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A New Approach for Reinforcing the Pavement Subjected to Solicitations and Admissible Deformations

Omar Ben Charhi* **and Khadija Baba**

GCE Laboratory, Mohammadia School of Engineers, Mohammed V University, Rabat, Morocco

***Correspondence to:**
Omar Ben Charhi
GCE Laboratory,
Mohammadia School of Engineers,
Mohammed V University, Rabat, Morocco.
E-mail: bencharhi.omar@gmail.com

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Abstract

Roads play a crucial role in the transportation of goods and people. Improving the road network is a key element of territorial upgrading strategies. The development and modernization of this network acts as a catalyst for socio-economic development and promotes regional and local integration. Analysis of existing roads has revealed that repeated use by heavy vehicles causes damage to road surfaces, primarily through the formation of transverse cracks resulting from thermal shrinkage of the asphalt concrete. Moreover, these cracks allow water penetration, leading to further damage and reduced ride comfort. Various principles and numerous methods are employed for pavement strengthening, which can be categorized into two groups: the first category utilizes the concept of residual pavement, while the second category relies on deformation data. The residual method measures the bearing capacity of the soil under worst-case conditions beneath the existing pavement and estimates the equivalent pavement thickness. The second category of reinforcement involves measuring the deflection of a flexible pavement under a heavy wheel load. These methods were initially developed abroad and faced challenges when adapting to the Moroccan context. In this study, we present a novel approach for reinforcing pavement structures. The methodology employed in this new method allows for synthesis and leads to a design that considers the influence of various parameters that determine the reinforcement solution.

Keywords

Roads, Transverse cracks, Equivalent pavement thickness, Residual method, Pavement strengthening

Introduction

The primary function of pavement extends beyond its mere existence as a surface for vehicles to traverse. Pavement plays a crucial role in providing a sturdy foundation that can withstand the repetitive stresses and strains imposed by vehicular traffic. It serves as a resilient infrastructure, designed to accommodate the diverse range of vehicles and their loads, while ensuring the comfort and safety of users.

One of the key objectives of pavement is to maintain an optimal level of ride quality. A well-designed pavement system absorbs and dissipates the forces generated by moving vehicles, minimizing the discomfort experienced by occupants. By distributing the load evenly and efficiently, the pavement reduces the intensity of vibrations and impacts that would otherwise be transmitted to the vehicles and their occupants. This ensures a smoother and more comfortable ride, enhancing the overall user experience. If a pavement surpasses its intended lifespan and is neglected without proper maintenance, it is bound to undergo a rapid deterioration process that leads to its eventual destruction. Recognizing this, it becomes imperative to implement timely measures to reinforce the pavement structure by adding one or more new layers of materials to its upper part. This reinforcement aims to restore and enhance the pavement's structural integrity, enabling it to withstand the mechanical actions imposed by vehicles for an extended period [1].

The integrity and performance of a pavement are directly influenced by the stresses it experiences, which stem from both road traffic and thermal effects, often occurring simultaneously. When a vehicle moves along the roadway, it generates various types of stresses that impact the pavement structure. These stresses include vertical stresses as well as tangential stresses, encompassing longitudinal and lateral forces that exert traction at the base of the pavement layers [2].

Vertical stresses comprise two components: a continuous component representing the static load exerted by the vehicle, and a variable component associated with dynamic loads resulting from the interactions between the tires and the road surface. The repetitive nature of axle loads leads to cyclic loading, causing the pavement to experience repeated stresses. Over time, these stresses can lead to permanent deformations on the pavement surface, attributable to the settlement of the asphalt concrete layers and the deformations within the lower layers [3].

The vertical stresses induced by the weight of the vehicle are primarily responsible for the compression and shearing forces exerted on the pavement layers. The cumulative effect of these stresses can lead to various forms of distress, including rutting, cracking, and fatigue failure. Rutting refers to the permanent deformation or groove formation in the wheel path caused by the repetitive loading and compaction of the pavement layers. Cracking occurs when the pavement is unable to withstand the tensile stresses induced by the traffic loads, resulting in fissures and fractures in the surface. Fatigue failure refers to the progressive development of cracks due to the repeated application of dynamic loads, leading to structural failure over time.

In addition to traffic-induced stresses, the pavement is also subjected to thermal stresses resulting from temperature variations. Asphalt concrete, a common material used in pavement construction, is particularly sensitive to temperature changes. When exposed to high temperatures, the pavement expands, while colder temperatures cause contraction. These thermal movements impose stresses on the pavement layers, contributing to the development of cracks and other forms of distress. The combined effects of traffic and thermal stress necessitate careful consideration during pavement design and maintenance to ensure the longevity and durability of the infrastructure.

By reinforcing the pavement, an opportunity arises to address the various distresses and signs of wear that have accumulated over time. Through the addition of new layers, the pavement gains renewed strength, stability, and resilience, restoring its ability to withstand the demanding forces exerted by vehicles.

The process of reinforcing the pavement involves carefully selecting and incorporating suitable materials that possess the necessary properties to endure the anticipated traffic loads and environmental conditions. The combination and arrangement of these materials are determined by the specific requirements of the pavement and the expected design life.

The newly reinforced pavement structure must be meticulously designed to withstand the anticipated mechanical actions of vehicles for as long as possible. This necessitates a comprehensive understanding of the traffic patterns, axle loads, and environmental factors that the pavement will be subjected to. In addition to withstanding the mechanical actions of vehicles, the reinforced pavement should also exhibit durability in the face of environmental factors such as temperature variations, moisture, and freeze-thaw cycles. Proper drainage and effective measures to mitigate the adverse effects of water infiltration are crucial in ensuring the long-term functionality and stability of the pavement structure.

Reinforcing the pavement not only extends its service life but also contributes to cost-effectiveness in the long run. Timely intervention and maintenance measures can help avoid the need for more extensive and costly rehabilitation or complete reconstruction of the pavement in the future. By investing in reinforcing the existing pavement, transportation authorities can efficiently manage infrastructure budgets and allocate resources effectively.

Ultimately, the reinforcement of a pavement structure serves as a proactive approach to preserving and optimizing the functionality of road networks. By undertaking the necessary measures to fortify the pavement against the relentless forces exerted by vehicles, it can continue to provide a safe, reliable, and smooth surface for transportation, ensuring the seamless flow of goods and people while minimizing disruptions and maximizing user satisfaction.

Pavement reinforcement employs various principles and methods, which can be categorized into two groups. The first category revolves around residual pavement, whereas the second category focuses on deformation data. The residual method involves assessing the soil's bearing capacity under worst-case conditions beneath the existing pavement and estimating the equivalent pavement thickness [4]. The equivalent total thickness of the pavement is determined based on sizing charts corresponding to the bearing capacity and traffic charts provided by the American Association of State Highway and Transportation Officials. By calculating the difference, we can obtain the equivalent thickness of the reinforcement, represented by a set of equivalence coefficients [5].

In the realm of pavement reinforcement, there exists another method that focuses on the determination of two crucial parameters: the soil's bearing capacity, particularly measured using the California Bearing Ratio (CBR) platform, and the equivalent traffic. By considering these factors, the method aims to provide effective reinforcement for residual pavements. The Road Note 2 charts, a widely accepted reference in pavement strengthening, offer guidance in defining the equivalent pavement thickness when utilizing this particular approach [6].

The second category of reinforcement entails measuring the deflection of a flexible pavement under a heavy wheel load. The objective of this method is to accurately assess how the pavement will behave under the anticipated traffic loads and to identify areas of potential concern or weakness. By subjecting the pavement to a heavy wheel load, typically through the use of a specialized testing, we can measure the resulting deflections or deformations that occur on the surface. These deflections serve as valuable indicators of the pavement's structural integrity and provide insights into its ability to withstand the applied loads.

The measurement of deflection under a heavy wheel load allows engineers to gain a deeper understanding of how the pavement will perform over time. By analyzing and interpreting the deflection data, they can assess the pavement's load-carrying capacity, its ability to distribute stresses effectively, and its overall response to traffic-induced loads. This information serves as a basis for making informed decisions regarding pavement maintenance, repair, or the application of bituminous materials.

One of the key considerations in this method is the CBR of the underlying soil. The CBR is a crucial geotechnical parameter that indicates the soil's strength and load-bearing capacity. In the context of this reinforcement method, it is particularly relevant to consider soils with a CBR ranging from 2.5 to 10. Soils within this range typically exhibit moderate to good strength characteristics, making them suitable for the application of this technique [7].

Another method involves using a technical guide for the Diagnosis and Design of Pavement Reinforcements, which provides a comprehensive approach to measuring the thickness of pavement reinforcement. This method involves the utilization of bituminous concrete-treated materials, offering an effective approach to enhancing the structural integrity and performance of the pavement. The guide serves as a valuable resource for the diagnosis and design of pavement reinforcements. It outlines a step-by-step procedure for accurately determining the required thickness of pavement reinforcement. By utilizing bituminous concrete-treated materials, which are known for their durability and effectiveness in strengthening pavements.

The measurement process begins with a thorough assessment of the existing pavement structure. This involves evaluating factors such as the pavement's condition, distresses, traffic loads, and environmental conditions. Based on this evaluation, we can determine the appropriate thickness and type of reinforcement needed to address the specific issues identified.

To measure the thickness of pavement reinforcement, bituminous concrete-treated materials are applied strategically to the pavement surface. These materials are specifically designed to enhance the load-carrying capacity and structural performance of the pavement. By precisely applying these materials in accordance with the technical guidelines outlined in the guide, we can effectively reinforce the pavement and restore its functionality.

The thickness measurement process is carried out at specific intervals and locations along the pavement, considering factors such as traffic patterns, areas of high stress concentration, and vulnerable sections prone to deterioration. By measuring the thickness of the applied reinforcement materials at these designated points, engineers can assess the uniformity and adequacy of the reinforcement throughout the pavement surface [8].

Although the previously mentioned methods were originally developed and implemented abroad, they encountered specific challenges when applied to the Moroccan context. Recognizing the need for tailored solutions, this research study introduces a novel approach to reinforce pavement structures within the unique conditions of Morocco. By addressing the limitations of existing methods, this study aims to provide an innovative and effective reinforcement solution specifically designed to meet the requirements and challenges of the Moroccan pavement infrastructure.

The methodology employed in this new approach allows for a comprehensive synthesis of various factors and considerations that influence the design of the reinforcement solution. By taking into account a wide range of parameters, such as traffic patterns, soil characteristics, climatic conditions, and local construction practices, the methodology ensures that the proposed reinforcement solution is well-suited to the specific context of Moroccan pavements.

The incorporation of multiple parameters in the design process allows for a more robust and tailored reinforcement solution. For instance, the study considers the traffic patterns and load characteristics specific to Moroccan roadways, taking into account factors such as axle loads and vehicle types. This information can help to accurately assess the anticipated stresses and strains that the pavement will experience, facilitating the development of a reinforcement solution that can withstand the local traffic demands.

Additionally, the study considers the unique soil properties prevalent in the Moroccan context. By analyzing the geotechnical characteristics of the subgrade and subbase materials, including their bearing capacity, CBR values, and compaction properties, the methodology ensures that the reinforcement solution is designed to effectively distribute loads and mitigate potential issues related to soil instability or settlement.

Furthermore, the influence of climatic conditions, such as temperature variations and moisture levels, is taken into account in the methodology. By considering the specific environmental factors that impact the performance of the pavement, the reinforcement solution can be designed to withstand the thermal stresses and moisture-related phenomena, ensuring long-term durability and resilience.

The synthesis of these various parameters and considerations results in a comprehensive and tailored reinforcement solution that addresses the specific challenges and requirements of Moroccan pavements. By integrating the knowledge gained from the adaptation of foreign methods with a deep understanding of the local context, this study contributes to the advancement of pavement reinforcement practices in Morocco.

Materials and Method

The general reinforcement methodology consists of data collection, which determines the behavior of the pavement, the choice of actions, the determination of the thicknesses and the modeling pavement structure. However, compared to other methods, these points have been well detailed and completed. The purpose of data collection is to gather as much information as possible concerning the following points: traffic geotechnical, auscultation data, and general data (climate, environment, and geology of the region).

The traffic classes considered are those of the Moroccan catalog of new pavement structures [9]. Some classes have been split into subclasses, which allow a wider choice of reinforcement and surface layer materials. The geotechnical and general data determines the thickness of the pavement. The general data concerns the history of the pavement as well as the geological, hydrogeological and climatic context, which characterizes the environment of the pavement. All of this data makes it possible to determine homogeneous zones which present the same characteristics and on which the actions to be undertaken will be defined. As far as the choice of structures to be put in place is concerned, this is preceded first by a choice of actions to rehabilitate the pavement, which constitutes the key to the study and a kind of pavement diagnosis. At this level, a decision is made regarding whether or not to maintain the homogeneous zone, in the case of a normal reinforcement study. Indeed, several routes are degraded only by environmental constraints. It is then that the choice of structures is made quantitatively and qualitatively.

In this regard, several types of non-classical materials in Moroccan road engineering have been introduced with the aim of taking maximum advantage of the possibilities of supplying local materials. The flowchart presented below summarizes the steps of the methodology adopted (Figure 1). Materials with nanoproperties were used for the work.

Experimentation

Our study focuses on the reinforcement of the provincial road 3011, located in the province of Berrechid, Morocco. The road spans a length of 16.1 km, as indicated in table 1.

The objective of our research is to analyze and evaluate the condition of the road and propose suitable reinforcement measures to enhance its quality and performance.

In support of our proposed reinforcement measures, we will employ a combination of field investigations, laboratory testing, and analysis. Field investigations will involve collecting samples of road materials for testing, conducting geotechnical surveys, and measuring the road's structural response. Laboratory testing will include assessing the properties of road materials, such as soil and aggregates, to determine their suitability for the proposed reinforcement techniques.

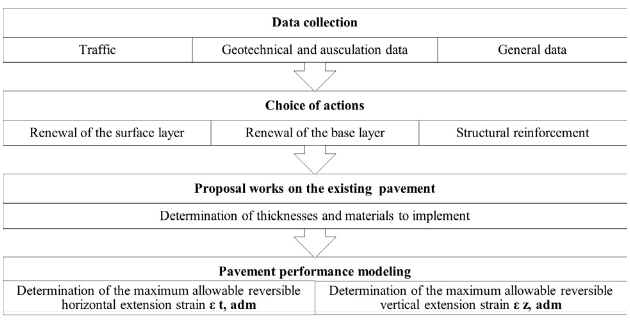

Figure 1: Flow chart of pavement reinforcement methodology.

Table 1: Project context.

Road length	Subgrade width	Roadway width	Pavement condition
16.1 Km	8 m	6 m	Several types of pavement deterioration

The pavement structure is flexible, and the choice of structure depends on the framework and specificities of the project (Table 2).

Table 2: Type of pavement structure.

Surface course	Base course	Subbase course
Asphaltic concrete	Bituminous concrete gravel (GBB)	Untreated gravel

The subbase course of a pavement consists of untreated granular materials, which possess a relatively low modulus of rigidity. When subjected to rolling loads from traffic, flexible pavements undergo deformation, and subsequently, the materials either rebound to their original position or retain a residual deformation. Due to the low stiffness of the granular materials in the pavement structure, the vertical forces generated by traffic loads are transmitted to the subgrade course.

As vehicles traverse the pavement surface, the weight and dynamic forces exerted on the pavement cause the granular subbase materials to compact and displace, resulting in temporary deformations. These deformations can manifest as vertical displacement or lateral movement of the granular particles. However, once the load is removed, the granular materials have the capacity to partially or completely recover their original shape and position, depending on the magnitude and duration of the applied loads.

It is crucial to recognize that the subbase materials in flexible pavements act as a load-distributing layer, transferring the vertical forces from the traffic loads to the underlying subgrade. The low modulus of rigidity of the granular materials allows them to deform and absorb a significant portion of the applied loads, thereby reducing the stress transmitted to the subgrade course. This load distribution mechanism helps prevent excessive stresses on the subgrade and promotes the overall stability and longevity of the pavement structure [10].

Pavement design

Pavement design is of utmost importance in establishing long-lasting, safe, and high-performing road infrastructure. Creating a robust and sustainable pavement structure involves meticulous analysis of several factors. Among the myriad parameters influencing pavement design, three emerge as particularly crucial: traffic, climatic environment, and the subgrade course. Understanding and properly addressing these key elements are fundamental to achieving optimal pavement performance and longevity.

Traffic estimate

Traffic is an essential element in pavement design because the weight of vehicles is transmitted to the pavement. It is generally expressed by two parameters (Table 3).

Table 3: Traffic data.

Daily traffic	Vehicle traffic greater than 8 T	Rate of increase	Pavement life
1405 V/d	20 % PL > 8 T	5%	10 years

Commissioning of traffic

This parameter is expressed as a function of the average daily intensity (V/d). It enables the selection of materials required for constructing the pavement, considering the anticipated traffic load.

Cumulative traffic

This parameter is expressed as the number of standard 13-ton axles that the pavement will experience during its service life. Determining the cumulative traffic involves selecting a growth rate, typically ranging from 0% to 6% per year, with an average of 4%. This parameter helps estimate the long-term durability and performance requirements of the pavement.

By considering both the commissioning of traffic and cumulative traffic, pavement designers can make informed decisions regarding material selection, thickness design, and reinforcement measures to ensure the pavement can withstand the expected traffic loads throughout its lifespan.

To determine the heavy vehicle traffic class, we will utilize the formula in Equation 1, as shown below:

NEE13T = C1 x C2 x C3 x C4 N4 x N2 x F SEQ Equation * ARABIC 1 (1)

Where, NEE13T represents the cumulative traffic expressed in the number of standard 13-ton vehicles, C1 denotes the width coefficient, C2 signifies the average aggressiveness coefficient, C3 accounts for the increase in heavy vehicles, C4 represents the growth of heavy vehicles, N4 indicates the cumulative traffic, N2 represents the updated traffic of heavy vehicles weighing more than 8 tons, and F represents the traffic distribution coefficient.

Climatic environment

Four zones are defined based on the average annual precipitation, expressed in millimeters (mm), and determined over a long recurrence period of approximately 30 years. The study area exhibits an average annual precipitation of 429 mm and an average annual temperature of 18 °C, as indicated in .

Subgrade course

In the design of a new pavement structure, the long-term bearing capacity is taken into consideration. It is defined both at the upper part of the earthworks and the subbase course level. The subgrade course of the pavement serves as a foundation and provides support. However, if the existing floor materials possess the necessary qualities, the subbase course may not be required [11].

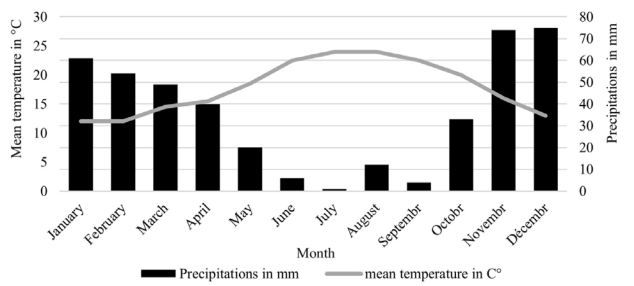

Figure 2: Precipitation and mean temperature data collected for each month in the study area.

Reinforcement structure

The pavement must have a thickness that ensures the vertical pressure transmitted to the ground remains sufficiently low, enabling it to support the load without degradation. Reinforcement of a pavement involves determining the additional thickness required to enhance its resistance against traffic-induced stresses. The key data required for the study of the reinforcement structure include traffic volume, visual and auscultation readings, as well as soil investigation data from the site. Traffic is expressed in terms of the number of axle equivalents for heavy vehicles, as indicated in Equation 2.

$$Ncp = Np \times C1 \times C2 \times C3 \times C4 \quad (2)$$

Where, Np represents the average daily traffic in the year of commissioning, C1 denotes the width of the roadway, C2 signifies the traffic aggressiveness, C3 indicates the percentage of heavyweights, and C4 represents the growth rate of heavy goods vehicle.

Results and Discussion

Reconnaissance work

A reconnaissance campaign was undertaken to gather valuable information about the study sections. This campaign involved conducting 40 manual surveys, strategically distributed across the designated areas. The aim was to obtain accurate data that would aid in the assessment and analysis of the project. The manual surveys provided the following results, as presented in table 4.

Based on the results of the conducted surveys, the land can be described in terms of its average configuration as follows:

- Asphalt cover with an average thickness of 10 cm.
- Subsequently, a coarse gravel layer with an average thickness of 50 cm.
- In the coastal region, there is a presence of sandy loam extending until the end of the soundings.

Table 4: Results of reconnaissance work.

Sounding depth	Type of material
[0 à -0,1 m]	Asphalt
[-0,1 m à -0,5 m]	Coarse gravel
[-0,5 m à -1,1 m]	Sandy loam

Laboratory tests results

The subgrade soils encountered in the boreholes underwent representative sampling, and these samples were then analyzed in the laboratory. The results of these analyses provided insights into the soil characteristics, leading to the identification of a specific soil family with the properties indicated in table 5.

Silt family: These soils exhibit a fines content ranging from 22.6% to 25.6% and a liquid limit (V.B) ranging from 0.17 to 0.35. Based on the Moroccan guide for road terraces [12], this soil is classified as B5.

To further assess the soil's properties, CBR tests were conducted [13]. The testing involved punching molded specimens with Modified Proctor optimal water content and compaction energy of either 25 or 50 Proctor blows. The Modified Proctor Compaction Test yielded the following results:

- Maximum dry density (γdmax) ranging from 1.80 to 1.90 T/m^3.
- Optimal water content (Wopt) ranging from 6.5% to 7.0%.
- The CBR after saturation, corresponding to a compaction level of 95% Modified Proctor Optimal, was found to be approximately 9 on average. This classification indicates a lift class of type P1 for the platform.

Adopted pavement structure

The dimensioning of pavements is a crucial step in the design process to ensure the durability and stability of road infrastructure. In this article, the dimensioning process was meticulously conducted, adhering to the guidelines provided in both the Manual for the Reinforcement of Pavements and the Catalog of Standard Structures for New Pavements. The results of the adopted pavement structure are presented in table 6.

Table 6: Results of the adopted pavement structure.

Enlarged structure	Reinforcement	Shoulder structure
5BB + 10GBB + 25GNF1 + 35GNF1	5BB	14MS + 25GNF1 + 35GNF1

Note: BB: Asphalt Concrete 0/10, GBB: Grave Bituminous Concrete 0/14, GNF1: Grave untreated 0/40, and MS: selected materials.

Pavement structural modeling

In order to validate the pavement structure presented above, a series of checks will be conducted. These checks involve modeling the pavement structure to assess the stresses and deformations resulting from a unit type load [14]. The approach focuses on several essential points, including the selection of structure type and materials, determination of permissible stresses in different materials, and calculation of appropriate thickness for each layer.

For the standard 13-ton axle, the following assumptions are made: twin-wheel axles supporting a load of 13 tons, vertical pressure of 0.6620 MPa, contact radius of 0.125 m, and twin center distance of 0.375 m. The pavement structure to be modeled is outlined in table 7.

Calculation of allowable stresses

Two damage mechanisms can be distinguished, each associated with specific expressions of acceptable requests:

Fatigue damage of bituminous materials

This is taken into account through the maximum allowable reversible horizontal extension deformation, εt,adm.

Accumulated permanent deformation in untreated materials

This is taken into account through the maximum allowable reversible vertical deformation, εz,adm.

Permissible deformation criterion for bituminous materials (εt,adm)

For a bituminous layer subjected to bending-induced extension, the allowable deformation for the equivalent temperature, θeq, is calculated using equation 3 [15]:

$$\varepsilon_{t,adm} = \varepsilon_6(10\,^{\circ}C;\,25\,Hz) \times \sqrt{\frac{E(10\,^{\circ}C;\,10\,Hz)}{E(\theta eq;\,10\,Hz)}} \times \left(\frac{NE}{10^6}\right)^b \times Kc \times Kr \times Ks \quad (3)$$

Where, ε6 (10 °C; 25 Hz): Represents the parameter of the fatigue law of the bituminous material, indicating the deformation corresponding to a service life of 10^6 cycles. ε6 is determined through standardized two-point bending fatigue

Table 5: Laboratory tests results.

Liquid limit (V.B)	The modified proctor compaction test		The California Bearing Ratio (CBR)
VB	Maximum dry density (γdmax)	Optimal water content (Wopt)	CBR
0,17 à 0,35	1,8 à 1,9 T/m^3	6,5 à 7 %	9

Table 7: Pavement structure to be modeled.

Pavement material	Thickness of the pavement layer	Young's modulus	Poisson's ratio
	cm	MPa	ν
BB	5	4320	0,35
GBB	10	7500	0,35
GNF1	25	600	0,35
GNF1	35	600	0,35
PF2 of the supporting floor	infinite	50	0,35

Table 8: Calculation results for deformations and stresses.

Solicitations	Calculated stresses in the pavement	Allowable solicitations
Deformation of bituminous materials εt	95,3 µdef	104,6 µdef
Deformation of pavement supports εz	231,4 µdef	531,1 µdef

tests conducted at 10 °C and 25 Hz. b: Represents the slope of the fatigue law of the bituminous material (-1 < b < 0). E (10 °C; 10 Hz): Represents the modulus of stiffness. E (θeq; 10 Hz): Represents the obtained stiffness modulus. NE: Represents the number of passages of the reference axle. Kc, Kr, and Ks: Adjustment coefficients.

Permissible deformation criterion for pavement supports (εz,adm)

For an untreated material layer and the underlying ground, the allowable stress is determined by the vertical deformation at the surface of the layer. This can be calculated using equation 4:

$$\text{åz,adm} = A \text{ x } \left(NE\right)^{b} \quad (4)$$

Where, A and b are parameters that depend on the level of traffic, the type of material, and the structure. NE represents the number of passages of the reference axle.

Deformations and stresses

The verification involves comparing two aspects: The mechanical quantities such as stresses and deformations, which represent the behavior of the pavement structure when a reference axle passes. These quantities are calculated using a linear elastic model.

The permissible values of these same quantities, which depend on the mechanical strength of the materials under repeated loadings. Various adjustment coefficients are associated with these permissible values, taking into account the probabilistic nature of the design approach and the discontinuities of rigid pavements.

It is crucial that the calculated stresses in the pavement are less than or equal to the permissible stresses. To meet this criterion, the minimum thickness of the layers is determined through successive iterations. The goal is to ensure compliance with this criterion as shown in table 7.

Final pavement structure

After conducting the necessary verifications, it has been confirmed that the calculated stresses within the pavement are well below the permissible stress limits. This indicates that the pavement structure is capable of withstanding the anticipated loads and traffic conditions without exceeding the safety thresholds.

Based on these findings, the final pavement structure is determined and outlined in table 8. The table provides comprehensive details regarding the composition and specifications of each layer within the pavement system. It includes information such as layer thickness and material types.

The presented final pavement structure is the result of careful analysis and consideration of various factors, including the anticipated traffic volume, the properties of the materials used, and the desired durability and performance of the pavement. It ensures that the pavement is adequately designed to withstand the expected stresses and maintain its integrity over its intended service life.

By adhering to the determined pavement structure, it is anticipated that the road infrastructure will exhibit optimal performance, effectively supporting vehicular traffic and providing a safe and reliable transportation network.

Table 9: The final pavement structure.

Enlarged structure	Reinforcement	Shoulder structure
5BB + 10GBB + 25GNF1 + 35GNF1	5BB	14MS + 25GNF1 + 35GNF1

Conclusion

In this article, we have introduced a new approach for reinforcing the pavement subjected to solicitations and admissible deformations. The proposed methodology encompasses several key steps, including data collection to assess pavement behavior, selection of appropriate actions, determination of layer thicknesses, and modeling of the pavement structure to evaluate stresses and deformations induced by traffic and climatic conditions. This approach focuses on critical aspects such as choosing the appropriate pavement structure type, selecting suitable materials, and establishing admissible stress limits for different materials and layer thicknesses. The results obtained from both experimental investigations and modeling demonstrate the effectiveness of the proposed reinforcement structure in withstanding various stresses. Notably, the calculated stresses within the pavement are found to be lower than the allowable stress thresholds, indicating the structural integrity and reliability of the reinforced pavement. By implementing this new approach, it is expected that the pavement will exhibit enhanced durability and resistance to the effects of traffic and environmental factors. The findings presented in this article provide valuable insights and guidance for the design and construction of reinforced pavements, ensuring their long-term performance and sustainability.

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None.

Conflict of Interest

None.

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