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Effect of Bonding Layer and Admixtures on Performance of Ultra Thin White Topping

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Abstract: *Traditionally, Cement concrete has been perceived as a material for newpavement construction, in particular for streets with heavy axle loads. However, with respect to pavement rehabilitation, agencies many a times consider bituminous overlays as the first option, regardless of the condition of the existing pavement structure. It is in this environment that Ultra-Thin White Topping (UTW) gaining popularity. The urban streets exhibit well stabilized base due to the repeated wheel load applications, but the riding quality of these streets are not satisfactory due to the deterioration of the surface layer, hence it is required to rehabilitate these pavements. At present these pavement are being rehabilitated with a bituminous overlay frequently, which is causing hindrance and delay to the traffic and the road user. To overcome this it is advisable to rehabilitate these pavement sections with such rehabilitating methods which will not require repeated maintenance and also provide the road user a better riding quality for a long duration of time. The bond between the new concrete and existing bituminous pavement plays an important role in exhibiting composite action, which will lead to better performance of UTW. This paper highlights the effect of different admixtures in concrete on the bond strength between the bituminous layer and a new cement concrete layer.*

Keywords: *Thin White Topping, Ultra-Thin White Topping, Admixtures, Cement Concrete, Rehabilitation, Bituminous Pavement*

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I. Introduction

Thin and Ultra-thin white topping

Although thin white topping (TWT) and ultra-thin white topping (UTW) overlays have been constructed for decades, their recent popularity is largely the result of a renewed demand for longer-lasting but cost-effective solutions for bituminous pavement rehabilitation. A white topping overlay is constructed when a new portland cement concrete layer is placed on top of an existing bituminous pavement system. The concrete thickness for a UTW is equal to or less than 100 mm. A TWT is greater than 100 mm but less than 200 mm. Conventional white topping is an overlay of 200 mm or more. In most cases, a bond between the new concrete and existing bituminous layers is not only assumed during design, but specific measures are taken to ensure such a bond during construction. The success of this bond, leading to composite action, has been found to be critical to the successful performance of this pavement-resurfacing alternative. Ultra-Thin White topping (UTW) is a relatively new pavement rehabilitation technique that is used mainly for the repair of deteriorated asphalt pavements. Typically, UTW is constructed by milling the distressed, top portion of the asphalt pavement, and placing a thin (not more than 100mm thickness) concrete overlay on top of the milled surface. Based on U.S. experience, ultra-thin white topping can be defined as a concrete overlay 50 mm to 100 mm thick with closely spaced joints, bonded to an existing bituminous pavement.

For an existing bituminous pavement nearing the end of its structural or functional life, the selection of the most appropriate rehabilitation alternative can be based on some specific criteria and a number of others. In many cases, the selection of the most appropriate strategy will be made by balancing several competing factors. Common factors include the following,

- Projected traffic loading
- Existing pavement – Condition, Layer thicknesses, Drainage
- Costs – Overlay construction cost, Total LCC, User delay costs, Vehicle operating costs
- Time factors – Number of construction operations, Total construction time, Repair and maintenance time, Frequency of repair and maintenance, Initial performance period
- Corridor impact – Noise level, Excess pollution level, Accident rate (vis-à-vis skid resistance), Ride quality (smoothness)
- Material availability – Cement, Asphalt binder, Aggregates

- Contractors – Availability (capacity), Experience, Competition (number of bidders).

Quite often, the design and constructability of the various overlay alternatives will contribute too many of the factors. Therefore, a need exists to assess some degree of engineering design in the planning and selection stages. For example, one potential pitfall in selecting a UTW or TWT alternative is the result of the oversimplified characterization of the properties of the existing bituminous pavement. Depending on these properties, the UTW or TWT can have a widely varied performance. It has been shown that all else being equal, the stiffness of the bituminous layers can have a significant impact on the performance of these types of overlays(Conversely, a bituminous overlay is sometimes prone to the redevelopment of certain distresses, such as shoving at intersections and reflection cracking). This consideration has been specifically cited in the survey responses, as well as in the literature, as a reason to select a white topping alternative.

Another consideration that is commonly reported in the literature pertains to the benefits of a more reflective surface as a result of the lighter color of concrete. The increased reflectivity has been reported to have a number of benefits, including

- Increased reflection of headlights and aircraft landing lights, improving safety
- A lower demand for external lighting, reducing operational costs and
- A cooling effect owing to lower absorption of solar energy, with environmental benefits.

Finally, another reported benefit is the resistance to fuel spillage, which is a possible consideration in the construction of parking lots, fueling stations, and aircraft aprons.

II. Fundamental behavior of Ultra-thin white topping

UTW and TWT overlays provide a unique pavement structure that is fundamentally different from other pavement types. UTW and, in most cases, TWT overlays are designed and constructed with consideration of a sound bond between the PCC and bituminous materials. The result is a composite structure that distributes traffic and environmental loading differently than more conventional PCC or bituminous pavement structures.

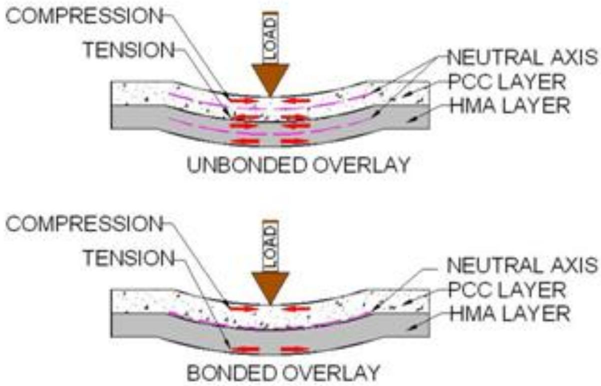

Fig. 2.1 Effect of composite action on UTW and TWT under loading

As Fig.2.1 illustrates the stress distribution in a bonded system versus that of an unbonded system can be significantly different. As a result of the composite section, the stresses in the top PCC layer are significantly lower in the bonded than those in the unbonded case. Furthermore, because much of the slab is in compression and because concrete is much stronger in compression than in tension, the design of the slab can be thinner for a bonded case than for an unbonded case.

Although a fully bonded system would be ideal, it has been shown that partial bond is usually realized as a result of a number of factors. In such case, the neutral axis will lie somewhere very much near to the interface of PCC layer and bituminous layer, as illustrated in Fig.2.1.

A thicker concrete overlay should be considered if the support layers have exhibited poor structural support, by contributing to the deformation and/or cracking of the original bituminous pavement. When designing the UTW or TWT overlay, consideration should be made of the condition of the existing bituminous pavement. The stiffness of the pavement system as a whole (including the bituminous layer and support layers) is known to have a significant effect on the performance of the white topping overlay. As a result, deflection bowls analysis will be required.

III. Background and Problem Statement

Sub arterial and residential main streets with considerable high volume of traffic within Bangalore City have been strengthened periodically with bituminous layers. These streets exhibit well stabilized base due to the repeated wheel load applications, but the riding quality of these streets are not satisfactory due to the deterioration of the surface layer, hence it is required to rehabilitate these pavements. At present these pavement are being rehabilitated with a bituminous layer frequently, which is causing hindrance and delay to the traffic and the road user. To overcome this it is advisable to rehabilitate these pavement sections with such rehabilitating methods which will not require repeated maintenance and also provide the road user a better riding quality for a long duration of time.

IV. Research Significance

It is evident that the performance of UTW and TWT depends on the bond strength between the existing bituminous layer and the PCC overlay. To attain the required compressive strength and to improve the concrete characteristics certain additives like fly ash, micro silica are used as admixtures to concrete. These admixtures can alter the bond strength of concrete overlay on an existing bituminous layer. Hence it is necessary to evaluate the bond strength and study the performance of concrete with admixtures when used as UTW or TWT.

V. Experimental Work

The main aim of this experimental work was to study the variation in bond strength due to the addition of admixtures to concrete used as UTW or TWT. As there are no standard testing equipment and procedure available to evaluate these properties a suitable instrumentation was developed and fabricated to suite the requirement further, since the spread of the deflection bowl has a greater influence on the stresses and strains developed in the structural layers of the pavement section, hence it was required to measure the spread of the deflection bowl along with the deflection in the field, which required a modified Benkelman Beam.

5.1 Field Tests

Various sub arterial and residential main streets with considerable volume of traffic within Bangalore City were selected and Benkelman Beam Studies were carried out to evaluate the structural condition of the pavement, the spread of the deflection bowl was measured using modified Benkelman Beam, further the pavement sections were cut open and the cross section details were collected. Out of the various streets surveyed, only those which had bituminous layer thickness greater than 100mm and base course thickness greater than 150mm were summarized. The summarized data clearly indicated that the characteristic deflection of these pavement sections were less than one millimeter (1mm) and the deflection bowls had spreads greater than 600mm.

5.2 Laboratory Studies

The mix proportion adopted in the experimentation was 1:2.02:3.05(coarse aggregate 1142kg/cum, fine aggregate 756kg/cum, cement 375kg/cum and water cement ratio of 0.4% which is 150lit/cum) which corresponds to M40 grade concrete. The mix design was carried out according to IS: 10262-1982. Homogeneous concrete mass was prepared as per the mix design. This mass was gently placed on the bituminous base in layers and consolidated by using just the required vibration for good compaction.

The cylindrical composite specimens having 75mm thick concrete layer over 75mm thick bituminous layer was subjected to direct tensile test by clamping the moulds with specially designed clamps, which could hold the specimen and could be clamped on to UTM for conducting the test. The rectangular composite specimens having 100mm thick concrete layer over 100mm thick bituminous layer was subjected wheel trafficking test on modified wheel trafficking equipment.

5.3 Test Results

The cylindrical composite specimens were tested for direct tensile test.

- Table.5.1 shows the compressive strength test results of plain cement concrete with different combinations of admixtures
- Table.5.2 shows the bond strength test results of plain cement concrete with different combinations of admixtures
- Fig. 5.3 shows the variation in compressive strength and
- Fig. 5.4 shows the variation in bond strength exhibited by cylindrical composite specimens of different combinations.

The rectangular composite specimens were tested for its performance under wheel trafficking equipment.

- Deflection values for 8kg/sqcm pressure for all combinations are shown in Table.5.3.
- Fig.5.5 shows the variations in deflection of Plain Concrete composite beam specimens with and without Roff Cement interface which were subjected to 8kg/sqcm pressure.

- Fig.5.6 shows the variations in deflection of Plain Concrete with Fly ash composite beam specimens subjected to 8kg/sqcm pressure.
- Fig.5.7 shows the variations in deflection of Plain Concrete with Micro Silica composite beam specimens subjected to 8kg/sqcm pressure.
- Fig.5.8 shows the variations in deflection for all combinations of composite beam specimens which were subjected to 8kg/sqcm pressure.

Photograph 5.1 Cylindrical Mould

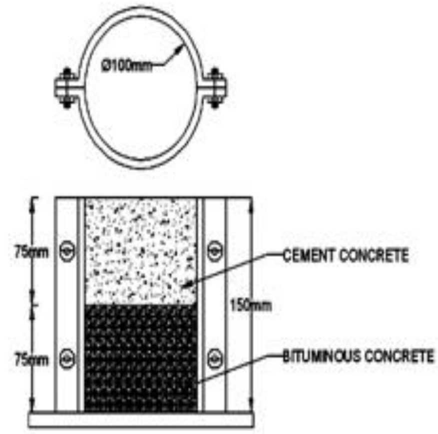

Fig.5.1 Dimensions of Composite Cylinder

Photograph 5.2 Direct Tensile Test

Photograph 5.3 Rectangular Mould

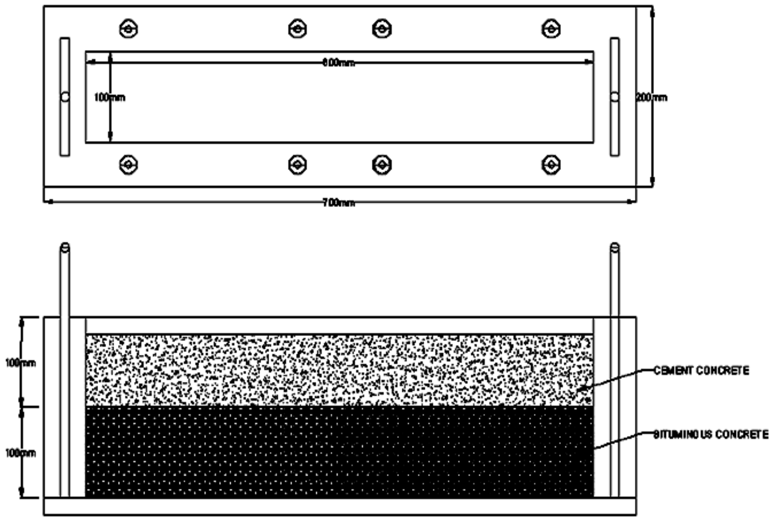

Fig.5.2 Dimensions of Rectangular Composite Beam Specimen

Photograph 5.4 Modified Immersion Wheel Trafficking Test Setup with Specimen

Table. 5.1. Compressive Strength Test Results

Sl No	Description	Compressive Strength in N/mm2
1	Plain Concrete (PC)	43.28
2	Plain Concrete with 20% FLY ASH (FA-20)	44.34
3	Plain Concrete with 25% FLY ASH (FA-25)	47.83
4	Plain Concrete with 30% FLY ASH (FA-30)	49.21
5	Plain Concrete with 2% MICRO SILICA (MS-2)	44.97
6	Plain Concrete with 4% MICRO SILICA (MS-4)	48.21
7	Plain Concrete with 6% MICRO SILICA (MS-6)	51.35

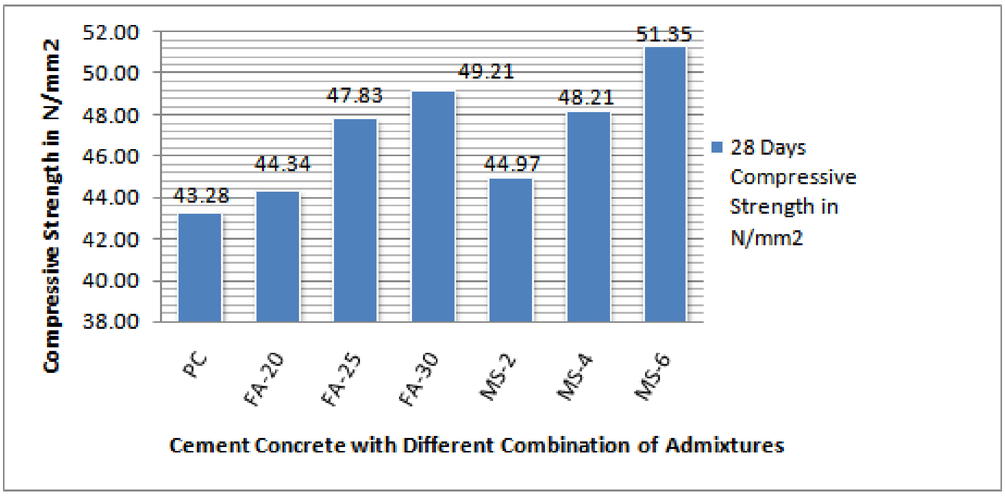

Fig. 5.3 Variation of Compressive strength for different combinations of admixtures

Table. 5.2. Bond Strength Test Results

Sl No	Description	Bond Strength in N/mm2
1	Plain Concrete without Roff Cement interface (PC)	0.093
2	Plain Concrete with Roff Cement interface (PCR)	0.176
3	Plain Concrete with 20% FLY ASH without Roff Cement interface (FA-20)	0.112
4	Plain Concrete with 20% FLY ASH with Roff Cement interface (FA-20R)	0.192
5	Plain Concrete with 25% FLY ASH without Roff Cement interface (FA-25)	0.174
6	Plain Concrete with 25% FLY ASH with Roff Cement interface (FA-25R)	0.201
7	Plain Concrete with 30% FLY ASH without Roff Cement interface (FA-30)	0.195
8	Plain Concrete with 30% FLY ASH with Roff Cement interface (FA-30R)	0.218
9	Plain Concrete with 2% MICRO SILICA without Roff Cement interface (MS-2)	0.198
10	Plain Concrete with 2% MICRO SILICA with Roff Cement interface (MS-2R)	0.217
11	Plain Concrete with 4% MICRO SILICA without Roff Cement interface (MS-4)	0.206
12	Plain Concrete with 4% MICRO SILICA with Roff Cement interface (MS-4R)	0.254
13	Plain Concrete with 6% MICRO SILICA without Roff Cement interface (MS-6)	0.220
14	Plain Concrete with 6% MICRO SILICA with Roff Cement interface (MS-6R)	0.275

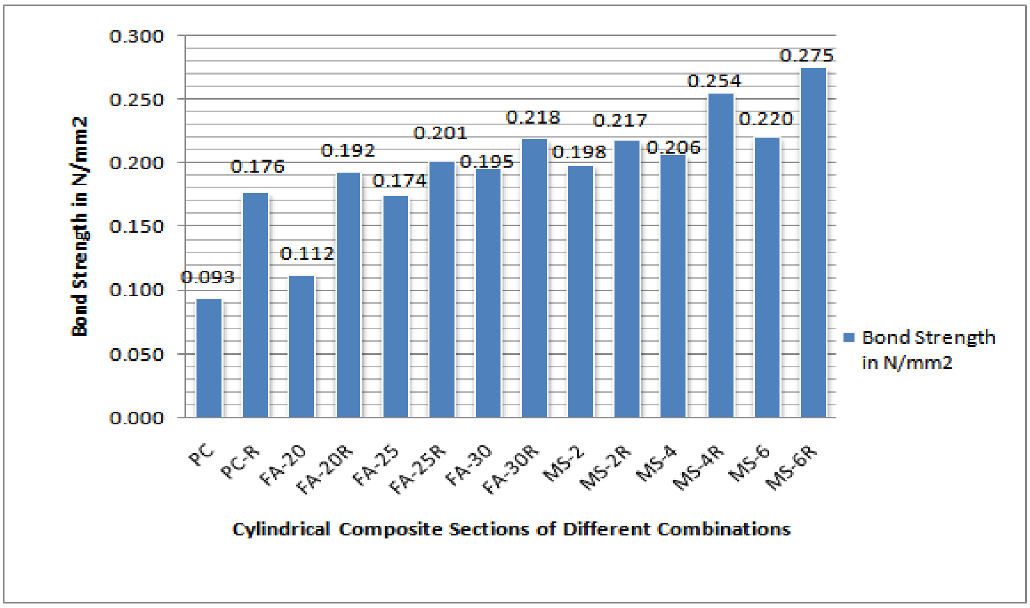

Fig. 5.4 Variation of Bond strength for different combinations of admixtures

Table. 5.3. Deflection values for 8kg/sqcm pressure for all combinations

Sl No	Description Repetitions →	Average deflection values in mm.					
		0	500	1000	1500	2000	2500
1	Plain Concrete (PC)	1.08	1.48	2.15	2.77	3.27	4.16
2	Plain Concrete with ROFF cement interface (PC)	0.65	0.71	0.98	1.35	1.42	1.73
3	Plain Concrete with 20% FLY ASH (FA-20)	0.81	1.32	1.95	2.43	2.86	3.2
4	Plain Concrete with 25% FLY ASH (FA-25)	0.74	1.24	1.76	2.42	2.57	2.71
5	Plain Concrete with 30% FLY ASH (FA-30)	0.71	0.86	1.03	1.49	1.65	1.81
6	Plain Concrete with 2% MICRO SILICA (MS-2)	1.14	1.76	2.62	3.04	3.42	3.96
7	Plain Concrete with 4% MICRO SILICA (MS-4)	0.95	1.67	1.94	2.28	2.82	3.13
8	Plain Concrete with 6% MICRO SILICA (MS-6)	0.86	1.22	1.59	1.82	2.07	2.51

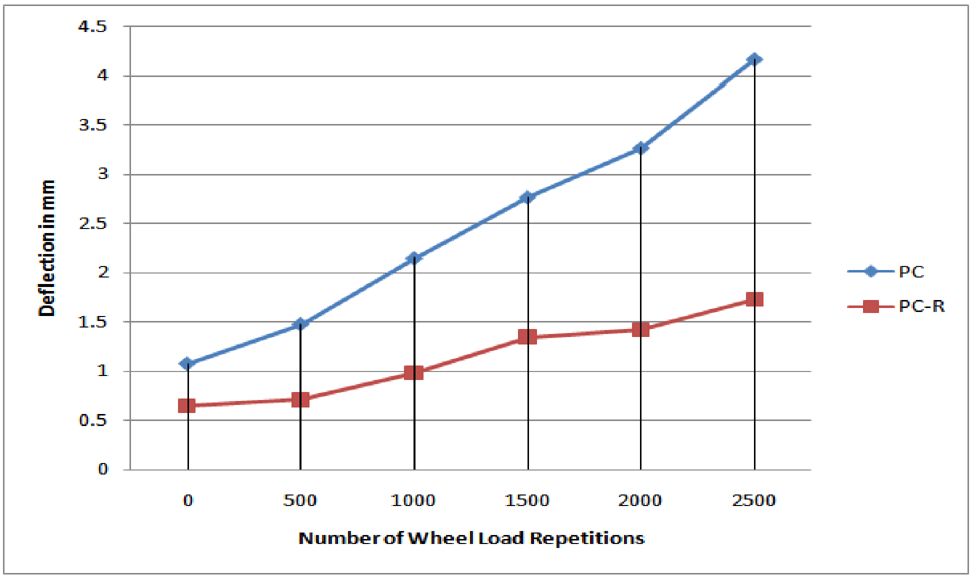

Fig.5.5 Variations in deflection of Plain Concrete composite beam specimens with and without Roff Cement interface subjected to 8kg/sqcm pressure

Fig.5.6 Variations in deflection of Plain Concrete with Fly ash composite beam specimens subjected to 8kg/sqcm pressure

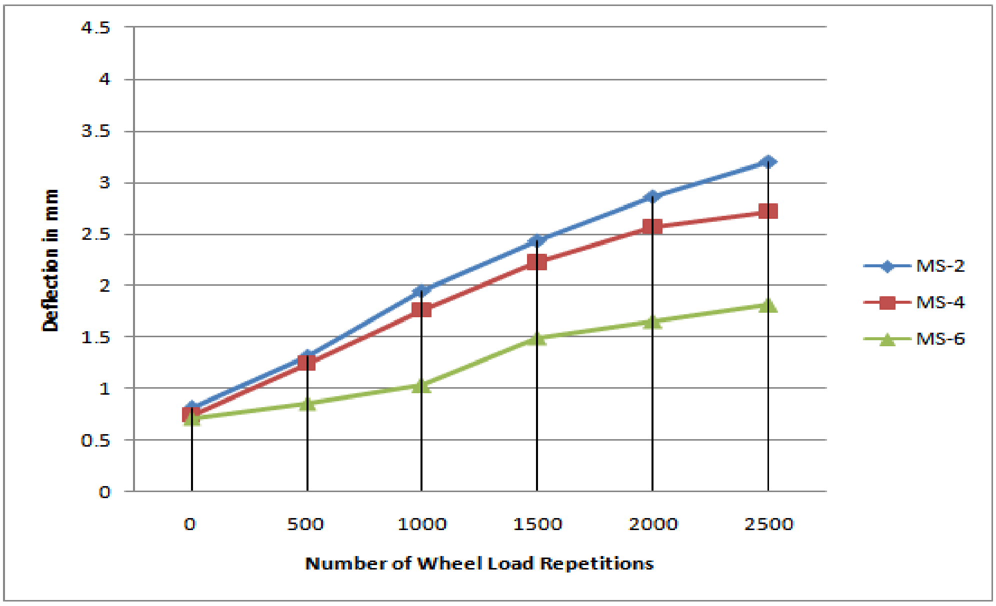

Fig.5.7 Variations in deflection of Plain Concrete with Micro Silica composite beam specimens subjected to 8kg/sqcm pressure

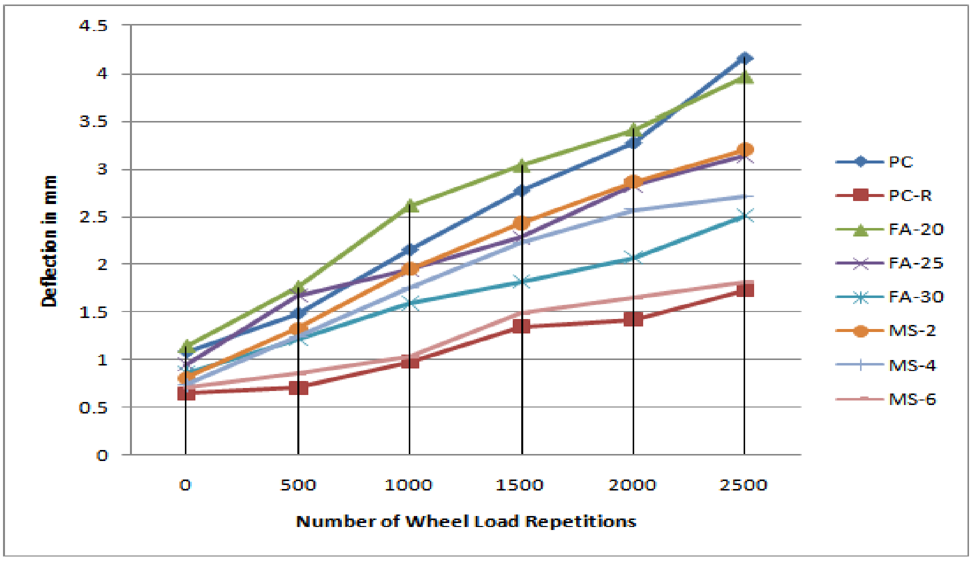

Fig.5.8 Variations in deflection for all combinations of composite beam specimens subjected to 8kg/sqcm pressure

VI. Discussions on test results

- Bond strength values (in N/mm^2) for fly ash increases with the increase in percentage of addition of fly ash.
- Bond strength values (in N/mm^2) for Micro silica increases with the increase in percentage of addition of Micro silica.
- Compressive load (N/mm^2) for 28 days increases with the increases in percentage of addition of Fly ash and similarly for Micro silica.
- Compressive strength (N/mm^2) of PCC with micro silica is comparatively higher than that of the fly ash.
- Bond strength (N/mm^2) of Plain Concrete with ROFF paste is double than that of Plain Concrete Values.
- Addition of Micro Silica (in 2%, 4% and 6%) is always a better option to increase the bond strength and Compressive strength of the Composite section.
- Addition of fly ash less than 30% is not preferable for the better results of the compressive and bond strength.
- Higher percentage of fly ash added to the Composite slab, lower the deflection values under the wheel load pressure of $8kg/cm^2$.

- Higher the percentage of micro silica added to the Composite slab, lower is the deflection values under the wheel load pressure of 8kg/cm^2.
- Comparing the deflection values for fly ash with different percentages, Micro silica for different percentages and plain cement with ROFF cement interface values, indicated that composite beam with ROFF cement paste gives the lowest deflection values at 8kg/cm^2 pressure.

VII. Conclusions

- The success of ultra-thin white topping mainly depends on deflection of the composite section under wheel loads. Repeated higher deflection of ultra-thin white topping will result in cracking of the concrete, which will lead to the failure of the composite section.
- The composite section with bituminous concrete base and plain cement concrete with ROFF cement interface exhibited greater stiffness and better bonding when compared to all other combinations.
- Higher bond strength was exhibited by the concrete with 6% micro silica the deflection values were very much similar when compared with plain cement concrete with ROFF cement interface.
- Hence the combination of plain cement concrete with ROFF cement interface or concrete with 6% micro silica can be recommended for ultra-thin white topping.

VIII. Acknowledgement

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References

[1]. AASHTO Guide for Design of Pavement Structures, American Association of State Highway and Transportation Officials, Washington, D.C., 1993.
[2]. Accelerated Rigid Paving Techniques: State-of-the-Art Report, FHWA Special Project 201, Report FHWASA- 94-080, Federal Highway Administration, Washington, D.C., Dec. 1994.
[3]. Accelerated Techniques for Concrete Paving, Technical Committee Document ACI 325.11R, Committee 325, American Concrete Institute, Farmington Hills, Mich., Jan. 2001, 18 pp.
[4]. Alternatives in Pavement Maintenance, Rehabilitation, and Reconstruction, Publication IS-178, Asphalt Institute, Lexington, Ky., 1994.
[5]. American Concrete Pavement Association, “Thin Whitetopping Sections Measure Up at MN/ROAD,” Concrete Products, Vol. 103, No. 2, Feb. 2000, pp. 8–10.
[6]. Armaghani, J. and D. Tu, “Implementation of Ultra- Thin Whitetopping in Florida,” Proceedings of the 8th International Symposium on Concrete Roads (Theme 4), Lisbon, Portugal, 1998, pp. 183–191.
[7]. Armaghani, J. and D. Tu, “Performance of Ultra-Thin Whitetopping in Florida,” Proceedings of the 6th International Purdue Conference on Concrete Pavement Design and Materials for High Performance, Vol. 2, Indianapolis, Ind., 1997, pp. 189–206.
[8]. Crawley, A.B. and J.M. Pepper, “Application of Fiber Reinforced Concrete for Thin and Ultra-Thin Whitetopping on I-20 in Mississippi,” Presented at the 78th Annual Meeting of the Transportation Research Board, Washington, D.C., 2000.
[9]. D. R. Jundhare, Dr. K. C. Khare; and Dr. R. K. Jain, “Performance Evaluation of Ultra-thin Whitetopping in India by BBD Test,” International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 1 Issue 4, June – 2012.
[10]. Darter, M.I., et al., “Development of the 2002 Guide for the Design of New and Rehabilitated Pavements,” Presented at the 79th Annual Meeting of the Transportation Research Board, Washington, D.C.,2000.
[11]. Guide for Construction of Concrete Pavements and Concrete Bases, Technical Committee Document ACI 325.9R, Committee 325, American Concrete Institute, Farmington Hills, Mich., July 1991.
[12]. Guide for Design of Jointed Concrete Pavements for Streets and Local Roads, Technical Committee Document ACI 325.12R, Committee 325, American Concrete Institute, Farmington Hills, Mich., Jan. 2001.
[13]. Guide for Specifying, Proportioning, Mixing, Placing, and Finishing Steel Fiber Reinforced Concrete, Technical Committee Document ACI 544.3R-93, Committee 544, American Concrete Institute, Farmington Hills, Mich., 1993.
[14]. Guide Specifications for Concrete Overlays of Pavement and Bridge Decks, Task Force 30 Report, AASHTO-AGC-ARTBA Joint Committee, American Association of State Highway and Transportation Officials, Washington, D.C., 1990, 127 pp.
[15]. Guide to Durable Concrete, Technical Committee Document ACI 201.2R-92, Committee 201, American Concrete Institute, Farmington Hills, Mich., 1992.
[16]. Guidelines for Concrete Overlays of Existing Asphalt Pavements, ACPA Publication TB009P, American Concrete Pavement Association, Skokie, Ill., 1991, 15 pp.
[17]. Guidelines for Full-Depth Repair, ACPA Publication TB002P, American Concrete Pavement Association, Skokie, Ill., 1989.

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