FREEZE-THAW DURABILITY OF CONCRETE CONTAING RECYCLED FINE AGGREGATE

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1. ABSTRACT

Economic use of recycled concrete aggregates should include the use of the fines to replace natural sand. Freezing and Thawing (freeze-thaw, in short) durability could be a vital issue regarding the widespread utilization of such concretes containing recycled fine aggregate (RFA). Investigations have been performed herein, with concrete specimens having natural air content and low water/binder ratio. Ordinary Portland Cement (OPC), as well as, other admixtures was tried through an experimental program. Experimental evaluation shows that the recycle aggregate concrete compared well with the natural aggregate concrete in most cases.

2. INTRODUCTION

The proportion of concrete in demolition waste is estimated to be about 80%, among which the amount of fines generated is approximately 40% to 50% of the total weight of the recycled concrete [1]. Therefore, economic use of recycled concrete aggregates should include the use of the fines to replace natural sand. Even though much is known about the mechanical properties of recycled aggregate concrete, an important question remains about its freeze-thaw durability and it appears that widespread utilization of such concrete will be limited until this question is addressed [2].

This paper reports the results of an experimental investigation into the use of RFA in new concrete. From durability point of view, prospects of using RFA have been reported to use only with low water to binder (w/b) ratio, since it (low w/b ratio) helps not only to have better strength, but also brings down the possibilities of environmental attacks, owing to ingression of harmful substances, like carbonation, chloride ion penetration etc. As reported [3], air entrainment is not necessary for mixtures with low w/b ratio; this investigation was done with this concept, i.e. no air-entrainment with low w/b ratio of 0.25. Freeze-thaw durability has been reported here in terms of Relative Dynamic Modulus (RDM) of elasticity, percentage of weight loss and visual inspection of surface scaling.

3. EXPERIMENTAL PROGRAM

3.1 Materials and Mixing

Five series of concrete mixes were prepared in this experiment. Two of them were reference mixes of OPC with natural sand (NS) and recycled fine aggregate (RS) respectively. The specific gravity and water absorption values for natural sand was 2.63 & 2.19% respectively and those for the recycled fines were 2.26 & 12.26% respectively. The coarse aggregate used for this experiment was natural gravel having specific gravity and water absorption as 2.68 and 0.61% respectively. All of the coarse and fine aggregates used here was in Saturated Surface Dry (SSD) condition during testing. Among the other three mixes, two were with ternary blends of OPC, Fly Ash (FA) and Blast Furnace Slag (BFS), designated as TB-1 with a composition of 50% OPC + 30% BFS + 20% FA and TB-2 with composition of 30% OPC + 50% BFS + 20% FA; and the rest one mix was with OPC and expansive agent, designated as EA. For all mixes water to binder (w/b) ratio was kept 0.25, and no air-entraining agent was used, therefore all the concrete was with natural air content. Superplasticizer (SP) was used to maintain same flow at low w/b ratio. Detail of the mix proportion has been shown in Table 1.

3.2 Testing

The frost resistance of the concrete was measured in two ways. ASTM C666 was performed using resonant frequency to assess damage in the core of the concrete and ASTM C672 was performed to evaluate the scaling resistance of the concrete surface. A small divergence from ASTM C666 is that, specimens were cured in water for 28 days at 20 ^{0}C and 60% RH, before testing. The reason behind this long-term curing is to allow the concrete specimens having admixtures to gain sufficient strength at later ages. Another deviation is that testing was started with an age difference of two days between series NS, RS & TB-1 and series TB-2 & EA, however, at 28-day testing age, an age difference of two days can be considered negligible.

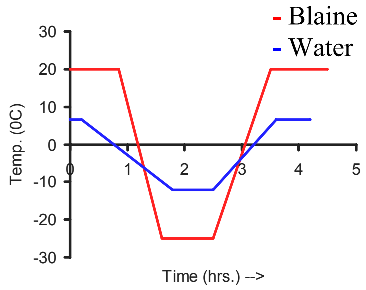

Fig 1: Typical temperature control diagram of freeze-thaw test for one cycle

Rapid freezing and thawing in water was performed at 6 cycles per day and measuring was done at every 36 cycles. Fig.1 shows the temperature control diagram for one complete cycle. The freezing and thawing machine uses a blaine-liquid to control the water or concrete temperature indirectly. The control temperature was set to vary from +20 to -25 ^{0}C in order to maintain the water temperature to vary from +7 to -13 ^{0}C for one complete cycle. The temperature was set so as to ensure complete freezing and thawing at every cycle.

KEYWORDS: Recycled fine aggregate, Freeing and Thawing, Durability, Admixtures, Ternary blends, Expansive agent
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Table 1: Mix Proportion (kg/m^3)

Series	Water	OPC	BFS	FA	EA	Sand	Coarse Aggregate	SP
NS	172	690	-	-	-	683	905	8.97
RS	172	690	-	-	-	588	905	10.35
TB-1	163	326	196	130	-	588	905	7.82
TB-2	162	194	323	129	-	588	905	7.75
EA	172	617	-	-	69	588	905	8.92

FA: Fly Ash, BFS: Blast Furnace Slag, EA: Expansive Agent, SP: Superplasticizers

4. RESULTS AND DISCUSSION

The Relative Dynamic Modulus (RDM) values versus the number of cycles for all cases are shown in Fig.2. It can be seen that both NS and RS concretes survived more than 300 cycles of freezing and thawing without showing any reduction in their RDM values. In fact, at some measuring points the actual RDM values were above 100%, however, for simplicity it has been considered as 100%. This increment of RDM values at later ages can be clarified as concrete is a time-dependent material, i.e. as it ages, its properties change due to influence of its environment and its internal hydration process, however, the standard test method doesn't involve any compensation for material aging [4]. Though 50% and 70% OPC was replaced by admixtures in case of series TB-1 &TB-2 respectively, only 2-3% reduction in RDM values was observed at 324 cycles. This significant improvement although at 50-70% replacement level might have due to the refinement of the water pore system caused by the vital distribution of FA and BFS. Since these are finer than cement, it can be expected that ternary blends concrete will have more cementitious particles per unit volume allowing a greater packing density and resulting in a more refined cement paste. Consequently, this would have reduced the amount of capillary pores resulting in a less porous paste. Since hydraulic pressures during freeze-thaw test are generated from the water stored in the capillary pores, hence formation of a denser micropore structure reduces the possibilities of that storage, as well as, prevents ingress of external free moisture in to the cement paste matrix. For expansive agent (EA) case, the RDM values reached to 91% having a continuous reduction upto the end of test; however its scaling resistance and weight loss percentage was satisfactory, this may also be clarified as the use of low w/b ratio. Visual inspection for surface scaling yielded to have a rating of 1 (very slight scaling) for all concrete mixes including series NS at the end of test and all others approximately after 216 cycles. For ternary blend cases (series TB-1 & TB-2), weight loss percentage crossed 1% (Fig. 3); since there was a large amount of FA & BFS presented in the mix, some of these are supposed to remain unhydrated until the end of testing period.

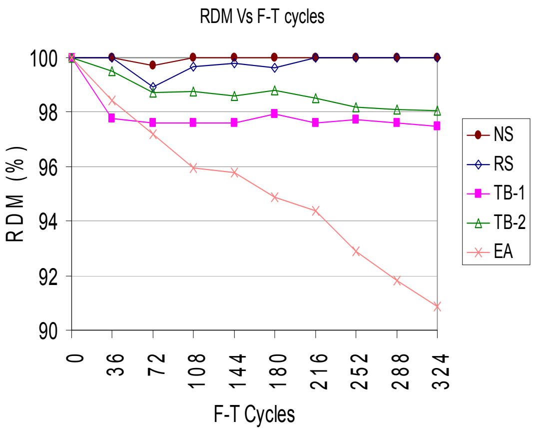

Fig 2: Relationship between RDM (%) and Freeze-thaw cycles

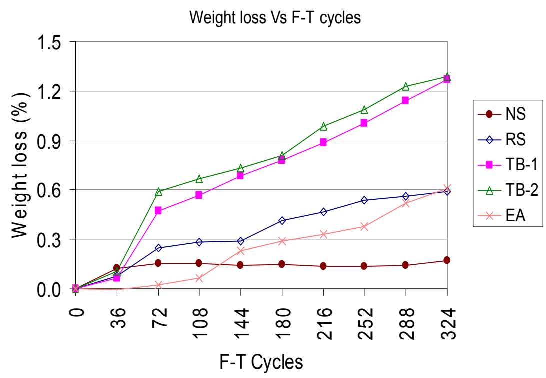

Fig 3: Relationship between Weight loss (%) and Freeze-thaw cycles

5. CONCLUSION

Frost resistant durability of concrete containing recycled fine aggregate has been investigated herein. The results show that at low w/b ratio, the capillaries are supposed not to exceed the critical saturation level (i.e. 91.7% filled with water) and hence the possibilities of development of hydraulic pressure are greatly reduced. A replacement of more than 50% of OPC by admixtures showed almost similar performance in frost resistance; this point can be considered beneficial from environmental view point, firstly, by minimizing the waste disposal problem and, secondly, by utilizing the by-products like FA, BFS etc., and also from economic point of view having a minimized construction cost, if other properties allow them using accordingly.

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