Works For Increasing Skid Resistance At The Highways In Turkey

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ABSTRACT

Skid resistance is one of the most important features of road pavements. Road surfaces must provide required skid resistance for the vehicles to facilitate safe driving distance in all conditions. Skid resistance also has a direct impact on road safety.
In the view of research and development activities on bituminous binders and bituminous mixtures along with knowledge and experience gained through road practices, it is specified the asphalt pavement with both technically sufficient durability and high skid resistance level as well as compatible with the conditions of Turkey. Following these studies, in order to increase the skid resistance of Turkish Highways Network, major changes have been made in the Highway Technical Specification. With the purpose of acquiring sufficient level of friction and texture on the asphalt road surface, starting from the source of aggregate, physical characteristics and gradation of aggregate, types of bituminous binder, mixture properties and surface characteristics of asphalt pavement have been improved.
In this paper, it is expressed the improvements made in constituent materials of surface layers (aggregate, bituminous binder) and mixture properties in order to increase skid resistance. Furthermore, it is also explained the required surface characteristics of the newly constructed surface layers.

Keywords: Safety, Skid Resistance, Surface Texture

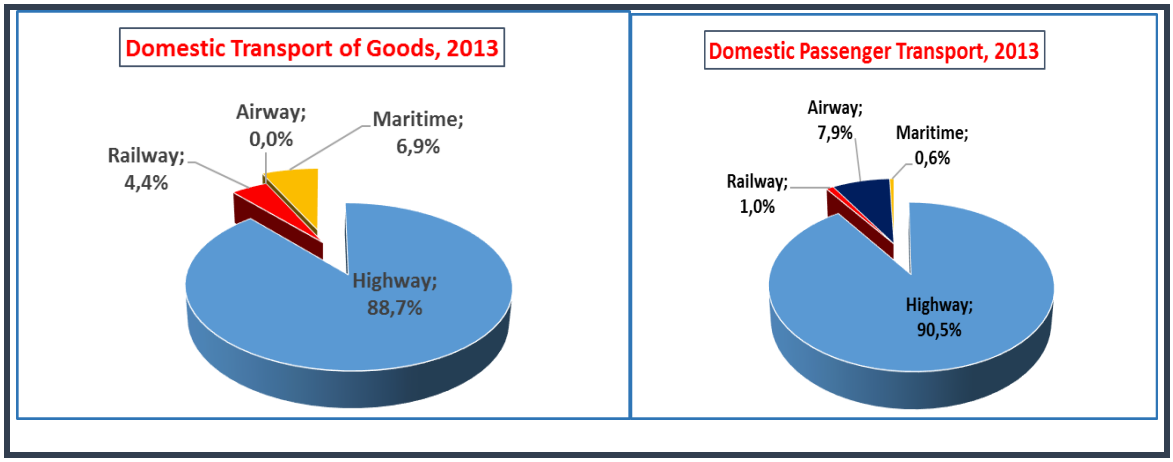
1. INTRODUCTION

Asphalt pavement is prepared and produced on the basis of being safe and durable with high driving comfort. In addition; source of materials, how these materials supplied and produced, and materials' properties during construction and usage stages as well as reuse and recycle of the materials should be considered in detail. The aim is to focus on finding sustainable solutions. Furthermore, it is a must to provide safe and comfort driving condition on the road for any weather conditions.

Amendments and additions to Highway Technical Specification is made by taking into consideration these abovementioned issues together with the needs and conditions of Turkey. The updated Specification is effective immediately upon publication in 2013.

Percentage of highway in transport of goods and passengers is quite high in Turkey. As it can be seen in Figure 1:, in 2013 highways percentage is 90,5% in passenger transport and 88,7% in transport of goods. While in 2003 95% of domestic passenger transport was via highways, in 2013 highways percentage is decreased to 91% as a result of rapid developments in other modes of transport.

Skid resistance is one of the important factors in terms of preventing traffic accidents and making transport of passengers and goods safer.



Source: Ministry of Transportation, Maritime Affairs and Communications (Ministerial Statistics 2003-2013)
Suburban Line is not included

Figure 1: According to mode of transport, domestic transport of goods and passenger

The length of Turkish highways is 65 909 km (January 2015). 70% of Turkish road network is surface treatment while the rest 30% is asphalt concrete. After 2009, asphalt production has been increased considerably, and the targeted policy is to pave the entire road network with asphalt concrete until 2023 (Figure 2-Figure 3).

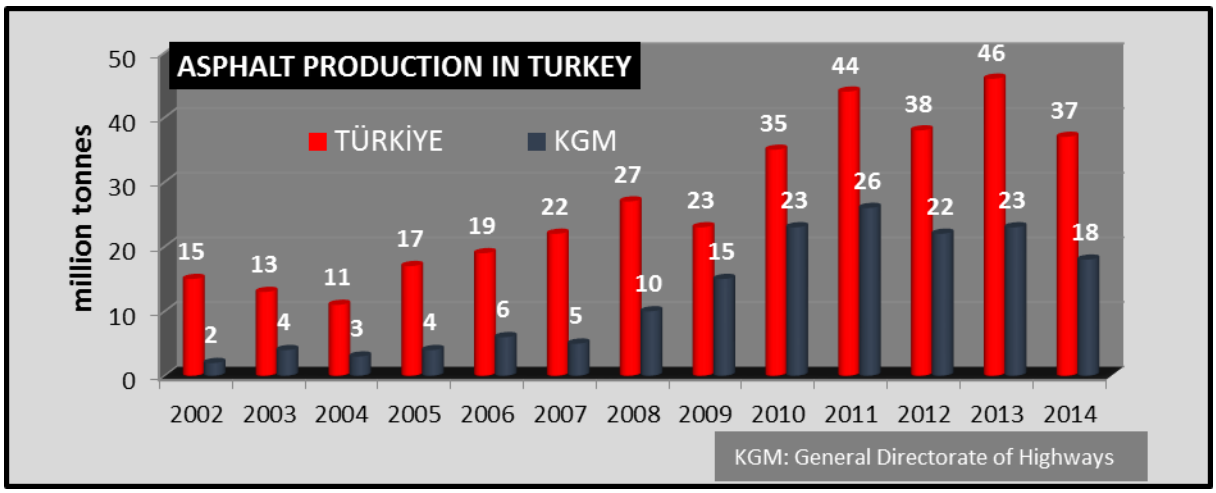


Figure 2: Asphalt production in Turkey

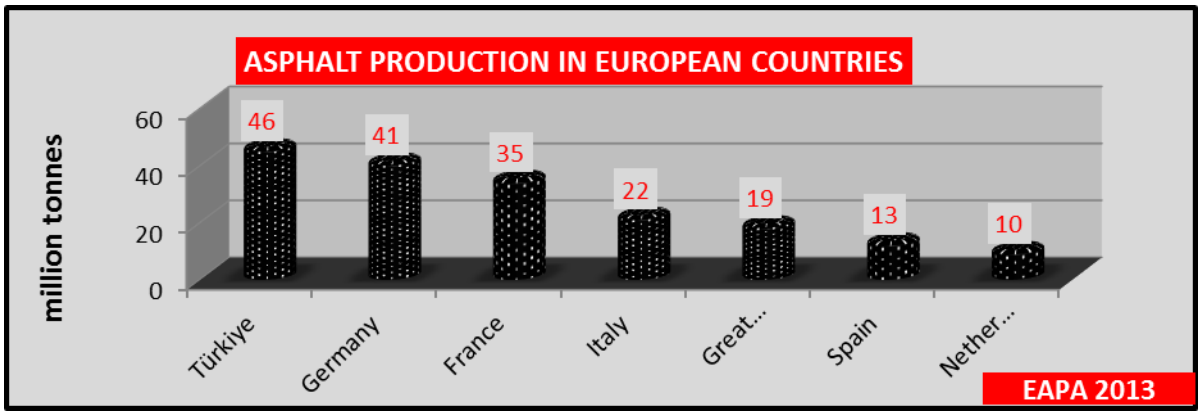


Figure 3: Asphalt production in some European countries

As a result of the abovementioned issues, it is important that asphalt concrete has the necessary skid resistance. Skid resistance is also important that Turkey has many rainy regions.

Pavement skid resistance is primarily a function of the surface texture, which includes both microtexture and macrotexture.

Microtexture, which is primarily a function of aggregate surface characteristics, is needed to provide a rough surface that disrupts the continuity of the water film and produces frictional resistance between the tire and pavement by creating intermolecular bonds.

Macrotexture, which primarily depends on aggregate gradation and method of construction, provides surface drainage paths for water to drain faster from the contact area between the tire and pavement. Macrotexture helps to prevent hydroplaning and improve wet frictional resistance particularly at high speed

While revising the specification, many changes and additions have been made to increase the skid resistance of the asphalt pavement. For this reason; starting from the source of aggregate, physical characteristics and gradation of aggregate, types of bituminous binder, mixture properties and surface characteristics of asphalt pavement have been improved.

Within the frame of EU technical legislation, as part of Regulation No 305/2011/EC of the European Parliament and of the European Council laying down harmonised conditions for the marketing of construction products (CPR) and

repealing Council Directive 89/106/EEC for construction products (CPD), Turkey harmonised the standards for road aggregates, bituminous materials and bituminous mixtures and CE markings became an obligation. These changes are also reflected to the Turkish Highway Technical Specification. In the following chapters, it is explained in detail what kind of studies has been done.

2. BITUMINOUS MIXTURE PROPERTIES

2.1 Asphalt concrete (binder and wearing course)

a) Asphalt concrete wearing course Type-1 gradation is changed semi-gap graded
b) Very Thin Layer (TS EN 13108-2) Type-3 is included as wearing course
Type -3 very thin layer wearing course;
- to increase skid resistance, and
- to prevent the intrusion of air and water
- 25-30mm thickness should be applied to the existing asphalt pavement that has maximum 6mm rut depth.

In the event of being suggested in Pavement Project Report, Type-3 very thin layer wearing course could be used as a wearing course in newly constructed and rehabilitated flexible pavements. In Type-3 very thin layer wearing course, modified bitumen or modified emulsion should be used as a tack coat, and modified bitumen should be used in the mixture. The combined aggregate gradation limits are given in Table 1.

Table 1: Gradation limits for AC wearing course

Sieve size	Type-1	Type-2	Type-3 Very Thin Layer
	Percentage passing by mass		
19 mm (3/4")	100		
12,5 mm (1/2")	88 - 100	100	100
9,5 mm (3/8")	72 - 90	80 - 100	90 - 100
6,0 mm (1/4")	-	-	25 - 33
4,75 mm (No.4)	42 - 52	55 - 72	23 - 31
2,00 mm (No.10)	25 - 35	36 - 53	20 - 27
0,425 mm (No.40)	10 - 20	16 - 28	12 - 18
0,180 mm (No.80)	7 - 14	8 - 16	
0,075 mm (No.200)	3 - 8	4 - 8	7 - 11

c) Polish stone value (PSV) of the aggregates to be used in wearing course should be at least 50.

However, the aggregates whose polish stone value is below 40 could only be used by administrative approval under unavoidable circumstances. In this case, in order to increase skid resistance, 1/3 mm-sizes and 1,5-2,0 kg/m^2 gritting aggregate that polish stone value is at least 50, other aggregate properties is within aggregate limits should be applied. Gritting material should be applied directly behind to the finisher or after the first roller passes. Very thin layer asphalt concrete gradation curve is given in **Error! Reference source not found.**.

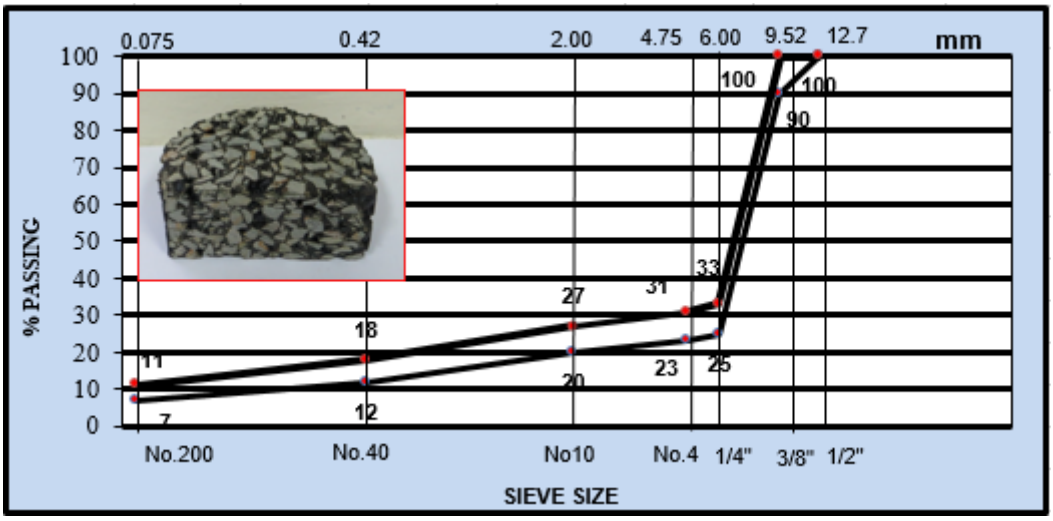


Figure 4: Gradation curve of very thin layer AC wearing course

2.2 Stone Mastic Asphalt (SMA)

SMA Type-1 is given in two different gradations as A and B (Table 2). SMA Type-1B mixture should be used by administrative approval in regions where no volcanic rocks with proper quality are available. In this case, since it is not possible to supply volcanic aggregate in SMA Type-1B mixture, the aggregates that polish stone value is below 40 could only be used by administrative approval.

However, in order to increase skid resistance, 1/3 mm-sizes and 1,5-2,0 kg/m^2 gritting aggregate that polish stone value is at least 50, other aggregate properties is within aggregate limits will be applied. Gritting material should be applied directly behind to the finisher or after the first roller passes. Crushed stone spreading system mounted on the cylinder should be used in order to spread the aggregate homogenously.

Table 2: SMA gradations limits

Sieve size		SMA Type-1		SMA Type-2
		A	B	
inch	**mm**	**Percentage passing by mass**		
3/4"	19,0	100	100	
1/2"	12,5	90-100	90-100	100
3/8"	9,5	50-75	50-67	90-100
No.4	4,75	25-40	25-35	25-45
No.10	2,00	20-30	20-30	20-30
No.40	0,425	12-22	12-22	12-22
No.80	0,180	9-17	9-17	9-17
No.200	0,075	8-12	8-12	8-12

2.3 Porous Asphalt (PA)

In order to increase skid resistance of surface course, PA mixture is added to the specification as a new layer. PA mixture will be used especially for rainy regions. Porous asphalt (TS EN 13108-7) should be applied in four different gradations as Type-1, 2, 3, 4 (Table 3). In PA production, aggregates with SMA aggregate properties, fibre (when needed) and suitable modified bitumen should be used.

Table 3: Porous asphalt gradation

Sieve size		Type-1	Type -2	Type -3	Type -4
inch	**mm**	**Percentage passing by mass**			
3/4"	19,0	100	100	100	
1/2"	12,5	5-15	90-100	85-95	100
3/8"	9,5	-	63-77	5-15	85-95
No.4	4,75	5-12	11-35	5-15	5-12
No.10	2.00	5-10	10-20	5-10	5-10
No.80	0,180	-	5-10	-	-
No.200	0,075	3-5	3-7	3-5	3-5

2.4 Seal Coat

With the objective to prolong the life span of the existing bituminous pavement and to improve surface texture, over the asphalt concrete, first thin layer of bituminous binder, then a layer of chipping (fine aggregate) are spread and compacted as the seal coat. Modified bitumen or modified emulsion is used as a bituminous binder. The functions of the binder are to bond the aggregate particles to the underlying surface and to provide a waterproof seal. The function of the aggregate or chips is to provide surface friction between the vehicle tires and the pavement.

Seal coat provides a relatively inexpensive permanent surface, protecting the pavement structure and driving surface, as well as the subgrade. The main functions of seal coat are;

a. To protect pavement from negative effects of air and moisture,
b. To increase skid resistance on slippery surfaces,
c. To renew old and stripped surfaces,
d. To enrich an existing oxidized or ravelled surface,
e. To keep moisture from penetrating the subgrade and pavement structure,
f. To provide a uniform-appearing surface.

In seal coat construction, F-Type gradation is generally used in order to increase skid resistance (Table 4).

Table 4: Seal coat gradation limits

Sieve size		Percentage passing by mass		
inch	mm	D-Type	E-Type	F-Type
1/2"	12,5	100		
3/8"	9,5	90 - 100	100	
1/4"	6,3		90 - 100	**100**
No.4	4,75	0 - 20	60 - 85	**90 - 100**
No.10	2,0	0 - 2	0 - 2	**0 - 5**
No.200	0,075			**0 - 1**

3. AGGREGATES FOR BITUMINOUS MIXTURES

Turkey harmonised EN standard for road aggregates (TS EN 13043) so, Turkish Highways has been started to use EN aggregates standards and EN test standards for bituminous mixtures.

Aggregates and asphalt mixtures properties for binder and wearing course are given in Table 5. Selection of polish-resistant aggregates with certain shape characteristics is important to improve the frictional performance of the pavement surface. It can be seen in this table that polished stone value (PSV) and flakiness index (FI) are compulsory for both binder and wearing course aggregates to obtain the microtexture.

Table 5: Aggregates and asphalt mixtures properties

TESTS	SPECIFICATION LIMITS			TEST STANDARD
	AC BINDER COURSE	AC WEARING COURSE	SMA WEARING COURSE	
Los Angeles Coefficient, max. %	LA_{30}	LA_{27}	LA_{20}	TS EN 1097-2
Thermal and weathering properties, Magnesium sulphate (Mg_2SO_4), max. %	MS_{18}	MS_{16}	MS_{14}	TS EN 1367-2
Crushed and broken surfaces , min. %	$C_{95/0}$	$C_{95/0}$	$C_{100/0}$	TS EN 933-5
Flakiness Index, max. %	FI_{25}	FI_{20}	FI_{20}	TS EN 933-3
Polished Stone Value, min. %	PSV_{35}	PSV_{50}	PSV_{50}	TS EN 1097-8
Water Absorption, max. %	WA_{24} 2.5	WA_{24} 2.0	WA_{24} 2.0	TS EN 1097-6
Stripping Resistance, min. %	60	60	60	TS EN 12697-11
Clay Lumps And Friable Particles, max. %	0,3	0,3	0	ASTM C-142
Methylene blue test, g/kg, max.	$MB_{1,5}$	$MB_{1,5}$	$MB_{1,5}$	TS EN 933-9
Air voids content, V_m , %	4-6	2-4	2-4	TS EN 12697-8
Void in the mineral aggregate, VMA, %	13-15	14-16	min.16	TS EN 12697-8
Voids in the mineral aggregate filled with binder, VFB, %	60-75	65-75	-	TS EN 12697-8
Binder drainage, max. %	-	-	0,3	TS EN 12697-18
Resistance Of Compacted Asphalt Mixtures to Moisture-Induced Damage, Tensile Strength Ratio (TSR), min. %	80	80	80	AASHTO T-283
Wheel Tracking, large size devices, (30000 cycle, 60°C) rut depth, max. %	-	8	6	TS EN 12697-22

4. BITUMINOUS BINDERS PROPERTIES

It is known that bituminous binder content of the asphalt mixture and binder grade used in the mixture affect the pavement friction. Consequently, binder content needed for durability and selected binder type should not cause the flushing/bleeding problems.

Bituminous Binder Selection Map for Hot Mix Asphalt Manual is used to select the suitable bituminous binder for road project.

According to SUPERPAVE Asphalt Binder Specification method, average highest and lowest pavement temperatures for regions are calculated by using daily highest and lowest weather temperature data of the last 20 years from Turkish meteorological stations together with road and station elevation. Performance Grade (PG) of normal bitumen in all grades produced in all four Turkish refineries and modified bitumen with different polymer content were determined. A research study concerning laboratory and construction sites was carried out. Then, according to average highest and average lowest temperature, Bituminous Binder Selection Map for Hot Mix Asphalt was prepared for Turkish road network.

Taken into consideration traffic volume and road geometry, the map has been used in order to select necessary bituminous binder for pavement design level of every project (Table 6). Bituminous Binder Selection Map for Hot Mix Asphalt Manual was published in 2012. Additionally polymer modified bitumen specification has been prepared (Table 7). After starting to use this map, it is observed that deterioration due to the bituminous binder did not occur on the road constructed with suitable binder.

Table 6: Turkish Highways' binder grade selection table

BINDER GRADE SELECTION TABLE						
		High temperature performance grade, °C				
		58	64	70	76	82
Low temperature performance grade °C	-16	B 50/70		Batman refinery B 50/70 or PMB	Polymer Modified Bitumen (PMB)	
	-22					
	-28	B 70/100	Batman refinery B 70/100 or PMB 64-28			

Table 7: Turkish Highways' Polymer Modified Bitumen Specification

No	TEST		STANDARD	UNIT	PMB 58-28	PMB 64-28	PMB 70-16	PMB 70-22	PMB 70-28	PMB 76-16	PMB 76-22	PMB 76-28	PMB 82-16	PMB 82-22
Tests on Unaged PMB														
1	PENETRATION (25°C,150g,5sn.)		TS EN 1426	0,1mm	90-150 (8)	40-100 (5)	45-80 (4)	45-80 (4)	45-80 (4)	25-55 (3)	25-55 (3)	25-55 (3)	25-55 (3)	25-55 (3)
2	SOFTENING POINT		TS EN 1427	°C	≥ 45 (8)	≥ 50 (8)	≥ 60 (6)	≥ 60 (6)	≥ 55 (7)	≥ 65 (5)	≥ 65 (5)	≥ 60 (6)	≥ 70 (4)	≥ 70 (4)
3	FORCE DUCTILITY (25°C, 5cm/dk)		TS EN 13589 TS EN13703	J/cm^2	≥ 0,5 (11)	≥ 0,5 (11)	≥ 0,5 (11)	≥ 0,5 (11)	≥ 0,5 (11)	≥ 0,5 (11)	≥ 0,5 (11)	≥ 0,5 (11)	≥ 0,5 (11)	≥ 0,5 (11)
4	ELASTIC RECOVERY (25°C)		TS EN 13398	%	≥ 80 (2)	≥ 80 (2)	≥ 60 (4)	≥ 70 (3)	≥ 80 (2)	≥ 60 (4)	≥ 70 (3)	≥ 80 (2)	≥ 60 (4)	≥ 70 (3)
5	FLASH POINT		TS EN ISO 2592	°C	≥ 220 (4)	≥ 220 (4)	≥ 220 (4)	≥ 220 (4)	≥ 220 (4)	≥ 220 (4)	≥ 220 (4)	≥ 220 (4)	≥ 220 (4)	≥ 220 (4)
6	SPECIFIC GRAVITY		TS EN 15326	g/cm^3	1.0-1.1									
7	DYNAMIC SHEAR RHEOMETER (DSR) (G*/sind >1kpa)	Failure Temp.	TS EN 14770	°C	≥ 58	≥ 64	≥ 70	≥ 70	≥ 70	≥ 76	≥ 76	≥ 76	≥ 82	≥ 82
8	*STORAGE STABILITY*		TS EN 13399											
8,1	Difference in Softening Point		TS EN 1427	°C	≤ 5 (2)	≤ 5 (2)	≤ 5 (2)	≤ 5 (2)	≤ 5 (2)	≤ 5 (2)	≤ 5 (2)	≤ 5 (2)	≤ 5 (2)	≤ 5 (2)
8,2	Difference in Penetration		TS EN 1426	0,1mm	≤ 13 (3)	≤ 13 (3)	≤ 13 (3)	≤ 13 (3)	≤ 13 (3)	≤ 9 (2)	≤ 9 (2)	≤ 9 (2)	≤ 9 (2)	≤ 9 (2)
9	*Tests On RTFOT (TS EN 12607-1)Aged Modified Bitumens*													
9,1	Change Of Mass		TS EN 12607-2	%	≤ 1 (5)	≤ 1 (5)	≤ 1 (5)	≤ 1 (5)	≤ 1 (5)	≤ 0.8 (4)	≤ 0.8 (4)	≤ 0.8 (4)	≤ 0.5 (3)	≤ 0.5 (3)
9,2	Increase In Softening Point		TS EN 1427	°C	≤ 8 (2)	≤ 8 (2)	≤ 8 (2)	≤ 8 (2)	≤ 8 (2)	≤ 8 (2)	≤ 8 (2)	≤ 8 (2)	≤ 8 (2)	≤ 8 (2)
9,3	Drop In Softening Point			°C	≤ 5 (3)	≤ 5 (3)	≤ 5 (3)	≤ 5 (3)	≤ 5 (3)	≤ 5 (3)	≤ 5 (3)	≤ 5 (3)	≤ 2 (2)	≤ 2 (2)
9,4	Retained Penetration		TS EN 1426	%	≥ 50 (5)	≥ 50 (5)	≥ 50 (5)	≥ 50 (5)	≥ 50 (5)	≥ 45 (4)	≥ 45 (4)	≥ 45 (4)	≥ 40 (3)	≥ 40 (3)
9,5	DYNAMIC SHEAR RHEOMETER (DSR) (G*/sind >2,2kpa)	Failure Temp.	TS EN 14770	°C	≥ 58	≥ 64		≥ 70	≥ 70	≥ 76	≥ 76	≥ 76	≥ 82	≥ 82
10	*Test on RTFOT (TS EN 12607-1)+PAV (TS EN 14769) Aged Modified Bitumen*													
10,1	DSR (G*sind <5000kpa)	Failure Temp.	TS EN 14770	°C	≤ 19	≤ 22	≤ 31	≤ 28	≤ 25	≤ 34	≤ 31	≤ 28	≤ 37	≤ 34
10,2	BENDING BEAM RHEOMETER (BBR) (S≤300 MPa, m≥0,300)	Temp.	TS EN 14771	°C	≤ -18	≤ -18	≤ -6	≤ -12	≤ -18	≤ -6	≤ -12	≤ -18	≤ -6	≤ -12

5. SURFACE CHARACTERISTICS

Pavement Friction Tester is used to measure the skid resistance of asphalt surface layer. The skid resistance of paved surfaces is measured by the use of a specified full-scale automotive tire. Skid resistance test method utilizes a measurement representing the steady-state friction force on a locked test wheel as it is dragged over a wetted pavement surface under constant load and at a constant speed while its major plane is parallel to its direction of motion and perpendicular to the pavement. Skid number (SN) must be greater than 30 for acceptance. If SN is less than 30, rehabilitation is needed.

Stone Mastic Asphalt layer is generally used as a wearing course in Turkey, and surface texture of new constructed SMA course shall be 1.0mm for Type-1 SMA (0-11) and 0,80mm for Type-2 SMA (0-8). TS EN 13036-1 Sand Patch Method is used for surface texture test.

Pavement roughness is one of the most important performance measures for pavement conditions and most frequently the triggering factor which identifies a roadway as a candidate for maintenance, rehabilitation and reconstruction. International Roughness Index (IRI) is measured by Turkish Highways for new roads and rehabilitated roads. For the acceptance of the construction of asphalt layers, it is needed that asphalt layers should provide specific IRI values. Payments for asphalt layers are made according to IRI values (Table 8).

Table 8: Payment adjustment depending on IRI

IRI (m / km)		
Binder course	**Wearing course**	**Payment Adjustment**
<1.30	<1.20	full payment
1.30 – 1.60	1.20 – 1.50	5% penalty
1.61 – 1.90	1.51 – 1.80	10% penalty
> 1.90	> 1.80	rejected (reconstruction)

6. CONCLUSION

In order to improve skid resistance of the asphalt surface layer in the Turkish highways:

- Microtexture is increased by using volcanic aggregate. Additionally, aggregate polishing is delayed.
- Macrotexture is increased by defining aggregate gradation of the asphalt mixture as open-graded, gab graded and semi-gab graded.
- Macrotexture is increased by applying gritting/sanding material over newly constructed asphalt surface layer.
- Macrotexture is increased by applying seal coat over exiting asphalt layer.
- Both fat spots and bleeding/flushing is prevented by using suitable bituminous binder for climatic conditions, and rutting is delayed
- Control of surface characteristic is provided by measuring surface texture depth and skid resistance
- Driving comfort is increased by roughness measurement and payment adjustment.

These new revisions provide opportunity for constructing safer highways with higher driving comfort.

It is not enough to make these changes within the specifications. The important point is to monitor and to evaluate these applications. These new applications should be complemented with follow-up activities. Main activities should include: the evaluation of skid resistance measurements to learn more about the impact of surface layer properties (e.g. aggregate type, gradation, binder, mix design) and the ranking of the factors (such as traffic, weather, environment) that have effect on skid resistance measurement.

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