

Comparative Study on Carbonated and Non-Carbonated Recycled Aggregate Concrete with Glass Powder as Partial Replacement for OPC

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Abstract—Recycled aggregates (RA) possess the ability to be recycled, if undesirable properties are counteracted viz, porous mortar attached to it, with high water absorption and low density, this technique, accelerated carbonation can be one such to technique to counteract undesirable properties of RA, replacement of 20% of cement by glass powder assists in reducing w/c ratio^{[1][6]} when used in concrete^[2] suppress ASR reaction^[1], this paper explains a new possibility of recycling concrete, work done and findings for improvising Recycled aggregate concrete (RAC) and exploring the feasibility for use of RA in the near future.

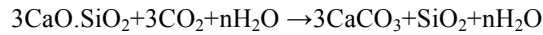
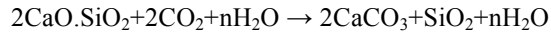
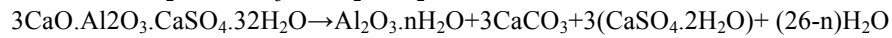
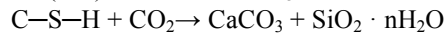
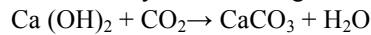
Keywords—Recycled aggregate, carbonation of recycled aggregate, recycled aggregate concrete.

1 Introduction

Due to rapid growth in the population and industry the demand for natural sources has increased which are reducing availability of resources and creating stress on natural resources, hence in order to fulfill the demand there is necessity to find alternate source and recycle materials back to industry, and closed loop recycling is the most appropriate sustainable methodology to reuse waste streams back into new production as it will create energy saving, reduce the demand on primary resources and deviate waste from reaching landfills nevertheless in some circumstances, waste streams cannot be reused in the production of new material of their restriction applied on quality, Several studies have been carried out to study feasibility of industrial waste and rejects, as pozzolanic and aggregates wastes like slag, rice husk ash, plastic, glass etc. in concrete, milled glass powder is a potential substitute for cement, Use of glass in construction application as a replacement for cement provided to be advantageous. Glass powder fine and possess pozzolanic property, when it is partially replaced assists in formation of CSH gel suppress ASR reaction and reduces w/c when in concrete^[1].

Due to the limited life of concrete structures large amount of structures are being demolished for erection of new and the debris of which causes again the problem of

landfill and environmental impacts. Hence aggregates obtained from C&D waste can be utilized as partial substitute for natural aggregate in new concrete, but due to their previous usage these aggregates surrounded by inter-transition zone mortar, develop undesirable properties such as high water absorption, prone to cracks under loading and weaker transition zone, limits the usage of these aggregates at higher content hence incorporation of glass powder will counteract the problem of water absorption^{[5][6]} and further carbonation of recycled aggregate in which CO₂ reacts with hydrated and un-hydrated byproducts of mortar attached to RA to form CaCO₃^[7], which is formulated by the following reactions^[7].



The hydrated bi-products present in attached cement mortar C-S-H, Ca(OH)₂, ettringite (calcium trisulpho aluminate) and calcium mono-aluminate and un-hydrated cement particles containing C3S and C2S are carbonated to form calcium carbonate, this calcium carbonate formed, fills the micro pores present in attached cement mortar which decreases porosity and water absorption and increases the density of recycled aggregate^[7].

2 Material Preparation

- **Milled Glass Powder:** particle size > 80μ and above with specific gravity 2.6 with chemical composition as shown in Table 1.
- **Recycled Aggregate and Processing:** Recycled aggregate (Fig.1) from demolition waste was crushed and processed through Los Angeles abrasion machine for 500 revolutions (Fig.3) and showered in water spray to minimize and wash the mortar surrounding RA (Fig.2)
- **Accelerated carbonation chamber:** accelerated carbonation chamber is an air tight sealed container where compressed CO₂ is maintained at pressure around 0.2 to 0.4 MPa, with 50-60% relative humidity (RH) with concentrated brine solution (water + NaCl) to prevent formation of carbonic acid on reacting with water (Fig.4 + 5) aggregates are processed for period of 48 hours.

Table 1. chemical composition of glass powder

Composition	Silica(SiO ₂)	Calcium oxide(CaO)	Magnesium Oxide (MgO)	Sodium Oxide(Na ₂ O)	Alumina (Al ₂ O ₃)	Iron Oxide (Fe ₂ O ₃)
Content (%age)	72	20	2.5	10.2	0.5	3.5



Fig. 1. RA before abrasion



Fig. 2. RA after abrasion



Fig. 3. Los Angles abrasion machine



Fig. 4. Carbonation Chamber set-up

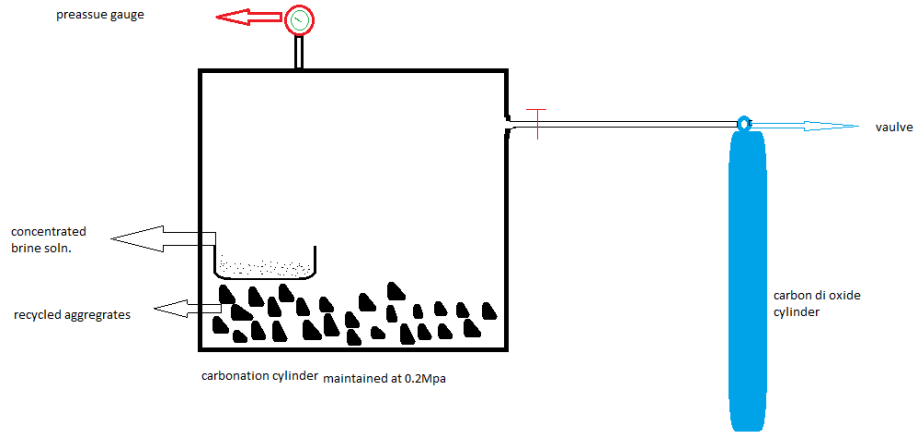


Fig. 5. Carbonation chamber line diagram

3 Tests on Recycled Aggregates and Concrete

3.1 Test on recycled aggregates

Table 2. Physical properties of carbonated and non-carbonated RA

	Water absorption (%)	Specific gravity
Non-carbonated	2.38	3
Carbonated	2.17	3.17

3.2 Workability of concrete

Slump cone test is carried out to determine the workability of the concrete. Slump values of different mixes are given in Table 3.

Table 3. Slump values for different mixes

	SLUMP VALUE (mm)				
	Conven-tional	40% re-placement	60% replace-ment	80% replace-ment	100% replace-ment
Non-carbonated RAC	140	110	122	143	152
Carbonated RAC	140	115	130	151	161

3.3 Compressive strength test

Compressive strength test was carried out on the cubes having size of 150mmx150mmx150mm as per IS516(1959) and the corresponding results have been tabulated in Table 4.

Table 4. Compressive strength of non-carbonated and carbonated RAC

	COMPRESSIVE STRENGTH (N/mm ²)				
	0% conventional	40% replacement	60% replacement	80% replacement	100% replacement
Non-carbonated RAC	26.12	28.48	26.59	25.14	22.79
Carbonated RAC	26.12	28.08	26.19	25.00	22.50

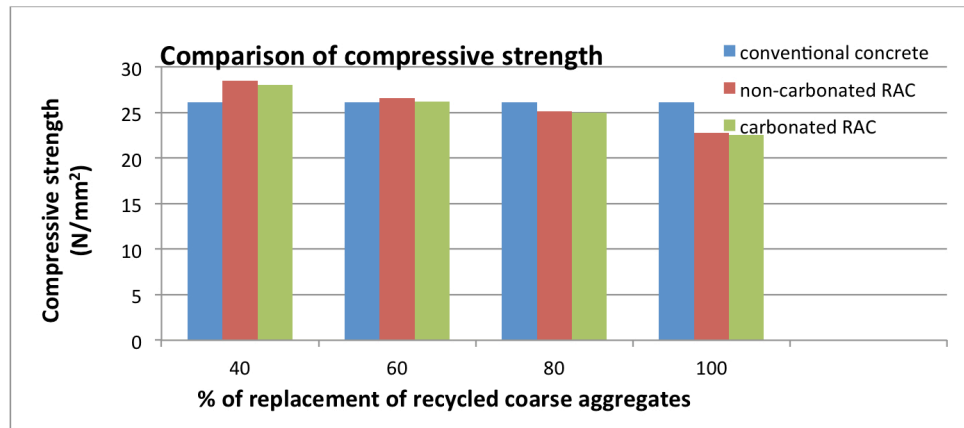


Fig. 6. Comparison of compressive strength of non-carbonated and non-carbonated RAC with conventional concrete

3.4 Tensile strength test

Split tensile strength was carried out on cylinders having length of 200mm and diameter of 100mm as per IS 5816 (1999).

The tensile strength of concrete cylinders containing non-carbonated and carbonated recycled aggregates on 28th day are represented in Table 5.

Table 5. Tensile strength of non-carbonated and carbonated recycled aggregate concrete

	TENSILE STRENGTH (N/mm ²)				
	0% conventional	40% replacement	60% replacement	80% replacement	100% replacement
Non-carbonated RAC	2.43	2.02	2.07	2.18	2.203
Carbonated RAC	2.43	2.00	1.96	2.00	2.00

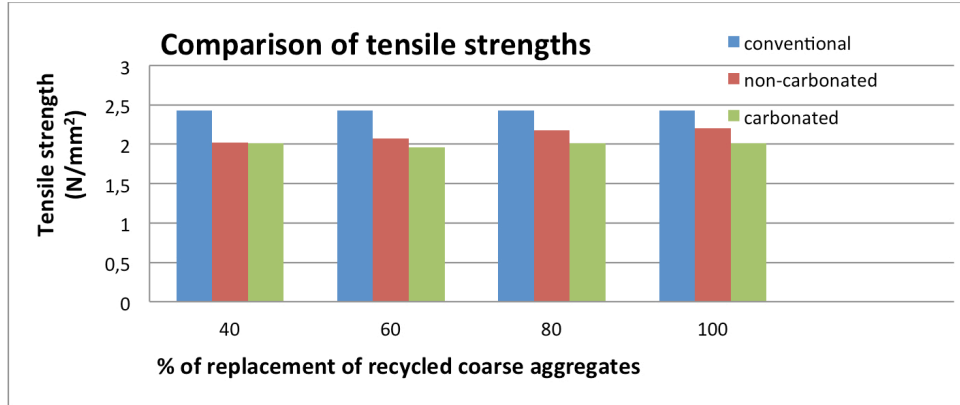


Fig. 7. Comparison of tensile strength non-carbonated and carbonated RAC with conventional concrete

4 Conclusions

Based on the experimental work carried out to study the properties of concrete with replacement of cement by glass powder and normal coarse RA and carbonated RA the following conclusions are drawn

1. water absorption was reduced from 2.38% to 2.17% and specific gravity of RA was increased from 3 to 3.17
2. Slump of RAC is lower than that of conventional concrete due to erosion of angularity on processing through abrasion machine^[fig.1&2], slump value of carbonated RA is lower than that of carbonated RA due to reduction in water absorption on carbonation
3. It has been observed from the tests conducted on cubes that the compressive strength of concrete with glass powder as partial replacement for OPC and RA is more than conventional concrete by 9% and 2%, for 40% and 60% respectively, it reduces with further increase in replacement due to reducing of bond strength as a result of abrasion.
4. The tensile strength of recycled coarse aggregate concrete shows that there is little reduction in the tensile strengths about 10-15%, however the tensile strength increases as the percentage replacement increases but overall being less than conventional concrete
5. Results conclude that replacement of carbonated RA up to 80% is feasible as results lie in standards.

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