Polymer-Modified Thin Layer Surface Coarse: Laboratory and Field Performance Evaluations

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Abstract

With the global policy going towards lowering the costs and preserving the available resources, preventive maintenance strategies have become the focus of many road agencies. The main benefits of this approach are the protection of existing pavement layers and repair of functional distresses. The polymer-modified thin layer is one of the preventive maintenance methods that has been successfully carried out in European countries especially France. In Iran, this method was used for the very first time in Road 79 project, located near Tehran. A road section with 30 kilometers length was paved with a thin layer of modified asphalt mix produced with a polymer-binder mix additive. At the same time, other traditional maintenance methods such as mill and fill were executed at other sections of Road 79. The aim of this study was to assess the effectiveness of the polymer modified thin layer compared to other preventive maintenance methods through performance-related laboratory tests and field performance evaluations.

In the laboratory, dynamic creep, indirect tensile strength, rutting resistance, and fatigue resistance of polymer modified and conventional asphalt mixes were evaluated and compared. Polymer modified asphalt mixes were designed and prepared according to EN13108-2 and also Iranian construction code 234 to evaluate the effects of mix design approach.

The condition of pavement sections in Road 79 was investigated before and two years after performing different preventive maintenance methods by determining the Pavement Condition Index (PCI) and the macro-texture of the surface layer. Results of laboratory tests and field performance evaluations reveal that the polymer modified thin layer overall had superior performance compared to other traditional preventive maintenance methods evaluated.

Keywords: Polymer modified thin layer, polymer-binder mix additive, preventive maintenance, performance-related tests, pavement condition index (PCI)

1. Introduction

Very thin layer asphalt concrete is one of the preventive maintenance methods to protect existing structurally sound asphalt pavements and improve its functional performance. The layer thickness of this method is usually 20 to 30 millimeters and nominal maximum aggregate size (NMAS) is between 6 to 10 mm. Its gap graded structure forms stone to stone contacts and creates porous surface texture. EN13108-2 [1] is the European specifications for designing and implementing very thin layer asphalt concrete. According to EN13108-2, this method can be used for road and airfield pavements with any traffic volume.

Reducing noise generated by passing cars on asphalt pavements, reducing splash of water by quick drainage of surface water, maintaining functional distresses, and improving the drivability of roads are the benefits acknowledged for using very thin layer asphalt concrete as preventive maintenance method. The very thin layer asphalt concrete has also shown high resistance to rutting.

Labi [2] showed that using very thin layer asphalt concrete, as a preventive maintenance method, can decrease IRI by 18% to 36%, crack depth by 55%, and increase PCI by 10% in a long-term evaluation. Corley and Lay [3] expressed that the average traffic noise decreases as much as 6.7 decibels. FHWA [4] also declared the noise abatement up to 5 decibels.

In 1998, Mallick and Kandhal [5] carried out experiments to study the application and performance of thin layer gap-graded asphalt concretes in the United States. Based on their investigation, the service life was more than eight years for about 70% of the pavements surfaced with very thin layer asphalt concrete. Sections with coarser aggregate gradation had a longer service life and those with polymer-modified binder noticeably performed better. A follow-up study by Mallick et al. [6], focused on the mix design and the behavior of very thin layer asphalt concrete. The results revealed that coarser grading for these asphalt mixes improved the performance and for example grading with 15% aggregates passing sieve #4 (4.75mm) resulted in better performance properties than the fine graded aggregates. Also, it was shown that modifiers such as polymers can have a considerable effect on improving the performance of these mixes. Mallick et al. stated that a proper mix design method is needed for the very thin layer asphalt concrete [6].

In Iran, very thin layer asphalt concrete was used in 2014 for the very first time at Road 79. Since then, it has started to gain nationwide popularity as a maintenance method. The motivation of this study was to assess the performance of the very thin layer asphalt concrete and compare it with the conventional asphalt mix overlay. To make a comprehensive comparison, both laboratory and field data were considered.

2. Materials

2.1. Asphalt binder

An unmodified asphalt binder with 60/70 penetration grade was used in this study. The binder was supplied by Pasargad refinery in Tehran. Results of conventional tests on this binder are presented in Table 1.

2.2. Aggregates

Crushed Dolomite aggregates used in asphalt mixtures were obtained from Asbcheran quarry located near Tehran, Iran. The nominal maximum aggregate size was 10.00 mm. Aggregate properties are summarized in Table 2.

2.3. Modifier additive

Asphalt mixes were modified using the polymer (SBS)-asphalt binder pellet additives. This polymer-binder pellet has been recently introduced to pavement industry to facilitate modification of asphalt mixes. The pellet additive contains 40% SBS and 40% base binder and the remaining 20% included proprietary materials used for stabilizing the blend. More information on the product is not accessible due to the commercial reasons.

The polymer-binder pellets were directly added to the aggregates before incorporation of asphalt binder during asphalt mix production at the dose of 10% by weight of the optimum bitumen required for the conventional mix (i.e., without polymer modifier).

TABLE 1. Test Results of 60/70 Penetration Graded Asphalt Binder Used

Test	Test method	Result
Penetration (0.1 mm)	ASTM D5	63
Flash point (°C)	ASTM D92	289
Ductility (cm)	ASTM D113	>100
Softening point (°C)	ASTM D36	50.9
Solubility (percent)	ASTM D2042	99.8
Kinematic viscosity at 135 °C (cSt)	ASTM D2170	377
Mass loss (Thin-Film Oven Test) (percent)	ASTM D1754	0.02
Penetration of residue bitumen (Thin-Film Oven Test) (0.1 mm)	ASTM D5	43
Ductility of residue bitumen (Thin-Film Oven Test) (cm)	ASTM D113	>50

TABLE 2. Aggregate Properties

Test methods		Test result
Los Angles abrasion loss (%) on coarse aggregate (AASHTO T96), Type of grading: C, Number of revolution: 500		23
Soundness of aggregate by use of Sodium Sulfate (%) on coarse aggregate (AASHTO T104)		0.1
Flat and elongated particles (%) on coarse aggregate (ASTM D4791)		0.3
Fracture particle (%) on coarse aggregate (ASTM D5821)	One face	100
	Two face	100
Atterberg limits on fine aggregate	Plasticity index (AASHTO T90)	NP
	Plastic limit (AASHTO T90)	-
	Liquid limit (AASHTO T89)	Na
Soundness of aggregate by use of Sodium Sulfate (%) on fine aggregate (AASHTO T104)		1
Fine aggregate angularity (%) on fine aggregate (ASTM C1252)		46
Sand equivalent (%) on fine aggregate (AASHTO T176)		84
Atterberg limits on filler	Plasticity index (AASHTO T90)	NP
	Plastic limit (AASHTO T90)	-
	Liquid limit (AASHTO T89)	na

3. Mix design

3.1. Conventional mix (Conv.)

Formulation of the conventional mix has been done following the Marshal mix design method according to MS-2 [7] procedures. Dense-graded job mix formula has been chosen for the grading of the mix as shown in Table 3. The NMAS was 10.00 mm and the optimum binder content was obtained as 4.8% corresponding to 4% air voids in the Marshal samples compacted with 75 drops on each side.

3.2. Very thin layer asphalt concrete (BBTM[1] 10A)

[1] BBTM stands for "Beton Bitumineux Tres Minces" in French meaning very thin layer asphalt concrete.

EN13108-2 is the code for design, production, and installation of very thin layer asphalt concrete pavements. This standard describes different gap-graded aggregate grading with different NMAS. BBTM 10A was chosen for this project with 10.00 mm NMAS. Required specification for different types of BBTM is shown in Table 4 according to EN13108-2.

Based on EN13108-2, asphalt samples are made in 100 mm diameter mold using the gyratory compactor with 25 gyrations. Due to the high surface water absorption, the density of the sample was calculated by ASTM D1188. The maximum theoretical specific weight of the samples with different binder content was obtained according to ASTM D2041. The optimum binder content of BBTM 10A was obtained to be 5% by total weight of the mix corresponding to 10% air voids. The chosen gap-graded job mix formula is shown in Table 5.

3.3.Polymer-modified very thin layer asphalt concrete (PmBBTM 10A)

BBTM 10A produced with unmodified 60/70 asphalt binder does not meet the requirements of EN13108-2 for ITSR[1] and Mechanical stability (rutting). Therefore, the polymer-binder pellets, with the dose of 10% of optimum binder content, were used to modify the asphalt mixture.

TABLE 3. Aggregate Grading of Conventional Mix

Sieve	Passing (%)
½ inch	100
3/8 inch	92
No. 4	68
No. 8	44
No. 50	12
No. 200	5.5

TABLE 4. Required Specification for Different Types of BBTM According to EN13108-2

Mixture index according to EN13108-2	Nominal maximum aggregate size, D (mm)[2]	Grading tolerance for each sieve[3]			Minimum bitumen content (%)	Air voids of the samples compacted with 25 gyrations (%)	ITSR (%)	Mechanical stability (maximum rut depth related to thickness) (%)
		D (mm)	2 (mm)	0.063 (mm)				
BBTM 6A	6.3	90-100	25-35	7-9	5	12-25	>75	20
BBTM 6B	6.3	90-100	15-25	4-6	5	12-25	>75	20
BBTM 10A	10	90-100	25-35	7-9	5	10-25	>75	15
BBTM 10B	10	90-100	15-25	4-6	5	10-25	>75	15

TABLE 5. Aggregate Grading of BBBTM 10a

Sieve	Passing (%)
½ inch	100
3/8 inch	95
No. 4	46
No. 8	35
No. 50	14
No. 200	6.7

[1] Indirect Tensile Strength Ratio

[2] Nominal maximum aggregate size is the size that all of the aggregates of the mixture pass from the sieve 1.4 times coarser than it.

[3] Depending to design final grading could have 2 optional sieves between 2 and D mm, and one optional sieve between 0.063 and 2 mm.

4. Results of the laboratory evaluation

In Table 6, a summary of the tests carried out in the laboratory and the corresponding results are given. The following observations can be made:

- Considering the test results for rutting and dynamic creep, BBTM 10A outperformed the conventional mix mainly due to its gap-graded structure.
- Without modifying the mix, BBTM 10A did not meet the requirements of EN for moisture sensitivity and permanent deformation. Adding polymer-binder pellets improved the resistance to rutting and reduced the moisture sensitivity considerably. Hence, the EN requirements were fulfilled.
- Although thin layer asphalt concrete is not designed to combat fatigue cracking, the results of beam fatigue test showed superior fatigue performance for PmBBTM 10A mix followed by the BBTM 10A compared to the conventional mix.

TABLE 6. Laboratory Tests and Results

Test method		**Conventional mix**	**BBTM 10A**	**PmBBTM 10A**
Hamburg wheel track, rut depth related to the thickness (%)	EN13108-20	25	17	8
Dynamic creep (cycle)	EN12697-25	1,050	11,052	Doesn't fail till 5% of deformation
Four-point beam fatigue, 700 microstrain, (cycle) Failure: 60% reduction in initial stiffness	AASHTO T321	120,220	150,770	260,940
ITSR	EN12697-12	81	72	89

5. Results of the field evaluation

Four different asphalt layer combinations were implemented within 30 kilometers in Road 79 located in the cold region at the east of Tehran, from Firoozkooh to Damavand city. Different combinations are as below:

- T: 25 mm PmBBTM 10A
- RT: Regulating layer (Conv.) + 25 mm PmBBTM 10A
- MRT: Milling + Regulating layer (Conv.) + 25 mm PmBBTM 10A
- MR: Milling + Regulating layer (Conv.)
- RS: Regulating layer (Conv.) + 50 mm conventional mix (Conv.)

Performance evaluation of field sections has been done after two years.

5.1.Pavement Condition Index

Prior to installation of different types of asphalt layer combinations, Pavement Condition Index (PCI) was calculated during site visits for nine points in the Road 79 according to ASTM D6433. The asphalt layer combinations mentioned above was implemented in the year 2014 on sections of Road 79. Two years later another site visit was organized and the PCI was evaluated for the same nine points again. The results from PCI evaluation are shown in Figure 1. The following observations can be made:

- Very thin layer asphalt concrete has given promising results even in sections with a very low initial PCI. It should be noticed that in places where structural damage exists, milling played an important role to avoid reflection of cracks to the surface. Also in sections with rutting, implementing regulating layer was of great importance.
- In sections on which only milling and installing regulating layer (MR) was done, the PCI after two years was almost the same as it was before installation. This indicates that (MR) rehabilitation was not a proper option in long-term.
- RS and RT yielded almost the same result after two years. The fact is that in RT the thickness is half the RS meaning a more economically and environmentally efficient method of rehabilitation.

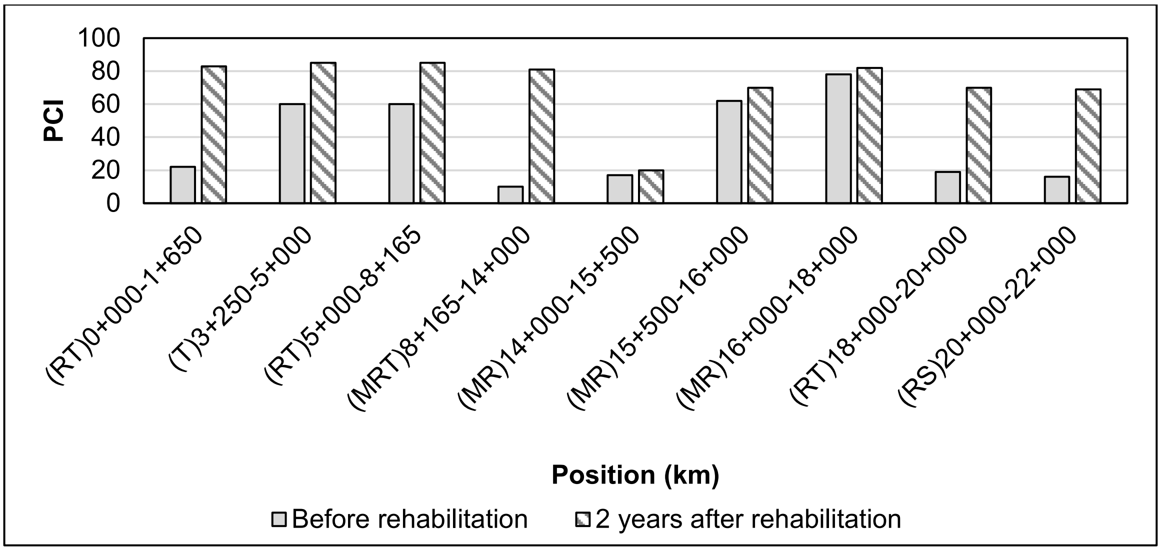

FIGURE 1. PCI Values Prior the Project Installation and Two Years After the Installation for Each Point

5.2.Macrotexture depth

According to ASTM E965, the sand patch was done in order to find the macrotexture depth of the pavement surface. This test was carried out on both the conventional mix and the PmBBTM 10A mix just after the installation and two years after the installation. The results are presented in Table 7. Accordingly, the BBTM had more friction compare to conventional mix due to its gap-graded structure. This advantages property decreased as the pavement becomes older (i.e., the ratio of MTD_{after}/MTD_{before} was 0.7 for PmBBTM 10A section compared to 0.8 for the conventional section). Therefore, maintenance actions, like washing the surface, seem to be necessary.

TABLE 7. Sand Patch Test Result

Type of mix	Sand patch result (Average MTD)	MTD_{after}/MTD_{before}
PmBBTM 10A – after installation	1.065 mm	0.71
PmBBTM 10A – two years after installation	0.752 mm	
Conventional mix – after installation	0.49	0.89
Conventional mix – two years after installation	0.437	

6. Summary and Conclusions

The Main findings of this study can be summarized as below:

1- Laboratory test results indicated that the polymer modified gap-graded mix outperformed the unmodified gap-graded mix and the conventional asphalt mix in terms of resistance to rutting, fatigue cracking, and moisture damage.
2- Comparing the PCI values at different points in Road 79 before and two years after placing different rehabilitation scenarios indicated that the very thin layer asphalt concrete is the preferred maintenance approach based on its cost and performance effectiveness.
3- Very thin layer modified asphalt concrete had higher friction compared to the conventional asphalt mix layer. However, this benefit decreased with the age of pavement.

Overall, the very thin layer asphalt concrete can be regarded as a successful and cost-effective method to improve functional performance of structurally sound asphalt pavements.

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