Performance evaluation of fly ash asphalt pavement

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ABSTRACT

This investigation was carried out to study the effect of fly ash on the field performance of asphalt pavement. Fly ash was used in stone mastic asphalt (SMA) during the construction of the wearing course of Gaziantep Ring Road. This SMA is the first application using fly ash in our country. The performance properties (rut depth and roughness and cracking in the pavement) were determined.
In this research the inertial profilometer with camera has been used to measure rut depth, roughness and cracking of the road in 5th Regional Division of Highways of Turkey.
As a result of this study, surface performance properties have been determined. Additional data will continue to be collected and analyzed during the next years. Performance models will be developed.

Keywords: Pavement Evenness, Stone Mastic Asphalt

1. INTRODUCTION

Gaziantep Ring Road is the first asphalt pavement using fly ash in the highway networks of Turkey. The pavement is the stone mastic asphalt (SMA) including basalt aggregate, fly ash (flue ash) 4,0 %, fiber 0,35 % and polymer modified bitumen (PMB). Because of the possible problems that can be faced with the distance of the source of the filler (calcite) and in the supplement of it, the fly ash is used.
The purpose of this study is to determine the performance of SMA pavement in the field prepared with fly ash having the characteristics of reducing the cost and increasing the performance. With this aim, the data of roughness, rut depth and cracking performance criteria are collected and evaluated.
In this study, the conditions of the performance criteria at the first date of built and the changes it faces in time are all observed. Accordingly, as a result of the observations held in 2012 and 2014, it is determined that the performance of the mixture prepared with fly ash is considerably high.
In the next step, the data collected in this study will be used for performance models. One of the aim of this study is to collect roughness, rut depth, and cracking data. It is necessary to develop pavement performance models for asphalt with fly and also PMS. The results will help to take a decision about priority program and allocate funds for maintenance at both the present time and the future.

Fly ash in asphalt pavements:
Fly ash can be used as a cost-effective mineral filler in asphalt paving applications. Where available locally, fly ash may cost less than other mineral fillers. Also, due to the lower specific gravity of fly ash, similar performance is obtained using less material by weight, further reducing the material cost of asphalt. Mineral fillers increase the stiffness of the asphalt mortar matrix, improving the rutting resistance of pavements. Mineral fillers also help reduce the amount of asphalt drain down in the mix during construction, which improves durability of the mix by maintaining the amount of asphalt initially used in the mix. Fly ash will normally meet mineral filler specification requirements for gradation, organic impurities and plasticity. Also, fly ash is hydrophobic (non-water wettable), reducing the potential for asphalt stripping; the presence of lime in some fly ashes may also reduce stripping. Mineral fillers have become more necessary as mixture gradations have become coarser. Asphalt pavements with coarse gradations are increasingly being designed because they perform well under heavy traffic conditions [1].

Pavement performance:
The pavement performance is largely defined by roughness, surface distress, skid resistance, structural evaluation – deflection.
Pavement performance is a function of its relative ability to serve traffic over a period of time. Typically, a system of objective measurements is used to quantify a pavements condition and performance. These system are used to aid in making the following types of decision [2]:

- Establish maintenance priorities. Condition data such as roughness, surface distress, and deflection are used to establish the projects most in need of maintenance and rehabilitation. Once identified, the projects in the poorest condition are more closely evaluated to determine repair strategies.
- Determine maintenance and rehabilitation strategies. Data from surface distress surveys are used to develop an action plan on a year-to-year basis; i.e., which strategy (patching, overlays, recycling, etc.) is most appropriate for given pavement condition.
- Predict pavement performance. Data such as roughness, skid resistance, surface distress, or a combined rating, are projected into the future to assist in preparing long-range budgets or to estimate the condition of the pavements in a network given a fixed budget.

Pavement surface condition is determined by the following conditions [3]:

- Roughness (The International Roughness Index -IRI): Pavement evenness is an important indicator of pavement riding comfort and safety.
- Rutting: Rutting is one of the predominant types of distresses observed in the asphalt pavements.
- Surface distress: Pavement distress rating system includes different distress types within the following categories.
    - Cracking**;** fatigue (alligator), block, edge, reflection, slippage, longitudinal (liner) and transverse cracking.
    - Surface Deformation; rutting, shoving, distortion.
    - Surface Defects; bleeding, potholes, ravelling.

The evaluation of performance involves the functional analysis of pavements based on the history of the riding quality. The riding comfort and pavement performance can be conveniently defined in terms of roughness and pavement distresses.

Pavement performance models are the best approximate predictors of expected conditions. Pavement performance modeling an important tool used by pavement managers in decision making in prioritization and budgeting for maintenance.
A model is also needed for calculating the permanent deformation of the pavement materials, which will result in rutting and roughness of pavement surface. Condition performance models are used at both the network and project levels to analyze the condition and determine maintenance and rehabilitation requirements. And also pavement prediction models represent a key element of PMS [4-5].

2. METHOD AND METHODOLOGY

This study explains the surface performance measurements and evaluations of the asphalt pavement for Gaziantep Ring Road. Roughness, rutting, and images for cracking data collected were analyzed and evaluated.
The performance measurements were collected using the Road Surface Profilometer (RSP). It was capable of real time measurements of longitudinal profile, International Roughness Index (IRI), transverse profile, and rut depth. Measurements were carried out at normal traffic speed, located with Differential Geographical Positioning System (DGPS) and complemented with digital photographs of the road inventory and surface.

2.1 Measuring Device

RSP is measurement device. World-Bank TP-46 and ASTM E-950 specified test procedures were followed in this survey [6-7]. The RSP test system can collect a wide variety of information ranging from ride quality measurements (International Roughness Index and Ride Number) to high accuracy transverse and longitudinal inertial profile as well as geometric information such as grade, crossfall, and curve radius or degree of curve. RSP compute, display and store longitudinal and transverse profile as well as roughness indices, rutting measurements and crossfall. The RSP can measure pavement texture and faulting.17 laser sensors, 2 accelerometers and Inertial Motion Sensor were mounted in rigid aluminum housing (rut bar) at the front of the vehicle. The RSP can collect data at speed of up to 110 km/h (the RSP is driven recommended speed which is 70 km/h) [8].

2.2 Road Measurement

Roads were measured with RSP which is a World Bank Class 1 roughness measurement device. The roughness measurements were performed for the extreme right lanes. Measurements are carried out at normal traffic speed **(**70 km/h), located with DGPS (satellite support) and complemented with digital photographs of the road environment and surface.

Roughness:

Longitudinal profile roughness measurements are collected for each wheel path on a continuous basis using a laser sensors. The data is collected continuously and reported at 1m intervals. IRI is calculated in accordance with procedures and specifications outlined in Word Bank Technical Paper Number 46'Guidelines for Conducting and Calibrating Road Roughness Measurements'.

Rutting:

The transverse profile of the travel lane is measured on a continuous basis. Sensor measurements are recorded across the full lane profile and used to calculate for each wheel path and the maximum rut depth in each wheel path. The data is collected continuously and reported at 10 cm intervals.

Digital Images:
Digital images are collected during the surveys that show the full right of way view of the roadway, including both the pavement surface. The data is collected continuously and reported at 10 m intervals.

2.3 Materials

The materials and their amounts used in SMA mixture are listed below.
Basalt aggregate and fly ash as additional filler material are used.
Basalt aggregate (produced in Atatürk Dam Basalt Quarry, Bozova Şanlıurfa)

Fly ash	4%	(The flue ash produced in the thermal power plant of Iskenderun)
Fiber	0,35%	(according to the weight of the mixture)
Bitumen content	6,52% PMB	(B-50/70 Batman bitumen is used)
Polymer additive	5%	(Kraton D 1101AT)

Gradation of aggregate is given below.

Sieve Size (mm)	Passing %
12-16	15
6-12	53
0-4	28

2.4 Data Analyzing

Two different computer programs were used for data analysis. Both of the computer programs have GPS coordinates value and Google Earth Map. One of both programs is 'Dynatest Explorer'. It was used for the roughness and rutting data analysis. IRI is calculated from the left and right wheel path profile. Rutting is calculated from the left, left max, right, and right max wheel path profile.
The other program is 'Multimedia Highway Information System (MHIS)'. MHIS and Dynatest Explorer were used to see inventory and surface images for 10 m length.

3. RESULTS AND DISCUSSION

The RSP was used to collect data which are roughness, rut depth, and images of asphalt pavement a part of Gaziantep Ring Road in Turkey. This section was measured with profilometer in 2012 when the road is new and 2014. Table 1 shows the road information and traffic volume.

Tablo 1: Gaziantep Ring Road information and traffic volume

Start/End (km)	Distance Total (km)	GPS- Start/End			AADT 2014 Annual average daily traffic (vecihle /day)	Measured criteria
		X Latitude	Y Longitude	Z Altitude		
0-2,250	2,25	37,035164/ 37,452871	37,437564/ 37,452871	791,1 /812	9870	Rutting
0-3,900	3,900	37,035164/ 37,049356	37,437564/ 37,458316	791,1 /823,3		Roughness
0-3,900	3,900	37,035164/ 37,049356	37,437564/ 37,458316	791,1 /823,3		Cracking (And Distress)

The measured data were analyzed with computer programs. Roughness and rutting data were evaluated and divided into homogeneous sections.
The data of roughness is collected in every 2,5 cm, calculated in 50 m intervals and separated into homogeneous groups shown in Table 2.

Table 2: IRI evaluation list

From (km)	To (km)	IRI (m/km) 2012	IRI (m/km) 2014
0,000	0,800	0,93	0,95
0,800	0,950	Overpass	
0,950	1,100	1,05	1,09
1,100	1,550	Viaduct	
1,550	3,900	0,98	0,99
3,900	4,700	1,19	1,20

The measurements held in two different dates show that the changes in the values of roughness are relatively in low levels. According to these evaluations, the changes (increases) between 0,01-0,04 m/km in the values of roughness can be seen in Figure 1.

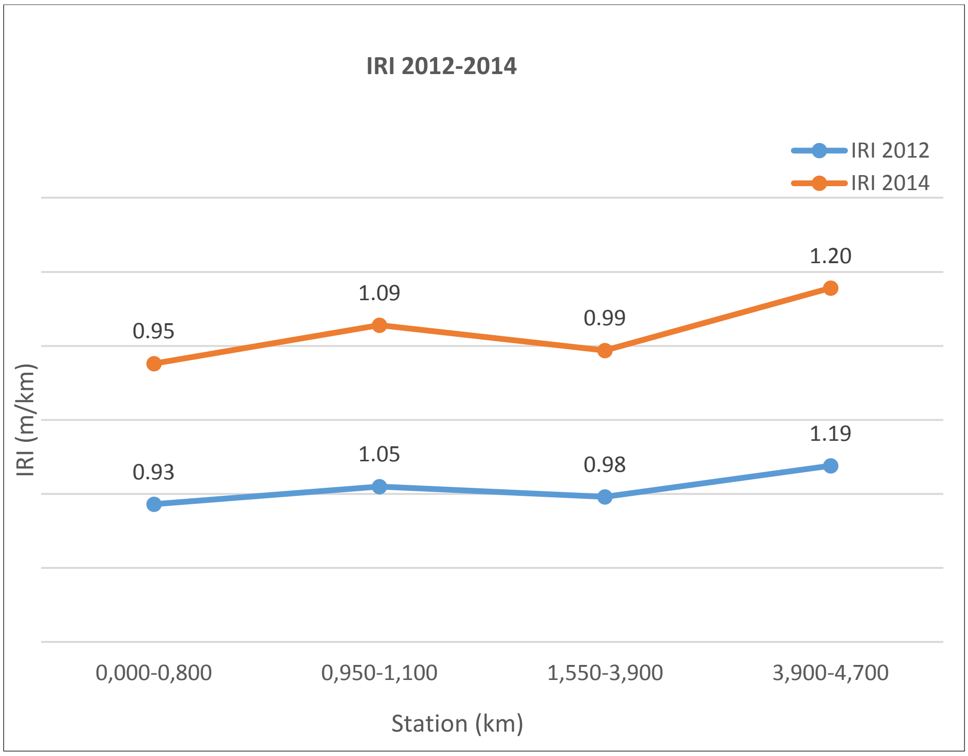

Figure 1: Distribution of IRI for 2012 and 2014

The data of rutting are calculated in 10 cm intervals and separated into homogeneous groups given in Table 3.

Table 3: Rutting evaluation list

Station (km)	Rutting (mm) 2012						Rutting (mm) 2014					
	Left	Center	Right	Leftmax	C.max	R.max	Left	Center	Right	Leftmax	C.max	R.max
0-0,420	1,0	2,1	1,7	1,0	2,1	1,8	2,5	4,6	4,6	2,5	4,6	4,6
0,420-0,830	0,9	1,5	0,8	0,9	1,5	0,8	2,9	3,5	3,5	2,9	3,5	3,5
0,830-1,460	0,8	1,8	0,7	0,8	1,8	0,7	1,8	3,0	2,9	1,8	3,0	2,9
1,460-1,650	0,9	1,7	1,6	0,9	1,7	1,6	2,6	2,7	2,2	2,6	2,7	2,2
1,650-1,960	0,7	1,2	0,8	0,7	1,2	0,8	2,3	2,5	2,2	2,3	2,5	2,2
1,960-2,250	1,6	2,1	1,1	1,7	2,1	1,1	2,5	2,6	2,2	2,5	2,6	2,2

The measurements held in two different dates show that the changes in the values of rutting increased in low levels relatively. According to these evaluations, the values of rutting:

- The changes (increases) in the left and left-max wheel values are between 0,8-2,0 mm and shown in Figure 2
- The changes (increases) in the right and right-max wheel values are between 0,6-2,8 mm and shown in Figure 3.

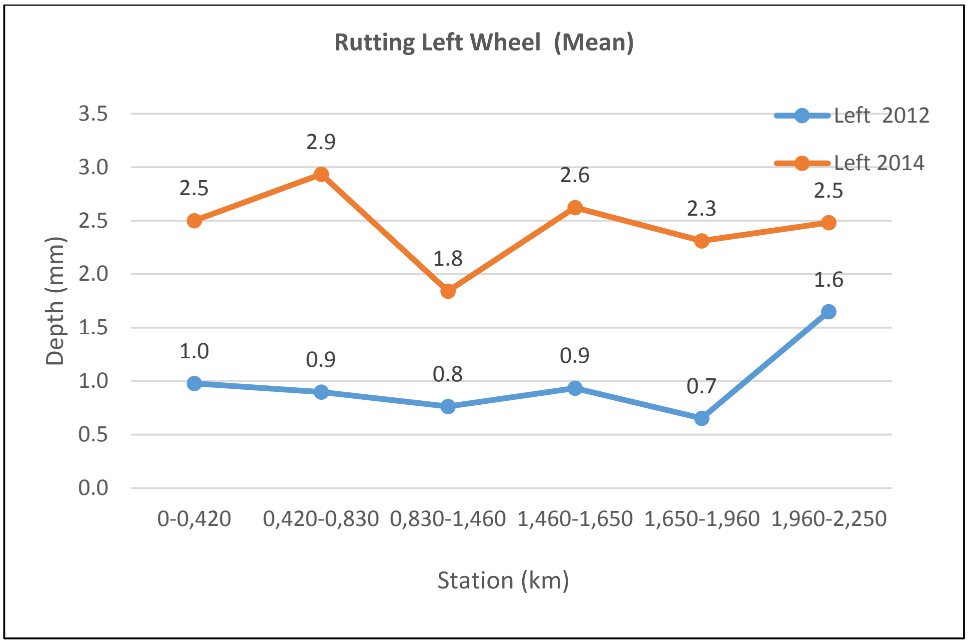

Figure 2: Rutting left wheel

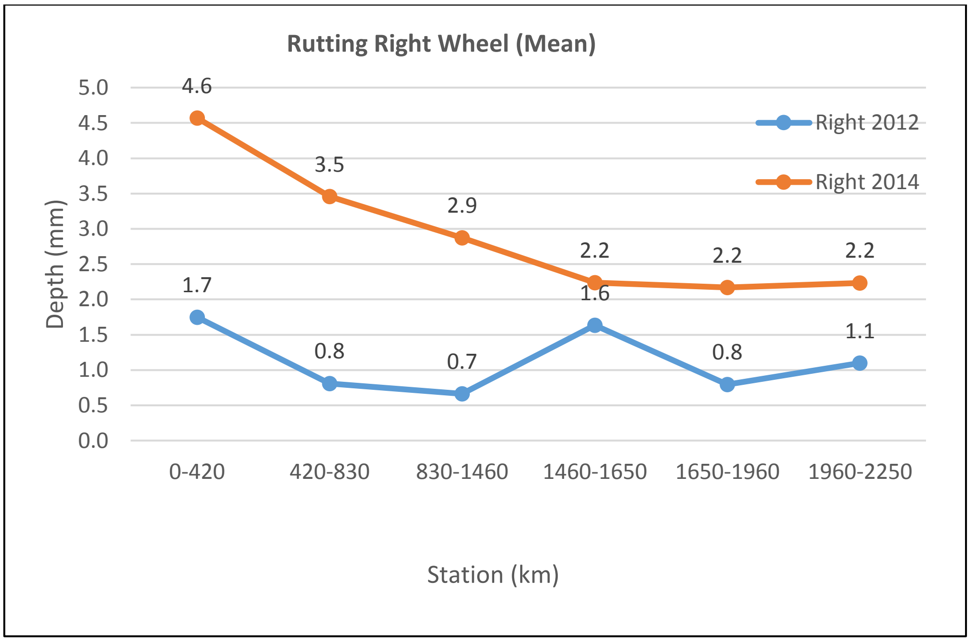

Figure 3: Rutting right wheel

Thanks to the photographs taken with RSP in every 10 meters and the on-site observations since 2012, it is determined that there has not been any cracking or other distresses types on the pavement.

The images belonging to the same part of the pavement (km: 0,280), of which surface condition is observed between 0,000-3,900 km and photographed with road surface and inventory cameras, can be seen in Figure 4 for 2012 and Figure 5 for 2014.

Figure 4: Surface images in 2012

Figure 5: Surface images in 2014

4.CONCLUSIONS

The first stone mastic asphalt pavement with fly ash addition is applied on Gaziantep Ring Road in the highway networks of Turkey. The performance evaluation of the SMA which is produced using basalt aggregate, 4,0 % fly ash (flue ash), 0,35 % fiber and 6,52 % bitumen (B-50/70) is also made.
The performance evaluation related with the roughness, rut depth and cracking of the highway pavement which was measured first in 2012 and secondly in 2014 after opening to traffic can be seen below:
The changes in the performance values belonging to 2012 and 2014.
It's evaluated that the changes in the values of roughness belonging to the years of 2012 and 2014 are increased in very low amounts between 0,01-0,04 m/km.

- The changes in the values of rut depths belonging to the years of 2012 and 2014 are increased in very low amounts as 0,8-2,0 mm in left wheel and 0,6-2,8 mm in right wheel.
- There has not occurred any cracking type and other pavement distress.

As a conclusion, it is observed that the values of roughness and rut depth stayed almost stable and there has not occurred any distress and cracking type.
In the following studies, performance models will be developed in order to follow the pavement performances and studies will be held within the scope of PMS.

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