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Static Analysis of Rigid Pavement Runway under the Influence of Aircraft Loading by Finite Element Technique

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ABSTRACT

The runway is the most crucial part of any airport infrastructure and is designed to withstand the weight and impact of large aircraft. Runways must be durable enough to resist deformation, cracking, and wear caused by constant traffic. Therefore, a lot of attention is paid to the design and construction of airport runways. This paper presents a finite element method-based modelling process for the study of a rigid pavement runway with a jointed plain concrete pavement (JPCP) and examines the various static response characteristics of the rigid pavement runway when loaded with different kinds of aircraft. A three-dimensional model of the rigid pavement runway was modelled and evaluated using nonclosed form finite element method (FEM) based ANSYS software. The model has been simulated, and the resultant deflections and stresses have been evaluated while taking into consideration the impact of various types of aircraft loading and other engineering parameters. Identifying critical variables that influence the model's various response parameters was one of the study's key findings, and the effects of each parameter had been thoroughly discussed. Furthermore, the software utilized in this work was verified by a closed-form numerical problem, and the results were in excellent agreement with earlier research findings with a maximum divergence of less than 1 percent, proving the accuracy of the program used in the present study. The rigid pavement runway model spanning 13.84 m was examined using the current modelling process. However, researchers can use the abovementioned modelling procedure to analyze any runway pavement structure.

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1. Introduction

The development of a country's transportation infrastructure may be utilized to estimate its future growth. Pavements are an important part of the urban transportation system because they offer an efficient means of carrying goods and services. Pavements are classified as flexible, rigid, or semi-flexible based on their stiffness in comparison to the subsoil. Because of their strength and durability, cheaper maintenance requirements, and smoother riding surface, cement concrete pavements have been used in many new road projects all over the world in recent years [1,2]. The current method for constructing rigid pavement on roads involves first laying a granular subbase over the subgrade, then a dry lean concrete foundation, and finally concrete pavement on top. Rigid pavement layers, as opposed to flexible pavement layers, do not transfer pressures from grain to grain to the bottom layer because they spread wheel loads across a larger area underneath and resist enormous amounts of load through slab action owing to their high flexural strength.

JPCP is a type of Portland cement concrete pavement that is made up of several discrete concrete slabs, longitudinal and transverse joints, and dowels. Although transverse joints are used to control cracks caused by thermal deformation and drying shrinkage of slabs, their use may reduce the load-carrying capacity of concrete slabs near the edge. This reduction should be kept under control to avoid pavement damage from repeated wheel loads [3]. There are several methods for evaluating the structural capacity of pavements based on deflection basin data, including non-destructive testing techniques, and numerical and analytical programmes such as statistical regression analysis, closed-form solutions, ISLAB2000 [4], DIPLOMAT [5], and KENSLABS [6], the majority of which are focused on the amount of load transfer across dowelled joints [7]. The finite element approach and the boundary element method overcame the restrictions of boundary conditions and load types in analytical techniques with the evolution of computational mechanics [8]. Several researchers used the finite element methodology (FEM), which is one of the most accurate and powerful computational tools for studying pavement layer characteristics and crucial pavement reactions under traffic and environmental loading situations [9–11]. Considering that airport concrete pavement is a large area of construction exposed to the natural environment, it suffers from long-term degradation from elements including ambient temperature, moisture, and solar radiation [12–14]. Although traffic loading is dynamic, concrete pavement design standards have traditionally represented it as static loads. However, dynamic analysis of concrete pavements has long interested academics. The American Association of State Highway and Transportation Officials [15] tested concrete pavements at vehicle velocities ranging from 3.2 km/h to 95.6 km/h using various single-axle truck vehicles. They found that increasing vehicle speed lowered pavement reactions by 29 percent. [16] observed that vehicle velocity may significantly increase base deflections or stresses on a concrete pavement sitting on a low-stiffness subbase under big truck loads. To evaluate the damage under different conditions, [17] built a dynamic model of a 2 DOF quarter car on a 3D semi-grid asphalt surface. In finite element analysis, concrete pavements were modelled as thick or thin plates, solid elements, or beam elements sitting on viscoelastic foundations [18,19]. In dynamic studies, a moving point load [20], wheel load [21], single axle load [22] or tandem axle load was used. Some research has looked at how differences in damping properties and surface roughness affect the dynamic

response of concrete pavements. Using the finite element method-based software ANSYS [23], the impact of temperature change on concrete pavement was examined by [24]. Using finite element-based MATLAB coding, static, free, and dynamic analysis on a curved thin-walled box-girder bridge was conducted to determine different stress resultants [25–28]. A combined differential and simplex method for calculating a beam's Pasternak elastic foundation characteristics has been explained by [29]. Some instances were solved to demonstrate the applicability, robustness, and of the mixed technique for estimating elastic foundation parameters of beams. The accuracy of the Winkler and Pasternak soil-structure interaction models in predicting the predominant natural frequency (PNF) of partially embedded structures was investigated by [30]. The findings demonstrated that, regardless of the test pier type or soil, the Winkler model predicts PNF better than the Pasternak model when structures are partially submerged in soil. [31] have performed a finite element simulation and a multi-factor stress prediction model for cement concrete pavement, considering the void under the slab.

[24] have done the mechanistic analysis of rigid pavement for wheel load stresses by the finite element method, considering different sub-grades with different percentages of metal fiber. [32] overcame the challenge of figuring out the unidentified parameters in Gibson elastic foundation models by using an iterative technique.

According to the literature review, previous researchers have made a good attempt to forecast the static response of rigid pavements using a variety of methodologies either considering a single panel with a closed-form or non-closed-form solution. These procedures, however, provide closed-form solutions that are far too complicated for engineers to use. The investigation of the static response of the rigid pavement runway comprising the JPCP system using a non-closed form-based methodology has received limited consideration in studies until now. In this study, the authors have modelled the joined plain concrete pavement model (JPCP), in which panels are joined together with dowels and tie bars, shoulders on sides, a cement-stabilized sub-base, and a subgrade. The main objective of the current study is to develop an assembled FEM model of a multi-span jointed plain concrete pavement model (JPCP) based on earlier research [34]. In the current study, the author used a modified geometrical configuration based on earlier research [33][and codes: IRC:58-2015 [34] and FAA guideline [35]. This research deals with analyzing the static response of runway pavements in terms of deformation and stress resultants. Also, a broad variety of parametric studies on the static response of rigid pavement were carried out. The completed study will be very useful for engineers in understanding various static response characteristics of the rigid pavement runway when loaded with different kinds of aircraft, which will further assist engineers in identifying areas of the runway pavement that are experiencing excessive stress or deformation and modifying the design accordingly. Researchers can use the above-mentioned modelling procedure to examine the static response of any pavement structure. Modelling and analysis are carried out using the ANSYS Workbench 2022 software. The practical and executive results of this numerical analysis are that an engineer should learn how a JPCP rigid pavement runway with various concrete grades and the elastic modulus of the subbase and subgrade responds under various aircraft types and wheel load positions in order to increase the structural capacity of the runway pavement.

The writers contribute the following works to this research, which are listed below:

- 1. The finite element modelling technique for rigid pavement runways comprising a JPCP system is provided to assist designers in generating models for design and analysis.
- 2. The model is statically analyzed under various types of aircraft loading and a wide range of parametric variations to interpret deformation and stress results.

2. Finite element model details

2.1. Structural parameters

The rigid pavement runway model developed for this study comprised three structural layers: a concrete pavement slab, a sub-base, and a subgrade. The length and width of the runway depend on the type of aircraft that will be using it. Larger commercial airplanes require longer runways than smaller private planes. Figure 1(a) depicts the model's cross-section, whereas Figure 1(b) depicts the dimensions of each component. Table 1 illustrates all the structural parameters considered in the model as per given in [33–35].



a) Cross-sectional view of the runway pavement model



b) Plane size of the model in mm

Fig. 1. a) Cross-sectional view of the finite element model, b) Plane size of the model in mm

Structural Component	Dimension (L × B) mm	Thickness (t) mm
Concrete slab	13840 × 5120	250
Shoulder	13840×1500	250
Cement-stabilized sub-base	13840 × 8120	250
Subgrade	17840×11120	500
Dowel bar	450	32 Ø
Tie bar	1000	16 Ø

Table 1Structural Parameters.

2.2. Finite element modeling of JPCP

The current study used ANSYS [23] to model a three-dimensional finite element model of a JPCP system for an airfield runway, as shown in Figure 2. Concrete slab panels, dowel and tie bars embedded in the slab panels, shoulders (a section of pavement outside an outer lane set aside for emergency usage by traffic and to guard against damage to the pavement's margins), a cement-stabilized sub-base, and a subgrade comprised the finite element rigid pavement model. To model the subgrade layer, a strong foundation was assumed. A small gap was left between the slab panels to prevent the concrete from cracking during expansion and contraction. Each individual slab panel's longitudinal joints had steel tie bars evenly spaced apart. Also, the number of dowel bars at the transverse joints was evenly distributed.



Fig. 2. Three-dimensional finite element model of JPCP.

2.3. Material parameters

Runway pavements are typically made of asphalt or concrete, which have different properties and benefits. Concrete is more durable and has a longer lifespan, while asphalt is more flexible and better suited for areas with frequent temperature changes. In the present study, conventional concrete was considered for the design of runway pavement. Although the system also includes subgrade and subbase material, both of which are important, the rigid concrete pavement's strength comes from the concrete itself. Every material was assumed to be homogeneous, isotropic, and elastic. The fundamental material characteristics of each component of the three-dimensional model are shown in Table 2 [33–35].

Table 2

Material parameters.

Structural Component	Modulus of elasticity (E) MPa	Density (ρ) kg/m ³	Poisson's ratio (µ)
Concrete slab or shoulder	28000	2400	0.2
Cement-stabilized sub-base	5000	2200	0.15
Subgrade	69	1850	0.4
Dowel or Tie bar	2×10^{5}	7850	0.3

2.4. Meshing of finite element model

Meshing is the major aspect of a finite element model. Although finer meshes can produce more accurate results, they also dramatically increase the number of elements and nodes in the finite element model, increasing the computational cost. The finite element type and size were determined using the mesh convergence analysis, which ensures the precision of runway pavement response with a minimal number of elements and reliable results. Figure 3 depicts the mesh convergence. It was evident that after a mesh size of 350 mm, there was a negligible deviation in the total deformation of the model with a decrease in mesh size. Table 3 includes details on mesh element size and type.



Fig. 3. Mesh convergence analysis.

Table 3	
Mesh element size and	type

la type.				
Structural Component	Element size (mm)	Element type		
Concrete slab	250	3D Solid 187		
Shoulder	250	3D Solid 187		
Cement-stabilized sub-base	300	3D Solid 186		
Subgrade	300	3D Solid 186		
Dowel bar	16	3D Solid 186		
Tie bar	8	3D Solid 186		

The Solid 187 element, which is a higher-order three-dimensional 10-node element, and the Solid 186 element, which is a higher-order three-dimensional 20-node element, were used as mesh elements for the current study, and their geometry is shown in Figure 4(a-b). As shown in Figure 5(a-c), coarser meshes were used for the larger components, while finer meshes were used for the smaller components of the runway pavement model.



Fig. 4. The geometry of three-dimensional solid elements.



Fig. 5. Runway pavement and its components with mesh elements.

2.5. Interlayer contact relation and boundary condition

Between the subgrade and subbase layers, the bonded interface condition was taken into consideration. The sub-base layer and the concrete panels were in frictional contact with each other (friction coefficient, 0.05). The dowel bar had one end in frictional contact with the slab panel (friction coefficient, 0.1), and the other end in bonded contact with the slab panel. To avoid

lane separation and differential deformation, one end of the tie bar was bonded to the slab panel, and the other end was tied to the panel with no separation contact available in ANSYS.

The four sides of the concrete pavement and subbase layer had three transverse degrees of freedom for the boundary conditions, whereas the four sides and bottom of the subgrade layer were simulated as fixed constraints. The subgrade layer must be longer and wider than the other layers to prevent imposing unnecessary boundary constraints on the side elements.

2.6. Loading parameters

The static response of the pavement is greatly influenced by factors including the contact shape, contact area, loading position, pressure distribution, and magnitude when tires are in direct contact with the pavement surface. In the current study, an Airbus 380-6 load [36] was subjected to a runway pavement model with wheels that were each under 1.47 MPa of pressure. The tire contact pressure distribution on the road is not circular and the tire footprint is closer to rectangular according to [17]. The aircraft load was assigned without taking the nose landing gear into account, as the main landing gears sustain 95% of the aircraft load. Figure 6(a) depicts the schematic wheel configuration of the Airbus 380-6 aircraft [36], and Figure 6(b) shows the rigid pavement model subjected to aircraft load.



a) Wheel configuration of the Airbus 380-6 aircraft.



b) Rigid pavement model subjected to aircraft load.

Fig. 6. a) Wheel configuration of the Airbus 380-6 aircraft, b) Rigid pavement model subjected to aircraft load.

3. Numerical results and discussion

3.1. Validation of the modelling procedure

To ensure the accuracy of ANSYS software, a closed-form problem, beam on the elastic foundation [37] was taken. The same problem was modeled and analyzed in 3-D using ANSYS, as shown in Figure 7. The flexural rigidity (EI) and Poisson's ratio (μ) of the beam were 2604.17 kN-m² and 0.15, respectively. SOLID 186 and SURF 154 elements were used as mesh elements for the beam. The load of 100 kN was applied at 2 m of the span from the left end. The subgrade was modeled by applying an elastic stiffness of 1×10^7 kN/m³ at the beam's bottom face. The ends of the beam were restricted from translation along any of the axes. The beam was meshed with a 125 mm mesh size. During the analysis, a path was created from the left end to the right end of the beam, which was used to get the deformation in the Y-axis of the beam. To see whether the pattern of the deformation of the beam on an elastic foundation solved by ANSYS matches the pattern given in the paper, both deformations are plotted in the same graph shown in Figure 8.





Fig. 8. Deviation in the deformation of the beam from the previous study.

Figure 8, shows the deviation in the deformation of the beam between the previous and present study, from which we can conclude that the numerical findings are in great agreement with the previous work, therefore verifying the accuracy of the ANSYS software used for the analysis.

3.2. Present problem

In this paper, a numerical problem involving a 3-D rigid pavement runway model comprising a JPCP system spanning 13.84 m and a width of 5.12 m subjected to aircraft loading is presented. The structural parameters of the components and different properties of materials are presented in Tables 1 and 2. The model had been examined for the Airbus 380-6 aircraft loading, and the results are shown in Table 4. The vertical deformation of the jointed plain concrete runway pavement is significantly lower than that of every other type of runway pavement. Figure 9(a-d), depicts the findings of overall deformation and deformation corresponding to various axes caused by aircraft load. The results reveal that the pavement's total deformation reached a maximum value of 0.463 mm, however, the deformation in the X and Z axes was very small and had no significant impact. The results of equivalent (von Mises) stress, maximum principal stress, and maximum shear stress for Airbus 380-6 aircraft loading are presented in Table 4. Overall, the study provides an in-depth evaluation of the static response of the rigid pavement runway under the effect of aircraft load. Using the current modelling approach, a rigid pavement runway model spanning 13.84 m was examined. However, researchers can analyze any pavement structure by using the modelling procedure explained in Appendix-A (Figure A.1).

Table 4

Parameters	Results
Maximum Deformation in mm	0.463
X-Directional Deformation in mm	0.089
Y-Directional Deformation in mm	0.463
Z-Directional Deformation in mm	0.084
Equivalent (von-Mises) stress in MPa	4.017
Maximum Principal stress in MPa	4.012
Maximum Shear stress in MPa	1.118

Response parameters for runway concrete pavement subjected to Airbus 380-6 aircraft loading.

4. Parametric study

A parametric analysis was performed to determine the impact of various factors on the rigid pavement runway model comprising the JPCP system. Each significant factor and every possible case of loading found on the rigid pavement runway structures was examined within the scope of this study, and the results are presented as plots. The parameters involved in this study are the grade of the concrete, the elastic modulus of the sub-base and subgrade, aircraft type, wheel load position, and the boundary condition.



4.1. Concrete grade (M)

In this section, the impact of concrete grade on the rigid pavement runway model's response parameters was investigated. For the analysis, concrete with a grade ranging from M30 to M60 was employed in the model [38]. The concrete's flexural strength improves with the grade, which also increases the rigid pavement's capacity to withstand more load. The total deformation was found to decrease consistently as the concrete grade increased. However, the stresses exhibited rising patterns of behavior with an increase in concrete grade. Figure 10(a-b) shows the effect of concrete grade on the runway pavement model's response parameters.



Fig. 10. Plots of deformation and stresses against different grades of concrete.

4.2. Elastic modulus of sub-base (E subbase)

The effect of the elastic modulus of the sub-base on the various response parameters of the rigid pavement runway model was investigated in this study. The elastic modulus of the sub-base was varied from 1000 to 6000 MPa in equal increments. It was found that as the elastic modulus of the sub-base is increased, the deformation and stress resultants reduce as the overall stiffness of the model rises. The change in modulus of elasticity of the sub-base showed a greater impact on stresses. The total deformation was reduced by an overall 10.74 percent, whereas the maximum principal stress was reduced by an overall 63.79 percent when the modulus of elasticity was increased from 1000 to 6000 MPa. The findings demonstrate that any runway pavement model's response parameters are greatly affected by changes in the modulus of elasticity of the sub-base. Figure 11(a-b) shows the effect of the modulus of elasticity of the sub-base on the runway pavement model's response parameters.



Fig. 11. Plots of deformation and stresses against different values of modulus of elasticity of sub-base.

4.3. Modulus of elasticity of subgrade (E subgrade)

The influence of the elastic modulus of the subgrade on the rigid pavement model was analyzed in this section. The modulus of elasticity of the subgrade was changed from 50 to 250 MPa in equal increments. It was found that as the elastic modulus of the subgrade increased, deformation decreased drastically, whereas stresses exhibited a rising pattern of behavior. The maximum decrease of 44.81 percent was seen in the total deformation when the modulus of elasticity of the subgrade increased from 50 to 100 MPa. In contrast, as the subgrade's elastic modulus raised from 50 to 100 MPa, the equivalent (von Mises) stress on the pavement initially dropped and then gradually increased as the elastic modulus of the subgrade raised from 100 to 250 MPa. Thus, the results reveal that the runway pavement model's response parameters are considerably affected by the modulus of elasticity of the subgrade. Figure 12 (a-b) show the effect of the modulus of elasticity of subgrade on the runway pavement model's response parameters.



Fig. 12. Plots of deformation and stresses against different values of modulus of elasticity of subgrade.

4.4. Aircraft type

The weight and size of an aircraft can cause different levels of deformation and stress on the runway pavement, which can lead to wear and tear over time. In addition, different types of aircraft have different types of landing gear, which can also affect the surface of the runway. For example, some landing gear may have multiple wheels that distribute weight more evenly, while others may have fewer wheels that create more concentrated pressure points. As a result, the type of aircraft resting on the runway can impact the maintenance and repair needs of the pavement, as well as its overall lifespan. In this parametric investigation, the impact of various types of aircraft on the response parameters of the runway pavement model was investigated. Three different types of aircraft (the Airbus 380-6, the Airbus 380-4, and the Boeing 777-200LR) have been taken into consideration for static analysis in this parametric study. The landing gear configuration of these aircraft is illustrated in Table 5. The variation in response parameters of

the runway pavement model due to the different aircraft mentioned above is shown in Figure 13(a-b). It was found that the (Boeing 777-200LR) aircraft caused the maximum deformation and stresses in the rigid pavement because of its higher tire pressure.



Fig. 13. Plots of deformation and stresses against different types of aircraft.

Table 5							
Landing gear configuration of various aircraft.							
	Type of aircraft Tire Single wheel Number Rectangular foot		Rectangular footprint,	Axle	Wheel		
		pressure	load (kN)	of wheels	dimension (mm)	spacing	spacing
		(MPa)				(mm)	(mm)
	Airbus 380-6	1.47	261	6	508×350	1700	1550
	Airbus 380-4	1.47	261	4	508 × 350	1800	1350
	Boeing 777-200LR	1.48	257	6	503 × 346	1800	1350

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4.5. Wheel load position

When an aircraft's wheel is positioned on a section of the runway pavement, the weight of the aircraft is transferred to the pavement through the tire contact area. This creates a stress distribution in the pavement layers that varies depending on the location of the wheel load. The stresses are typically highest directly under the wheel load and decrease as the distance from the load increases. This section explains how to wheel load position on the runway pavement's surface affects the runway pavement response parameters. The behavior of the rigid pavement was found to be greatly affected by wheel load position. In this parametric study, the position of the loading wheels was shifted on the surface of the runway pavement concerning the line marked at the center of the runway pavement model, as shown in Figure 14.



Fig. 14. Wheel load position on the surface of runway pavement.

Case 1 depicts the wheel load position near the center of the slab panel. Then, as shown in Cases 2 to 4, the wheel load position was moving away from the center and moving toward the edge of the concrete slab panel near the longitudinal joint. Case 5 shows the wheel position at the edge of the slab panel near the longitudinal joint. It was observed that as the wheel load position moved away from the center of the slab panel, the deformation started decreasing, which increased further as the wheel load position moved towards the slab edge near the longitudinal joint. Maximum deformation and stresses were observed when the wheel load location was near the slab edge or longitudinal joint (Case 5) because, at the slab edge, the load was dispersed over a smaller area. Thus, the concrete slab edges or joints may be considered crucial points because they have higher chances of early breakage. Figure 15 (a-b) depicts the behavior of the runway pavement model regarding the wheel load position.



Fig. 15. Plots of deformation and stresses against different cases of wheel load position.

4.6. Boundary condition

The boundary conditions can have a significant impact on the distribution of stress within the pavement structure, which can affect the pavement's ability to withstand deformation and cracking. The influence of boundary conditions on the static response of a rigid pavement runway model was investigated in this section. Table 6 shows the five cases with different boundary conditions that were considered in this study.

Boundary conditions for the finite element model.				
Case 1	• All four sides and the bottom of the subgrade are fixed.			
[36]	• No boundary condition on the sub-base and top layer.			
Case 2	• The subgrade bottom is fixed and the sides have pinned support.			
[39]	• All the sides of the sub-base layer are having pinned support.			
	• Roller support on the top layer along the X-axis and kept free along the Y-axis.			
Case 3	• Elastic support to the bottom of the subgrade with a modulus of subgrade reaction (k)			
[31]	value of 0.12 N/mm^3 .			
	• Fixed boundary conditions on all the sides of the subgrade and sub-base layer.			
	• The top layer is kept free in all directions.			
Case 4	• The subgrade bottom is kept fixed.			
[40]	• All the vertical boundaries are having one degree of freedom in the appropriate			
	direction X or Z, on the vertical boundaries.			
Case 5	• The subgrade bottom is kept fixed.			
[41]	• Rollers are placed on the lateral planes (XY and YZ), which constrain movement in the			
	x and z directions.			



 Table 6

 Boundary conditions for the finite element model



Fig. 16. Plots of deformation and stresses against different cases of boundary conditions.

The behavior of the runway pavement model about the different boundary conditions is shown in Figure 16(a-b). According to the findings, the maximum deformation of 1.410 mm and the maximum shear stress of 4.236 MPa were found in Case 3, in which elastic support was provided to the bottom of the subgrade with a modulus of subgrade reaction (k) value of 0.12 N/mm^3 .

5. Conclusions

This paper introduces a major concept of FEM modelling and investigates the static response of runway pavement with a JPCP system subjected to aircraft loading. The analysis was carried out on a runway pavement composed of multiple slab panels with transverse and longitudinal joints between them, using a non-closed form solution based on ANSYS[26] software, and various responses of deformations and stresses were determined. The finite element technique used in this study was validated by analyzing a closed-form problem, and the results agree very well with previous research findings, proving the accuracy of the software used in this study. It is observed that various types of aircraft have different tire contact areas and loading configurations, which causes the pavement response to vary with the type of aircraft. This analysis can help identify the critical loading conditions that the runway may be subjected to, so that information can be used to design the runway to withstand these loads without excessive stress or deformation. Also, the analysis can provide information about the stress and deformation characteristics of the runway under different loading conditions. This can help engineers identify areas of the runway pavement that are experiencing excessive stress or deformation and modify the design accordingly. Furthermore, this analysis can also help optimize the usage of materials in the runway pavement design. By identifying areas of the runway that are experiencing low stress or deformation, engineers can reduce the amount of material used in these areas, which can help reduce the overall cost of the project. The most significant parameter studied, the wheel load position, shows that joints or slab edges are the most crucial points because deformation and stress values were higher when aircraft load was considered near a slab edge or joint. When designing the JPCP runway pavement, slab edges, and joints should be given specific consideration. In the model, the maximum equivalent (von Mises) stress caused by the Airbus 380-6 aircraft was observed to be 4.017 MPa. In addition to that, the maximum principal stress and maximum shear stress were found to be 4.012 MPa and 1.118 MPa, respectively. The static analysis of a rigid pavement runway using the finite element technique is a complex process that requires expertise in both pavement engineering and computational modeling. It is important to consider factors such as the material properties of the pavement, structural parameters, loading conditions, and environmental factors properly when designing a runway to ensure its safety and efficiency. Overall, the finite element technique is a powerful tool for analyzing the behavior of complex structures like pavement runways under different loading conditions and can provide valuable insights into the design and maintenance of such structures. The practical and executive conclusions of this numerical analysis are that one should learn, as an engineer, how a JPCP rigid pavement runway with various grades of concrete, the elastic modulus of the sub-base and subgrade behaves under various aircraft types, and various wheel load positions.

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Conflicts of interest

The author(s) declare no conflict of interest.

Authors contribution statement

SB and NK: Conceptualization; SB and NK: Data curation; SB: Formal analysis; SB: Investigation; SB and NK: Methodology; KFW: Resources; SB and KFW: Software; NK: Supervision; SB and KFW: Validation; SB: Visualization; SB and KFW: Roles/Writing – original draft; SB, KFW, and NK: Writing – review & editing.

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Fig. A.1. A flow chart representing the complete procedure for analyzing the rigid pavement runway model's static response.