

Influence of Design Methodologies on Rigid Pavement Structures: Comparative Analysis Using Alizé LCPC, StreetPave, and KENPAVE

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Abstract—Pavement design software plays a crucial role in modern road engineering by allowing engineers to model structural responses under traffic and environmental loads. Different design tools rely on distinct theoretical assumptions and calibration methods, which can lead to different structural solutions for the same project conditions. This study compares three widely used rigid pavement design programs representing different engineering traditions: Alizé LCPC (France), developed by the Laboratoire Central des Ponts et Chaussées (LCPC) and SETRA; StreetPave (USA), developed by the American Concrete Pavement Association (ACPA); and KENPAVE (USA), developed by Professor Yang H. Huang at the University of Kentucky. A standardized highway case study was defined using identical traffic, climate, and soil parameters and simulated on all three platforms. Alizé LCPC produced a required concrete slab thickness of 32 cm, StreetPave recommended 30.5 cm (12 inches), and KENPAVE highlighted strong sensitivity to subgrade modeling assumptions. The approximately 4.7% difference in slab thickness between tools carries significant economic implications for large-scale infrastructure projects. This study provides comparative insights and practical guidance for engineers selecting appropriate pavement design tools based on regional conditions, available calibration data, and regulatory frameworks.

Keywords—Alizé LCPC; concrete slab thickness; KENPAVE; mechanistic–empirical design; pavement design; rigid pavements; StreetPave

I. INTRODUCTION

The structural design of pavement systems is a critical phase in road infrastructure planning, directly influencing performance, service life, and long-term maintenance costs [5], [13]. Modern road engineering relies heavily on computerised design tools that simulate structural responses under combined traffic and environmental loading. However, different software platforms embody fundamentally different theoretical frameworks, regional calibration histories, and empirical databases, which can lead to divergent structural recommendations even when applied to identical input conditions [13].

This study compares three internationally recognised rigid pavement design software tools: (i) Alizé LCPC, implementing the French mechanistic rational method developed by LCPC and SETRA [12]; (ii) StreetPave, developed by the American Concrete Pavement Association for mechanistic–empirical concrete pavement design [2]; and (iii) KENPAVE, developed by Professor Yang H. Huang at the University of Kentucky based on multilayer elastic theory [11]. These tools represent the French, American, and academic engineering traditions, respectively.

The primary objective is to quantify differences in design outputs—specifically concrete slab thickness—that arise from

different modelling assumptions when all other inputs are held constant. Secondary objectives include examining how each tool models the subgrade, represents traffic loading, and defines structural failure criteria [1], [18].

A standardised single-layer concrete pavement case study was defined with identical traffic, climate, and geotechnical parameters and simulated on all three platforms. Results are analysed in terms of required thickness, predicted stresses and strains, and sensitivity to modelling assumptions. Section II reviews related literature. Section III describes the software tools. Section IV presents the case study. Section V reports results. Sections VI and VII discuss findings and draw conclusions.

Abbreviations

AASHTO — American Association of State Highway and Transportation Officials; ACPA — American Concrete Pavement Association; CBR — California Bearing Ratio; CTB — Cement-Treated Base; ESALs — Equivalent Single Axle Loads; KENPAVE — Kentucky Pavement Analysis Program; LCPC — Laboratoire Central des Ponts et Chaussées; M-E — Mechanistic–Empirical; MEPDG — Mechanistic–Empirical Pavement Design Guide; PCC — Portland Cement Concrete; SETRA — Service d’Études Techniques des Routes et Autoroutes

Layer	Material	E (MPa)	ν	Thickness (mm)	Other
Surface (PCC slab)	Portland Cement Concrete	35,000	0.25	250–320	$f_r \approx 4.5$ MPa
Base	Cement-Treated Base (CTB)	1,500	0.20	150	$f_c \approx 5\text{--}7$ MPa
Subbase	Compacted Granular Material	300	0.35	200	Good drainage

II. RELATED WORK

A. Empirical Design Methods

Empirical pavement design methods are derived from field performance observations and controlled experiments. These methods use regression models to relate design inputs—including traffic loads, material properties, and environmental conditions—to pavement performance outcomes [1]. The principal advantage is simplicity; the principal limitation is that predictions are only reliable within the range of conditions from which the empirical data were collected [6], [18].

The AASHTO 1993 Guide for Design of Pavement Structures is the most widely adopted empirical tool globally [1]. It is based on field performance data from the AASHTO road test conducted in Ottawa, Illinois, during the late 1950s. Despite widespread adoption, its applicability is inherently constrained by those original experimental conditions [11], [4].

B. Mechanistic Design Methods

Mechanistic methods model the pavement as a layered elastic or viscoelastic system, computing stresses, strains, and deflections in response to applied loads using the theory of elasticity [11]. These methods are particularly well suited to novel materials, non-standard load configurations, and sites with extreme environmental conditions [12]. Key input parameters include layer elastic moduli, Poisson's ratios, and the subgrade reaction modulus.

The resilient modulus M_R is the primary soil property in mechanistic design. Its laboratory determination is resource-intensive, which can limit practical application [6]. Environmental factors—freeze–thaw cycling, seasonal moisture variation—affect material properties over time in ways that purely mechanistic models may not fully capture without additional field calibration [14], [8].

C. Mechanistic–Empirical Methods and Software Comparisons

Mechanistic–empirical (M-E) methods combine mechanistic structural analysis with empirically calibrated performance transfer functions [5]. The MEPDG, now implemented as AASHTOWare Pavement ME Design, simulates incremental pavement damage over the design life accounting for seasonal variations in temperature and moisture [11]. The mechanistic component predicts structural responses; the empirical component links those responses to observed field deterioration modes such as fatigue cracking and rutting [4], [17].

Comparative studies of design software outcomes across different theoretical frameworks remain limited in the published literature [13]. The present work differs from prior studies by holding all inputs constant and attributing divergence purely to methodological differences, providing a clean framework for tool selection guidance.

III. SOFTWARE DESCRIPTION

A. Alizé LCPC

Alizé LCPC implements the French rational pavement design method codified by LCPC and SETRA [12]. The method treats the pavement as a multilayer elastic system and applies conservative safety coefficients derived from decades of French road network performance observations. Structural verification is based on allowable tensile stress in bound layers and allowable compressive strain on the subgrade. The method is standardised by AFNOR NF P 98-086 [3] and widely used in France, French-speaking Africa, and Latin America.

B. StreetPave

StreetPave 12, developed by ACPA [2], applies M-E engineering analyses to the design of jointed plain concrete pavements. It incorporates empirically derived fatigue damage models calibrated against the AASHTO road test and subsequent long-term pavement performance data. The software evaluates six standard structural configurations and can estimate remaining service life for existing concrete pavements and overlays. Traffic inputs are expressed in ESALs derived from AASHTO equivalence factors [1].

C. KENPAVE

KENPAVE was developed by Professor Yang H. Huang at the University of Kentucky [11]. The package consists of two modules: KENLAYER, for multilayer flexible pavement analysis, and KENSLAB, for slab-on-grade rigid pavement analysis using a Winkler foundation model. KENPAVE is widely used in academic curricula and in engineering practice across Asia, the Middle East, Africa, and Latin America [15]. Unlike Alizé LCPC and StreetPave, KENPAVE does not embed empirical performance transfer functions, making it primarily an analysis tool.

IV. CASE STUDY DEFINITION

A. Reference Highway

To isolate the effect of design methodology, a standardised reference scenario was defined with identical input parameters across all three software tools. The reference infrastructure is a two-lane national highway (one direction)

width 3.5 m; shoulder width 2.5 m; design life 20 years; rigid (concrete) pavement surface.

B. Traffic Parameters

Traffic inputs: AADT of 900 vehicles per day; heavy vehicle proportion 90% (810 heavy vehicles/day); geometric traffic growth rate 5% per year. For StreetPave, traffic was converted to ESALs using AASHTO equivalence factors, yielding approximately 1,592,916 ESALs over the 20-year design life [1], [11]. For Alizé LCPC, 810 heavy vehicles/day corresponds to traffic class T0 under the French classification system [12].

C. Climate and Environment

A temperate climatic condition was adopted across all simulations, minimising the influence of environmental variability. Design climate parameters: mean annual temperature 15 °C; annual precipitation ≈800 mm; moderate frost index. These conditions are representative of central France, mid-latitude USA, and similar temperate zones where all three tools are commonly applied [12], [14].

D. Geotechnical Parameters

The subgrade is classified as silty clay (CL per USCS) with a subgrade reaction modulus $k=100$ MPa/m and groundwater table 2 m below the surface [6], [9]. Material properties are given in Table I (above). The subgrade classification scheme used in Alizé LCPC is shown in Table II.

TABLE II — SUBGRADE CLASSIFICATION IN ALIZÉ LCPC (LCPC-SETRA, 1994)

Subgrade class	E (MPa)	Typical soils
Good	80–120	Dense gravels, compacted sands
Average	50–80	Silty-sandy soils
Poor	30–50	Silty clays, clay soils
Very Poor	<30	Very soft clays, organic soils

V. RESULTS AND DISCUSSION

A. Alizé LCPC Results

Subgrade modulus conversion. Alizé LCPC requires an elastic modulus E rather than a Winkler k-value. Conversion was performed using the Boussinesq relationship $E = k \times \pi \times a / (1 - \nu^2)$, with plate radius $a = 0.15$ m and $\nu = 0.35$, yielding $E \approx 54$ MPa (class PF2 — Average) [12].

Traffic and material inputs. Traffic class T0 (810 heavy vehicles/day) was applied. Portland Cement Concrete was assigned material type BC5. The iterative design evaluated slab thicknesses from 15 cm to 40 cm [10], [12].

Allowable stress parameters. Type C equipment (slipform paver) was selected. The construction equipment parameter S_h (Table III) and load distribution coefficient $1/k_d$ (Table IV) were applied per AFNOR NF P 98-086 [3].

086, 2019)

Material type	Type A	Type B	Type C
Single concrete slab on subgrade	0.03 m	0.03 m	0.03 m
Wearing course on GH, BM or asphalt base	0.03 m	0.02 m	0.01 m

TABLE IV — VALUES OF COEFFICIENT $1/k_d$ FOR CEMENT CONCRETE LAYERS (AFNOR, 2019)

Pavement configuration	$1/k_d$
Concrete slabs on subgrade or BC/BM or BC/GH	1/1.7
BCg/BM or BCg/GH	1/1.47
BAC/BM	1/1.37
BCg/asphalt	1/1.37
BAC/GB3	1/1.07

Design outcome. At 15 cm, the calculated tensile stress $\sigma_T = 3.035$ MPa exceeded the allowable limit $\sigma_{T,allow} = 1.005$ MPa. Iterative increases reduced σ_T to 0.995 MPa at 31 cm. A final design thickness of 32 cm was adopted to provide a construction tolerance margin [12], [3].

B. StreetPave Results

Traffic input. StreetPave used the ‘Collector’ typical traffic spectrum [2]. Traffic was input as 1,592,916 ESALs over 20 years. A Winkler k-value of 395 psi/in was assigned to the subgrade.

Design outcome. The design was controlled by slab fatigue cracking. Analysis returned a minimum required thickness of 11.74 inches (29.8 cm); a design thickness of 12 inches (30.5 cm) was selected. Joint spacing of 15 ft (4.6 m) was applied consistent with ACPA practice [2], [1].

C. KENPAVE Results

Structural modelling. KENPAVE’s KENSLAB module models the concrete slab as a plate on a Winkler foundation. The Winkler subgrade modulus $SUBMOD = \alpha \times E$ was adopted with $\alpha = 10$, yielding $SUBMOD = 500$ MN/m³. Slab properties: $E = 35,000$ MPa, $\nu = 0.25$ [11].

Design outcome. KENPAVE confirmed structural insufficiency at 20 cm. Model outputs are highly sensitive to the SUBMOD value; KENPAVE should be used as an analytical verification tool requiring site-specific calibration of α [11], [9].

D. Comparative Summary

Table V (overleaf) summarises the key design parameters and outcomes across all three software tools for the identical reference case.

Parameter	Alizé LCPC	StreetPave	KENPAVE
Design framework	Mechanistic — French LCPC	Mechanistic–empirical — ACPA	Multilayer elastic — Univ. Kentucky
Slab thickness	32 cm	30.5 cm (12 in)	Sensitive to α ; 20 cm insufficient
Subgrade model	Linear elastic $E = 54$ MPa	Winkler $k = 395$ psi/in	Winkler SUBMOD = 500 MN/m ³
Design life	20 years	20 years	20 years
Failure criterion	Tensile stress $\sigma_T \leq 1.005$ MPa	Slab cracking (fatigue)	Subgrade strain (α -sensitive)
Key uncertainty	Conservative calibration	Load transfer efficiency	α conversion coefficient

VI. DISCUSSION

The 4.7% difference in slab thickness (30.5 cm from StreetPave vs 32 cm from Alizé LCPC) has direct economic consequences: on a 10 km dual-carriageway with four lanes, a 1.5 cm difference in slab thickness corresponds to a significant difference in concrete volume, material cost, and self-weight loading on the substructure [16], [13].

The higher thickness from Alizé LCPC reflects its conservative calibration heritage. The French rational method incorporates safety factors derived from long-term observations of French national road performance [12], [3], [7]. The allowable tensile stress criterion ($\sigma_{T,allow} = 1.005$ MPa) is calibrated to a 95th-percentile reliability level under French traffic conditions.

StreetPave's M-E framework incorporates empirical fatigue functions calibrated against AASHTO and LTPP data, permitting a more economical design at equivalent reliability levels under American traffic conditions [2], [1]. The cracking-controlled failure mode reflects the physical mechanism most critical to rigid pavement deterioration [4], [17].

KENPAVE's sensitivity to the α conversion coefficient is the key practical limitation highlighted by this comparison. Uncertainty in SUBMOD can translate to thickness variations of up to 20–30% across the plausible α range (5–20)—significantly exceeding the 4.7% difference between Alizé LCPC and StreetPave [11], [6], [9]. KENPAVE should be used as an analytical verification tool complementing a calibrated M-E design platform.

In France and francophone countries, Alizé LCPC is both technically appropriate and regulatory-compliant [3], [7]. In the United States and countries following AASHTO practice, StreetPave or AASHTOWare are the standard choices. KENPAVE is best deployed where analytical transparency is a research or educational asset [11], [15].

A limitation of the present study is that software interface figures could not be reproduced here. Future directions include: (i) extending the comparison to flexible pavements; (ii) formal sensitivity analysis of α in KENPAVE; (iii) validation against field performance data; and (iv) examination of extreme climate conditions [14], [8], [16], [17].

VII. CONCLUSION AND FUTURE WORK

This study conducted a systematic comparative evaluation of Alizé LCPC, StreetPave, and KENPAVE applied to an identical reference highway case. Key conclusions are:

(1) Alizé LCPC produced the most conservative design (32 cm), consistent with the conservative calibration of the French mechanistic rational method and the allowable tensile stress criterion ($\sigma_{T,allow} = 1.005$ MPa) embedded in LCPC-SETRA [12] and AFNOR [3].

(2) StreetPave yielded an optimised design (30.5 cm) based on M-E fatigue damage principles and empirical calibration derived from AASHTO and LTPP data. The cracking-controlled failure mode is appropriate for rigid pavement design in the American engineering tradition [2].

(3) KENPAVE confirmed structural insufficiency at 20 cm but highlighted high sensitivity to the subgrade conversion coefficient α . The absence of an integrated empirical performance module means KENPAVE requires user-supplied calibration [11].

(4) The 4.7% difference in slab thickness carries significant economic implications in concrete volume, material cost, and construction time for large-scale projects [16], [13].

(5) No tool is universally superior; each is most reliable within the engineering tradition from which it was calibrated [18], [7], [2]. Tool selection should be guided by the available calibration dataset, applicable regulatory framework, and regional performance history.

Future work should: (i) extend comparisons to flexible pavements; (ii) conduct formal sensitivity analysis of α in KENPAVE; (iii) validate outputs against field performance data; and (iv) examine the influence of extreme climate conditions.

VIII. DECLARATIONS

A. Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

B. Conflict of Interest

The author declares no conflict of interest.

C. Data Availability

The data that support the findings of this study are available from the corresponding author on reasonable request.

This study did not involve human or animal subjects.

E. Author Contributions

Conceptualization, M.M.A-N.; Methodology, M.M.A-N.; Software, M.M.A-N.; Validation, M.M.A-N.; Investigation, M.M.A-N.; Writing — original draft, M.M.A-N.; Writing — review and editing, M.M.A-N. The author has read and agreed to the published version of the manuscript.

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X. REFERENCES

- [1] AASHTO, 1993. AASHTO Guide for Design of Pavement Structures. American Association of State Highway and Transportation Officials, Washington, D.C.
- [2] ACPA, 2025. StreetPave 12. American Concrete Pavement Association, Rosemont, IL. Available: <https://www.acpa.org/streetpave/>
- [3] AFNOR, 2019. NF P 98-086: Dimensionnement structurel des chaussées routières. Association Française de Normalisation, Saint-Denis.
- [4] Al-Qadi, I.L., Loulizi, A., Janajreh, I., Freeman, T.E., 2008. Dynamic analysis and in situ validation of perpetual pavement response to vehicular loading. *Transportation Research Record* 2087(1), 29–39.
- [5] Ali, H.A., Tayabji, S.D., 1998. Evaluation of mechanistic-empirical performance prediction models for flexible pavements. *Transportation Research Record* 1629(1), 169–180.
- [6] Bowles, J.E., 1996. *Foundation Analysis and Design*, 5th ed. McGraw-Hill, New York.
- [7] Cerema, 2021. *Conception et dimensionnement des structures de chaussée: Guide technique*. Cerema, Bron.
- [8] Daodu, O.F., Babatunde, D.E., Oduola, M., 2025. Pavement construction: A review of current advancements and challenges. *Construction and Building Materials* (in press).
- [9] FHWA, 2006. *Geotechnical Aspects of Pavements Reference Manual (FHWA-NHI-05-037)*. Federal Highway Administration, Washington, D.C.
- [10] Hafidi, A., 2019. *Catalogue des structures types de chaussées neuves (LCPC-SETRA)*.
- [11] Huang, Y.H., 2004. *Pavement Analysis and Design*, 2nd ed. Pearson Prentice Hall, Upper Saddle River, NJ.
- [12] LCPC-SETRA, 1994. *Conception et dimensionnement des structures de chaussée: Guide technique*. LCPC/SETRA, Paris.
- [13] Losa, M., Leandri, P., Bacci, R., 2008. Statistical assessment of empirical and mechanistic-empirical rutting models. *Transportation Research Record* 2057(1), 24–31.
- [14] Overseas Road Note 31, 1993. *A Guide to the Structural Design of Bitumen-Surfaced Roads in Tropical and Sub-Tropical Countries*. Transport Research Laboratory, Crowthorne, UK.
- [15] Sarang, G., 2017. KENPAVE software documentation.
- [16] Styer, J., Vandenbossche, J.M., Sherwood, J.A., 2024. Innovations in pavement design and engineering: A 2023 sustainability review. *Heliyon* 10(13), e33602.
- [17] Tian, Y., Luo, X., Lytton, R.L., 2018. Calibrating the mechanistic-empirical pavement design guide rutting models. *Transportation Research Record* 2672(40), 304–314.
- [18] Yoder, E.J., Witzak, M.W., 1975. *Principles of Pavement Design*, 2nd ed. John Wiley & Sons, Hoboken, NJ.

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