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# DURABILITY STUDIES OF PQC MIX INCORPORATING RECYCLED CONCRETE AGGREGATE AND MINERAL ADMIXTURES

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Concrete as known globally is the most widely used construction material in all type of construction works. Recycled concrete aggregates have been eyed as a viable option for part replacement of natural coarse aggregates for concrete production by researchers for quite some time. However, their tendency to bring down the property parameters of new concrete makes it very important to investigate the extent of variation in durability properties of fresh concrete incorporating recycled concrete aggregates. Mineral admixtures are believed to improve the durability and mechanical aspects of concretes. This study makes an effort to understand the effects of incorporating recycled concrete aggregates and different mineral admixtures on durability aspects of pavement quality concrete mixes. In order to investigate the same, recycled concrete aggregates were used along with mineral admixtures in different proportions to study the variation in properties. Concrete mixes prepared with natural aggregates, recycled concrete aggregates and mixes containing recycled concrete aggregates and mineral admixtures were prepared and tested for variations in their durability properties. Laboratory investigations revealed that incorporating mineral admixtures does improves the durability aspects of pavement quality concrete having recycled concrete aggregates. Reduction in values for water absorption, sorptivity coefficients and chloride ion concentrations supported better durability aspects for mixes prepared with recycled concrete aggregates incorporating mineral admixtures.

*Keywords:* Concrete recycling, Rice husk ash, Bagasse ash.

## 1 INTRODUCTION

Recycled concrete aggregates as the name suggests are recycled aggregate obtained from concrete wastes. Demolished concrete waste can be procured from various sources such as construction and building waste, waste from demolished road slabs, waste from testing laboratories at construction sites etc. This waste could be processed for obtaining recycled concrete aggregates in requisite sizes as per the work requirements. Recycled concrete aggregates contains aggregates coated upon by the adhered mortar, this mortar is weak and porous in nature which tends to decrease the quality of concrete when incorporated in new works. Few surface treatment methods have been proposed by researchers for separating aggregate particles from adhered mortar. Tam and Le (2007) proposed an acid treatment technique for removing adhered mortar from recycled concrete aggregates. Tsujino *et al.* (2007) proposed a surface treatment technique to peel off adhered mortar from recycled aggregate particles by application of oil-type improving agent and silane-type improving agent. Akbarnezhad *et al.* (2011) proposed a new microwave assisted technique for removal of adhered mortar from recycled concrete aggregates in order to improve their quality. Larbi *et al.* (2000) tried a thermal treatment method to improve the quality of recycled aggregate.

Few researchers such as Hasaba *et al.* (1981), Hansen and Narud (1983) Katz (2003) investigated the content of old mortar and their effects in concrete. Studies carried out by Symonds (1999), Akash *et al.* (2007), Hendriks and Pietersen, Acker (1998), Ransinchung *et al.* (2012), Poon *et al.* (2002) and Farid Debieb (2005) discussed the inferiority and properties of concrete upon the incorporations of recycled concrete aggregates.

The motive of this study is to examine the improvements in durability properties of recycled aggregate concrete with the inclusions of mineral admixtures. Two different mineral admixtures were used as an addition to binder to understand the possible improvements in durability of recycled aggregate concrete due to mineral admixtures thereby suggesting the probable use of concrete for general construction works. This paper discusses a part of continuous study investigating the feasibility of incorporating recycled concrete aggregates in fresh concrete. In this part of study replacement of natural aggregates by recycled concrete aggregates is carried out for 30% as optimum percentage of using recycled concrete aggregates, investigated in previous part of study.

## 2 MATERIALS AND MIX

### 2.1 Materials

Recycled concrete aggregates used in the study were manufactured from processing of concrete waste in laboratory. Recycled concrete aggregates were surface treated by pre-soaking them in 0.1 molar acidic solution of $H_2SO_4$ followed by abrasion, leading to the removal of some adhered mortar in form of powder. In order to obtain best results, all the coarse aggregates were used in pre-saturated moisture state. Table 1 discusses the properties of all aggregates types used in study.

Rice husk ash and Bagasse ash were used as mineral admixtures in this study. Conplast SP430SRV obtained from Fosroc Chemicals India pvt. Ltd. was used in this study as superplasticizer to maintain required slump for the concrete mixes.

Table 1. Physical and mechanical properties of coarse aggregates.

| Type of Aggregate | Specific Gravity | Water Absorption (%) | Aggregate Impact Value (%) | Crushing Value (%) |
|---|---|---|---|---|
| Natural Aggregate | 2.677 | 0.274 | 13.88 | 17.775 |
| Untreated RCA | 2.417 | 3.18 | 22.23 | 19.42 |
| Beneficiated RCA | 2.660 | 1.88 | 15.67 | 17.91 |

### 2.2 Concrete Mixtures

A total of 8 mixes were prepared and investigated in this study. One concrete mix with natural aggregates alone was prepared to serve as control mix for conventional concrete (NAC mix), one mix was prepared with recycled concrete aggregates incorporated as 30% part replacement of natural coarse aggregates (RAC mix). Three concrete mixes were prepared for each mineral admixture, incorporating 30% recycled concrete aggregates and 5%, 10%, and 15% mineral admixtures by weight of cement.

Table 2. Mix proportions for materials.

| Notation | Mineral Admixture | | Recycled Aggregate | | Cement ($Kg/m^3$) | Water (Kg) | Fine Aggregate ($Kg/m^3$) | Coarse Aggregate ($Kg/m^3$) | Super plasticizer (%) |
|---|---|---|---|---|---|---|---|---|---|
| | % | Kg | % | Kg | | | | | |
| NAC | 0 | 0 | 0 | 0 | 400 | 173 | 660.22 | 1180 | 0 |
| RAC | 0 | 0 | 30 | 354 | 400 | 167 | 660.22 | 826 | 0 |
| RACRA-1 | 5 | 20 | 30 | 354 | 400 | 167 | 660.22 | 826 | 0.5 |
| RACRA-2 | 10 | 40 | 30 | 354 | 400 | 167 | 660.22 | 826 | 0.5 |
| RACRA-3 | 15 | 60 | 30 | 354 | 400 | 167 | 660.22 | 826 | 0.5 |
| RACBA-1 | 5 | 20 | 30 | 354 | 400 | 167 | 660.22 | 826 | 0.5 |
| RACBA-2 | 10 | 40 | 30 | 354 | 400 | 167 | 660.22 | 826 | 0.5 |
| RACBA-3 | 15 | 60 | 30 | 354 | 400 | 167 | 660.22 | 826 | 0.5 |

# 3 TESTING AND RESULTS

## 3.1 Compressive Strength

Incorporating recycled concrete aggregates reduced the compressive strength of concrete for RAC mix to around 11% in comparison to NAC mix at 28 days as visible from table 3, while the reductions at initial age of testing were not significant. Considerable increase in strength was noticed for concrete mixes with rice husk ash such as RACRA-2 showing a strength increase of around 9% with respect to RAC mix. Further increasing the content of mineral admixture to 15% brought the strength values of RACRA-3 mix at par with those of NAC mix. RACRA-3 mix observed a strength increment of approximately 13% and 2% w.r.t. RAC and NAC mixes respectively. Similar strength results were observed for mixes incorporating bagasse ash with RACBA-3 showing an increase of around 13% and 2.5% w.r.t. RAC and NAC mixes respectively.

Table 3. Properties of concrete mix under study.

| Mix Designation | Compressive Strength (MPa) | | | W. A. (%) | Sorptivity (mm/min^0.5) | Cl Ion (mg/L) | Abrasion (gm) |
|---|---|---|---|---|---|---|---|
| | 3 days | 7 days | 28 days | 28 days | 28 days | 28 days | 28 days |
| NAC | 18.162 | 27.169 | 39.573 | 2.117 | 0.116289 | 25 | 7.5 |
| RAC | 16.242 | 23.773 | 35.586 | 2.311 | 0.151176 | 31 | 9.5 |
| RACRA-1 | 17.128 | 23.773 | 37.210 | 2.310 | 0.137221 | 28 | 9.5 |
| RACRA-2 | 16.833 | 23.035 | 39.130 | 2.295 | 0.113964 | 25 | 8.5 |
| RACRA-3 | 17.424 | 23.773 | 40.458 | 2.250 | 0.100009 | 22 | 7 |
| RACBA-1 | 17.867 | 25.102 | 37.358 | 2.350 | 0.134896 | 24 | 10.5 |
| RACBA-2 | 17.276 | 24.068 | 38.539 | 2.295 | 0.116289 | 22 | 9 |
| RACBA-3 | 18.310 | 24.364 | 40.606 | 2.210 | 0.106986 | 18.5 | 8 |

## 3.2 Water Absorption

RAC mix reported water absorption values approximately 9% higher than that for NAC mix. For rice husk ash and bagasse ash admixed concrete mixes, RACRA-3 observed water absorption value only 6.09% higher than that of NAC mix while for RACBA-3 the increase was observed to be 4.29%. However, when compared to parameters recorded for RAC mix, the water absorption values were found to be decreasing for concrete upon admixing mineral admixtures.

Concrete mixes with bagasse ash reported highest reductions with RACBA-3 showing a reduction of around 4.5% w.r.t. RAC mix while rice husk ash admixed concrete showed a maximum reduction of 2.69% for mix RACRA-3. This reduction in water absorption values could be attributed to ultrafine particles of mineral admixtures rendering the mix thereby making it less permeable.

### 3.3 Chloride Ion Concentration

The increase of resistance to chloride concentration in concrete mixes was observed to be pronounced for concrete mixes containing bagasse ash. Mix RACBA-3 observed the concentration of 18.5 mg/L which was way lower than 25 mg/L as obtained for NAC mix. Addition of mineral admixtures up to 15% did reduced the concentrations of chloride ion in concrete mixes thereby bringing them within the permissible limits as specified by IS-456:2001 and ACI committee.

### 3.4 Sorptivity

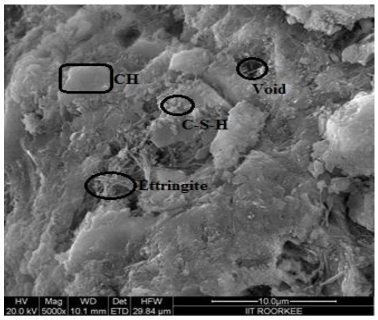
The value of sorptivity coefficient was found to be increased when RCA were induced in the concrete mix making the concrete more water absorbing. Fine particles of rice husk ash when incorporated due to their pozollanic properties and higher surface area tends to reduce the pores thereby bringing down the porosity of concrete. This effect was observed to be enhanced with increase in percentage of mineral admixtures up to 15%. For mixes containing rice husk ash, RACRA-3 reported sorptivity values lower than that of NAC mix while for bagasse ash admixed concrete, RACBA-3 reported values comparable to those of NAC mix thereby indicating an improvement in durability of recycled aggregate concrete.

### 3.5 Abrasion

Concrete mixes prepared with rice husk ash and bagasse ash reported reductions in abrasion loss parameters. This reduction in abraded weight was observed to be highest for mixes with 15% mineral admixtures RACRA-3 followed by RACBA-3 having comparable parameters to that of NAC mix. Among different concrete mixes, increase in percentage of mineral admixtures led to increase in their resistance to abrasion. RAC mix observed abrasion loss approximately 23% higher than that for NAC mix. However, mixes admixed with rice husk ash recorded 11% and 33% reduction in abrasion loss for RACRA-2 and RACRA-3 mix respectively while RACBA-3 showed a reduction of approximately 17% from that of RAC mix.

### 3.6 SEM Analysis

SEM examinations were carried out on the fracture surfaces of the different concretes mixes. Figure 1 gives a view of SEM image of NAC mix virgin aggregate concrete-cement interface microstructure noticing formation of Calcium Silicate Hydrate (C-S-H) gels and hydrated compounds. Presence of hexagonal and fine bundle type structures indicate toward the abundance of hydroxide compounds and C-S-H gels as indicated in images below. While the SEM image of RAC mix Figure 2 shows abundance of needle type ettringite and hexagonal calcium hydroxide particles. Investigations of SEM images for mix containing rice husk ash showed increase in content of hydration products. This increase was well expected due to pozzolanic properties of rice husk ash which adds up to the hydration process.



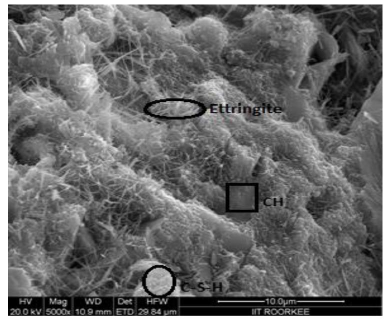




Figure 1. SEM Image of NAC Mix      Figure 2. SEM Image of RAC Mix.

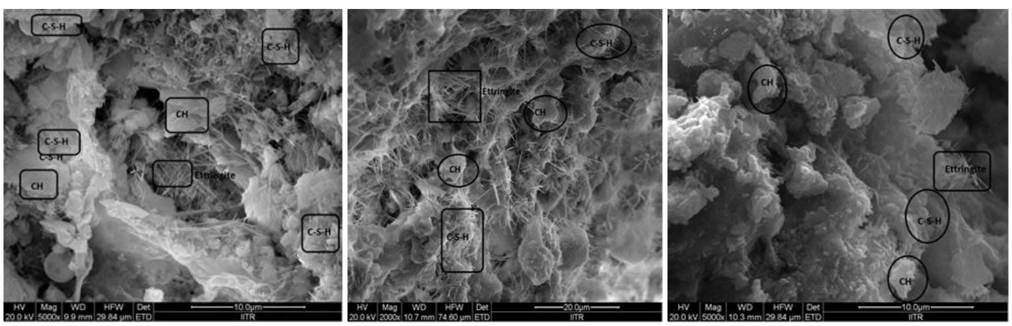



Figure 3, 4, 5. SEM Image of RACRA-1, RACRA-2 and RACRA-3 Mix.

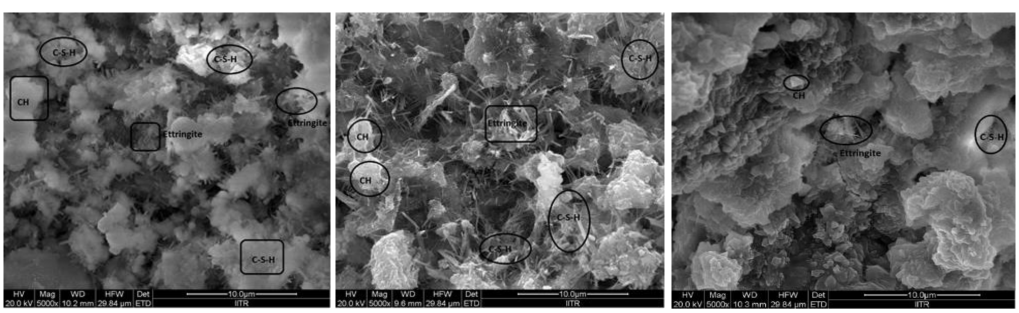



Figure 6, 7, 8. SEM Image of RACRA-1, RACBA-2 and RACBA-3 Mix.

SEM Figures 6 – 8 show that the particles of bagasse ash also added to the hydration products, thereby reducing the voids in concrete and improving the durability aspects. Aigbodion (2008) studied and concluded that the structure of bagasse ash particles could be classified in three main group's i.e. prismatic group, spherical and fibrous groups.

The increase in content of CSH due to pozzolanic properties of mineral admixtures led to better bonding between aggregate particle and mortar thus forming a strong interfacial transition zone (ITZ) among them. This strength of ITZ is visibly reflected as gain in strength parameters of compressive and betterment of durability aspects of concrete.

## 4 CONCLUSIONS

In the light of above discussed results it could be concluded that incorporating recycled concrete aggregates does leads to inferiority in properties of concrete however, inducing rice husk ash or bagasse ash improves the recycled aggregate concrete thereby depicting similar durability aspects as those of conventional concrete.

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