slump test shown in **Table 3** indicates a considerable increase in workability of recycled aggregate concrete with plastic coating. The mix design was 1:2:2.5 with w/c = 0.45.

Table 3. Concrete Slump Test

Type of Aggregate	w/c	Slump, inch (mm)	Plasticizer (%)
Fully Coated RCA	0.45	6 (152.4)	1.0
Partially Coated RCA	0.45	3.25 (82.55)	1.5
Uncoated RCA	0.45	2 (50.8)	2.3

MECHANICAL PROPERTIES OF RCAs

Figure 5 shows the development of compressive strength of at different age ranging from 7 to 56 days. **Table 4** illustrates the compressive, split tensile strength and young's modulus of natural aggregate concrete (NAC), uncoated recycled aggregate concrete (URAC), partially coated recycled aggregate concrete (PRAC) and fully coated recycled aggregate concrete (FRAC).

Table 4. Compressive, split tensile strength and young's modulus of concrete

Type of Concrete	7 Days Compressive Strength, psi (MPa)	14 Days Compressive strength, psi (MPa)	28 Days Compressive Strength, psi (MPa)	56 Days compressive strength, psi (MPa)	Split tensile, psi (MPa)	Young's modulus, ksi (GPa)
URAC	3550 (24.48)	3806 (26.25)	4482 (30.91)	4634 (31.96)	452 (3.12)	1288 (8.88)
PRAC	2014 (13.89)	2179 (15.03)	2628 (18.12)	3054 (21.06)	288 (1.99)	860 (5.93)
FRAC	1404 (9.68)	1591 (10.97)	2231 (15.39)	2499 (17.23)	262 (1.81)	841 (5.8)
NAC			4920 (33.93)		474 (3.27)	1453 (10.02)

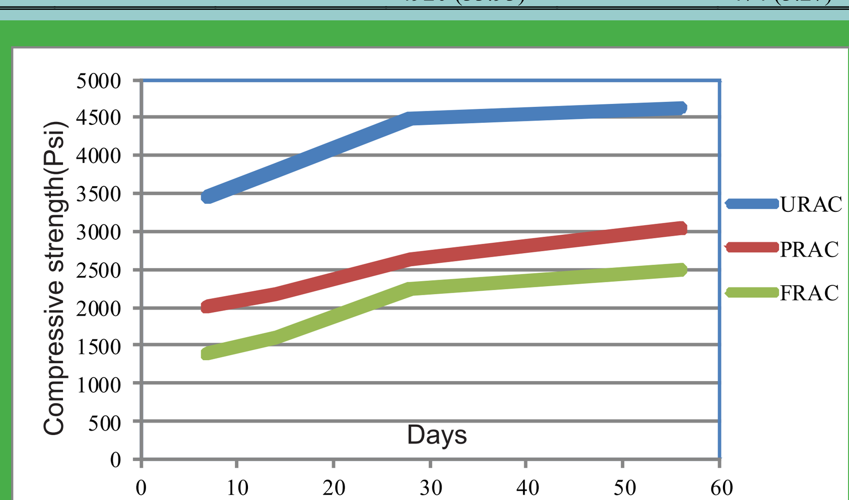

Figure 5. Development of compressive strength of URAC, PRAC and FRAC at different ages

SURVEY

32 participants were surveyed of which 2 from demolition site and others were engineers from construction site. More than 70% participants surveyed were of the opinion that "people are unsure whether the use of construction and demolished waste materials are useful and it is easier to dispose these waste materials"

About 40% participants have an idea that the transportation of wastes to the dump site is the major transportation hazard in Peshawar.

Figure 6 shows the results from survey suggests that the following barriers are more serious to be addressed.

1- Lack of training awareness
2- Increase in cost administration and time.

Furthermore, core tests were performed on demolished concrete samples from columns and slabs. The average strength of old concrete from core tests was found to be around 2400 psi (16.5MPa).

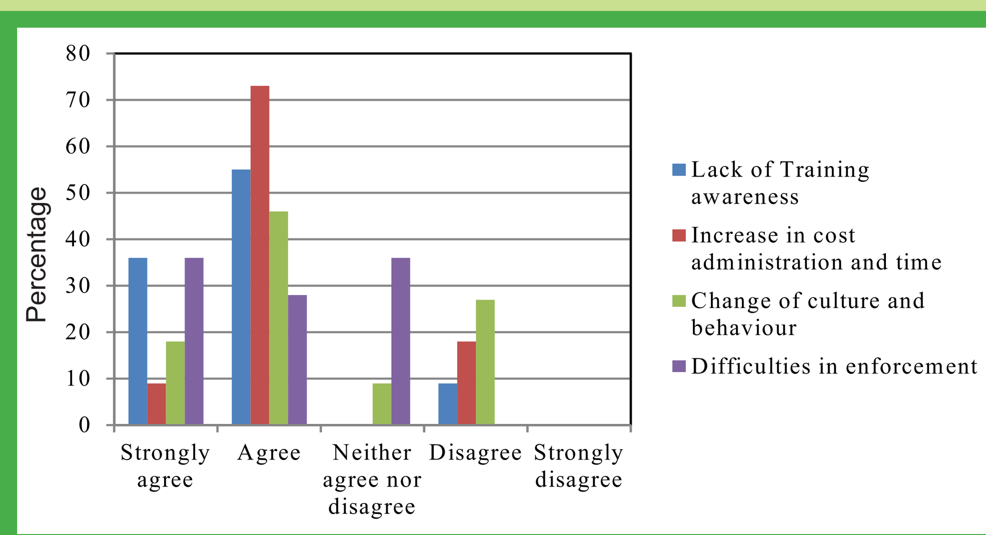

Figure 6. Plastic construction & demolition waste survey

DISCUSSION

Improving the mechanical performance of RCAs by utilizing D&C waste has a lot of potential. All the important parameters, except compressive strength, of RCAs were significantly improved. The plastic coating of RCAs result in increased workability and durability of concrete. However, the plastic coating of RCAs resulted in decreased bonding between RCAs and cement paste, leading to lower compressive strength.

This practice, if adopted will allow the use of RCAs in local construction industry and will significantly reduce the D&C waste component of MSW. Hence, leading to a more sustainability.

CONCLUSION

This research has produced PCRCAs that can be adopted with the following enhancement in properties.

- significantly reduced absorption upto 200%
- gives three times more slump than uncoated RCAs
- abrasion resistance increased to 100%
- significantly increased resistant to sulphate attack
- satisfactory compressive strength for producing load bearing concrete.

FUTURE RECOMMENDATIONS

There is week bond between PCRCA and cement paste in concrete leading to a low strength of concrete than uncoated RCA concrete.

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