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“Effect of Different Cementitious Materials on Sustainable Concrete Used for White Topping”

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Abstract: White topping is a solution to increase the durability of bituminous pavement in urban areas. Concrete is a material that is substantially stronger and less sensitive to high temperatures. Due to its superior performance against rutting and cracking, concrete overlay is displacing traditional bituminous overlay even in rehabilitation and repair (Sinha et al.2007). This paper presents the findings of experimental investigation with the objective of studying the properties of concrete required for white topping in fresh and hardened state with different cementitious materials and fiber additions. Trials are taken to prepare the mix design of the concrete with different cementitious materials with different % substitutions of substituted materials namely fly ash, micro silica and rice husk ash. An attempt is also made to enhance diminished property which may be caused due to cementitious material by addition of polypropylene fibers. In this research the results are experimentally validated and further extended with addition of other sustainable materials such as micro silica and rice husk ash. The research is carried out on concrete cubes for compressive strength and concrete beams for flexural strength properties with trial mix designs.

Key Words: thin white topping (twt), micro silica, rice husk ash, polypropylene fibres, flexural strength, compressive strength, sustainable material

A. Introduction

The majority of the pavements in India are made of bituminous material and a thin binder course. Due to rising loads, increased traffic volume, high wheel pressure, etc., bituminous pavements are beginning to show early signs of deterioration worldwide. Rutting, cracking, and other distress are frequently observed.

Reflective cracking in bituminous overlays is another problem. Since bitumen is extremely sensitive to high temperatures, these problems are more obvious in countries with hot climates like India. Thus, it is becoming less certain how well bituminous pavements perform in warmer climates.

Contrarily, concrete is recognized as a material that is substantially stronger and less sensitive to high temperatures. As a result, concrete pavements are becoming a more popular choice than traditional bituminous pavements. Due to its superior performance against rutting and cracking, concrete overlay is also being used to replace typical bituminous overlay in rehabilitation and repair work (Sinha et al. 2007).

Whitetopping is the process of overlaying an existing, deteriorated Hot Mix Asphalt (HMA) pavement with a thin layer of concrete (Julie 2002). Consequently, whitetopping is PCC resurfacing (overlay) as a rehabilitation or alternative for structurally strengthening bituminous pavement. In a hot country like India, big truck loads that frequently start and stop pose a serious challenge.

It is frequently used in areas where bituminous pavement rutting is a persistent issue. Concrete overlays have the ability to provide a bituminous overlay alternative as well as an extended service life, higher structural capacity, and decreased maintenance needs (IRC SP 76, 2015).

Additionally, the white color of the concrete used in whitetopping offers benefits in terms of visibility and safety. The lighter color reflects more sunlight, reducing heat absorption and the associated expansion and contraction of the road surface. This can help prevent cracks and other forms of deterioration. The improved visibility of the white surface can also enhance safety, especially during nighttime driving.

Bonded Concrete overlays offer much higher structural improvements than bituminous overlays. Thus, the same edge load stress created under a 75mm (3") bonded overlay requires 150mm to 155mm (6" to 7") of bituminous overlay. Per unit thickness of material, bonded concrete overlays are more structurally effective (Kamal, 2001).

B. Experimental work

a. Materials and mix proportion

Concrete mix m 40 were designed using 53 grades ordinary Portland cement, artificial crushed sand and combination of 19 mm and 9.5 mm aggregates. The concrete mix proportion obtained was 1:1.73:2.97 with water cement ratio of 0.34. Cementations materials such as fly ash, rice husk ash, microsilica with different % used to improve workability, durability, and reduce heat of hydration. Flexural strength is criteria for acceptance of concrete mix. The beams were tested by a flexural testing machine. fibre addition experimented to enhance fresh and hardened state of concrete to be used in whitetopping. The video gauge equipment was used for determining strain of concrete specimen to study deformation.

Pavement Quality Concrete is typically used to provide a strong surface for rigid pavements. The substantial impact force from the wheels to the subgrade layers is distributed using PQC when building airport runways. It is advised to produce M40 grade and higher to meet the requirements of PQC, as traditional regular grade concrete is technically unsuitable for PQC preparation. The slump value is comparatively lower than that of traditional concrete of the same grade because a lower w/c ratio is considered to provide more strength.

In addition to cementitious materials, aggregate content is crucial for the development of PQC's strength. Before creating the PQC, the coarse aggregate (CA) and fine aggregate (FA) are both continually chosen and free of any dirt deposits. Only hard, clear CA with a maximum size of 20 to 25 mm is appropriate for PQC development.

The mix design of concrete is extremely important and should be as cost-effective as possible in order to discover appropriate ingredients for concrete that have the needed workability, durability, and strength. The IRC 44-2017 regulations were used to carry out the PQC mix design method.

Trial mixes should be used to demonstrate the design's appropriateness in accordance with IRC 44-2017 regulations. The approved mixer and permitted materials must be used to make the trial mixes of the concrete mixture that is suggested to satisfy the design specifications for Pavement Quality Concrete indicated in the guidelines.

For mixture proposed, a set of three pairs of 150×150mm cubes for compressive strength, a set of two pairs of 100×100×500mm beam for flexural strength, shall be made, cured and tested at 7 days and 28 days.

b. Study of proportions of concrete

According to the specifications of the concrete mix design, the concrete was precisely cast. By adding the fibres to the mix in little amounts at a time, the balling-up of fibres was avoided during mixing. For evaluating the quality of the concrete, specimens were cast using standard moulds measuring 150x150x150 mm and standard beam of 100x100x500 from each mix.

For the flexural tests of the concrete and composite specimens, the beam specimens were cast in 3 layers, and each layer was subjected to vibration for 10s.

C. Results:

Several mixes were cast with following variations:

1) Different water-cement ratio.
2) Different % substitution of flyash, Rice husk ash, Microsilica and Polypropylene fibre.
3) Different mix proportions.
4) The cube and beams were cast, and compressive and flexural strength.

Table 1: Different concrete mix proportions with fresh and hardened properties for pavement quality concrete

	Mix properties									Strength "MPa"	
Sr. No	Mix name	w/c ratio	Adx (%)	Fly ash FA (%)	RHA (%)	MS %	mix proportion (%)	Polypropylene fibre (%)	Slump-mm	Compressive	Flexural
1	C	0.45	1.1	-	-	-	1:1.84:3.02	-	100	45	5.5
2	F10	0.43	1	10	-	-	1:1.84:3.02	-	70	42	4.95
3	F20	0.42	1	20	-	-	1:1.84:3.02	-	60	38	5.6
4	R5	0.42	1	-	5	-	1:1.84:3.02	-	50	44	5.2
5	R10	0.42	1	-	10	-	1:1.84:3.02	-	50	39	4.8
6	R15	0.42	1	-	15	-	1:1.84:3.02	-	50	34	4.6
8	F20R15	0.34	0.7	20	15		1:1.73:2.97	-	35	22.66	6.3
9	F30M10	0.33	0.7	30	-	9	1:1.3:2.37	0.75	50	16.6	1.16
10	F30R15M5	0.33	0.7	30	13	7	1:1.3:2.37	-	60	15.8	2.9

a. Compressive strength of concrete:

1) Table 1 shows that mix C having no substitution gives maximum compressive strength.
2) Concrete Mix F10 and mix F20 having substitution of flyash (FA) 10% and 20% shows slight decrease in compressive strength.
3) Concrete mix R5, R10 and mix R15 having substitution of rice husk ash (RHA) 5%, 10% and 15% resulted in gradual decrease in compressive strength same as substitution of flyash in concrete.
4) The concrete mix F20R15 having combination of FA and RHA resulted in low compressive strength due to increasing RHA to 15%.
5) Concrete mix F30M10 resulted in poor compressive strength after addition of fibre in substitution combination of 39%.
6) Concrete mix F30R15M5 resulted in lowest compressive strength after 50% substitution in mix.

b. Flexural strength of concrete:

1) As flexural strength is accepting criteria for whitetopping concrete, flexural strength seems to increase as substitution of cementitious material increases.
2) From table 1, mix C having no substitution have passed flexural strength which should be greater than $4.5 N/mm^2$.
3) Mix F10 and mix F20 having substitution of flyash (FA) 10% and 20% shows no impact on flexural strength and passed minimum flexural strength requirement.
4) Concrete mix R5, R10 and mix R15 having substitution of rice husk ash (RHA) 5%, 10% and 15% resulted in gradual decrease in flexural strength still passed minimum flexural strength requirement.
5) Concrete mix F30M10 resulted in the lowest flexural strength after addition of fibre in substitution combination of 40%.

6) Concrete mix F30R15M5 failed to pass minimum 4.5N/mm^2 flexural strength after 50% substitution in mix.

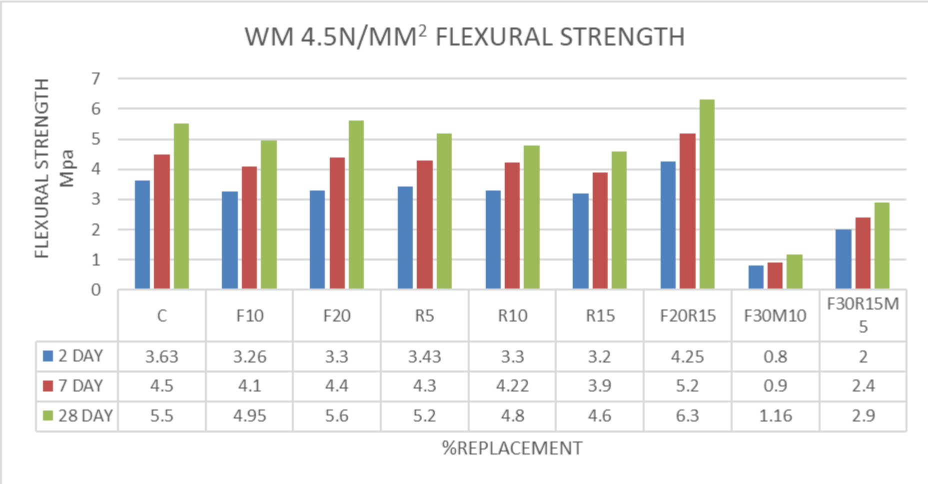

Figure 2: variation in flexural strength

D. Conclusion:

PQC concrete in which flexural strength is an important parameter. The concrete for whitetopping is required to achieve 2/3rd of strength within a short period of 48 hours. The road with whitetopping will have to be open for traffic within 48 hours. An attempt is made to develop the concrete of early age flexural strength with substituting material for cement based on experimentations following conclusions are drawn.

1) In concrete mix F30R15M5 the maximum combination of substitution was 50% in which 30%FA, 13%RHA, 7%MS. This mix failed in compressive strength as well as in flexural strength.
2) In concrete mix F30M10 combination of 30%FA, 9%MS addition of polypropylene fibre which is 0.75% resulted in failure in compressive strength as well as flexural strength.

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