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SELECTED PROBLEMS OF INDUSTRIAL CONCRETE GROUND FLOORS DESIGN

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ABSTRACT

The main function of the ground floor is to transmit static and dynamic loads and to save performance over required time in environment of the influence of different agents. Because of the hard exploitation conditions, together with the influence of different agents that destruct the ground floors, they must fulfill some usable requirements. To fulfill the service life requirements that are connected with the concrete ground floors, they must get the proper structure. To estimate the exertion of the analyzed concrete ground floors, it is necessary to take into consideration the complex state of stresses, which takes palace where the floor slab is subjected to pointed loads. The method, which makes possible to include the complex state of stresses in ground concrete slab calculations and to estimate the level of slab stresses in characteristic, analyzed of Wetergaard`s places objected by loads, has been proposed.
That is why only some issues, connected with this topic, are presented in this paper. The model of concrete slab exertion, which makes possible to take under consideration the complex state of stresses in the slab at the place of putting the loads, is proposed. On the basis of considerations, analyses and calculations the method of defining the vertical susceptibility of the subsoil in the function of the subsoil deformation modulus is proposed. The selected issues connected with the structural solutions of concrete ground floors are presented as well.

Key words: Concrete structures; concrete ground floor; wearing course; subsoil; bending strength; complex state of stresses; exertion model of concrete slab; ground reactive coefficient; ground deformation modulus.

INTRODUCTION

Ground floors constructing has had a long history. They had been built earlier than typical buildings. Primitive people who were living in caves isolated their habitats by means of trampled grout from clay that was modified by dried organic material. They did it to improve their conditions of living. These were the first realizations of floors. It indicates that the problem is old but nethertheless important even today. The same goals are achieved nowadays and more modern materials and technologies are used. Using the best solutions concerning the floors is obligatory not only in dwelling building. With the development of industry and mechanical communication there appeared problems concerning the use of proper surface solutions. Much attention has been paid to these problems lately. The International Colloquia organized in Technical Academy in Esslingen with dr P. Seidler`s direction have been taking place since 1987 every for years. Recently in January 16-18, 2007 the 6. Colloquium "Industrial Floors'07" was placed in Ostfildern/Stuttgart in Germany. Taking it into consideration, in the presented paper, only the selected issues concerning structural-material solutions of concrete industrial floors on the ground, are presented.

GENERAL RULES OF SHAPING THE INDUSTRIAL CONCRETE GROUND FLOORS

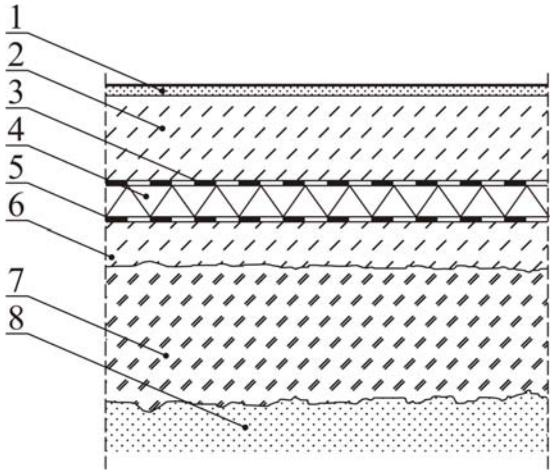
The main function of the ground floor is to transfer static and dynamic loads and to save its usefulness for a particular period of time in conditions of particular factors' influence. Because of the hard conditions of exploitation in the conditions of different agents' influence, destructing the industrial surfaces, they must fulfill some usable requirements. Such situation is the reason that they must get some particular properties that ensure the external reaction resistance. It is important to point out the basic properties [1, 2, 4, 32]:

- resistance to mechanical loads,
- chemical resistance,
- resistance to thermal influence,
- anti-sliding property,
- easiness of keeping it clean,
- resistance to corrosion,
- non-inflammability,
- anti-electrostatic property,
- capacity to dampen sounds,
- thermal protection,
- resistance to the sun radiance (UV),
- aesthetics.

The essence of the ground floors

To fulfill the usage requirements that are connected with the industrial concrete ground floors, they must get the proper structure, which essence is presented in Fig. 1.
It was elaborated with the compliance of the definitions of floors that are used in different papers [1, 4, 5, 7].

Fig. 1. The proper scheme of the ground floors structure: 1 – wearing surface, 2 – concrete slab, 3 – slip membrane (gas barrier), 4 – sub base (thermal isolation), 5 – against water protection cover (gas barrier), 6 – plain concrete, 7 – subgrade (hardcore), 8 – natural ground



In justifiable cases the structure of the surface presented in Fig. 1 may be reduced to the layers number 2, 5, 7, 8. In such case the concrete board should have specifically prepared surface that is capable of taking over the functions of a flooring layer (number 1 in the Fig. 1). In addition the layer number 5 (Fig.1.) must also act as a sliding layer and the substructure (layer 7 in the Fig. 1) should be properly flat to make it possible that the use of layer 6 (thin concrete) is unnecessary. The author wants to point out that using the layer 5 as protection against permeating of gas (i.e. methane or radon) is necessary in closed space. In special cases the structure of the surface presented in Fig. 1. may be limited to the layers 2, 7 and 8, and even 2 and 8. However, it requires the detailed analysis with compliance of the local conditions and investor's expectations.

Geometry of concrete ground slab

The concrete ground slabs should be dilatized to provide the possibility of indemnity of thermal and shrinkage deformations. Because of the character of cement materials there are [4, 8]:

- dilatation fissures,
- counter-action fissures (common and sham),
- joint fissures.

Dilatation fissures according to [8] have to compensate thermal deformations while counter-action fissures (shrinking ones) have to compensate shrinkage deformations or ground deformations. Joint fissures emerge when the new concrete mixture is put after the break in the process of concreting. Details concerning the construction of fissures in the industrial surfaces can be found in the paper [8] but also in the materials prepared for this conference [4, 5]. Space between dilatation fissures depends on [8]:

- temperature fluctuations,
- shrinkage of the hardening concrete,
- concrete humidity,
- mechanic properties of concrete,
- the degree of concrete modification,
- the type of the ground.

The intervals between contiguous dilatation fissures may be determined on the basis of deliberations presented in paper [8]. With the decreasing in temperature a board will aim at shrinking in both directions. Because of the ground resistance, there will be distending tension in the board. The space between dilatation fissures L may be specified from condition [8]:

$$L = \frac{f_{ctg} \cdot h}{1.4 \cdot (h \cdot \gamma \cdot f + c)} \tag{2.1}$$

where:
f_{ctg} – bending strength of concrete durability [kN.m^{-2}],
h – thickness of a board [m],
γ – volume load of concrete [kN.m^{-3}],
f – coefficient of friction on the ground surface,
c – unitary adherence power [kN.m^{-2}].

The coefficients c and f occurring in model (2.1) are presented in Table 1 [8].

Table 1. Numeral values c and f [8]

The type of a ground surface	f [-]	c [kN.m^{-2}]
Sand and clay ground	1.0	70
Sand	0.7	30
Broken stone	1.2	20
Huge fornax slag	0.8	90
Isolating layer from water hermetic paper	0.9	50

The exemplary results of calculations (on the basis of the model 2.1) of space between the fissures L for the concrete board with f_{ctg} = 2.37 MPa are presented in Table 2. [9].

Table 2. Spaces between dilatation fissures [9]

Thickness of a board [1)] [m]	Space L [m]		
	1.5 [2)]	2.37 [2)]	3.50 [2)]
0.15	2.2	3.5	5.1
0.20	2.9	4.5	6.7
0.25	3.5	5.6	8.3
0.30	4.2	6.6	9.8
[1)] It was assumed that the surface is built from sand and clay ground [2)] Values f_{ctg} for concrete			

The principles of dividing the surface with dilatation fissures according to norm recommendations [10] are presented in Table 3.

Table 3. The spaces between the dilatation fissures [10]

Location of the surface	The biggest size of	
	the surface [m^2]	the length of the side of a rectangle [m]
Outside	5	3
Inside	10	4
Rooms with small temperature fluctuations	30	6

According to the norm [10] the dilatations should be made in the dilatation places in the building, near the foundations of machines, along the axis of construction columns, and in the lines that separate the surfaces of different loadings. The results obtained on the basis of the model (2.1) for the concrete f_{ctg} = 2.27 MPa (see Table 2) are comparable to the demands of the norm [10]. The analysis of the results (Table 2) indicates also that the space between the dilatation fissures depend on both the thickness of a board and board concrete durability for stretching when it is bent. The influence of parameters f and c on the distance L (model 2.1) is obvious.

The details of dilatation, joint and sham (counter-action) fissures, and of distance between them are given by the authors [4]. Recommended distance between the fissures is comparable to values obtained on the basis of the considerations made in this work.

The width of dilatation fissures may be stated because of the possibility of dilation of concrete boards while the temperature increases. An indicatory width of dilatation fissure “s” may be circumscribed on the basis of a commonly known model:

$$s = \varepsilon_T \cdot L \cdot \Delta T \tag{2.2}$$

where:
ε_T – thermal linear expansibility coefficient (for concrete $\varepsilon_T = 10^{-5}$ [$^{o}C^{-1}$], [11]),
L – linear measurement of a slab [m],
ΔT – difference of temperatures [^{o}C].

The difference of temperatures may be stated on the basis of the analysis of potential possibilities of heating the analyzed slab and identification of temperature in which the concrete mixture was laid down. If the temperature is not known then T_o = 10 ^{o}C may be accepted for the calculations. Taking into consideration that a slab (outside) may heat to approximately 65 ^{o}C in extreme conditions and in our climate, then the difference of temperatures ΔT = 55 ^{o}C. In such a case the width of a fissure “s” calculated on the basis of a model (2.2) will be:

$$s = \begin{cases} 1.65 \cdot 10^{-3}\ \text{m} & \text{for } L = 3.0\ \text{m} \\ 3.30 \cdot 10^{-3}\ \text{m} & \text{for } L = 6.0\ \text{m} \\ 4.95 \cdot 10^{-3}\ \text{m} & \text{for } L = 9.0\ \text{m} \end{cases}$$

The calculations indicate that such width of dilatation fissures would be difficult to construct and apply in practice. These problems will be analyzed in next chapter.

THE METHOD OF CONCRETE GROUND FLOORS DESIGN

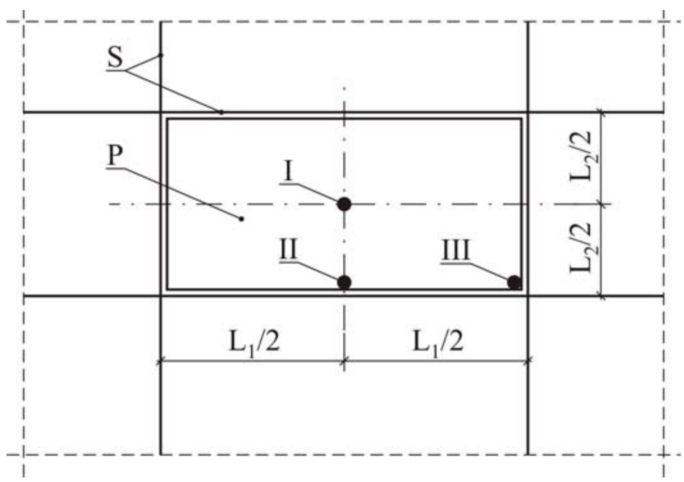
General remarks

To estimate the exertion of the analyzed surface board, it is necessary to take into consideration the complex state of tightness in the place where the condensed loading is present. Wetergaard`s method [8] allows to estimate the highest tensile stresses at the moment of the concrete board bending and at only three characteristic points where the force is applied. That is why for the purposes of practical application of this solution, its modification is necessary. The method, that makes possible to include the complex state of tightness in board calculations and to estimate the level of slab strain in characteristic and analyzed by Wetergaard`s places of putting the loading, has been proposed.

Stresses calculating

Practical solutions concerning the calculations of concrete boards was given by Westergaard in 1926. Later, they were modified by him and then checked experimentally by Public Roads Office USA. These calculations were made on the assumption that a board works as isotropic elastic substance that lies on Winkler's surface. Such a simplification was the main reason for the criticism of this solution. However, it is still used nowadays and is recommended for example by [7]. In the method, the three types of possibilities to estimate thickness of a board instances of a ring position (condensed load.) are being considered, as it is shown in Fig. 2.

Fig. 2. Characteristic places of load application [8]:
P – the analyzed board, S – dilatation fissures` axis,
I, II, III – points of load application



For the cases of equally disposed loading (as in the Fig. 2) on the surface of adhesion with radius c, Westergaard introduced the following equations defining the highest stretching tightness at the moment of bending the concrete board [8]:

$$\sigma_I = \frac{0.275}{h^2} \; P\left(1+\nu\right) \; \log \frac{E\,h^3}{k\,b^4} \tag{3.1}$$

$$\sigma_{II} = \frac{0.529}{h^2} \; P\left(1+0.54\nu\right) \left(\log \frac{E\,h^3}{k\;b^4} - 0.71 \right) \tag{3.2}$$

$$\sigma_{III} = \frac{3}{h^2} \, P \; \left\{ 1 - \left[\frac{12\;\left(1-\nu^2\right)k}{E\,h^3} \right]^{0.15} \cdot \left[c\,\sqrt{2}\right]^{0.6} \right\} \tag{3.3}$$

where:

σ_I – the highest stretching tightness on the lower middle surface of a board fragment in the axis of thrust force action [$kN.m^{-2}$],

σ_{II} – the highest stretching tightness on the lower surface of a board along its edges [$kN.m^{-2}$],

σ_{III} – the highest stretching tightness on the upper surface of a board at the proximity of its corner [$kN.m^{-2}$],

E – elasticity modulus of concrete [MPa],

ν – Poisson's coefficient for the concrete,

h – thickness of a board [m],

k – ground reaction coefficient [$MN.m^{-3}$],

P – condensed loading [kN],

C – equipollent radius, substitute surface of ring and board [m] joint, determined on the basis of the polish standard [12].

Coefficient b, present in models (3.1) and (3.2) looks as it follows:

$$b = \sqrt{1.6 \cdot c^2 + h^2} - 0.675 \cdot h \text{, for } c < 1.724 \cdot h \tag{3.4.1}$$

$$b = c \text{, for } c > 1.724 \cdot h \tag{3.4.2}$$

The biggest bending arrow (subsidence) of a board in the middle position of loading equals [8]:

$$e_I = \frac{P}{8k\ i^2} \tag{3.5}$$

Stiffness board radius and [m] is described by the dependency:

$$i = \sqrt[4]{\frac{E\ h^3}{12\left(1-\nu^2\right)k}} \tag{3.6}$$

The adduced models (3.1) ÷ (3.3) were introduced with the presumption of the ground model with stable value of coefficient k.

The subsoil characteristic

The ground reaction coefficient k

The coefficient of vertical ground receptivity, also known as a coefficient of ground reaction, is defined out of the assumption that the value of tightness in the ground surface in any point under the board is directly proportional to the value of board subsidence at the given point. The dependency [8, 13] describes it:

$$\sigma = k \cdot w\ . \tag{3.7}$$

where:

σ – stresses in the ground under the slab [MPa],

k – coefficient of vertical ground receptivity [$MN.m^{-3}$],

w – value of board subsidence at the given point [m].

There is some inaccuracy in the above assumption as in reality the values of board subsidence depend not only on the values of thrust but also on the superficies of a board, its shape [8, 13] and thickness [8].
The dependencies between coefficients of ground reactions k and modulus of ground deformation E_o were defined by N. M. Giersievanov by comparing the models for bending the beams on the elastic ground. Taking into consideration the Winkler-Zimmerman's hypothesis and the fact that the ground undergoes the linear deformation laws, this dependency is presented by the model [8]:

$$k = \frac{0.65\ E_o}{h} \sqrt[3]{\frac{E_o}{E}} \tag{3.8}$$

where:
E_o– ground deformation modulus [MPa],
E – concrete deformation modulus [MPa],
H – the height of a beam (thickness of a slab) [m].

The calculations made on the basis of the model (3.8) allowed to identify the dependencies between the ground deformation modulus E_o and the vertical ground docility coefficient k. The results of these calculations are presented in Table. 4.

Table 4. Dependence k on E_o

E_o [MPa]	k [MN.m^{-3}]
10	1.96
30	8.47
50	16.73
70	26.20
90	36.64
110	47.88
130	59.83
150	72.40
170	85.55
190	99.23
210	113.40
230	128.02
250	143.10
270	158.53
The calculations were made for the slab with thickness h = 0.22 m and concrete with E = 34 400 MPa [9]	

The calculations made on the basis of the model (3.8) [8] allowed to identify the dependencies of a coefficient k on the thickness of a board. The results of the calculations for different types of ground are presented in Table 5.

Table 5. The dependency between k and E_o

Thickness of a board [m]	k [MN.m^{-3}] for the ground with E_o [MPa]			
	100	150	200	250
0.2	46.4	79.6	116.9	157.4
03.	30.9	53.1	77.9	104.9
0.4	23.2	39.8	58.4	78.7
0.5	18.55	31.9	46.7	62.9
The calculations were made for the concrete with E = 34 400 MPa [9]				

The calculations, made on the basis of [13] for boards 1×1, 3×3 and 6×6 (in meters) that were equally loaded and with the same intensity, with taking into consideration that the boards are not deformed, showed that there are considerable differences in the values of coefficient k. The results of these considerations are shown in Table 6.

Table 6. The dependency of „k" from the slab surface

The ground deformation modulus E_o [MPa]	k [MN.m^{-3}]		
	Slab 1×1	Slab 3×3	Slab 6×6
100	117,2	39,1	19,5
150	175,9	58,6	29,3
200	234,5	78,2	39,1
250	293,1	97,7	48,9

To identify, for the proper practical application, the relation between coefficient k and modulus of ground deformation $E_{o,}$ the analysis of subsidence's of a round slab with the radius R for different types of ground was made. The subsidence of a slab that was equally loaded (load q) were analyzed taking into consideration the board of absolutely stiffness (E = ∞) and flaccidness (E = 0). The subsidence of a flaccid board was calculated taking into consideration the Boussinesque`s elastic halfspace [13]:

- In the inside of a board

$$w_o = \frac{2\left(1-\nu^2\right) q \ R}{E_o} \tag{3.9}$$

- On the edge of a board

$$w_{kr} = w_o \frac{2}{\pi} \tag{3.10}$$

- Medialed

$$w_{śr} = w_o \frac{8}{3\pi} \tag{3.11}$$

The subsidence of the absolutely stiff board were calculated taking into consideration the elastic halfspace, using Boussinesque`s model [13]:

$$w = \frac{P\left(1-\nu^2\right)}{2 \, R \, E_o} \tag{3.12}$$

It was also accepted that:

$$P = q \, \pi \, R^2 \tag{3.13}$$

The condition of the same intensity of loading for all analyzed instances will be fulfilled in this case. The results of the calculations are presented in Table 7.

Using the equation (3.7.), the calculated values of board subsidence (Table 7) and dependency [8, 13]:

$$E_o = \frac{\sigma \cdot 2 \cdot R}{W} \tag{3.14}$$

it was ascertained that in the case of the analysis of flaccid board (E = 0) one obtains concurrent estimations of the ground deformation modulus E_o. The values $E_{o,}$ that were calculated on the basis of the equation (3.14) with the usage of the results of the middle of the flaccid board subsiding (Table 3.4), were compared to the values assumed a priori to calculate the subsidences. The results of the analysis are presented in Table 8.

Table 7. The results of a round slab subsidences' calculations.

Ground deformation modulus E_o [MPa]	Subsidence [mm] according to [13]			
	flaccid slab			stiff slab
	middle	average	edge	
50	0.375	0.318	0.239	0.295
100	0.188	0.160	0.119	0.147
150	0.125	0.106	0.080	0.098

$q = 10.0$ kN.m^{-2}
R = 1. 0 m

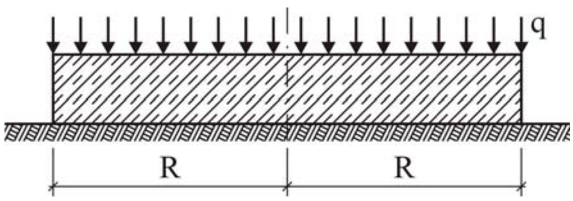
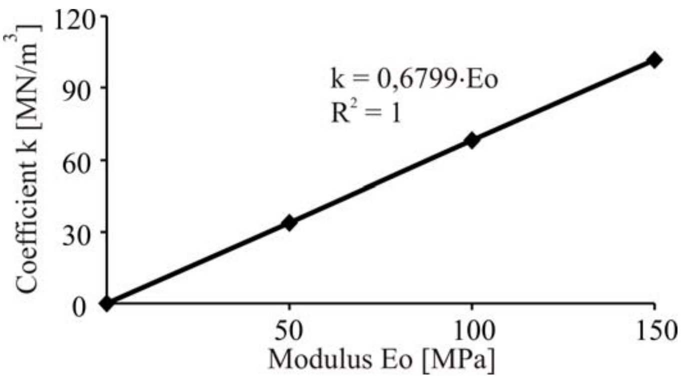


Table 8. Comparison of the values E_o

Assumed values E_o [MPa]	Calculated values E_o [MPa]	Error [%]
50	53.3	+ 6.6
100	106.4	+ 6.4
150	160.0	+ 6.7

Accepting the accuracy of estimating the values E_o as sufficient (Table 8), the correlation between the vertical ground reaction coefficient k and ground deformation modulus E_o may be presented as in Fig. 3.

Fig. 3. The correlation of k and E_o



The above considerations showed an agreement between the calculated and real values. The numeral values of coefficient k, although they should be experimentally defined [8, 13, 15], for the practical aims of application they may be estimated on the basis of the dependency showed on the graph – Fig. 3.

The active depth of the subsoil

The active depth of the subsoil under slab may be defined on the basis of the Polish National Standard model [14]:

$$\sigma_{zd} \leq 0.3 \cdot \sigma_{z\rho} \tag{3.15}$$

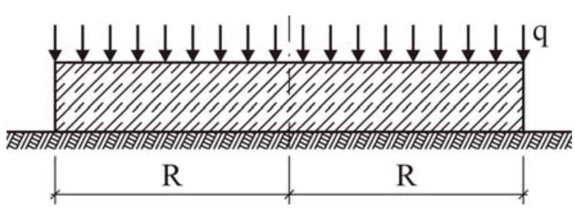
where:
σ_{zd} – the additional tension,
$\sigma_{z\rho}$ – the primeval tension.

To identify the active depth of the ground surface, the subsidence of a stiff circular foundation with the radius R = 1,0 m loaded with the equally placed load with the intensity q = 10,0 kN.m^{-2}, was analyzed. The values of subsidence of this foundation for different types of ground are presented in Table 9.

Table 9. The subsidence of a circular foundation

Edomethrical modulus of general compressibility of a ground M_o [MPa]	Subsidence values [mm] calculated from the depth Z:				
	1.2R	2.0R	3.0R	4.0R	5.0R
50	0.199	0.263	0.305	0.328	0.342
100	0.100	0.132	0.152	0.164	0.171
150	0.066	0.088	0.101	0.109	0.114

q = 10. 0 kN.m^{-2}
R = 1. 0 m

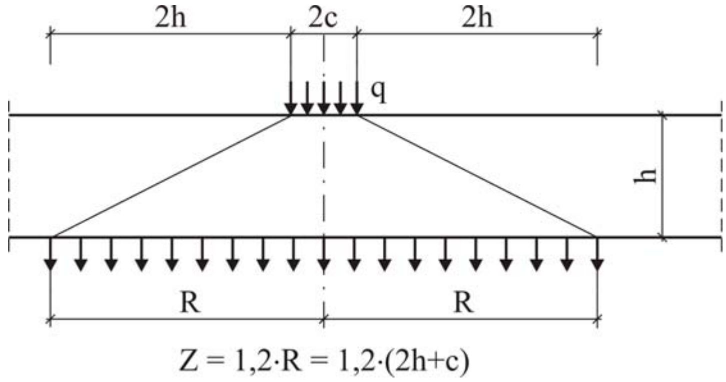


The calculations showed that at the depth of Z = 1,2 R the condition is fulfilled:

$$\sigma_{zd} = 0.25 \cdot \sigma_{z\rho} \tag{3.16}$$

which means that according to the relation (3.15) the depth Z= 1,2 R may be defined as the active one. Generalizing these considerations, a rule which defines the active depth presented in picture 3.3 [9] may be accepted.

Fig. 4. The way of defining the active depth of the subsoil: h – thickness of a board, c – vicarious radius of loading sign, Z – active depth of the subsoil, R – substitute radius of the circular foundation – see Table 9



Substitute modulus of ground deformation

In case of the layered surface, the grounds occurring to the active depth Z (see Fig. 4), should be accepted in present considerations. The value of the substitute deformation modulus may be nominated from the model:

$$E_{oz} = \frac{\sum_{i=1}^{n} E_{oi} \cdot h_i}{\sum_{i=1}^{n} h_i} \tag{3.17}$$

where:
E_{oi} – deformation modulus of an “i” layer,
h_i – pulp of the “i” layer.

It is worth noticing that there is also:

$$Z = \sum_{i=1}^{n} h_i \tag{3.18}$$

Thermal stresses

As the result of the temperature differences between the upper and lower surface, a board could easily deform if the elms did not cumber it (joint with the ground surface, connection between the contiguous boards). As the result of these bonds there are different kinds of tension that may be estimated on the basis of the models [8]:

$$\sigma_{KL,KB} = \frac{1}{2} \cdot C_{L,B} \cdot E \cdot \varepsilon_T \cdot \Delta T \tag{3.19}$$

$$\sigma_L = \frac{E \cdot \varepsilon_T \cdot \Delta T}{2 \cdot \left(1 - \nu^2\right)} \cdot \left(C_L + \nu \cdot C_B\right) \tag{3.20}$$

$$\sigma_B = \frac{E \cdot \varepsilon_T \cdot \Delta T}{2 \cdot \left(1 - \nu^2\right)} \cdot \left(C_B + \nu \cdot C_L\right) \tag{3.21}$$

where:
L, B – size of the board [m],
$\sigma_{KL, KB}$ – the tension on the parallel edge respectively to L and B [MPa],
$\sigma_{L, B}$ – the tension in the middle of the slab in the direction L, B [MPa],
E – the springiness modulus of concrete [MPa],
ν – Poisson's coefficient for the concrete (ν = 0,2 [11]),
ε_T – thermal linear expansibility coefficient (for the concrete $\varepsilon_T = 10^{-5}$ [$^oC^{-1}$], [11]),
ΔT– the temperature difference between the upper and lower surface of the slab [$^oC^{-1}$],
$C_{L,B}$ – coefficients depending on the size of the slabs and the stiffness radius "l".

The stiffness radius "l" is described by the model [8]:

$$l = 0.6 \cdot h \cdot \sqrt[3]{\frac{E}{E_o}} \qquad (3.22)$$

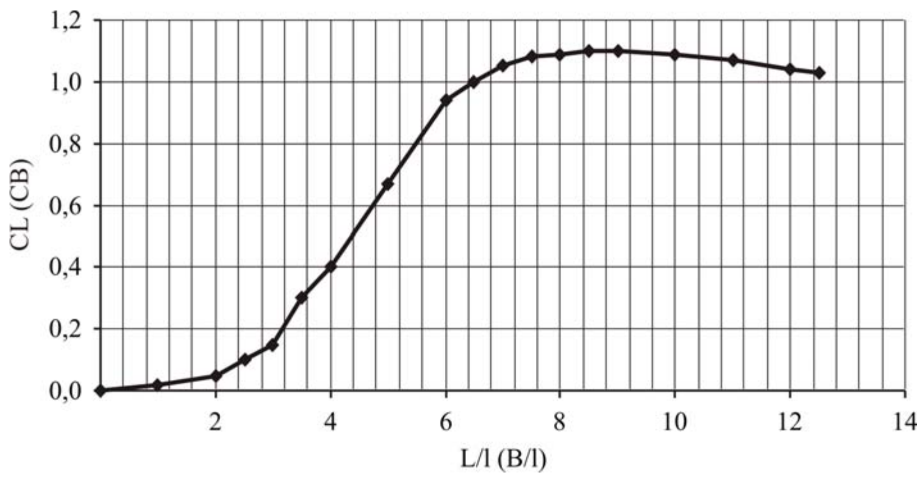
where:
h – the thickness of the board [m],
E_o – t he ground deformation modulus [MPa].

The types of tension in the corners of the board should be estimated on the basis of:

$$\sigma_o = \sqrt{\sigma_{KL}^2 + \sigma_{KB}^2} \qquad (3.23)$$

The values of coefficients C_L and C_B are presented in the picture 3.4 [8].

Fig. 5. The values of coefficients C_L i C_B



If the thermal tension, estimated on the basis of dependencies (3.19) ÷ (3.21) i (3.23), may be accepted as working in the prolonged way, it is justifiable to take into account the relaxation of tension caused by creeping of concrete. For the enough hardened concrete the relaxation of tension may be taken into account on the basis of the model [16]:

$$\sigma_{(t)} = \sigma_{(t_0)} \left[1 - \psi_{(t,t_0)}\right] \qquad (3.24)$$

where:
t_o – the time of the initial loading,
t – the time for which the calculations are made,
$\sigma_{(to)}$ – tension at the moment t_o, $\sigma_{(t)}$ – tension at the moment t (after the time (t - t_o)),
$\psi_{(t,to)}$ – the relaxation of tension coefficient at the time (t - t_o).

The relaxation coefficient may be defined from the dependency [16, 19]:

$$\psi_{(t,t_o)} = \frac{\Phi_{(t,t_o)} \dfrac{E_{(t,t_o)}}{E_{28}}}{1 + k\Phi_{(t,t_o)} \dfrac{E_{(t,t_o)}}{E_{28}}} \tag{3.25}$$

where:
$\Phi_{(t,to)}$ – the creeping coefficient [-] (may be defined on the basis of the Table A1 in [11]),
$E_{(t,to)}$ – the elasticity modulus of concrete after time t_o [MPa],
E_{28} – the elasticity modulus of concrete after 28 days [MPa],
k – the ageing coefficient (may be accepted k = 0,8 [19]).

Shrinkage stresses

The shrinkage stresses in the board may be estimated on the basis of the models given earlier (3.19.) ÷ (3.21.) and (3.23.), substituting the product $\varepsilon_T \cdot \Delta T$ with the value ε_{SK}, which means the shrinkage deformation of concrete. The value ε_{SK} may be estimated on the basis of the considerations present in annex B of the norm [11]. In case of the shrinkage stresses, the rheological effects described by the models (3.24) and (3.25) may be taken into account.

The model of concrete slab exertion

To the analysis of the exertion the Zandel`s hypothesis may be used. Its basic presumptions were given in the work [17]. According to this hypothesis, the boundary state of concrete exertion is present when the maximum deformation shape is reached. By use of the general presumptions of this hypothesis, the model of concrete exertion was proposed and is described by the model [16]:

$$W = \frac{\sigma_1}{f_{ctg}} + \left(1 - \frac{f_{ctg}}{f_{cd}}\right) \cdot \frac{\sigma_2}{2 \cdot f_{ctg}} - \frac{1}{f_{cd}} \cdot \sigma_3 \tag{3.26}$$

where:
$\sigma_1 \geq \sigma_2 \geq \sigma_3$ – the main tensions,
f_{cd} – design compression strength of concrete [MPa],
f_{ctg} – design bending strength of concrete [MPa].

The design bending strength of concrete f_{ctg} may be estimated on the basis of the properly modified Weitzman's model [18]:

$$f_{ctg} = \frac{2 \cdot f_{ctd} \cdot f_{cd}}{f_{cd} + f_{ctd}} \tag{3.27}$$

where:
f_{ctd} – design tensile strength of concrete [MPa].

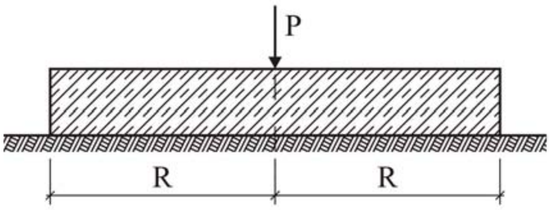
In the analyzed case of boards on the elastic ground, the complex state of tensions is present. If one presumes that the main directions are consistent with the directions of L and B size of the analyzed board, it seems then that the equation (3.26) will allow to estimate more precisely the level of the board concrete tension.

To estimate the values of the tension σ_3 that is present in the model (3.26) the analysis of the arrangement of ground stand for the different types of stiffness boards [13] was made. The results of these considerations for the round boards are presented in Table 10.

Table 10. Stands for the different types of stiffness slabs [13]

Slab \ ρ	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Comple-tely stiff	0.159	0.160	0.162	0.167	0.174	0.184	0.199	0.223	0.265	0.365	∞
With the finite stiffness	0.35	0.34	0.31	0.29	0.26	0.25	0.25	0.26	0.28	0.37	-
Flaccid	1.33	1.25	1.04	0.78	0.56	0.42	0.33	0.20	0.0	-	-

- Round slabs were considered, with the radius R loaded with the condensed load P =1 put in the middle of the slabs.
- $\rho = \frac{r}{R}$ – relational radius of the point of stand



Taking into account to the further considerations the board with the finite stiffness, the tension σ_3 in the lower surface of the slab around its center will be [13]:

$$\sigma_3 = \overline{p} \cdot \frac{P}{R^2} \quad (3.28)$$

The further considerations made in [9] showed that the participation of tension σ_3 in exerting the concrete does not surpass 0,5%. So for the practical aims it may be accepted that $\sigma_3 = 0$. The main tensions σ_1 i σ_2 present in the equation (3.26) may be calculated on the basis of the dependencies (3.1) ÷ (3.3), taking into account the thermal and shrinkage influences. It may be written that:

- for the center of the board

$$\sigma_1 = \sigma_I + \sigma_{L,\,T,\,\Phi} + \sigma_{L,\,SK,\,\Phi} \quad (3.29.1)$$

$$\sigma_2 = \sigma_I + \sigma_{B,\,T,\,\Phi} + \sigma_{B,\,SK,\,\Phi} \quad (3.29.2)$$

$$\sigma_3 = 0 \quad (3.29.3)$$

- for the L and B edge

$$\sigma_1 = \sigma_{II} + \sigma_{KL\,(KB),\,T,\,\Phi} + \sigma_{KL\,(KB),\,SK,\,\Phi}, \quad (3.30.1)$$

$$\sigma_2 = 0 \quad (3.30.2)$$

$$\sigma_3 = 0 \quad (3.30.3)$$

- for the corner of the board

$$\sigma_1 = \sigma_{III} + \sigma_{o,\,T,\,\Phi} + \sigma_{o,\,SK,\,\Phi}, \quad (3.31.1)$$

$$\sigma_2 = 0 \quad (3.31.2)$$

$$\sigma_3 = 0 \quad (3.31.3)$$

The stresses (except σ_I, σ_{II}, σ_{III}) that are present in models (3.29) ÷ (3.31) indicate respectively thermal or shrinkage tensions taking into consideration the rheological effects.

THE SOLUTIONS OF PAVEMENT SLAB DILATATIONS

Structural-material solutions of neighboring slabs should be chosen with regard of [21, 34]:

- it joins kind,
- the kind of movement (pedestrian, trolleys, cars etc.),
- it joins structural solutions,
- resistance on external factors action,
- aesthetical requirements.

Among these solutions should be in favour:

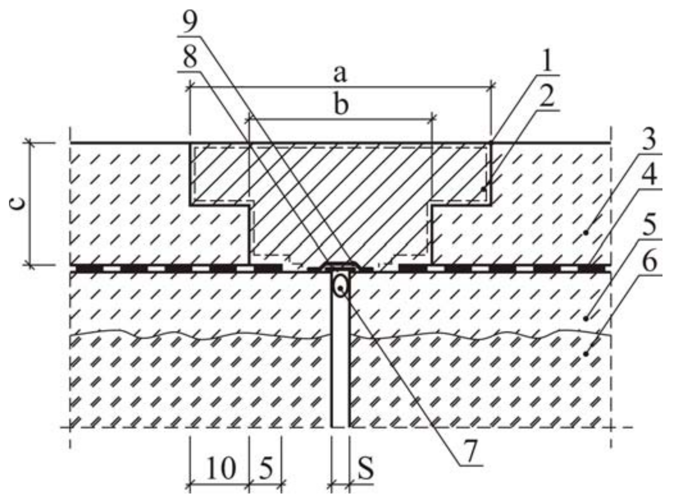
- elastic fulfillments,
- dilatation tapes,
- dilatation profiles.

As elastic fulfillments will be applied the different kinds of mastics. For example there are:

- silicate mastic [30],
- elastic mastic [31, 33],
- dilatation gel [32],
- two-component enrolment resin [33],
- elastic two-component enrolment resin [36],
- polyurethane mastic [37, 39],
- self-leveling polyurethane mass [38],
- bituminous mastic [39],
- enrolment-polyurethane mastic [39],
- bituminous dilatation fulfillment [40].

A special attention deserves the bituminous dilatation fulfillment, making up the integral part of pavement [40]. It is a part of vertical important useful loads transferring area and deformations compensating zone as well. Scheme of bituminous dilatation fulfillment was showed on Figure 6.

**Fig. 6. Scheme of bituminous dilatation fulfilment [40]:
1 – primer coat, 2 – aggregate+binding agent, 3 – concrete pavement slab, 4 – isolation, 5 – concrete subgrade, 6 – foundation, 7 – spongy elastic insertion, 8 – stabiliser, 9 – membrane**



The dilatation tapes are represented mainly by:

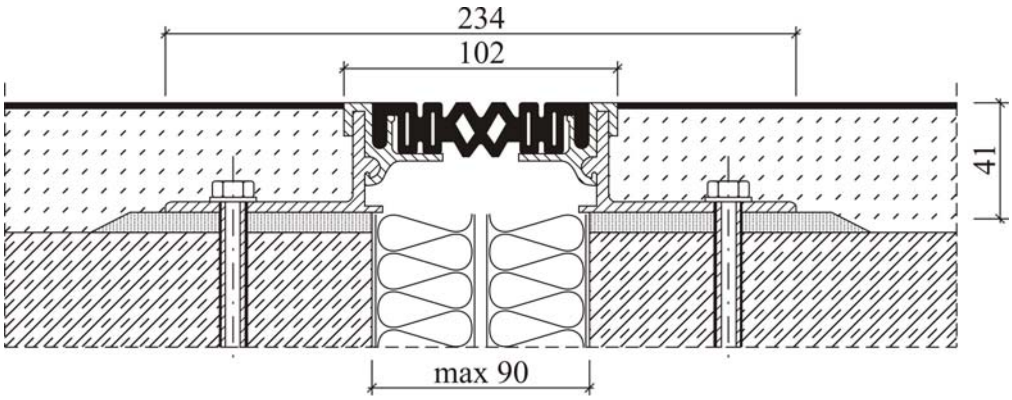
- elastic tapes stuck with the help of elastic enrolment glue [36],
- elastic tapes of PVC [34],
- modified bituminous coats [36].

Dilatation profiles are produced from materials resistant on mechanical action and corrosion as well. There are represented mainly by:

- aluminum profiles [34],
- aluminum profiles with elastic fulfillment [34, 35],
- precious steel with elastic fulfillment [34].

The example of dilatation profiles is introduce on Fig. 7. The different solutions of dilatation profiles can be found in study [35].

Fig. 7. Aluminium profile with elastic fulfilment [34]



MODERN SCIENTIFIC-RESEARCH PROBLEMS OF CONCRETE GROUND FLOORS

On the basis of the analysis of conference materials [23÷28] the main interest of the researchers has concentrated lately on:

- estimating the efficiency of the surface improving methods [23, 24],
- searching for the estimation of the boards durability near its external surface methods [26, 27],
- the analysis of the necessity of using dilatation fissures [28],
- the analysis of the properties of the concrete armed with fibers [27],
- the analysis of the quality of the aggregate and its influence on the durability of concrete surface [26]
- problems of the surface humidity control.

The authors [24] analyzed the problem of adhesion between the layer of flooring and the concrete board. This problem is important in case of both: the industrial floors and repairing, and protective systems. By means of the test “pull – off”, the authors [24] analyzed the influence of the chosen agents on the adhesion of both materials. In the paper [25] the harmful influence of humidity on buildings and health of the users of these buildings was presented. The humidity coming in from the external sources may be very arduous. The problems and issues connected with the control of buildings humidity were described and the new channel system, which causes the increase in the speed of drying the surface just after the concrete is laid and during the time of usage, was presented. The authors [28] analyzed this problem connected with looking for the methods of the reduction of concrete materials shrinking that rest on using the expansive materials. They analyzed the impact of the expansion connected with:

- forming of $Mg(OH)_2$ from MgO with the presence of water,
- forming of $Ca(OH)_2$ from CaO with the presence of water,
- emerging of three calcic sulphate aluminum for the reduction of the cement materials
- shrinkage.

Recently the following topics were discussed on the 6. Colloquium “Industrial Floors ‘07” [45]:

- slabs on ground under climatic,
- rubber concretes,
- repair of damage by chloride induced corrosion,
- self-compacting fiber reinforced concrete,
- revitalization-industrial rehabilitation etc.

CONCLUSIONS

The main function of the ground floor is to transmit static and dynamic loads and to save performance over required time in environment of the influence of different agents. Because of the hard exploitation conditions, together with the influence of different agents destructing the ground floors, they must fulfill some usable requirements. To fulfill the service life requirements that are connected with the concrete ground floors, they must get the proper structure.

The proper essence of the ground floors was defined in this paper. Literature analysis made possible to defined the basis for shaping of geometry of concrete ground slabs. On the basis of considerations, analyses and calculations the proper method of defining the vertical susceptibility of the subsoil in the function of the subsoil deformation modulus was proposed. The proper active depth of the subsoil was defined as well.

The model of concrete slab exertion, which makes it possible to take under consideration the complex state of stresses in the slab at the place of putting the loads, was proposed. The rheological effects may be taken into consideration. The relaxation coefficient make this possible.

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