**International Journal of Engineering and Applied Sciences (IJEAS)**
**ISSN: 2394-3661, Volume-6, Issue-9, September 2019**

# Effect of Non-Uniformity of Subgrade Soil on Asphalt Pavement Performance (A Case Study of Qena-Luxor West Desert Road)

**Dr. Hassan Darwish Hassanin**

*Abstract* - **The subgrade soil bearing capacity represented by its Modulus of Resilient (Mr) or California Bearing Ratio (CBR) is considered the most dependent factor in all methods of pavement design. The structural failure and the performance of the pavement are greatly related to the subgrade soil conditions. All researchers accepted that the subgrade soils under the pavements are not perfectly homogeneous because of different conditions are existing in the field including environmental, geological, water table and construction conditions. A major factor that affects the pavement performance is the non-uniformity of subgrade soil type along the road section due to the existence of various soil types in some special areas. This study was conducted based on the collected geotechnical, traffic and pavement condition data of the project of dualization of Qena – Luxor west desert road 50 km length. The road project consists of two road sections; Qena – Al Mahrosa 14 km & Al Mahrosa – Al Taref 36 km. The objective of this study is to investigate the effect of non-uniformity of subgrade soil type on the pavement performance of the constructed pavement. The investigation program included pavement surface condition and geotechnical & Laboratory investigations for the existing road bed soils. Results indicated that the performance of the pavement is greatly affected by the change of the subgrade bearing capacity due to changes in soil types. By checking the correlation between the pavement performance represented by PCI values and the subgrade bearing capacity represented by its CBR, it is found that the $R^2$ value for the predicted linear relationship is 0.6281 which does not justified due to the existence of many other factors affects the pavement performance in addition to the subgrade bearing capacity.**

*Index Terms* - **Bearing Capacity, Pavement Condition Index, Pavement Performance, Non-Uniform Subgrade Soil**

## I. INTRODUCTION

This paper studies the effect of non-uniformity of subgrade soil types and properties on the overall performance of the asphalt pavement roads. Asphalt pavement is suffering from noticeable many distresses which encountered on the pavement surface due to many reasons which differ greatly on road sections. The reasons for occurred distresses include structural and functional types; functional distresses are related to the usage of traffic loading of the pavement while the structural distresses are related to the relation between the traffic loading and the capacity of the pavement. The capacity of the pavement section is affected by the capacity of the pavement layers i.e. asphalt layers, aggregate base layers as well as the subgrade layer.

The subgrade bearing capacity is considered the major effective factor in the pavement performance since it is considered the foundation of the pavement. The bearing capacity of the subgrade is affected by the soil type and properties. The bearing capacity of the subgrade soil can be represented, as accepted by AASHTO and all other international road agencies, by either of its California Bearing ratio (CBR), Resistance value (R), and/or Modulus of Resilience (Mr). The most famous criterion used for describing the subgrade characteristics is the CBR value.

This study is conducted based on the data/information collected from the project of dualization of Qena – Luxor west desert road, 50 km length. During conducting the preliminary data collection and investigations of the project, it is noticed that there are many sections of the road are suffering from a deteriorated pavement surface. The riding quality on these sections is very low because they included many distresses such as depression, cracking and potholes. By exploring the adjacent areas of the road right of way along these sections as well as the entire road length, it is found that the existing soils besides the deteriorated sections includes various silt mixed soils and differ greatly from one location to the others.

So, it found that there is a need to firstly investigate the reasons for the deteriorations of the existing asphalt pavement before forwarding to the dualization process of the road through conducting preliminary evaluation of the existing road to study the effect of non-uniformity of subgrade soils on the pavement performance.

Jyoti S. Trivedi, and Dr. Rakesh Kummar [1] studied the effect of subgrade properties on rutting as a performance parameter. They used the multi linear regression and the artificial neural network techniques to investigate the effect of a combination of the different subgrade and layers parameters on the permanent deformations (rutting). They found that there is a good relation between the CBR of the subgrade and the rutting with a correlation $R^2$ factor of value 0.84 [15].

Sreedevi B.G [2] studied the performance of flexible pavements on mature soil subgrade. She found that the strength of the pavement represented by the measured deflection at the surface on mature soil subgrades is influenced by the subgrade soil properties and layer composition on an in-service pavement in urban conditions [16].

Manal A. Ahmed et al. [3] studied the effect of changing of subgrade properties on pavement performance. Results indicated that increasing the water content in the subgrade

**Dr. Hassan Darwish Hassanin** is currently lecturer of Highway Eng. & Airports, Construction Eng. & Utilities Dept., Faculty of Eng., Zagazig University, Egypt.

soils especially that induced by an external source, has a major role in the pavement distress during the serviceability state. Results also indicated that differential settlement in the subgrade soil is the major source of such pavement distress [17].

Khogeli and Mohamed, 2004 [4]; Theyse, et al., 2006 [5] stated that subgrade stiffness & strength are very important for pavement performance and up to 2006 there is no systematic study that performed to investigate the effects of weak subgrade soils conditions on pavement design & and prediction of performance.

Rafiqul A. Tarefder et al. [6] studied the effect of weak subgrade soils on the design, construction, and performance of asphalt pavement. He uses the R-value as an indicator for subgrade strength. He concluded that the surface permanent deformation of the asphalt pavement is sensitive to strength of subgrade. He indicated that a significant amount of vertical displacement is related to the shortage in the subgrade strength.

Iowa State University, Center for Portland Cement Concrete Pavement technology [7] conducted a study "Fly Ash Soil Stabilization for Non-Uniform Subgrade Soils, Volume II: Influence of Subgrade Non-Uniformity on PCC Pavement Performance" to improve the understanding of the influence of subgrade non-uniformity on the PCC pavement responses that affecting the pavement long-term performance. They concluded that non-uniform subgrade soils increases the local deflections and concentrate the stresses in the PCC pavements. This can increase the tendency to increase fatigue cracking, pumping, rutting, faulting, … etc. The end conclusion of the study is that there is an adversely relationship between the pavement performance and the non-uniformity of pavement subgrade. The uniform subgrade should reduce the responses occurred in the pavement structure and it is considered an important factor for sustaining the performance on the long-term [7].

Archilla, A. R., and Madanat, S., and et al. studied the effect of percentage fines on the plasticity index of the subgrade soil and they found that increasing the % fines shall increase the plasticity index due to increasing the liquid limit of the soil as a result of increasing the surface area of the fine material. The increase in plasticity index shall lead to decrease the overall strength of the soil. [8, 9].

Allen, D., Deen, et al. studied the effects of different parameters that affect the subgrade performance. They found that pavement performance of the subgrade is a function of its moisture content, type of soil, and the applied stress conditions [10, 11, 12].

## II. Objectives and Methodology

The main objective of this study is to investigate the effect of non-uniformity of subgrade soil type and properties on the asphalt pavement performance and checking the correlation between the pavement performance and the subgrade soil bearing capacity.

To achieve the study objective, a comprehensive methodology was prepared to include a set of field measurements/investigations and a laboratory testing program. The field measurements/investigations included; Pavement Condition Index (PCI) inspection, geotechnical investigations, and traffic survey. The laboratory testing program included the California Bearing Ratio (CBR), swelling, compaction, soil classification and Atterberg Limits tests.

Extracted soil samples were taken from the site through conducting 50 borings (one boring with 5.00 m depth at each 1 km of the selected road sections). Open pits were conducted to extract subgrade samples from the pavement edges. A traffic survey was conducted at specified chosen locations on the selected road sections to define the moving traffic level on each section. Two peak periods; morning and afternoon, were chosen for conducting the classified traffic survey; each period included four hours. The morning peak hours were from 7:00 AM to 11:00 AM while the afternoon peak hours were from 01:00 PM to 05:00 PM.

## III. Selected Road Sections

To achieve the study objective, two road section were chosen such that the area of the project has a widely variations of roadbed soils. The visual investigation of the original roadbed soil along the road path indicated that there are various types of soils that included silt soils, silt soil with sand, silt soil with gravel, sandy soil, sandy soil with silt, sandy soil with gravel, gravely soil, gravely soil with silt, and gravely soil with sand and silt. These different types of the original roadbed soils are distributed along the entire roads sub-sections and are greatly different from one sub-section to the following along the entire road. The selected road sections included the following:

### *A. Qena – Al Mahrosa Road*

The total length of this road section is 14.00 km starting from Giza–Aswan road near the entrance road of Qena City and ending at Al Mahrosa district. The pavement width of the road is 8.00 m and has an asphalt shoulders with 1.50m width on each side. The road section is passing along agricultural and desert areas with different types of roadbed soils which easily be noticed at the surface of existing ground.

### *B. Al Mahrosa – Al Tarif Road*

The total length of the road is 36.00 km starting from Al Mahrosa district and ending at Al Tarif district near of Luxor City. The pavement width of the road is 8.00 m and has an asphalt shoulders with 1.50m width on each side. The road section is passing through a desert area except the last two kilometers that passing through an agricultural area.

## IV. Field Investigation and Data Collection

The field investigations included three types; pavement condition survey for evaluating surface pavement performance, geotechnical investigations to describe and characterize the subgrade soil bearing capacity, and traffic survey to define the traffic level affected on the existing pavement. The detailed investigations are described in the following sections

### *A. Pavement Condition Survey*

The pavement condition survey was conducted to define the pavement performance through defining the Pavement Condition Index (PCI) which widely used to describe the performance of the flexible pavements. The method is divided into many steps; they include defining road sub-sections, defining section samples, defining sample size, visual inspection of distresses for each sample, calculation of deduct values for all distresses with their severity and density, correcting the total deduct value for each sample, calculating the PCI for each sample which represents the PCI of each km of the road section.

The first road section with length 14 km is divided into 14 sub-sections; while the second road section was divided to 36 sub-sections; each sub-section is 1.00 km length. The sample length is chosen to be 100 m length and 8.00 m width with total sample area 800 $m^2$. The first sample was chosen randomly to be the third sample of the first sub-section (km 1.00). The sample number was repeated to be the third one for each of the following sub-sections. The calculated PCI values for each sub-section of the two road sections are shown on Tables 3 and 4.

### *B. Geotechnical Investigations*

Geotechnical investigations were conducted to describe and characterize the subgrade soil for each road sub-section along the entire roads under study. The geotechnical investigations included two types; they included boring pits and open pits. The details of these investigations are presented in the following sections:

1. Boring Pits

48 borings with depth 5.00 m were conducted along the entire roads lengths. One boring was conducted for each 1.00 km of the roads sub-sections. The location of the boring pit was chosen to be uniformly describing the whole sub-section roadbed subgrade soil. Molded samples were taken from each 1.00 m depth of the boring pit and sent to the laboratory to conduct the required tests.

2. Open Test Pits

The second geotechnical investigation type was the open test pits which conducted at the edge of the existing pavement to a depth of about 1.00 to 1.50 m and 1.00 m wide. A test sample from the subgrade was taken from each open test pit and sent to the laboratory to conduct the required tests.

### *C. Laboratory Tests*

The laboratory tests which conducted on the taken samples included the following:

1. For Boring Pits
   - Liquid Limit (L.L.) and Plastic Limit (P.L.)
   - Sieve Analysis
   - Soil Classification
   - Swelling
   - Chemical Analysis

2. For Open Test Pits
   - Liquid Limit (L.L.) and Plastic Limit (P.L.)
   - Sieve Analysis
   - Soil Classification
   - Compaction Test
   - CBR and Swelling

The laboratory tests for the 48 boring samples and seven open pits samples were conducted by the geotechnical consultant. The seven open pits samples were taken at km 4, 8, 12, 15, 20, 30, and 40 and the tests were conducted at the General Center for Engineering Studies & Consultants, Qena Faculty of Engineering.

Unfortunately, the 7 test pits samples did not cover the subgrade soil variations along the whole length of the two road sections which consist of 50 km.

To conduct a comprehensive description and correlation between the pavement performance and the non-uniformity of subgrade soil types and characteristics, additional 12 subgrade open pits samples were taken by the author in order to represent all variations of the subgrade soil along the intended road sections and the tests were conducted at Zagazig University laboratory.

The 12 samples included 3 verification samples at km 8, 12, and 30 and the other 9 added samples are at km 1, 6, 10, 14, 25, 33, 38, 47, and 49. The results of the tested samples are presented in Tables 3 and 4 for road sections 1 and 2 respectively.

The tables show that the CBR values for the tested samples include the following categories:

- CBR ≤ 6 for km 5, 6, 9, 10, 11, 12, and 13 for Section 1.
- CBR ≤ 6 for km 25, 49, and 50 for Section 2.
- 6 < CBR ≤ 10 for km 1, 2, 3, 4, and 30.
- CBR > 10 for the remaining km in both of Sections 1 & 2.
- The % swelling of the tested samples ranging from 60% to 70% for the samples that achieved CBR ≤ 6.
- Three samples achieved swelling % about 25% at km 33, 38, and 47.
- The remaining samples in the two sections achieved 0% swelling.

### *D. Traffic Survey*

A traffic survey was conducted on different locations on the selected road sections to define the volume of traffic on these roads and accordingly defining the traffic composition and the percentage and types of the heavy vehicles.

The traffic survey was conducted for one week starting from Sunday to Thursday. The survey was conducted for two peak periods; morning and afternoon with four hours for each period. The morning period was from 07:00 AM to 11:00 AM and the afternoon period was from 01:00 PM to 05:00 PM. A classified survey was conducted using the suitable form to define the traffic characteristics along the selected Road Sections.

The average daily Traffic was predicted for each of the surveyed locations using the prediction factors to convert the surveyed eight hours volume to the daily traffic volume during the weekday and the weekend.

Table 1 presents the daily traffic volumes on the two road sections. It shows that Section 1 has daily traffic volume 19295 vpd whereas Section 2 has an average daily traffic of 4810 vpd and all are at the weekend.

Table 2 presents the peak hourly volumes on the two sections during the weekday and the weekend. It shows that the peak hour volume on Section 1 is 1707 vph while on Section 2 is 498 vph and all are at the weekend.

Table 1: Average Daily Traffic (ADT), vpd - 2019

| Section No. | Week Day | Thursday |
|---|---|---|
| 1 | 17742 | 19295 |
| 2 | 4385 | 4810 |

Table 2: Peak Hour Volume Traffic, vph - 2019

| Section No. | Week Day | Thursday |
|---|---|---|
| 1 | 1721 AM | 1707 AM |
| 2 | 394 PM | 498 PM |

## V. Results and Discussion

This section presents the obtained results and discussion of the different conducted surveys and investigations. It shall present the relationships between the pavement performance represented by the PCI and the subgrade bearing capacity represented by its CBR and its swelling characteristics.

### *A. Pavement Performance*

Pavement performance was measured by the Pavement Condition Index (PCI) which defined for each sample that represents its kilometer of the road section length. The first road section with length 14 km includes 14 samples. The sample size represents 10% of the kilometer pavement area. A pavement condition survey was conducted by the visual inspection method using the needed tools and forms as per the international standard manuals.

By analyzing the collected and surveyed data of the pavement condition inspection and making the required calculations and corrections using Paver software, the PCI value for each sample and thus for each kilometer of the road section is specified as shown on Table 3.

The table shows that the PCI values for section 1 are varying greatly from one sample to the other. It shows that km 1, 4, 8, and 14 are fair while km 2, 3, and 7 are good while km 5, 6, 9, 10, 11, 12, and 13 are very poor.

Table 4 shows that the performance of section 2 samples are ranging from fair – good – to very good and excellent for the majority of its samples (about 33 out of 36 samples). The remaining three samples for road section 2 at km 25, 49, and 50 had a very poor performance.

Table 3: Obtained Results for Road Section 1

| Km | PCI | Soil Type | CBR, % | Swell, % |
|---|---|---|---|---|
| 1 | 53 | Sand & Gravel & Some Silt | 8 | 0 |
| 2 | 79 | Sand & Gravel & Some Silt | 9 | 0 |
| 3 | 75 | Sand & Gravel & Some Silt | 9 | 0 |
| 4 | 56 | Sand & Gravel & Some Silt | 9 | 0 |
| 5 | 32 | Silt plus some Gravel | 6 | 65 |
| 6 | 31 | Silt plus some Gravel | 6 | 60 |
| 7 | 79 | Gravel & Some Silt | 15 | 0 |
| 8 | 63 | Sand & Some Gravel | 15 | 0 |
| 9 | 25 | Silt plus some Gravel | 6 | 60 |
| 10 | 0 | Silt & Some Gravel | 6 | 70 |
| 11 | 14 | Silt plus some Gravel | 6 | 65 |
| 12 | 0 | Silt & Some Gravel | 6 | 60 |
| 13 | 3 | Silt plus some Gravel | 6 | 65 |
| 14 | 69 | Sand & Some Gravel | 15 | 0 |

Table 4: Obtained Results for Road Section 2

| Km | PCI | Soil Type | CBR, % | Swell, % |
|---|---|---|---|---|
| 15 | 87 | Silt & Some Gravel | 8 | 63 |
| 16 | 89 | Gravel & Some Sand | 15 | 0 |
| 17 | 93 | Silt & Some Gravel | 8 | 63 |
| 18 | 85 | Gravel & Agg. & Some Silt | 15 | 0 |
| 19 | 86 | Gravel & Some Silt | 16 | 0 |
| 20 | 90 | Gravel & Some Silt | 16 | 0 |
| 21 | 89 | Gravel & Some Silt | 16 | 0 |
| 22 | 97 | Sand & Gravel & Some Silt | 16 | 0 |
| 23 | 76 | Gravel & Some Silt | 16 | 0 |
| 24 | 79 | Gravel & Some Silt | 16 | 0 |
| 25 | 25 | Gravel & Some Silt | 6 | 70 |
| 26 | 57 | Gravel & Some Silt | 16 | 0 |
| 27 | 91 | Gravel & Some Silt | 16 | 0 |
| 28 | 96 | Gravel & Some Silt | 16 | 0 |
| 29 | 72 | Gravel & Some Silt | 16 | 0 |
| 30 | 54 | Silt and some Gravel | 7 | 65 |
| 31 | 95 | Gravel & Some Silt | 16 | 0 |
| 32 | 89 | Gravel & Some Silt | 16 | 0 |
| 33 | 61 | Gravel & Silt & Some Sand | 10 | 25 |
| 34 | 69 | Gravel & Some Sand | 16 | 0 |
| 35 | 82 | Gravel & Some Silt & Sand | 16 | 0 |
| 36 | 86 | Gravel & Some Silt | 16 | 0 |
| 37 | 64 | Gravel & Some Silt | 16 | 0 |
| 38 | 53 | Gravel & Silt & Some Sand | 10 | 25 |
| 39 | 76 | Gravel & Some Silt | 16 | 0 |
| 40 | 93 | Gravel & Some Silt | 16 | 0 |
| 41 | 89 | Gravel & Some Silt | 16 | 0 |
| 42 | 81 | Gravel & Some Silt | 16 | 0 |
| 43 | 91 | Gravel & Some Silt | 16 | 0 |
| 44 | 96 | Gravel & Some Silt | 16 | 0 |
| 45 | 98 | Gravel & Some Silt | 16 | 0 |
| 46 | 82 | Gravel & Some Silt & Sand | 16 | 0 |
| 47 | 53 | Gravel & Silt & Some Sand | 10 | 25 |
| 48 | 68 | Gravel & Some Silt & Sand | 16 | 0 |
| 49 | 26 | Silt & Some Gravel | 6 | 65 |
| 50 | 26 | Silt & Some Gravel | 6 | 65 |

### *B. Effect of Subgrade Bearing Capacity on Pavement Performance for Section 1 (High Traffic)*

Figures 1 & 2 present the obtained values of the pavement condition index (PCI) for each km of road section 1 versus the corresponding CBR values for subgrade soil for each of them. The figures show that higher values of PCI had been obtained for pavement constructed over subgrade soils with CBR values greater than 10%. In contrast of that, lower PCI values were obtained for pavement constructed over subgrade soils with low CBR values. This is clear shown on km 5, 6, 9, 10, 11, 12, and 13 that have CBR value 6%. These parts of road section 1 have failed pavement performance and shall need major rehabilitation.

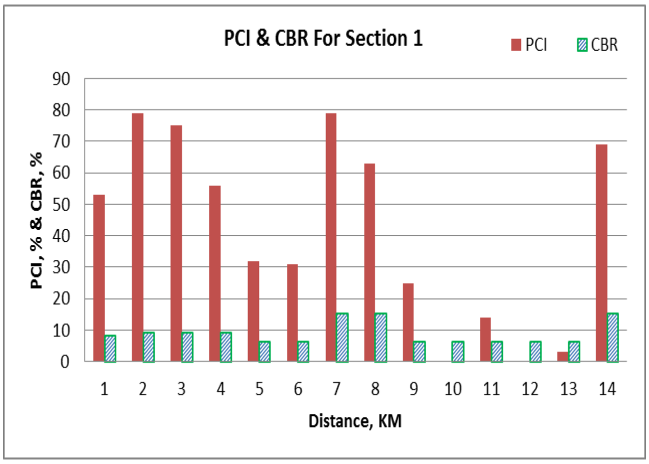


Figure 1: Pavement Performance vs. Subgrade CBR for Road Section 1

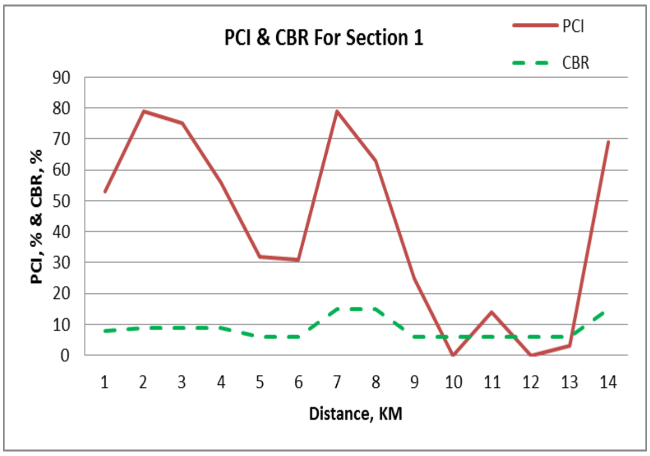


Figure 2: Pavement Performance vs. Subgrade CBR for Road Section 1

*C. Effect of Subgrade Swelling on Pavement Performance for Section 1 (High Traffic Volume)*

Figures 3 & 4 present the obtained values of the pavement condition index (PCI) for each km of road section 1 versus the corresponding swelling percentage for subgrade soil for each of them. The figures show that higher values of PCI had been obtained for pavement constructed over subgrade soils with lower swelling values.

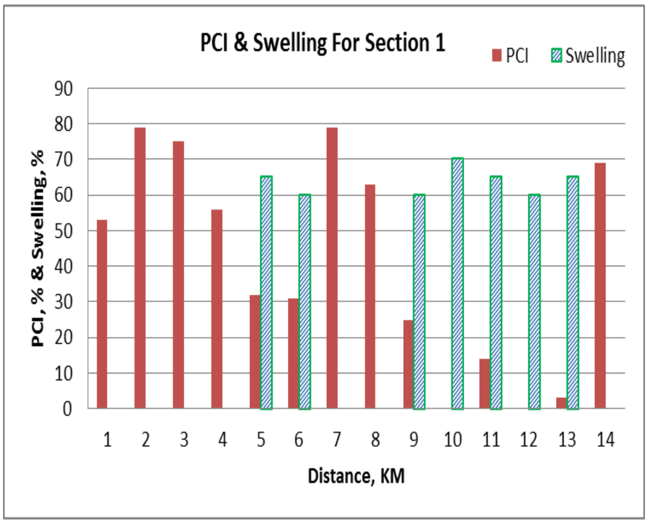


Figure 3: Pavement Performance vs. Subgrade Swelling for Road Section 1

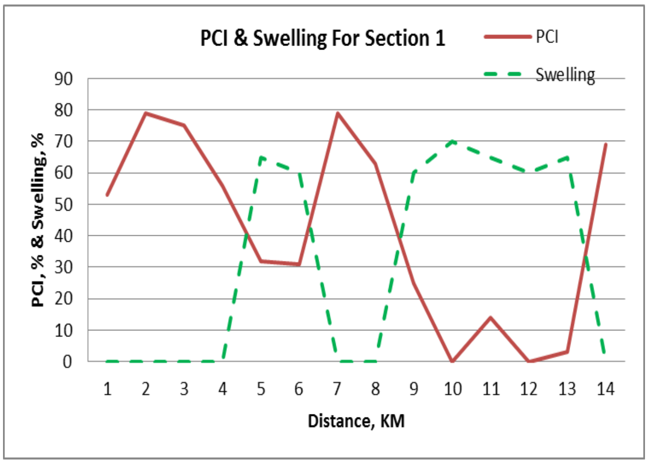


Figure 4: Pavement Performance vs. Subgrade Swelling for Road Section 1

In contrast of that, lower PCI values were obtained for pavement constructed over subgrade soils with greater swelling values. This is clear shown on km 5, 6, 9, 10, 11, 12, and 13 that have swelling values ranging from 60% to 70%. These parts of road section 1 have failed pavement performance and shall need major rehabilitation.

*D. Effect of Subgrade Bearing Capacity on Pavement Performance for Section 2 (Low Traffic Volume)*

Figures 5 & 6 present the obtained values of the pavement condition index (PCI) for each km of road section 2 versus the corresponding CBR values for subgrade soil for each of them. The figures show that higher values of PCI had been obtained for pavement constructed over subgrade soils with CBR values greater than 10%. In contrast of that, lower PCI values were obtained for pavement constructed over subgrade soils with low CBR values.

This is clear shown on km 25, 49, and 50 that have CBR value 6%; these parts of road section 2 have failed pavement performance and shall need major rehabilitation. Other parts of road section 2 at km 15, 17, 30, 33, 38, and 47 have moderate CBR values ranging from 7% to 10% achieved PCI values ranging from 53% to 61% except those at km 15 and 17 achieved higher PCI values; these parts of road section 2 shall need moderate rehabilitation strategies

*E. Effect of Subgrade Swelling on Pavement Performance for Section 2 (Low Traffic Volume)*

Figures 7 & 8 present the obtained values of the pavement condition index (PCI) for each km of road section 2 versus the corresponding swelling percentage for subgrade soil for each of them. The figures show that higher values of PCI had been obtained for pavement constructed over subgrade soils with lower swelling values. In contrast of that, lower PCI values were obtained for pavement constructed over subgrade soils with greater swelling values. This is clear shown on km 25, 49, and 50 that have swelling values ranging from 60% to 70%; these parts of road section 2 have failed pavement performance and shall need major rehabilitation.

Other parts of road section 2 at km 30, 33, 38, and 47 have moderate swelling values ranging about 25% achieved PCI values ranging from 53% to 61%; these parts of road section 2 shall need moderate rehabilitation strategies.

.

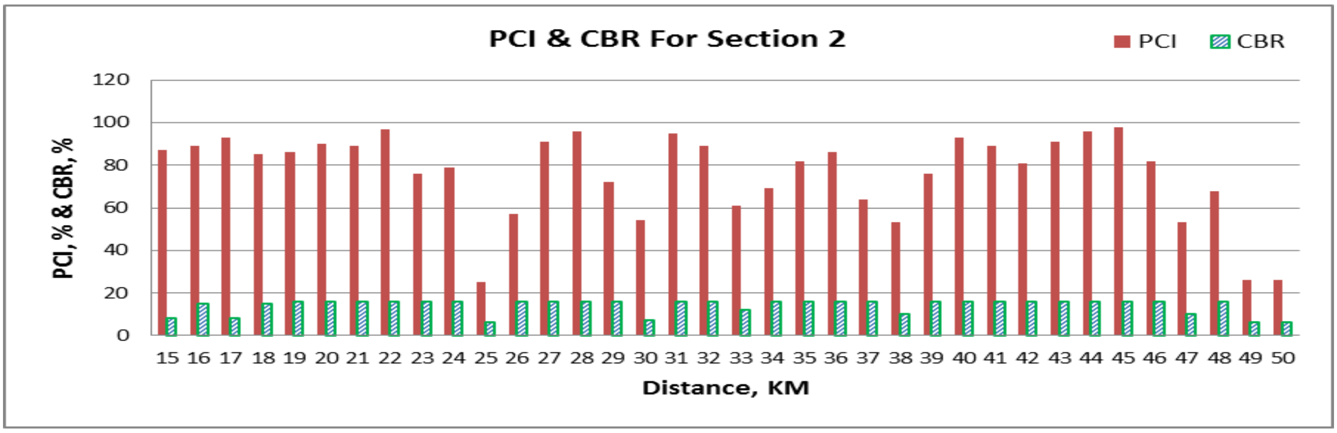


Figure 5: Pavement Performance vs. Subgrade CBR for Road Section 2

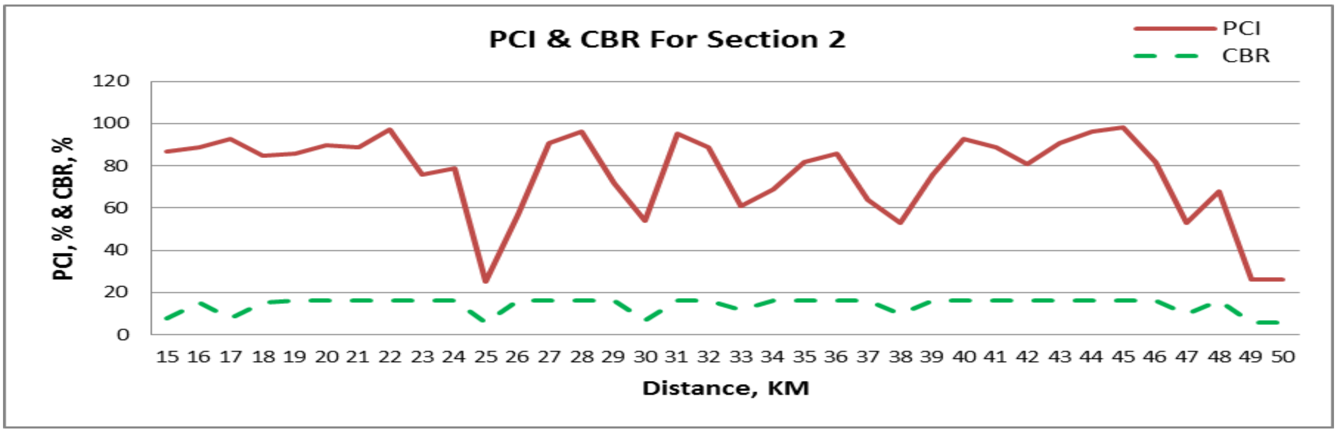


Figure 6: Pavement Performance vs. Subgrade CBR for Road Section 2

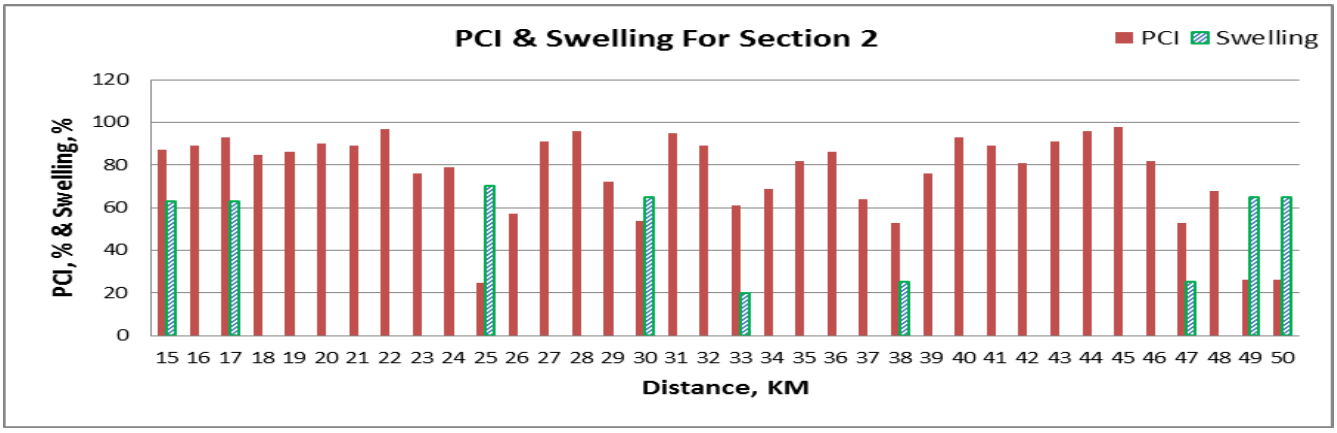


Figure 7: Pavement Performance vs. Subgrade Swelling for Road Section 2

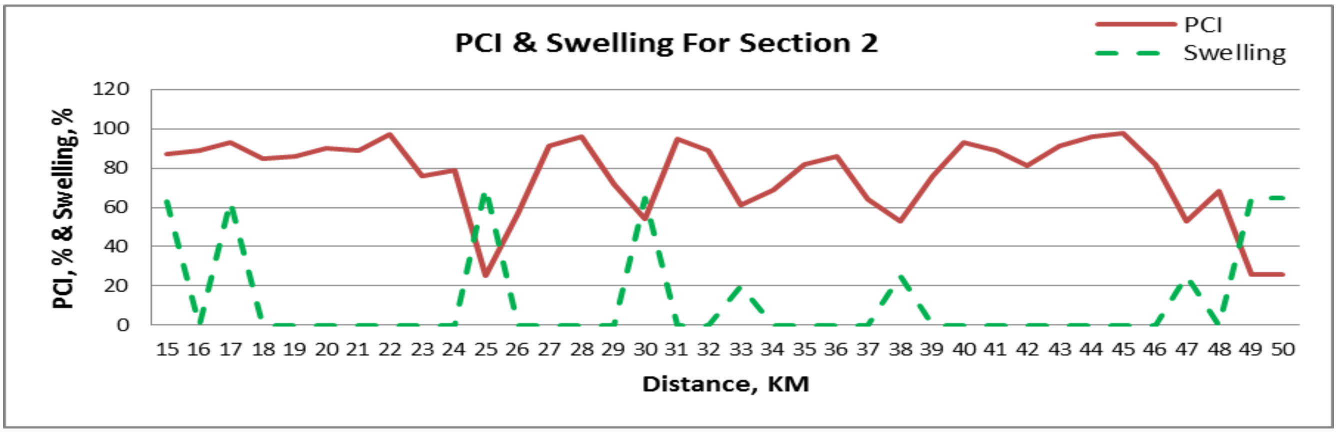


Figure 8: Pavement Performance vs. Subgrade Swelling for Road Section 2

By analyzing the above results and outputs, it clear known that the subgrade properties are considered a key role in the overall pavement structure capacity because it actually the foundation of the pavement structure even if the pavement is flexible or rigid.

The subgrade bearing capacity represented in this paper by the CBR value affects greatly the overall pavement performance as presented above for different soil types on the studied roads sub-sections. The variation of soil types along the road section leads to make the subgrade has different CBR values and accordingly different bearing capacities. The variation in the bearing capacities along the entire road sub-sections and due to the continuous compaction occurred due to the affected traffic loads along time lead to make a differential settlement between different road sub-sections which may lead to cracking and depression of the pavement surface.

By studying the correlation between the pavement performance and the bearing capacity of the subgrade represented by its CBR value, it is found that the correlation is not justified since the there are many other factors affects the pavement performance other than the CBR such as environmental, climatic, water table traffic loading, and others.

Figure 9 presents an attempt to define the correlation between the pavement performance represented by the pavement condition index (PCI) and the subgrade bearing capacity represented by CBR values for the obtained results of road sections 1 & 2.

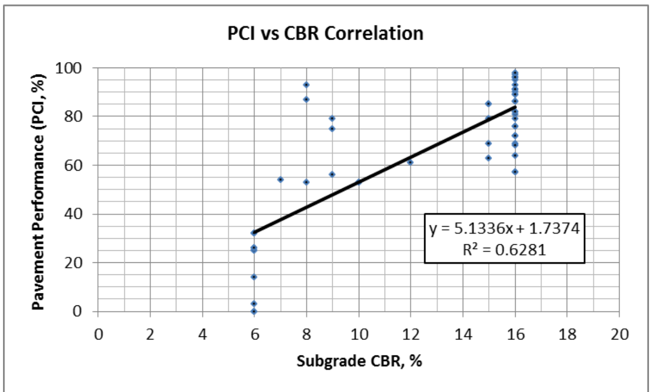


Figure 9: Correlation between Pavement Performance and Subgrade Bearing Capacity

The figure shows that as mentioned above as the subgrade bearing capacity increased, the pavement performance increased. But the correlation has $R^2$ factor of 0.6281 which considered low value. This low value resulted from the variations in the factors that affect the pavement performance other than the CBR values. As an example, at CBR = 16%, it is found that there are many sub-sections that have CBR = 16% and have different values of PCI ranging from 53% up 98%.

Similarly, for CBR = 6%, it is found many sections have PCI values ranging from 0% to 26% while for CBR = 8% many sub-sections have PCI values ranging from 53% to 93%. Also, for CBR = 15% many sub-sections have PCI values ranging from 63% to 85%.

The mentioned wide variation in PCI values at the same value of the CBR is occurred because of the non-considered factors that affect the pavement performance.

Although, it is concluded that the pavement performance is greatly affected by the subgrade non-uniformity, the confidence level to predict a correlation between pavement performance and the subgrade bearing capacity directly without considering the overall parameters and factors that affect the pavement distresses and performance is not justified.

## VI. Conclusion

This study is conducted to investigate the effect of non-uniformity of subgrade soil on the pavement performance. The field and laboratory investigations and data collection were collected from the preliminary studies of the project of dualization of Qena-Luxor west desert road in Egypt since the preliminary studies showed that the subgrade soils along the entire length of the existing road include a wide range of various subgrade soil types.

It concluded that the non-uniformity of subgrade bearing capacity is greatly affecting the pavement performance. It is recommended to assure of the uniformity of subgrade soil during construction by replacing the non-suitable materials. By predicting a correlation between the pavement performance represented by the PCI values and the subgrade bearing capacity represented by its CBR, it is found that the linear correlation is not greatly justified because there are many other factors that affect the pavement performance; the $R^2$ for the predicted linear relationship is 0.6281 which considered not justified.

## Acknowledgment

The Author would like to thank all team members encouraged in the performing and completion of the preliminary studies of the dualization Qena-Luxor road project especially both of Eng. Ahmed Taher and Eng. Amr Soliman and their teams of traffic survey and pavement condition inspection. Also, thanks for the geotechnical sub-consultant of Qena University.

## References

[1] Jyoti S.Trivedi, and Dr.Rakesh Kumar, “Impact of Subgrade and Granular Layer Material Properties on Rutting.” American Journal of Civil Engineering and Architecture, vol. 3, no. 3 (2015): 64-70. doi: 10.12691/ajcea-3-3-2.

[2] Sreedevi B.G "A Study on the Performance of Flexible Pavements on Mature Soil Subgrades" a PHD These in Faculty of Engineering, Cochin University of Science and Technology, Kochi, 682022 – India, August 2014.

[3] Abdalla, Manal et al (2008), "Effect of Subgrade Properties on Pavement Performance", Gulf Conference on Transportation, 23-24 January 2008, Dubai, UAE.

[4] Khogeli, W. E. I.. and Mohamed, E. H. H. “Novel approach for characterization of unbound materials.” Journal of the Transportation Research Board, No. 1874, Washington, D.C., 2004, 38−46.

[5] Theyse, H. L., Hoover, T. P., Harvey, J. T., Monismith, C. L. and Coetzee, N. F. “A mechanistic-empirical subgrade de- sign model based on heavy vehicle simulator test results.” Geo-technical Special *Publication No.154, Pavement Mechanics and Performance*, B., Huang, R., Meier, J., Prozzi, E., Tutum-luer, Geo Institute, ASCE, 2006, 195−202.

[6] Rafiqul A. Tarefder, Nayan Saha, Jerome W. Hall, and Percy T.-T. Ng (2008). "Evaluating Weak Subgrade for Pavement Design and Performance Prediction: A Case Study of US 550", Journal of GeoEngineering,Vol. 3, No. 1, pp. 13-24, April 2008.

[7] David J. White "Fly Ash Soil Stabilization for Non-Uniform Subgrade Soils, Volume II: Influence of Subgrade Non-Uniformity on PCC Pavement Performance", Iowa State University, Center for Portland Cement Concrete Pavement technology, Final Report, April 2005.

[8] Archilla, A. R., and Madanat, S., "Development of a pavement rutting model from experimental data". Journal of transportation engineering / July/august 2000,126, pp. 291-299.

[9] Chukka, D., and Chakravarthi, V. K., "Evaluation of Properties of Soil Subgrade Using Dynamic Cone Penetration Index – A Case Study", Volume 4, Issue 4 (October 2012), PP. 07-15.

[10] Allen, D., Deen, R.C., "Rutting Models for Asphaltic Concrete and Dense Graded Aggregate from Repeated Load Tests", Proceedings of the Association of Asphalt Paving Technologists, Louisville, Kentucky 1980.

[11] AASHTO T 307-99(2003) Design Guidelines Standard Method of Test for Determining Resilient Modulus of soils and Aggregate Materials.

[12] Wang, R., Zhou, F., Chen, D. H., Zheng, G., Scullion, T., and Walubita L. F., "Characterization of Rutting (Permanent Strain) Development of A-2-4 and A-4 Subgrade Soils under the HVS Loading", Journal of performance of constructed facilities © ASCE, 010.24:pp382-389.

**Author profile:**

**Dr. Hassan Darwish Hassanin Darwish**
Lecturer Roads & Airports and Traffic Engineering

**Education:**

1. **Ph.D.** in Construction Engineering & Utilities (Highway Engineering) - (**Application of Artificial Intelligence Technology in the Structural Capacity Evaluation of Asphalt Pavement**), Construction Engineering Department, Zagazig University, 2003.
2. **M.Sc.** in Highway Engineering & Construction (**Effect of Using Salty Water in Compaction Processes on Some Properties of Base Courses**), Construction Engineering Department, Zagazig University, 1996.
3. **B.Sc.** Construction Engineering (Civil Engineering) with grade of **Very Good with Honor** and the grade of **Excellent** in the project of Highway Construction, Construction Engineering Department, Zagazig University, Egypt, 1989.

**Publications:**

1. Hassan D. Hassanin**,** et al. **"Compaction of Base Courses Using Salty Water"**, Arab Roads Magazine, 1993.
2. Hassan D. Hassanin, et al. "Effect of Using Salty Water in Compaction Processes on the Structural Capacity of Base Courses", Conference of civil Eng., Faculty of Eng. at Port Said, Sues Canal University, 1995.
3. Hassan D. Hassanin, et al. "Using Case-Based Reasoning in the Structural Capacity Evaluation of Asphalt Pavement", First International Conference on Intelligent Computing and Information Systems, ICICIS 2002.
4. Hassan D. Hassanin, et al. "A Prototype Case-Based Reasoning System for Prediction of the Structural Number of Asphalt Pavement", Accepted for Publication in the Egyptian Journal for Engineering Sciences and Technology (EJEST), 2003.
5. Hassan D. Hassanin and Essam A. Sharaf, "Prediction of Pavement Performance using Artificial Intelligent System", 10th International Conference on Applications of Advanced Technologies in Transportation, AATT 2008, May 2008.
6. Hassan D. Hassanin, "Sensitivity Analysis of Economic Evaluation Parameters of Upgraded Rural Roads Projects", Mansoura Engineering Journal (MEJ) – Volume 40 – No. 3, September 2015.
7. Ahmed Mohamady Abd-Allah, Hassan Darwish Hassanin, Manal Abd-Allah Ahmed and Abdelrahman Baz Abdelsemii, "Evaluation of Common Traffic Operation Software on the Basis of Relevance to Roads and Intersections", Mansoura Engineering Journal (MEJ) – Volume 41 – No. 2, June 2016.
8. Manal A. Ahmed, Magdy T. Zaky, Hassan D. Hassanin, Ahmed M. Alnahas, "Warm Mix Asphalt Production Using Cheap Wax Additives", Al Azhar University, Civil Engineering Research Magazine (CERM), August 2016.
9. Hassan D. Hassanin, "Quantifying Multi-Criteria Approach for Identifying the Priority Level of Rural Road Projects", International Organization of Scientific Research, Journal of Mechanical and Civil Engineering, ISOR-JMCE, November 2016
10. Metwally G. Al-Taher, Hassan D. Hassanin, Mokhtar F. Elgendy and Ahmed M. Sawan, "Improving the Performance of Asphalt Mixtures Using Nano Silica", International Digital Organization for Scientific Information IDOSI, World Applied Sciences Journal (WASJ), December 2017.
11. Metwally G. Al-Taher, Hassan D. Hassanin, Mokhtar F. Ibrahim and Ahmed M. Sawan, "Investigation of the Effect of Adding Silica Fume on Asphalt Concrete Properties", International Journal of Engineering Research (IJER), March 2018.
12. Metwally G. Al-Taher, Hassan D. Hassanin, Mokhtar F Ibrahim and Ahmed M. Sawan, "Comparative Study of Performance of Modified Asphalt Mixtures using different Traditional and Nano Additives", International Journal of Scientific and Engineering Research (IJSER), March 2018.