Comparison of Flexible Pavement Geotechnical Parameters in Highways Technical Specifications

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ABSTRACT

Flexible pavements, also called asphalt pavements, are constituted of a bituminous surface course, subbase, and base layer constructed over a subgrade. The bituminous surface layer consisting of one or two layers transfers the traffic loads to the lower layers. The subbase and base layers of flexible pavements are constructed to support the surface layers and to distribute the loads from these layers to the subgrade safely. These layers must have the sufficient bearing capacity to support the surface layers and should also be resistant to detrimental environmental effects. In addition, the thickness of pavements is directly dependent on the bearing capacity of the subgrade. The materials used for the construction of the subgrade, subbase, and base layers in Turkey must meet the requirements specified in the Turkish Highways Technical Specifications. The previous specification published in 2006 was replaced by a new specification in 2013, which is still in effect. The current study compares the geotechnical parameters of the Highways Technical Specification published in 2006 and 2013 with a particular focus on flexible pavements. For an appropriate flexible pavement design, the importance of using high-quality and rigid materials that are more resistant to heavy loads, fragmentation, water sensitivity, and wearing effects of freezing and thawing is highlighted.

Keywords: Subbase, Flexible Pavement, Geotechnic, Highways Technical Specification, Subgrade, Base

Karayolları Teknik Şartnamelerinde Yer Alan Esnek Üstyapı Geoteknik Parametrelerinin Karşılaştırılması

ÖZ

Asfalt kaplamalar olarak da adlandırılan esnek kaplamalar, taban zemini üzerine inşa edilmiş bitümlü bir yüzey tabakası, alt temel ve temel tabakalarından oluşurlar. Bitümlü yüzey tabakası, bir veya iki katmandan oluşur ve trafik yüklerini alt katmanlara aktarır. Esnek kaplamaların alt temel ve temel tabakaları yüzey tabakalarını desteklemek ve bu tabakalardan gelen yükleri taban zeminine güvenle yaymak için inşaa edilirler. Bu tabakalar, bitümlü yüzey tabakalarını desteklemek için yeterli taşıma kapasitesine sahip olmalı ve ayrıca zararlı çevresel etkilere karşı dayanıklı olmalıdırlar. Ayrıca kaplama kalınlıkları doğrudan taban zeminin taşıma kapasitesine bağlıdır. Türkiye'de taban zemini, alttemel ve temel tabakalarının yapımında kullanılan malzemeler, Karayolu Teknik Şartnamesinde belirtilen gereksinimleri karşılamalıdır. 2006 yılından sonra yayınlanan ve halen yürürlükte olan mevcut şartname 2013 yılında yayınlanmıştır. Mevcut çalışma, 2006 ve 2013 yıllarında yayınlanan Karayolları Teknik Şartnamesi'nin geoteknik parametrelerini, özellikle esnek üstyapılara odaklanarak karşılaştırmaktadır. Uygun bir esnek üstyapı tasarımı için ağır yüklere, parçalanmaya, su hassasiyetine, donma ve çözünmenin aşındırıcı etkilerine karşı daha dirençli, kaliteli ve rijit malzemelerin kullanılmasının önemi vurgulanmıştır.

Anahtar Kelimeler: Alt Temel, Esnek Kaplama, Geoteknik, Karayolları Teknik Şartnamesi, Taban Zemini, Temel

INTRODUCTION

Road superstructures are generally classified into two categories based on structural behavior: Flexible and rigid pavement. While bitumen is used as binding material in flexible pavements, cement is used in rigid pavements (1). A flexible road structure is constituted of two parts substructure and superstructure. The substructure is composed of cuts and fills (2). On the other hand, the superstructure is a layered structure comprised of a surface course, base, and subbase that distributes the traffic loads to the infrastructure (3-5). The flexible pavement layers transfer the stress to the sub-layers by grain-to-grain transfer through the points of contact of the granular structure. A well-compacted and well-graded granular layer spread the loads over a wider area. The load distribution ability of these layers depends on the quality of the material used in layers (6-

8). The schematic view of the stress distribution of flexible pavement is given in Figure 1 (9).

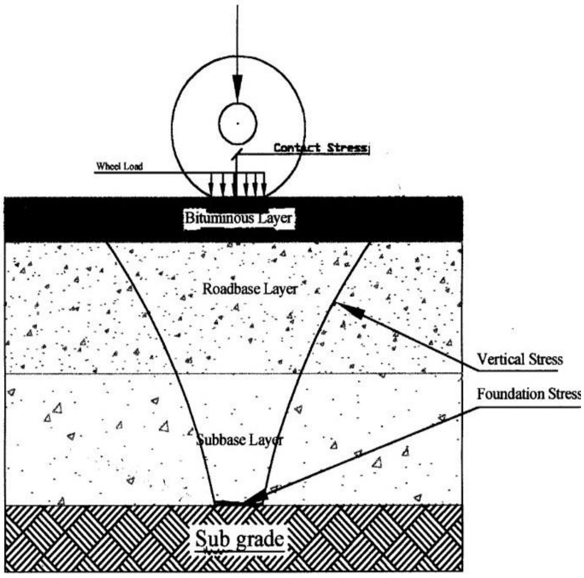

Figure 1. Stress Distribution in Flexible Pavement (9).

The surface course usually constitutes two bituminous layers as a binder and wearing or surface course. The subbase and base are constructed with granular materials as seen in Figure 2. Before building a superstructure, the substructure (subgrade) is prepared following the specifications to provide the desired support to the superstructure. The pavement performance is directly related to the granular layers. Therefore, providing a well-built subgrade, subbase, or base course under the surface course of flexible pavement enhances the pavement service life significantly and thus works out economically in the long term (8, 9).

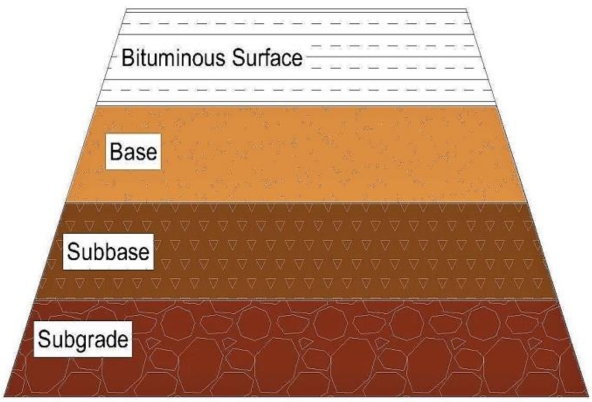

Figure 2. Layers of Flexible Pavement

The engineering properties of materials used in road construction are specified with technical specifications in societies. In Turkey, the required properties of road materials are determined by Highways Technical Specifications. Following the establishment of the General Directorate of Highways, the first technical specification was published in 1952. The Highways Technical Specification was updated in various years, including 1963, 1973, 1978, 1989, and 2006 taking into account the developments in the world and the innovations that our country needs. Finally, the specification, which is still current, was published in 2013 and is still up-to-date (10). In this study, a comparison of geotechnical parameters of Highways Technical Specification published in 2006 and 2013 for flexible road subgrade, subbase, and base layers was made and presented briefly. A comprehensive review of the literature indicates that this study is the first of its kind. It contributes to the current literature, providing significant insights, particularly into the position and development of the geotechnical parameters of flexible pavements in the technical specification.

MATERIALS AND METHODS

In this study, the Highways Technical Specifications published in 2006 and 2013 were used as material. The geotechnical properties of the subgrade, subbase and base layers were compared according to the 2006 and 2013 technical specifications.

Subgrade

The subgrade that is made of natural soil is the substructure layer of pavement and is prepared to withstand the loads transferred from superstructures (11). A real in-situ view of subgrade preparation is presented in Figure 3.

Figure 3. A subgrade construction

The subgrade is comprised of cuts and fills. If the elevation of natural soil is above the grade elevation (project elevation of road structure), the subgrade structure is formed with cuts work. In the opposite case, it consists of fills. The fill materials must be adequate for the technical properties indicated in Highways Technical Specification. The comparison of geotechnical properties of fill material according to the specifications of 2006 (HTS 2006) and 2013 (HTS 2013) is presented in Table 1.

Table 1. Geotechnical comparison of fill material for subgrade

Test	Specification Limits	
	HTS (2006)	**HTS (2013)**
Liquid Limit (LL), %	≤ 60	≤ 60
Plasticity Index (PI), %	≤ 35	≤ 35
Max. Dry Unit Weight (Standard Proctor)	≥ 1450 t/m^3	≥ 1450 t/m^3
Soaked CBR, %	≥ 8	> 8

When analyzing Table 1, it is determined that there is no change in limiting values for geotechnical properties of fill materials indicated in 2006 and 2013 technical specifications except the soaked CBR (California Bearing Ratio) value. While it was accepted that the CBR value should be greater than or equal to 8 in 2006, this value was requested to be greater than 8 in 2013 and it was desired to stay on the safer side by asking for more rigid material. The subgrade soil is required to constitute materials that are insensitive to freezing and thawing. There is no change in the limit values specified in both 2006 and 2013 technical specifications for materials that are not sensitive to freezing and thawing. The soil that is resistant to freezing and thawing must have a liquid limit value equal to or greater than 25%. The plasticity index value and water absorption in coarse aggregate must be equal to or less than 6% and 3%, respectively. In addition, the percentage of material that passes through the 0.075 mm sieve must be less than 12 (12, 13).

If the subgrade soil does not meet the criteria for the CBR value, it is replaced in the required thickness with soil that is called a protective layer and has a CBR value greater than 10%. The criteria specified for the protective layer are the same in both technical specifications. The liquid limit (LL), plasticity index (PI), and materials that pass through the 0.075 mm sieve are less than 40, 15, and 50%, respectively for the materials of the protective layer (12, 13).

The limit values of compaction for the fill section of the subgrade are the same in both technical specifications. The required compaction for the first 80 cm fill thickness is 100%, and 95% for the fill layers beneath 80 cm and determined using the proctor test (12, 13).

Subbase

A subbase is a layer of pavement constituted of granular materials and formed to support the base layer and transfer the loads to the subbase safely [8]. The subbase is an important layer for pavement for being a secondary load distribution and drainage layer and acts as a preparatory platform for the construction of the base layer of the road structure. The bearing capacity of the subbase is an important criterion as it affects the strength and durability of flexible pavement. The lower subbase material quality results in thicker pavement layers, increasing the cost of road construction. It may be omitted for the roads that only serve foot traffic; however, it is necessary for the roads that serve the vehicle (14-17). A view of subbase preparation from in situ is given in Figure 4.

Figure 4. A subbase layer construction

The materials to be used in subbase construction could be sand, gravel, bank gravel, decomposed rock, slag, crushed stone, and scraped asphalt. The term scraped asphalt is used first in HTS (2013). The ratio of scraped asphalt to be used in the mixture is a maximum of 25% as given in the specification and will only be used in the manufacture of Type B subbase given in Table 2 (12, 13). The comparison of types of subbase according to the sieve analysis is presented in Table 2. When examining Table 2, it is recognized that only gradation limits of Type B changed in HTS published in 2006 and 2013 to obtain more dense mixtures (12, 13).

When the subbase material is supplied from sand-gravel quarries, the gradation of the run-of-the-mine material will be following the Type A gradation limits. In case the subbase material is prepared by crushing from sand-gravel or quarries, the gradation of the material should obey Type-B gradation limits (12,13).

The comparison of required geotechnical properties of the subbase layer in HTS (2006) and HTS (2013) is presented in Table 3 (12, 13).

When examining Table 3, it is recognized that the required specification limits of liquid limit (LL), and plasticity index (PI) remained the same for both technical specifications. While in HTS (2006) the Los Angeles value is desired to be equal to or less than 50%, in HTS (2013) this limit is reduced to 45, and it is recommended to stay on the safer side by asking for more resistant aggregates against fragmentation. In addition, there were no limitations on water absorption of the subbase material in HTS (2006). However, it was limited to a maximum of 3.5% in HTS (2013) targeting more durable aggregate against freezing-thawing cycles. The quantity of organic matter in subbase material was limited to a maximum of 1% in HTS (2006), whereas it was required not to contain any organic material in HTS (2013) because of affecting the durability of the road structure adversely. As for thermal and weathering durability of subbase material, in HTS (2006), this test was specified to conduct with Na_2SO_4 solution and it was required not to pass the value of 20%. However, this test was declared to conduct with $MgSO_4$ solution in HTS (2013) and was required not to exceed the value of 25%.

Table 2. Comparison of gradation limits of subbase material

Sieve	Specification limits			
	Type-A % Passing		Type-B % Passing	
	HTS (2006)	HTS (2013)	HTS (2006)	HTS (2013)
75	100	100	-	-
50	-	-	100	100
37,5	85-100	85-100	80-100	80-100
25	-	-	60-90	60-90
19	70-100	70-100	-	45-80
9,5	45-80	45-80	30-70	30-70
4,75	30-75	30-75	25-60	25-55
2,00	-	-	15-40	15-40
0,425	10-25	10-25	10-20	10-20
0,075	0-12	0-12	0-12	0-12

Table 3. Geotechnical comparison of subbase material

Test	Specification Limits	
	HTS (2006)	HTS (2013)
Liquid Limit (LL), %	≤ 25	≤ 25
Plasticity Index (PI), %	≤ 6	≤ 6
Los Angeles, %	≤ 50	≤ 45
Water Absorption, % (For fine and coarse agg.)	-	≤ 3,5
Organic Matter, %	≤ 1	Negative
Clay Lump and Dispersible Grain ratio, %	≤ 2	≤ 2
Thermal and Weathering Durability, %	≤20 (Na_2SO_4)	≤25 ($MgSO_4$)

The soaked CBR value for the subbase material that is compacted to the degree of 97% maximum dry density should be a minimum of 30% and 50% for Type-A and Type-B, respectively specified in HTS (2006). In HTS (2013), only the compaction degree was increased to 98%, the other parameters for CBR remained the same (12, 13). The comparison of compaction parameters according to the modified proctor test of subbase material in HTS (2006) and HTS (2013) is presented in Table 4. It was determined from Table 4 that the required compaction degree was increased by 1% for both types of subbase materials in HTS (2013) targeting denser structures compared with HTS (2006). The moisture content remained unchanged in both two technical specifications (12, 13).

Table 4. Compaction criteria comparison of subbase material

Test	Specification limit			
	Type-A		Type-B	
	HTS (2006)	HTS (2013)	HTS (2006)	HTS (2013)
Minimum Compaction, %	95	96	97	98
Optimum Moisture Content, %	$W_{opt} \pm 2$		$(W_{opt} - 2)$- W_{opt}	

Base

The base which is one of the main superstructure layers with certain characteristics is constructed in a determined thickness over the subbase layer to support the surface course layer, distribute the stress, provide good drainage and minimize the freezing and thawing effect. The base layer should have sufficient thickness to receive and distribute traffic loads and should be constructed with good-quality materials (8, 15, 17, 18). A situ view of the base layer construction is given in Figure 5.

Figure 5. A base layer construction

The foundation layer is built on a subbase or subgrade with sufficient bearing capacity in three types as specified in the Highways Technical Specification:

1- Granular Base: A type of layer that is constructed by using gravel, crushed gravel, crushed slag or crushed stone, and fine material, mixing the material prepared to give continuous gradation within certain gradation limits with water and, in one or more layers, on the subbase or subgrade layer with sufficient bearing capacity prepared following the specifications, in the form of one or more layers, according to the plan specified in the project. It is the layer formed by laying and compacting per the profile and cross-sections.

2- Plant-mix Base: A type of base layer is constructed on the prepared surface of the material formed by mixing at least three different particle size groups, coarse and fine, in a plant with appropriate proportions of water, using crushed gravel, crushed slag, crushed stone, and fine material to provide continuous gradation within certain gradation limits. It is the layer formed by laying and compacting one or more layers following the specified plan, profile and cross-section.

3-Cement-bound granular base layer: A type of layer that is constructed with the material prepared by mixing the cement-bound foundation layer, crushed gravel, crushed slag, crushed stone, and fine material to give continuous gradation within certain gradation limits in a plant with appropriate proportions of cement and water, and on an adequate subbase, the plan, profile specified in the project and it is the layer formed by laying and compacting one or more layers following the cross-sections (12, 13, 19).

In the construction of the three types of base layers given above, an aggregate could be gravel, crushed gravel, crushed stone, sand, and slag. The required coarse and fine aggregate properties from three types of the base layer and their comparison between technical specifications published in 2006 and 2013 are presented in Table 5 and Table 6, respectively (12, 13).

When Table 5 is analyzed, it is recognized that some geotechnical specifications changed with HTS (2013). In HTS (2006), the flakiness index was determined for the granular base and plant-mix base separately for each standard. However, it was given for the whole layer in HTS (2013). The flakiness index ratio decreased with HTS (2013) by targeting a more rigid aggregate because of aggregate that has high flakiness index is crushed under heavy loads simply. The Los Angeles value decreased from 40% to 35% with HTS (2013) thus again staying on the safe side in selecting aggregate. As for water absorption, it is not given a limit value in HTS (2006). However, it was noted that if the aggregate has a water absorption value greater than 4%, it will be decided whether the aggregate will be used after the freezing test. In HTS (2013), the water absorption value of aggregate was limited to 3%. Similar to the subbase, the thermal and weathering test was specified to conduct with different solutions. In HTS (2006), this test was declared to conduct with Na_2SO_4 solution and the maximum value was 15%. However, in HTS (2006), the preferred solution was $MgSO_4$ and the limit value was 20%. In Table 6 for fine material, while the limit values of liquid limit and plasticity index are given in HTS (2006), it was requested to be non-plastic material in HTS (2013). So, it was aimed to use an aggregate that is not sensitive to water. It is stated that the administration will decide whether to use aggregates with a water absorption value of more than four percent in the fine material, similar to the coarse material, after the natural frost test. The organic matter ratio was limited to 1% in HTS (2006). However, in HTS (2013), it was requested that the material should not contain any organic matter (12,13).

Table 5. Geotechnical comparison of base for coarse material

Test	Specification Limits	
	HTS (2006)	HTS (2013)
Flakiness Index, %	≤ 40[1] ≤ 35[2]	≤ 30[3] ≤ 25[4]
Clay Lump and Dispersible Grain Ratio, %	≤ 1	≤ 1
Los Angeles, %	≤ 40	≤ 35
Water Absorption, %	-	≤ 3
Organic Matter, %	Negative	Negative
Thermal and Weathering Durability, %	≤15 (Na_2SO_4)	≤ 20 ($MgSO_4$)

[1]:Flakiness index for granular base following BS 812
[2]:Flakiness index for plant-mix base following BS 812
[3]:Flakiness index for base following BS 812
[4]:Flakiness index for base following TS EN 933-3

Table 6. Geotechnical comparison of base for fine material

Test	Specification Limits	
	HTS (2006)	HTS (2013)
Liquid Limit (LL), %	≤ 25	NP
Plasticity Index (PI), %	≤ 6	NP
Clay Lump and Dispersible Grain Ratio, %	≤ 1	≤ 1
Water Absorption, %	-	≤ 3
Organic Matter, %	≤ 1	Negative

The base material for the granular base layer was divided into three groups Type-A, Type-B, and Type-C according to the gradation limits in HTS (2006) and HTS (2013). The material that is used for the base layer is required to be within gradation limits and should be well-graded. Table 7 states the comparison of HTS (2006) and HTS (2013) for granular bases according to the gradation limits. When Table 7 is analyzed, it is recognized that there is a change in gradation limits in Type-A material. The gradation limits remained the same in both technical specifications. In HTS (2013), it is requested that Type-A and Type-B granular base material is used in asphalt concrete roads. In state roads that will be constructed as chip seals, Type-A or Type-B gradation limits should be used. In provincial roads that will be constructed as chip seals, one of Type-A, Type-B and Type-C could be used depending on the project conditions.
In HTS (2006), the gradation limits of granular base material should meet one of Type-A, Type-B, and Type-C in asphalt concrete roads (11,12). In chip seal roads, if the thickness of the base layer specified in the project is less than 20 cm, the entire layer of the granular base will be constructed with Type-C. If it is more than 20 cm, the granular base could be constructed with one of Type-A, Type-B, and Type-C.

Table 7. Comparison of gradation limits of granular base material

Sieve	Specification limits Type-A % Passing HTS (2006)	Type-A % Passing HTS (2013)	Type-B % Passing HTS (2006) HTS (2013)	Type-C %Passing HTS (2006) HTS (2013)
50	100	100	-	-
37,5	80-100	80-100	100	-
25	60-90	60-90	70-100	100
19	-	45-80	60-92	75-100
9,5	30-70	30-70	40-75	50-85
4,75	25-55	30-75	30-60	35-65
2,00	15-40	-	25-40	25-50
0,425	8-20	10-25	10-25	12-30
0,075	2-8	0-12	0-12	0-12

In both technical specifications, the soaked CBR values of the granular base materials that are compressed to 98% of the maximum dry unit weight found with the Modified Proctor should not be less than 100%. The compaction parameters remained the same in both HTS (2006) and HTS (2013). The minimum compaction degree and moisture content according to the modified proctor test is 98% and (Wopt - 2) – Wopt, respectively in both technical specifications.

The plant-mix base material is divided into two groups according to the gradation limits as Type-I and Type-II in HTS (2006) and HTS (2013). In both technical specifications, the plant-mix base layer materials have the same gradation limits as given in Table 8 (12,13).

Table 8. Comparison of gradation limits of plant-mix base material

Sieve	Specification limits Type-I % Passing HTS (2006)	Type-I % Passing HTS (2013)	Type-II % Passing HTS (2006)	Type-II % Passing HTS (2013)
37,5	100	100	-	-
25	72-100	72-100	100	100
19	60-92	60-92	80-100	80-100
9,5	40-75	40-75	50-82	50-82
4,75	30-60	30-60	35-65	35-65
2,00	20-45	20-45	23-50	23-50
0,425	8-25	8-25	12-30	12-30
0,075	0-10	0-10	2-12	2-12

In HTS (2013), it was specified that if the thickness of the plant-mix base layer is equal to or greater than 15 cm based on the design project, the plant-mix base materials must stay within Type-I gradation limits. If it is less than 15 cm, Type-II gradation will be used then. However, in HTS (2006), there was no information on which type of rating should be used and under what conditions. In both technical specifications, the soaked CBR values of the plant-mix base materials that are compressed to 100% of the maximum dry unit weight found with the Modified Proctor should not be less than 120%. The compaction parameters remained the same in both HTS (2006) and HTS (2013). The minimum compaction degree and moisture content according to the modified proctor test are 100% and (Wopt–1) – Wopt, respectively.

In the cement-bound granular base layer in both technical specifications of HTS (2006) and HTS (2013), one type of gradation limit was used and there was seen no change in gradation limits as seen in Table 9. In both technical specifications, it was stated that the compressive strength of the 7 days cured cement-bound granular base materials that are compacted to the degree of 98% of the maximum dry unit weight that is found with the modified proctor test should be between 35-55 kg/cm^2. The compaction degree that is found following the modified proctor test for both technical specifications should not be less than 98%.

Table 9. Comparison of gradation limits of cement-bound granular base material

Sieve	Specification Limits % Passing HTS (2006)	Specification Limits % Passing HTS (2013)
37,5	100	100
25	72-100	72-100
19	60-92	60-92
9,5	40-75	40-75
4,75	30-60	30-60
2,00	20-45	20-45
0,425	8-25	8-25
0,075	0-10	0-10

CONCLUSION

The Highways technical specification was last published in 2013 by the General Directorate of Highways and is still in effect. As a result of the development of technologies, the specifications are constantly updated and renewed by the administrations in line with the requirements. In this study, a comparison was made between the Highways Technical Specifications published in Turkey in 2006 and 2013 in terms of geotechnical parameters of flexible pavements. The subgrade, subbase, and base layers of flexible pavement are the main topics of this study. The geotechnical parameters in the technical specifications were compared comprehensively. When the last specification is compared with the previous specification, it is seen that the geotechnical parameters are more stringent in terms of material quality. In the current specification, it is requested that the aggregates used in flexible pavement granular layers have higher stability, fragmentation and abrasion resistance, and durability performance, thus it is aimed to obtain more rigid and stable mixtures. In addition, it is recommended to produce denser mixtures by changing the aggregate gradation with the current specification. It is thought that this study will contribute to the current literature on the position and development of the geotechnical parameters of flexible pavements in the technical specifications.

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