International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 1 Issue 4, June - 2012

Performance Evaluation of Ultra-thin Whitetopping in India by BBD Test

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Abstract

Ultra-Thin Whitetopping (UTW) is a technology to construct 50-100 mm thick cement concrete overlay on distressed asphalt pavement as a rehabilitation technique. There were twelve conventional, ultra-thin and thin whitetopping overlay projects built in India from 2003 to 2011 but to date, there has been no specific follow-up regarding their performance. Hence, there is a need to study performance evaluation of UTW for Indian traffic and climatic conditions by using suitable technique. In this study, performance evaluation of UTW is presented by conducting Benkelman Beam Deflection test (BBD) as per guidelines given in IRC: 81-1997. This paper discusses about surface deflection at three critical load positions in a panel having age of two years and the Load Transfer Efficiency (LTE) at the transverse joints of 100mm thick in-service UTW overlay constructed in Pune city, Maharashtra State, India by carrying out the non-destructive test of Benkelman Beam for its performance evaluation subjected to Indian traffic and climatic conditions.

1. Introduction

Whitetopping overlay is a relatively new rehabilitation technology for deteriorated asphalt pavement. Over the past two decades, whitetopping overlay has gained considerable interest and great acceptance as an alternative to HMA overlay (ACPA 1998). A Portland Cement Concrete (PCC) overlay constructed on the top of an existing bituminous pavement is termed as whitetopping. It can be classified as Conventional Whitetopping (CT), Thin Whitetopping (TWT) and Ultra-Thin Whitetopping (UTW) based on its overlay thickness. It can be applied where rutting of bituminous pavement is a recurring problem. Concrete overlays have been used to rehabilitate existing concrete pavements since 1913 and to rehabilitate existing asphalt pavements since 1918 (Hutchinson 1982). Beginning around the mid-1960s, highway agencies began to search for alternative means of rehabilitating existing pavements, and the use of concrete overlays increased significantly (McGhee, 1994). Whitetopping in its various forms have been used in U.S.A, Europe and other countries on Airports, Inter-state roads, Primary and Secondary Highways, Local roads, Streets and Parking lots. Presently "Tentative Guidelines for Conventional, Thin and Ultra-Thin Whitetopping" given in IRC: SP: 76-2008 is followed in India for the design of Conventional, TWT and UTW overlays. Many studies have been done focusing on the mechanical analysis, design and construction procedure, and performance of conventional whitetopping and UTW overlay. Lessons have been learned from these research projects to promote the development of conventional whitetopping and UTW overlays. As the use of whitetopping overlay construction is on increase in India, it is necessary to have an improved understanding of the analysis, behavior of whitetopping overlays in order to enhance the rationality of the current design standards and its performance to Indian scenario.

Use of Falling Weight Deflectometer (FWD) for the evaluation of pavements is gaining popularity in many countries, as it is possible to simulate the magnitude and duration of load applied by a fast moving vehicle on highways using this equipment. However, the use of FWD in India has been very limited so far because of its high cost and difficulties encountered in maintaining the equipment. Therefore, a need has been aroused to identify an alternative to FWD test, which can be cost effective and easily available. Benkelman Beam test is one the static load deflection equipment which measures the maximum deflection response of a pavement to static or slowly applied loads. Advantages of the Benkelman Beam include ease to use, low equipment cost, and large database can be created about performance of the pavement over the years. But, the guidelines given by IRC: 81-1997 for conducting Benkelman Beam test are applicable only for flexible pavements. In this study attempt has been made to conduct this test on the top of UTW. Hence, for performance evaluation of in-service 100 mm thick UTW overlay constructed in Pune city, Benkelman Beam test has been carried out to find deflection on top of UTW overlay, as per IRC: 81-1997. The deflection on the surface of slab at three critical positions i. e. at interior, corner and edge were measured after two years.

Load transfer is an important for pavement longevity. Most of the performance related problems with concrete pavements are resultant of poor joints performance. Distress occurs in the pavement in the form of faults, pumping and corner breaks at the joints due to poor load transfer efficiency. Load Transfer Efficiency (LTE) of aggregate interlocking at transverse joints has been calculated using two Benkelman Beams. These results are compared with the other researcher's results available in the literature.

2. Parameters of UTW Overlays

A parametric study has been conducted to study the deflections in three critical load positions and LTE across the transverse joints of UTW overlay constructed in Dahanukar Colony, Kothrud in Pune city, Maharashtra, India.

- Thickness of thin whitetopping overlay = 100 mm
- Panel size = 1.0 m x 1.0 m
- Thickness of existing HMA pavement = 100 mm
- Dense bituminous macadam (DBM) (For profile correction) = 50 mm
- Grade of concrete (Fiber Reinforced Concrete) = M 40
- Modulus of subgrade reaction = 0.0372 MPa/ mm
- Modified Modulus of subgrade reaction = 0.281 MPa/ mm
- CBR value = 20 %
- Modulus of Elasticity (Plain cement concrete) = 30000 MPa
- Poisson's ratio (Plain cement concrete) = 0.15
- Characteristic compressive strength = 40 MPa
- Flexural strength = 4 MPa
- Maximum w. c. ratio = 0.45
- Maximum size of aggregate = 20 mm
- Tyre pressure = 0.8 MPa
- Design life of pavement = 20 years

3. Benkelman Beam Deflection (BBD) Test

Static load deflection equipment measures the maximum deflection response of a pavement to static or slowly applied loads. The most commonly used static deflection device is the Benkelman Beam. Surface deflection data from UTW overlay test sections at Pune City was obtained using non-destructive test of Benkelman Beam. This test has been carried out on top surface of existing UTW to obtain the deflection measurements at interior, corner and edge of each slab as shown in Figures 1. The vehicle used to carry out BBD test was having 81.70 kN rear axle weight as per guidelines given in IRC: 81-1997. The pavement temperature was measured after every one hour interval during the deflection measurements using a digital thermometer as shown in Figure 2. The cross section of UTW is shown in Figure 3. The deflection data was analysed and characteristic deflection calculated after incorporating necessary corrections for temperature and seasonal variations. All the values were averaged out to get mean deflection and standard deviation was calculated. The characteristic rebound deflection was worked out as per guidelines given in IRC: 81-1997. The observations, results and comparison are given in Table 1, 2 and 3 in Annexure I.

Figure 1: BBD Test on UWT in Progress

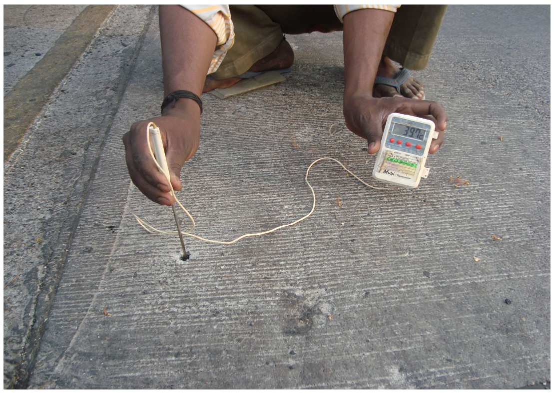

Figure 2: Measuring Pavement Temperature (Inside)

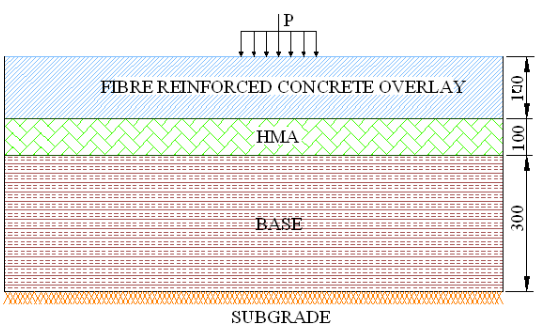

Figure 3: Cross Section of UTW

4. Load Transfer Mechanism

Load transfer values were calculated by the deflection method. The percent load transfer is equal to the deflection on the leave side of the joint, divided by the deflection of the loaded approach side of the joint, then multiplied by 100. The deflections relating to the 8170 kg load were used in the analysis. Target values of 75%–100% indicate a very good aggregate–interlocking load transfer for an overlay of this type that has no joint reinforcement (Papagiannakis, A. T. and Masad, E. A., 2007).

When dowels are not used (for UTW and TWT), joints depend solely upon aggregate interlock for load transfer. Aggregate interlock is the mechanical locking which forms between the fractured surfaces along the crack below the joint saw cut. Reliance on aggregate interlock without dowels is acceptable on low-volume or secondary road systems, Ultra-thin and thin whitetopping overlays where truck traffic is low. Shear between aggregate particles below the saw cut is shown in Figure 4.

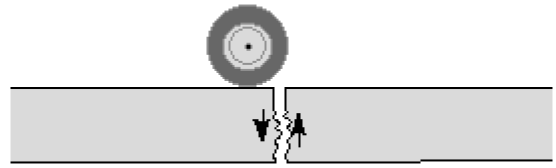

Figure 4: Aggregate Interlock (LTE)

4.1 Load Transfer Efficiency (LTE) Across the Joints

The efficiency of a joint is generally expressed in terms of its ability to transfer load from one side of the joint/ crack to the other side and is termed as Load Transfer Efficiency (LTE). LTE is expressed as a percentage of the unloaded slab deflection to the loaded slab deflection. The equation 1 is most commonly used for calculating LTE (Papagiannakis, A. T. and Masad, E. A., 2007).

$$LTE = \frac{\partial_{ul}}{\partial_{l}} \times 100\% \qquad \ldots\ldots\ldots\ldots (1)$$

Where,

δ_{ul} =the surface vertical deflection at the unloaded edges of the joint of approach slab

δ_{l} = the surface vertical deflection at the loaded edges of the joint of leave slab

LTE ranges from 0% for no vertical load transfer to 100% for perfect load transfer between adjacent slabs. LTE values above 70%, between 50% - 70% and below 50% characterize load transfer as good, fair and poor respectively (Papagiannakis, A. T. and Masad, E. A., 2007).

In this study, BBD test has been conducted using two Benkelman Beams simultaneously placed on two adjacent panels (named as approach and leave slabs) near transverse joint as shown in the Figures 5 for determining the LTE. Figure 6 shows isometric view of UTW with loaded and unloaded slabs for calculating LTE. Figure 6 shows finished view of UTW overlay. Load is applied on Benkelman Beam (BB1) placed at approach slab having 8170 kg rear axle weight as per guidelines given in IRC: 81-1997 and Benkelman Beam (BB2) has placed on leave slab near transverse joint. BBD test on both Benkelman Beams (BB1 and BB2) has been carried out simultaneously as per IRC: 81-1997, and vertical deflection of approach slab (δ_{l}) and leave slabs (δ_{ul}) near the transverse joints have been obtained. Equation 1 has been used to calculate LTE. The observations and results are given in Table 4 and 5 in Annexure I. LTE found out in this study are from the range of 88.03% to 100%. These results of LTE have been compared with the results of 120 mm thick overlay. (Cable, J. K., et al., 2006). In their study, LTE value obtained from the range of 99.60% to 99.90%. In another study, based on the finite element method using KENSLAB computer program (Huang 1985) 84% of LTE value has been observed at transverse joint of bonded type of interface.

Fig.5: Two Benkelman Beam Used for LTE

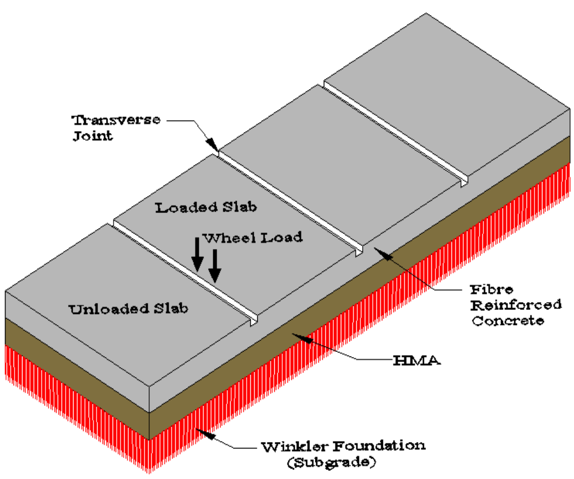

Fig. 6: Isometric View of UTW with Loaded and Unloaded Slabs (LTE)

Fig.7: Finished View of UWT Overlay

Table 6: Load Transfer Efficiencies Obtained from BBD Test

Panel / Slab No.	Unloaded slab Deflection (mm)	Loaded slab Deflection (mm)	Load Transfer Efficiency (%)
1	0.309	0.351	88.03
2	0.351	0.373	94.10
3	0.362	0.362	100.00
4	0.378	0.399	94.73
5	0.388	0.409	94.87
6	0.399	0.42	95.00
7	0.42	0.43	97.67
8	0.409	0.43	95.12
9	0.325	0.3465	93.93
10	0.525	0.535	98.13

5. Conclusion

Following conclusions are reached from the detailed study carried out using BBD as per guidelines given in IRC: 81-1997, as NDT for determining deflection at three critical load positions and LTE has been calculated at the transverse joints of 100 mm thick on in-service UTW overlay constructed in Pune city, Maharashtra State (India), for its performance evaluation subjected to various traffic and climatic conditions relevant to Indian scenario.

- The deflections obtained in this study after two year is 0.461mm, 0.415 mm and 0.265 mm at the edge, corner and interior respectively. These deflection results have been compared with the results of three dimensional FE model (Jundhare D. R. et al., 2012), these values show good agreement.

- LTE in the 100 mm thick UTW overlay for this study has been ranging from 88.03% to 100.00 % in the 1.00 m x 1.00 m panel size. These results of LTE have been compared with the results of 120 mm thick overlay (Cable, J. K. et al., 2006). LTE obtained for their study ranges from 99.60% to 99.90%. In another study, based on the finite element method using KENSLAB computer program (Huang 1985) 84% of LTE value has been observed at transverse joint of bonded type of interface.

- When results of BBD test from this study have been compared with the deflection values obtained by three dimensional FE model (Jundhare D. R. et al., 2012) and LTE values obtained by Cable, J. K. et al. (2006) as well as KENSLAB computer program, these values show good agreement. Therefore it can be concluded that BBD test can be a useful, reliable and alternative tool to FWD for the study the performance evaluation of UTW overlay.

6. Acknowledgement

The authors are grateful to Municipal Corporation of Pune for kind permission and availing the required data. The authors are also thankful to Prof. Dr. B. B. Pandey, Indian Institute of Technology, Kharagpur, India for guidance and encouragement for conducting this study.

References

1. American Concrete Pavement Association, "Whitetopping – State of Practice." *ACPA Publication* EB210P, Skokie, Illinois, 1998.
2. Cable, J. K., Morud, J. L. and Tabbert T. R., "Evaluation of Composite Pavement Unbonded Overlay: Phase III." *Final Report, Iowa State University*, 2006.
3. Huang, Y. H., "A Computer Package for Structural Analysis of Concrete Pavements." *Proceedings, 3rd International Conference on Concrete Pavement Design and Rehabilitation,* pp.295-307; Purdue University, 1985.
4. Hutchinson, R. L., "NCHRP Synthesis of Highway Practice 99: Resurfacing with Portland Cement Concrete." *Transportation Research Board, National Research Council*, Washington, D.C., 1982.
5. IRC: 81 – 1997, "Guidelines for Strengthening of Flexible Road Pavements using Benkelman Beam Deflection Technique." *India Road Congress,* New Delhi, 1997.
6. IRC: SP: 76 – 2008, "Tentative Guidelines for Conventional, Thin and Ultra-Thin Whitetopping." *Indian Road Congress,* New Delhi, 2008.
7. Jundhare D. R., Khare K.C., Jain R. K., "Structural Analysis of Ultra-Thin Whitetopping under Wheel Loading using Computer Code ANSYS " *International Journal of Structural Engineering,* 3(3), 208-228, 2012.
8. McGhee, K. H., "Synthesis of Highway Practice 204: Portland Cement Concrete Resurfacing." *Transportation Research Board, National Research Council,* Washington, D.C., pp. 73-82, 1994.
9. Papagiannakis, A. T., Masad, E. A., "Pavement Design and Materials". *John Wiley and Sons, Inc.,* Hoboken, New Jersey, 2007.

BIOGRAPHICAL NOTES:

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Dr. R. K. Jain, Ph. D., is a Principal and Professor in Civil Engineering Department of Padamshree Dr. D.Y.Patil Institute of Engineering and Technology, Pimpri, Pune. His areas of interest include highway and transportation engineering, town and country planning, design and construction of rigid pavements and whitetopping overlays. He has 2 years of experience in construction industry and 22 years in academics. Over 25 research papers to his credit in various international / national conferences and journals.

ANNEXTURE I

Table 1: Benkelman Beam Deflection Test Analysis for Edge Wheel Loading

Panel / Slab No.	Dial Gauge Reading (mm)			Deflection in mm	Pavement Temp. (^{0}C)	Temperature correction (mm)	Seasonal Correction Factor	Corrected Deflection (D)	$(D_{avg} - D)^2$
	Initial	Intermediate	Final						
1	100	81	80	0.4	41.5	-0.065	1.05	0.351	0.00298116
2	97	77	76	0.42	41.5	-0.065	1.05	0.373	0.00106276
3	34	14	13.5	0.41	41.5	-0.065	1.05	0.362	0.00190096
4	89	68	67	0.44	41	-0.06	1.05	0.399	4.356E-05
5	76	58	57	0.38	34	0.01	1.05	0.409	1.156E-05
6	58	39	38.5	0.39	34	0.01	1.05	0.42	0.00020736
7	90	71	70	0.4	34	0.01	1.05	0.43	0.00059536
8	66	47	46	0.4	34	0.01	1.05	0.43	0.00059536
9	65	50	49	0.32	34	0.01	1.05	0.3465	0.00349281
10	86	62	61	0.5	34	0.01	1.05	0.5355	0.01687401
Average = (D_{avg})								**0.405**	-
$\sum (D_{avg} - D)^2$									0.0277649
Standard Deviation									0.0555
Characteristic Deflection (mm) for 40.85kN Wheel Load = $D_{avg} + \sigma$									**0.461**

Table 2: Benkelman Beam Deflection Test Analysis for Corner Wheel Loading

Panel / Slab No.	Dial Gauge Reading (mm)			Deflection in mm	Pavement Temp. (^{0}C)	Temperature correction (mm)	Seasonal Correction Factor Factor	Corrected Deflection (D)	$(D_{avg} - D)^2$
	Initial	Intermediate	Final						
1	34	14	13.5	0.41	41.5	-0.065	1.05	0.36225	5.40225E-05
2	100	81	80	0.40	41.5	-0.065	1.05	0.35175	0.00031862
3	89	68	67	0.44	41	-0.06	1.05	0.399	0.00086436
4	59	41	40	0.38	41	-0.06	1.05	0.336	0.00112896
5	88	69.5	68.5	0.39	41	-0.06	1.05	0.3465	0.00053361
6	37	20.5	19.5	0.35	41	-0.06	1.05	0.3045	0.00423801
7	45	24.5	23.5	0.43	34	0.01	1.05	0.462	0.00853776
8	88	72	71	0.34	34	0.01	1.05	0.3675	4.41E-06
9	66	47.5	46.5	0.39	34	0.01	1.05	0.42	0.00254016
10	65	50	49	0.32	34	0.01	1.05	0.3465	0.00053361
Average = (D_{avg})								**0.3696**	-
$\sum (D_{avg} - D)^2$									0.01875
Standard Deviation									0.0456
Characteristic Deflection (mm) for 40.85kN Wheel Load									**0.415**

Table 3: Benkelman Beam Deflection Test Analysis for Interior Wheel Loading

Panel / Slab No.	Dial Gauge Reading (mm)			Deflection in mm	Pavement Temp. (^{0}C)	Temperature correction (mm)	Seasonal Correction Factor Factor	Corrected Deflection (D)	$(D_{avg} - D)^2$
	Initial	Intermediate	Final						
1	39	29.5	28.5	0.21	41.5	-0.065	1.05	0.15225	4.52E-03
2	66	58	57	0.18	41.5	-0.065	1.05	0.12075	0.00974169
3	89	74	73	0.32	41	-0.06	1.05	0.273	0.002867603
4	22	13.5	12.5	0.19	41	-0.06	1.05	0.1365	0.006880703
5	67	59	58	0.18	41	-0.06	1.05	0.126	0.008732903
6	87	80	79	0.16	41	-0.06	1.05	0.105	0.013098803
7	65	56	55	0.20	34	0.01	1.05	0.2205	1.1025E-06
8	45	29	28	0.34	34	0.01	1.05	0.3675	2.19E-02
9	78	59.5	58.5	0.39	34	0.01	1.05	0.42	0.040220303
10	86	74.5	73.5	0.25	34	0.01	1.05	0.273	0.002867603
Average = (D_{avg})								**0.21945**	-
$\sum (D_{avg} - D)^2$									0.018753
Standard Deviation									0.0456
Characteristic Deflection (mm) for 40.85kN Wheel Load									**0.265**

Table 4: BBD Test Analysis for Calculating LTE across the Unloaded Edges of the Joint

Panel / Slab No.	Dial Gauge Reading (mm)			Deflection in mm	Pavement Temp. (^{0}C)	Temperature correction (mm)	Seasonal Correction Factor	Corrected Deflection (D)
	Initial	Intermediate	Final					
1	100	83	82	0.36	41.5	-0.065	1.05	0.309
2	95	76	75	0.40	41.5	-0.065	1.05	0.351
3	44	24	23.5	0.41	41.5	-0.065	1.05	0.362
4	78	58	57	0.42	41	-0.06	1.05	0.378
5	85	68	67	0.36	34	0.01	1.05	0.388
6	68	50	49.5	0.37	34	0.01	1.05	0.399
7	92	73	72.5	0.39	34	0.01	1.05	0.42
8	66	48	47	0.38	34	0.01	1.05	0.409
9	79	65	64	0.30	34	0.01	1.05	0.325
10	69	45	44.5	0.49	34	0.01	1.05	0.525

Table 5: BBD Test Analysis for Calculating LTE across the Loaded Edges of the Joint

Panel / Slab No.	Dial Gauge Reading (mm)			Deflection in mm	Pavement Temp. (^{0}C)	Temperature correction (mm)	Seasonal Correction Factor	Corrected Deflection (D)
	Initial	Intermediate	Final					
1	100	81	80	0.4	41.5	-0.065	1.05	0.351
2	97	77	76	0.42	41.5	-0.065	1.05	0.373
3	34	14	13.5	0.41	41.5	-0.065	1.05	0.362
4	89	68	67	0.44	41	-0.06	1.05	0.399
5	76	58	57	0.38	34	0.01	1.05	0.409
6	58	39	38.5	0.39	34	0.01	1.05	0.42
7	90	71	70	0.4	34	0.01	1.05	0.43
8	66	47	46	0.4	34	0.01	1.05	0.43
9	65	50	49	0.32	34	0.01	1.05	0.3465
10	86	62	61	0.5	34	0.01	1.05	0.5355