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Study on Asphalt Pavement Distress: A Case Study in Turkish Republic of Northern Cyprus

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ABSTRACT. *In past few years, Pavement Engineers are exploring new techniques and methods to reduce the cost of pavement construction, while increasing its service life. So it manages the ingredient of pavement material due to the pavement failure, although to characterize the thickness of pavement layers. The road must be designed and properly constructed in the site and then proper maintenance necessary. Meanwhile, the road must not be designed in a short period because of deterioration will start and shows the distress on the pavement surface like surface deformation, surface defect bleeding, disintegration pothole, and cracking. The causes of deterioration are environmental factors (moisture, climate), improper maintenance, Poor material, improper pavement design, traffic over load, traffic volume and subgrade failure. This research paper evaluates the current condition of asphalt pavement distresses which are existed in North Cyprus. A condition survey conducted from Lefkosa to Famagusta and the length of the highway is 57.9 km. It has achieved and proved 10 types of pavement distress in the study area such as potholes, Patching, Bleeding Slippage, Block, Transverse, Longitudinal, alligator. Furthermore, it analyzes the severity separately. It was concluded that the best maintenance alternative for the treatment of distresses in North Cyprus is crack filling, patching, an overlay, and shoulder enhancement.*

Keywords: Pavement design, Pavement assessment, Pavement distress, Pavement failure

1. INTRODUCTION

This document is template. In order to define pavement design, the procedure in the combination of pavement layers must be economic and based on two different aspects; thickness and type of materials [1]. Though the design should be fair for soil foundation and predicted traffic on the target design [1]. Pavement design is completely different from the buildings and bridges. Basically it relates to experimental or semi-experimental approach and yet we do not have a reasonable design method in Cyprus. Pavement design is categorized into two parts; the first part is admixture material design which includes the materials to be used in the design layers [2]. The second part is the pavement structure which measures and defines the thickness and types of component layers in the pavement. Several factors influence in pavement design such as traffic, climate, road geometry, soil, site topography, availability of local materials, and drainage. After all road systems need maintenance which plays an important and vital role in the life of the pavement. Not to be forgotten even well-designed roads are in need of maintenance but the extent is different which depends on multiple factors like pavement types etc.

In order to find the failures of asphalt pavement, the following factors should be assessed: potholes, ruts, cracks, localized depressions, settlements, etc. each of them have different causes like localized depression infect increasingly in its neighborhood, its sequence actually creates wave on the surface of the roads [3]. The pavement failures as mentioned, the pavement structure individually or composedly create waves, longitudinal ruts and shoving on the pavement surface. Even though the exceeding unevenness of the pavement could be a failure while the failure or distress is due to several elements which defines the deterioration of pavement failure. Some other shapes are the elderly and oxidation. Of bituminous films which are going to deteriorate and water retention in the void spaces will increase the detrimental actions rapidly.

2.HIGHLIGHING THE PROBLEM

As the road is made available for use, traffic their deteriorations would definitely start but each at different scales. In early times the deterioration used to be slow and most probably after a period, it goes faster and affects quicker. Many studies proved the road deterioration reach a limit of 60% which causes functional failures in a period of 20 years. Therefore, Pavement maintenance delays the age of the road which is resulted with a high budget for maintenance and reconstruction [4]. Based on Hass at el, (1994) claim if the road condition is poor, the maintenance cost goes 4 to 5 times higher. Also, road maintenance cost is minimized while it is in good condition [5].

3. PURPOSE OF STUDY

This research paper evaluates the condition of asphalt pavement distresses due to maintenance planning and long term strategy in North Cyprus. It is important to evaluate and determine the causes of pavement distress in order to suggest a suitable repair option.

4.LITERATURE REVIEW

The surface roughness ratings are highly dependent on the functional failures. The flexible pavement structural failures are caused by many factors. The main causes of pavement structural failure are moisture and fatigue share that penetrated into the asphalt binders, base course, hydraulic bond mixture or sub base, and subgrade respectively [6]. Basically it is so slow at first when the road traffic is inaugurated but after all, after a period of time the distress will increase and its rating will increase fast [7].

A study conducted by Markwick and Starks in 1941 calculates “light-weight truck tires and pavement” contact stresses [8]. The study claims that “inflation pressure was 0.28 – 0.35 MPa (40 to 50 psi)” [8]. The researcher measures both normal stresses induced by pneumatic tire, and inflation pressure the result show that normal stresses are 1.5 times higher. It seems that the truck speed does not affect normal stresses. According to founding, the shear stresses were directed inwards but while it goes under a solid tire, the direction of the shear stresses are pointed outsides.

Other experiments were performed by using a radially passenger car tire while it’s without profile and perceived the contact with inward shear stresses. The research claims that because of the compressed tread rubber or Poisson’s effect and sidewall binding or pneumatic effect just decrease the contact shear stresses of magnitude. It happens not due to the direction but rather the bending.

According to Lippmann (1986) the measurement of the distribution of stresses on pavement and tread of passenger radial-ply tire shows that bulging of the tire end up at the edge of the tire with an inward shear stresses [9].

Gerritsen (1987) performed static indirect tensile tested how a surface cracking has occurred in asphalt pavement and what are the causes of surface cracking in the Netherlands [10]. The test experimented on core samples, it shows that when the asphalt concrete is outside of the wheel paths, usually in low temperatures it has low strength [10]. A survey on multiple pavement parts has done in the south of France by Dauzats and Rampal (1987) based on this, excessive thermal stresses harnessed pavements [11]. Study claims usually 3 to 5 years later the road has been ever constructed the longitudinal surface cracks appears on both slow and fast lanes of roads [11].

Radial-ply, bias-ply and wide-base radial-ply single tires tested with various inflation pressure values from 0.52 to 0.76 MPa (75 to 110 psi). Also the distribution of contact pressure was non-uniform which is 1.75 times bigger/smaller than inflation pressures [12]. For the three tires with the center tread, the contact pressure was maximum while the outer tread gives the minimum contact pressures.

In a sight perception of longitudinal surface cracking of asphalt pavement in japan by Matsuno (1992) illustrated the crack appearance occurred in passing lanes after 1 to 5 years of the constructed roads [13]. Most likely the cracks were close to the wheel paths while at the same time there were no cracks close to overpass bridges and other shadowed places [13].

4.1 Road Deterioration Causes

Factors that affect the deterioration of pavements are environment, material characteristics, traffic volume, type of design standards, pavement age, pavement construction quality which is discussed further below.

4.2Traffic volume and loading

One of the critical factors that directly affect pavement performance is traffic. Despite the fact that while designing the pavement structure, it is considered that it should carry and insist against the expected traffic load but traffic loads are terribly harming the roads which is the result of vehicle loads and their volumes [14].

4.3 Environmental factors (humidity and water)

A significant decrease in strength of the subgrade and gravel materials is happening from the penetration of the Moisture, humidity or dampness. It simply enters the cracks through holes on the surface into the subgrade and although from the capillary suction with water on that part of the structure. Swelling and shrinkage are environmental result. It is clarified in reflective cracking [15].

4.4 Subgrade

Subgrade is the other impactful factor of the pavement failures. It transfers the wheel loads via the underlying soil. The sensitivity of the subgrade helps the wheel loads if it could not do this, then the pavement will deform extendedly and of course, this is the reason of pavement failures. The pavement performance will be different and vary if the natural alliteration for the subgrade aggregate does not properly and precisely provide in the pavement design structure [7].

4.5 Age of pavement

Aging in the pavement is a matter of fact which the road will show distress in the surface after more than 40 to 50 years. Actually, when the traffic is growing larger and the time passes, road begins accumulation. For instance, solidity increases the hardness of asphalt gradually with its aging, though it improves the sensitivity of thermal cracking [16].

4.6 Quality of construction

Several factors are included in the quality of construction. For instance, materials quality, distress for good compaction, moisture conditions, and thickness of layers after compressions effects the road [17]. The above issues justify the needs for trained expertise and good control and monitoring procedures during the construction.

4.7 Material properties and composition

Materials selection is critical in pavement layers' construction it can easily cause the deterioration of the pavement. Considerably it is due to the different conditions of the soil which affects the type of materials to be used. It affects the strength of the pavement or bearing capacity, mix properties, flexibility degree, and elasticity. Therefor material selection directly increases or decrease the performance of the pavement based on our design [17].

4.8 Road maintenance standards

Maintenance is the other element to keep the pavement well and standard. Maintenance standards are based on the deterioration of the roads that it is conducted treating road defects. A standard gives a limit for the deterioration level which the roads allow. The low-level standards are the reason for the fast deterioration of the pavements [18].

4.9 Pavement Distress

The most visible flaw or defect in the road surface is pavement distress which is one of the deterioration factors. Organizations nowadays collect periodic distress data with Pavement Maintenance Management System (PMMS) in their surveys. Mostly the surface distress is categorized into 4 sections [18]. They are disintegration pothole, surface deformation, cracking, and surface defect bleeding which is illustrated in Table 1.

Table -1: Type of Distresses [18].

Distress Classification				
No	Cracks	Surface deformation	Disintegration Pothole	Surface defect bleeding
1	Transvers	Corrugation	Patches	Raveling
2	Longitudinal	Shoving	Pothole	Delamination
3	Fatigue	Rutting		Shoving
4	Fatigue	Swell		
5	Reflective			
6	Edge			
7	Block			

Source: (Hafizyar and Mosaberpanah, 2018).

4.9.1 Crocodile Cracks

This crack is also defined as a fatigue crack. At first, when it appears on the pavement surface, it looks like longitudinal cracks in the wheel paths but after growing and advancing, it interconnects and looks like an alligator crack though finally, it shows potholes [19]. As shown in Figure 1. There are many factors causing this crack like heavy traffic, base course, insufficient surface, subgrade strength, thin surface, poor drainage which causes penetration to the subgrade and base course and destroy the pavement [20].

Fig. 1: Crocodile Cracks in flexible Pavement

4.9.2 Longitudinal cracks

There are some fractions that are mostly appearing in the centerlines of the pavements which is called longitudinal cracks [21]. As shown in Figure 2. Climate affects the shrinkage of the asphalt layer and it helps these cracks to grow. The same time joining two sections of the pavement with a poor construction is another cause and temperature cycling or unfair operations on the paver could be the reasons for these cracks [22].

Fig. 2: Longitudinal crack in flexible Pavement

4.9.3 Thermal cracking (transverse)

These cracks are mostly happening in a perpendicular direction to the centerlines and would not locate on Portland where cement and concrete joins as shown in Figure 3. It also can appear on the surface [23]. Some causes of these cracks are: wrong set up of the asphalt mixtures, low temperature and sub-base of pavement layers [23].

Fig. 3: Transverse crack in flexible Pavement [24].

Source: (Hafizyar & Mosaberpanah, 2018).

4.9.4 Block Cracking

Block cracking happens unlike other cracks specifically alligator cracks, they are a collection of interconnected rectangular peace which could be all throughout the width of the pavement not just in the wheels' paths as demonstrated in Figure 4. If the severity is low in these cracks, it is possible to repair and fix it with a "thin wearing course". But high severity may need overlay and recycling. The causes are proved to be aging, oxidative hardening of the Asphalt Concrete (AC), wrong binder mixture, high void content, shrinkage and temperature cycling [25].

Fig. 4: Block crack in flexible Pavement

4.9.5 Edge cracking

Distress in narrow pavements are edge cracks which start from the edge and extends, it looks similar to fatigue cracks. They happen because of weak material or excess moisture which is not supporting the shoulder of the pavement well as demonstrated in Figure 5. Causes are different according to the pavement situation. For instance, it could be from poor drainage which the water is near to the edge, soil movement beneath the pavement, heavy traffic close to edge, infiltration of water to the base, lack of strength in surface and base [26].

Fig. 5: Edge crack in flexible Pavement

4.9.6 Rutting

Depression of the longitudinal surface in wheel path is rutting which deteriorate the asphalt and cause other cracks. It is actually a surface failure which holds water in the wheel path [27]. A wide narrow crack shows a subgrade failure as demonstrated in Figure 6. It is possible to say that causes are low air voids, too much dust, rounded aggregate, high asphalt content, and too much natural sand [28].

Fig.6: Rutting crack in flexible Pavement

4.9.7 Pothole

There are holes like depressions in a bowl-shape, which is a progressive failure and called pothole. A tiny piece of the first layer is destroyed and gradually distress goes down to other layers in the bottom of the pavement as demonstrated in Figure 7. The causes are a lack of pavement thickness to handle traffic in freeze or thaw times. Meanwhile, Poor drainage as others, raveling of cracks which cause pothole. They can be repaired with rebuilding or excavating, the repaired area may require immense potholes [29].

Fig.7: Pothole in flexible Pavement

4.9.8 Patching

There are small pieces of asphalt pavement in the surface which is more than 0.1 square meters and they are replaced or their materials increased in a portion in the construction of pavement called patch deterioration as demonstrated in Figure 8. Several issues cause patching for instance when the original distress spreads, poor connection would be between the patch and existing pavement, wrong compaction while patching, wrong material mixing, and rut settlement appealing at the perimeter or inside the interior side of the patch [29].

Fig.8: Flexible pavement Patching sample

5. METHODOLOGY

One type of research design can apply for the implementation of this study which a condition is surveying to understand the pavement failure, the surveying conducted from Lefkosa to Magosa city. This road is one of the important highways in North Cyprus. The primary data were collected from the study area and the secondary data were collected from journal papers, news-papers, thesis conference papers and so forth.

5.1 Description of Study Area

The surveying was conducted from Lefkosa to Magosa city in three sections A, B, and C. It is two carriageways, four lines and the width of each lane is 3.5m, total width is (3.5*4) = 14m and with shoulder approximately 16m. The length of this highway is 57.9 km, the condition survey has been conducted for observation pavement surface. During the condition survey which was visiting, the site and explore sections and exhibiting a variety of distresses which compared with all pavement networks in North Cyprus in Figure 9 demonstrated the study area.

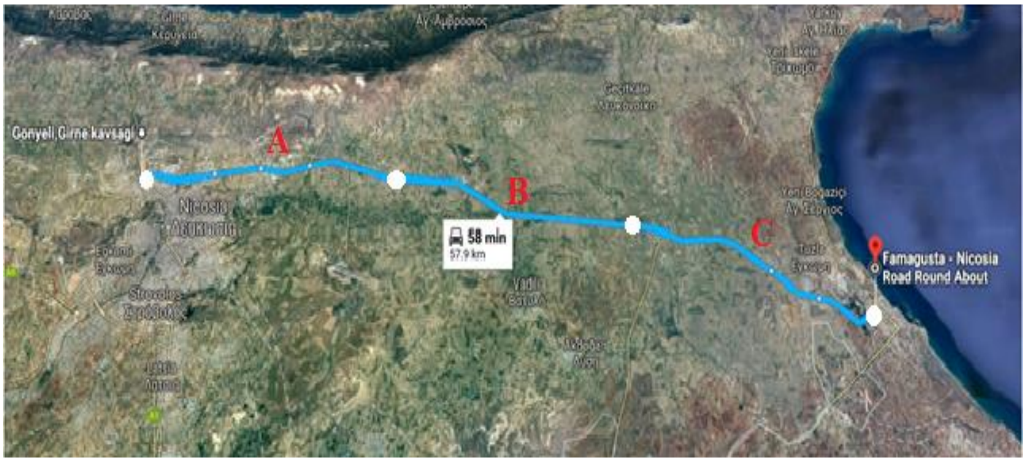

Fig. 9: Description of study area

6. Results and discussion

Newly the survey was done from Gonyeli, Girne Kavsagi to Gazimagusa Lefkosa Yolu chamber highway network on November 2018. It was found that different types of pavement distress existed at a varying severity level as shown in Table 2. This table is discussed further in details.

Table -1: Distresses Severity Level as Measured

Result of Distresses Severity Level				
No	Distresses	Section A	Section B	Section C
1	Transvers	High	High	Moderate
2	Longitudinal	High	High	Moderate
3	Patching	Low	Low	Low
4	Fatigue	High	High	Moderate
5	Rutting	Moderate	Low	Moderate
6	Edge	Low	Moderate	High
7	Pothole	High	High	7
8	Block	Moderate	High	Moderate

The magnitude of each section covered with distresses were specified and compared with total area that was damaged. In Chart -1 as shown the percentage of distresses is calculated.

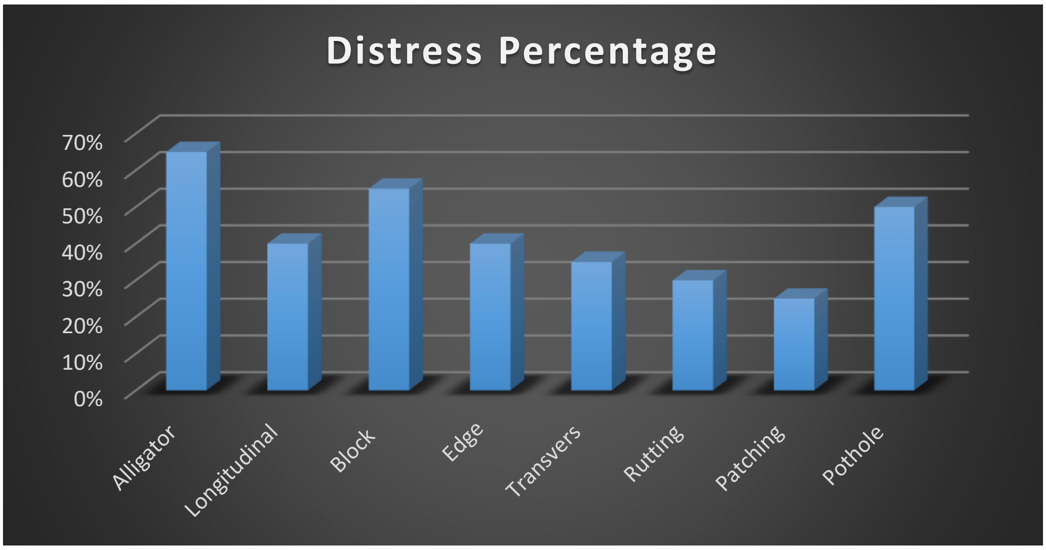

Chart -1: Magnitude of each section covered with distresses

7. CONCLUSION

This paper was conducted to evaluate the functional pavement surface failure and purpose of this paper to investigate the current condition of asphalt pavement distresses for maintenance planning in North Cyprus. It is so important to evaluate and determine the causes of pavement distress to suggest a suitable rapier option.

Pavement failure causes in North Cyprus such inadequate drainage facilities, Poor design and construction, infiltration of surface runoff to the underlying course, thickness of asphaltic cement and poor soil material at some sections of the roads.

During the visual condition, surveying was found different types of distresses with severity level and the magnitude in each section covered with distresses were specified and compared with the total area was damaged.

Result shows alligator crack severity in three sections of highway (H, H, M) covered the highway 60%, potholes severity in three section of highway (H, M, H) covered the highway 49%, block severity in three section of highway (H, M, H) covered the highway 56%, longitudinal crack severity in three section of highway (H, H, M) covered the highway 38%, transverse crack severity in three section of highway (H, M, l) covered the highway 35%, edge crack severity in three sections of highway (L, M, H) covered the highway 38%, rutting severity in three section of highway (M, L, L) covered the highway 30%, patching severity in three sections of highway (L, L, M) covered the highway 22%.

Based on the study findings, it is recommended to use crack filling and sealing, overlay, patching and shoulder improvement due to the others treatment alternative is not available there.

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