



# Design Analysis of Airport Runway Pavement Overlay using FAARFIELD 2.1 (Case Study: Fatmawati Soekarno Airport, Bengkulu)

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## Abstract

The design and upkeep of airport pavements are essential for guaranteeing safe and efficient air travel. This study assesses the overlay thickness specifications for the Fatmawati Soekarno Airport runway utilizing FAARFIELD 2.1, a pavement design software created by the Federal Aviation Administration (FAA). The evaluation relies on primary and secondary data, encompassing Pavement Condition Index (PCI) analysis, Dynamic Cone Penetration (DCP) tests, and estimates of aircraft traffic. The FAARFIELD methodology uses layered elastic and finite element analysis to simulate pavement performance under escalating load requirements. The findings demonstrate that for STA 0+000 to 1+800, with a subgrade bearing capacity (CBR) of 6%, the necessary overlay thickness is 51mm (5cm) of Hot Mix Asphalt (HMA). Likewise, for STA 1+800 to 2+250, with a subgrade CBR of 10%, the overlay thickness is maintained at 51mm (5cm). The design considers anticipated aircraft traffic expansion over 20 years while retaining the pavement's structural integrity. This study demonstrates the efficacy of FAARFIELD in enhancing overlay designs for airport pavements, hence improving maintenance strategies for aviation infrastructure.

**Keywords:** overlay, runway, FAARFIELD, airport pavement

## 1. Introduction

Appropriate design and continuous maintenance, such as overlay of airport pavements, are essential for ensuring air transportation systems' safety, dependability, and overall efficiency [1]. Airport Pavements must meet strict criteria to support substantial aircraft traffic loads [2], withstand aging and weather conditions [3], and accommodate maintenance and rehabilitation (M&R) [4]. M&R refers to strategies or practices to maintain or restore pavement functionality [5]. These strategies are closely tied to the airport pavement life cycle trends [6]. A key strategy to improve pavement service life is treating surfaces with the overlay method, which has proven to be a viable solution [7]. Additionally, the designed overlay thickness must account for future aircraft traffic growth to ensure reliable, high-performance pavements. FAARFIELD is software developed by the Federal Aviation Administration (FAA) that utilizes layered elastic and finite element analysis to design flexible and rigid pavements.

Engineers must understand the existing pavement structure conditions and structural capacity to design the overlay. The FAA issued Advisory Circular (AC) 150/5320 about Airport Pavement Design and Evaluation, explaining the typical pavement structure. The upper pavement layer is called the surface courses, which typically include cement concrete or

asphalt mixture. Under the surface course, the base courses consist of crushed and uncrushed aggregates. The next layer is the subbase, which consists of granular material. Both base and subbase courses can be stabilized or unstabilized. The lowest layer, the subgrade course, consists of natural or modified soils.

A pavement's structural capacity is defined as its capability to support traffic loads without enduring severe distress [8]. The characteristics of the aircraft, such as the mass, directly affect the calculation of overlay thickness [9]. Hence, determining the types and number of aircraft operating in the studied airport is crucial. For instance, the Airport Pavement Management System (APMS) 2022 report of the Fatmawati Soekarno Airport shows that the Boeing 737-900ER, Boeing 737-800, and Airbus A320-200 have the highest number of traffic, serving as the dominant and critical aircraft in the overlay design. Proper evaluation of these parameters ensures that the overlay design meets the airport's operational requirements and performance criteria, as detailed in the methodology section.

FAARFIELD is the standard software for modeling airfield pavement. For example, a recent study by Irvanaya et al. used FAARFIELD to determine the overlay thickness of I Gusti Ngurah Rai Internasional Airport's runway [10]. The analysis above shows that the existing airport runway would require an overlay of 7.7 inches to accommodate the most critical aircraft, the Boeing 777-300ER, for a pavement life of 20 years.

For this study, we aim to assess the required thickness overlay for the existing runway pavement structure at Fatmawati Soekarno Airport. The assessment responds to surface deterioration, traffic growth, and scheduled M&R documented in the Airport Pavement Management System (APMS) using FAARFIELD software. The results of this study may help develop more effective and sustainable airport pavement management strategies using FAARFIELD, particularly for airports across Indonesia.

## 2. Methodology

This chapter describes the primary and secondary data collection methods for establishing the FAARFIELD input parameter. The primary data includes on-field data to evaluate the existing runway pavement surface distress and soil foundation bearing capacity. The secondary data consists of the Fatmawati Soekarno Airport's APMS document (IATA Code: BKS), which includes runway pavement structural specifications, M&R data, operating aircraft types, and traffic data up to 2022. Recent literature from journals or research is also presented to support the schematic methodology.

### 2.1. Existing Runway Pavement Structure

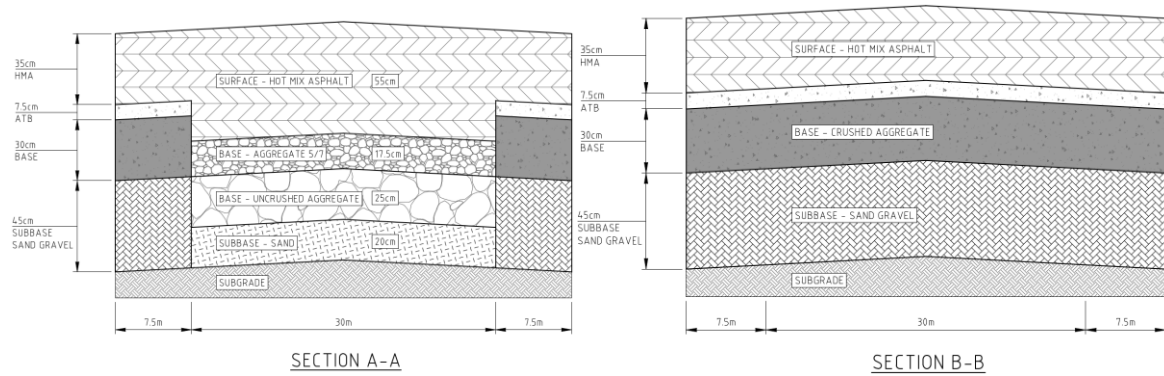
Figure 1 shows the runway length in two parts to understand the historical layering of the BKS pavement structure. STA 0+000 to STA 1+800 is the initial runway length, which was 30 meters wide and extended to a total length and width of 2250 and 45 meters, respectively. Figure 2 illustrates two cross-sections for the runway pavement. Section A-A (STA 0+000 to 1+800) shows the different layering systems between the 0-15m wide against the extended runway at 15-22.5m wide from the center line. Section B-B (STA 1+800 to 2+250) shows that the pavement shares similar layers with 0+000 to 1+800 extension as they were constructed at the same period.

Due to the difference in the layering systems, both runway layering systems will produce two FAARFIELD overlay thickness results, which may give different overlay thicknesses. The output with the higher overlay thickness requirement would be the base thickness for the whole runway. However, for STA 0+000 to 1+800, the runway layering system at 0-15m from the center line is determined as the predominant input parameter for the critical aircraft wheel path for the specified width.



Source: Google Earth Analysis, 2025

**Figure 1.** BKS Airport Runway pavement

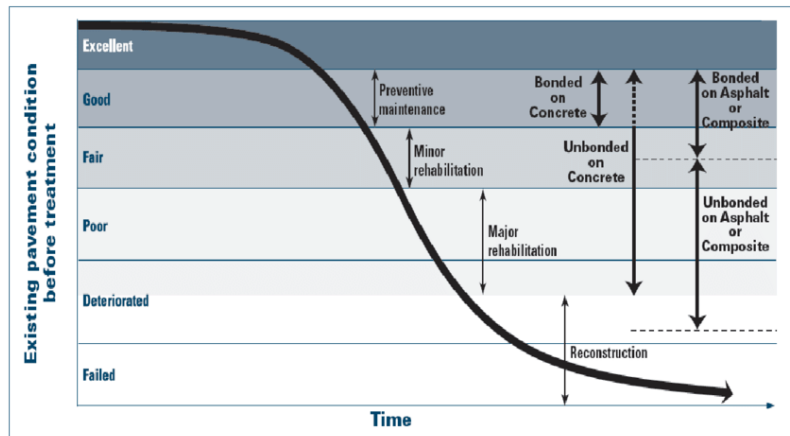


Source: APMS BKS Airport 2022 (refined with BricsCAD), 2025

**Figure 2.** Runway Pavement Cross-Sections

## 2.1. Pavement Condition Index (PCI) Analysis

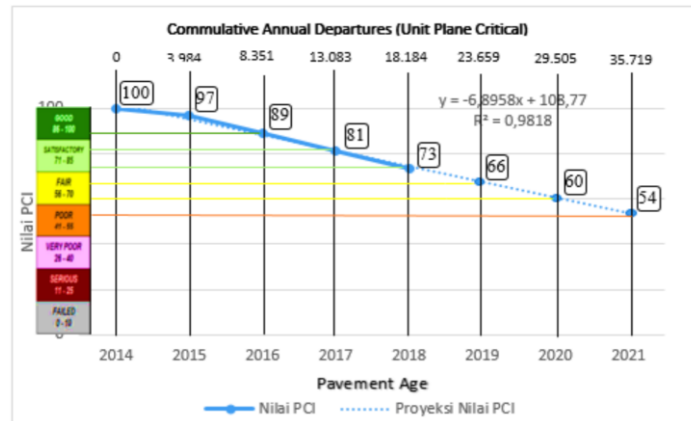
The PCI survey measures pavement surface conditions based on the type of distress, using the collective judgment of pavement maintenance engineers. It uses a numerical rating that ranges from 0 to 100, with 0 being the worst possible condition and 100 being the best possible condition. The PCI value directly corresponds to the M&R treatments for runway pavement or pavement in general, as illustrated in Figure 3 below.



Source: Hossain and Sultana [11]

**Figure 3.** Typical Pavement Condition Curve over Time and M&R Treatments

Amanah linearly projected the PCI value of the BKS Airport runway using the previous annual PCI data from 2014 to 2018 to get the PCI value until the year 2021, which they then developed a simple linear model as follows:



Source: Amanah [12]

**Figure 4.** BKS Airport Runway PCI value Projection

However, this model has been proven to adopt several weaknesses. Firstly, according to the APMS BKS Airport 2022, a PCI survey was conducted in 2019, and it was found that the PCI value is 82.7, which is higher than the previous PCI undertaken in 2018. Based on Figure 3, it is assumed that minor rehabilitations were done between 2018 and 2019, and then a reassessment of the surface condition was conducted in 2019. Amanah's model can be improved by adding the actual PCI survey value in 2019. Secondly, the PCI value of a runway pavement corresponds to the M&R treatments that are annually conducted. The known life cycle trend will typically not be linear but follow the trend based on Figure 3.

However, the PCI survey was only conducted once again in 2023 to find out that the PCI value had reached a critical level of 20.73. Based on the M&R treatments, reconstruction must be conducted on the pavement before performing an overlay design. This steep decrease can be explained by understanding that with each M&R treatment completed, the overall PCI value deteriorates and is not the same as it was initially before the treatment. The pavement life and quality drop after the critical PCI range would be significant and imminent. For the design's sake, it is assumed that the reconstruction is done until all surface distresses are removed completely.

## 2.2. Subgrade Bearing Capacity Analysis

The subgrade bearing capacity that will be used for the FAARFIELD input parameter is the California Bearing Ratio or CBR. Typically, the CBR test is conducted after the subgrade is constructed. According to the APMS document, the CBR for the runway pavement subgrade is 6%. To further improve the reliability of the CBR, Dynamic Cone Penetration (DCP) tests are conducted throughout the side of the runway, which are then converted into CBR using the following model:

$$\text{For } 30^\circ \text{ cone size, CBR} = 10^{(1.352 - 1.125 \text{Log}_{10}(\frac{cm}{blow}))} \quad (1)$$

$$\text{For } 60^\circ \text{ cone size, CBR} = 10^{(2.8135 - 1.313 \text{Log}_{10}(\frac{mm}{blow}))} \quad (2)$$

The models above were issued by the Ministry of Public Works and Public Housing of Indonesia through circular letter No. 04/SE/M/2010 regarding the CBR guide using the DCP test. Table 1 shows the converted DCP test results with the approximate test locations.

Table 1. Converted DCP Test Results on the Runway Sides (60° cone size)

DCP	STA	CBR Range (%)	DCP	STA	CBR Range (%)
DCP-01	0+040	2.95 - 3.93	DCP-07	1+850	3.26 - 7.68
DCP-02	0+440	2.31 - 8.89	DCP-08	2+000	7.23 - 24.92
DCP-03	0+850	2.63 - 4.81	DCP-09	2+135	3.93 - 10.14
DCP-04	1+270	4.60 - 4.96			
DCP-05	1+475	3.33 - 5.40			
DCP-06	1+750	3.18 - 11.42			
Average (%)		4.87	Average (%)		9.53
Standard Deviation (%)		5.18			

The average CBR value calculated from DCP tests conducted on the side of the runway at STA 0+000 to 1+800 is 4.87%, or rounded to 5%, while at STA 1+800 to 2+250, it is 9.53%, or rounded to 10%, both for a more conservative input parameter. Both results show significant deviations from the reported CBR value in the APMS document. This methodology to acquire CBR values is deemed less adequate as the DCP tests are conducted on the side of the runway and are less representative of the actual condition. However, this does not mean the overlay design does not consider the analyzed bearing capacity using this method. Based on historical data, the runway pavement at STA 1+800 to 2+250 is an extension length and may represent a different subgrade condition. Hence, the overlay design for runway pavement at STA 0+000 to 1+800 and 1+800 to 2+250 will use 6% and 10% CBR, respectively.

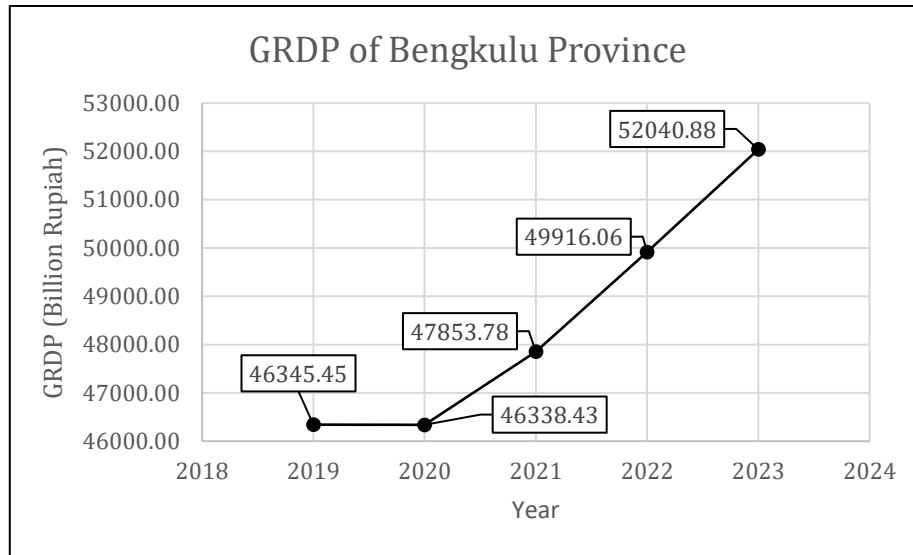
### 2.3. Aircraft Traffic Analysis

The aircraft type of BKS airport is taken from the APMS document as secondary data. Understanding the standard aircraft type operating within the studied airport is critical to projecting future traffic as closely and conservatively as possible. Table 2 shows the aircraft operating in BKS airport in 2022, with modifications to accommodate more critical aircraft, in addition to the data from the APMS document.

Table 2. Air Traffic Summary for Input Parameters

Aircraft Type	Annual Departures	Annual Growth (%)
Boeing 737-900ER	1518	2.96
Boeing 737-800	1116	2.96
Airbus 320-200	1116	2.96
Cessna 208B	636	2.96
Beechcraft King Air 350	16	2.96
Gulfstream G-V	6	2.96
ERJ-135	4	2.96
P-3C	4	2.96
ATR 42-500	4	2.96
Cessna Citation X	4	2.96
C-130	2	2.96

A percentage of annual growth cannot be concluded from the acquired aircraft traffic data from 2020 up to 2022 due to the emergence of the COVID-19 pandemic, which is affecting the entire world of aviation. Alternatively, the aircraft traffic analysis is concluded from the Gross Regional Domestic Product (GRDP) of the Bengkulu Province. Figure 5 shows the GRDP of Bengkulu Province over the last five years. It is calculated that the average annual growth rate over the studied period, 2019 to 2023, is 2.96%.



Source: BPS-Statistics Indonesia for Bengkulu Province, 2025

**Figure 5.** GRDP of Bengkulu Province from 2019 to 2023

## 2.4. Structure Modelling for Overlay Design

The input parameters for the overlay design using the FAARFIELD program need to be adjusted based on the existing pavement conditions and traffic data to produce the minimum overlay thickness with the highest safety and accuracy for practical constructions.

### 2.4.1. Existing HMA Resilient Modulus

Time and temperature differences are two factors affecting HMA mixtures' performance. Idham et al. found that the resilient modulus of aged HMA mixtures can degrade up to 77% from its initial performance at a higher temperature [13]. As explained in the PCI section, reconstructing the existing HMA layers is preferable to remove surface distress. The reconstruction depth is assumed to be approximately 20cm deep, leaving 15cm of existing HMA. Hence, the remaining HMA layers will be modeled with a resilient modulus of only 50% (conservative judgment).

### 2.4.1. Adjustment to the Aircraft Traffic Annual Growth

Based on the GRDP of Bengkulu Province, it has an average annual growth rate of 2.96%. However, for the input parameters in FAARFIELD, a yearly growth rate of 5% is used for all aircraft types to illustrate the overlay design sensitivity against the annual growth rate. Figure 6 shows all aircraft types and the modification to the annual growth rate in FAARFIELD. The overlay design is analyzed to accommodate a design life of 20 years.

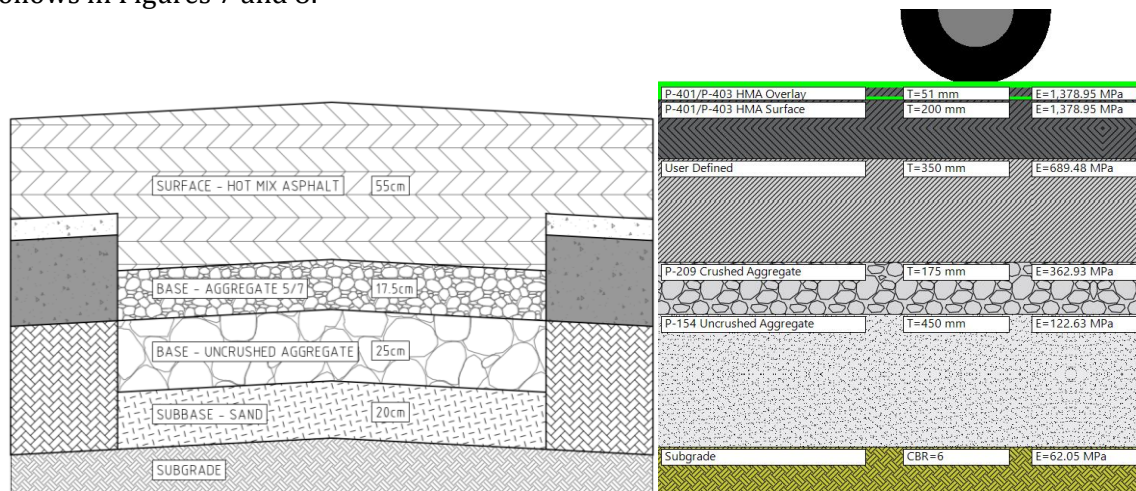
Airplane Name	Gross Taxi Weight (kg)	Annual Departures	Annual Growth (%)	Total Departures
B737-900 ER	85,366	1,518	5	8,539
A320-200 std	73,900	1,116	5	6,278
B737-800	79,242	1,116	5	6,278
Cessna 208B Grand Caravan	3,969	636	5	3,578
Beechcraft King Air 350	6,849	16	5	90
Gulfstream G-V/G500/G550	41,232	6	5	34
ERJ-135	19,100	4	5	22
P-3C	64,410	4	5	22
ATR 42-500	18,770	4	5	22
Cessna Citation X	16,329	4	5	22
C-130	70,307	2	5	11

Source: FAARFIELD Input Parameters, 2025

**Figure 6.** Aircraft Types on FAARFIELD

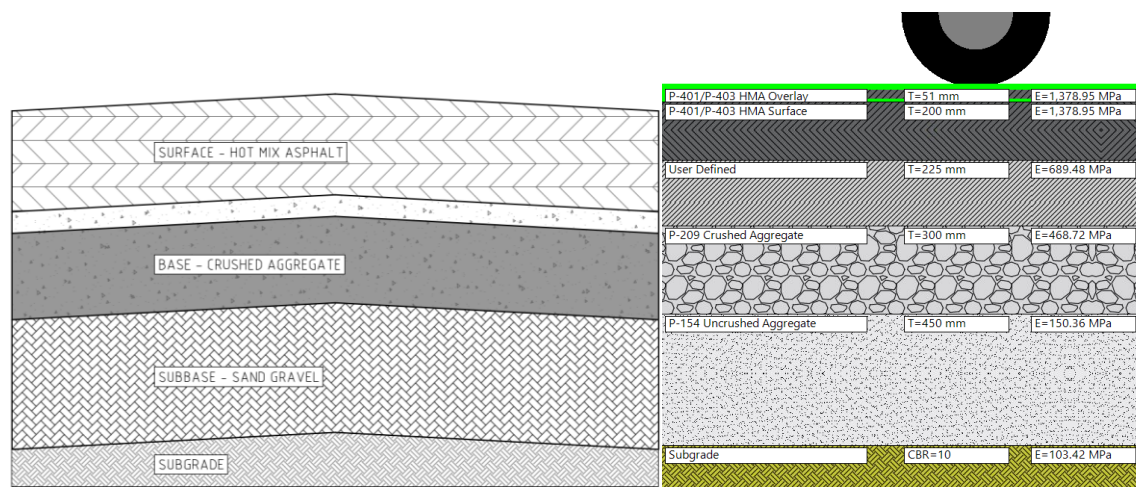
### 3. Results and Discussion

All the input parameters, as well as the adjustments, are used in the FAARFIELD program to determine the required minimum overlay thickness of the BKS airport runway as follows in Figures 7 and 8:



Source: FAARFIELD Overlay Result, 2025

**Figure 7.** FAARFIELD Overlay Design for STA 0+000 to 1+800



Source: FAARFIELD Overlay Result, 2025

**Figure 8.** FAARFIELD Overlay Design for STA 1+800 to 2+250

### **3.1. Overlay Design for STA 0+000 to 1+800**

The pavement modeling in Figure 7 in FAARFIELD follows the previously illustrated existing pavement condition. The lowest pavement layer, or the subgrade, used the CBR value of 6%, as described in section 2.2, for bearing capacity. The uncrushed aggregate on the FAARFIELD program consists of both subbase (sand) and base, to a combined depth of 45cm and initial design modulus of 275.79 MPa. The crushed aggregate base has a design depth of 17.5cm and an initial design modulus of 517.11 MPa. The “User Defined” layer is the existing HMA layer not affected by the assumed reconstruction; hence, it needed a justification to reduce its resilient modulus by 50% due to aging and temperature fluctuations. The HMA surface is the assumed reconstructed HMA mixture required to remove the severe existing surface conditions after the PCI survey conducted in 2023. The top layer or the designed overlay thickness is 51mm or 5cm of HMA mixture. It can also be concluded that the proposed pavement design life of 20 years affects both crushed and uncrushed base courses, deteriorating their performance to 44% and 70%, respectively.

### **3.2. Overlay Design for STA 1+800 to 2+250**

The pavement modeling in Figure 8 in FAARFIELD follows the previously illustrated existing pavement condition. The lowest pavement layer, or the subgrade, used the CBR value of 10%. The uncrushed aggregate consists of the subbase—sand gravel to a depth of 45cm and an initial design modulus of 275.79 MPa. The crushed aggregate base has a design depth of 30cm and an initial design modulus of 517.11 MPa. The “User Defined” consists of the existing HMA layer not affected by the assumed reconstruction, which also needs a justification to reduce its resilient modulus by 50%. The asphalt-treated base, or the ATB, is also justified as a part of the “User Defined” layer, bringing the total depth to 22.5cm. The HMA surface is the assumed reconstructed HMA mixture. The top layer or the designed overlay thickness is 51mm or 5cm of HMA mixture. Lastly, this overlay design has the same proposed design life of 20 years, affecting both crushed and uncrushed base courses to a decreased modulus performance of 55% and 91%, respectively.

## **4. Conclusion**

This study used the FAARFIELD software to evaluate and determine the necessary overlay thickness for the current runway pavement structure at Fatmawati Soekarno Airport. FAARFIELD, created by the FAA, employs a layered elastic and finite element analysis methodology to assess pavement performance and ascertain overlay specifications. The process entailed the collection of both primary and secondary data to determine precise input parameters. Primary data comprised on-site evaluations, including Pavement Condition Index (PCI) analysis and Dynamic Cone Penetration (DCP) testing to estimate subgrade bearing capability. Secondary data were gathered from the Airport Pavement Management System (APMS), which stored historical pavement conditions, maintenance records, and aircraft traffic statistics. Projections for aircraft traffic increase were based on the Gross Regional Domestic Product (GRDP) of Bengkulu Province to assess future load requirements.

The FAARFIELD research yielded two overlay thickness outcomes derived from distinct runway segments. For STA 0+000 to 1+800, with a subgrade bearing capacity (CBR) of 6%, the necessary overlay thickness was 51mm (5cm) of Hot Mix Asphalt (HMA). Likewise, for STA 1+800 to 2+250, with a subgrade CBR of 10%, the necessary overlay thickness was 51mm (5cm). These results consider anticipated aircraft traffic growth over a 20-year design lifespan while preserving structural integrity and performance under escalating load requirements.

Future research using the FAARFIELD should consider establishing a more suitable methodology for determining the bearing capacity of the subgrade layer. It is typically unnecessary to decide on the bearing capacity if the historical CBR value is present. However, the latest on-field data collection can help researchers cross-check older data. Furthermore, DCP tests conducted at the side of the runway may not accurately present the subgrade

condition at the runway's center. The PCI value only shows the overall pavement surface condition and does not show the pavement distress at depth. A pavement core drill is recommended to check the runway pavement at severe locations. The reconstruction depth can be accurately determined based on the deterioration depths from the core drill samples.

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