USING LOCAL MATERIALS SUCH AS CORAL TO IMPROVE A PAVEMENT STRUCRURAL DESIGN - CASE OF THE AERONAUTICAL PAVEMENT IN SAINTE MARIE MADAGASCAR INTERNATIONAL AIRPORT

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ABSTRACT

The Sainte Marie airport is strategically an economic pillar of the region, and in consequence the country, as one of the few in number international gateway to Madagascar. In fact, its technical characteristics, in addition to financial or environmental aspects, is more than important, as far as it should met international recognized standards. Knowing that the airport was originally built and met air transport requirements according to ATR 42 aircraft, until 2006. The admission of new aircraft such as ATR 72 requires on the one hand the questioning of the aerodrome lift and on the other hand the lengthening of the runway.

This manuscript focuses on the evaluation of the bearing capacity of the aeronautical pavement referring to ACN/PCN method, in order to propose variants for the project realization. The study was conducted in order to adding a new coral layer in the structure of the aeronautical pavement, as coral is a local material, available in large quantity at least on the seashores of the area, and should be valued accordingly.

The structural design of the aeronautical pavement uses the total equivalent thickness "e" for a platform wich there Californian Bearing Ration "C.B.R." was given, taking into account the maximum loading of the aircraft. In fact, our research and analysis is expected to lead up to a conclusion, demonstrated by a scientific reasoning, and in the ground, practical of constructing, renovating, repairing and maintaining infrastructure, especially in remote location where supplying material is not always an evidence.

Keyword: *Structural design, aerodrome, aeronautical, aircraft, ACN/PCN method, coral, equivalent thickness, CBR, maximal loading*

1. INTRODUCTION

Sainte Marie Airport [Figure 1] is located near the southern tip of the island, in front of "Ile aux Nattes" smaller island, separated by a pass, with the following geographic coordinates:

Lat : 17°05'25''S

Long : 49°48'56''E

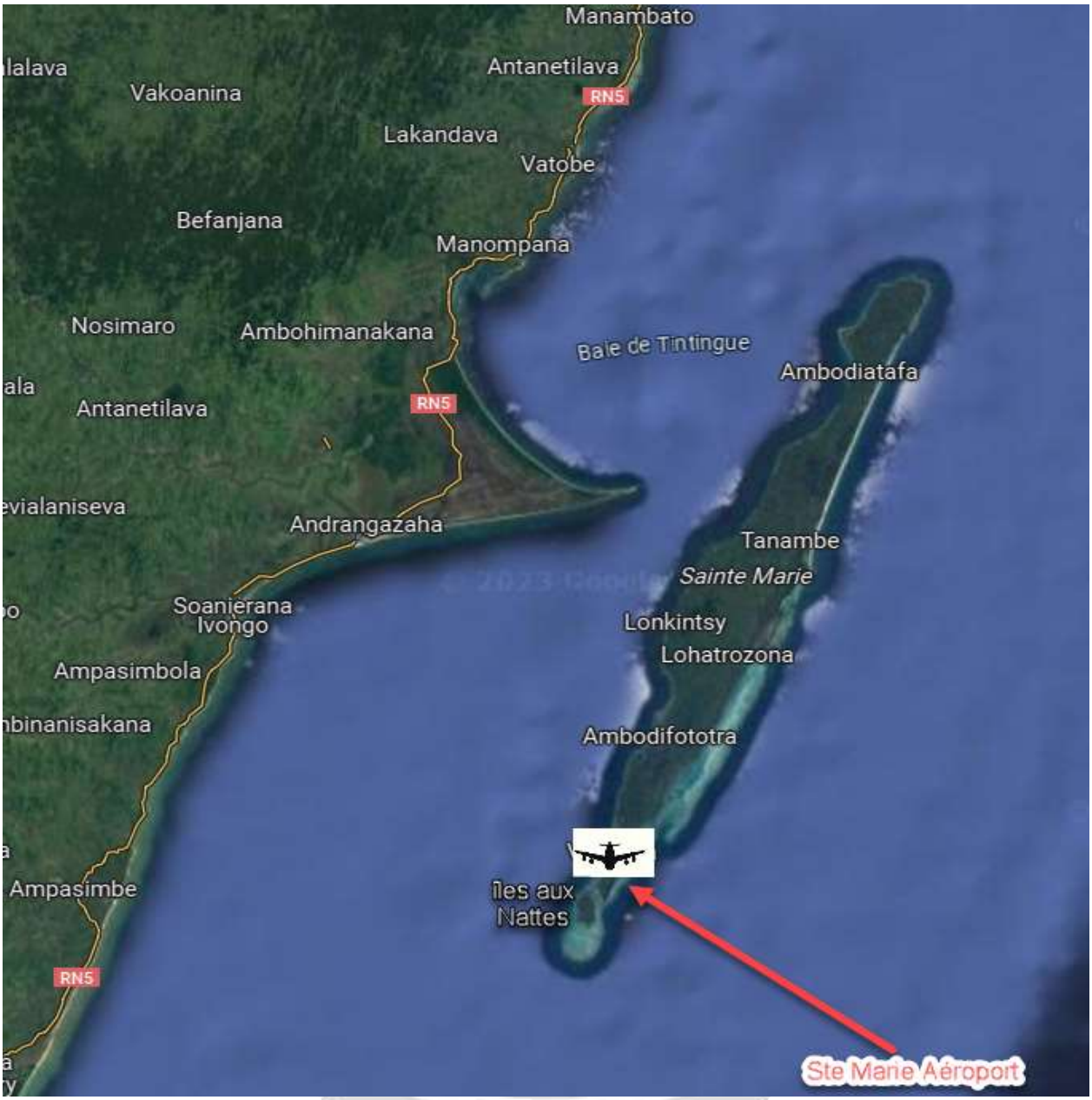

Figure 1: geographic location of the project

In 2006, the aerodrome was the subject of a study to support the ATR 72 aircraft equivalent capacity, which previously only supports ATR42 ones. For this purpose, a study project was carried out to have on the one hand the lift of the existing runway expressed in PCN and on the other hand to make the geotechnical study of runway side extension «Threshold 29». [Figure 2]

This was an occasion to conduct further researches about using local materials such as the coral layer, which is available in large quantity at least on the seashores of Saint Marie island.

The study was conducted in order to adding a new coral layer in the pavement structural, as coral is some local materials, available in large quantity on the seashores of the area.

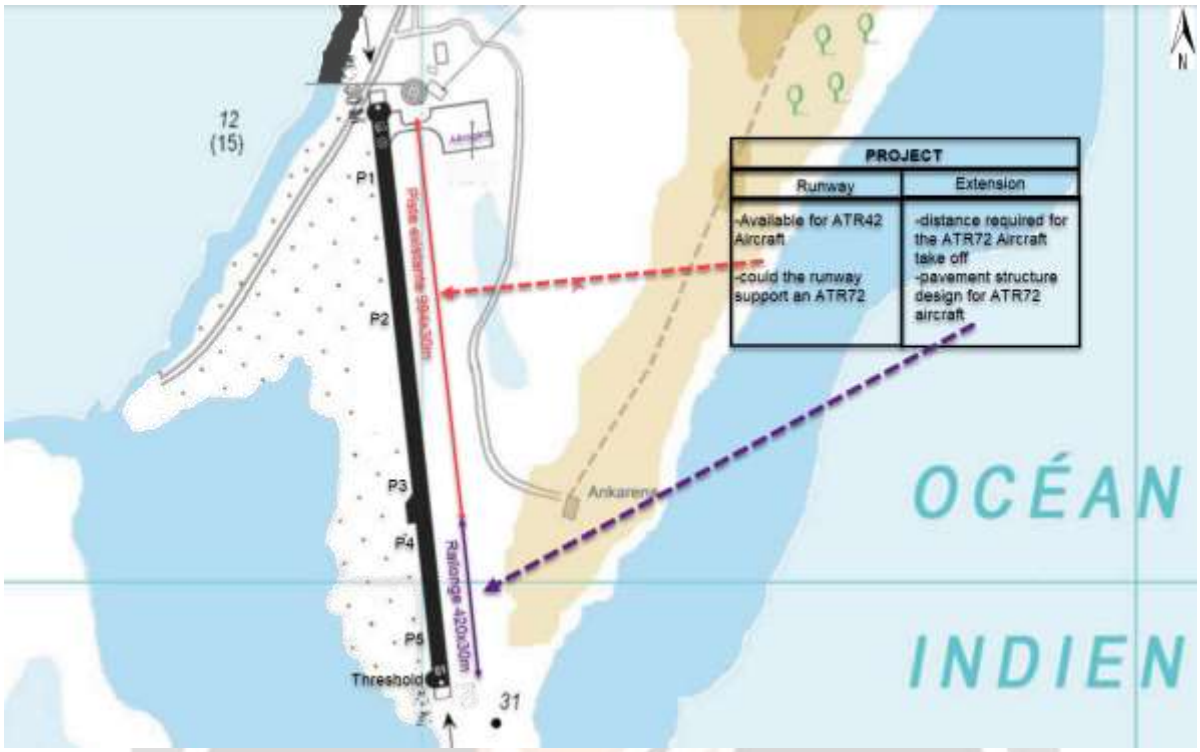

Figure 2: Design and Point of the polls

2. METHODOLOGY

The geotechnical survey focus on exploring work on the existing pavement structure as well as the the platform soil. Five manual wells were made, three (03) of them on the existing runway and two (02) on the area expected for the eventual extension [Figure 2];

The samples of soil in the platform were subjected to laboratory tests to determine the geotechnical characteristics of the platform (identification, C.B.R.).

The ACN/PCN method, which is the international standard system developed by the International Civil Aviation Organization (ICAO), were used. It is intended to provide information about an aircraft's eligibility, based on the pavement strength of the platform in question. This method has been applicable since 1983 by all ICAO Member States, for the management of their aerodromes. The ACN (Aircraft Classification Number) is a number expressing the effect of a given aircraft type on a given type of pavement (flexible or rigid). The PCN (Pavement Classification Number) is a number expressing the lift of a given pavement. The general principle of this method is as follows: an aeroplane with an ACN less than or equal to the PCN of a roadway is allowed to use this roadway without any other restriction than one related to its tires pressure.

The runway pavement being tested is a "flexible pavement", the PCN calculation will be performed using the approximate method involving the CBR of the ground support and the equivalent thickness "e" according to following formula:

$$PCN = \frac{1}{500} \times \frac{e^2}{\frac{1}{0{,}57CBR} - 0{,}025} \qquad (Formula\,1)$$

"e" mean thickness of the roadway in cm

The equivalent thickness will be determined according to the different pavement layers encountered in-situ. It will be calculated from below formula:

$$e = \sum_{i}^{n} a_i H_i \qquad (Formule 2)$$

a_1, a_2…a_n is the equivalence coefficient of the 1st, de la 2nd and nd layer
H_1, H_2…H_n is the actual thicknesses of each layer

The equivalence coefficient is given by the following general formula:

$$a_i = \sqrt[3]{\frac{E_i}{5000}} \text{ and E = 50CBR (unit is kg/cm²)}$$

- for asphalt concrete 0/14: a = 2
- for a Gravel 0/315 : a = 1
- for a Coral : a = 0.8

The ACN calculation takes into account of the reference aircraft ATR 72 basic, as well as the CBR index of the ground support [Table 1];

Table 1: ATR 72 ACN Number (Source: ADEMA)

Aircraft type	Weight (kg)	Load on the main lander (%)	tire pressure (MPa)	Aircraft Classification Number "CAN"				
				Value	CBR = 15	CBR = 10	CBR = 6	CBR = 3
ATR 72 basic	**M** : 21 530 **m** : 12 200	47,8	0,79	Maxi Mini	11 5	12 6	14 7	15 8

M: maximum take-off weight
m: operational vacuum mass

3. RESULTS

Starting from the digging by well on the track to see the different layers of the road structure, a soil sample was also taken for laboratory tests

3.1 Laboratory tests

The results of the laboratory tests are [Table 1]:
Table 2: Laboratory tests [Source: LNTPB, 2006]

Réf.	W_{nat} (%)	IDENTIFICATION					CLASSIFICATION		O.P.M		C.B.R		Location
		W_L (%)	I_P (%)	%F	γ_s (KN/m^3)	ES (%)	H.R.B.	L.P.C.	γ_{dmax} (KN/m3)	W_{opt} (%)	I_{CBR} 96h	Gonfl (%)	
P_1	10,1	–	–	1	27,6	94	A_3	Sm	14,92	14	9	0,00	Actual runway
P_2	21,6	–	–	9	26,6	69	A_3	Sm	16,5	13,6	21	0,00	
P_3	21,1	21,9	5,2	13	26,8	54	A_{1b}	SA	17,28	15,2	29	0,02	
P_4	41,0	58,1	21,1	75	28,5	–	A_{7-5}	L_t	16,64	22,3	11	1,26	Extension area
P_5	31,1	66,7	24,1	63	26,5	–	A_{7-5}	L_t	16,64	20,7	6	1,98	

Abbreviation:
%F : Percent finer
WL : Liquidity limit
IP : Plasticity index
ES : Sand equivalent test
HBR : Classification Highway Research Board
LCP : Classification of the Laboratory of Civil Engineering
γd_{max}: Optimum dry density in KN/m^3
Wopt: Optimum moisture content
CBR: Californian Bearing Ratio (index after 4 days immersion)
%G: swelling Percentage

3.2 Under road survey

The existing runway structure is:

- 8 cm thick of asphalt concrete 0/14.
- 16 cm thick of Gravel TV 0/315
- 15 cm thick of coral
- Platform: fine sand, C.B.R. = 9-29

The representative layers in the area provided for the extension of the runway is a succession of:

- Topsoil
- Fine sand
- Clay and. CBR = 6 to 11

3.3 NCP value for existing runway

According to Formula 1, the equivalent thickness of the current runway is **44cm**. At the extraction of the coral layer, the equivalent thickness becomes **32cm**. We used the CBR = 9 (worst case) for the PCN calculation

By applying Formula 1 in paragraph II, the pavement classification number expressed in PCN for the current runway becomes 12 to 22.8 tons [Table 3]:

Table 3: PCN Calculation

Case	CBR	equivalent thickness (cm)	PCN (ton)
Case1 : actual structure (with coral layer)	9	44	**22,8**
Case2 : without coral layer		32	**12**

According to database provided by ADEMA (Madagascar Aeroports), with CBR = 9 (Unfavourable value), the maximum value of the corresponding A.C.N. is 12.5 tons [Table 1] with F/B class [Table 4]. From this we deduce:

- with coral layer case : PCN=22.8tonnes [Chart 3] > ACN=12.5tonnes
- Case without coral layer : PCN=12tonnes [Chart 3] < ACN=12.5tonnes

Table 4: Class

Concerned	Case	Letter code
Pavement type	Flexible pavement	F
	Rigid pavement	R
Résistance du terrain de fondation	High resistance (CBR>13)	A
	Medium resistance (CBR=10)	B
	Low resistance (CBR=6)	C
	Ultra low resistance (CBR<4)	D

Source: STBA, 1983, Instruction sur le dimensionnement des chaussées d'aérodromes

The pavement classification number of the existing runway expressed in PCN is widely above the ATR 72 basic aircraft classification number expressed in ACN. The track reinforcement will not be necessary to supporting the ATR 72 basic.
However, if the 15cm coral layer is voluntarily removed, the PCN value decreases and becomes lower than the ACN value. It is deduced that the coral layer existence strengthens the structure of the existing runway

3. RUNWAY EXTENSION DESIGN

The length of the elongation is 420.00m to the Threshold 29 in the South coast «Canal de l'île aux nattes»
The structure design consists on the total equivalent thickness determination, taking into account the maximum load of the aircraft, the CBR characteristics of the ground support and the traffic intensity.

- the CBR index ranges from 6 to 11 [Table 2], a CBR index of 6 was chosen for the calculations;
- the Aircraft ATR 72 basic load is 21.5 tons [Table 1];
- traffic: 10 movements per day are expected for 10 years (flat rate movement) corresponding to a perfectly reasonable and prudent hypothesis.

3.1. Determination of Equivalent Thickness

The equivalent thickness is calculated from the abacus for single-wheel landing gear blocks [Chart 1]

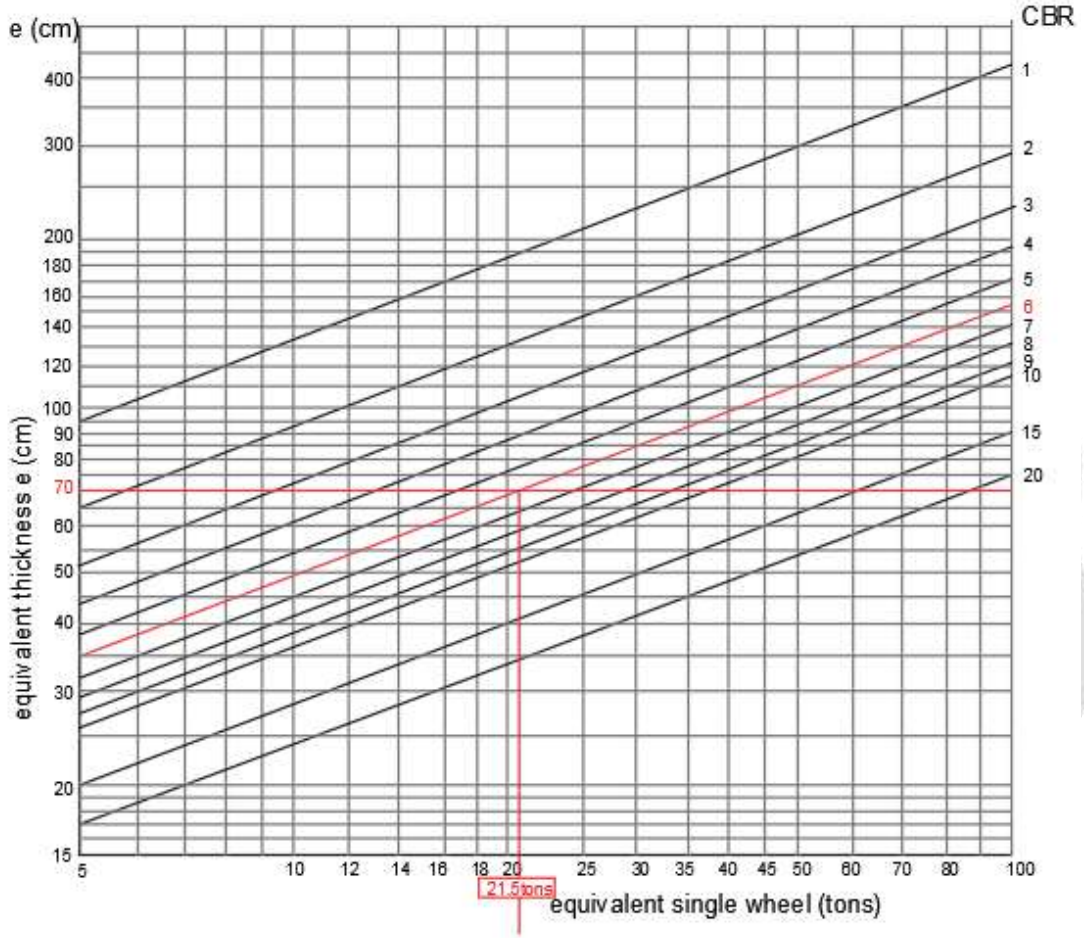

Chart 1: Abacus for single-wheel landing gear blocks corresponding to a pneumatic pressure of 0.6±0.3MPa
The total equivalent thickness of the pavement is 70cm

4.2. Pavement Structure design

To introducing a coral layer of varying thickness is proposed into the pavement structure which is one of the widely available materials on site by gradually reducing the Gravel TV0/315 layer. The pavement structure design is:

- 8cm thick of asphalt concrete 0/14;
- H_2 thick of gravel TV $0/31^5$;
- H_3 thick of coral;
- Platform: fine sand.

According to Formula 2, we have:

$$e_{équiv} = 70cm = 2\times 8 + 1\times H_2 + 0{,}8\times H_3 \quad from where\, H_3 = \frac{(54 - H_2)}{0{,}8} \quad [cm]$$

[Table 5] and [Chart 2] give the variants of the thickness of the agreed coral layer by reducing the layer of Gravel TV 0/31[5]:

Table 5: TV0/31[5] - Corail

Variant	Thikness (cm)		Coral%TV0/31[5]
	TV0/31[5]	Coral	
1	47	8.75	16%
2	40	17.5	30%
3	35	23.75	40%
4	30	30	50%
5	25	36.25	59%
6	20	42.5	68%
7	15	48.75	76%
8	0	67.5	100%

The chart:

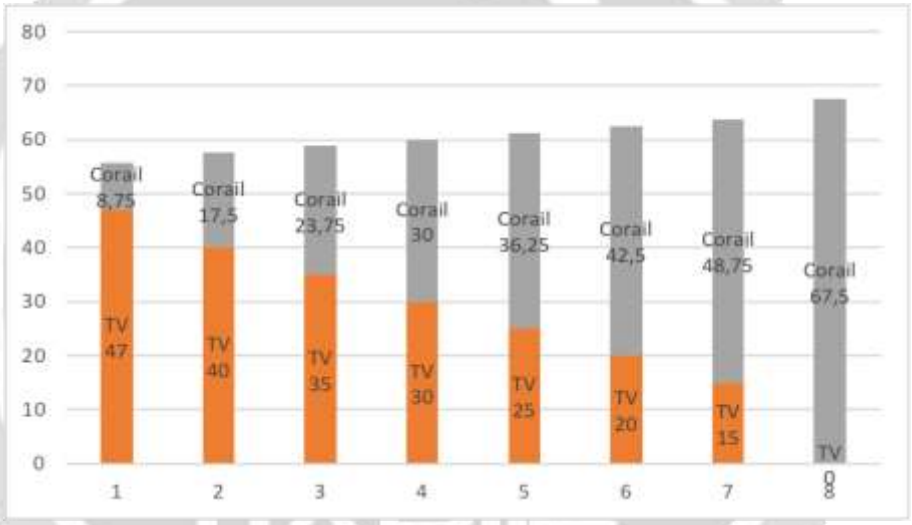

Chart 2: Diagram showing coral layer thickness ratio - TV0/315

The layer of gravel TV0/315 can be substituted by the coral layer with a variable thickness. Thickness choice depends on the project red line. The average thickness is about 30cm for coral and Gravel TV 0/31[5].

4. CONCLUSION

The geotechnical study of the Sainte Marie aerodrome concluded that:

- the 22.5 tonnes PCN of the current runway indicates that it can accommodate the ATR 72 basic with a F/B class of 12.5 tonnes ACN;
- the pavement structure design with coral layer in the extension area can support the aircraft equivalent to ATR 72 aircraft. The choice of thickness substitute depends on the project red line. It is on average about 30cm.

5. REFERENCES

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BIOGRAPHIES (Not Essential)

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