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THE DESIGN OF THE AIRPORT RIGID PAVEMENT STRUCTURE

BY

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Abstract. Alongside airplane and airport pavement structure materials evolution, modification and development of designing methods are needed.

This paper presents the design scheme and parameters which occur in the designing process, as well as possible completions of the romanian NP 034-99 method. One completion is the enlargement of the values range of both the E dynamic elasticity modulus, and the Poisson’s v coefficient. The importance of these design parameters is highlighted by the results of the computer simulation with the help of ANSYS11 calculation software for a classical rigid airport pavement structure.

The significant difference of tensile values for different values of the parameters confirms the need to increase the precision of the design diagrams. One of the necessary completion is the introduction in the designing method of loads from the complex landing gear airplanes, such as Airbus-A380 or Boeing-B777 type.

Key words: design parameters; design sheme; finite element; design method; landing gear.

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1. Introduction

This paper presents the finite element calculation scheme for the computation of a rigid airport pavement structure and parameters involved in the design process.

For the analysis of the design parameters for rigid pavement airport structures it has been used a computer based analysis on finite element ANSYS 11 (U.S.A.). The calculation scheme is made by using three-dimensional finite elements, parallelepiped (Solid – BRICK), with eight nodes and six faces (Fig.1). Each node has three degrees of freedom, represented by the three-way translations. The calculation model is made of cement concrete slab resting on elastic springs (Fig. 2 *b*) whose rigidity is given by the modulus of reaction, *k*.

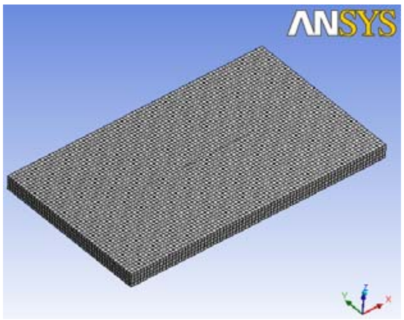
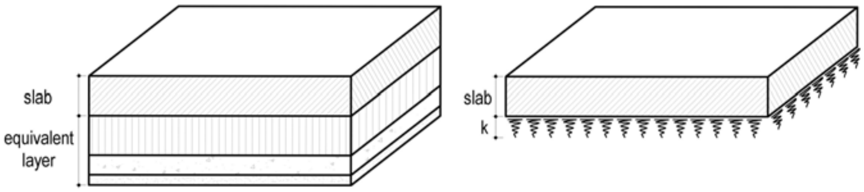


Fig. 1– Finite element mesh of the slab.

The reaction modulus at the equivalent layer surface is obtained from diagrams depending on the k_0 values (the reaction modulus at ground level) and the equivalent thickness of the subadiacente layers, calculated with a relationship type AASHO Road Test / SBA-STBA.

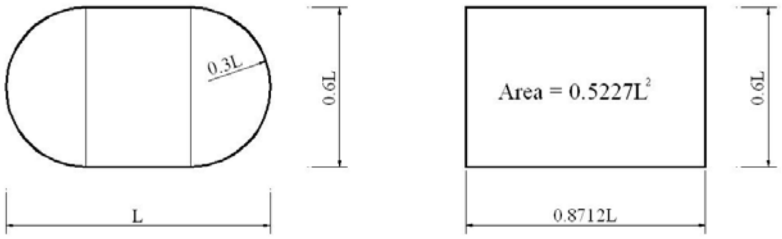


a *b*

Fig. 2 – *a* – Components of rigid pavement strucure; *b* – computation model.

2. Design Parameters

The analysis of the design parameters was accomplished after various simulations of cement concrete slab behavior simulation were made. Tracks / rigid airport pavements are divided in concrete slabs; between these contraction–bending joints the expansion joints are provided. The slab dimensions in plane that were chosen are 5.00 × 7.00m which represent maximum working width of the concrete casting machine and the maximum length allowed between contraction–bending transverse joints. After several simulations with different dimension in plane of the concrete slabs, the 5.00 × × 7.00 m slab generates the maximum covering stress. The aircraft weights are transmited to the airport pavement structure in the form of the uniformly distributed load at the contact surface between the tire and the track. The size of the contact area depends on the tire pressure (Table 1). In Fig. 3 *a* it is shown the approximate shape of the contact area for a single tire, which is composed of three areas, one rectangular and two semicircular. To streamline the designing process, equivalent contact rectangular areas are admitted wich lead to coverings σ_t values (Zarojanu *et al.*, 2000).



a *b*

Fig. 3 – *a* – Quasi elliptical real area; *b* – rectangular equivalent area.

Given the variety of landing gear geometric characteristics, representative landing gears have been chosen for the four existing categories: single wheel, dual, twin-tandem and tandem (Fig. 4) whose characteristics are presented in Table 1.

Table 1

Characteristics of Representative Landing Gear (Ind NP 034-99)

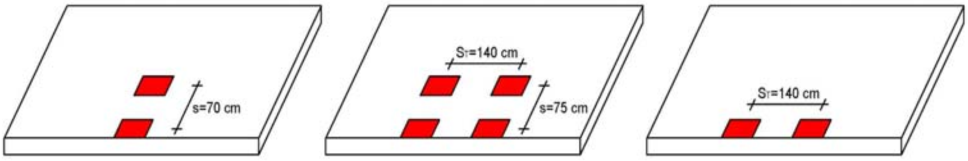
Representative landing gear	Gauge, *s* cm	Tire print, ST cm	Tire pressure Mpa	Maximum load, [t]
Single wheel	–	–	0.60	0.3 ... 0.6
Dual	70	–	0.90	0.6 ... 1.2
Twin -Tandem	75	140	1.20	1.0 ... 1.6
Tandem	–	140	0.60	0.4 ... 0.8

The design load represents the load of the main landing gear determined by considering the take-off mass of the aircraft. The reference/critical aircraft is represented by the aircraft requiring the greatest thickness of slab.

Table 2
Dimensions of Design Tire Print (Ind NP 034-99)

Representative landing gears	Nomber of tire prints	*P*, [tf]	Dimensions $L \times l$, [cm]
Single wheel	1	30	85 × 59
Dual	2	7.5	25 × 17
Twin -Tandem	4	15	21 × 15
		105	56 × 39
Single wheel	2	25	50 × 34
		30	55 × 37

Researches regarding the influence of loading positions (*D*1 – centre of slab, *D*2 – long side tangent to the slab, *D*3 – at the corner of the slab, *D*4 – tangent to contraction–expansion joint) concluded that *D*2 loading position is the most disadvantaged if the uniform resting of the slab condition is satisfied.



a – dual *b* – twin-tandem *c* – tandem

Fig. 4 – Tire prints of representative landing gears and *D*2 loading position.

4. Stress Resulting From Temperature Variations

The seasonal temperature variations of the slabs changes their lengths.

Since the two faces (top and bottom) of the slabs have in almost all cases different temperatures, the extreme fibers have different lengths and, therefore, the slabs are deformed. During the day, particularly in autumn and spring, the upper face of the slab is heated more than the bottom, which in contact with the foundation keeps the temperature lower during the night.

Therefore, the slab deformes with the nods/joints down (Fig. 5).

During the night, specially in dawn, the phenomenon that occurs is contrarily to the other, the slabs deform with the nods up (Fig. 6).

Since the weight of the slab opposes to the tendency of the deformation, at the bottom of the slab tensile stresses arise in the first case (Fig. 5), and compression in the second one (Fig. 6).

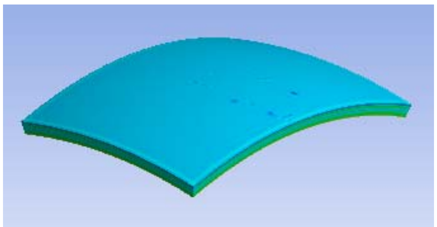


Fig. 5 – Deformed from temperature variation.

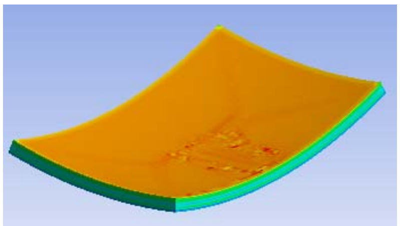


Fig. 6 – Deformed from temperature variation.

With the evolution of finite element software it is possible to calculate the stress from temperature variations in the $D2$ loading position using a temperature gradient equal to $0.67H_{\text{slab}}$.

The stress $\Delta\sigma_t\Delta t$ comes from the temperature variations calculated with FEM that have significantly lower values compared to those calculated with the Bradbury formulas that justifies their use in order to avoid the oversize.

3. The Design Criterion

The designing criterion is expressed by inequality (Zarojanu *et al.*, 2010)

$$\sigma_t \leq \sigma_{t\text{adm}},$$

where σ_t is the flexural tensile stress at the base slab and $\sigma_{t\text{adm}}$ represents concrete admisible flexural tensile stress. The allowable $\sigma_{t\text{adm}}$ flexural tensile stress is considered equal to the concrete tensile strength, R_{ti90}, determined at the age of 90 days, corrected by the c_s safety coefficient

$$\sigma_{t\text{adm}} = \frac{R_{ti28}}{c_s}.$$

The values of the assurance factor, $c_s = 1.8\ldots2.6$, depend on the type of the transfer device used in the joints, as well as the geotechnical, climatic and traffic conditions.

5. Case Study

5.1 The Study of the Influence of Dynamic Elasticity Modulus Value (E-MPa)

The study is justifiable for the evaluation of calculation accuracy if the designing was made only for a single value of the elasticity module, E, and for a single value of the Poisson coefficient, ν, as in the NP034-99 method.

The study has been made for a 5 × 7 m concrete slab and a 30 cm thickness. The loading position is the $D2$ position. The loading was applied by a dual type landing gear. The concrete slab has been meshed in four layers of finite elements of "BRICK" type with constant thickness/height so that a later thickening of the element would not lead to variations of σ_t stress grater than 0.5%.

The reaction modulus at the surface of the foundation layer was considered in three variants: $k_1 = 15$ MN/m^3, $k_2 = 70$ MN/m^3, $k_3 = 150$ MN/m^3.

To highlight the rise of the σ_t stress, the simulation was made for three values of the dynamic elasticity modulus: $E_1 = 30{,}000$ MPa, $E_2 = 42{,}500$ MPa, $E_3 = 55{,}000$ MPa.

The obtained differences, of up to 12% on the σ_t stress values (Fig. 7), justify the designing of rigid pavement airport structures for efective values of the dynamic elasticity modulus, E.

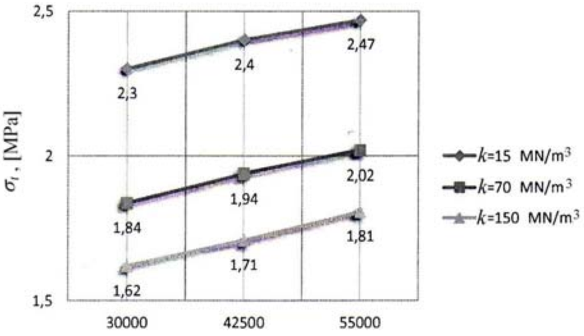


Fig. 7 – The rise of σ_t value depending on the rise of the E dynamic elasticity modulus.

5.2. The Study of Poisson Coefficient Influence (ν)

Table 3 presents the differences regarding the value of σ_t for $\nu = 0.25$, using the value $\nu = 0.15$ as a benchmark for the same variations ranges of the calculation parameters (Fig. 8). Differences of up to 4% of the σ_t value can be observed (Fig. 9), which justify the accomplishment of designing diagrams for different values of the Poisson's coefficient, ν.

Table 3

The Influence of Poisson Coefficient (ν) on σ_t Stress

k MN/m^3	ν	E = 30,000 MPa	%	E = 42,500 MPa	%	E = 55,000 MPa	%
15	0.15	2.30	–	2.40	–	2.47	–
	0.25	2.39	3.91	2.49	3.75	2.56	3.64
70	0.15	1.84	–	1.94	–	2.02	–
	0.25	1.90	3.26	2.01	3.61	2.09	3.47
150	0.15	1.62	–	1.71	–	1.81	–
	0.25	1.67	3.09	1.77	3.51	1.88	3.87

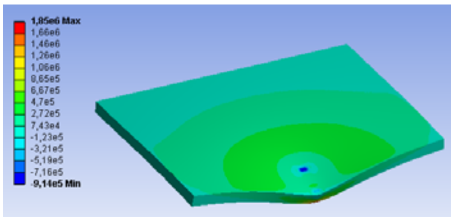


Fig. 9 – σ_t – deformed in position *D*2.

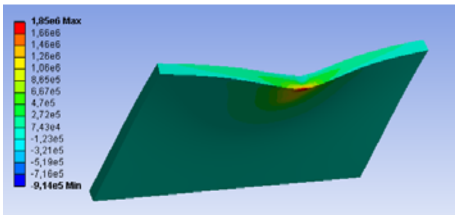
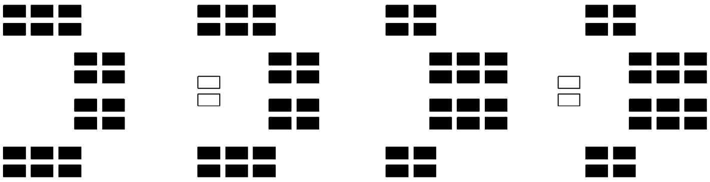


Fig. 9 – σ_t – deformed in position *D*2 (base of the slab).

6. Tendency in the Elaboration of Design Methods of Airport Pavement

The evolution of airplanes features (Airbus-A380, Boeing-B777) and also of the pavement materials justify the switch to methods whose design scheme allow the simulation of complex landing gear's actions (Fig. 10), and whose design parameters are based on the laws of pavement material behaviour. The tendency is to elaborate the design scheme by FEM-3D, and to ensure the design for effective airplanes features by the use of calculations software. Work in this direction can be mentioned in France through the use of ALIZE-CESAR (Zarojanu & Bulgaru, 2010) program by SBA-LCPC, as well as the FAA in the US, through the use of FAARFIELD program (Navneet, 2009).



a *b* *c* *d*

Fig. 10 – Airbus-A380; variants of the landing gear.

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DIMENSIONAREA STRUCTURILOR RUTIERE RIGIDE AEROPORTUARE

(Rezumat)

Odată cu evoluţia aeronavelor şi a materialelor de construcţii înglobate în structura rutieră aeroportuară sunt necesare adaptări/dezvoltări ale metodelor de dimensionare.

Se prezintă schema de calcul şi parametrii de calcul ce intervin în procesul de dimensionare cât şi posibile completări ale metodei româneşti NP 034-99. O completare o reprezintă mărirea gamei de valori ale modulului de elasticitate dinamic, E, şi a coeficientul lui Poisson, v. Importanţa acestor parametri de dimensionare este evidenţiată prin rezultatele simulării cu ajutorul programului de calcul cu element finit tridimen-sional ANSYS, versiunea 11, a unei structuri rutiere rigide aeroportuare clasice.

Diferenţa semnificativă a valorii tensiunilor rezultate pentru diferite valori ale parametrilor confirmă necesitatea măririi preciziei diagramelor de dimensionare. Una din completările necesare este introducerea în metoda de dimensionarea a încărcărilor provenite de la aeronave cu aterizoare complexe de tipul Airbus-A380 sau Boeing-B777.