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Rigid Pavement Thickness Analysis on the Apron of Kalimarau Airport Berau Using Federal Aviation Administration and Portland Cement Association Methods

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A B S T R A C T

Berau Regency is one of the regencies in East Kalimantan Province that is rich in tourism, mining, and agricultural resources. The results indicate that the FAA method produces a rigid pavement thickness of 41 cm with an estimated cost of IDR 56,385,600,000. The PCA method using a safety factor results in a pavement thickness of 37 cm with an estimated cost of IDR 51,806,400,000, while the PCA fatigue-based method yields a thickness of 33 cm with an estimated cost of IDR 47,227,200,000. An increase in rigid pavement thickness leads to higher material requirements, labor demand, and long-term maintenance costs. The differences in results between the FAA and PCA methods should be considered in relation to the planning objectives, acceptable risk levels, and the availability of the project budget.

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INTRODUCTION

Located around 500 kilometers from the capital, Berau is a regency in the province of East Kalimantan. Maratua Island, Derawan Island, Biduk-Biduk Island, and other coastal islands in Berau are popular tourist destinations. Berau has abundant natural resources, including as mining, plantations, and fisheries, in addition to tourism. People from outside Berau come here for job and tourism because of these resources. Air travel is one of the reasons these folks come.

People may quickly travel from Berau to other cities or vice versa thanks to air travel, which is an essential mode of transportation. As a result, the need for air travel has grown annually. This infrastructure is essential to Berau's social welfare and economic development.

Kalimarau Airport in Berau is one establishment that has been upgraded. A domestic airport, Kalimarau Airport offers a number of flight paths to Indonesia's largest cities. The Kalimarau Class I Airport Operations Unit (UPBU), a division of the Ministry of Transportation's Directorate General of Air Transportation, is in charge of this airport. The airport has a 2,250-meter runway and is situated on Jl. Kalimarau in Teluk Bayur, Berau, East Kalimantan.

One type of transportation infrastructure that is strategically important to the country's transportation network is airports. In addition to facilitating the movement of people and goods, airports play a significant role in the expansion of regional economies, the increase of tourism, and enhanced interregional connection, especially for physically isolated regions. As mandated by the national transportation development strategy, the construction and enhancement of airport infrastructure is a crucial component of initiatives to accomplish equitable development and bolster regional integration in the context of Indonesia's national growth.

Airport operations can be significantly impacted in practice by apron pavement deterioration. Flexural fractures, slab sinking, and joint degradation can lower airport service levels, raise maintenance and rehabilitation costs, and jeopardize aircraft safety. A section of the operational area may even need to be closed in some situations due to apron pavement damage, which would have a direct effect on airport performance and capacity. As a result, planning for apron pavement thickness needs to be done precisely and on the basis of trustworthy technical study.

In East Kalimantan Province, Kalimarau Berau Airport is a regional airport that is essential to the connectivity and economic growth of Berau Regency and its environs. Given the substantial potential for natural tourism in Berau Regency, this airport services both regular commercial flights and aircraft that promote the tourism industry. The need for dependable and durable apron infrastructure is become more pressing due to rising flight activity and the possibility of future airport expansion.

The Federal Aviation Administration (FAA) and the Portland Cement Association (PCA) are two worldwide recommendations that are frequently consulted while designing stiff pavements for Indonesian airports. Although these approaches are extensively utilized and well-known worldwide, they were created using materials, operating features, and environmental circumstances that are different from those in Indonesia. Pavement thickness values for the identical conditions are frequently different due to the contrasting design philosophies of the more mechanical PCA technique and the FAA's empirical-statistical method.

These variations in design outcomes raise significant concerns about whether approach is most suited for use at Indonesia's small airport aprons, especially at Kalimarau Airport in Berau. The choice of design technique may be selected without fully comprehending its technical and financial ramifications in the absence of a thorough comparative analysis.

Portland cement concrete serves as the primary structural layer in rigid pavement. Rigid pavements can disperse loads over a larger area through the concrete slab mechanism, which produces a comparatively more robust structural response to severe loads than flexible pavements, which mainly depend on the strength of the subgrade. For airport airside facilities, especially runways, taxiways, and aprons that handle large aircraft loads, this feature makes stiff pavements the best option.

Rigid pavements serve as concrete slabs positioned above the subgrade and subbase from a structural mechanical standpoint.

The concrete slab's underside experiences bending strains due to aircraft wheel loads, and the subgrade responds with upward pressure, which is frequently represented by the subgrade response modulus (k). Structural fractures may appear and impair pavement performance if the flexural stress is greater than the concrete's flexural strength or if it happens often over an extended period of time.

The predominance of static loads from airplanes parked for extended periods of time on airport aprons complicates loading conditions. In some places, particularly beneath the main landing gear and nose gear, these static loads may result in stress building. Additionally, recurrent and unequal load combinations are produced by turning maneuvers, sluggish aircraft movements, and ground support equipment (GSE) operations. These circumstances necessitate the construction of stiff pavements that are resistant to fatigue and long-term deformation in addition to being safe against maximum loads.

Rigid pavements are further impacted by significant fluctuations in temperature, humidity, and precipitation in a tropical environment like Indonesia. Concrete can expand and contract due to temperature fluctuations, which can hasten cracking if suitable joint design and slab thickness are not taken into account. If the drainage system is not operating correctly, heavy rains may lower the subgrade's carrying capacity and hasten deterioration. As a result, structural, environmental, and operational factors must all be taken into account while designing stiff pavement on aprons.

Apron pavement collapse has major operational and economic ramifications in addition to technical ones. Damage to the pavement can raise maintenance and restoration costs, interfere with aircraft schedules and lower airport service levels. On a larger scale, an airport's appeal as a transportation and tourism center may be diminished by inconsistent pavement conditions.

Thus, accurate rigid pavement thickness analysis is essential to effective airport infrastructure management.

The pavement stresses caused by traffic and aircraft tire loads are calculated using the FAA (Federal Aviation Administration) technique. The FAA approach is developed by the FAA's Advisory Circular Airport and Evaluation (AC 150/5320-6D), which compares the modulus of response of the subgrade, drainage system, and aircraft loads. The Westergaard approach, which presupposes that a concrete slab sitting on a subgrade is solely elastic in the vertical direction, is also the foundation of the FAA method. This technique uses repeated loading, where the stress is delivered at the joints or close to the slab's edge.

The choice of apron pavement design techniques in Indonesian airport planning is frequently relied on published or custom recommendations rather than a methodical comparative investigation of local variables. This leads to a discrepancy between the real demands on the ground and the theoretical techniques employed in planning, particularly at regional airports with distinct soil, climate, and aircraft traffic characteristics.

The vital relevance of Kalimarau Berau Airport in promoting regional connections and the growth of East Kalimantan's tourism industry further emphasizes the urgency of this study. This airport's increased aircraft activity necessitates an apron pavement that can deliver excellent structural performance for the duration of its intended service life. The performance of the pavement may deteriorate in the absence of an appropriate design foundation.

In light of these circumstances, this study attempts to use the FAA and PCA techniques to solve the requirement for airport apron size. In this study, two international design approaches are explicitly applied to Indonesian regional airport aprons using a comparative analysis technique. This circumstance highlights the necessity of doing study on the apron at Kalimarau Airport in Berau utilizing the FAA and PCA methodologies for rigid pavement thickness assessments.

THEORETICAL REVIEW

Rigid pavement thickness analysis is a critical component in the design and maintenance of airport aprons to ensure structural performance under heavy aircraft loads, and prominent methodologies such as those developed by the Federal Aviation Administration (FAA) and the Portland Cement Association (PCA) have been widely referenced in the literature. The FAA method emphasizes a mechanistic-empirical design approach that incorporates aircraft traffic, subgrade strength, and environmental factors to determine optimal concrete pavement thickness, ensuring safety and durability for specific airport operations. Similarly, the PCA approach integrates empirical data with mechanistic principles to evaluate stress distribution and fatigue characteristics in rigid pavements, providing guidelines for thickness selection based on load repetition and concrete properties. Comparative studies indicate that while both methods aim to achieve performance objectives, variations in design inputs—such as aircraft gear configurations, reliability levels, and material characteristics—can lead to differences in recommended thickness. Research also underscores the usefulness of using nondestructive testing, finite element modeling, and local climate adjustments to enhance the applicability of these methods to specific contexts like Kalimarau Airport in Berau.

METHODOLOGY

Pavement thickness design using the FAA (Federal Aviation Administration) and the PCA (Portland Cement Association) methods.

FAA Method

The FAA method used in this study is the FAA method with series number AC 150/5320-6D from 1995. This method still uses manual calculations using graphs, making it easier for researchers to process research data. Currently, the latest FAA method is available with series number 150/5320-6G from 2021, with calculations using the FAARFILED application program. The FAA method, in the Advisory Circular Airport and Evaluation, number AC 150/5320-6D, develops the FAA method based on a comparison of the modulus of subgrade reaction, drainage system, and aircraft loads. The FAA method is also based on the Westergaard method, which assumes that a concrete slab resting on a subgrade is elastic only in the vertical direction. Furthermore, the concrete slab is assumed to be homogeneous, dense, elastic, and isotropic, with wheel loads distributed over an elliptical area. This method relies on repetitive loading, where the load is applied near the edge of the slab or at the joints. The Westergaard method analyzes stresses and deflections in rigid pavements.

PCA Method

The Portland Cement Association (PCA) method is a method for designing pavement thickness based on safety factors and fatigue concepts. The PCA method is used to evaluate the structural capacity of a predetermined rigid pavement thickness. Concrete pavements can be built directly on the subgrade, but for various reasons, a subbase layer of sand, gravel, or crushed stone is usually first placed on top of the subgrade, and then the concrete pavement is built over this subbase layer. The concrete pavement thickness required to support a given wheel load is determined by applying an equation developed for this purpose by H. M. Westergaard.

The Westergaard equation relates the maximum allowable bending stress in concrete to the wheel load and other pavement characteristics, such as the radius of relative stiffness. The value of this latter term depends on the bearing capacity of the subgrade, which is indicated by the modulus of subgrade reaction (PCA, 1984).

According to Sartono et al. (2016), an apron is a specific area above the airport ground surface where aircraft perform activities such as boarding and disembarking passengers, loading and unloading cargo, refueling, parking, and aircraft maintenance. Factors considered in designing an apron include:

Surface Gradient

Surface gradient significantly affects aircraft movement on the surface, including push tractors, drainage, fixed utilities, and fueling. The requirement for surface gradient is that the maximum slope must not exceed 1%.

Gate Position Size

The gate position is where passengers board and disembark and cargo are loaded and unloaded. Factors influencing the size of the gate position include:

1. Aircraft size and minimum turning radius.
2. How the aircraft enters and exits the gate position, either under its own power or under a tractor.
3. Aircraft parking configuration (nose-in) requires a smaller apron area for parking. Figure 2.1

Number of Gate Positions

The number of gate positions is the number of aircraft that can be accommodated by a given gate within a given time period.

Aircraft Parking System

The aircraft parking system is the design of the passenger terminal and apron, which are interconnected with the passenger terminal concept.

Passenger Handling Concept

The passenger handling concept is a consideration in the design of the apron layout.

Pavement Structure

According to the FAA (1995), a rigid pavement structure consists of Portland cement concrete placed on a granular foundation layer and supported by a compacted subgrade. The three structural elements of a rigid pavement are:

Subgrade

The subgrade in a pavement structure must be able to support the loads placed on it. The strength of the subgrade will affect the pavement thickness; the greater the load-bearing strength, the smaller the required pavement thickness. The subgrade material must be compacted to ensure even distribution of stability or bearing capacity. The results of subgrade stability testing are expressed in the California Bearing Ratio (CBR) and the modulus of subgrade reaction (k). The value of k is the spring constant for the material supporting the rigid pavement and indicates the bearing value of the supporting material (ICAO, 1983).

Subbase Layer

Stabilization of the subbase layer is necessary to increase the k value of the rigid pavement subgrade.

Concrete Slab (Surface Course)

The concrete slab (Surface Course) serves as a structural support to support vehicle loads. The surface of the concrete slab must be non-skid and prevent infiltration (seepage of surface water).

The time series method considers growth over time or historical activity patterns (Sartono et al., 2016). Time series methods are divided into two models: linear regression and exponential smoothing. The advantage of this method is that data (flight activity) can be projected and extrapolated from the past to the future, demonstrating cause-and-effect relationships (dependent and independent variables). Extrapolation assumes that factors in a historical activity pattern will determine variations in traffic in the past and continue to demonstrate similar relationships in the future. This time series method uses air traffic data, specifically the number of departures from the last 10 years, and is analyzed using simple linear regression and exponential smoothing applied in Microsoft Excel to obtain an equation that will later be used in forecasting for the next 20 years.

Market Share Method (Market Reach)

The market share method is a top-down approach that has the advantage of forecasting flight demand at the local level by leveraging large-scale flight activity for use at the local scale. Historical data is examined to determine the percentage (ratio) of local airport traffic data to total national traffic. According to Sartono et al. (2016), the market share method is sometimes used in two steps: determining the ratio of national flight activity to flights at the local level and determining the proportion of each airport at the local level.

Econometric Method

The econometric method considers factors that can influence flight activity, such as economic, social, market, intermodal competition, and operational factors (Sartono et al., 2016). The advantage of this method is that it predicts changes that occur using a systematic model to establish a relationship between the dependent variable and several independent factors that influence air travel demand.

RESULTS AND DISCUSSION

Based on the analysis of rigid pavement thickness on the apron of Kalimarau Berau Airport using the FAA and PCA methods, significant results were obtained. This indicates that the choice of analysis method has a direct impact on the dimensions of the rigid pavement thickness and the resulting costs.

The FAA method produced a rigid pavement thickness of 41 cm with a planned budget of Rp 56,385,600,000.00, the largest thickness compared to the PCA method. This thickness was obtained based on the main parameters of the Equivalent Annual Departure (EAD), the Modulus of Rupture (MR) of concrete, and the modulus of subgrade reaction (k). The FAA approach is empirical-statistical, where the relationship between aircraft load, departure frequency, and pavement thickness is determined using a design curve.

The PCA method using the Safety Factor approach resulted in a pavement thickness of 37 cm with a planned budget of Rp 51,806,400,000.00 billion, lower than the FAA method. This method uses a mechanistic approach, evaluating the working stress in the concrete slab and comparing it to the allowable stress.

Furthermore, the PCA–Fatigue method produced the smallest pavement thickness, 33 cm, with a planned budget of Rp 47,227,200,000.00. This method not only considers maximum stress but also explicitly accounts for concrete fatigue due to repeated aircraft loads during the construction process The design life is determined using the stress ratio and allowable repetition parameters. This approach reflects the operational conditions of the apron, which is subjected to repeated loads over the long term, making the design more sensitive to aircraft traffic characteristics. The result is a structure that still meets performance criteria, but with the most efficient thickness and cost.

The differences in pavement thickness and planned cost results between the FAA and PCA methods confirm that the choice of planning method significantly impacts the design and cost of rigid pavements. The FAA method is more suitable for designs with high levels of uncertainty and maximum safety requirements, while the PCA method, particularly PCA–Fatigue, is more appropriate when traffic data and material parameters are readily available and structural and economic efficiency are required. The differences in results between the FAA and PCA methods must be adjusted based on the planning objectives, acceptable risk levels, and project budget constraints.

CONCLUSION

Based on the analysis conducted on the Kalimarau Berau Airport apron, the following research conclusions were obtained.

1. The rigid pavement thickness on the Kalimarau Berau Airport apron for the next 20-year design life using the FAA method is 41 cm, the PCA-Safety Factor method is 37 cm, and the PCA-Fatigue method is 33 cm.
2. The cost of the rigid pavement thickness on the Kalimarau Berau Airport apron for the next 20 years using the FAA method is Rp 56,385,600,000.00, the PCA-Safety Factor method is Rp 51,806,400,000.00, and the PCA-Fatigue method is Rp 47,227,200,000.00.

RECOMMENDATION

Based on the research results and the established problem limitations, the following suggestions for further research are provided:

1. Future research is recommended to expand the scope of analysis beyond apron pavement thickness design to include other airside facilities, such as runways and taxiways, to achieve a more comprehensive airport pavement design.
2. Aircraft movement forecasting in this study was conducted using time series and graphical methods. Therefore, further research is recommended to use specialized airport pavement software or methods, such as FAARFIELD, to compare the forecasting results and the resulting pavement thickness design.

3. This study used a single aircraft type, the Boeing 737-900ER, with a design life of 20 years. Future research is recommended to consider a variety of aircraft types (mixed traffic) or larger aircraft types to make the pavement design more relevant to future airport operational conditions.
4. The data used in this study is secondary data obtained from the Kalimarau Class I Airport Operations Unit (UPBU).

FURTHER STUDY

Further research is recommended to examine the pavement design needs of airports with special characteristics, such as Hajj embarkation airports, which experience higher traffic intensity and aircraft loads, to identify differences in pavement thickness requirements and structural performance.

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