TREATMENT OF DISTRESSED URBAN ROADS USING ULTRATHIN WHITE-TOPPING: A CASE STUDY OF DAMAN CITY (U.T.), INDIA

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ABSTRACT. Ultra-Thin White topping (UTW) is an emerging and innovative technology for asphalt pavement rehabilitation in India. In this study, design of UTW has been carried out as per IRC 58:2002 guidelines and IRC: SP: 76-2008 for a cluster of roads in Moti Daman, Daman & Diu, Union Territory (U.T.). These streets of urban areas of Moti Daman earlier constructed with HMA are subjected to medium traffic flow and commercial vehicles, due to which they got deteriorated and need rehabilitation. It was decided by Public Works Department (PWD) under Union Territory Administration of Daman & Diu to upgrade and improve these roads with UTW overlay. Design parameters for design thickness for UTW are arrived by carrying out field and laboratory investigation. Stresses due to load, temperature curling and fatigue are determined by following IRC guidelines. The design of ultra-thin white topping has done for urban road carrying traffic less 450 cvpd. Thickness of 100mm with joint spacing of 60cm is found to be safe as per the calculations using IRC SP 76 2015. This paper presents a design methodology to adopt white topping as rehabilitation treatment and cost-effective rehabilitation alternative for preserving bituminous pavements on long-term basis.

Keywords: UTWT, Pavement, Rehabilitation, Concrete.

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INTRODUCTION

India has a rural road network of over 3,000,000 km, and urban roads total more than 250,000 km. In urban areas, road development has been helped by a national urban renewal mission program, through which the central government assists city governments with federal funds (9). Maintenance and rehabilitation of these pavements to the desired level of serviceability is one of the challenging problems faced by pavement engineers and administration in the highway sector (8). Significant amounts of time and financial expenses are spent annually by government for the rejuvenation of road infrastructure to mitigate road distress like cracking and potholes. In India, most of the pavements are Bituminous, which have short life because of failures in the form of fatigue cracking, rutting and other failures. In general maintenance of the pavement was done with a bituminous overlay but due to short service life and inadequacy of skilled man force for quality bituminous work other alternative of bituminous overlay needs to be evaluated. Ultrathin White-Topping (UTWT) is proven potential alternative for rejuvenation distressed bituminous pavement. White topping is a cement concrete overlay over the bituminous pavement, which has fewer failures, and act as good base layer for the overlay which will be a best option as the life of the pavement will be more when compared with bituminous overlay. This paper presents a case study of design of UTWT for rehabilitation of urban roads of Daman city of India. The methodology adopted in this paper can be utilized for maintenance and rehabilitation of urban infrastructure.

UTWT has PCC overlay of less than 100 mm. Bonding between overlay and underlying bituminous layer is mandatory (10). To ensure this, the existing layer of bitumen is either milled (to a depth of 25 mm) or surface scrapped (with a non-impact scrapper) or gently chiselled. Joints are provided at a spacing of 0.6 to 1.25. UTWT thickness is typically between 2 in. to 4in. The UTWT requires a good bond with underlying HMA ayer to perform well as indicated by the literature (5). White topping overlays also restore the ride-ability of the existing asphalt pavements suffering from ruts and deformations, in addition to rectifying other defects such asloss of texture. White topping being stronger than asphalt overlay is more resistant to rutting and surface initiated cracking and thus this technique pose potential economic and technical benefits (6).

STUDY AREA

The study area is Union Territory in India and are essentially small enclaves located in Western India. Daman is a small city on the mouth of the Daman Ganga River bounded on all sides by the state of Gujarat, while Diu is a small island off the coast of Gujarat state of India. This study is carried out in Moti Daman fort area covers area of 75 acres, which comprises of major government buildings, major heritage structures and education institutes. Total of 4.1 km roads, 3.44 Km of Asphalt road, 0.61 m of concrete roads and 0.15 m of paved roads.

METHODOLOGY

Different countries have different methods for the design of thin white-topping. Some of the methods such as AASHTO, PCA, ACPA and CDOT. In India, the design of thin white-topping is done by (Indian Road Congress) IRC: SP: 76-2008 (2) using 1RC:58- 2002 (1) to determine the load and warping stresses and the fatigue life consumed.

Figure 1 Study area map showing Moti-Daman fort area

Figure 2 Fort area road networks

In this study, IRC guidelines are used to design UTWT. Following steps are involved to design UTWT for Moti Daman area of India:

- Crest details: General data regarding the pavement width, existing crest details and collection of subgrade soil sample will be done in this stage.

- Traffic volume count survey: Traffic in commercial vehicle per day (CVPD) can be known by conducting volume count survey for 7 days 24 hours and Average Daily Traffic can be estimated. Traffic growth factor is generally taken as 5%.

- Pavement distress survey: This is one of the key aspects required for assessing the pavement condition which would help in finding rehabilitation alternatives. In the present work four types of physical distresses namely cracks, potholes, patches and rutting were considered.

- The identification of distress type, severity and amount were done through on-site visual survey according to IRC guidelines. The pavement distress measurements were carried out for every 50 m intervals on the selected roads manually.

- Deflection measurements: Average deflection value of the existing pavement is known by conducting Benkelman Beam (BBD) according to the IRC 81-1981 (3).

- Measurement of field dry density and field moisture content: The field dry density test using sand replacment method as per IS: 2720 Part 28 should be carried out to ensure on site density and moisture content.

- Laboratory testing collected soil samples: Determination of engineering properties of sub grade soil samples collected in the field will be done in the laboratory which includes soil classification, Atterberg limits, proctor density, free swell index and California Bearing ratio (CBR).

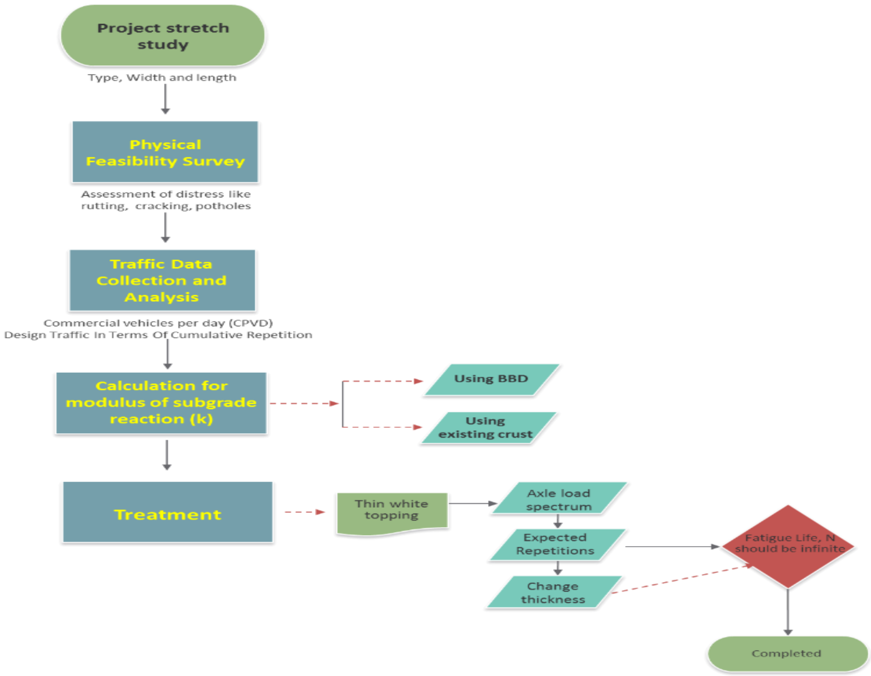

Figure 3 Methodology adopted for design of UTWT

FIELD AND LABORATORY INVESTIGATION

Pavement investigations play a significant role in the assessment of pavement condition. The preliminary objective of these investigations is to identify the distress condition, strength, physical and mechanical properties of the pavement layers. Pavement investigations are categorized as follows, Field investigations and Laboratory investigations.

Crust Thickness

A total of 6 trial pits were taken to ascertain the pavement composition. A trial pit was dug along each homogeneous road section in a staggered manner. The test pits were immediately filled and compacted after completing the necessary testing.

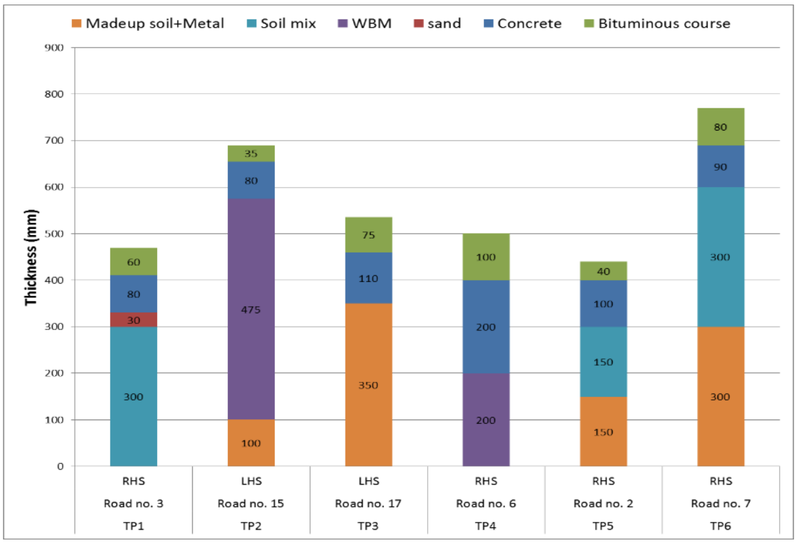

Figure 4 Existing crust thickness at various road sections

Existing Pavement Condition Evaluation

The objective of the pavement condition surveys is to identify defects and sections with similar characteristics. All defects systematically referenced, recorded and quantified for determining the optimum design alternative. The pavement condition surveys carried out using visual observations, supplemented by actual measurements and in accordance with the widely accepted methodology. The measurement of rut depth measured using standard straight edges. The shoulder and embankment conditions evaluated by visual means and the existence of distress modes (cuts, erosion marks, failure, drops) and extent (none, moderate, frequent and very frequent) of such distress manifestations are recorded. The data obtained from the condition surveys analyzed and the road segments of more or less equal performance identified using the criteria given in IRC: 81-1997 (3). Detailed field studies carried out to collect pavement surface conditions.

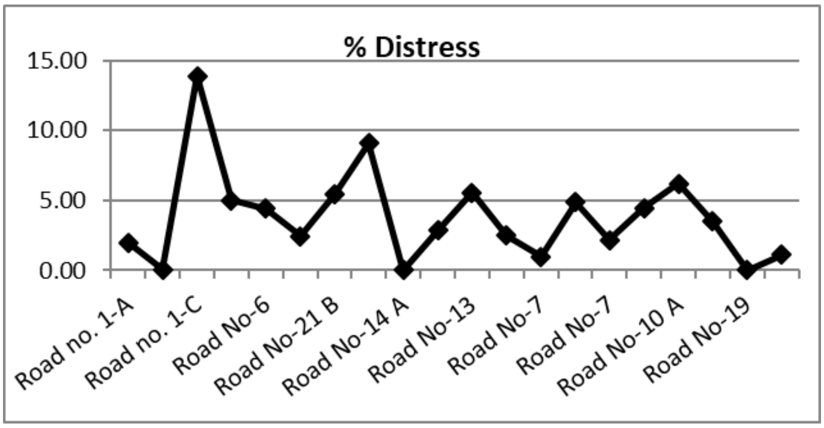

Figure 4 Existing pavement distress percentage at various road sections

Laboratory investigations

Laboratory investigations were performed in the laboratory with samples collected from the trial pits at every chainage. Following layer wise laboratory tests were performed to identify the physical properties and strength properties. The following tests were performed for the as per the Indian standard and Military of Road Transport and Highway (MORTH), Movement of India specifications as listed in table.

Table 1 Test conducted for determination of physical properties of soil

Sr. No.	Name of the test	Property	Test procedure	MORT&H Specifications
1	Soil Classification	Type of Soil	IS 1498	Except OL,OI and OH, Peat
2	Sieve Analysis	Grading Requirements	IS 2720 (Part – 4)	Maximum size of Lumps 50 mm
3	Atterberg's Limits	LL, PL, PI	IS 2720 (Part – 5)	LL≤40; PI≤20
4	Modified Proctor Test	Dry density	IS 2720 (Part – 8)	1.75 gm/cc & ≥ 97% of MDD
5	Soaked CBR at FDD and MDD	Bearing capacity	IS 2720 (Part – 16)	Soaked C.B.R. @ 97% of FDD and M.D.D

Deflection measurement of existing pavement

For the structural evaluation of the pavement structure, deflection measurement by Benkelman Beam equipment is carried out as per the guidelines laid down in the IRC: 81-1997 (3). Benkelman Beam is a 5-ton truck is recommended as the reaction. The vehicle shall have 8170 kg. rear axle load equally distributed over the two wheels, equipped with dual tires. Spacing between the tire walls should be 30-40 mm. The tire shall be inflated to a pressure of 5.60 kg/cm2. Based on the in-situ pavement deflection data obtained from the BBD test, characteristic deflection was estimated as per IRC: 81-1997 (3) and the variation of characteristic deflection are shown in Figure.

Table 2 Results obtained from laboratory investigation of soil

Road Name	I.S. Classification	(field Dry Density) FDD in gm/cc	(Field Moisture Content) FMC %	(Maximum Dry Density) MDD g/cc	(Optimum Moisture Content) OMC %	CBR Value	
						at of FDD	at 98 % of MDD
Road no. 3	SMSC	1.725	14.29	1.98	8.90	4.94	6.30
Road no. 15	SMSC	1.713	11.73	1.96	9.10	6.22	7.80
Road no. 17	SMSC	1.750	12.99	1.99	8.50	5.66	7.00
Road no. 6	SC	1.720	15.61	1.98	10.20	5.57	6.90
Road no. 2	SC	1.755	13.64	1.99	8.00	6.33	7.80
Road no. 7	SMSC	1.789	12.36	2.02	8.30	6.45	8.00

DESIGN OF ULTRA-THIN WHITE TOPPING

Ultra-thin white topping is one of the types of white topping in which a thin layer of concrete varying from 50 to 100mm thick with fibers is placed over a prepared surface of distressed asphalt pavement. Ultra-Thin White topping (UTWT), which has PCC overlay of less than 100 mm. Bonding between overlay & underlying bituminous layer is mandatory. To ensure this, the existing layer of bitumen is either milled (to a depth of 25 mm) or surface scrapped (with a nonimpact scrapper) or gently chiselled.

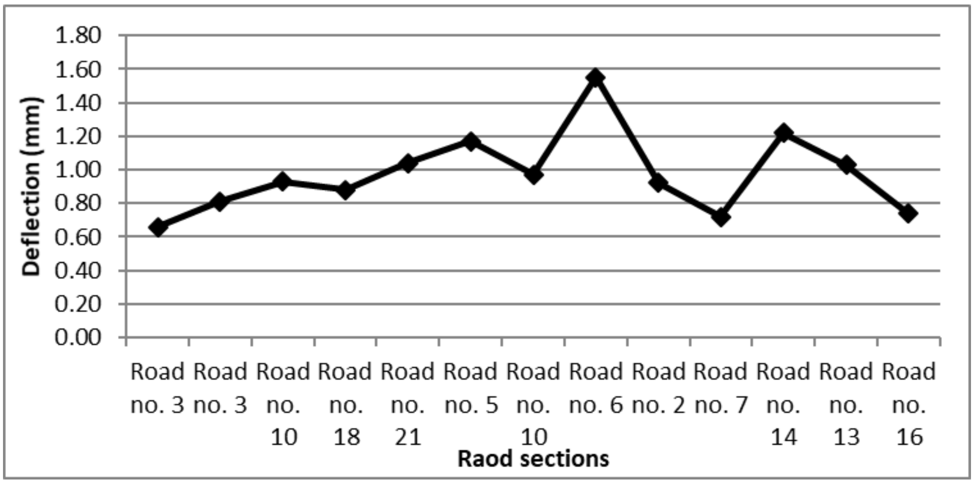

Figure 4 Deflection at various road sections

Modified Modulus of subgrade reaction (K-Value)

K-value of the existing pavement is determined with average deflection value obtained from Benkelman Beam according to the IRC 81-1981 (3) or by knowing the modulus of subgrade reaction of subgrade and other layers can be computed from charts given in IRC-SP-76-2015 (2).

Modulus of rupture: Modulus of rupture of the concrete to be used in the pavement must be tested according to IS 516 (4), value obtained from three-point bending test was 4.5 MPa.

Stresses due to Load

The primary stresses exhibited by the UTWT projects have been corner cracks. The corner breaking the primary distress suggests that the critical stress location for design of UTWT overlays is the corner stress. The corner tensile bending stress in a slab for 8T single axle load and 16T tandem axle load can be computed by equation 1 and equation 2.

$$\text{Log}\ (\sigma 8) = 3.6525 - 0.465\log(k) + 0.686\log(L/Le) - 1.29\log(Le) \qquad .(1)$$

$$\text{Log}\ (\sigma 16) = 3.249 - 0.559\log(k) + 1.395\log(L/Le) - 0.963\log(Le) - 0.088(L/Le) \qquad (2)$$

Where

$\sigma 8$= bending tensile stresses at corner for 8T single axle load, kg/cm^2,
$\sigma 16$= bending tensile stresses at corner for 16T tandem axle load, kg/cm^2,
k=modulus of sub grade reaction, kg/cm^3
L=length of square slab, cm, Le=radius of relative stiffness, cm.

The corner bending tensile stresses for other single and tandem axle loads can be computed proportionally by using σ8 and σ16 values respectively. If the panel size is less than 1.30cm, then two axles of a tandem axle vehicle will not fall on the same simultaneously, hence, stresses should only be considered for single axle. The possibility of wheels of two adjacent vehicles simultaneously placed on one panel on one panel is also excluded.

Stresses due to Temperature Curling

Negative temperature gradients (top cooler than the bottom) produce tensile curling stresses on top of the slab at the corner. The temperature curling stresses σt at the top of the slab corner can be computed by the equation 1(7). The equation has been adopted by modified ACPA design procedure for white topping overlays (7).

$$\sigma t = 1.933 - 241000(\alpha \Delta T) + 1.267(L/Le) \qquad 3)$$

Where,

σt= curling tensile stress at corner, kg/cm^2,
σ=coefficient of thermal expansion, /◦C,
ΔT=negative temperature differential/◦C,
L=length of square slab, cm,
Le=radius of relative Stiffness, cm.

Maximum negative temperature differential measured through 30 cm to 34cm thick instrumented concrete slabs and 0.20◦C/cm of temperature differential is adopted based on climatic data.

Stresses Ratio and Fatigue of Concrete Slab

Fatigue criteria based on IRC: 58 have been considered. The fatigue resistance not consumed by repetition of one load is available for repetitions of loads from other vehicles (other loads). In the design, total fatigue should not generally exceed 100 percent. The concrete fatigue criterion based on stresses ratio and allowable repetitions are given in IRC: 58. Stress ratio is computed as the load stresses divided by the flexural strength or Modulus of Rupture (MOR) of the concrete.

The design of ultra-thin white topping has done for a Fort area, Moti daman road carrying traffic less 450 cvpd. Thickness of 100 mm with joint spacing of 60 cm is found to be safe as per the calculations using IRC SP 76 2015.

CONCLUSION

The fort area of Moti daman area, was classified based on type of existing pavement surfaces such as flexible, rigid and paver block. It was obtained that quantum of flexible, rigid and paver block road was 70%, 26% and 4% respectively. The results of road classification survey revealed that majority of fort area roads are comprised of flexible pavement. For improvement in existing road condition, it was planned to re-strengthen the existing roads by UTWT. The design of ultra-thin white topping has done for a Fort area, Moti daman road carrying traffic less 450 cvpd. Thickness of 100 mm with joint spacing of 60 cm is found to be safe as per the calculations using IRC SP 76 2015. The framework presented in design of UTWT can be adopted to re-strengthen the existing urban roads in developing countries as a cost effective alternative of bituminous overlay.

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