Analysis of Pavement Construction on a Sample Forest Road Section in Sarıyer Region

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Abstract

The maintenance of the forest roads includes constructing and reconditioning the pavements, maintaining the stream crossing structures along the route, cleaning and improving the ditches, and straightening the holes and barrows on the roadway. In this study, pavement construction activities in a sample forest road section, especially with heavy traffic loads, are examined in various aspects. The research was performed in the forest of Sarıyer Forest Enterprises, located in the Istanbul District Directorate of Forestry. The pavement of a B type forest road with 02 code in Rumeli Feneri was examined and various field measurements were taken such as cross section, slope, and soil compaction values. The deformation of the pavements in first year after construction was examined and the suitability of the pavement was also analyzed.

Key Words: Pavement, forest road, compaction, crushed material

1. Introduction

In order to take the advantage of main forestry activities such as protection, afforestation, management, recreation, and fire fighting, a well constructed and maintained forest road network should be established at first. There are Type A and Type B forest roads in Turkey to provide access into the forested areas (GDF, 1984). These forest roads are constructed by considering road types and sizes, intended usage, and land conditions. After the construction, the forest roads should be maintained and repaired at certain periods to preserve structural integrity and travel quality of the forest

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roads (Akay, 2006). If the maintenance and repair activities are not performed, deformations formed on road surface may block the usage of the road. The pavement construction activities on approximately 17% of the forest roads have been completed in Turkey (Acar and Eker, 2001).

Wheel load and nominal ground pressure results in temporary deformations on both pavement and substructure along the roadway (Bayoğlu, 1997). Due to the pressure of the wheels on the ground, the substructure moves to the sideward, causing the breakdowns. Additionally, after a certain period, the access of the road can be completely closed due to the excessive amount of moisture, breakdowns, and ruins caused by heavy load and lack of road maintenance (Figure 1).

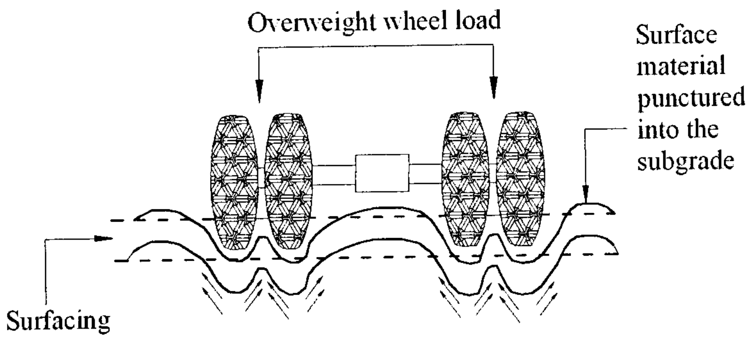

Figure 1. Shear failure of a road surface because of overweight wheel load
Şekil 1. Tekerlek yükü altında yol yüzeyinin biçim değişiklikleri
(Keller and Sherar, 2003)

According to FAO (1998), local factors such as the surfacing material, climate and traffic mix, gradient, and vehicle speed influence the rate of surface deterioration. For example, re-grading is suggested after 20000 vehicle passes as a typical interval. The following indicates the average number of vehicle passes with respect to re-grading intervals:

Vehicles per year	Re-grading interval
> 20000	less than one year
12000 – 20000	1 year
8000 – 12000	2 years
6000 – 8000	3 years
5000 – 6000	4 years
< 5000	5 years

Surface maintenance can be also computed depending on the timber volume transported over the road such as 2.5 cm rock displacement for every 4500 m^3 timber haul (Akay and Sessions, 2003). Kramer (2001) stated that maintenance, road drainage, pavement, and ditch improvement activities must be periodically scheduled in every year.

The type of surfacing material should be chosen by considering traffic load, frequency of usage, grade of road, soil type in natural roadbed, available materials, cost, and aesthetics. To ensure a good bond between the soil and surfacing material and to provide early protection against soil erosion, crushed rocks or gravel surfacing materials should be placed on the surface instantly after road construction (Anonymous, 2005). Road maintenance is also very important for water quality, considering drainage control and streamside management (Turton et.al., 2005). After periodic forest operations have been completed and major storm events has passed, forest roads must be maintained during active use to ensure that the drainage structures are functioning properly. In spreading pavement materials on the road surface, graders should be used (Skorseth and Selim, 2000).

Heavy rainstorms may cause cut slope failures that blocks ditches, directs water flows to the road surface, and erodes the surface and fill slope. Proper road surface is usually desirable and, in many cases, necessary to add subgrade structural support by improving the roadbed of native soil surface with materials such as gravel, coarse rocky soil, crushed aggregate, cobblestone, concrete block, or some type of bituminous seal coat or asphalt pavement (Bayoğlu, 1969). Gravel materials are mostly used to ensure stable pavement on forest surface.

The periodic maintenance of the roads should be completed before forest transportation starts in spring or after the forest transportation ends in autumn. Besides, a pavement should be constructed on the forest roads where daily and annual vehicle traffic volume is very high and that should be kept open during the year.

Pavement constructed on a forest road limits the movement of the ground to sideways and therefore it prevents a vertical deformation (GDF, 1984). Pavement of a forest road is divided into two layers including surface course and base course (Figure 2).

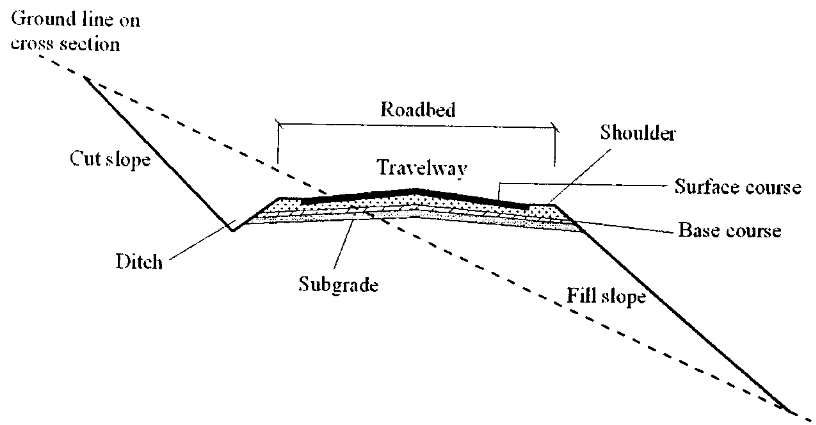

Figure 2. Road template elements
Şekil 2. Yol enkesit elemanları

Materials used in pavement construction activities are;

1) Natural stone materials (ingenious rock, sedimentary rock, metamorphic rocks)
2) Natural aggregates (gravel, sand)
3) Artificial aggregates (cement)
4) Asphalt (Umar and Agar, 1985).

In the forest roads of Turkey, gravel and crushed rocks are generally used for pavement materials. Asphalt is used for the forest roads located in national parks, recreational areas, and some forest village roads. In last few years, industrial wastes such as lime mud have been aslo used in pavement construction activities (Eroğlu, 2003; Machado et.al., 2004).The objective of this study is to examine the pavement construction activities in a sample forest road section, especially with heavy traffic loads. The study was conducted in forest of Sariyer Region Forest Enterprises, located in the Istanbul District Directorate of Forestry. A sample Type B forest road section with 02 code was selected from Rumeli Feneri. Various field data were collected such as cross section, slope, and soil compaction values. Deformation of the pavements after the first year of construction was also examined to evaluate the suitability of the pavement.

2. Material and Methods

2.1. Pavement thickness

Strew thickness of the surface materials is generally determined by "Group Index (GI)" method, which was developed by Steele (1945). There are five categories in this method and these categories are determined according to average daily traffic. The pavement is calculated according to ground compaction, which is measured based on Group Index. Ground compaction varies with the following factors;

1) Moisture proportion of ground
2) Dry density of ground
3) Configuration of ground

Since the first and the second factors can be controlled by a good drainage and compression of subgrade, ground compaction shall only be reflected by the third factor, which refers to the structure of ground. Group Index method was developed based on this assumption.

Group Index of a ground can be calculated by the following equation (Umar and Agar, 1985);

$$GI = 0.2 \times (a) + 0.005\ (a \times c) + 0.01\ (b \times d)$$

where

a = The amount of the ground sifted with the sieve no. 200 that is greater than 35 % and less than 75% (it is expressed as a cardinal number between 0 – 40)

b = The amount of the ground sifted with the sieve no. 200 that is greater than 15% and less than 55% (it is expressed as a cardinal number between 0 – 40)

c = The part of numerical liquidity limit of the ground that is greater than 40 and less than 60 (it is expressed as a cardinal number between 0 – 20)

d = The part of numerical plasticity indices of the ground that is greater than 10 and less than 30 (it is expressed as a cardinal number between 0 – 20)

After all these values are obtained, the thickness of the pavement material can be found. An abacus was developed to determine the pavement thickness required for the forest road (Umar and Agar, 1985; Aykut, 1978).

2.2. Study area

The study area consists of Type B forest roads with 02 code, located in Sariyer Region Forest Enterprises in Istanbul. Total length of the sample road is about 2700 m with the average road width of 4 m. The soil type in the study area is sandy loamy. 02 code forest roads were constructed as dirt roads about 15 year ago and pavement construction was not performed on this road .

The observations of the sample road prior to the pavement activity indicated that ditches were filled and some parts of the road surface were deformed. Based on the field investigation, no passage could be provided, due to excessive deformation on some parts of the road. The further investigation indicated that damages have occurred on head wall parts of drainage structures and on culvert aprons (Figure 3).

Figure 3. The conditions of 02 code forest road, ditch, and roadbed prior to pavement activities (Photo: T.Ozturk)
Şekil 3. 02 Kod nolu orman yolunun üstyapıdan önceki durumu

2.3. Pavement activity

First, the deformation on Type B forest road and the general condition was examined and photographed. It was observed that almost all road pavements were in poor condition, filled with eroded soil, siltation, trees, trunks, and branch residues. It was also inspected that some of them were broken and eroded partially. On the other hand, it was seen that beneath the head and sideways of some culverts have been eroded.

Along the roadway, cross sections were taken at every 50 meters and soil compaction value was measured from 5 different points on each cross section by using a Eijelkamp pocket penetrometer; one point on cut slope, one point on fill slope, and three points on travelway of the road template (Figure 4). The average measurements were computed for two stages of the sample road where the first stage is from cross section 1 to 20 and the second stage is from cross section 21 to 50.

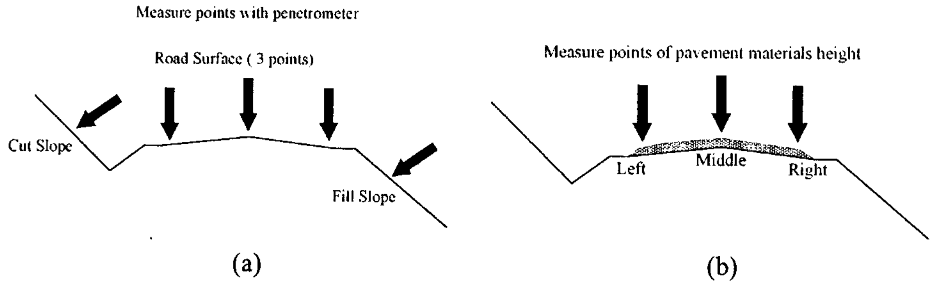

Figure 4. a) Measurement points where soil compactions were taken by penetrometer
b) Measurement points where thicknesses of the pavement materials were taken
Şekil 4. a) Penetrometre ile toprak sıkışmasının ölçüldüğü noktalar
b) Üstyapı materyalinin kalınlığının ölçüldüğü noktalar

The road gradient was measured between each cross section point. For each cross section, road template data such as lengths and ratios of cut slope and fill slope, width of ditch, and road width were measured. Then, the cross section data were stored into the computer using AutoCad 2005 software. It was also marked that there were size 8 culverts and size 2 concrete pipes along the roadway. In the second part of field study, pavement activity was conducted. In this part, the construction machines working on the pavement activity were examined, and the thickness of material spread on the road surface was measured from three different points on the cross sections (Figure 4). Besides, the width of the pavement material was determined at each measurement point.

It has been observed that three different sizes of materials were used along the roadway. Thick material has been used on the wet and marshy road surfaces and normal-size and smaller material has been used on sound road surfaces. The materials were transported by double-shafted BMC and Mercedes branded trucks and spread on the road surface by a Caterpillar loader. After the pavement material was spread on the road, the pavement was compacted by a Dynapa type cylinder. Figure 5 indicates the

final status of pavement. After the pavement activity, harvesting operation was conducted in the forest around sample road and trees were extracted by using the tractors through the sample road. Total timber volume transported was approximately 600 m^3.

Figure 5. A view from the forest road after pavement activity (Photo: T.Ozturk)
Şekil 5. Üstyapı çalışmasından sonra orman yolundan bir görünüş

3. Results and Discussion

Within the boundary of the Sariyer Regional Forest Enterprises, pavement construction of 02 code road was planned in 2005, and got bid by the forest directorate, and then built by a contractor. The determination of material quantity, computation of construction costs, and other necessary activities were carried out by technicians in the Branch of the Machine Maintenance Directorate within Istanbul Regional Forestry District. The total road length and the amount of pavement material were calculated as 2700 meters and 2310 m^3, respectively. The distance between the road and material storage was 14.1 kilometers. Throughout the road, six crossfields were determined and the construction costs of those crossfields were added onto the total costs of the project. Within the first 800 meters of the road, the estimated material height was determined as 20 cm, whereas it was determined as 30 cm in the rest of the road. Table 1 shows the average values of pavement thickness and pavement widths for two road stages.

Before starting pavement construction activities, the average values of soil compaction at cut slope, fill slope, and road surface was 1.75 kg/cm^2, 1.55 kg/cm^2, and 4.00 kg/cm^2, respectively. After constructing the pavement, the penetrometer values over the road were measured as larger than 5 kg/cm^2. This proved that after the maintenance activity, the road became more enduring, stronger, and more suitable for transportation than that of prior to maintenance. Table 2 indicates the average compaction values and road grades for two road stages. Total construction cost of the road is calculated as $24000 with the unit cost of $8890 per km.

Table 1. The average values of pavement thicknesses and widths for the road section

Tablo 1. Yol bölümleri için üstyapı kalınlığı ve genişliğinin ortalama değerleri

Road Stages Yol Kısımları	Road gradient (%) Yol eğimi	Average soil compaction (kg/cm²) Ortalama toprak sıkışması		
		Cut slope Kazı şevi	Road Surface Yol yüzeyi	Fill slope Dolgu şevi
1	- 6	1.70	4.50	1.10
2	+ 3	1.80	3.50	2.00
Average Ortalama		1.75	4.00	1.55

Table 2. The average values of soil compaction and gradient data for the unpaved road
Tablo 2. Üstyapısız yolda ortalama toprak sıkışma değerleri

Road stages Yol Kısımları	Average pavement thickness (cm) Ortalama üstyapı kalınlığı			Average pavement width (m) Ortalama üstyapı genişliği
	Left Sol	Middle Orta	Right Sağ	
1	19	18	20	3.80
2	21	20	21	3.90
Average Ortalama	20	19	20.5	3.85

During the pavement construction activities, material thickness was measured periodically in each 50 meters. For the first 1000 meters, average material thickness was measured as 19 cm, whereas it was measured as 21 cm for the rest of the road. After 800 m section of the road, material scattering thickness was planned as 30 cm, but it was measured less than that of planned thickness. The width of material scattering through the road was planned as 3 meters and it was measured as it was.

After completing pavement activity, the width of scattered materials was measured as 3.90 meters as an average for the first 1000 meters of the road, while it was measured 3.80 meters as an average for the rest of the road (Figure 6). The reason for such a difference is because of using loader when scattering the materials, instead of grader. Simply, loader cannot scatter the materials evenly and homogenously, therefore, the material thickness became different in different parts of the road. In contrast, grader may take the overflowed materials back to the middle of the road and scatters the materials more homogenous than that of loader.

The quantity of the materials used for pavement, including crossfields, was calculated as 2310 m ^{3}. The planned material thickness was similar to the thickness of the pavement material used in the application. The reason for that the material scattering width was wider than 3 meters (3.80 m and 3.90 m).

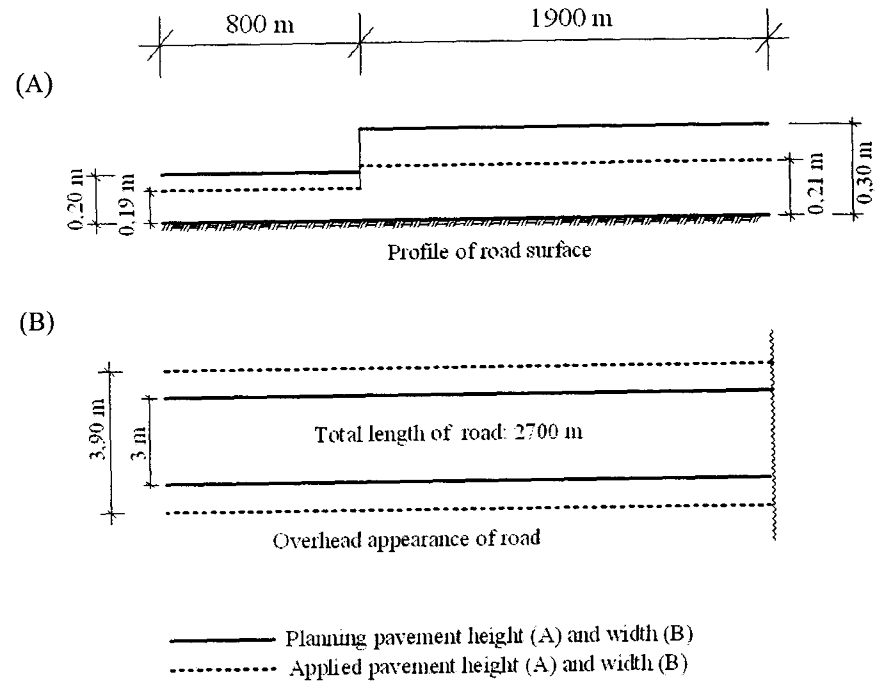

Figure 6. Thickness and width of planned and applied pavement materials
Şekil 6. Planlanan ve uygulanan üstyapı kalınlığı ve genişliği

In the last part of the pavement, scattered material was tightened by a road roller. Due to insufficiently tightening and unevenly distributing the materials, the materials have been scattered throughout the road after passing a winter season (Figure 7). On the other hand, since the side ditches could not be opened enough when locating pavement, the ditches could not function well and the materials have caused damage to the surface of the road, following winter and spring rainfalls. Suitable materials have been used for pavement, which means that, in the swamps, large materials were used, whereas, in the regular road structure, small materials were preferred. In Table 3, the results from the sieve analyses of pavement materials were listed, considering thick, normal, and thin materials.

Figure 7. The condition of a part of paved road – one year later (Photo: T.Ozturk)
Şekil 7. Bir yıl sonra üstyapı yapılmış yolun bir bölümünün durumu

During the road construction work, culverts and concert pipes were needed within nine different points of the forest road with 02 code. Then, it was contemplated that this problem was solved by constructing culverts and concert pipes in a particular size. Due to constructing insufficient number of culverts and concert pipes in necessary places, water from rainfall and cut slopes have been accumulated in side ditches and could not be transferred across the road, and thus, the road and its coat were always left humid and damped.

As a result, when heavy vehicles and trucks were driven, the road has been seriously deformed and damaged. On the other hand, the scattered materials were sunk into the ground and could not function well.

The trees, trunks, soil, and other materials were filled in the entrance and exit of the culverts and concert pipes, and blocking overflow were cleared by a small excavator. Therefore, the constructions have been functioned again. Then, throughout the road, it was investigated that parts of the some culverts and concert pipes were broken and dropped into the creeks. As a solution, it was recommended that the structures should be repaired and their maintenance work should be carried out regularly. Deformation at ditches and lost of pavement materials are showed in Figure 8.

Table 3. The summary of sieve analyses for the pavement material
Tablo 3. Üstyapı materyali için elek analizinin özeti

Normal Pavement Material Samples Normal üstyapı materyalinin Örnekleri		(Bag weight 3.10 gr) (Torba ağırlığı)	
Screen diameter Elek yarıçapı (mm)	Bag number Torba Numarası	Sample weight (gr) Örnek ağırlığı	Percent (%) Yüzde
38.1	1	197.90	8.14
25.4	2	453.76	18.66
19.0	3	691.59	28.44
9.51	4	706.64	29.06
4.75	5	254.88	10.48
Binder	6	127.15	5.22
		2431.92	100
Thick Pavement Material Samples İnce Üstyapı Materyalinin Örnekleri		(Bag weight 3.10 gr)	
Screen diameter (mm)	Bag number	Sample weight (gr)	Percent (%)
50.8	1	914.69	35.77
38.1	2	400.93	15.68
25.4	3	622.73	24.35
19.0	4	316.84	12.39
9.51	5	228.03	8.92
4.75	6	53.77	2.10
Binder	7	20.16	0.79
		2557.15	100
Thin Pavement Material Samples Kalın üstyapı materyalinin Örnekleri		(Bag weight 3.10 gr)	
Screen diameter (mm)	Bag number	Sample weight (gr)	Percent (%)
38.1	1	122.80	8.40
25.4	2	143.39	9.80
19.0	3	113.54	7.76
9.51	4	263.07	17.99
4.75	5	381.09	26.05
Binder	6	438.81	30.00
		1462.70	100

Figure 8. Deformation at ditches and lost of pavement materials (Photo: T.Ozturk)
Şekil 8. Üstyapı materyalinin kaybı ve hendeklerdeki deformasyon

4. Conclusions

In this study, the challenges in pavement activity on forest roads are presented and some suggestions are provided in the light of the results from a sample pavement construction activity on a forest road section from Sariyer region in Turkey. Before starting pavement on a forest road, the crashed and pressed areas on the distorted parts of the road should be prepared for pavement work and the coat part of the road should be smoothed by means of bulldozer. At this preparation stage of the road, to properly spread material, sufficiently wide area should be scraped at least 10 cm deep by bulldozer, which will yield a good result. Therefore, the risk of the sliding material to right and left of the road will be also reduced, and the borders of the work places will be kept clear.

During pavement work, the recommended spreading width of the material should be complied. The material that spread wider than it was necessary flows to ditches or downwards from the fill slope and lost. As a result, the material thickness will be lower and more material will be wasted. The materials should be spread on the road by a bulldozer. Bulldozer can distribute the material on the road homogeneously and can better adjust the thickness of the spread material.

One of the most important matters that should be noted is that the pavement material that flows to ditches or road sides should not be taken from the area that exists and should not be re-used as mixed with soil. Pavement material mixed with forest soil can reduce the resistance of road surface. The other important task in a pavement activity of a forest road is opening the ditches and performing the maintenance of the ditches. Lacking or closing of the ditches along the road sides enables the rain water frequently moves on the road that damages the road and the pavement material. Besides, bevel should be banked on both sides of road axis on flat places, and the material should be spread in pavement activity by considering these bevels.

Sarıyer Bölgesinde Örnek Bir Orman Yolu Bölümünde Üst Yapı Çalışmalarının Analizi

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Özet

Orman yollarının bakım çalışmaları, kenar hendeklerinin düzeltilmesi ve açılması, yol üst yapısının inşası veya yenilenmesi, yol güzergahında yer alan sanat yapılarının bakımlarının yapılması, yol üzerindeki çukur ve tümseklerin düzeltilmesini içermektedir. Bu çalışmada, orman yolları için çok önemli olan ve özellikle trafik yükü fazla olan orman yollarında gerekli olan üst yapı çalışmaları tüm yönleriyle incelenmiştir. Bu araştırma İstanbul Orman Bölge Müdürlüğü bünyesinde bulunan Sarıyer Orman İşletme Şefliği ormanlarında yapılmıştır. Çalışmada, Rumeli feneri mevkiinde yer alan 02 kod nolu B tipi orman yolunun üst yapı çalışmaları incelenerek, çeşitli ölçmeler yapılmış (enkesit, eğim, zemin sıkışma değerleri vb.) ve üst yapı çalışmalarının bitirilmesinden sonraki bir yıl içerisinde yol üst yapısında meydana gelen deformasyonlar araştırılmıştır ve inşa edilen yol üst yapısının uygun olup olmadığı ortaya konmuştur.

Anahtar Sözcükler: Üst yapı, orman yolu, sıkışma, kırılmış malzeme

1. Giriş

Orman yollarının yapım çalışmalarından sonra belirli periyodlarda bakım ve onarım çalışmalarının yapılması gerekmektedir. Üretim çalışmaları sırasında orman yollarında taşıma yapan ağır kamyonlar nedeniyle yol üst tabakası büyük zarar görmektedir. Üretim çalışmaları bitirilip üretim alanından ayrıldıktan ve kış sezonu bittikten sonra yeni üretim sezonundan önce mutlaka yolun bakımı yapılmalıdır. Bakım

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ve onarım çalışmalarının düzenli ve planlı olarak yapılması yolun kullanım ömrünü uzatmaktadır.

Bu çalışmada, Marmara Bölgesinde yer alan bir orman yolunun üst yapı çalışmaları incelenmiştir. Çalışma alanında üst yapı kalınlıkları, üst yapı malzemesinin serilişi, dağıtılışı ve sıkıştırılmasındaki kullanılan teknikler ve üst yapı yapıldıktan sonraki bir yıl içerisindeki durumu incelenmiş ve sonuçlar çıkarılmıştır.

2. Materyal ve Metod

Çalışma alanı olarak, İstanbul Orman Bölge Müdürlüğü bünyesinde bulunan Bahçeköy Orman İşletme Müdürlüğü'ne bağlı Sarıyer Orman İşletme Şefliği'nde bir orman yolu seçilmiştir. Alanın seçilmesinde göz önünde bulundurulan en önemli özellik, yolun 15 yıl once yapılmış ve hiç bakım görmemiş ham bir orman yolu olmasıdır. Orman alanı içerisinde 2700 m uzunluğunda, B tipi bir orman yolunun üst yapısı yapılmıştır. Yolun genişliği 4 m ve hendek genişliği 1 m olarak projelendirilmiştir. Bölgenin eğimi %10-70 arasında değişiklikler göstermektedir. Üst yapı çalışmasında Caterpillar marka bir kepçe, Dynapa marka bir silindir ve çeşitli markalardaki kamyonlar kullanılmıştır.

Yapılan bu çalışmada, öncelikle üst yapı çalışması yapılmadan önce yolun mevcut durumu fotoğraflanmış ve incelenmiştir. Yol güzergahındaki deforme olmuş alanlar, sanat yapılarındaki eksiklikler, üst yapı çalışmaları sırasında dikkat edilecek noktalar işaretlenmiştir. Enkesitler alınarak bu enkesit noktalarında yolun üç bölümünde toprağın sıkışma oranı ölçülmüştür. İkinci olarak, enkesit alınan noktalarda bu kez, serilen malzemenin kalınlıkları ölçülmüştür. Malzeme kalınlıkları yanında, malzemenin serilme genişlikleri de belirlenmiştir. Üçüncü ve son olarak, üst yapı çalışmaları bitirildikten bir yıl sonra aynı alana gidilerek yolun son durumu incelenmiş ve üst yapının başarı oranı ortaya konmaya çalışılmıştır.

3. Sonuçlar

Yol üzerinde alınan enkesitler üzerinde yapılan penetrometre ölçümleri sonucunda tüm yol boyunca yol yüzeyinin sıkışma değerleri 5 kg/cm^2'nin altında bulunmuştur. Üst yapı çalışması yapıldıktan sonra yapılan tüm ölçümler sonucunda sıkışma değerleri 5 kg/cm^2'nin üzerinde çıkmıştır. Yani orman yolunun dayanıklılığı üstyapı ile arttırılmıştır.

B tipi bu orman yolunda serilecek malzeme kalınlığı ilk 800 metre için 20 cm ve geriye kalan 1900 metre için 30 cm olarak planlanmıştır . Malzeme serme genişliği 3 m olarak belirlenmiştir. Bu hesaplara göre serilecek malzeme miktarı 2310 m^3 olarak bulunmuştur. Yapılan ölçümlerde, serilen malzeme kalınlıkları ilk 800 metre için ortalama 19 cm, yolun geri kalan 1900 metresi için ise ortalama 21 cm olarak hesaplanmıştır. Malzeme serme genişliği ise ortalama 3.85 m olarak ölçülmüştür. Özellikle yolun ikinci kısmında serilen malzeme kalınlığı planlanandan yarı yarıya az olmuştur. Üstyapı malzemesinin serim işinin bir yükleyici ile yapılması nedeniyle, malzemenin serim kalınlıklarında ve genişliklerinde büyük farklar ortaya çıkmıştır. Bu durumda, malzemenin kaybı, yani ekonomik kayıp anlamına gelmektedir.

4. Teşekkür

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