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ORIGINAL

Finite Element Modeling to Predicting Rutting in Flexible Pavements under Overloading

Modelización por elementos finitos para predecir la formación de surcos en pavimentos flexibles sometidos a sobrecarga

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ABSTRACT

Road infrastructure is seriously threatened by heavy vehicle overloading, causing substantial damage, particularly rutting. This study uses advanced finite element analysis (FEA) techniques to improve pavement performance prediction. Six models were created using the ABAQUS/CAE program to evaluate the rutting performance of flexible pavement under overloaded conditions. These models simulated the existing pavement design and a proposed design, each subjected to three axle load configurations: single axle-single tire, tandem axle-dual tire, and tridem axle-dual tire. The research includes conducting surveys on traffic volume and axle load, to precisely evaluate the current traffic situation and identify problems associated with overloading. Core extractions enabled a thorough comparison of the existing pavement's thickness, density, and material characteristics with the proposed design. Based on these findings, a new design for a flexible pavement was developed, focusing on enhancing its ability to withstand rutting. The analysis determines that the existing pavement cannot withstand overloading vehicles, necessitating a 6,67 % increase in the thickness of the surface, a 37,5 % increase in the thickness of the binder, a 50 % increase in the thickness of the base, and a 32 % increase in the thickness of the subbase layers. Significantly, these modifications and improvements to material qualities were discovered to effectively decrease rut depth, an important factor in the durability and performance of pavement.

Keywords: Axle Load; Finite Element Method; Rut Depth; Core Extraction; Overloading; Abaqus Software Program.

RESUMEN

La infraestructura viaria se ve seriamente amenazada por la sobrecarga de vehículos pesados, que provoca daños sustanciales, en particular la formación de roderas. Este estudio utiliza técnicas avanzadas de análisis de elementos finitos (AEF) para mejorar la predicción del comportamiento de los firmes. Se crearon seis modelos utilizando el programa ABAQUS/CAE para evaluar el comportamiento frente al ahuellamiento del pavimento flexible en condiciones de sobrecarga. Estos modelos simularon el diseño de pavimento existente y un diseño propuesto, cada uno sometido a tres configuraciones de carga por eje: eje simple-neumático simple, eje tándem-neumático doble y eje trídem-neumático doble. La investigación incluye la realización de encuestas sobre el volumen de tráfico y la carga por eje, para evaluar con precisión la situación actual del tráfico e identificar los problemas asociados a la sobrecarga. Las extracciones de testigos permitieron comparar minuciosamente el espesor, la densidad y las características de los materiales del firme existente con el diseño propuesto. Sobre la base de estos resultados, se desarrolló un nuevo diseño para un pavimento flexible, centrándose en la mejora de su capacidad para soportar la formación de roderas. El análisis determina que el pavimento existente no puede soportar la sobrecarga de los vehículos, lo que requiere un aumento del 6,67 % en el espesor de la superficie, un aumento del 37,5 % en el espesor del ligante, un aumento del 50 % en el espesor de la base y un aumento del 32 % en el espesor de las capas de subbase. Se descubrió que estas modificaciones y mejoras de las calidades de los materiales reducían eficazmente la profundidad de ahuellamiento, un factor importante para la durabilidad y el rendimiento de los firmes.

Palabras clave: Carga por Eje; Método de los Elementos Finitos; Profundidad de Surco; Extracción de Testigos; Sobrecarga; Programa Informático Abaqus.

INTRODUCTION

Traffic in Iraq is constantly increasing, which increases traffic loads directly, leading to additional damage, specifically rutting, that requires road rehabilitation after a brief period of construction. However, the composition and thickness of each pavement layer, as well as other structural factors, affect how a pavement behaves. Therefore, it is important to perform a comprehensive study before designing pavement to ensure safe and efficient roads for their users. Heavy trucks dominate the pavement network and place the heaviest loads, which wears out the pavement. Nevertheless, a trend is developing in preference for employing mechanistic methodologies for pavement design in order to address challenges associated with the estimation of stress, strain, and displacement.

It is significant to consider that different materials behave differently under different conditions of loading and strain levels. Depending on how they react to these variables, materials are categorized as linear, nonlinear, or viscoelastic.[1] For instance, the behavior of the layered flexible pavement material has been modeled using the ABAQUS software. Overloading makes the maintenance more challenging, with bad road conditions or high maintenance. Increased traffic accidents, vehicle damage, slower speeds and inefficiency, delays in traffic, and congested areas are other negative effects of overloading.[2] Rutting is a phenomenon that appears as a groove in the wheel path that may also be followed by pavement rise along the rut's sides. It begins with a permanent deformation of the subgrade or one of the pavement layers brought on by lateral or consolidation movement of the materials brought on by traffic loading or by plastic movement of the asphalt mix brought on by hot weather or insufficient compaction.[3] Rut depth in asphalt mixtures is influenced by temperature, loading, and the properties of bituminous materials.[4] Fares[5] alleged that pavement damages would endanger road users and result in collisions. When maintenance is not within the specifications, road distress will rise. Pavement deterioration is the process by which cracks develop in the pavement due to the combined effects of environmental factors and traffic loading. Pavement deterioration can significantly impact the usability and ride quality of the road[6] Multi-layer elastic theory and displacement-based finite element methods are commonly used in the response modeling of pavements subjected to dynamic surface loading. These methods provide a more comprehensive understanding of the stress and displacement distribution within the pavement structure under overloading.[7] Overloading causes the pavement to bear more weight than it was intended to, which causes the pavement to collapse quickly and prematurely.[8] When a thicker pavement fails permanently by deforming, the Equivalent Axle Load Factor (EALF) is higher; otherwise, the EALF is lower. A parameter for constructing new pavement structures or determining how long existing pavement structures have left in operation is the total amount of standard axle loads.[9] Raheel et al.[10] found a 2-axle vehicle's truck factor was roughly 3,33 times greater than a 3-axle vehicle, and 5,45 times greater than a 6-axle semi-trailer of axle design on the pavement. In addition, it was found that doubling the thickness of the asphalt layer resulted in a nearly 47 % reduction in the truck factor. Wang et al.[11] emphasize the significance of employing a three-dimensional finite-element pavement model with a nonlinear and anisotropic model to predict the maximum viscoelastic responses of pavements under moving vehicular loading.

The aim of this study is to predict rut depth and analysis the performance of a new flexible pavement design under different axle loads (single axle-single tire, tandem axle-dual tire, and tridem axle-dual tire) in overloading conditions using finite element method (FEM) and compare its performance with existing flexible pavement designs.

Traffic Calculation and Field Survey

The research area is Hilla city, the administrative center of Babylon's governorate, and the research road chosen is Hilla-Baghdad (Athar entrance), the second most important road connecting Hilla city with Baghdad. The study area included a road section with a length of 1,50 kilometers it is located at coordinates (32°34'14"N, 44°25'30"E) with two directions and two lanes for each direction. Data obtained from traffic volume calculation, axle load survey, and testing of the extracted asphaltic samples results were used to perform a reverse analysis process to find existing flexible pavement thickness and compare it with the new proposed structural design for current traffic with illegal axle load.

It also includes the details of the AASHTO[12] method for the structural design of flexible pavement. To create a new design for the suggested flexible pavements, an analysis of the current pavements was done using the AASHTO design approach.

Traffic Volume Counts

To determine the current traffic volume and classification of vehicles used within the study area, the traffic study utilized the video camera technique by installing cameras for the road section. Working days were chosen for traffic volume calculation, on Monday, Tuesday, and Wednesday, from (3/10/2022 to 5/10/2022), the hour with the highest traffic volumes chosen started from (7: 00 A.M) ends at (10:00 A.M) in the morning and started from (12:00 P.M) ends at (5:00 P.M) in the evening period is selected as the peak time for Heavy vehicles entering Hilla city as shown in figures 1-3. The types of trucks mentioned in figures 1-3 are classified according to the regulations of Iraq.[13] Design Hourly Volume (DHV) is an hourly volume that occurs during traffic peaks the basis for designing roads is the design hourly volume (DHV) of traffic.[14] The DHV is normally expressed as percent (K) of the ADT, as shown in equation 1:[13]

$$DHV = K \times ADT \qquad (1)$$

K: percentage of DVH against ADT
ADT: average daily traffic.

From figures 1-3, it is evident that the highest traffic volume (DHV) was on Wednesday (8:00 - 9:00 A.M), and ADT was equal to 2647 (Veh/day).

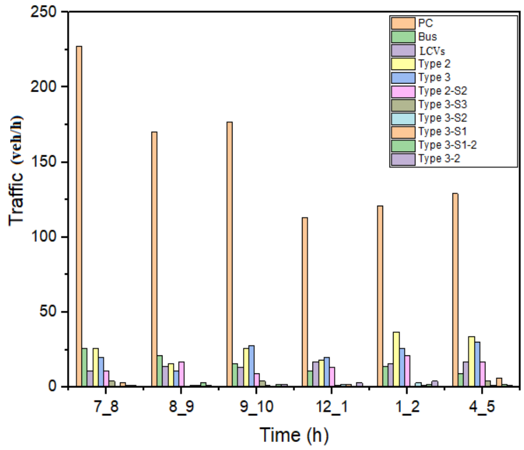

Figure 1. Traffic volume calculation for the study area on (Monday)

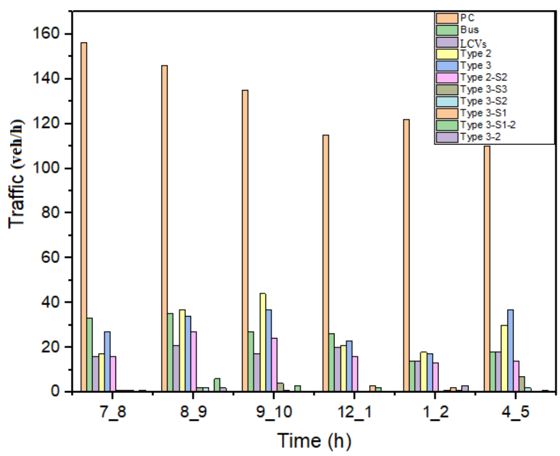

Figure 2. Traffic volume calculation for study area on (Tuesday)

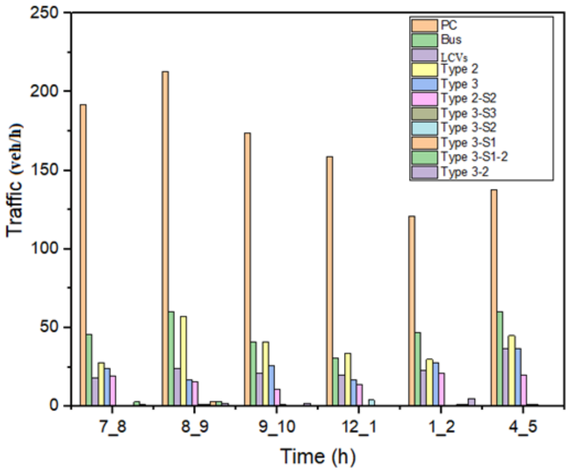

Figure 3. Traffic volume calculation for the study area on (Wednesday)

Axle load survey

The annual average axle load is dependent on the type of vehicle. The amount of overloading in the total number of trucks can be determined by the proportion of vehicles that are overloaded. The percentage of overload can be quite high in developing countries with low levels of traffic control, ranging from 60 % to 80 %.[15] According to the first examination of the traffic data exceeding the maximum axle load specified by SCRB[16], and after studying the reality of the situation and surveying, it became clear that the actual axle load was higher than the legal axle and gross weights permitted in Baghdad-Hilla roadway as shown in figure 4. All results of traffic volume calculation and axle load used to determine ESAL as shown in table 1.

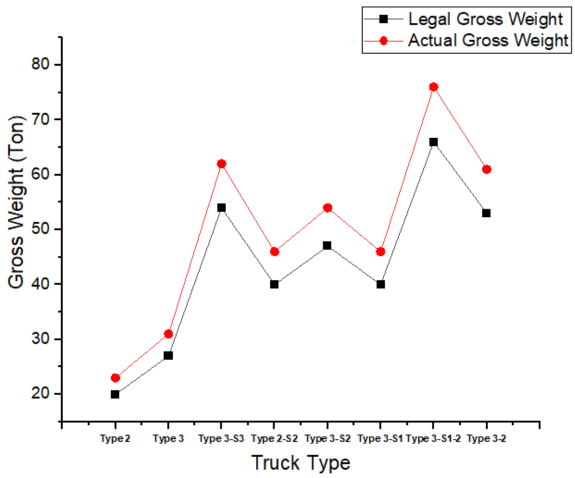

Figure 4. Legal Axle and actual axle load in study area

Equivalent Standard Axle Load Calculation (ESAL)

Equivalent Single Axle Load (ESAL) it is a method used in pavement engineering to represent the damage caused by various types of vehicles on roads. It converts the cumulative effect of all vehicle loads into a hypothetical load that would cause the same damage as the combined actual loads. The equivalent approach used to compute a load for a regular axle and overloading can be used to determine the load brought on by traffic. In equation 2 the ESAL formula can be utilized to calculate the accumulation of traffic axle load over design life. The output of the ESAL calculation for the illegal loads is shown in table 1.

The following formula determines the equivalent single axle load:[12]

$$ESAL = N \times TF \quad (2)$$

Where:
N: Number of trucks
TF: Truck Factor

From table 1, the total ESAL is 1121,4108, used to calculate W_{18} by equation 3:

$$W_{18} = D_D \times D_L \times ESAL \times TGF \times 356 \quad (3)$$

Where:
W_{18}: Cumulative axle load for two directional
D_D: Directional distribution = 50 % (DD = 0,5 Typically)
D_L: Lane Distribution-Typically designed for the heaviest loaded lane while the Hilla-Baghdad roadway is two lanes (DL = 0,9)

Experimental and Structural Design Approach

Extraction and Testing of Field Cores Samples

To achieve the study's objectives, data was extracted from core samples taken from the asphaltic layers of the pavement (AC base, AC binder, and AC wearing) to determine the thickness of the existing flexible pavement. The road was categorized into different types of failures based on a condition survey. Four field cores, each with a diameter of 6 inches (150 mm), were extracted from the roadway section, one from each lane. Core samples are taken using a core drill machine and measuring the depth or thickness of the cores is done using a vernier caliper. The results obtained from the extracted cores include the thickness of the pavement layers based on the requirements of ASTM D3549, the field density, and laboratory density of the samples based on ASTM D2726, which is an important input in FEM by Abaqus as shown in table 5.

Pavements Structural Analysis and Design

Table 1. ESAL for vehicle's exceeding the legal gross weight in the study area (0verloading)

Truck Type	Legal Gross Weight (Ton)	Actual Gross Weight (Ton)	Axle Load (Ton)	Axle Load Equivalency Factor	Truck Factor	Number of Truck	ESAL
Type 2	20	23	8 S	0,921	10,933	57	623,1838443
			15 S	10,0120499			
Type 3	27	31	8 S	0,92	5,991	17	101,853205
			23 Ta	5,071365			
Type 3-S3	54	62	8 S	0,921	10,073	16	161,17384
			23 Ta	5,071365			
			31 Tr	4,081			
Type 2-S2	40	46	8 S	0,921	16,004	1	16,0044149
			15 S	10,0120499			
			23 Ta	5,071365			
Type 3-S2	47	54	8 S	0,921	11,064	1	11,06373
			23 Ta	5,071365			
			23 Tan	5,071365			
Type 3-S1	40	46	8 S	0,921	16,004	3	48,0132447
			23 Ta	5,071365			
			15 S	10,0120499			
Type 3-S1-2	66	76	8 S	0,921	36,029	3	108,0855441
			23 Ta	5,071365			
			15 S	10,0120499			
			15 S	10,0120499			
			15 S	10,0120499			
Type 3-2	53	61	8 S	0,921	26,016	2	52,0329296
			23 Ta	5,071365			
			15 S	10,0120499			
			15 S	10,0120499			

Road design plays a crucial role in ensuring the long-term performance and safety of our transportation infrastructure. By properly planning and maintaining roads, we can accommodate the anticipated traffic load throughout their service life. After conducting the traffic count of the road within the study and investigating the axle load used by vehicle drivers. The AASHTO design method was employed during the design process as an efficient method. When existing flexible pavements needed to be reconstructed, this technique was used to design the pavement system. Equation 4 used to determine the structural capacity of the road structure, symbolized by SN:(12)

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SN = a1D1 + a2D2m2 + a3D3m3 (4)

Where:
D_1, D_2, D_3: the thicknesses of the surface, base, and subbase layers respectively.
a_1, a_2, a_3: Layer coefficient of asphaltic layer, base layer, and subbase layer respectively.
Based on the procedure and data analysis from previous sections, the thickness of each layer for the Hilla-Baghdad roadway in overloading conditions is explained in table 2.

Dawood[18] provides a detailed explanation of the AASHTO 1993 design method for pavements the paper summarizes the two conditions, if the existing applied load (W18) are greater than or equal to the allowable (W18), then the pavement is considered to be at the end of its service life and needs to be reconstructed. If the existing applied load are less than the allowable (W18), then the year when the existing ESALs will reach the allowable ESALs can be estimated from the reverse analysis process for existing flexible pavement, the applied traffic load (W18) for proposed flexible pavement greater than allowable traffic load (W18), reconstruction becomes necessary as shown in table 2 and table 3.

Table 2. Suggested flexible pavement design in an overloaded condition

Parameter	Drainage Coefficient (m)[17]	CBR[13]	Thickness
Asphaltic Layers	-	-	8 cm for surface 6 cm for binder
Base Layer	0,8	80 %	20 cm
Granular Subbase Layer	0,8	30 %	33 cm
Subgrade Layer	-	5 %	-
W18 =$4,8796\times10^6$			

Table 3. Flexible pavement structural analysis for existing roadway pavement

Parameter	Drainage Coefficient (m)[17]	CBR[13]	Thickness
Wearing	-	-	5,6 cm
Binder	-	-	5 cm
Base	0,8	-	10 cm
Granular Subbase	0,8	37 %	25 cm
Subgrade	-	4 %	-
$W_{18} = 2,767011\times10^6$			

Finite Element Modeling

Axle Load and Tire Contact Area

A total of six models have been created to predict the rut and the behavior of flexible pavement under different types of axles loads by using finite element software (Abaqus/CAE). Single axle-single tires, tandem axle-dual tires, and tridem axle-dual tires are used. Load and axle configurations were used are based on the predominant type of truck in Hilla roads, which is type 3-S3, as shown in figure 5. The axle loads in overloading conditions, each divided in a different model. Considering the thickness of proposed and existing pavement to identify the behavior of flexible pavement with different thicknesses and material properties.

The flexible pavements are designed based on a standard axle with dual tires at each end and an 80 kN gross weight. The semi-elliptical contact area of each tire is determined by combining a rectangle and two semicircles shape can be converted into an equivalent rectangular area by equation 5.[19]

$$CA= \pi (0,3L)^2 + (0,4L) (0,6L) = 0,5227L^2, \text{ hence } L =\sqrt{(CA/0,5227)} \quad (5)$$

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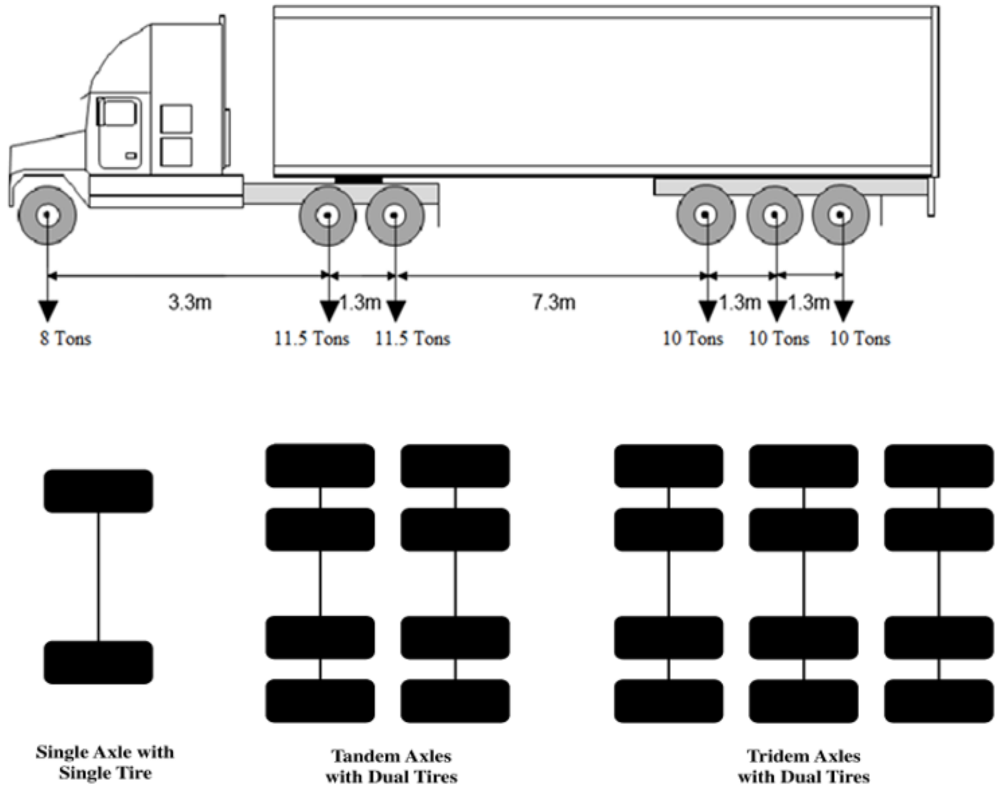

Figure 5. Axle loads used in models for truck type 3-S3

Where CA is the tire's contact area, a rectangular area is considered, where the length is 0,8712 L times the value of L and the width is 0,6 L, which has the same area of 0,5227 L^2. For numerical modeling, the width and length of contact area are considered as 350mm × 250 mm, as shown in figure 6.

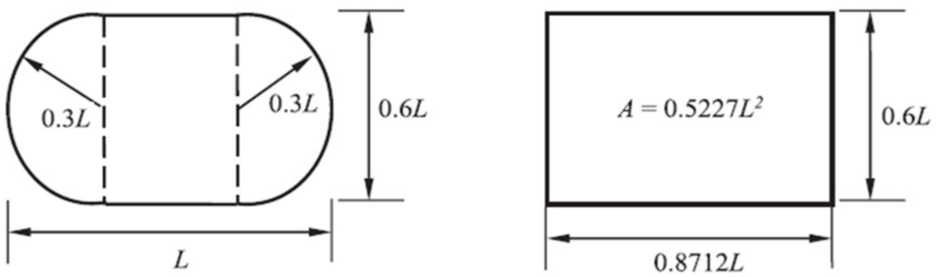

Figure 6. Tire contact area[3]

Pavement Geometry and Material Properties

The accuracy of Finite Element Method (FEM) results is dependent upon the mechanical response of materials, hence requiring the carefully choice of materials that more faithfully depict their inherent properties through the selection of a suitable theory for modeling the behavior of flexible pavement layers. The careful selection of a suitable constitutive equation to accurately depict the behavior of an asphalt mix when subjected to external loads is a critical component in the study of pavement performance. The asphalt surface layer was modeled using a viscoelastic model. However, the nonlinear model shows good agreement for granular layers. Flexible pavement models for the three-axle loads types include different layer thicknesses of the proposed design and existing pavement, and longitudinal and transverse directions (3600 mm × 5000 mm), as shown in figure 7. The interaction between layers is modeled by selecting the contact surfaces as "master" and "slave" roles. All of the contact interactions in the model that assumed a relatively little sliding take into account the surface-to-surface contact with small sliding. The material properties considered for these layers were the modulus of elasticity (E), Poisson's ratio (v), density from test of extracted core, and temperature °C, as summarized in table 4 for proposed flexible pavement, while table 5 for existing flexible pavement.

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Table 4. Material properties of proposed flexible pavement models (Inputs)

Pavement layer	Elastic Modulus (MPa)	Poisson's ratio (v)(3)	Density (gm/cm3)	Temperature ºC
Asphalt concrete surface (AC)	2000	0,35	2,32	50
Base	199	0,35	2,29	50
Subbase	110	0,3	2,28	50

Table 5. Material properties of existing flexible pavement models (Inputs)

Pavement layer	Elastic Modulus (MPa)	Poisson's ratio (v)(3)	Density (gm/cm3)	Temperature ºC
Asphalt concrete surface (AC)	1240	0,35	2,27	50
Base	200	0,35	2,283	50
Subbase	103	0,3	2,24	50

Boundary Condition and Mesh Type of the Models

It is important to note that the impact of boundary conditions on static analysis varies from that of dynamic analysis. In static analysis, it is common practice to establish fixed boundary conditions (BC) to describe a system's behavior accurately. These BC are often placed along the vertical direction to simulate the vehicle route, in the longitudinal direction to mimic the presence of rollers, and at the bottom "ENCASTER" where the deflection and rotation are restrained in all directions (U1=U2=U3=UR1=UR2=UR3=0) to prevent any vertical or horizontal movement of the subgrade layer as illustrated in figure 7.

The C3D8R element is a solid element suitable for modeling the pavement structure as a continuum, allowing for an accurate representation of the pavement's mechanical behavior, as shown in figure 8. The mesh size and density must be carefully chosen to accurately represent the pavement structure and its components and improve the convergence rate. After consecutive sensitivity analysis, the mesh size of 50 mm was appropriate for results accuracy. The total number of elements in the mesh was 203616, and the total number of nodes was 223380.

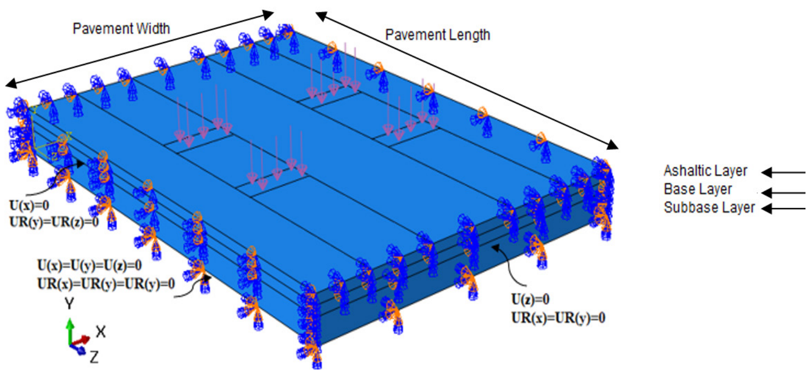

Figure 7. Pavement geometry and boundary condition of models

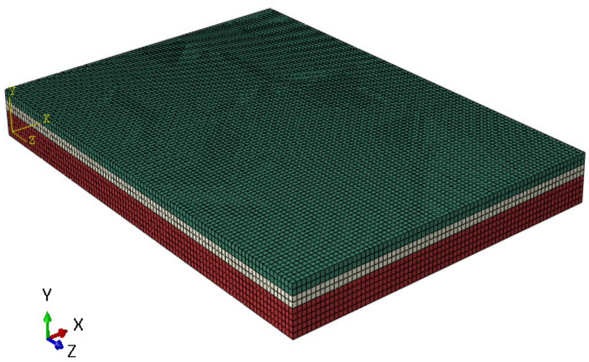

Figure 8. The meshing of the model

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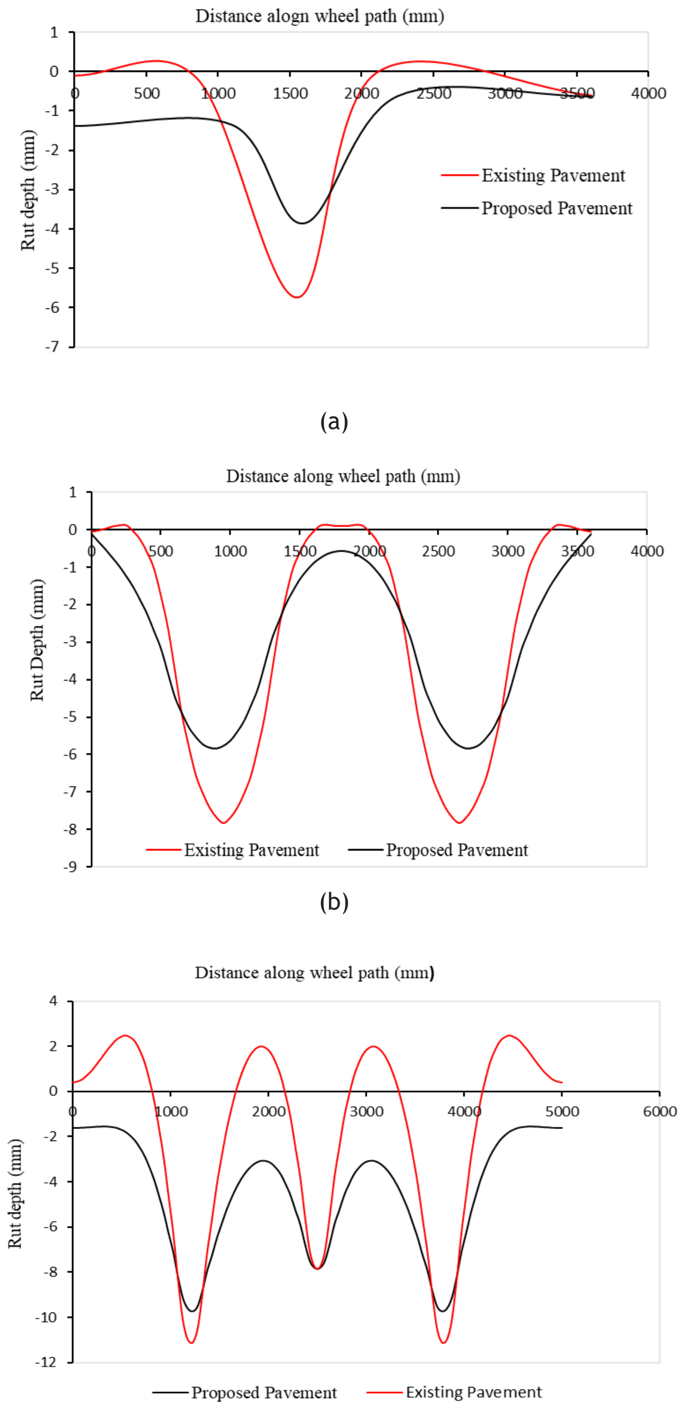
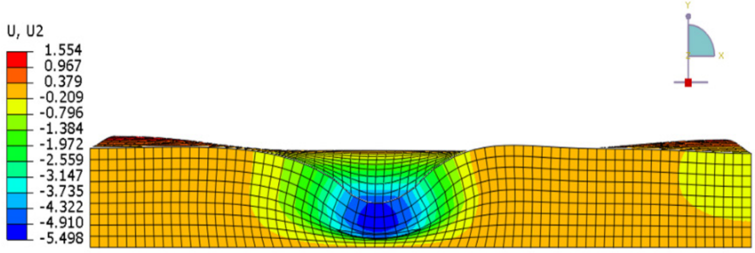
Finite Element Analysis Rut Depth

Predicting rut depth is crucial for assessing the condition of existing pavements and designing new pavements that are more resistant to rutting. As illustrated in figure 9 (a-c), after increasing the thickness of the paving layers for the road in Hillah, Baghdad, the results show a change in the rate of rut depth, where the rut depth decreases with increasing thickness. As shown in figure 13 (c), the middle tire of the tridem axle causes less deflection than the front and rear tires. This is because the axle supports the middle tire, while the suspension supports the front and rear tires in contrast to a tandem load, where the first load cancels the second, and vice versa. Figures 10, 11, and 12 show rutting visualization of proposed pavement and existing under single axle load, tandem axle load, and tridem axle load, respectively, in X-Y axis. It shows that the groove increased in existing pavement to have less load-bearing capacity, while the groove is less in the proposed pavement.

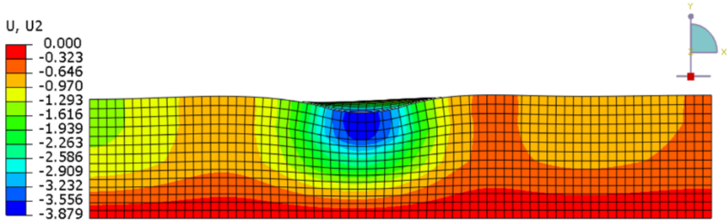


(c)

Figure 9. Rut depth along wheel path for (a) single axle-single tire (b) tandem axle-dual tire (c) tridem axle-dual wheel

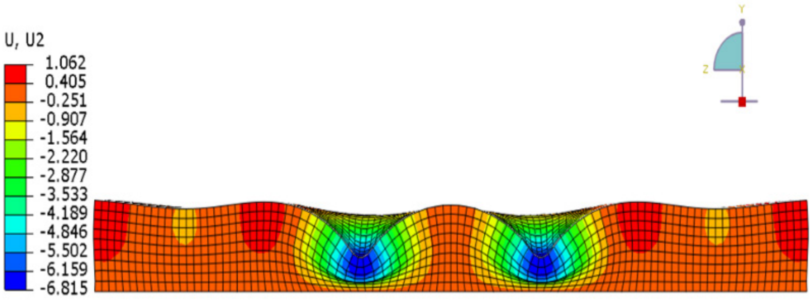


(a)

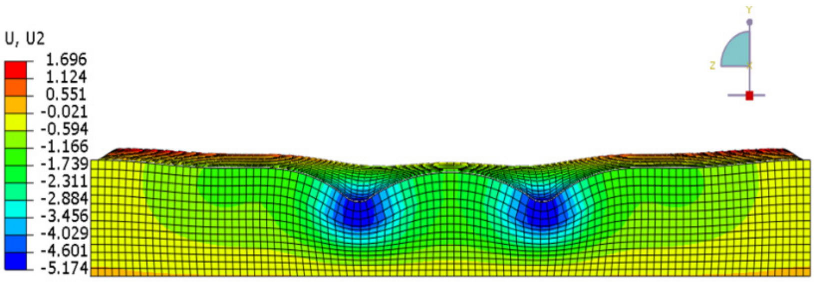


(b)

Figure 10. Vertical deflection of flexible pavement under single axle load for (a) existing pavement (b) proposed pavement

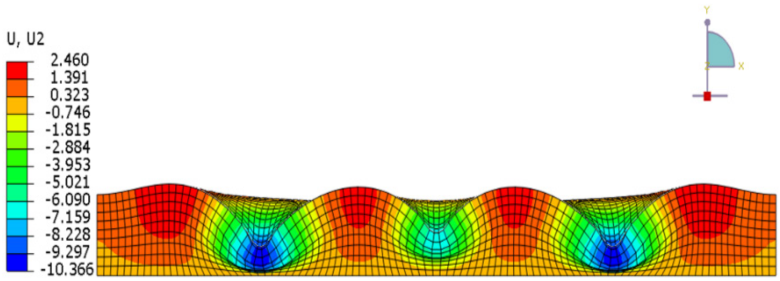


(a)

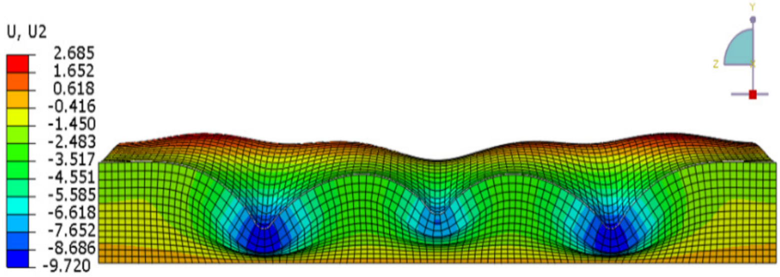


(b)

Figure 11. Vertical deflection of flexible pavement under tandem axle load for (a) existing pavement (b) proposed pavement



(a)



(b)

Figure 12. Vertical deflection of flexible pavement under tridem axle load for (a) existing pavement (b) proposed pavement

CONCLUSIONS

This study aims to predict rut depth and comprehensively evaluate the performance of a new flexible pavement design under overloaded conditions with various axle configurations, using advanced finite element analysis (FEA) techniques. The main findings are summarized as follows:

Compared to previous years, traffic volume has significantly increased, increasing traffic loads on existing pavements. The proposed design's allowable traffic load of W_{18} exceeded the W_{18} calculated for the existing pavement, emphasizing the need for improved design strategies.

Loading patterns vary depending on the axle configuration, with each axle weight causing temporary pressure contributing to pavement wear and potential failure. This emphasizes the importance of considering various axle configurations during pavement design.

The findings of the finite element analysis demonstrate that increasing the thickness of all pavement layers, coupled with enhancements to material properties, significantly reduces rut depth under various axle loads. This is a crucial finding for pavement engineers and policymakers, highlighting a tangible design strategy for developing more resilient and long-lasting pavements.

The existing flexible pavement's thickness is insufficient to accommodate overloading. The proposed design necessitates a significant increase in the thickness of all layers, surface (6,67 %), binder (37,5 %), base (50 %), and subbase (32 %).

REFERENCES

1. Q. T. Nguyen, H. Di Benedetto, and C. Sauzéat, 'Linear and nonlinear viscoelastic behaviour of bituminous mixtures', Materials and Structures/Materiaux et Constructions, vol. 48, no. 7, Jul. 2015 2339–2351.

2. M. Kaushal and J. Rasool, 'A STUDY ON IMPACT OF VEHICLE OVERLOADING ON JAMMU-SRINAGAR NATIONAL HIGHWAY', International Journal of Innovative Research in Engineering & Management, 2022.

3. Y. H. Huang, Pavement analysis and design. Pearson/Prentice Hall, 2004.

4. H. Wang et al., 'Effects of Field Aging on Material Properties and Rutting Performance of Asphalt Pavement', Materials, vol. 16, no. 1, Jan. 2023.

5. H. Fares et al., 'Modelling the performance of pavement marking in cold weather conditions', Structure and Infrastructure Engineering, vol. 8, no. 11, Nov. 2012 1067–1079.

6. M. Zumrawi and M. M. E. Zumrawi, 'Investigating Causes of Pavement Deterioration In Khartoum State', International Journal of Civil Engineering and Technology (IJCIET), vol. 7, no. 2, pp. 2006 203–214.

7. M. Asim, M. Ahmad, M. Alam, S. Ullah, M. J. Iqbal, and S. Ali, 'Prediction of rutting in flexible pavements using finite element method', Civil Engineering Journal (Iran), vol. 7, no. 8, 2021 1310–1326.

8. O. J. Oyekanmi and E. A. Ejem, 'Load Damaging Effects of Overloaded Trucks on Federal Highway Pavement Structures in Nigeria', in Research Developments in Science and Technology Vol. 5, Book Publisher International (a part of SCIENCEDOMAIN International), 2022, 140–156.

9. A. Tjan and C. Fung, 'DETERMINATION OF EQUIVALENT AXLE LOAD FACTOR OF TRAILER WITH MULTIPLE AXLES ON FLEXIBLE PAVEMENT STRUCTURES', 2005.

https://doi.org/10.56294/sctconf2024822

10. M. Raheel et al., 'Impact of axle overload, asphalt pavement thickness and subgrade modulus on load equivalency factor using modified ESALs equation', Cogent Eng, vol. 5, no. 1., Jan. 2018 1–12.

11. H. Wang and I. L. Al-Qadi, 'Importance of Nonlinear Anisotropic Modeling of Granular Base for Predicting Maximum Viscoelastic Pavement Responses under Moving Vehicular Loading', J Eng Mech, vol. 139, no. 1, Jan. 2013 29–38.

12. American Association of State Highway and Transportation Officials, Guide for design of pavement structures, 2nd ed. Washington: AASHTO, 1993.

13. Highway Design Manual, SCRB. Republic of Iraq Ministry of Housing and Construction State Commission of Road and Bridges, 2005.

14. F. Ma, J. Xu, C. Gao, and Y. Bi, 'Study on the Applicability and Modification of the Design Hourly Volume on Rural Expressways Considering Holiday Traffic Polarization', Int J Environ Res Public Health, vol. 19, no. 16, Aug. 2022.

15. J. Jihanny, B. S. Subagio, and E. S. Hariyadi, 'The analysis of overloaded trucks in Indonesia based on weigh in motion data (east of sumatera national road case study)', in MATEC Web of Conferences, EDP Sciences, Jan. 2018.

16. Republic of Iraq Ministry of Housing and Construction State Commission of Roads and Bridges SCRB, 'Legal Axle Load and Gross Weight Permitted on Motor Vehicle in Regular Operation in Iraq', 2013.

17. A. M. Mosa, A. H. Taher, and L. A. Al-Jaberi, 'Improvement of poor subgrade soils using cement kiln dust', Case Studies in Construction Materials, vol. 7, Dec. 2017, 138-143.

18. Dawood, 'Determining of Remaining Life of Existing Flexible Pavement Using AASHTO 1993 Design Method', Journal of Engineering Science and Technology, vol. 13, no. 1, 2018 23–34.

19. E. J. Yoder and M. W. Witczak, 'Principles of Pavement Design', Second ed., New York: Wiley, 1975.

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