XXII SITRAER 2025
Simpósio de Transporte Aéreo

COMPARATIVE ANALYSIS BETWEEN THE ALIZÉ-AÉRONAUTIQUE AND PARAMETRIZED FAARFIELD APPROACHES IN AIRFIELD PAVEMENT DESIGN

Matteo Gallone[1], Lucas Cavalcante de Almeida [2], Michaël Broutin [3], José Wémenson Rabelo Chaves[2] and Francisco Heber Lacerda de Oliveira [2]
1. Ecole Nationale de l'Aviation Civile
2. Federal University of Ceará – UFC
3. Service Technique de l'Aviation Civile - STAC

*** Corresponding author e-mail address**: lucascavalcante@det.ufc.br

PAPER ID: SIT1238321

ABSTRACT

The design of airfield pavements is predominantly carried out using empirical-mechanistic methods, employing software based on Layered Elastic Design (LED). However, each software uses a distinct calibration model, based on laboratory tests and field data, which may influence its results. This article aims to carry out a comparative analysis between the French approach, implemented in Alizé-Aéronautique, and a parameterized version of the FAA methodology (FAARFIELD). For this purpose, the Cumulative Damage Factor (CDF) and the strains at the top of the subgrade obtained in each design software were compared for four airfields. The results showed that FAARFIELD estimated greater subgrade deformations than Alizé-Aéronautique, with differences of up to 149.2%, indicating a more conservative approach. The CDF values were also different. The differences arise from distinct modeling criteria, such as the use of a critical point in FAARFIELD and a two-dimensional mesh in Alizé. Adjustments in structural thickness allowed approximation between the results, without eliminating the conceptual divergences between the methods. Finally, it was concluded that although both use similar methods for calculating deformations at the top of the subgrade, there are important distinctions that directly impact the results. Depending on the software chosen, different results may be obtained, influencing pavement design even when considering the same aircraft mix and similar structure.

Keywords: FAARFIELD, Alizé-Aéronautique, Strain, CDF.

ACKNOWLEDGEMENTS

The authors would like to thank CAPES (Coordination for the Improvement of Higher Education Personnel – Brazil) for granting scholarships to Lucas Cavalcante de Almeida and José Wémenson Rabelo Chaves. The authors also acknowledge the Service Technique de l'Aviation Civile (STAC) for providing access to the Alizé-Aéronautique software.

GENERATIVE AI USAGE STATEMENT

The authors declare that generative AI tools were used solely for English grammar revision and language enhancement. The scientific content, analysis, and conclusions were entirely developed by the authors.

PAPER ID: 1238321

COMPARATIVE ANALYSIS BETWEEN THE ALIZÉ-AÉRONAUTIQUE AND PARAMETRIZED FAARFIELD APPROACHES IN AIRFIELD PAVEMENT DESIGN

1 INTRODUCTION

The increase in gross operational weight and tire pressure of modern aircraft, driven by the continuous expansion of air transport, imposes growing demands on airfield infrastructure (Garg *et al.*, 2018). This scenario requires the development of more robust pavement structures, whose integrity is important for operational safety, since their deterioration due to environmental or traffic factors is recognized as a contributing factor to the occurrence of aeronautical incidents (Oliveira, 2016).

The predominant design approach for airfield pavements today is the empirical-mechanistic one, applied through software such as Federal Aviation Administration Rigid and Flexible Iterative Elastic Layered Design (FAARFIELD) (American), Alizé-Aéronautique (French), and Airport Pavement Structural Design System (APSDS) (Australia). Although they have their particularities, these programs share a common theoretical basis, using Layered Elastic Design (LED) to calculate stresses and strain in the pavement structure (Vieira, 2015). At the same time, there is a movement toward refining these methods, with the growing incorporation of models calibrated from laboratory tests and field data for a more accurate representation of material properties and landing gear configurations (Tarahomi *et al*., 2022).

Given the different methodological assumptions employed by the design software, this article aims to carry out a comparative analysis between the French approach, implemented in Alizé-Aéronautique, and a parameterized version of the FAA methodology (FAARFIELD). The comparison includes not only the design results, but also the differences in input parameters and calculation models of the software.

2 LITERATURE REVIEW

The development of computational tools has contributed to the consolidation of empirical-mechanistic methods, allowing for accurate analyses of pavement structural response. Software such as FAARFIELD, Alizé-Aéronautique, and APSDS incorporate these principles, associating mechanical models with empirical calibration using field data, which enables the practical application of these concepts in airfield pavement design (Heymsfield and Tingle, 2019).

Both FAARFIELD and Alizé-Aéronautique represent an evolution of empirical methods, adopting a similar rational approach. The calculation basis of both is Layered Elastic Design (LED), used to determine the state of stresses and strain in the pavement structure (Heymsfield and Tingle, 2019). A comparative study showed that, when forcing identical structural and loading conditions, the mechanical values calculated (stresses and strain) at the critical points are nearly identical in both programs (Figure 1). This indicates that the calculation basis on elastic theory is similar (Caron, Theillout and Brill, 2010).

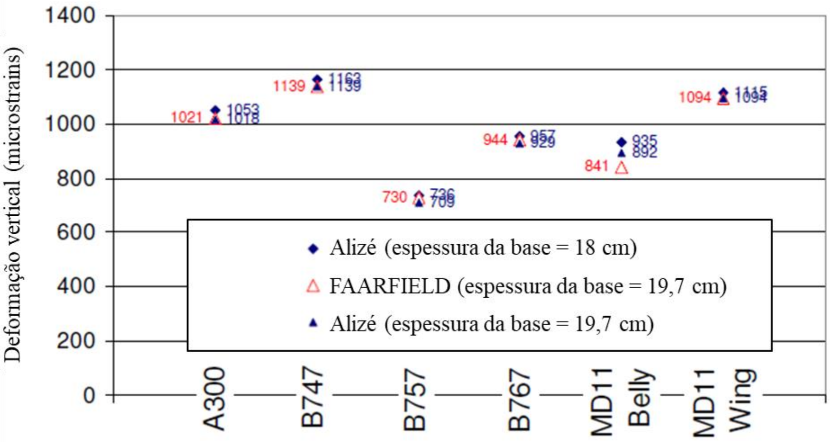

Figure 1: Comparison of vertical strain at the top of the subgrade (FAARFIELD e *Alizé*). Source: Caron, Theillout e Brill (2010)

Despite the similar calculation basis, the main difference between the software lies in the determination of allowable strain, which is based on distinct calibration processes FAARFIELD's procedure derives its failure models from full-scale accelerated traffic testing results while Alizé combines laboratory tests and calibration coefficients derived from full-scale experimentations: results from Accelerated Pavement Testing (APT) calibration campaigns performed on Laboratoire Central des Ponts et Chaussées (LCPC) carrousel for low traffic mixes (STAC, 2011), and from Pavement Experimental Programme (PEP) (AIRBUS, 2001) and High Tire Pressure Test (HTPT) for heavy loads (Balay and Caron, 2008).

The failure criteria are also addressed with different emphases. Both methods consider the vertical strain at the top of the subgrade (associated with permanent deformation) and the tensile strain at the bottom of the asphalt layers (associated with fatigue). However, FAARFIELD, by default, focuses on subgrade failure as the predominant mode, and the verification of fatigue in the surface layer is an optional recommendation, a criterion questioned by some designers as it is rarely observed in the field (White, 2020). In contrast, Alizé-Aéronautique recommends the verification of both criteria, as it considers that surface fatigue may be more critical in more robust structures (Mounier, Fauchet and Broutin, 2014).

Another fundamental divergence lies in traffic modeling. Both software tools use the Cumulative Damage Factor (CDF) method, based on Miner’s rule (1945), which aggregates the contribution of each aircraft and discards the practice of using a single design aircraft (FAA, 2021). However, the way lateral wander is accounted for differs. FAARFIELD uses the concept of Pass-to-Coverage ratio (P/C), calculated at the top of the subgrade, and assumes a normal distribution with a fixed standard deviation of 0.773 m. Alizé-Aéronautique, on the other hand, discards the concept of P/C (STAC, 2016). In the French method, damage is calculated by combining the individual effects of the aircraft at different transverse distances, allowing the designer to specify the wander standard deviation for each aircraft (Caron, Theillout and Brill, 2010).

Regarding materials, Alizé-Aéronautique calculates the resilient modulus of the surface layer as a function of temperature and load frequency (derived from aircraft speed), considering the fatigue of the asphalt surface. FAARFIELD, in turn, considers the module of the asphalt surface as representative of a single temperature (FAA, 2021). Furthermore, Alizé-Aéronautique includes a probabilistic parameter for failure risk, allowing the manager to specify an acceptable damage level, a feature that does not exist in the FAA procedure (Caron, Theillout and Brill, 2010).

3 RESEARCH METHOD

The research method consisted of a comparative case study of strain at the top of the subgrade and CDF values obtained using two airfield pavement design software programs. The analysis was based on the characteristics of the operating mix (takeoff operations) and the structural properties of the pavements of four Brazilian airfields: Boa Vista International Airport (SBBV), Navegantes International Airport (SBNF), Tefé Regional Airport (SBTF), and São Luís International Airport (SBSL), according to the survey and analysis conducted by Santilli and Correia (2024). For the analysis of accumulated damage in the FAARFIELD and Alizé-Aéronautique software, the respective Resilient Modulus (MR) and the materials presented in Table 1 were used. It is noteworthy that the MR values were obtained through a backcalculation procedure (Back FAA).

Table 1: Characteristics of the airfields (structure and aircraft mix). Source: Santilli e Correia (2024)

Aircraft - ICAO and Characteristics	SBBV		SBNF		SBTF		SBSL	
	MR (MPa)	Thickness (cm)	MR (MPa)	Thickness (cm)	MR (MPa)	Thickness (cm)	MR (MPa)	Thickness (cm)
Surface	3000	15	3389	17	1265	17	1783	6
Base	300	30	388	29	559	13	784	25
Sub-base	-	-	117	10	315	12	561	20
Subgrade	170	-	64	-	67	-	216	-
Aircrafts (Mix)								
ATR 42-300	-		-		42		-	
ATR 72-600	-		-		398		-	
CESSNA 208	-		-		1584		-	
A319	-		1273		-		294	
A320	1208		3275		-		3074	
A321	-		-		-		2020	
B737-300	-		-		-		201	
B737-400			-		-		40	
B737-700	34		1732		-		306	
B737-800	688		4602		-		2863	
EMB 190	-		1370		-		36	
EMB 195	292		3836		322		4749	

For each airfield, the traffic data and pavement configurations were used as input data in the two distinct design platforms: the French software Alizé-Aéronautique and a computational tool in Python developed by the authors of this article, which implements the FAA (FAARFIELD) methodology in an open and parameterized way. Table 2 presents the input parameters used in the software, to establish the greatest possible similarity with the aim of discussing the particularities of the tools.

Table 2: Software parameters

Characteristics	Alizé-Aéronautique	FAARFIELD (modified)
Poisson's Ratio	0,35 – All layers	0,35 – All layers
Aircraft Speed	Static	Static
Temperature	25°	25°
Interlayer Bonding	Full	Full
Fatigue (surface layer)	Yes	No
Strain – Top of the Subgrade	Yes	Yes
Cumulative Damage Factor (CDF)	Yes	Yes

4 RESULTS AND DISCUSSION

From the analyses carried out, it was found that, for all airfields and aircraft considered, the strain values at the top of the subgrade calculated by FAARFIELD were higher than those obtained with Alizé-Aéronautique. For example, for the A320 aircraft at the SBBV airfield, the estimated strains were 1466.38 με by FAARFIELD and 588.29 με by Alizé-Aéronautique, representing a difference of 149.2% (Table 3). This discrepancy may be attributed to the more conservative nature of the approach adopted by FAARFIELD. Figure 2 graphically shows the comparison between strain values at the top of the subgrade for the aircraft mix.

Table 3: Strain results at the top of the subgrade obtained with the modified FAARFILED and with Alizé-Aéronautique

	FAARFIELD (Modified)				**ALIZÉ-AÉRONAUTIQUE**			
ICAO	**SBBV**	**SBNF**	**SBTF**	**SBSL**	**SBBV**	**SBNF**	**SBTF**	**SBSL**
CDF Total	0,03	37,69	1,37	≈ 0	0,097	4,888	0,089	0,151
Aircraft Strain (με) – Top of the subgrade								
ATR 42-300	-	-	910,22		-	-	176,94	-
ATR 72-600	-	-	1035,76		-	-	247,01	-
CESSNA 208	-	-	258,14		-	-	-	-
A319	-	1498,22	-	843,70	-	678,12	-	369,15
A320	1116,73	1466,38	-	830,72	448,74	588,29	-	320,22
A321	-	-	-	1063,83	-	-	-	277,19
B737-300	-	-	-	757,34	-	-	-	243,59
B737-400	-	-	-	798,82	-	-	-	276,91
B737-700	1082,81	1432,56	-	805,18	394,26	488,51	-	284,62
B737-800	1207,68	1606,32	-	897,19	351,87	435,99	-	254,02
EMB 190	-	981,64	-	555,23	-	405,71	-	237,56
EMB 195	764,21	1004,39	1580,93	569,08	308,70	381,05	594,01	233,10

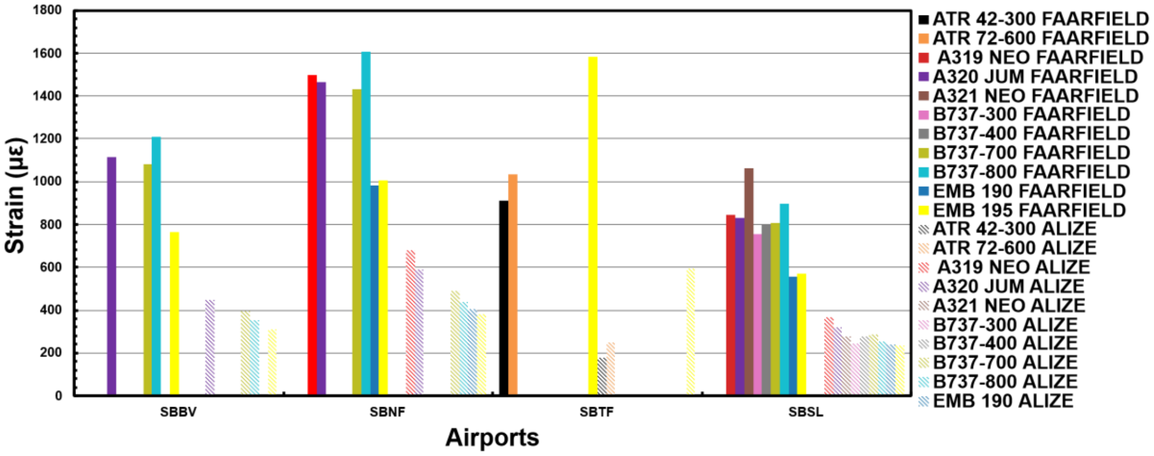

Figure 2: Comparison of vertical strain at the top of the subgrade (aircraft mix)

While FAARFIELD considers only the vertical strain at the top of the subgrade, Alizé-Aéronautique simultaneously evaluates the damage at the top of the subgrade and at the bottom fiber of the surface layer. In addition, FAARFIELD focuses on the maximum point strain (critical point), whereas Alizé distributes the calculations over a two-dimensional mesh of the runway, weighting the damage according to the frequency of load passage at different positions.

Furthermore, there are differences in how the parameters of the asphalt surface layer are entered. In Alizé-Aéronautique, surface layer characteristics derived from fatigue tests are directly provided by the user. In contrast, in FAARFIELD, the only parameters related to the asphalt surface layer are the resilient modulus and the Poisson's ratio. There are also variations in the probabilistic failure risk criteria used by Alizé-Aéronautique, which directly influence the final damage values.

As shown in Figure 3, the CDF values varied and could be higher or lower depending on the specific case. This is due to the differences in damage criteria adopted by each software. For SBNF, FAARFIELD estimated a CDF of 37.69, while Alizé-Aéronautique estimated 4.888, representing a value 87% lower than FAARFIELD.

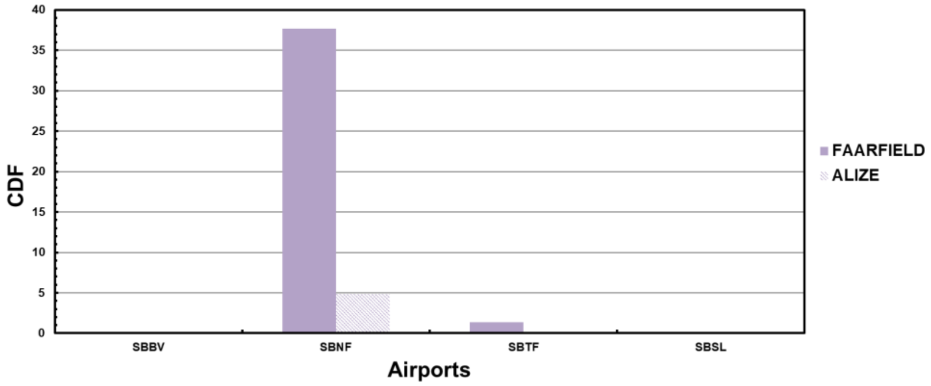

Figure 3: Comparison of the CDF obtained by the FAARFIELD and Alizé software for each airfield

Aiming to understand the differences observed between the CDF values calculated by FAARFIELD and Alizé-Aéronautique, a complementary simulation was carried out in FAARFIELD (Table 4), in which the thicknesses of some structural layers were adjusted to approximate the CDF calculated by FAARFIELD to those obtained by Alizé-Aéronautique. The strategy adopted was to calibrate the thickness of the surface layer (or, in one specific case, the base), while keeping the other structural parameters constant.

Table 4: Layer thicknesses obtained by FAARFIELD and Alizé-Aéronautique

Aircraft - ICAO	SBBV		SBNF		SBTF		SBSL	
	New CDF FAARFIELD	Surface Thickness (cm)	New CDF FAARFIELD	Surface Thickness (cm)	New CDF FAARFIELD	Surface Thickness (cm)	New CDF FAARFIELD	Base Thi-ckness (cm)
	0,095	14,2	4,92	20,6	0,084	21,8	0,168	20

At the SBBV airfield, the surface layer thickness was reduced from 15 cm to 14.2 cm. For the SBNF and SBTF airfields, the surface layer thickness had to be increased, from 17 cm to 20.6 cm and from 17 cm to 21.8 cm, respectively. In the case of SBSL, since the original surface layer was already thin (6 cm), it was decided to reduce the base thickness from 25 cm to 20 cm.

The calibrated values were defined based on an iterative process, in which the layer thickness was gradually adjusted until the CDF calculated by FAARFIELD approached the value obtained by Alizé-Aéronautique. The choice to modify the surface layer thickness, in most cases, was due to its direct influence on the strains at the top of the subgrade and on the overall structural response of the pavement. In the case of the SBSL airfield, the original surface layer was very thin (6 cm), which limited the possibility of further adjustments. Therefore, it was decided to modify the base thickness, which also plays an important role in distributing stresses to the lower layers.

These modifications allowed the FAARFIELD to produce CDF values closer to those provided by Alizé-Aéronautique, even without changing the material type or resilient modulus of the layers. This shows that, although the damage modeling and calculation criteria are different, it is possible to make structural adjustments that align the levels of accumulated damage predicted by both methods. However, it is important to emphasize that this approximation does not imply equivalence between the models and does not eliminate the conceptual differences that remain between the software tools, especially regarding the consideration of multiple damage criteria (in Alizé-Aéronautique) and the use of a critical point as a reference (in FAARFIELD).

5 CONCLUSION

Based on the analyzed results, it was found that there are differences between the strains at the top of the subgrade and the CDF values obtained by the airfield pavement design software Alizé-Aéronautique and the modified FAARFIELD. In general, FAARFIELD presented higher strain values for all aircraft and airfields studied, indicating a conservative approach.

The differences between the two software tools result largely from their methodological approaches. FAARFIELD considers only the vertical strain at the top of the subgrade, using the most critical point of the structure as a reference. Alizé-Aéronautique, in turn, simultaneously evaluates the damage in the subgrade and in the bottom fiber of the surface layer, distributing the calculations in a two-dimensional mesh that incorporates the frequency of load passage in different positions. In addition, differences in the input parameters of each software also contribute to the variation in the results obtained.

Finally, it is concluded that although both use similar methods to calculate the strain at the top of the subgrade, there are distinctions that directly impact the results. Depending on the software chosen, different values may be obtained, which influence the pavement design. Therefore, the joint analysis of the results is important to understand the assumptions and limitations of each software in the design process. The choice between methods should consider not only the numerical values obtained but also the adopted criteria and the definition of input parameters.

6 REFERENCES

AIRBUS. *Pavement publications.* 2001. Available in: https://aircraft.airbus.com/en/customer-care/fleet-wide-care/airport-operations-and-aircraft-characteristics/pavement-publications. Access at: 31 jul. 2025.

Balay, J., & Caron, C. *Airfields pavements characteristics design and evaluation: a rational design method for airfield pavements: the French Alizé-Airfield Pavement Software*. 2008. Disponível em: https://lames.univ-gustave-eiffel.fr/en/equipments/the-pavement-fatigue-carrousel. Acesso em: 31 jul. 2025.

Caron, C., Theillout, J. N., & Brill, D. R. (2010). *Comparison of US and French Rational Procedures for the Design of Flexible Airfield Pavements*. In 2010 FAA Worldwide Airport Technology Transfer Conference Federal Aviation Administration American Association of Airport Executives.

FEDERAL AVIATION ADMINISTRATION - FAA. AC No 150/5320-6G: *Airport Pavement Design and Evaluation (2021)*. Washington, DC: Federal Aviation Administration.

Garg, N., Kazmee, H., Ricalde, L., & Parsons, T. (2018). *Rutting evaluation of hot and warm mix asphalt concrete under high aircraft tire pressure and temperature at national airport pavement and materials research center*. Transportation Research Record, 2672(23), 117-127.

Heymsfield, E., & Tingle, J. (2019). *State of the practice in pavement structural design/analysis codes relevant to airfield pavement design*. Engineering Failure Analysis, 105, 12–24.

Miner, M. A. (1945). Cumulative Damage in Fatigue. *Journal of Applied Mechanics, 12*(3), A159-A164.

Mounier, D., Fauchet, S., & Broutin, M. (2014). *A New French Rational Design Method for Airfield Pavements*. Journal of Civil Engineering and Architecture, 8(12), 1593–1601.

Oliveira, F. H. L. (2016). Desenvolvimento de um modelo de gerenciamento de pavimentos aeroportuários como apoio à tomada de decisão sobre estratégias de manutenção e reabilitação. 178 f. 2016. Tese (Doutorado em Engenharia de Transportes) – Centro de Tecnologia, Universidade Federal do Ceará, Fortaleza.

Santilli, S. R; de Souza Correia, N. (2024). *Evaluating Cumulative Damage Factor (CDF) of 20 Brazilian Airfield Pavement structures using FAARFIELD and BAKFAA*. TRANSPORTES, 32(2).

STAC, Service Technique de l'Aviation Civile. (2016). *Seminaire du Lancement du Module Alizé Aéronautique De Dimensionnement Des Chaussées Aéronautiques Souples*. Présentation du logiciel et demonstration. France.

STAC. High *tire pressure test: study report. Paris: Service Technique de l'Aviation Civile,* 2011. 120 p. Avaliable in: https://www.stac.aviation-civile.gouv.fr/fr/publications/high-tire-pressure-test. Access at: 31 jul. 2025.

Tarahomi, A. R., Kaya, O., Ceylan, H., Gopalakrishnan, K., Kim, S., & Brill, D. R. (2022). *ANNFAA: Artificial neural network-based tool for the analysis of Federal Aviation Administration's rigid pavement systems*. International Journal of Pavement Engineering, 23(2), 400-413.

Vieira, R. A. C. (2015). *Dimensionamentos de Pavimentos Aeroportuários: A Consideração de Novas Orientações.* 111 f. Dissertação (Mestrado em Engenharia Civil) – Instituto Superior Técnico, Lisboa, Portugal.

White, G. (2020). *Incorporating binder type into asphalt fatigue life characterization of airport pavement surfaces*. International Journal of Pavement Research and Technology, 13, 40-47.