

Investigation on Properties of Reactive Powder Concrete with Automobile Grinding Steel Waste as Fine Aggregate

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Abstract. High strength concrete is seldom used in normal construction practice due to its high cost and difficulties in achieving the desired design strength. This paper gives an insight on using waste material which has been disposed in lands as a sustainable construction material to replace sand and to achieve desired strength. The compressive strength of Reactive powder concrete (RPC) produced in this work was 88 MPa and the flexural strength was 20 MPa. Also the influence of different curing methods on the properties of RPC has been investigated. Durability studies also show that the material satisfies the durable parameters to be used as a construction material.

Keywords: strength, durability, curing, pores, sustainable, sorptivity

1.Introduction

Reactive Powder Concrete (RPC) is a type of ultra-high strength concrete which can be proportioned to have a compressive strength greater than 80 MPa to 300 MPa. It has been used in very specific applications like bridge structures where impact resistance is required, in tall buildings where the member thickness has to be reduced to carry invariably heavy loads and also in places where it is prone to withstand high temperatures like cooling towers, chimneys and many more such specific applications in structures to shield radiations like atomic power stations. The use of RPC is very limited due to the reasons that the proportioning of concrete with admixtures is a challenge with low w/c ratio and the cost of production of this concrete is very high due to high cement content. This concrete does not have any coarse aggregate and it is a blend of cementitious materials, mineral admixtures and fine aggregate. It is a general practice to use silica sand and iron dust as fine aggregate. Extensive research work has been carried by researchers in optimizing the RPC reducing the cement content and using slag from steel industries [1] [2]. Slag has been used a mineral admixture in concrete for several decades. The advantage of using slag is that it refines the porosity of the concrete increasing the durability properties [3]. Fly ash and lime stone powder has also been used in proportioning high strength RPC [4]. Extensive research on detrimental effects of using mineral admixtures were also studied it was

observed that expansion of concrete was predominant when these additives were used. Use of these additives in ultra-fine particle size was found to overcome this expansion [5]. On the other hand use of nano cement as an additive has been very advantageous in producing this high strength concrete. It enhanced the hydration process by seeding the enhancement of ions for the hydration products [6]. In order to reduce the cement content high volume of about 60% of class C fly ash and using ultra-fine mineral admixtures was used as the binding material in RPC [2][7]. Apart from these basic ingredients fibres play a major role in enhancing the flexural toughness of the RPC. As the cement content is increased concrete tends to behave in a brittle manner. To overcome this behaviour different types of fibres have been used and their properties have been investigated [8]. Steel fibres which are very fine and easily dispersed in the matrix have been predominantly used to improve the flexural strength [9]. Hybrid fibre composition with two different fibres like steel and PVA fibres have also been used which has beneficial effect in improving the flexural strength and imparting more ductility to the concrete [10]. To overcome the balling effect of steel fibres synthetic macro fibres like polypropylene, polyolefin have been used [11] which has additional effect of being non corrosive. It has also proven to be impact resistance along with crack and fatigue resistance. Basalt fibres which also have the capacity of being non corrosive have been proved to impart high flexural and compressive strength up to 120 MPa

along with good durability properties [12]. RPC has been customized to be used as a repair material with glass fibres and it has proved to have good binding strength with the old concrete substrate[13]. Apart from the type of fibres the size of the fibres based on aspect ratio plays a major role in determining the properties of RPC and researchers have extensively worked on studying the behaviour of RPC with different size fraction of fibres [14]. The curing of RPC required high temperature and pressure. Hence autoclaving is highly preferred in producing RPC structural members. The advantage of using autoclave curing has resulted in high strength in a very short duration enabling the material to be used in precast construction. The influence of different curing methods [15] [16] and also the variation in temperature and pressure along with the duration of curing plays a major role in the strength of RPC[17][18] . Durability of RPC due to high pressure curing is prone to shrinkage [19] [20] and studies have been carried out to measure other durability properties like corrosion ingress in RPC [21] and service life prediction [22]when used in structures the Apart from material properties the research on using RPC in structural members has been evaluated for static and dynamic loading conditions [23] [24]. Based on the intrinsic properties of all these parameters the focus of this paper is based on utilizing waste generated from automobile industry as a replacement for the quartz sand in producing RPC and studying the properties thereby.

2. Materials

Reactive powder concrete in this work was made using PPC of grade 53 complying to IS 12269 and sand as fine aggregate for control mix. The composition of the mix was 50% of cement, 20% Fly ash-F, 20% ground granulated blast furnace slag , 10% silica fume with binder to sand ratio as 1: 1.2. The chemical properties of fly ash and GGBFS are given in Table-1. Water cement ratio used was 0.25 with superplasticiser of 1.2% by weight of the binder. Steel fibres of aspect ratio -60 with hooked ends of 0.38 mm diameter and 23 mm length was used by 5% by volume of cement. The control mix was modified with automobile grinding waste with replacement level of 10 to 30% of sand with the waste. The grinding waste used in this work was obtained from an automobile industry which manufactures stainless steel brake disc. The waste was in the form of powdered sludge mixed with coolant oil. The sludge was washed in water to remove the coolant oil and then dried. The fine powder was used as sand replacement.

Table-1 Chemical properties of fly ash and slag

Chemical properties	Fly ash –F (% by mass)	GGBFS (% by mass)
SiO ₂	64.16	35.6
CaO	2.32	42.65
Al ₂ O ₃	28.12	14.12
Fe ₂ O ₃	3.12	1.23
MgO	0.66	-
Na ₂ O	0.089	0.6
K ₂ O	0.071	0.8
SO ₃	0.46	4.2
MnO	0.03	
Loss on Ignition, %	0.97	0.8
SiO ₂ +Al ₂ O ₃ +Fe ₂ O ₃	95.4	50.95

3. Methodology

The concrete was prepared using a pan mixer which is operated in a uniform speed. The dry mix was mixed for 2 minutes along with fibres. Water was added to the mix along with superplasticiser. The mix was then filled in concrete cube moulds of 10 cm and beams of size 10 x 10 cm cross sectional area with 50 cm length. The specimens were subjected to three different curing regimes as normal water curing for 28 days, steam curing at 90°C for 24 hours and autoclaving at 120°C and 2.5 kg/cm² for 12 hours. The compressive strength and flexural strength of the specimen were tested after the stipulated curing time. Durability of the concrete was examined using sorptivity and rapid chloride penetration test (RCPT). Sorptivity test was done of 5 cm cube specimen with the test set up as shown in Figure-1 and RCPT was done as per ASTM C 1202 using 10 cm dia disc with 5 cm height. The cell is filled with 3% NaCl solution on one end and 0.3M NaOH solution on the other end. A voltage of 60 V is passed through the cell and the charge that passes through the cell is recorded in coulombs.

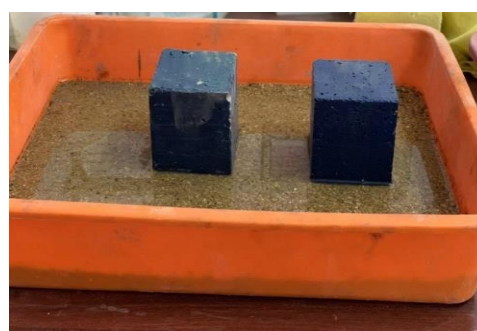


Figure-1 Sorptivity Test set up

Figure-2 RCPT set-up

4. Results and Discussions

The results of the RPC based on different curing regimes as mentioned in the previous section for different mix proportions are given in this section. Mc is the control mix without any waste material. M1 is the mix with 10% of the grinding waste as sand replacement, M2 and M3 with 20 and 30% respectively. The compressive strength of the specimens increased with increase in the replacement level as given in Figure-3. Curing conditions play a major role in determining the strength properties. Samples that were subjected to autoclave had higher compressive strength due to the acceleration of the hydration reaction. The maximum compressive strength achieved was 88.76 MPa

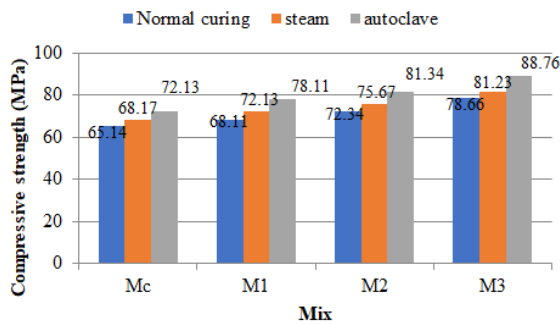


Figure-3 Compressive strength of RPC with different curing condition

The flexural strength tested by central point loading with simply support condition of beams resulted in 20.11 MPa for samples cured in autoclave with 30% replacement of the automobile waste (Figure-4). The samples cured by normal water curing resulted in a maximum strength of 15.18 MPa. The steel fibres added to the concrete improved the flexural toughness of the beam.

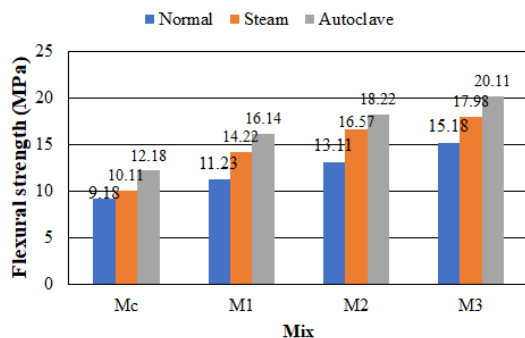


Figure-4 Flexural strength of RPC with different

curing condition

Durability tests were conducted on the specimens to ensure that the pores in the concrete are not



interconnected and do not result in adverse deterioration when exposed to environment. The RCPR test results given in Figure-5 show that the electrical resistance as charge passed in coulombs is very less and it varies with the type of curing. Samples cured using autoclave resulted in less RCPT values which could be attributed to the dense microstructure of the concrete due to more hydration products formed at elevated temperature.

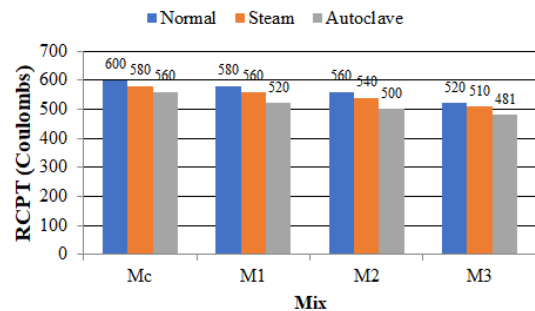


Figure-5 RCPT results of RPC with different curing condition

Similarly the sorptivity test which enables the suction of water due to capillary rise ascertains that the sorptivity values are very low ensuring the presence of minimum pores in the matrix. The sorptivity values for samples cured in autoclave show the least compared to other specimens.

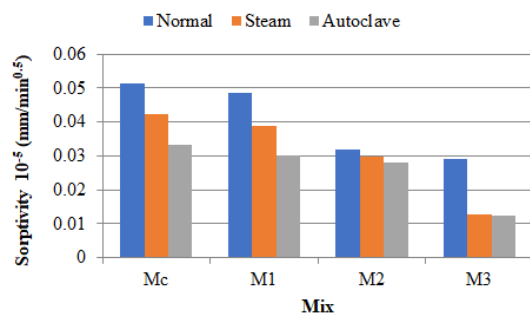


Figure-6 Sorptivity of RPC with different curing

condition

5. Conclusion:

The outcome of this work can be summarized as follows based on the experimental results:

- Automobile waste which is considered to be dumped in lands causing land pollution can be effectively used on a large scale as a construction material for replacement of sand.
- The compressive strength and flexural strength was found to increase with increase in replacement level of the waste.
- The durability parameters were also satisfied with the material being used as sand replacement.

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