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FREEZE-THAW DURABILITY OF M30 PAVER BLOCKS REPLACING OPC BY FLY ASH AND ADDING PPF

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ABSTRACT. This paper presents the freeze-thaw durability of 60 mm thick paver blocks of M30 grade concrete replacing OPC by 30% fly ash and adding PPF in varying proportions from 0.0%, 0.1%, 0.2%, 0.3%, 0.4% and 0.5%, water cement ratio 0.43. The freeze-thaw durability of paver Blocks was investigated at 28 days after 10, 25 and 50 cycles. Based on the experimental results, it was found that the durability of paver blocks with fly ash and PPF is well within the codal provisions, confirming that these paver blocks are usable in all the atmospheric conditions. The results show that these paver blocks are economical from durability point of view.

1. INTRODUCTION

Precast cement concrete paver blocks are solid, unreinforced products made out of cement concrete of low water-cement ratio. These are made in varied dimensions with different grades of concrete to fulfill the need of diversified traffic environmental conditions. These are used in surface layer of pavements, urban and semi urban roads, village roads, streets, foot paths, gardens, passengers waiting sheds, petrol pumps bus stops, platforms, industry, etc. Paver blocks are economical as they do not break and these have 100% salvage value

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in case of replacement [1]. The term precast means that the blocks are manufactured and hardened before laying and are brought to job site. The paver blocks are manufactured in such a fashion that these interlock with each other during laying to maintain structural strength. These are laid on prepared sub grade with sand bed below bounded by edge restraints from both sides. The joints are filled with sand of suitable grading. Concrete block pavements have certain advantages over asphalt and concrete pavements [2,3]. The general advantages are maintenance, operational, structural, aesthetics and economical. The use of fly ash in concrete paver blocks as part replacement of Portland cement is with the objective to reduce cement particulate content which results in economy and durability enhancement [4]. It will also help in energy saving in cement production. The utilization of fly ash in manufacturing of paver blocks will provide relief for safe and economic disposal of fly ash. Ghafoori and Mathis [2] predicted concrete paver blocks, freezing and thawing durability by keeping aggregate cement ratio between 9:1 to 3:1 and reported minimum cement content of 395 kg/m^3 can provide acceptable durability. Uygunoglu et al. [5] studied freeze-thaw resistance of pre-fabricated concrete by replacing OPC with fly ash, fine aggregates replaced by concrete waste and marble waste @0% to 40% with increment of 10% respectively and reported favourable freeze thaw cycles results. Clark [6] carried out freeze-thaw durability test on concrete paving block and reported that 380kg/m^3 is absolute minimum level of cement content to obtain good durability. Cement concrete is strong under compressive loads at the same time it is inherently poor under tensile stresses. It is of brittle nature so it is not advisable to make paver blocks from concrete of such nature. The material for paver blocks has to be ductile. Thus to make concrete ductile, polypropylene fibers are added in small proportions during manufacturing of paver blocks to encounter the impact and flexural stresses which are inevitable on road surface during running of traffic.

2. Experimental Study

This study involves the fabrication of 18 number specimens of paver blocks of size 200 mm X 165 mm X 60 mm of M30 grade concrete composite in which OPC has been replaced by 30% fly ash and PPF has been added in varying proportion of 0.0%, 0.1%, 0.2%, 0.3%, 0.4% and 0.5% by weight of cementitious material.

The study of freeze thaw is to access the possible use of paver blocks in varying temperature of Indian sub-continent.

2.1. **Materials Used.**

- **Ordinary Portland Cement (OPC)** The physical properties of OPC 43 grade cement have been tested in accordance with IS:8112 [7] and the results were found satisfactory.
- **Aggregates** The aggregates are added to get bulk of the total volume of concrete. The recommended maximum nominal size of aggregates is 12 mm as per IS: 15658 [8]. However in the present study the maximum nominal size used is 10 mm.
- **Fine Aggregate (FA)** The sand has been tested as per IS: 383 [9] and IS: 2386 [10]. FM of sand 2.73, specific gravity 2.57, bulk density (loose) 1567 Kg/m^3, water absorption 0.6%, the sand conforms to grading zone II.
- **Coarse Aggregates (CA)** The coarse aggregates were tested according to IS: 383 [9] and IS: 2386 [10]. Bulk density (Loose) 1440 Kg/m^3, specific gravity 2.63, water absorption 0.48, impact value 14, abrasion value 19 and fineness modulus of 6.0 were obtained for coarse aggregate.
- **Fly Ash (FA)** Fly ash is a by product of thermal power plants. Ash is of two types i.e. Fly Ash and Bottom Ash. The physical and chemical properties of Fly ash used were tested and it was found that fly ash has specific gravity 2.08 and it belongs to class F.
- **Chemical Admixture (Super Plasticizer)** BASF Master Glenium SKY 8233 was used and test data supplied by the supplier complies with IS: 9103 [11]. In the present study, the dosage of super plasticizer used is 500 ml per 100 kg of cementitious material.
- **Water** Potable tap water was used for casting and curing of paver blocks. The water confirms to the requirements of IS: 456 [12].
- **Polypropylene (PP)** The polypropylene has been used in the form of polypropylene fiber (PPF) of Reliance India Ltd. The brand name of PPF is Recron 3s. Standard dosage of 125 g/50 kg bag of cement is recommended by the manufacturer.

3. METHODS

3.1. **Mix Design.** Mix design aims at selecting suitable ingredients for paver block composite to meet the requirements of paver blocks economically. No specific IS code is available for concrete mix design of zero slump concrete paver blocks. The codes followed in the present study are IS: 15658 [8], IS: 456 [12], IS: 10262 [13] and IRC: 44 [14] for mix design. The mix design adopted in the manufacture of paver blocks is as shown in Table 1.

TABLE 1. Mix Design

MixID	Cementitious material		Water	Fine Aggregate	Coarse Aggregate	SP	PPF	Water Cement Ratio
	Cement	FA						
	Kg/m^3							
M30F30P0.0	269	116	152	953	879	2.08	0.000	0.43
M30F30P0.1	269	116	152	953	879	2.08	0.385	
M30F30P0.2	269	116	152	953	879	2.08	0.770	
M30F30P0.3	269	116	152	953	879	2.08	1.155	
M30F30P0.4	269	116	152	953	879	2.08	1.540	
M30F30P0.5	269	116	152	953	879	2.08	1.925	

3.2. **Testing of Specimens.** The freeze-thaw durability test was conducted following IS: 15658 at 10, 25 and 50 cycles. The test was performed on three specimens selected randomly as per IS: 15658 [8]. The constant dry weight of all the specimens of different grades was recorded before the start of test. The specimens for each grade were fully submerged in 3% sodium chloride solution with 95% area in contact at the bottom before start of freeze-thaw test for 24 hours duration. The level of solution was kept 2mm above the surface of the specimen at temperature 23$\pm$03°C. After preparation, the specimens were subjected to freeze-thaw cycles of 10, 25 and 50 cycles in continuity. Each cycle completes with 16 hours of freezing at -15°C and 8 hours of thawing at 23$\pm$03°C. After 10 cycles of freeze and thaw the specimens were washed with 3% sodium chloride solution. The spalled material after washing was collected in a beaker and strained through filter paper. Weight the filter paper before use (W1). The filter paper with spalled material was dried in an oven and weight of filter paper with spalled material was recorded (W2). Calculate weight of spalled material by using formula (W2 - W1) in gm. The same procedure was repeated for 25 cycles and 50 cycles. The cumulative residue weight loss calculated after completion of the test and percentage weight loss calculated. Visual

inspection of the specimens is carried out after 10, 25 and 50 cycles and reported as per scale of the IS: 15658.

4. Results and Discussion

4.1. **Freeze-Thaw Resistance Test Results.** As the paver blocks are exposed to alternate cycles of high and low temperature due to change in environmental conditions, the freeze thaw test gives a clear idea of durability of paver blocks. The test was conducted in accordance with IS: 15658 [8].

4.2. **Results of Freeze-Thaw Resistance of M30 Grade 60mm Thick Paver Blocks after 10, 25 And 50 cycles.** The cumulative weight loss after 10, 25 and 50 cycles of freeze-thaw test on 60mm thick paver blocks of M30 grade with varying percentages of PPF has been shown in Table 2, Table 3 and Table 4 respectively. The blocks were visually inspected. No serious defect was noticed. Figure 1 shows the images of freeze-thaw experiment after 50 cycles.

Table 2. Freeze-Thaw Resistance Test Results of M30 grade paver blocks (60mm thick) after 10 Cycles

Mix ID	Average Initial Dry Weight (gm)	Average Weight Loss After 10 Cycles (gm)	Percentage Loss of Weight	Visual Inspection
M30F30P0.0%	3645	0.48	0.013	Very slight scaling was observed in reference mix as well as in other mixes of PPF
M30F30P0.1%	3688	0.91	0.025	
M30F30P0.2%	3683	1.05	0.028	
M30F30P0.3%	3597	1.33	0.037	
M30F30P0.4%	3542	1.20	0.034	
M30F30P0.5%	3575	1.04	0.029	

The study results and visual inspection shows that after 50 cycles of freeze-thaw test of M30 grade designation paver blocks of thickness 60mm, it can be concluded that the visual rating of the specimen have little impact after 10 cycles and some effect after 25 cycles and finally after 50 cycles there is slight to moderate scaling with less than 5% of coarse aggregates visible on the edges only. The cumulative weight loss after 50 cycles of freeze-thaw cycles as per code shall not exceed 1% of initial constant dry weight of the specimen. Addition

TABLE 3. Freeze-Thaw Resistance Test Results of M30 grade paver blocks (60mm thick) after 25 Cycles

Mix ID	Average Initial Dry Weight (gm)	Cumulative Weight Loss After 25 Cycles (gm)	Percentage Loss of Weight	Visual Inspection
M30F30P0.0%	3645	0.677	0.0186	Slight to moderate scaling and no coarse aggregate visible
M30F30P0.1%	3688	1.210	0.0328	
M30F30P0.2%	3683	1.343	0.0365	
M30F30P0.3%	3597	1.633	0.0454	
M30F30P0.4%	3542	1.533	0.0433	
M30F30P0.5%	3575	1.407	0.0394	

of PPF results in increase in percentage weight loss from 0.1% to 0.3%, PPF after that weight loss reduces. However, all the mixes satisfy the freeze-thaw durability provisions of the code. The maximum percentage weight loss was observed with 0.3% PPF, with 385 kg/m^3 of cementitious material.

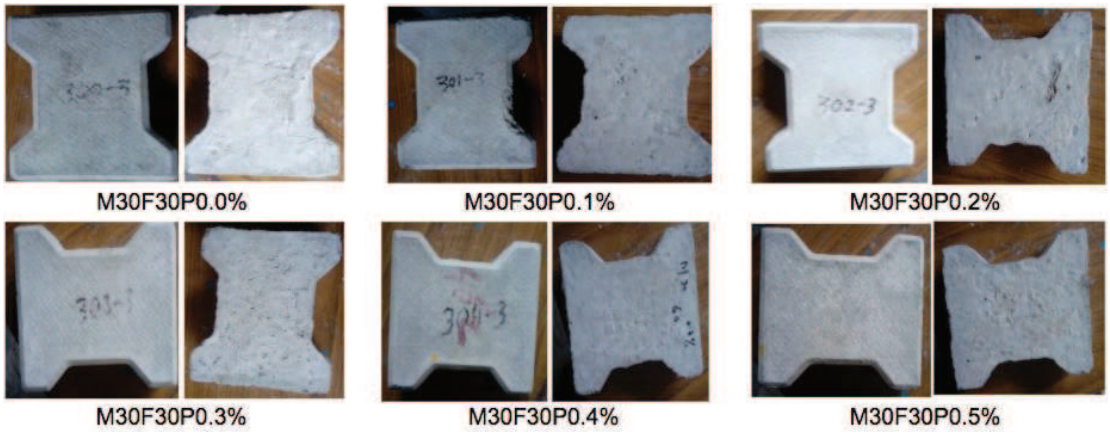

FIGURE 1. Top and bottom surface images of freeze-thaw experiment after 50 cycles (60mm thick)

5. CONCLUSION

From the present study the following conclusions can be drawn :

TABLE 4. Freeze Thaw Resistance Test Results of M30 grade paver blocks (60mm thick) after 50 Cycles

Mix ID	Average Initial Dry Weight (gm)	Cumulative Weight Loss After 50 Cycles (gm)	Percentage Loss of Weight	Visual Inspection
M30F30P0.0%	3645	0.857	0.024	Top surface suffered no damage, Bottom surface has small tiny holes,some corner matrix damaged
M30F30P0.1%	3688	1.417	0.038	Top surface suffered No damage, bottom surface shows numerous small tiny holes with increased depth
M30F30P0.2%	3683	1.607	0.044	Top surface suffered No damage, bottom surface showed minor tiny holes with corner matrix damaged
M30F30P0.3%	3597	1.930	0.054	Top surface suffered No damage, bottom surface has increased number of tiny holes with more depth, less corner damage with respect to reference
M30F30P0.4%	3542	1.850	0.052	Top surface suffered No damage, bottom surface number of tiny holes reduced and less corner matrix damage
M30F30P0.5%	3575	1.787	0.050	Top surface suffered No damage, bottom surface has tiny holes reduced and slight corner matrix damages

(1) Cementitious material used for M30 grade paver blocks for 60mm thick was 385kg/m^3 which confirmed the condition of 380 kg/m^3 reported by Clark (5) for better freeze- thaw durability.
(2) Optimum percentage of PPF addition can be taken as 0.3% from freeze-thaw point of view.
(3) Cumulative percentage weight loss after 50 cycles in the mixes are within code provision of 1% (IS: 15658) [8].

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