# Design of Perpetual Highway Pavement in Libya Using PerRoad softwaer: Solutions for Maintenance Gaps and Traffic Overload

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*Abstract*—**This study aims to identify solutions for the early failure of roads in Libya due to the lack of a pavement management system and an effective load weighing system. The coastal highway in the city of Misrata was taken as a case study, which has high traffic volumes, especially heavy vehicles. The companies involved in the road's reconstruction provided data on average yearly temperatures and the physical properties of the construction materials, This included the modulus of elasticity and Poisson's ratio for both the asphalt mix and the soil used, The design for traffic volumes was based on ESALs reaching 24 M.S.A which is the calculated value for this road. , the ESALS were increased by 5 M.S.A and designed by using PerRoad program, for perpetual pavement method, and the mechanical experimental method. After the design, both methodologies were compared, and the effect of increasing the number of axles and ESALs on the thickness of the asphalt layers was studied، The results showed that the design of this road using the perpetual pavement method is not affected by the increase in the number of axles and ESALs, which is suitable for achieving a design life of up to 50 years without being affected by the increase in ESALs. The asphalt layers were 25cm thick, while the subgrade layer was 20 cm thick، On the other hand, the mechanical experimental showed a clear impact from the increase in the number of axles and ESALs, as the thickness of the asphalt layer increased from 19 cm to 28 cm, and the thickness of the subgrade layer increased from 30 cm to 40 cm. This design achieves a lifespan of 20 years. The study also indicated that for designs with 15 M.S.A and above, the traditional design is considered over-designed, and the use of permanent pavement is preferred. As for the design of this road, the permanent pavement method was adopted**

***Keywords— perpetual pavement, perroad, Axle Group, Mechanistic empirical ,flexible pavement***

## I. INTRODUCTION

Perpetual pavement is a new way of doing pavement engineering that aims to make a pavement system that can handle heavy traffic for more than 50 years and is structurally sound.This type of pavement is made to keep important tensile and compressive strains in the layers below it from getting too high. This stops structural failures like fatigue cracking and too much permanent deformation. Because of this, maintenance work usually only involves replacing the top layer instead of completely fixing the structure. This makes it last longer and costs less over its lifetime [1][2]. The roads in Libya have been getting worse faster in the last few years.This is mostly because there aren't any regular or preventative maintenance programs in place, and there aren't enough weigh stations to control axle loads. Because of this, many roads have too much traffic for the way they were meant to be used. This makes structural problems like cracking, rutting, and failing to support weight happen sooner than they should. Because of these problems, highways often have to be rebuilt too soon, which costs a lot of money and makes getting around less efficient [3][4].Because of these problems, there is a growing need for different kinds of pavement design that can handle a lot of traffic without needing to be fixed or rebuilt very often. Perpetual pavement is a good and long-lasting solution because its structure can handle repeated stress without breaking down over time. This makes the pavement last longer and work better overall [2][5].

This study aims to:

1. Designing flexible pavement layers for highways in Libya using the perpetual pavement methodology as well as the experimental mechanical methodology at different axle load levels and various of Equivalent Single Axle Loads (ESALs) scenarios using the PerRoad program.
2. Preparation of several sections that simulate the mechanical experimental and perpetual pavement of the coastal highway in the central section of Misrata, with ESALs levels ranging from 0 to 24 Million Standard Axles(M.S.A), increasing by 5 M.S.A each time.
3. Determining the impact of increasing axle group sizes and ESALs on the thickness of asphalt layers for both perpetual and mechanical experimental pavements.
4. Establishing the specifications for the materials used in the construction of perpetual pavement layers.

## II. LITERATURE REVIEW

This section reviews previous studies related to the design of perpetual pavements, with a particular focus on the use of the PerRoad software in the design and analysis of flexible perpetual pavements. The following studies are discussed below.

### A. *Design and Performance of Perpetual Pavements*

"Texas Perpetual Pavement Design and Construction Guidelines" [6] was the first study to examine the design and construction of Texas's eternal asphalt pavements. Lubinda, Sang, and Sheng were the authors. The main goal of the research was to come up with requirements for a sustainable pavement design that could handle long-term, structurally sound traffic loads. To gauge the pavement's efficacy, it aimed to manipulate critical distress mechanisms like fatigue cracking and irreversible deformation. Both the conventional 20-year asphalt pavement designs and the everlasting pavement systems were compared in terms of total cost of ownership by the study's participants. Our research suggests that, because of their low repair and maintenance requirements, everlasting pavement systems might be a sustainable and financially sound option.

The study titled "Mechanistic Empirical Design of Perpetual Road Pavement Using Strain Based Design Approach" by Sahis, Biswas, Sadhukhan, and Saha [1] the perpetual pavements was designed by using a mechanistic empirical methodology. The study aimed to create a pavement structure that could withstand heavy traffic loads by carefully managing the critical strains in both the asphalt layers and the subgrade. a pavement system with three-layers was tested and comparisons with using mechanistic modelling tools to see if the design is effectiveness

### B. *Strain Control Using PerRoad Software*

This study, presented by the National Center for Asphalt Technology (NCAT) and titled "NCAT Report 15-05R and Perpetual Pavement Strain Distribution Criteria,"[7] presents a new mechanistic framework for designing perpetual asphalt pavements by substituting traditional single- limiting strain concepts with a strain distribution-based methodology. The research examined long-term field performance data from the NCAT Pavement Test Track to enhance the evaluation of fatigue cracking and rutting processes in asphalt pavements. The greatest tensile strain at the base of the asphalt layer is inadequate for characterising the pavement's fatigue response. . For this reason, the report recommended consideration of the cumulative distribution of horizontal tensile strains at various percentiles as a more accurate measure of long life performance level for pavement. Pavement structures with lower strains throughout the distribution showed improved resistance to bottom-up fatigue cracking

In addition, the report highlighted the necessity to control vertical compressive strains at the top of subgrade applying distribution-based criteria for long-term deformation mitigation. This work has retarded the development of performance-based and probabilistic perpetual pavement design methods, and formed part of the technical foundation for tools such as PerRoad which used strain distribution criteria to determine.

This study was proposed by NCAT entitled" Redesign and updates of the perpetual pavement design software: PerRoad version 4.3 [8].The following paper presents the development of a new release named PerRoad Version 4.3, an updated software that is focused on enhancing transient and permanent strains in perpetual asphalt pavements. Perpetual pavements are designed to have long service lives and yet fatigue cracking and rutting associated with structural distress that requires rehabilitation in excess of a few decades, as well as only limited surface maintenance due to aging. Preliminary versions of the PerRoad software have beenwere These versions were also only for perpetual pavement design and didn't work with traditional mechanistic-empirical design methods, which made them less useful for comparative design studies. The new software uses advanced design criteria based on recent research. It focuses on controlling fatigue at the bottom of the asphalt concrete layer based on strain distribution and controlling compressive strain at the top of the subgrade based on percentiles to reduce rutting. These improvements make it possible to better represent how pavement reacts and to better choose the right thickness and materials for each layer. With PerRoad Version 4.3, you can now do traditional mechanistic-empirical pavement design, which lets you compare perpetual and traditional pavement options directly. Because the interface, is not much simpler to determine whether or not the design requirements have been satisfied, which results in a more transparent decision-making process. For the purpose of engineering projects, the program also generates organised reports based on Excel that maintain track of all design inputs and outputs. This makes the software more easy to use the modifications that were implemented in PerRoad Version 4.3 make the design of everlasting pavement far more precise, adaptable, and user-friendly. Individuals are able to make better and more informed judgements on the design of pavement as a results

The study by the Asphalt Pavement Alliance APA[9] titled "Overview of PerRoad Design Methodology" was intended to present an overview of the PerRoad's approach to design perpetual pavements. The research was in response to the need of incorporating combined sap and material properties loading, environmental effects into pavement design. PerRoad was offered as an answer, which directly coupled multilayer elastic theory with the performance-based simulation and allowed engineers to optimise thicknesses in various layers and material type for long-term trafficking.

## III. METHODOLOGY

The study focused on addressing the early failure of flexible asphalt due to a lack of routine maintenance and the absence of scales for heavy traffic loads by finding modern design

DOI: **10.5281/zenodo.20397898**

solutions capable of providing long service without early failure. This was achieved using a theoretical-analytical approach by studying the pavement layer design of the coastal road in Libya. The central section of the city of Misrata was adopted, as it represents the city economically and industrially, leading to an increase in traffic volumes and heavy vehicles on the coastal road. This was achieved by applying the concept of perpetual pavement using the PerRoad 4.4 program، Annual temperature data for the city of Misrata were used, along with the material properties for this city derived from previous studies, such as the Poisson's ratio and the modulus of elasticity. Additionally, the spectral distribution of traffic loads was applied based on the specifications of the traffic monitoring guide issued by the Federal Highway Administration(FHWA). The vertical and horizontal strains for the perpetual pavement methodology were controlled according to the standards of the National Center for Asphalt Technology (NCAT). The experimental mechanical method used experimental equations to design for tensile failure or rutting, which are available in the PerRoad program.

These data were entered into the PerRoad 4.4 program, and the pavement layers were designed using the perpetual pavement methodology and the traditional Mechanistic-empirical methodology for different traffic loading scenarios up to the actual ESAL value on the coastal road of Misrata City, which is 24 M.S.A. The ESALs was increased by 5 M.S.A to study the impact of this increase on the layer thicknesses for both methodologies. The materials used in construction were described, including asphalt and soil layers .

## IV. Perpetual Pavement Design Steps Using PerRoad

In this study, PerRoad 4.4 was chosen as the main tool for designing perpetual pavement due to its suitability and advanced features . The program allows for precise input and output, includes stress distributions from previous research, and integrates fatigue resistance limits derived from laboratory tests. These capabilities enable the precise calculation of control stress distributions, providing a reliable framework for evaluating and improving long-term pavement structures according to modern performance standards. The program uses the experimental mechanical methodology and has the capability to design traditional pavements, the main wind window is shown in figure 1.This study includes several steps, as shown in Figure 2


Figure 1.PerRoad 4.4 Main window

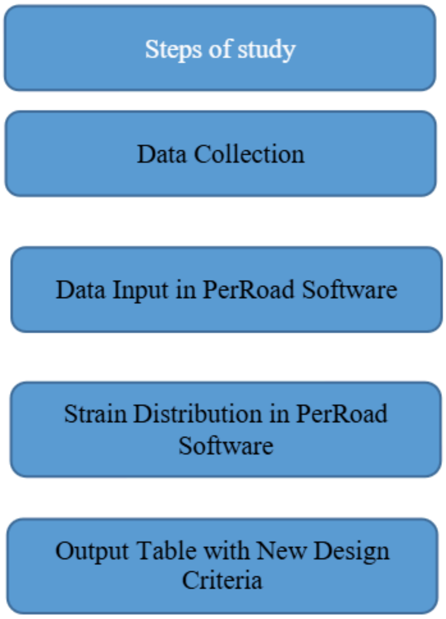


Figure 2. Studies man steppes

### A. *Data Collection*

Data on the key inputs for perpetual pavement design were collected from previous studies on the following aspects:

- Data on the properties of asphalt layers and soil layers, such as the modulus of elasticity and Poisson's ratio, for the city of Misrata have been collected. This information is detailed in the report from the consulting company affiliated with the Ministry of Transportation.
- The performance grade (PG) of the asphalt binder was determined based on its distribution across the coastal regions, as reported in a previous study [10].
- The average annual temperatures for the city of Misrata have been collected. As mentioned in a previous study[12].
- Traffic load data and the corresponding load spectrum distribution were developed based on the road classification available in the program (urban Intersection) and Federal Highway Administration (FHWA) data. This classification is particularly suitable for coastal roads in Misrata, where the proportion of heavy trucks is relatively high. The gathered data served to establish the input parameters essential for pavement design, thereby ensuring a precise reflection of anticipated traffic conditions within the analytical framework. These inputs, when integrated with regional climatic factors and material characteristics, provide a thorough foundation for the design of pavements characterized by both durability and superior performance, as documented in prior research. [9]

### *B. Data Input in PerRoad Software*

The software includes two sections for data input and they are:

- Structure input : the average seasonal temperature data for Misrata it was obtained from [12] entered as shown in table I and the different ways the pavement layers were set up. The perpetual pavement design had three layers of asphalt and one layer of soil. The design, on the other hand, experimental mechanical pavement design had two layers of asphalt and two layers of soil. The results will show these configurations and the material properties for each layer، The data were defined in the program for the thickness of the layers until it got the theoretical thickness, that was shown in table I and all the data listed in the the table were taken from Sama Company, the project executor, and are found in a study at the Faculty of Engineering, Misrata [13]. And figure 3 shows PerRoad 4.4 Structural window .

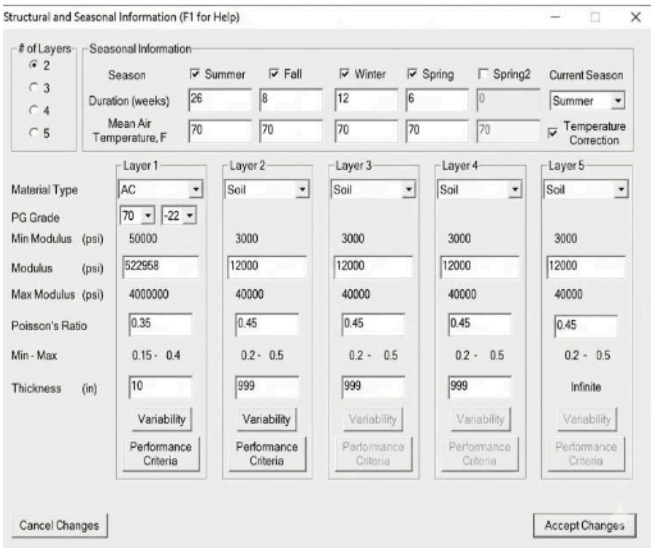


Figure 3. .PerRoad 4.4 Structural window

TABL I. average temperature & properties of layers

| season | summer | fall | winter | spring | |
|---|---|---|---|---|---|
| average temperature F | 83 | 75 | 61 | 68 | |
| average temperature C° | 28 | 24 | 16 | 20 | |
| Design type | perpetual pavement Layers properties | | | | |
| layers | layer 1 | layer 2 | layer 3 | layer 4 | Ground |
| Material type | AC | AC | AC | Granular base | soil |
| Performance grade | 70-10 | 70-10 | 70-10 | - | - |
| Modulus of elasticity ( Mpa) | 2158 | 4707 | 2158 | 207 | 100 |
| Poisson's ratio | 0.4 | 0.4 | 0.4 | 0.35 | 0.35 |
| California Bearing ratio (CBR) | - | - | - | CBR≥80 | CBR≥10 |
| First design thickness attempt (cm) | 3 | 9 | 6 | 15 | - |
| Design type | Mechanical empirical | | | | |
| Design type | layer 1 | Layer2 | layer 3 | layer 4 | Ground |
| Material typ | AC | AC | Granular base | Granular base | soil |
| Performance grade | 70-10 | 70-10 | - | - | - |
| Modulus of elasticity ( Mpa) | 4707 | 2158 | 207 | 207 | 100 |
| Poisson's ratio | 0.4 | 0.4 | 0.35 | 0.35 | 0.35 |
| California Bearing ratio (CBR) | - | - | - | CBR≥ 80 | CBR≥ 10 |
| First design thickness attempt (cm) | 4 | 13 | 15 | 10 | - |

- Load spectra: This section was used to input traffic volumes, The classification system considers several factors: the different types of load spectra, the amount of traffic, the percentage of trucks, the type of road, percentage of trucks in design lane (D.L), direction distribution ( D.D) and the growth rate(r).

and axle loads were classified based on the load spectra applied in the program, according to the road classification specified as an interstate urban road. This classification was used for both methodologies employed in the design as shown Figure 4, so the program will divide the axle load groups, That's showed in table II withe the truck factor calculation. The parameters were entered with a truck percentage of 15%, a design lane truck percentage of 90%, a directional distribution of 50%, and a growth rate of 4% as shown in table III .
The traffic volume was simulated to match ESAL levels ranging from 0 to 24 M.S.A, with an increase of 5 M.S.A each time, and these were used for designing both permanent and traditional pavements .and studies conducted in Misrata showed that the ESALS values at the Khrouba intersection on the highway were 21.2 MSA, and it was also observed that at the heavy intersection it was 23.9 M.S.A. Therefore, the design was based on 24 MSA. The study[13] mentioned that the Average Daily Traffic (ADT) was calculated during peak hours, a traffic count was conducted, and ESALs were calculated. This was done for two locations in the coastal area with high traffic volumes the Khrouba intersection and the heavy vehicle route. And it was conducted in the year of 2025.

DOI: **10.5281/zenodo.20397898**

TABL II. calculations for truck factor & Load spectra classification

| Vehicle classification(n) | %AADT | Single | Tandem | Tridem | LEF |
|---|---|---|---|---|---|
| 4 | 1.2 | 1.62 | 0.39 | 0 | 0.0198 |
| 5 | 9.4 | 2 | 0 | 0 | 0.1880 |
| 6 | 3.3 | 1.02 | 0.99 | 0 | 0.0363 |
| 7 | 0.5 | 1 | 0.26 | 0.83 | 0.0052 |
| 8 | 7.4 | 2.38 | 0.67 | 0 | 0.1801 |
| 9 | 68.9 | 1.13 | 1.93 | 0 | 0.8849 |
| 10 | 1.2 | 1.19 | 1.09 | 0.89 | 0.0155 |
| 11 | 6.1 | 4.29 | 0.26 | 0.06 | 0.2630 |
| 12 | 0.8 | 3.52 | 1.14 | 0.06 | 0.0289 |
| 13 | 1.2 | 2.15 | 2.13 | 0.35 | 0.0280 |
| Total | 100 | | | | 1.65 |

TABL III. raffic volumes

| M.S.L | Axle groups /day | %Trukese | %r | D.D | D.L | T.F |
|---|---|---|---|---|---|---|
| 5 | 810 | 15 | 4 | 0.5 | 0.9 | 1.65 |
| 10 | 1692 | 15 | 4 | 0.5 | 0.9 | 1.65 |
| 15 | 2430 | 15 | 4 | 0.5 | 0.9 | 1.65 |
| 20 | 3241 | 15 | 4 | 0.5 | 0.9 | 1.65 |
| 24 | 3889 | 15 | 4 | 0.5 | 0.9 | 1.65 |

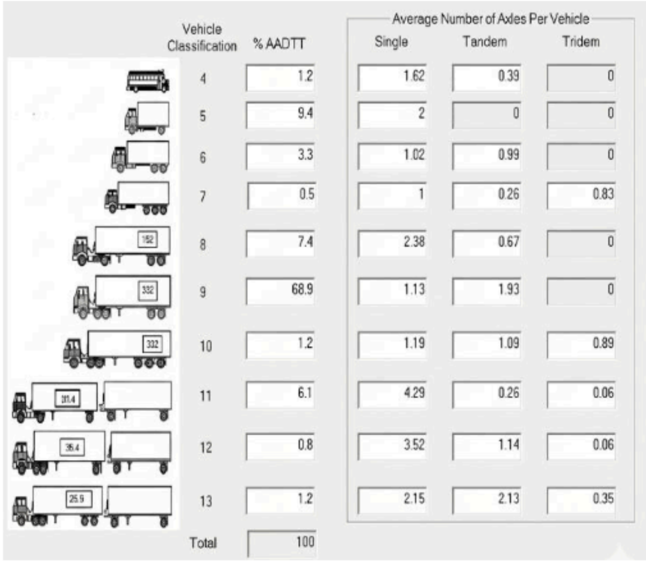


Figure 4. PerRoad 4.4 Load spectra classification

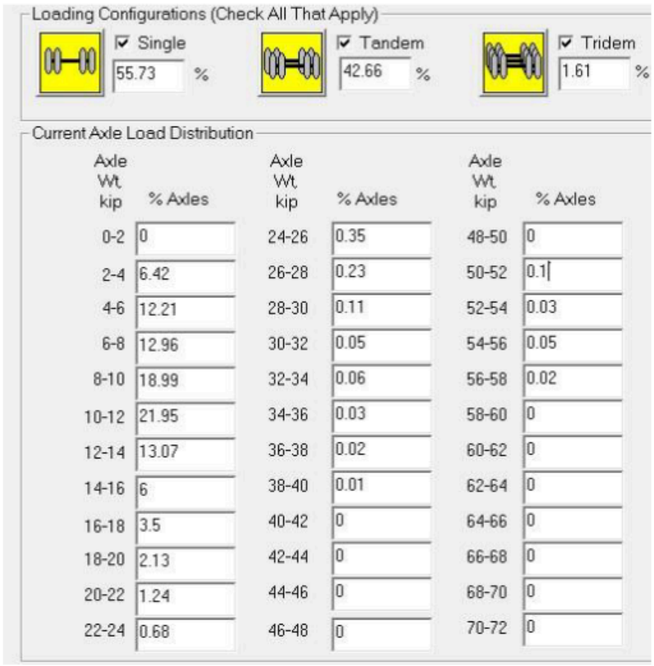


Figure 5. PerRoad 4.4 Load spectra window 2

### C. *Stain Disribution in PerRoad Software*

Horizontal stresses beneath the binder layer were controlled at specified strain levels based on the NCAP study. In addition, the vertical strains at the top of the subgrade were controlled. This was achieved by following a systematic strain-control procedure to satisfy the requirements of long-life for Perpetual pavement design. These are the stipes used in the Per Road software :

- Data Input ; The strain distributions were included using an improved input interface, as shown in

Figure 6 and the strain distribution values are shown in table V

- Integration of Design Requirements: Design requirements were embedded within the output module to address the most recent criteria and to ensure consistency between the analytical process and the targeted performance objectives.
- Compliance Evaluation: Compliance was examined and the outcomes were summarized in the results table Figure 7, providing a clear indication of acceptance or non-acceptance based on the specified criteria.
- Verification of Critical Limits; A critical design condition was verified by ensuring that no less than 95% of the tensile strain values remained below the limit of 257 microstrain (−257).

TABLE V. strain distribution values for perpetual pavement

| AC layer | Horizontal strain distribution Microstrain | Percentile% |
|---|---|---|
| bottom Layer 3 | -257 | 95 |
| bottom Layer 3 | -194 | 85 |
| bottom Layer 3 | -158 | 75 |
| bottom Layer 3 | -131 | 65 |
| bottom Layer 3 | -110 | 55 |
| Vertical strain | | |
| Top of ground | 200 | 50 |

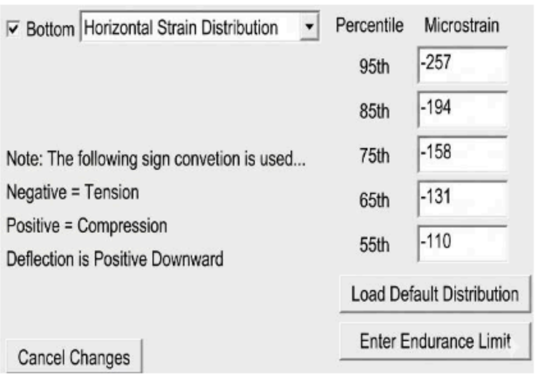


Figure 6. PerRoad 4.4 Horizontal strain distribution window

## D. Output Table with New Design Criteria

After controlling the stresses and adjusting the layer thicknesses, the final design is approved. The software provides a final table of the design results and allows exporting the results to Excel spreadsheets.as shown in figure 7.

**Perpetual Pavement Design Results: Percentile Responses**

| Layer | Location | Criteria | Target Units | Target %tile | Actual %tile | Pass/Fail? |
|---|---|---|---|---|---|---|
| 1 | Bottom | Tensile Strain | -257 microstrain | 95 | 99 | Pass |
| | | | -194 microstrain | 85 | 98 | Pass |
| | | | -158 microstrain | 75 | 92 | Pass |
| | | | -131 microstrain | 65 | 82 | Pass |
| | | | -110 microstrain | 55 | 69 | Pass |
| 3 | Top | Vertical Strain | 200 microstrain | 50 | 76 | Pass |

Figure 7. PerRoad Output Table

## V. Mechanistic-empirical Design Steps Using PerRoad

The same program was used in this design, and the same previous steps were followed with a slight difference in the number of layers. There were two asphalt layers and two soil layers. Additionally, the method of controlling strains was different. The experimental mechanical methodology is based on empirical equations present in the program, which is designed to account for horizontal tensile failure at the bottom of the last asphalt layer and vertical failure at the top surface of the natural ground. Figure 8 illustrates the inputs used in the empirical equations, while Figure 9 displays the design outputs that indicate the design life provided by the programme, which corresponds to the shorter lifespan between the two failure cases. In this study, the design was for 20 years.

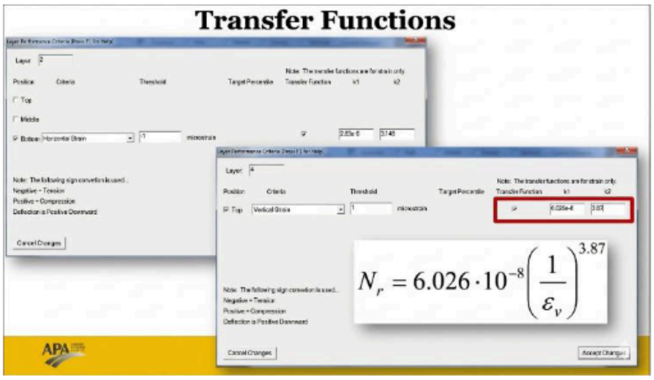


Figure 8 .Transfer functions

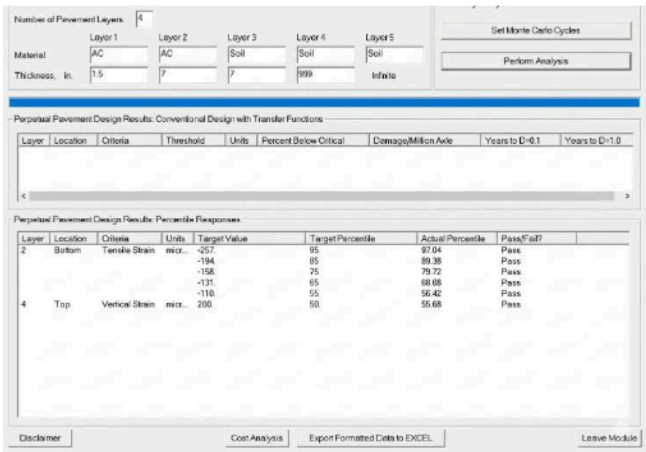


Figure 9 .design outputs

DOI: **10.5281/zenodo.20397898** 

## VI. RESULTS .

### A. *Perpetual Pavement Design*

This section illustrates the final design of the coastal highway in the city of Misrata using the permanent paving methodology, and the materials used in the construction of perpetual pavement layers.

- Design out put: the Figure 10 shows the thickness of the asphalt and soil paving layers, This section is suitable for all ESAL cases from 0 to 24 M.S.A.

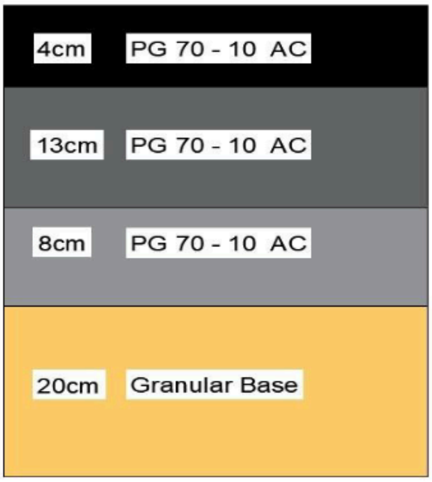


Figure 10. perpetual pavement layers.

- Construction and materials: Table II shows the properties of the materials used in the design of each layer based on Performance Grade (PG) fore asphalt layers. and California Bearing Ratio(CBR). for soil.
- Strain distributions : The following table VI shows the target strain values and target percentile, actual percentile and a correlation has been drawn between them in figure11.

TABLE VI. strain distribution values for perpetual pavement

| target strain values | target percentile | actual percentile | Pass/fail? |
|---|---|---|---|
| 254 | 95 | 98 | pass |
| 194 | 85 | 91 | pass |
| 158 | 75 | 85 | pass |
| 131 | 65 | 78 | pass |
| 110 | 55 | 70 | pass |

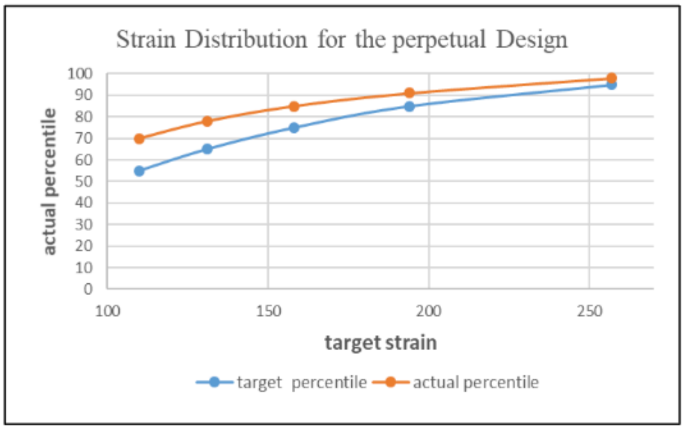


Figure11. design outputs

TABLE VII. properties of materials and layer thickens

| **Thickens and type of Layers cm M.S.A≤ 24** | | **Properties of materials** | | | |
|---|---|---|---|---|---|
| | | ***Property*** | ***Performance Grade*** | ***Poisson's ratio*** | ***Modulus of elasticity Mpa*** |
| 1 | AC 4cm | High quality | PG 70-10 | 0.4 | 2158 |
| 2 | AC13cm | Rut resistant | PG 70-10 | 0.4 | 4707 |
| 3 | AC 8cm | Fatigue resistant | PG 70-10 | 0.4 | 2158 |
| 4 | Gran base 20cm | CBR≥80 | - | 0.35 | 207 |
| 5 | Ground Infinite | CBR≥10 | - | 0.30 | 100 |

### B. *Mechanistic-Empirical Pavement Design*

This section illustrates the final design of the coastal highway in the city of Misrata using the mechanistic empirical methodology,

- Design out put: the Figure 12 shows the thickness of the asphalt and soil paving layers, Section (a) shows the design suitable for 5 M.S.A or less; section (b) is designed for 10 M.S.A and more than 5 M.S.A; section (C) is designed for 15 M.S.A and more than 10 M.S.A; section (d) is designed for 20 M.S.A and more than 15 M.S.A; and the last section (e) is suitable for the actual number of lanes on the Misrata coastal highway, which is estimated to be 24 M.S.A.

DOI: **10.5281/zenodo.20397898**

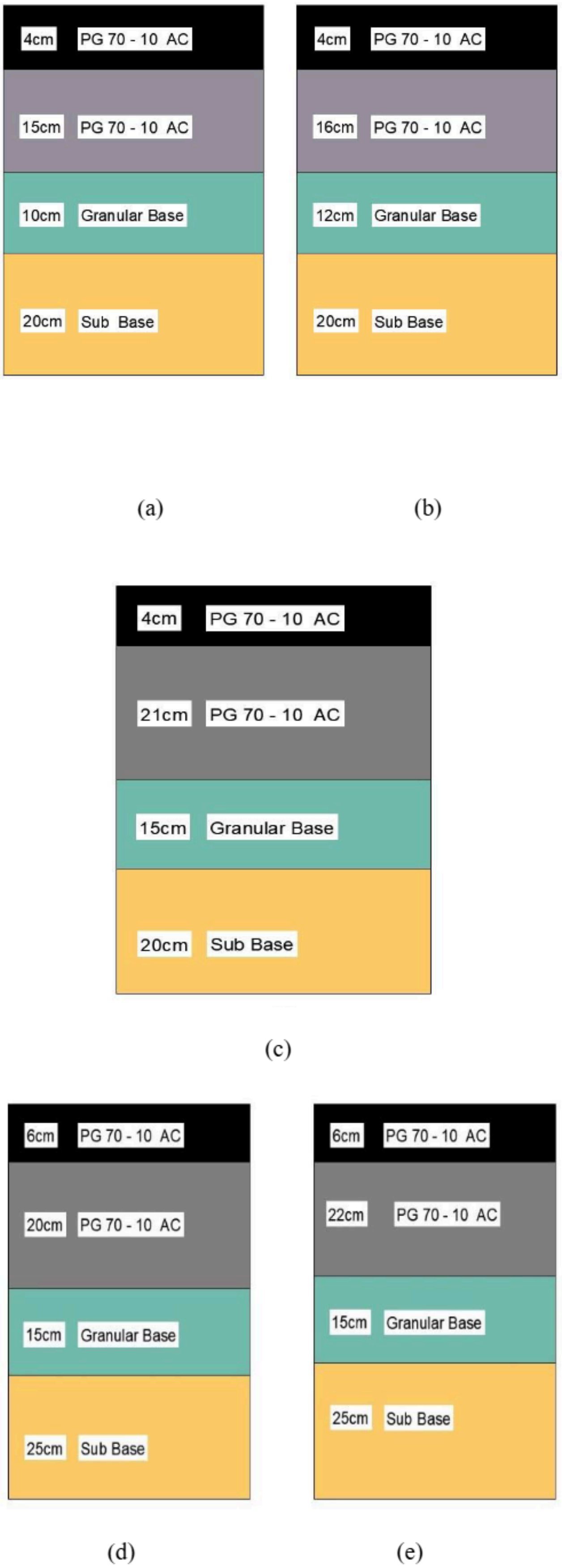


Figure 12. Mechanistic-empirical layers

- Construction and materials: Table VIII shows the properties of the materials used in the design of each layar.

TABLE VIII. properties of materials and layer thickens

| **Thickens and type of Layers cm M.S.A<5** | | **Properties of materials** | | | |
|---|---|---|---|---|---|
| | | ***Property*** | ***Performance Grade*** | ***Poisson's ratio*** | ***Modulus of elasticity Mpa*** |
| 1 | AC 4cm | Polymer-modified mix | PG 70-10 | 0.4 | 4707 |
| 2 | AC15cm | Dense mix | PG 70-10 | 0.4 | 2158 |
| 3 | Gran base 10cm | CBR≥80 | - | 0.35 | 207 |
| 4 | Gran base 20cm | CBR≥80 | - | 0.35 | 207 |
| 5 | Ground Infinite | CBR≥10 | - | 0.30 | 100 |

| **Thickens and type of Layers cm M.S.A=10** | | **Properties of materials** | | | |
|---|---|---|---|---|---|
| | | ***Property*** | ***Performance Grade*** | ***Poisson's ratio*** | ***Modulus of elasticity Mpa*** |
| 1 | AC 4cm | Polymer-modified mix | PG 70-10 | 0.4 | 4707 |
| 2 | AC16cm | Dense mix | PG 70-10 | 0.4 | 2158 |
| 3 | Gran base 12cm | CBR≥80 | - | 0.35 | 207 |
| 4 | Gran base 20cm | CBR≥80 | - | 0.35 | 207 |
| 5 | Ground Infinite | CBR≥10 | - | 0.30 | 100 |

| **Thickens and type of Layers cm M.S.A=15** | | **Properties of materials** | | | |
|---|---|---|---|---|---|
| | | ***Property*** | ***Performance Grade*** | ***Poisson's ratio*** | ***Modulus of elasticity Mpa*** |
| 1 | AC 4cm | Polymer-modified mix | PG 70-10 | 0.4 | 4707 |
| 2 | AC21cm | Dense mix | PG 70-10 | 0.4 | 2158 |
| 3 | Gran base 15cm | CBR≥80 | - | 0.35 | 207 |
| 4 | Gran base 20cm | CBR≥80 | - | 0.35 | 207 |
| 5 | Ground Infinite | CBR≥10 | - | 0.30 | 100 |

DOI: **10.5281/zenodo.20397898**

| Thickens and type of Layers cm M.S.A=20 | | Properties of materials | | | |
|---|---|---|---|---|---|
| | | *Property* | *Performance Grade* | *Poisson's ratio* | *Modulus of elasticity Mpa* |
| 1 | AC 6cm | Polymer-modified mix | PG 70-10 | 0.4 | 4707 |
| 2 | AC 20cm | Dense mix | PG 70-10 | 0.4 | 2158 |
| 3 | Gran base 15 cm | CBR≥80 | - | 0.35 | 207 |
| 4 | Gran base 25cm | CBR≥80 | - | 0.35 | 207 |
| 5 | Ground Infinite | CBR≥10 | - | 0.30 | 100 |

| Thickens and type of Layers cm M.S.A=24 | | Properties of materials | | | |
|---|---|---|---|---|---|
| | | *Property* | *Performance Grade* | *Poisson's ratio* | *Modulus of elasticity Mpa* |
| 1 | AC 6cm | Polymer-modified mix | PG 70-10 | 0.4 | 4707 |
| 2 | AC 22cm | Dense mix | PG 70-10 | 0.4 | 2158 |
| 3 | Gran base15cm | CBR≥80 | - | 0.35 | 207 |
| 4 | Soil 25cm | CBR≥80 | - | 0.35 | 207 |
| 5 | Ground Infinite | CBR≥10 | - | 0.30 | 100 |

### *C. The effect of Axle Group and ESAL on the thickness of asphalt layers.*

After designing the asphalt pavement layers for both methodologies, studies were conducted on the effect of Axle Groups and ESALs on thickness of asphalt layers for different changes of Axle Groups and ESALs Table IV shows the thickness of asphalt layers and Axle Groups and ESALS, Fieger 13and 14 shows the mechanistic empirical design versus the perpetual design.

TABLE IX. thickness of asphalt layers for Axle Groups and ESALs

| P.P AC Thickness cm | M.E AC Thickness cm | M.S.A | Axle /DAS |
|---|---|---|---|
| 25 | 19 | 5 | 810 |
| 25 | 20 | 10 | 1620 |
| 25 | 25 | 15 | 2430 |
| 25 | 26 | 20 | 3241 |
| 25 | 28 | 24 | 3889 |

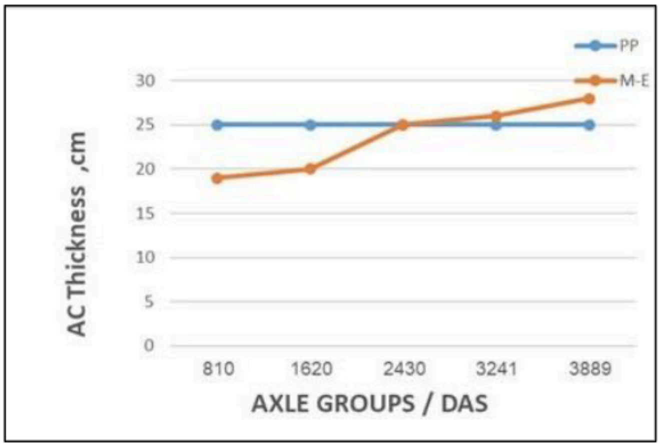


Figure 13. M-E versus Perpetual Design by axle groups

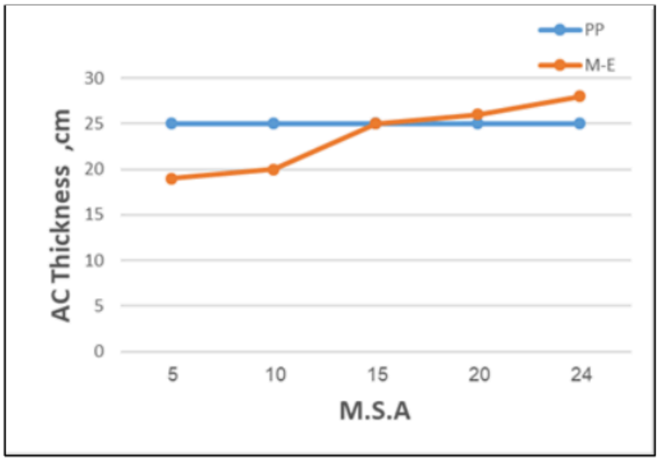


Figure 14. M-E versus Perpetual Design by ESALs

## VII. DISCUSSON

- First we will discuss the study results and the differences between the two designs.

Through the design of the perpetual pavement, we notice that there is no change in the layer thickness. The increase in traffic volumes with ESAL and axle groups indicates that the perpetual pavement is not affected by axle volume but is influenced by axle weight. This characteristic is what enables it to serve for the longest period without structural failure, as the design was done under less than critical stresses.

The perpetual pavement design had no need for a sub base layer this is due to the presence of a layer designed with materials capable of withstanding deformation, rich in bitumen, and with a thickness of 13 cm, which makes it capable of reducing the values of stresses applied to the natural ground. Consequently, we observe a reduction in the thickness of the soil layers was observed.

The Mechanistic-empirical design showed that increase of traffic volumes with ESALs and axle groups caused an increase in the thickness of the asphalt layers from 19 cm to 28 cm, indicating its impact on the change in the volume of axles and traffic volume and this requires a system to monitor traffic loads and regular maintenance to preserve the structural integrity and design life without causing damage.

The soil layer in the Mechanistic-empirical design had a high thickens fore soil layers the road base increased from 10cm to 15cm and the sub base increased from 20cm to 25cm that's needed to To resist the stresses that cause failure

In Figure 11and 12,it can be seen that the points intersect at a asphalt thickens of 25cm with a esal number 15M.SA and a axle groupes number 2430 axle per day this shows that the design above these numbers in the Mechanistic-empirical way is considered over-designed and the perpetual pavement design can be usedasa as a substitution and considering into account the properties of the materials used in this method to achieve a long service life for the road.

- Secondly, the most important results of the study regarding the design of asphalt layers using the Perpetual pavement method will be discussed, along with tow similar studies.

In the first study titled "Perpetual Pavement Design Guide" [10], the ESALs are between 10 and 30 M.S.A. the surface layer thickness in the range between 4 and 5 cm, which is broadly consistent with the 4 cm adopted in this study, indicating similar requirements for surface wear resistance on major roads. Regarding the underlying asphalt layer, the study suggested a thickness of about 6 to 8 cm, which is very close to the 8 cm used here, reflecting a comparable design approach. In contrast, the middle rutting resistant layer in the first study was thinner 10 to 12 cm than the 13 cm applied in this study, suggesting that the present design adopts a more conservative .

In the second study titled"Perpetual Pavement Performance in Coastal Highway" [11] the ESALs are between 15 and 40 M.S.A. the surface thickness layer in this study is 4 cm were almost identical to those of this study, confirming the consistency of this thickness in coastal road designs. As for the final layer, its thickness was 8 cm, which is the same as what was adopted (8 cm). Meanwhile, the middle rutting resistant layer reached 15 cm in the study, which is greater than the 13 cm recorded in this study

## VIII. CONCLUSION AND RECOMMEDATIONS

### A. *CONCLUSIONS*

The following points are extracted from the study:

- The design, developed using the perpetual pavement method, remains unaffected by varying traffic volumes, changes in numbers of axle loads, and Equivalent Single Axle Loads (ESALs). Therefore, it can be concluded that this design successfully adheres to the principle of perpetual pavement, which entails minimal impact from axle loads, as the design operates at points below critical stress levels.
- It appears from the design of the permanent pavement that the mechanical properties of the materials play a significant and primary role in reducing the impact of stresses, as they help resist loads to avoid tensile strains and rutting.
- The second layer, which is the thickest and one of the most important in permanent pavements rich in bitumen, is capable of resisting deformation, thereby reducing the impact of stresses on other layers and helping to decrease the thickness of the soil layers.

### B. *RECOMMEDATIONS*

The following recommendations are crucial for guiding future research and practical application:

- Based on the study results, it is recommended to adopt the permanent paving method in the design of the coastal highway in Misrata, as it has achieved superior performance compared to the traditional design method
- The perpetual pavement method involves using materials resistant to tensile stresses in the last asphalt layer, such as polymer-modified asphalt, to prevent cracking caused by tensile strains.
- This study recommends calculating the life cycle cost of the road using both methodologies to understand the key differences in operational and construction costs, which will help decision-makers adopt the most efficient design for the Libyan context.
- Regarding the Libyan reality, which does not adopt a comprehensive system for managing highways, in the absence of a load weighing system, the permanent paving method remains a long-term solution and is recommended for use on highways and heavy-traffic roads.

## IX. ACKNOWLEDGMENTS

The authors wish to express their sincere gratitude to the Libyan Academy for Postgraduate Studies for its invaluable institutional support, which made this research possible. They also wish to extend their heartfelt thanks to everyone who contributed to and supported this study, whose assistance and cooperation played a vital role in its successful completion.

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