Analysis of Apron Pavement Thickness in Central Airport Based On the Amount and Type of Aircraft

Ika Putri Hendriyani, Sakti Adji Adjisasmita, Achmad Faisal Aboe

***Abstract:** Sentani Airport is one of the airports that became a liaison between districts in Papua. Growth that occurs annually makes Sentani airport gets busier. Analysis of the rigid pavement apron of Sentani airport was done with the aim to determine the thickness of pavement layers at airports. The method used is a method of planning the FAA (Federal Aviation Administration). The first step to consider is the value of CBR (California Bearing Ratio) subgrade, the determination of the value of the modulus of subgrade, selecting the best plan, maximum take-off weight (MTOW) of the aircraft, the load of the aircraft wheels (w2), departure corrected (R2), the load of the aircraft wheels plans (w1) and annual equivalent flight departures plan (R1). This pavement analysis using aircraft Boeing plans 737-900ER. Based on the data obtained from the value of aircraft MTOW plan, the quality of concrete, modulus of subgrade and the value of R1 were plotted on a curve to obtain the FAA pavement thickness. The results of this study showed that the best plan for the 737-900ER required a pavement thickness of 61 cm by 41 cm layer of concrete slab and 20 cm subbase layer.*

***Keywords:** pavement, apron, aircraft, airport, Sentani Airport*

I. INTRODUCTION

Sentani Airport is located about 36 km west of Jayapura. Jayapura is the capital of Papua Province. The addition of flight routes affects the number of planes parked at central airports. The aircraft movements that occur every day at Sentani airports are 170-200 aircrafts and the number of passengers that increased every year is around 20%. This greatly impacts the performance of every access in Sentani Airport, one of which is the apron. Apron is also used as a parking lot for aircraft, refuelling stations, boarding and disembarking passengers [1-2].Apron located on the air side directly intersects with the terminal building which of course has a big impact on the ability of the apron to serve aircraft that will park and do other activities. This affects the type of aircraft that will use the airport, and of course also affects what type of pavement suitable to be used at this airport. The airport pavement structure is different from the pavement structures of ordinary roads, because of the load at the airports as the standard axis is different from the road in general.

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Bethary, Pradana and Basidik (2015) did a study on Soekarno-Hatta airport pavement strength using International Civil Aviation Organization (ICAO) method and found that the pavement was able to withstand loads of up to 80,000 lbs [3]. This value is far greater than the weight of the Airbus A-380 aircraft which is 57,000 lbs. Then this is strengthened by the Pavement Classification Number (PCN) value at Soekarno airport Hatta is 120 R / D / W / T and 96 R / D / W / T (in terminal 3 Apron) greater than the value of Aircraft Classification Number of Airbus A-380 type is 94 R / D / W /T. Furthermore, block and fatigue cracking of pavement surface was focused at the touch down part of the runway, whereas faulting of joints, and scaling of concrete surface were the common type of distresses at the remaining part of the runway[4]. A comparison study was conducted by Triwibowo (2014) using FAA method, PCA (Portland Cement Association), and the LCN (Load Classification Number) to determine the thickness of the apron using three different methods for Juandaairport [5]. From the calculation results, the thickness of rigid pavement structure obtained is at 44 cm for FAA method, 33.5 cm for PCA and 32.5 for LCN method. The existing pavement thickness is 45 cm, exceeding the analysis results. Existing rigid pavement thickness of 45 cm was still able to receive the traffic load on air until 2026. These researches proved that different airports have different requirements for its airport apron. Therefore, it is necessary to analyse the thickness of the pavement layer at Sentani Airport based on the total number and type of aircrafts.

II. METHODOLOGY

In this design, the FAA (Federal Aviation Administration) method is used as one of the guidelines in designing airport rigid pavement. The things that need to be considered in designing rigid pavements using the FAA method are as follows:

1. Modulus of subgrade reaction (k)
2. Modular flexural strength (flexural strength)
3. Air traffic volume (Equivalent Annual Departures)
4. Plane characteristics (Critical Aircraft)

The study of the aircraft parking area includes direct observation and documentation of the aircraft parking area. The retrieved data are in the form of number of aircraft parked at the airport apron for the month of March 2017. Data obtained from observations at the site are presented in the form of tables, and layout drawings.

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The steps taken in analyzing the data obtained are as follows: analyzing the thickness of existing pavement in the apron by observing the number and type of aircraft.

III. RESULTS AND DISCUSSION

Condition of Airport Apron

The available apron area is obtained from the database of the UPBU Class 1 Transportation Office, Sentani Airport. For an extensive area of 60,720 m², it can accommodate 32 aircrafts in the Sentani Airport aircraft parking lot.

Air Traffic Data

In accordance with air transport data from the Transportation Agency of UPBU Class 1 Sentani Airport traffic data of aircraft movements and passengers arriving, departing and transit from and to Sentani Airport from 2012 to 2016 are presented as follow in Table 1.Based on the highest departure traffic data by aircraft type which can be seen in Table 2, it was found that the total numbers of aircrafts that can be parked are 15285.

Table. 1 Data on the Growth of Aircraft and Passengers at Sentani Airport [6]

Year	Aircraft		Passengers	
	Total	Growth	Total	Growth
2012	8763	-	1 088 078	-
2013	10843	23.74%	1 265 589	16.31%
2014	12972	19.63%	1 348 793	6.57%
2015	11325	-12.69%	1 201 337	-10.39%
2016	15285	35.00%	1 655 564	37.81%

Table. 2 Data of flight departure at Sentani Airport

Type of aircraft	Total aircrafts	Type of aircraft	Total aircrafts
A-320	521	C-208	98
ATP	432	C-212	88
ATR-42	410	CHALLENGER 30	36
ATR-72	221	CRJ-100	351
B-105	118	DHC-6	20
B-200	85	G-500	5
B-206	89	KODIAK	398
B-732	1075	MD-83	356
B-733	2241	MI-17	288
B-735	3324	PAC-750	113
B-738	2087	PC-12T	165
B-739ER	2376	PC-6T	148
BELL-412	155	SA-330	9
C-130	65	F-27	11
Total			**15285**

Rigid Pavement Planning Analysis with the FAA Method

The design of rigid pavement layers using the FAA method is carried out in the following 3 stages:

1. Determine plan planes (Critical Aircraft)

The planes are selected according to the type of aircraft operating at Sentani Airport, namely the B737-900ER aircraft and the largest aircraft that is parked at Sentani Airport.

2.Determine the aircraft wheel load (w_2) and planned aircraft wheel load (w_1)

In calculating aircraft wheel load, the load used is the load of each wheel located on the main gear. In determining the load for each wheel, the load distribution in the main gear is equal to 95% of the MTOW of the aircraft for all types of aircraft.Wheel load plan aircraft (w_1) B737-900ER with 6 landing wheels is calculated using Equation 1

$$w_1\ (inlbs) = \%\ distributionofmaingear \times plannedMTOWofaircraft \times \frac{1}{N} \quad (1)$$

Where

w_1 = aircraft wheel load in lbs

N = number of landing wheels

Wheel type: dual wheel

MTOW: 174.200 lbs

Thus,

$$w_1 = 95\% \times 174.200 \times \frac{1}{6} = 29719\ lbs$$

Airplane wheel load (w_2) is equated using Equation 2

$$w_2\ (inlbs)\ \%\ distributionofmaingear \times plannedMTOWofaircraft \times \frac{1}{N} \quad (2)$$

Where

w_2 = aircraft wheel load in lbs

N = number of landing wheels

For dual wheel type Airbus 320-200 with 6 landing wheels, the airplane wheel load is:

$$w_2 = 95\% \times 170.474 \times \frac{1}{6} = 26992\ lbs$$

Using the fixed MTOW of each airplane, Table 3 tabulated the data on type of aircraft, wheel configuration and wheel load.

Table. 3 Data on aircraft type, wheel configuration and wheel load

Type of aircraft	MTOW	Type of wheel	Total wheels	W_2 (lbs)
ATR 42	36.596	Dual wheel	6	5794
A 320	170474	Dual wheel	6	26992
B 737	154500	Dual wheel	6	24463
B 737-ER	174200	Dual wheel	6	29719
B 738	174200	Dual wheel	6	27582
DHC 6	11566	Single wheel	3	3663
C 208	7800	Single wheel	3	2470

3. Determine equivalent annual departures of aircraft

The number of departures for each type of aircraft is converted into plan planes. The value of equivalent annual departures is determined by the number of corrected aircraft departures (R_2) converted according to the ratio between the aircraft wheel load (w_2) and the planes' aircraft wheel load (w_1) using Equation 3 where the value of R_2 is obtained using Equation 4.

$$\log = \log R_2 \left(\frac{w_2}{w_1}\right)^{0.5} \quad (3)$$

Where:

R_1= equivalent annual departures

R_2 = corrected flight departure

w_1 = planned aircraft wheel load

w_2 = aircraft wheel load

$$correctedflightdeparture, R_2 = totalnumberofaircraft \times conversionvalue \quad (4)$$

The computations of these values are presented in Table 4. The result of the equivalent annual departure (R1) on aircraft B737-900ER is 117. Equivalent Annual Departures (EAD) planes are the result of the total number of EADs of all types of aircraft that have been converted to planes with a comparison of aircraft wheel loads and aircraft wheel configuration types. EAD plan aircraft must be less than 25000 if the total EAD is more than 25,000, it is necessary to have corrections on rigid hard layers in accordance with the FAA method.

Table.4 Results of EAD for the different types of aircraft

Type of aircraft	w_1 (lbs)	w_2 (lbs)	Total number of aircraft departure	Conversion value	Corrected flight departure (R2)	EAD (R_1)
ATR 42	5794	29719	2932	0.6	1759	8
A 320	26992	29719	195	0.6	117	94
B 737	24463	29719	1711	0.6	1027	75
B 739-ER	29719	29719	2376	0.6	1425	117
B 738	27582	29719	5461	0.6	3277	98
DHC 6	3663	29719	1615	0.5	807	5
C 208	2470	29719	9622	0.5	4811	4
			Total			401

Rigid Pavement Thickness Analysis Subgrade

Based on the results of soil investigation, it was found that the classification of soil types with reference to USCS (unified soil classification system) that the partial soil density is good with a California Bearing Ratio (CBR) value of 6%. In this pavement planning, the subgrade CBR used was 6%. This value is in accordance with the standard CBR value in the specifications and requirements of the Department of Public Works, Directorate General of Highways. From this CBR value, it can be seen the subgrade value (modulus reaction of subgrade) with the following calculation using Equation 5 and 6:

$$Modulusofsoilreaction, k = \left[\frac{1500 \times CBR}{26}\right] 0.7788 \quad (5)$$

$$= \left[\frac{1500 \times 6}{26}\right] 0.7788$$

$$= 94.9692\ pci$$

$$Elastic\ modulus,\ E = 26 \times k^{1.284} \quad (6)$$

$$= 26 \times 94.9692^{1.284}$$

$$= 8998.9043\ psi$$

Subbase

Based on the FAA AC 150 / 5320-6E Airport Pavement Design and Evaluations, subbase must have a minimum thickness of 4 in (102 mm) [7]. The FAA AC 150 / 537010F standards for specifying construction of airport for the use of cement treated base course (CTB) under rigid pavement surfaces, it must have a compressive strength (f'c) of at least 500 psi (3,447 kpa) and a maximum of 1000 psi (6,895 kpa) [7]. Subbase design is based on the following parameters:

a. Subgrade strength (k subgrade): CBR = 6% k: 94.9692095 pci (25,831 MN / m^3)

E: 8998.90553 psi (61,621 Mpa)

b. In accordance with the available data, the assumption of subbase repair thickness is the same thickness as the existing subbase repair: d_0 = 200 mm = 7.87 in

To determine the modulus of soil reaction stabilization subbase, the chart in Figure 1 is used to enter the subgrade value and subbase thickness.

From the subgrade thickness value in Figure 1, the subbase repair value is obtained (k = 94) for modulus of soil reaction stabilization subbase at 240 pci. For the modulus of elasticity (E), the recommended value is 600.000-2000.000 psi (4,140-13,800 MN / m^2).

For this study, E = 4,140 MPa, thus solving Equation 6 using the given E value, $k_{subbase}$ = 51.87 pci.

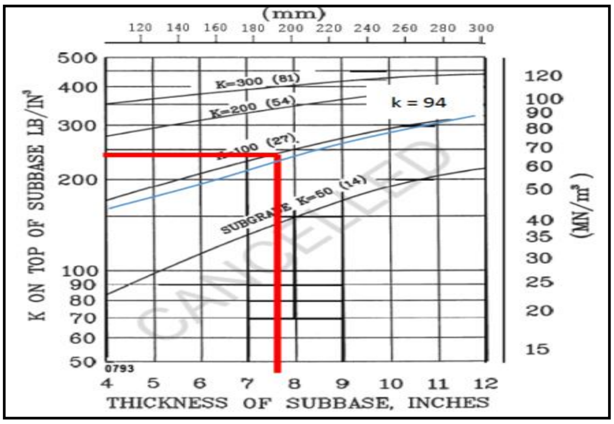

Fig. 1 The effect of aggregate on the value of k in the subbase

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For concrete slabs, K-350 concrete quality is used with compressive strength of 350 kg / cm^2. This value corresponds to planning on secondary data. In the FAA method, there is no standard for concrete quality limits for an airport's apron. As for Director General Regulations for an airport apron in the Directorate General of Air Transportation regulation number SKEP / 77 / VI / 2005 concerning technical requirements for the operation of airport engineering facilities, it is explained that the strength of each part of aircraft parking must be able to withstand aircraft traffic loads served (at least the same as the runway), with particular consideration from the aircraft parking lot that parts depend on traffic that is more dense due to aircraft that are slow or silent, so that higher aircraft traffic and traffic loads are more dense due to aircraft that are slow or still, hence that it is higher than the runway which results in tension on the apron pavement [7].

For Fc` = 290.5 kg / cm^2 = 4131.88124, using the formula in Equation 7, the modulus of rapture (MR) is 642.80 psi.

$$MR = Kfc' = 10\sqrt{4131.88124} = 642.80\,psi \quad (7)$$

The thickness of the concrete slab is determined using the rigid thick pavement planning curve AC 150 / 5320-6D FAA (refer Figure 2) at

MTOW = 174.200 lb

Annual departure = 2376

MR = 642.80 psi

Based on the rigid thickness pavement planning AC / 150 / 5320-6D, the slab thickness obtained was 16 inch or 41 cm. In this planning, the thickness of pavement obtained by the FAA method whereby subbase = 20 cm concrete slab = 16 inch = 41 cm. The security factors considered are the thickness of pavement for the Equivalent Annual Departure level, because the annual departure in this plan is less than 25 000, which is 2376 aircrafts. Therefore, the safety factor is 1. The final thickness of the pavement is gotten from the multiplication with the safe factor of 100%. Henceforth, concrete slab = 100% x 41 = 41 cm.

The results of rigid pavement analysis at Sentani Airport apron using the FAA method are as follows:

1. The thickness design of rigid pavement structures plan aircraft used are the Boeing 737-900ER which the largest aircraft is parked at the Sentani Airport
2. The thickness design of rigid pavement structures on Sentani Airport apron were calculated using the FAA method produced a 41 cm thick concrete layer and 20 cm subbase thickness. So that the total thickness of the rigid pavement is 61 cm. Details of rigid pavement from rigid pavement analysis at Sentani Airport apron can be seen in the Figure 3.

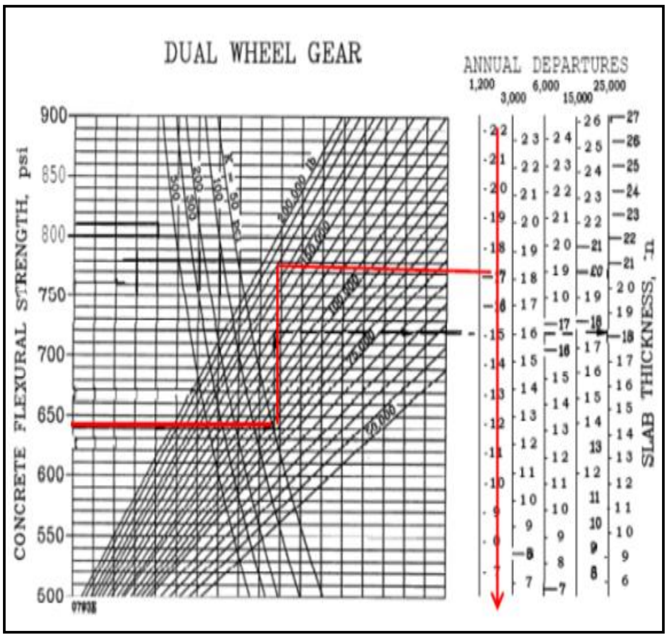

Fig. 2 Pavement thickness design curve

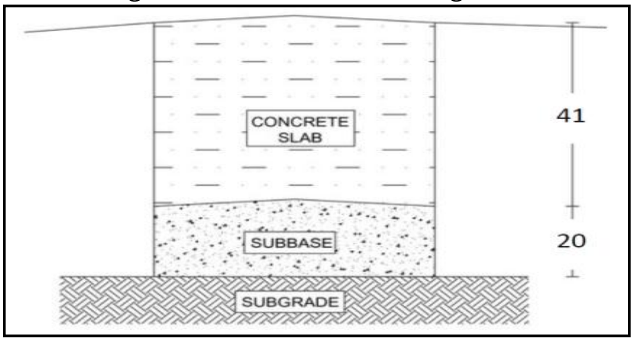

Fig.3 final design of the proposed pavement thickness for sentani airport

IV. CONCLUSION

Based on the results of the analysis and calculations that have been done using the FAA method for the thickness of rigid pavement of Sentani Airport, the following conclusions are obtained:

1. From the land CBR value of 6%, the modulus of subgrade reaction is 25.831 MN / m^3.
2. From the data on the number of aircraft movements, the planned aircraft is Boeing 737-900 ER with MTOW 174200 lb.
3. Concrete layer used K350 quality with a modulus of rupture (flexural strength) value of 642.80 psi
4. The equivalent annual departure value of Boeing 737-900ER aircraft is 2376
5. The analysis results have been used using the FAA method for concrete slab thickness rigid pavement at Sentani Airport apron is 41 cm and subbase thickness is 20 cm in which the total thickness of the rigid pavement is 61cm.

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REFERENCES

1. R.D. Horonjeff, Y. Kimural, N.P. Robert & C.F. Rossano, Aircraft Management Studies. Acoustic Data Collected at Grand Canyon, Haleakala and Hawaii Volcanoes National Parks (1993).
2. T. Kazda and B. Caves, Airport Design and Operation 127 (2017).
3. Bethary, Pradana and Basidik43, 105 (2015).
4. S.I. Sarsam,International Journal of Transportation Engineering and Traffic System IJTETS**2**(1), 1 (2016).
5. Triwibowo, JurnalGradasiTeknikSipil 1, 70 (2014)
6. Udara, D. J. P. KeputusanDirekturjenderalperhubunganUdaraNomor SKEP. 161/IX/03 tentangpetunjukpelaksanaanperencanaan/perancanganLandasanPacu, Taxiway, Apronpada Bandar Udara.
7. Federal Aviation Administration (FAA).Advisory Circular (AC) No.AC/150/5320-10F Standart for Specifying Contruction of Airport. Washington DC : US Departement Of Transportation (2009).