Unpaved runways surface: what we know and what we need to know

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ABSTRACT

After the authors' experience in the design, execution, operation of the EMBRAER KC 390 test track in Gavião Peixoto in critical situations and countless moments of reflection upon the project, the need of discussing this topic in a broader way arose.

When we talk about runways as a tool for social integration, the first question we hear is: why not pave? This is very difficult to answer, as it involves several aspects such as scarcity of financial resources in most countries, which according to the World Bank (2022), 10% of the planetary population lives below the poverty line (less than US$ 1,90/day). A track has the role of meeting the need of social integration with the poorest communities, providing medical and social assistance; it also involves the security of countries, where the armed forces must have access to the most remote places and the rescue caused by cataclysms in any way anyway. It is not to be thought that an airfield is intended only to meet the demands of business or tourism.

Therefore, the Planet needs and will always need many unpaved airfields.

This paper presents some studies and technical standards available in the literature on this technology and presents the existing unanswered questions necessary to meet the engineering project requirements, which needs to guarantee useful lifetime, operation risk and a maintenance matrix containing the number of operations and technologies available on site. Along with these uncertainties, what possible researches to be carried out in a scenario of financial scarcity are also discussed.

The divergences and uncertainties arise from the lack of knowledge of both the geotechnics of tropical soils from the international society and the support capacity and plastic deformation of the soil and even loose coarse aggregates, passing through the longitudinal and transversal irregularities

Keywords: Unpaved Runways, Design, Execution, Operation, Tropical soils.

1 INTRODUTION

Brazil is a country of continental dimensions, with approximately 3.5 million km^2 in the Amazon region alone. Thus, in a region with a very low population concentration and a large portion of this population, concentrated in small villages on the banks of rivers that become unsuitable for navigation for up to six months, in the dry season, social integration without airports becomes difficult.

However, the cost of paving a runway (RW), associated with the operation of transporting materials that can reach a 2-thousand-km distance and take at least 2 months by boat and road, can make the choice to use this solution.

On the other hand, it has been observed in the international scenario, countries such as Canada and Australia developing procedures that can enable the operation of not only of small, but also medium-sized aircraft on unpaved runways.

In this scenario, this paper aims to show some procedures already established in the airport environment and to bring to light the needs of Brazil and the entire Amazon region, which in the authors' opinion, given the biodiversity/climate/geotechnics, it ranges from covering Guatemala up to close to Brasília, in terms of latitude.

Finally, it is important to point out that the use of surface mine haulage roads, as there is a world-wide experience in this subject, has been considered. Thus, throughout this paper, it will be presented, in terms of literature, some solutions to obtain already established design parameters and themes that need further study of its concepts.

2 TYPICAL STRUCTURE FOR AIRFIELD UNPAVED PAVEMENT

In terms of the typical structure of an unpaved pavement, it can be simply explained as: there are the three basic layers of a flexible structure, namely: subgrade, base and wearing course.

Figure 1 shows typical layers of an unpaved pavement structure in which the cladding and base layers minimize the vertical pressure on the subgrade, minimizing its permanent deformation (Légère, 2015) .

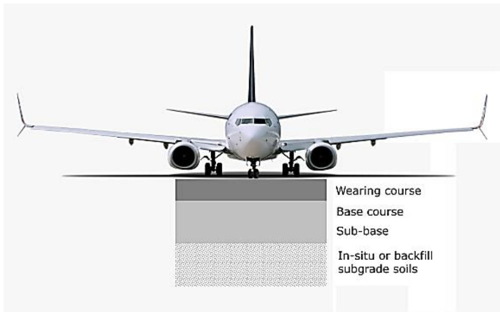

Figure 1 Typical unpaved pavement structure

3 PAVEMENT DESIGN: THICKNESS OF STRUCTURE

One of the most widely used methods to obtain structure determination of surface mine haulage roads is using the curved referred to as CBR (California Bearing Ratio) curves. This method was originally developed in 1942 and continues to be used by designers of roads in mines, particularly in Brazil, for example, in VALE Company and Anglo-American Company.

Figure 2 presents the subbase thickness requirements curves in function of a wide range of CBR subgrade. It should be noted that, according to Kaufman and Ault (1977), the thickness calculation is a function of the load on 1 wheel.

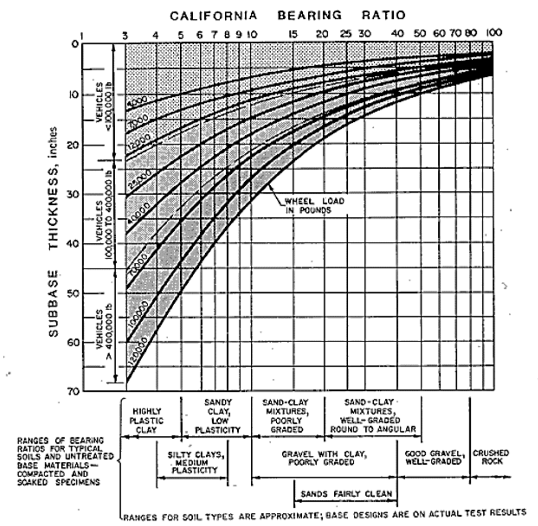

Figure 2 Subbase thickness versus subgrade CBR (Kaufman, Ault, 1977)

It is very important to observe that in figure 2, the wheel load is only for one tire.

According to the document Operational Life of Airport Pavements DOT/FAA/AR-04/46, since 1942 design curves have been proposed using the single-wheel criterion and were developed for 7,000- and 12,000-lb wheel. There has been evolution over the years and, since the document AC 150/5320-6F Airport Pavement Design and Evaluation, 2012, the total thickness "t" of the structure in the Pavement Design, using the CBR equation, is for C = coverages ≤ 5,000.

It is important to note that there is multiple-wheel heavy gear load (MWHGL) in these equations

The α-factor was used in the second equation to adjust thickness "t" for over than 5,000 coverages.

$$\frac{t}{\sqrt{A}} = -0.0481 - 1.1562\left[Log\frac{\overline{CBR}}{p}\right] - 0.6414\left[Log\frac{\overline{CBR}}{p}\right]^2 - 0.4730\left[Log\frac{\overline{CBR}}{p}\right]^3 \quad (1)$$

$$\frac{t}{\sqrt{A}} = \alpha\left\{-0.0481 - 1.1562\left[Log\frac{\overline{CBR}}{p}\right] - 0.6414\left[Log\frac{\overline{CBR}}{p}\right]^2 - 0.4730\left[Log\frac{\overline{CBR}}{p}\right]^3\right\} \quad (2)$$

Thus, in terms of calculating the pavement total thickness "t", using the equations that consider the value of the subgrade CBR, the total thickness of granular material necessary to protect the subgrade from permanent deformation is also calculated.

The design procedures presented in the FAA document (AC 150/5320-6G) are based on the Waterways Experiment Station WES criteria, the CBR value and thickness of the structure as described above. Large scale test data and pavement observations in service performed at WES, generated the document Multiple-Wheel Heavy Gear Load Pavement Test, volume 1, Basic Report, with credits to Kaufman, Ault (1977) which served as the basis for transforming the effect of a wheel into multiple-wheel heavy gear load (MWHGL), used in the FAARFIELD software up to the current version 2.0.

In conclusion, the existing formulation for the determination of the granular thickness of a pavement structure aiming to protect the subgrade layer, according to documents used in the Surface Mine Haulage Roads projects, are based on the mechanical strength expressed in CBR value but still, they are based on the wheel load.

In order to protect the subgrade, the FAA model for calculating the thickness of a granular layer, meeting this premise. In the case of ESWL, is based on the mechanical strength expressed in CBR value, and the adjustment for Multiple-Wheel (MWHGL) criterion, must be carried out, considering the studies of the work by Alvin et all in the formulation on page (69/219), therefore considering the effect of deflection for one wheel and several wheels.

4 THE USE OF MCT METHODOLOGY FOR RAPID CLASSIFICATION OF SOILS

The construction of pavement structures and the reinforcement of subgrade soils must be preceded by accurate characterization of pavement materials and soils. The behavior of soils can vary from point to point, even if the soils have the same genetic origin. The drainage condition of the subsoil can modify the characteristics of its mechanical behavior (Fortes, 1990).

Thus, the success in the use of soils as a construction material requires a vast number of laboratory tests, time, and adequate financial resources. These factors and low costs associated with abundantly available soil deposits, allow the designers to optimize the management of highway construction projects.

A rapid methodology for classifying soils in accordance with the MCT (Miniature, Compacted, Tropical classification) is described to fill the gap in geotechnical investigation of soils used for road construction (Fortes, 1990; Fortes, 1997; Fortes, Merighi, 2003).

The MCT classification can be used for all kind of soils. Considerable time and cost savings are achieved by implementing the rapid disk method of the MCT classification to characterize soils.

The method is based on the fabrication of small disks of soil (20-mm diameter) that are molded in stainless steel rings and dried. After drying, the diametrical contraction of the inserts cast in stainless steel rings is measured. Then the inserts are submitted to a sorptivity test, which makes it possible to see cracking, expansion activity, and resistance to the penetration of a standard needle. A mini penetrometer is used to determine the shrinkage and consistency after soaking dried specimens in water (Fortes, Merighi, 2003).

In 1997, Fortes presented a proposal to standardize this rapid disk procedure at the First Permanent Chamber of Occurred Technological Development conference at the Presbyterian University of Mackenzie.

The advantage of using the rapid disk method of the MCT classification is that it is possible to observe and estimate the behavior of the soil, as a structure, in the face of weathering. Table 1 presents the Properties and relative desirability in transportation applications based on MCT soil classification groups (Nogami, Villibor, 1995).

Table 1. Properties and relative desirability in transportation applications based on MCT soil classification groups

BEHAVIOR		N = NON-LATERITIC				L = LATERITIC		
MCT GROUP		NA	NA'	NS'	NG'	LA	LA'	LG'
PROPERTIES (1)	MINI-CBR NOT SOAKED	M, H	H	M, H	H	H	V, H	H
	MINI-CBR SOAKED	M, H	M, H	L, M	L	H	H	H
V = VERY HIGH H = HIGH M = MEDIUM L = LOW	EXPANSION	L	L	H	M, H	L	L	L
	SHRINKAGE	L	L, M	M	M, H	L	L, M	M, H
	PERMEABILITY (K)	M, H	L	L, M	L, M	L, M	L	L
	SORPTIVITY (s)	H	L, M	H	M, H	L	L	L
RELATIVE DESIRABILITY AS: n = NOT SUITABLE	PAVEMENT BASE	N	4th	n	n	2nd	1st	3rd
	SELECT SUBGRADE	4th	5th	n	n	2nd	1st	3rd
	COMPACTED SUBGRADE	4th	5th	7th	6th	2nd	1st	3rd
	EMBANKMENT (CORE)	4th	5th	6th	7th	2nd	1st	3rd
	EMBANKMENT (SHELL)	N	3rd	n	n	n	2nd	1st
	EARTH ROAD SURFACING	5th	3rd	n	n	4th	1st	2nd
CLASSIFICATION OBTAINED FROM TRADITIONAL INDEX PROPERTIES	USCS/ASTM	SP SM	SM SC ML	SM, CL ML MH	MH CH	SP SC	SC	MH ML CH
	AASHTO	A-2	A-2 A-4 A-7	A-4 A-5 A-7	A-6 A-7-5 A-7-6	A-2	A-2 A-4	A-6 A-7-5

(1) Specimens compacted near the maximum dry density and optimum moisture using standard compaction effort

5 SURFACE LAYER

The methods are based upon theoretical analysis, empirical design procedures, observed performance, and field and laboratory tests. The theoretical analysis is a function of the ultimate bearing capacity of the existing soils and the load applied to the compacted base material.

The Surfacing layer or wearing course is a very important layer in the unpaved pavement's structure.

However, it is a layer that must attend the following demands:

a) The load support.
b) Rain effect, therefore, it must be resistant to erosion and does not lose its bearing capacity.
c) Resist permanent deformation either longitudinally (translated by the IRI value) or transversally, which informs the existence of grooves and possible hydroplaning points) (Merighi, Uddin, 2014)

The items a) and c) can be summarized in the figure 3 that presents the minimum requirement to meet the requesting efforts.

If the pavement surface does not withstand the vertical loads, permanent deformation or rutting or a narrow depression relative to the original surface occurs. Subsequently, the loads progressively cause rutting to the base and finally to the subgrade surface.

The ruts allow water to accumulate on the surface pavement which can generate hydroplaning and cause water to soak into the pavement, promoting rapid pavement deterioration.

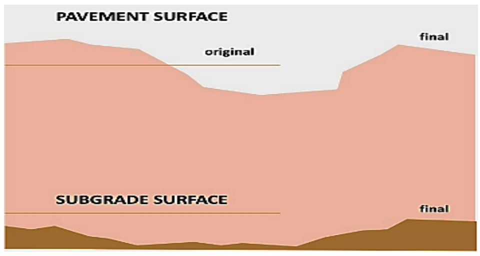

Figure 3 The minimum requirement to meet the requesting efforts (Dawson and Kolisoja, 2017)

Strong compaction can minimize the amount of rutting.

The document Dawson and Kolisoja divides into four fundamental types of mechanisms where rutting can occur.

The main cases will be presented:

a) The good compaction – low surface rutting

According these authors. good compaction minimizes the amount of rutting observed.

In the following two figures, extracted from the cited reference, there is a summary of the statement "good compaction" for reducing rutting or low rutting only in the surface layer.

This concept applies to mine roads but not to airfield pavement. Airfield pavement must have zero permanent deformation.

Figure 4 extracted from Dawson and Kolisoja shows number of load cycles versus permanent strains for a good compaction.

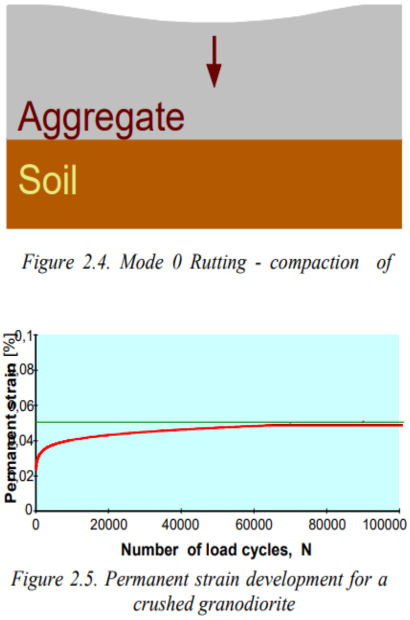

Figure 4 Number of load cycles versus permanent strains for a good compaction (Dawson and Kolisoja, 2017)

b) Rutting in pavement surface

The second distress type or superficial rutting occurs due to inadequate shear strength in the first layer.

Figure 5 shows rutting shear deformation within the base layers of the pavement, near the surface.

Figure 5 Rutting Shear deformation within the base layers of the pavement, near the surface. (Adapted from Dawson and Kolisoja, 2017).

c) Generalized rutting

Shear deformation within the subgrade with the surface and base layer following the subgrade.

Figure 6 presents generalized rutting in the structure pavement (Adapted from Dawson and Kolisoja).

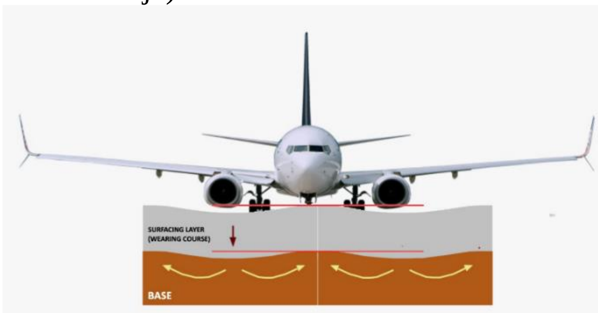

Figure 6 Generalized rutting in the structure pavement. (Adapted from Dawson and Kolisoja, 2017)

In summary, it is clear that the rupture or rutting occurs after layers not presenting good shear strength, inadequate/low shear strength or low shear deformation resistance

In the literature consulted on unpaved pavement, the recommendation of shear test for the layers of the unpaved pavement structure was not evidenced, considering that the rupture of the layers occurs by shear.

6 COMMENTS

There is no doubt that unpaved pavement is a necessary solution not only to meet the cost reduction requirement, but also to allow the construction of aerodromes in the most remote regions of the planet and with scarcity of materials and means of transport.

It is understood that for the Amazon region, rich in laterite concretions and "ore yoke", it is possible to meet the demand for shear strength.

7 CONCLUSIONS

1. Simultaneously using the documents Operational Life of Airport Pavements DOT/FAA/AR-04/46 and Multiple-W printwheel Heavy Gear Load Pavement Test, volume 1, Basic Report of Kaufma and Ault (1977), it is possible to calculate the total thickness of a pavement structure considering a layer.

2. The MCT methodology allows, in a very simple way, the predictability of the behavior of the fine material (fine material of

granular layers) in relation to the performance in terms of expansion, contraction and erodibility.

3. Triaxial tests simulating field conditions, it is possible to verify if the material supports the shear stresses obtained from calculations obtained through classical theory of pavement mechanics or through software for mechanistic analysis.

4. There is an urgent need to develop laboratory tests to evaluate the resistance to permanent deformation.

5. There is a need for test tracks to assess existing unpaved pavement finishing technologies today for unevenness.

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