

The Dimensioning of the Rigid Runway Structures

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Abstract

The article presents the dimensioning and design methods for airport runway systems (new/ reinforced) and roads elaborated in Romania.

There are emphasized the design solutions by the means of the computational schemes (using FEM) the hypothesis and computational parameters.

Finally, there are depicted several design diagrams.

KEYWORDS: Rigid runway structure, runway, airport structure, reinforcement, computational scheme, dimensioning diagram



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1. INTRODUCTION

During the last decade of the past century the dimensioning method of the rigid runway structures – P.D-177-76 – represented the adaptation of the Soiuzdornâi method to the Romanian conditions; this method had been provided not only some limitations concerning the scheme/ relationship/ computational parameters (the initial Westergaard relationship in the Mednicov format, the runway cement concrete characterized through the mark, the characteristic of the linear deflection environment that sustained the plate, represented by the deflection modulus, the fatigue law expressed as a function of the equivalent traffic) but also the disadvantage of some laborious interpolations.

For the dimensioning of the rigid airport runway structures there wasn't a self method, one used for instance the Pickett-Ray method [6].

This paperwork presents – in a synthetic way- the elements of the dimensioning methods carried on in the frame of a grant with INCERTRANS Bucharest, both for the airport rigid runway structures, new (A)/ reinforced (B) and new runways (C).

2. COMMON FEATURES OF THE CREATED DIMENSIONING METHODS

2.1. The Computational Scheme

2.1.1. The computational scheme is made through the FEM (the Finite Element Method), the multilayer approach, correlated with the symmetry.

Tri- dimensional finite elements are used (solid –Brick, parallelepiped) with 8 joints. Each joint is granted with 3 DOFs i.e. the three direction translations.

The models are made in the linear-elastic domain, with isoparametric elements of 2nd order integration.

The level of the horizontal mesh assures the optimization of the element number, further refinements leading to variations of maximum 0,5% of the results.

A mesh refinement was carried on in the traces in order to tune precisely the structural response.

The use of successive layers is justified by the vertical stress distribution; the pressures onto the lane were transmitted to the finite elements.



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The dimensions of the successive layers allows the optimization of the finite element dimension rations: the number/thickness of the layers pays respect to the condition of stress compatibility (a further model, supplementary refined, didn't lead to a variation of the stress distribution larger than 0,5% in the vertical plane).

The model presents geometric, elastic and mechanic symmetry in several situations; therefore the hemi-structures were used instead (Fig. 1).

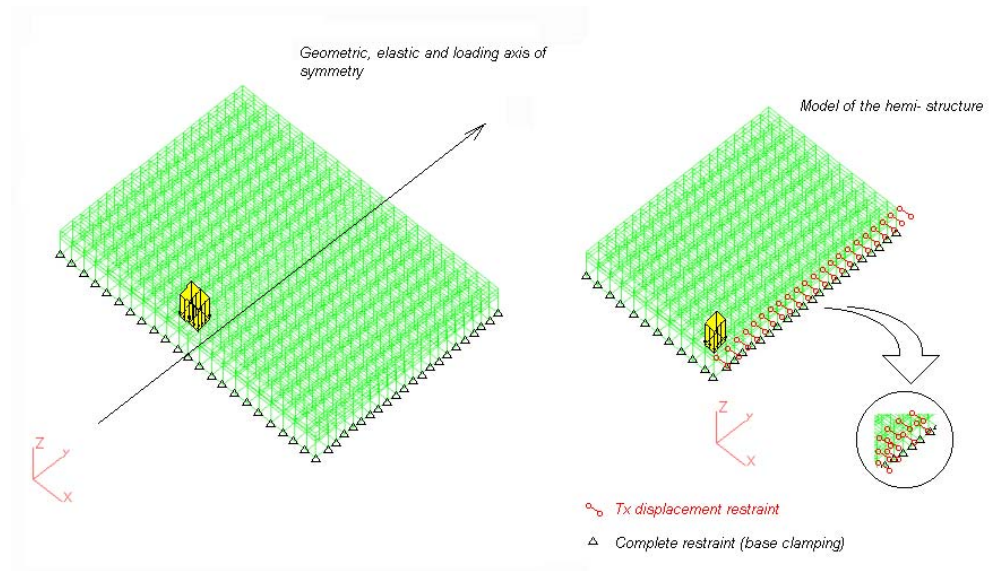


Figure no. 1

2.1.2. The models were built by assembling the substructures specific to the various runway structures (new structures/ reinforced).

In all cases (A... C), the “basic” substructure is made of a single layer of finite elements. The layer is equivalent to the sub- adjacent layers of the runway cement concrete plate; it has a 40cm thickness and the dynamic modulus of elasticity (E) is obtained using the (2.1) transform:

$$E = K_o \cdot (h = 40\text{cm}) [\text{MN}/\text{m}^3] \tag{2.1}$$

The reaction modulus at the surface of the equivalent layer is obtained from the diagrams, as a function of the equivalent thicknesses of the sub- adjacent layers, which are computed by the means of an AASHTO Road Test/ SBA-STBA relationship.



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2.1.3. For the (A) and (C) cases the model is composed of two substructures; the upper one is represented by the runway cement concrete plate; this was made of 2... 4 layers of BRICK elements, depending on the thickness.

2.1.4. For the (B) case, beyond the “basic” substructure, the modeling process takes into account the following layers:

(a) The hypothesis of non- adherent plates: the reinforcing plate/ the intermediate layer made of asphalt mixture/ the existent plate.

(b) The hypothesis of partially adherent plates: the reinforcing plate/ the connection in-between plates/ the existent plate.

The thickness of the intermediate layer of asphalt mixture was stated following a stress/ strain analysis; after analyzing the study it resulted a stress increase in the reinforcing slab proportional with the layer thickness; this variation is stabilized for a 5 cm thickness.

The “intermediate layer of asphalt mixture” substructure is modeled by the means of a single layer of BRICK elements.

The reinforcing slab substructure is made of 2... 4 layers of BRICK elements, depending on the thickness.

2.1.5. The mathematical models were run, tested, validated and applied using the ALGOR Software for the structural analysis based on the Finite Element Method.

2.2. The deflection characteristic, for all the constituent materials is represented by the dynamic modulus of elasticity (E- MPa).

The deflection characteristic for the foundation ground is the reaction modulus (K- MN/m³).

The runway cement concrete (BcR) is characterized by the means of classes; the class defines the characteristic bending tensile strengths (Rkinc150) at 28 days.

An unique value of E=30,000MPa was adopted for the BcR in order to carry out the dimensioning diagrams; this value is motivated by the need to limit the number of the diagrams (under the circumstances of a limited influence of E [5]).

2.3. The dimensioning criterion is defined by the (2.2) condition:

$$\sigma_t \leq \sigma_{t-adm} \quad [\text{MPa}] \quad (2.2)$$

Where:

σ_t - the bending tensile stress in the plate;

σ_{t-adm} - the limit bending tensile stress of the BcR.



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2.3.1. In the “A” case:

$$\sigma_{t\text{-adm}} = \frac{R_{\text{inc.150}}^K \cdot \alpha}{C_S} \text{ [MPa]} \quad (2.3)$$

Where:

α - Coefficient that takes into account the increase of the concrete strength in the range 28... 90 days; $\alpha=1,1$;

C_S – safety factor is a function of the transfer devices and the unpropitious geotechnical, climatic and traffic conditions. The values for $C_S = 1,8$ and $C = 2,6$ are similar to those of the French Codes [5].

2.3.2. In the “B” case:

$$\sigma_{t\text{-adm}} = \frac{R_{\text{inc.150}}^K \cdot \alpha}{C_S} \cdot C_{SS} \text{ [MPa]} \quad (2.4)$$

Where:

α, C_S – idem case “A”;

C_{SS} – coefficient of the structural state for the slab that is to be reinforced:

$C_{SS} = 0,35$ - very damaged (cracked) plates with damaged gaps;

$C_{SS} = 0,75$ - cracked plates but without generalized damages; slabs with broken corners or with some structural cracks;

$C_{SS} = 1,00$ - slabs in good condition, without structural damages; for this kind of plates the reinforcing is imposed by the outrunning of the traffic foreseeing.

2.3.3. In the “A” and “B” cases, the fatigue law (eq. no. 2.5) is taken into account to establish the regular load for the computation

$$C = 1,2 - 0,2 \cdot \log N \quad (2.5)$$

2.3.4. In the “C” case:

$$\sigma_{t\text{-adm}} = R_{\text{inc.150}}^K \cdot \alpha \cdot \beta \cdot (1 - \gamma \cdot \log N) \text{ [MPa]} \quad (2.6)$$

Where:

α – Idem, case “A”;

β – Coefficient that takes into account the increasing value of the concrete strength in time; $\beta=1,1$. If is absent in the owner studies, one may use it in the case of local roads.

N – The computational traffic (m.o.s.); OS115 KN.

$\gamma = 1/14$.

$\sigma_{t\text{-adm}}$ is to be referred to the lower layer, the resistant layer, in the case of the plate made of 2 layers because of the economic reasons.



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2.4. The elliptical prints from the “A” case – the standard hemi- axle (57,5 KN) and from the “B” and “C” cases (simple, twin, boogie and tandem landing gears) are transformed into rectangular prints for the computational model (Fig. no. 2).

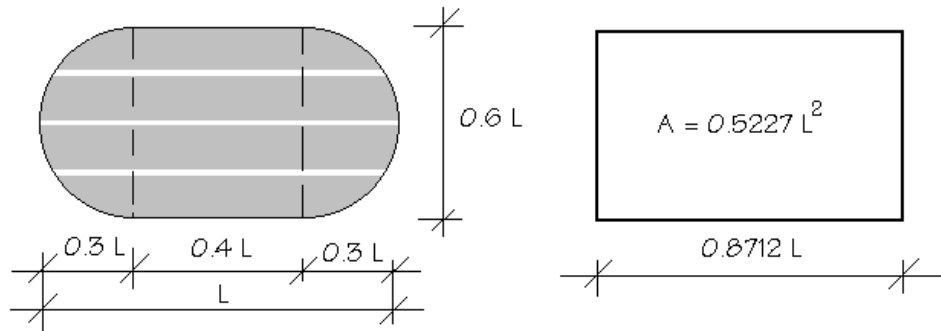


Fig. 2 The real gear print and the computational print

2.5. The loading position: the print/ prints are tangent to the longest edge of the slab, in the conditions of the uniformly restrained slab.

In the Figure no. 3 it is depicted an example of the dual and boogie print positions.

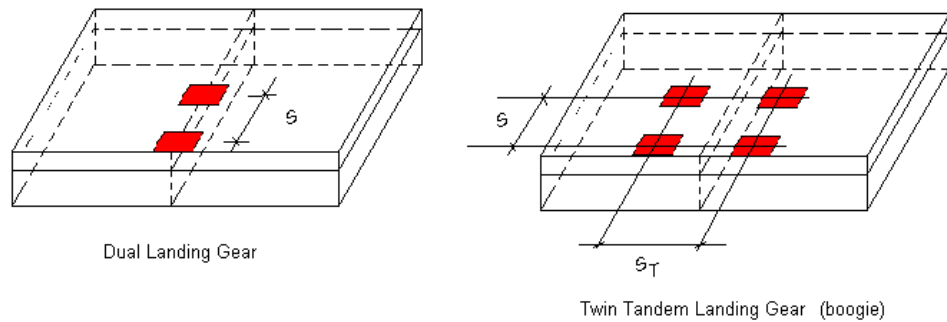


Fig. 3 The 2nd load position



*The Dimensioning of the Rigid Runway Structures**2.6. Geometric Elements*

In order to limit the number of the dimensioning diagrams, it was selected a number of representative plates (by taking into account the plane dimensions), for each case (A... C), as follows:

(A) The 7,00 x 5,00m slab, legitimated by:

- the working span of the concrete spreading machine;
- the maximum allowable distance between the gaps.

(B) The 3,75 x 5,00m slab (the existent plate that has to be reinforced/ it imposes the gap positions of the reinforcing slab). For the range (3,00 x 5,00m) ... (5,00 x 5,00m), the reinforcing thicknesses are maintained between the limits $\pm 1,0\text{cm}$ (the degree of precision assured by the use of the diagrams). For particular dimensions (for instance 3,00 x 6,00m) the differences are significant and require individual project; in this case the making of the diagrams is not justified.

(C) The (5,00... 6,00m) x (3,25... 4,25m) slab; the slab width variation domain assures the correlation with the technical class (I... V)/ the economic category of the road (highway... local road).

3. THE SPECIFIC ITEMS

3.1. In the cases "A" and "B": the SBA/STBA [5] methodology is considered for:

- the geometric characteristics (gauge, wheelbase) of the standard landing gear (see. Table No.1);
- the pounded real load, as a function of the type/ destination of the airport surface (landing/ take-off runway/ run path/ fast come off; stop prolongation – SWY, platforms);
- the normal computation load, that takes into account the superposition of the prints in case of several motions of the aircrafts (landing/ take-off/ run);
- the general dimensioning method for the standard aircraft;
- the optimized dimensioning method.

Table 1 The features of the standard landing gears

Landing Gear Type	Gauge (s) - cm	Wheelbase (Sp) - cm
Twin	70	-
Boogie	75	140

3.2. A computer software was developed, based on the AASHTO methodology [7]; the software optimizes the division of the structures into sectors that have to be reinforced. The program allows the definition of several criteria (the damaging



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indexes, C_{SS} , the FWD/ HWD deflections, the type/ characteristics of the foundation ground/ foundation layers).

3.3. The dimensioning diagrams are drawn for the following domains:

3.3.1. (A):	Simple gear:	P = 5...40 tf.
	Twin gear:	P = 7,5...42,5tf.
	Boogie gear:	P = 15... 105tf.
	Tandem gear:	P = 25... 37,7tf.

In the Figure No.4 it is depicted an example of a boogie landing gear (P = 45... 75tf.)

3.3.1. (B):	Twin gear:	P = 27,5...42,5tf.
	Boogie gear:	P = 60... 105tf.

The diagrams are drawn in the following hypothesis:

Partially adherent slabs: $C_{SS} = 0,75; 1,00$.

Non- adherent slabs: $C_{SS} = 0,35; 0,75$.

The minimum thickness of the reinforcing slab is of 15cm but the recommended value is 18cm.

The figure no. 5 presents the diagram for the twin gear, P = 42,5tf, in the assumption of the non- adherent slabs.

3.3.3. (C) The dimensioning diagrams are taking into account the computational assumptions regarding the load combination (from traffic - σ_t ; from the daily temperature gradient - $\sigma_{t\Delta t}$); these assumptions are correlated with the technical class of the runway:

$$\sigma = \sigma_t + \mu \cdot v \cdot \sigma_{t\Delta t} \leq \sigma_{tadm} \quad [\text{MPa}] \quad (3.1)$$

Technical class I, II: $\mu = 0,8; v = 1,0$;

Technical class III, IV: $\mu = 0,8; v = 0,65$;

Technical class V: $\mu = 0; v = 0$.

In the figure no. 6 it is presented the diagram for the runways from the technical class I, II.



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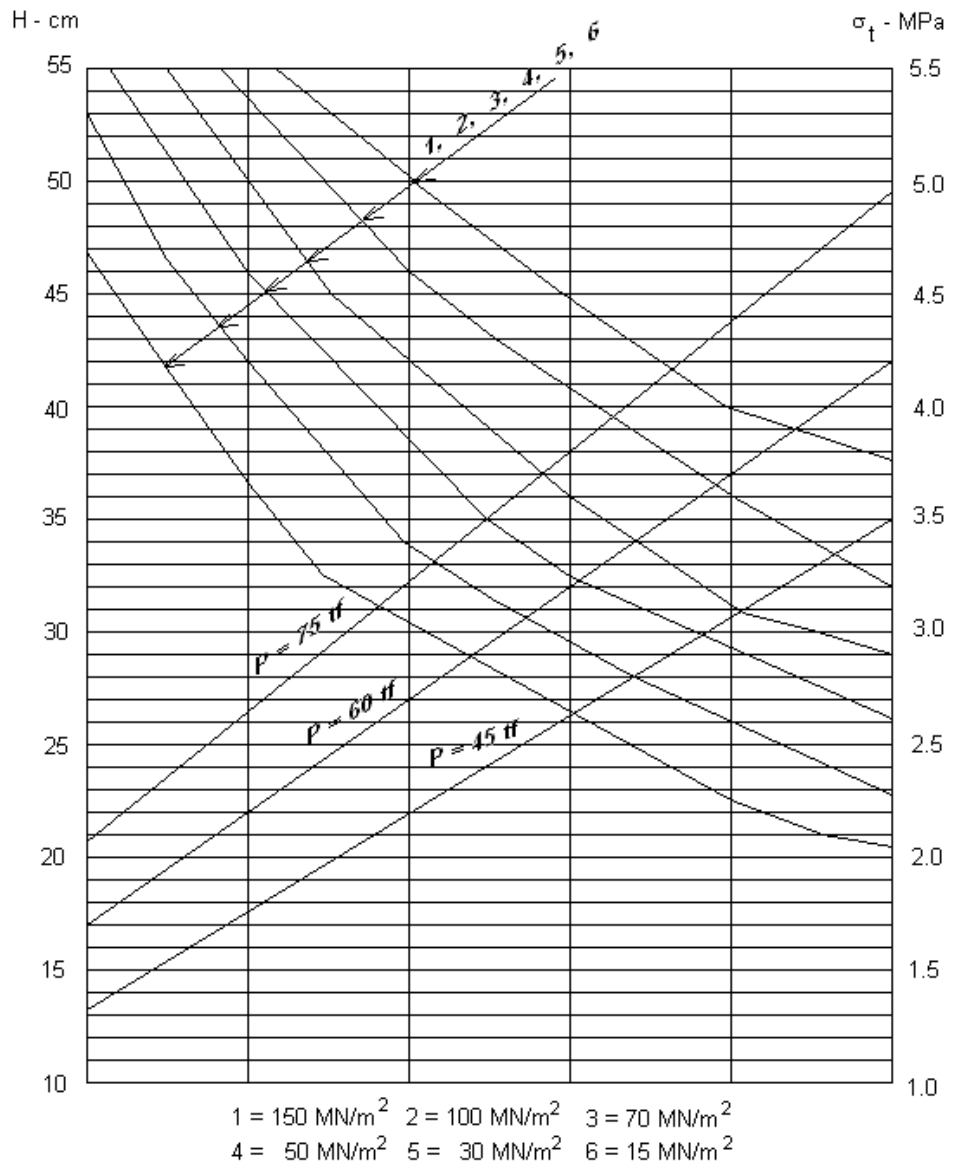
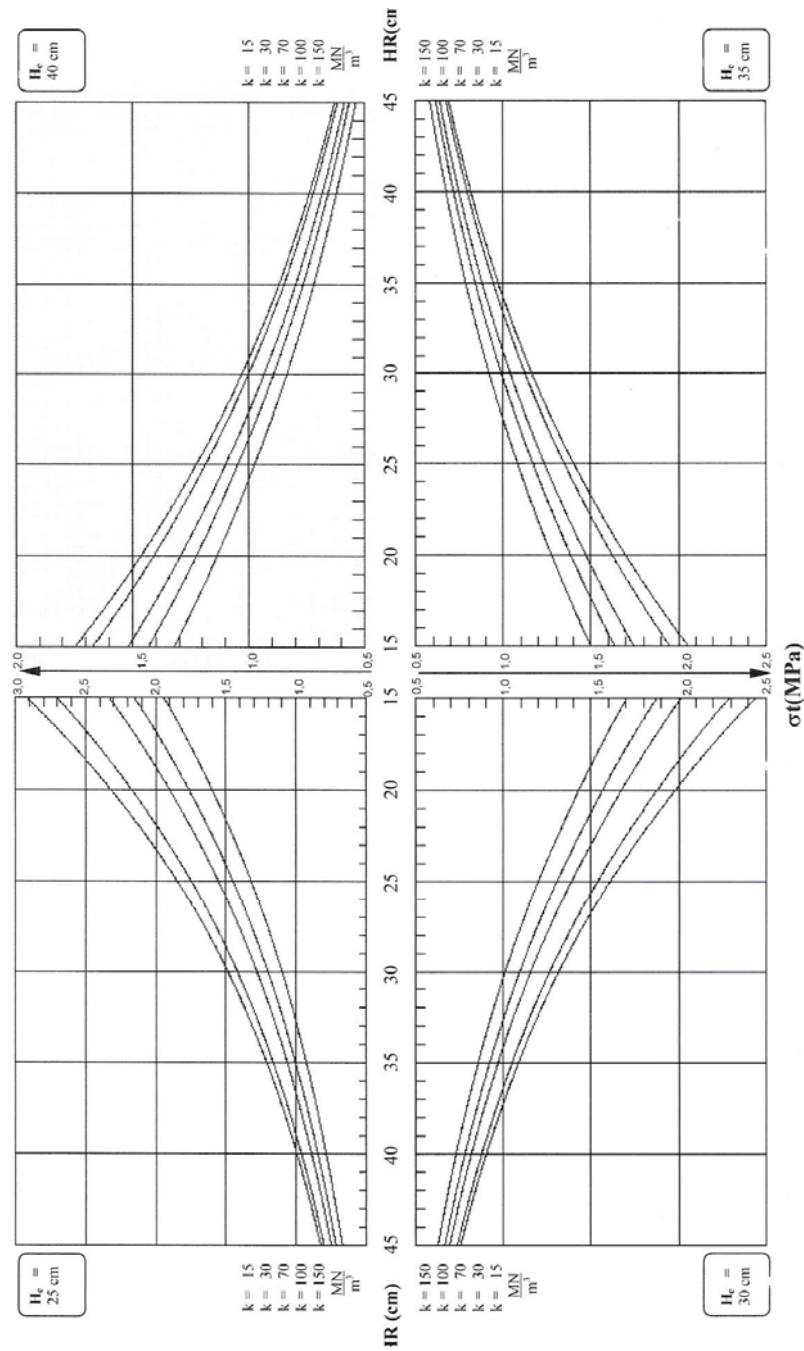


Fig. 4 The twin tandem landing gear $P = 45, 60, 75$ tf.



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Twin Gear P=42,5 tf.
 Hypothesis: Non-adherent slabs
 $C_{ss} = 0,35$ $E = 10500$ MPa

Fig. 5 The twin landing gear P = 42,5tf.



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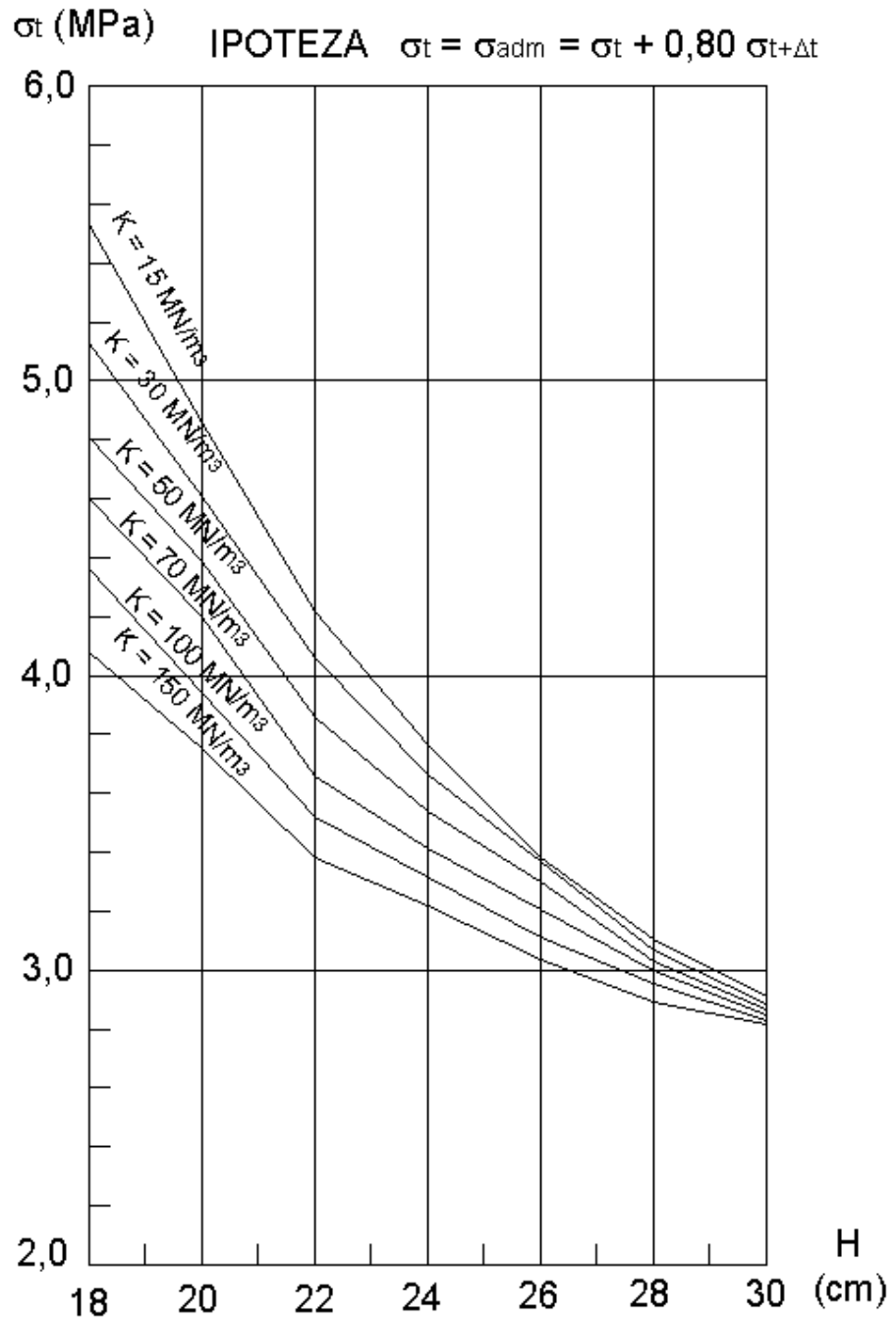


Fig. 6 The diagram for runways from the technical class I, II



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3.3.4. The 4th degree polynomial correlations are allowing the increase of the computational precision for the slab thickness.

4. CONCLUSIONS

For all the classes of rigid runway structures – new airport runway/ reinforced, new runways – the computational schemes are carried on by the means of FEM.

The computational scheme for the new structures of roads is taken – in the IPTANA Bucharest format – also for the reinforcing of the simple runway structures/ hemi- rigid with runway cement concrete [4].

The slab thicknesses are derived from diagrams carried on for slabs that have representative plane dimensions with respect to the classes of the runway structures/ current building conditions. The 4th order polynomial correlations are certifying the increase of the computational precision.

In case of particular plane dimensions of the slab the individual project is required.

The rigid runway structures are checked to the frost/thaw action, according to the provisions of the Romanian Code STAS 1709-90.

The items presented in this paperwork are included in the final drafts of the dedicated Design Codes [1, 2, 3] by INCERTRANS Bucharest.

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