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Secţia
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STUDIES ON GAS DIFFUSION COEFFICIENT IN SOIL

BY

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Abstract. Knowing the diffusion coefficient is very important to develop formulas for the course of gas in porous medium and to improve basic understanding of involved transport processes. Key parameters of the gas transport in soil, their diffusion capacity air permeability and the variation of these according to the soil type plays an important role in the gas leakage problems in the soil, including chemical volatilization for contaminated areas, production and release of gas emissions.

Key words: gas diffusion coefficient; diffusion laws; tortuosity-connectivity factor; air porosity; soil-water characteristic curve.

1. Introduction

Knowing the diffusion coefficient is very important for the development and application of mathematical models describing the movement in porous media and to improve understanding the involving transport processes.

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Soil gas diffusion coefficient is influenced by soil porosity, which itself is determined by texture, structure and compaction or aeration degree.

Soil pores have different shapes and sizes, irregular routes and they are less or more occupied with water. For this reasons the transport coefficients depends on: water saturation degree, pore geometry and the combined pore tortuosity–connectivity factor (Bear, 1972). Especially pore geometry, pore size distribution, their topology area and internal space links influence the flow and transport of water, air, solute and heat (Vogel & Roth, 1998; Allaire-Leung, 2000; Vogel, 2000). For example, because of the soil pore geometry and their variable size, the pore water velocity is extremely variable. Larger pores conduct water more rapidly, and the resistance of pore walls causes a decreasing water velocity from the center of the pore to outside. But other factors such as continuity and connectivity of liquid phase in porous space control the movement of water. When the soil is saturated, all pores are filled with water and the liquid phase is constant.

Establishing the exact relationships between transport coefficients and pore geometry seems extremely difficult and, therefore, usually are adopted some simple models. Bear (1972) stated that microscopic characterization of porous area is impossible. Therefore, it is assumed that the porous space is represented by a group of parallel cylindrical capillary tubes and the distribution of equivalent size capillary tubes was used to characterize soil pore size. The first fundamental equation used to establish a connection between the regular rate of saturated fluids and the size of porous area is Poiseuille's law. According to this law, if a cylindrical capillary tube has a R radius, the volume of water drained per unit time through that tube, under a given pressure, is proportional to the fourth power of the radius

$$Q = \frac{\pi R^4 \Delta P}{8 \mu L_{\mathrm{st}}}, \tag{1}$$

where: Q represents the volumetric flow rate of the water, (L^3T^{-1}); μ – the dynamic viscosity, ($M\,L^{-1}T^{-1}$); ΔP – the hydrostatic pressure difference, (FL^{-2}), across straight tube length L_{st}.

To establish a link between emergente point formula and pore structure, Fisher (1998) had developed a series of procedures to determine: soil water retention, gas conductivity and pore geometry of undisturbed soil samples. In particular, the combination of thin sections and image analysis technique of the undisturbed samples was used to identify the pore structure of samples. Their analysis showed that the air phase continuity is the major factor controlling its conductivity. On the other hand, filling the cracks with soil particles is blocking the pathways of air phase due to the absorption of the liquid phase on the particles surface reducing air conductivity. Therefore, application of continuous phase model, as was proposed by Fisher (1996, 1997, 1998) and Dury (1998), could be useful for calculations, only in limited circumstances. However, to improve the efficiency calculations of these models are required physically based models or new concepts that explain sinuosity and connectivity parameter.

Another important parameter, in addition to the emergent point is the tortuosity and connectivity parameter. The effect is expressed by the tortuosity and connectivity exponent, and their size is synonymous with the pore size distribution terms of Burdine and Mualem permeability models. Since the tortuosity exponent is not based on theoretical arguments, it is usually considered a optimized parameter with a common value (= 0.5 for Mualem's eqs. and = 2 for those of Burdine), as well as for water conductivity . Theoretically, the tortuosity and connectivity parameter for water and air conductivity should be different because of the separate trajectories and connectons of the corresponding fluid phases

Therefore, different models explaining the variation of tortuosity and connectivity should be used to observe transport in water and liquid phases of unsaturated soils for both convective and diffusive transport processes. The tortuosity involved in diffusive transport processes is just a property of the porous media, which is the average path length of molecules (or particles) passing through a cross sectional area of porous media at a certain time.

All the transport processes, including diffusion, are mainly controlled by soil structure. The characterization of geometric properties of the soil structure is so important that these properties should be considered and incorporated into the diffusion formulas for different structural units (Vogel, 1997). Due to the complex geometry of soil structure, it is necessary to perform simplified geometry characterization of soil components, such as spherical, cylindrical or flat components of soil (Currie, 1961; Millington & Shearer, 1971; Collin & Rasmuson, 1988; Rappoldt, 1990; Bird & Dexter, 1994). Millington & Quirk (1961) and Currie (1961) had developed some relative formulas of diffusion based on statistical pore geometry concepts. To explain the influence of complex geometry on diffusion, were adopted techniques based on capillary tube model, bi- or three-dimensional, Fick's law and relatively simple formulas of diffusion (Horgan & Ball, 1994, Steele & Nieber, 1994; Friedman, 1995; Horgan, 1999).

2. Mathematical Models Describing Gas Diffusion in Soil

Knowing that molecular diffusion is a dynamic process, Fick developed diffusion laws in analogy with Fourier's heat law (Crank, 1975; Jaynes & Rogowski, 1983; Rolston, 1986; Cussler, 1997, Ball & Smith, 2001).

One-dimensional diffusion of gases in soil can be described by

$$\frac{V_{\text{gas}}}{At} = v_{\text{gas}} = -D_g \frac{\partial C}{\partial x}, \tag{2}$$

where: V_{gas} is the amount of diffusing gas, (M); A – the cross sectional area of the soil; t – time; v_{gas} – the gas flux density; C – the bulk soil concentration of gaseous phase; x – soil distance; D_g – the so-called gas diffusion coefficient in soil.

Buckingham (1904) was among the first to suggest that there is a general relationship between gas diffusion coefficient and air-filled soil porosity

$$\frac{D_g}{D_0} = a^2, \tag{3}$$

where: exponent 2 – account for tortuosity; D_g – gas diffusion coefficient in soil; D_0 – gas diffusion coefficient in air; a – air porosity.

Later, Penman (1940) proposed a universal formula for saturated porous media

$$\frac{D_g}{D_0} = \frac{1}{\tau}a, \ (0 < a < 0.7), \tag{4}$$

where: $\tau \cong 2$ represents a tortuosity-related constant.

Then Penman adapted eq. (4) to experimental data and obtained the known linear expression

$$\frac{D_g}{D_0} = 0.66a, \tag{5}$$

where 0.66 is a universal tortuosity coefficient for all porous materials.

Marshall (1959) pointed out that the Penman formula (1940), (s. eq. (5)), did not consider air phase discontinuities. In the research, Marshall concluded that the constant 0.66 from eq. (5) should be replaced by $a^{1/2}$, suggesting the eq.

$$\frac{D_g}{D_0} = a^{3/2}. \tag{6}$$

Millington (1959) modified Penman's eq. (1940), introducing a tortuosity coefficient, as a function of air-filled soil porosity ($\tau = 1/a^{1/3}$) namely

$$\frac{D_g}{D_0} = a^{4/3}. \tag{7}$$

The relationship between gas diffusion capacity and air content was considered as an exponential function of air content and porosity (Millington & Quirk, 1960)

$$\frac{D_g}{D_0} = \frac{a^{10/3}}{PT^2}. \tag{8}$$

In this eq., it is assumed that all-filled pores contribute equally to the diffusion. Sallam (1984), Xu (1992), Petersen (1994), Washington (1994), Jin & Jury (1996) and Moldrup (1996) compared eq. (8) with other models of diffusion capacity. Although usually eq. (8) gives lower values diffusion capacity for certain soils is possible to be applied with good results.

Another type of relationship is the Millington-Quirk's eq.

$$\frac{D_g}{D_0} = \frac{a^2}{PT^{2/3}}. \tag{9}$$

Compared with the experimental results this eq. leads to much better results for different types of soils with different textures (Jin & Jury, 1996; Washington, 1994). On the other hand, Petersen (1994) demonstrated that eq. (9) underestimates the diffusion coefficient of several gases, especially when the air content in soil is high. However, when the air content is low, this formula is appropriate.

Moldrup developed another formula valid for the disturbed structure soils by introducing a linear term. This term is equal to the ratio between air content and total porosity of the soil

$$\frac{D_g}{D_0} = a^{3/2}\left(\frac{a}{PT}\right) = \frac{a^{2.5}}{PT}. \tag{10}$$

This formula is best considered when are used data from the materials. Moreover, Moldrup (2000) has shown that this formula is not suitable for organic soils because wet organic materials have a different tortuosity variation from those minerals. In general, gas diffusion formulas above, extended by the basic formula of Buckingham (1904) to the new formula (10), depend only on the total porosity of the soil, which is slightly higher for fine textured soils than the grossly textured. Recently, a number of studies concerning the undisturbed soil samples showed the dependence of the diffusion coefficient on the type of soil (Freijer, 1994; Moldrup, 1996, 1997, 2000; Schjønning, 1999), indicating the need to include some soil pore parameters in the predictive gas diffusivity models.

Using the gas diffusion coefficient at higher air content, Moldrup (1996) proposed the following formula of the gas diffusion:

$$\frac{D_g}{D^*} = \left(\frac{a}{a^*}\right)^{\delta}, \tag{11}$$

where: D^* is a matching point diffusion coefficient measured at the highest air content, a^*; δ – a soil-dependent exponent that takes into account pore tortuosity, constrictivity and connectivity

He adopted three well-known expression for δ, but he developed an own formula namely

$$\delta = 1.5 + \frac{3}{b}. \tag{12}$$

That fit well with the experimentally obtained results of the gas diffusion coefficient. The value of 1.5 is considered average tortuosity and $3/b$ is defined as pore water release factor.

Moreover, Moldrup (1997) combines the diffusion formula of Penman(1940) and Millington & Quirk's (1960,1961) to develop a formula that does not depend on soil type, by introducing a tortuosity parameter, *d*, called Penman-Millington-Quirk (PMQ) formula

$$\frac{D_g}{D_0} = 0.66PT\left(\frac{a}{PT}\right)^{(12-d)/3}. \tag{13}$$

Fitting this eq. to measured data, they showed that a *d*-value of 3 (high tortuosity) in undisturbed soil and a *d*-value of 6 (medium tortuosity) for sieved, repacked soils improved predictions, as compared to earlier two-parameter models.

Using a database of 126 undisturbed soil samples, Moldrup (2000) established a general empirical relationship between diffusion coefficient and the air content value at –100 cm soil suction. Combining these expressions with the Burdine-Campbell formula and the model proposed by Moldrup (1996, 1997), was developed a simple relative diffusivity model based on soil–water characteristic curve

$$\frac{D_g}{D_0} = \left(2a_{100}^3 + 0.04a_{100}\right)\left(\frac{a}{a_{100}}\right)^{2+3/b}, \tag{14}$$

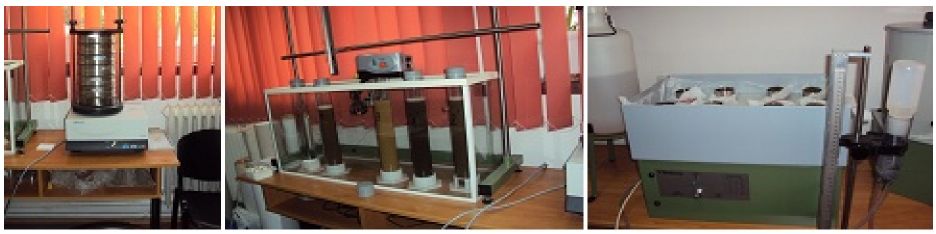
where: the $3/b$ term was defined as a pore water release factor.

This new formula gave the best results compared to all others that have been used so far, but requires knowledge of soil water data, at least two different values for soil–water characteristic curve, including characterization of porosity.

3. Laboratory Measurements and Calculation of Gas Diffusion Coefficient

To determine the gas diffusion coefficient in soil were made a series of tests on a type of soil in Soil Science Laboratory of the Faculty of

Hydrotechnics, Geodesy and Environmental Engineering of Iaşi, with the devices shown in Fig. 1.



a *b* *c*

Fig.1 – Used devices: *a* – the sieve device; *b* – pipetting device; *c* – sand box to determine the soil-water characteristic curve.

Laboratory researches have followed the soil characterization in terms of: texture, stability, structure, bulk density and porosity.

The obtained data of texture composition and bulk density were introduced in SOILPARA program, which has generated soil-water characteristic curve (Fig. 2).

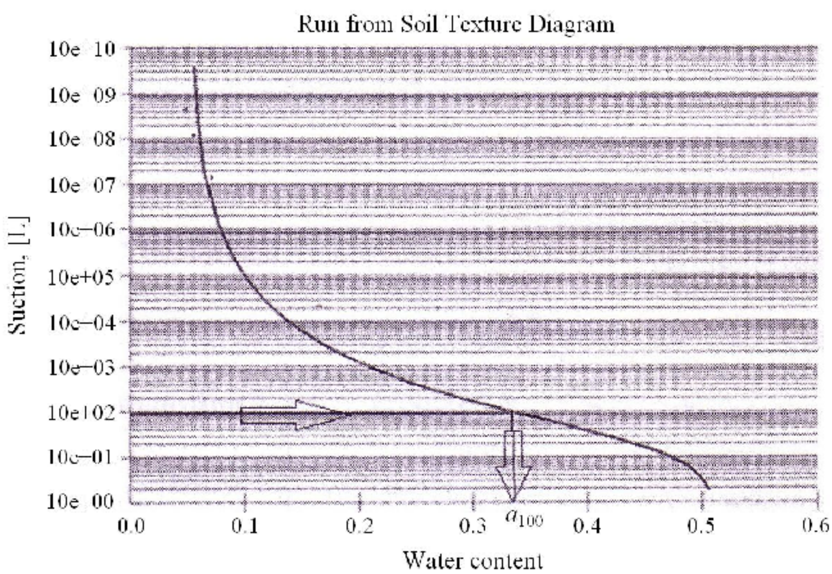


Fig. 2 – Soil-water characteristic curve.

Table 1 presents the results obtained in the laboratory for characterization of soil under study, and in Table 2 the results of relative gas diffusion coefficient in soil, calculated with different relationships in wich have been used experimentally obtained values determined for the parameters of these relationships.

Table 1
Soil Characterization

Sample	Texture			D_a g/m^3	PT %	a %	a_{100} %	θ %
	A, [%]	P, [%]	N, [%]					
1	24.13	62.07	13.80	1.30	50.9	22.4	33	28.5

A – clay; P – silt; H – sand.

Table 2
Calculation of Gas Diffusion Coefficient Relative in Soil

D_g/D_0							
1	2	3	4	5	6	7	8
$0.66a$	$a^{2/3}$	$a^{4/3}$	$a^{10/3}/PT^2$	$a^2/PT^{2/3}$	$a^{2.5}/PT$	$0.66PT(a / PT)^{(12-d)/3}$	X
0.1478	0.3725	0.1367	0.1210	0.1148	0.0833	0.1482 for high tortuosity 0.2075 for medium tortuosity	0.0382

$X = \left(2a_{100}^3 + 0.04a_{100}\right)\left(a/a_{100}\right)^{2+3/b}$

From the analysis of the values shown in Table 2 it results the following observations:

1. Calculated values of gas diffusion coefficient relative in soil varied in very wide limits being influenced by the structure of models used.

2. The models used for calculating the gas diffusion coefficient relative in soil can be grouped as follows:

a) Models based on the air porosity (1, 2, 3).

b) Models based on the air porosity and total porosity (4, 5, 6).

c) Models based on the air porosity, total porosity and tortuosity (7).

d) Models based on the air porosity at a tortuosity value of 100 cm CA.

3. Comparing the results with the models from the first category we can see that the models from second category are more uniform than those from first category; in the first case the difference between maximum and minimum value is 27.44%, than 63.30% in the second case.

4. The tortuosity is a significant pore size characteristic which influence the gas diffusion coefficient in soil (0.1482 for high tortuosity and 0.2075 for medium tortuosity, the difference being 28.57%).

The lowest values of the gas diffusion coefficient relative in soil were obtained with the model 7.

4. Conclusions

Knowledge of soil characteristics and traits is a fundamental scientific material for sustainable exploitation of a territory, which includes, besides the edaphic information and that of environmental conditions.

Currently in the national and international literature are found more and more studies and researches concerning the mathematical models for determining the gas diffusion coefficient in soil. Physical chemical and biological analysis, performed out in laboratories, are often used only to calibrate mathematical models. This is actually aimed at reducing the costs of investigation.

Gas diffusion in soil and its dependence on its characteristics controls the transport of diffuse oxygen, gas emissions and the volatile organic pollutants from agriculture, forest and urban soils. Appropriate formulas are needed to determine the gas diffusion as a function of air-filled soil porosity (*PT*) in natural uniform soils.

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STUDII PRIVIND COEFICIENTUL DE DIFUZIE A GAZELOR ÎN SOL

(Rezumat)

Cunoaşterea coeficientului de difuzie este foarte importantă pentru elaborarea formulelor pentru cursul gazelor în mediul poros şi pentru a îmbunătăți înțelegerea proceselor de bază de transport implicate. Parametrii principali ai transportului gazelor în sol, capacitatea de difuzie a acestora permeabilitatea aerului şi variația acestora în funcție de tipul solului joacă un rol important în problemele de degajare a gazelor din sol, incluzând volatizarea chimicalelor din zonele poluate, producerea şi degajarea gazelor de seră.

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THE EFFECT OF THE OLT RIVER'S BED ERROSION UPSTREAM TUŞNAD ON THE HYDRO-GEOLOGY OF THE FLOOD PLANE AND DRAINAGE SYSTEMS

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Abstract. The regulation and embankment of the River Olt in the Mădăraş – Tuşnad sector, inside the Harghita depression, has been followed by changes of the river bed by erosion and silting, this bringing negative influence on tributaries, too. The natural drainage of the hydro-geographical network has strong effects on the flood plane hydro-geology and on the neighboring land groundwater table. The altering of the groundwater table significantly changed the functionality of drainage systems. The lowering of water table in the erosion areas and its effects on drainage systems has been outlined in the paper by direct observations and also by a mathematical modeling of the phenomenon.

Key words: drainage; erosion; groundwater table; river regulation.

1. Introduction

The shortcomings caused by floods, event that occurs two or three times a year in the Ciuc depression, between Mădăraş and Tuşnad, involved the river regulation. Referring to this issue various studies have been commenced even

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since 1901, and in 1985 the River Olt has been finally regularized on the above mentioned sector.

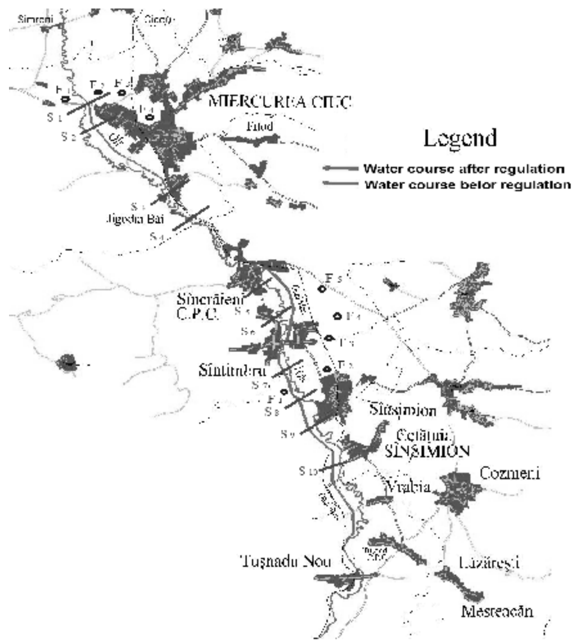


Fig. 1 – The Olt River course before and after its regulation between Mădăraş and Tuşnad.

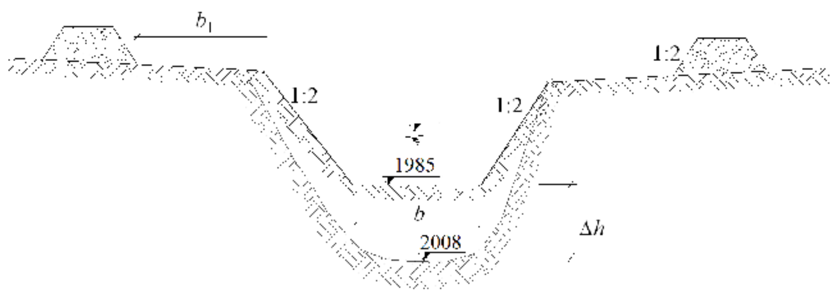


Fig. 2 – S2 cross section, original river bed (1985) and deformed river bed (2008).

These works consist in: a new bed of the Olt River between Sicureni and Tuşnad; correction and consolidation of the channel on the most important sectors (towns, villages, overcrossings of communication services); embankment of the course and backwater dams on tributaries. The river length on the regularized sector has been reduced by 20.8 km, that is from 61.3 km to 41.5 km, this representing about 34% of the original length. The river new cross section, after the regulation and embanking, has a double trapezoidal profile (Fig. 2), with different sizes in the built up area and outside (Table 1). Due to regulation works the general slope has increased from about 0.6‰ to about 1.25‰, with variability from up- to downstream. Fig. 2 and Table 1 are showing the riverbed deformation surveyed during the 1980…2008 period. The new riverbed has not been provided with reinforced ledger structures for stability of the riverbed.

Table 1

Characteristics of Completed Transversal Sections (1985) and Deformed Ones (2008)

Section	Bottom level		Δh	Distance	i	b	b_1
S	CF (1985)	CF (2008)	m	m	‰	m	
1	657.43	656.11	–1.29	0+000	1.25	10	10
2	657.30	654.36	–2.94	0+105	1.25	10	10
3	653.05	652.79	–0.26	3+500	1.25	10	3
4	652.76	651.32	–1.41	3+570	4.15	10	10
5	644.39	646.20	1.21	13+950	0.6	10	10
6	643.64	643.89	0.25	15+200	0.6	20	50
7	643.51	643.88	0.37	15+420	0.6	20	50
8	640.66	641.41	0.75	20+170	0.6	20	50
9	640.33	640.92	0.39	20+720	0.6	10	10
10	639.90	640.11	0.21	21+440	0.6	10	10

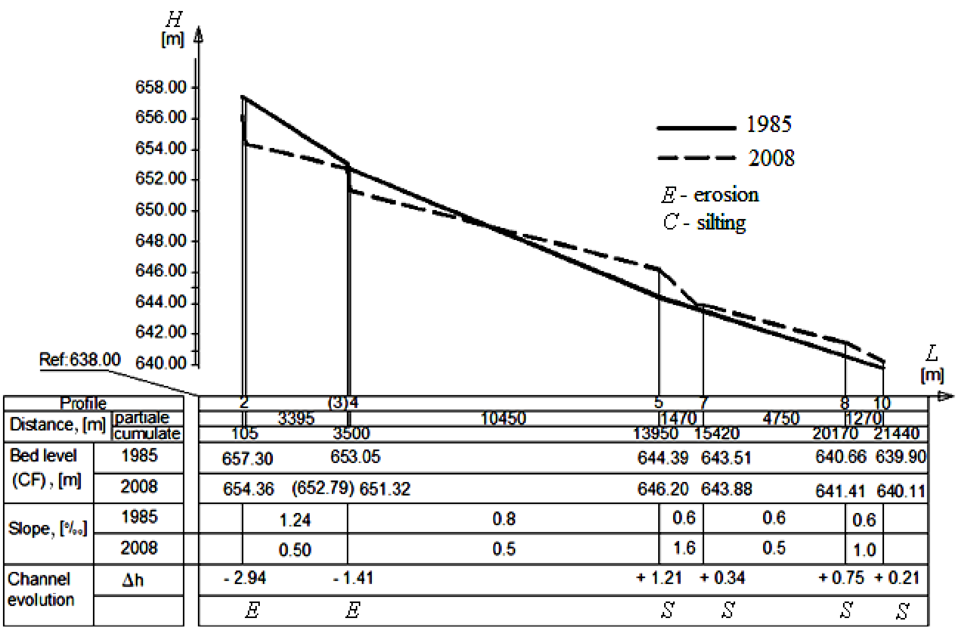


Fig. 3 – Olt River, longitudinal profile, the Miercurea Ciuc-Sânsimion sector.

The longitudinal profile shown in Fig. 3 has been drafted at the end of construction period (1985) and again after 23 years of operation (2008). The P2 cross section in Fig. 2 and the riverbed level differences, recorded at the beginning and the end of survey period, are proof of morphological changes.

On the upstream sector, up to Sâncrăieni, erosions are present (maximum 2.94 m river bed deepening). Downstream, the alluvial silt layer reaches a 1.21 m maximum thickness (in 2011 at Sâncrăieni and downstream de-clogging works have been conducted, representing a volume of about 60 000 m^3).

After the completion of regularization works, in 1985, at Jigodin (profile 3) a threshold-ledger has been constructed, for catchments of industrial water. The need for such threshold has resulted from the severe erosions that were hampering all catchments systems.

2. Effects of Morphological Changes of the Olt River Bed on the Hydro-Geology of Embanked Flood Plane

Simultaneously with the Olt River regulation and embankment works carried in Ciuc Depression, on the protected flood plane other drainage works have been conducted in order to improve lands which, finally, have been transformed from a meadow with water excess into arable land (Finney, 1997). The drainage systems (open–closed) convey the discharge of surface runoffs (water from rain and melting snow) and also the drainage water (at a depth corresponding to the drainage rate in the conditions of water excess balance) to the river.

The 13 drainage systems inside the embanked flood plane (*e.g*. Fig. 4) are located on both sides of the Olt River, from Ciceu to Tuşnad. These systems are evacuating by gravity the collected waters towards the emissary as long as the level differences are positive (*i.e.* the differences between the drainage channels and the river level). During flood on the river, those differences become negative and the reversed water flowing (towards the drained enclosures) is prevented by check valves (in the embankments under-crossings).

The hydrographic network of the analysed area consists in the River Olt and its tributaries; they ensure the collection and discharging of both surface and ground water. The embankments are interrupting the natural possibility for surface runoffs discharge to the river and that is why there must be some collecting channels besides the embankment. These channels must provide a controlled discharge that ensures unidirectional flows, from the channels to the river. The artificial drainage network (with open canals or possibly closed drains) is speeding-up the drainage of surface water (up to the time limit allowed for crops flooding), and also the drainage of groundwater from the superficial soil layer (up to the standard drainage depth) (Pálfai, 2004). The collection/evacuation channels, respectively the drains (open or closed) are controlling the levels and the water volumes (including groundwater) on their area of influence (Blidaru, 1962, 1969; Cazacu *et al*., 1985; Wehry *et al*., 1985). The artificial drainage network is in fact an extension of the natural one, in order to achieve a drainage of surface runoff and underground waters at high water table (imposed by the admissible period allowed by the crop flooding) (Fig. 5).

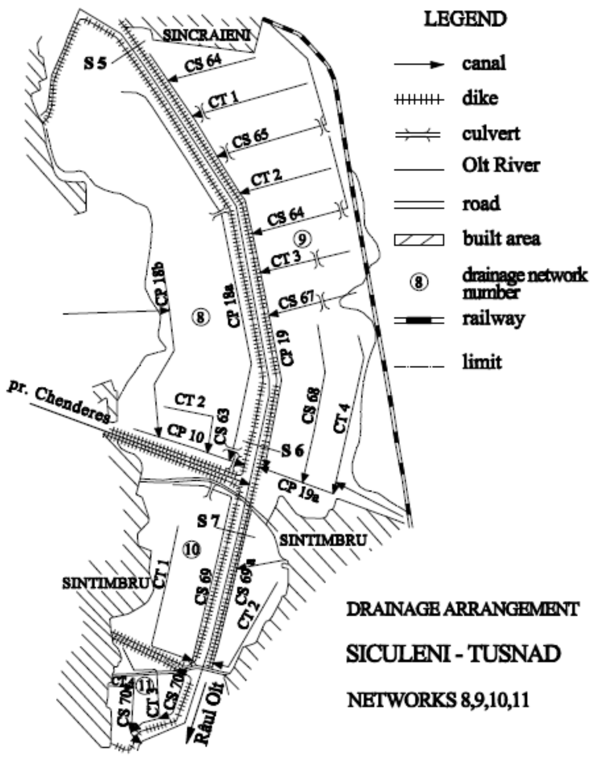


Fig. 4 – The Siculeni-Tuşnad drainage system.

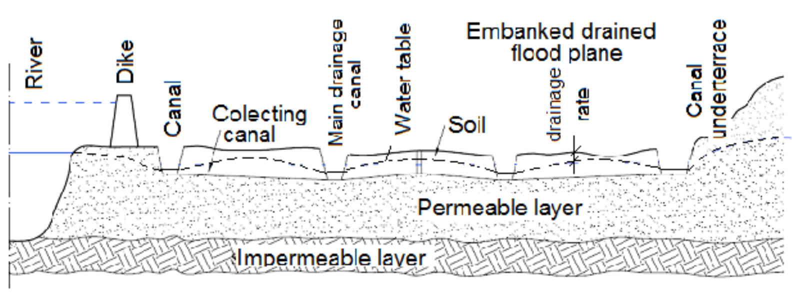


Fig. 5 – The embanked and drained water meadow – transversal section.

The drainage channels should be provided with level regulating gates (weirs) in order to create the possibility of groundwater retention during drought periods (Grosu, 1995; Ivan, 1985; Man, 2007). The density of such gates (weirs) shall depend on the channel slope. Thus, such weirs, inside a Δh

interval, imposed within the channel, and being of approximately 10...15 cm, must have the capacity to adjust the level on that section (Ivan, 1985; Wehry *et al*., 1985). The level changes inside the natural collector network (in the river and its tributaries) are generating a sideways dynamic influence (in the flood plane). This dynamic influence has an impact on the groundwater table elevation, according to Fig. 6, this being under the influence of river bed position and the hydrograph (Pietraru, 1970). The altering (by erosion or sedimentation) of the river bed elevation, the main natural collector has direct influence on groundwater table and on the tributaries erosion base level.

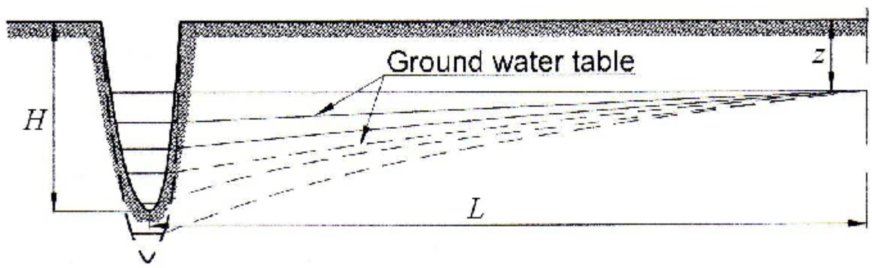


Fig. 6 – Effect of the river hydrograph and bed erosion on the floodplain groundwater table.

In such cases the erosion of river's and its tributaries' bed, due to groundwater table dropping, has effect on the operation, and maybe even on the usefulness of drainage systems, with significant environmental impact.

3. Simulation of Groundwater Dynamics under the Influence of Olt River Regulation and Embankment on the Miercurea Ciuc Sector

The analysis covers the years 1985 (commissioning of hydraulic works) and 2008 (the last year of measurement), on the 1st of March...31st of October period, yearly (245 days without frost).

3.1. Basic Data

The Ciuc Depression, between Sândominic and Tuşnad, is located at an elevation of 640...780 m and is bordered by high mountains (Harghita 1,800 m, Hăşmaş 1,550 m and Ciucului 1,300 m). Towards South (downstream), the depression is limited by the Tuşnad Băi threshold (made of hard rocks) at an elevation of about 637 m.

The climate is a mountain-type, sheltered one, typical for enclosed depressions, involving average annual temperatures of up to 6°C (at Miercurea Ciuc 5.9°C), with variations within the range of –36...+ 30°C. The average yearly rainfall in the depression is of 602 mm, ranging between 580 and 800 mm, depending on altitude; the monthly span being of is 29...106 mm (in

February and respectively July). The annual potential evaporation reaches 564 mm. Thus, the annual water balance (precipitations minus the evaporation volumes) represents an excess of 38 mm/year. Overall, in this area a boreal humid climate is present, with harsh winters and cool summers.

The relief (landscape) is varied, and with a step-like configuration towards the Olt Valley: mountains, pre-alpine hills, terraces and flood plain. The flood plain consists of sandy clay, mud, gravel and peat, and includes the meandered water course, drained sand banks, swampy intermediary zones on which the main river's tributaries are split. Soils formed in depression bioclimatic conditions are clayish alluvial soils, and alluvial soils with ground water table at small depth of different types. After the thin layer of vegetal topsoil (0.25 m) at surface, it follows a peat layer reaching 1.55...1.75 m peat, and then layers of earth, more or less permeable (from gravel up to clay). Hydrological the Olt River, on the regularized sector, receives seven tributaries and is characterized by the flows entered in Table 2.

Table 2
Characteristic Flows of the Olt River

River	Section	Q_m m^3/s	Q_{max}, [m^3/s], for various calculation						
			0.1%	0.5%	1%	2%	3%	5%	10%
Olt	Downstream the V.Mădăraş confluence	2.45	280	205	170	147	120	105	85
Olt	Sâncrăieni gauge station	4.76	290	210	180	140	120	105	90
Olt	Tuşnad Băi	6.79	605	440	360	305	255	205	160

Hydro-geologically, the Olt River flood plain is characterized by a groundwater layer supported by an impermeable bed that reaches thicknesses of 0.4...1.4 m and a pressurized water-bearing layer, at different depths. The two layers are linked in the area of tributaries' valleys.

3.2. Data Pre-Processing

1. With AUTOCAD (Popescu, 1999) several actions have been carried. One has been the digitization of the analysed surface (Fig. 7), and its subdividing into 872 finite elements, with drawing the contour lines: the surface levels, the impermeable bed of the first groundwater and the location of filtration factors.

2. Characteristics of river bed in 1985 and 2008 – corresponding to Fig. 8.

3. Into the six profiles (P1…P6), considered in the calculations, the Olt River level hydrographs have been generated (Fig. 9) and in seven profiles on Şumuleu tributary (Fig. 10).

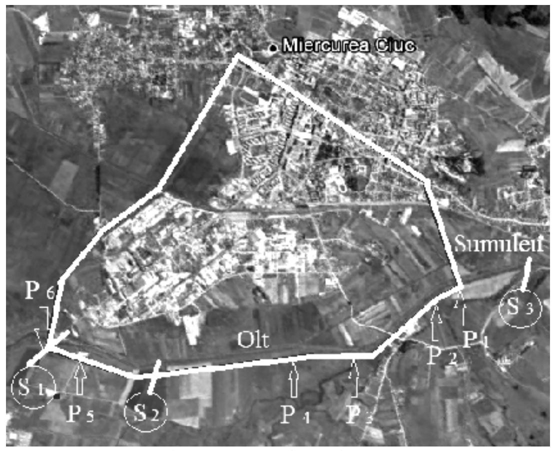
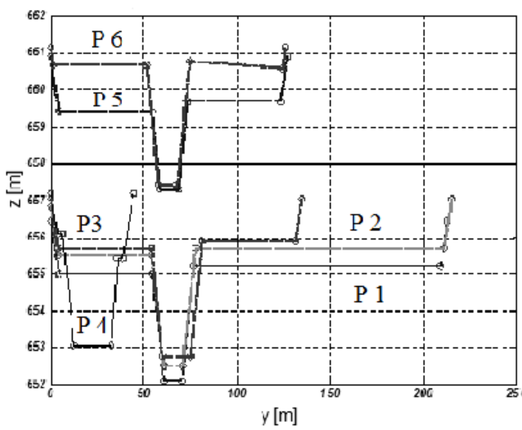
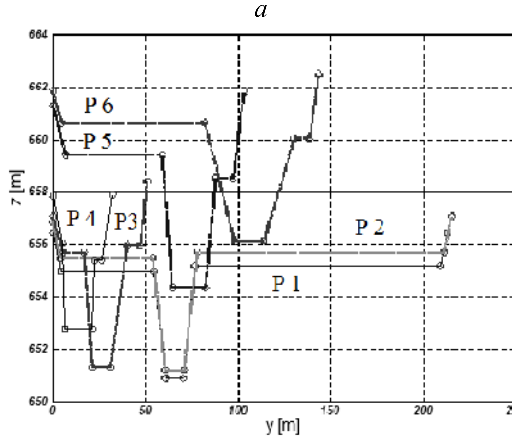


Fig. 7 – Analysed area.

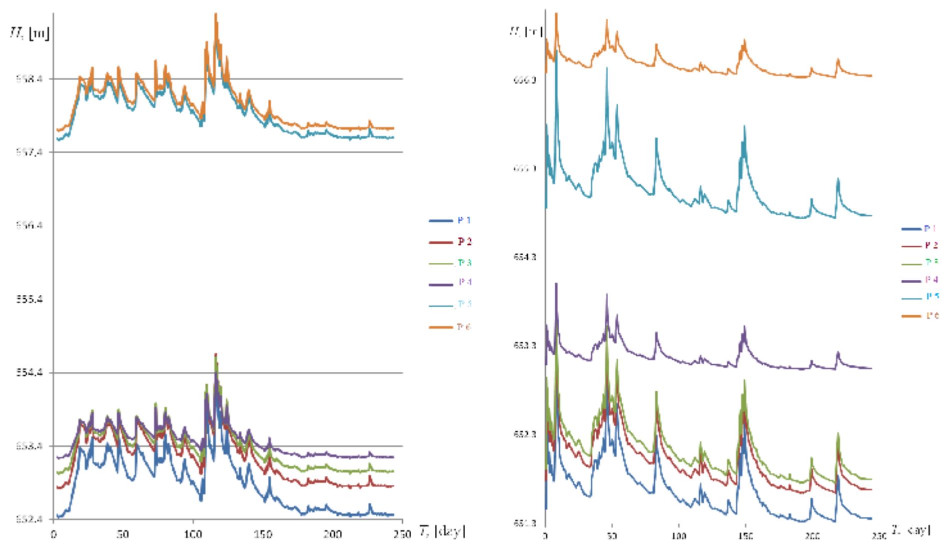


a



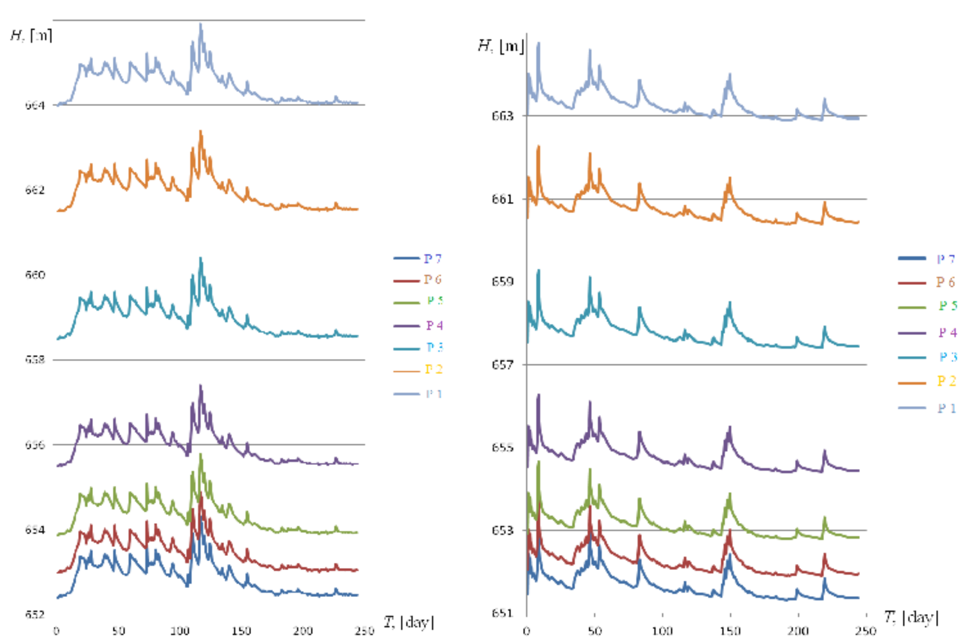
b

Fig. 8 – Transversal sections through the regularized river bed: *a* – in 1985; *b* – in 2008.



a *b*

Fig. 9 – Level hydrograph on Olt River in: *a* – 1985; *b* – 2008.

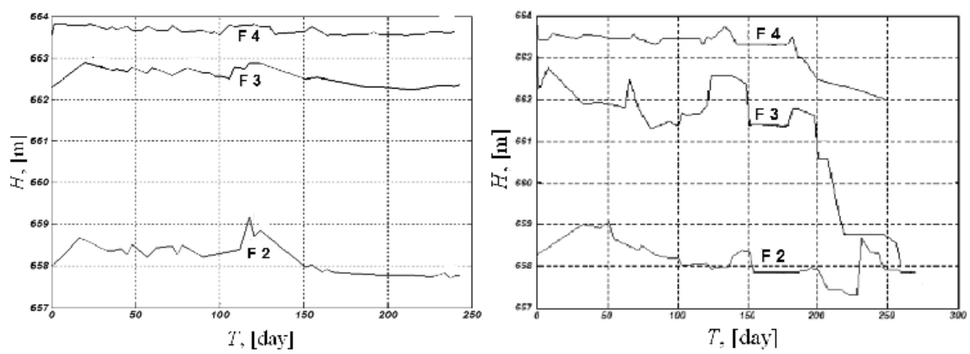


a *b*

Fig. 10 – Level hydrograph on Şumuleu River in: *a* – 1985; *b* – 2008.

These hydrographs correspond to years 1985 and 2008, outside freezing periods, that is, March 1st...October 31st , this meaning a total of 245 days.

4. The evolution of groundwater level has been systematically measured into wells bored in the studied area: F2, F3 and F4. The daily groundwater levels have been collected for the periods corresponding to the hydrographs on the river and on the tributaries (Fig. 11).



a *b*

Fig. 11 – Level hydrograph, $H = H(t)$, within wells F2, F3 and F4, between March 1st and October 31st: *a* – 1985; *b* – 2008.

From the data collected during drillings and wells pumping tests the filtration coefficients for bearing layers have resulted as it follows: for the first groundwater layer $k_f = 6.5 \times 10^{-5} \ldots 1.6 \times 10^{-4}$ m/s, and for the pressurized layers $k_p = 2.7 \times 10^{-4} \ldots 6.1 \times 10^{-4}$ m/s.

5. The humidity excess or deficit (precipitations minus evaporation), calculated for the same intervals that have been considered above in 1985 and 2008, are given in Table 3.

Table 3

Surface Supply of the Studied Area

Year	1985							
Month	3	4	5	6	7	8	9	10
Rain, [mm]	1.0	64.8	98.9	151.7	50.9	36.9	20.1	16.6
Evaporation, [mm]	0.3	38.9	84.1	136.5	48.4	33.2	16.1	10.0
Q_p, [10^{-4}m/day]	0.23	8.64	4.79	5.06	0.82	1.19	1.34	2.14
Year	2008							
Month	3	4	5	6	7	8	9	10
Rain, [mm]	61	95.1	81.6	66.3	137.4	13.7	60.4	70.6
Evaporation, [mm]	18.3	57.1	69.4	59.7	130.5	12.3	12.3	42.4
Q_p, [10^{-4}m/day]	13.8	12.7	3.95	2.21	2.22	0.44	4.03	9.11

6. The intensity of underground supply flows, from high areas, for simulation periods, is shown in Fig. 12.

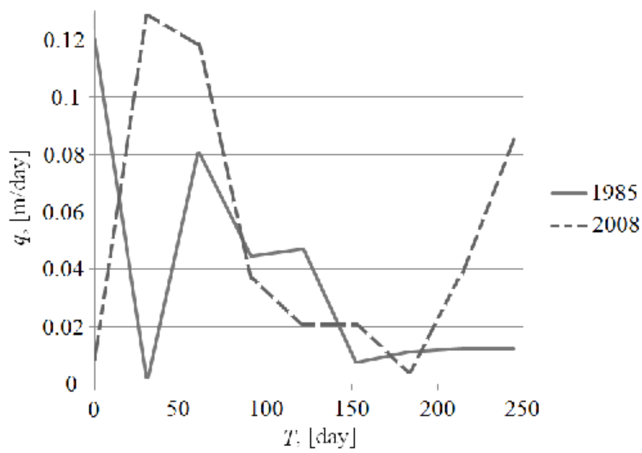


Fig. 12 – Intensity of specific flows, [m^2/day], on the Γ^3 boundary, in period March 1…October 31.

3.3. Numerical Simulation of the Groundwater Evolution

The groundwater 2-D (two dimensional) hydrodynamic model has been used for studying its evolution during time. The non-permanent underground 2-D flow is governed by the generalized Darcy's equation, resulting from mass and moment conservation equation, which can be brought to the following form:

$$\rho S_s \frac{\partial H}{\partial t} - \frac{\partial}{\partial x}\left(\rho k_x \frac{\partial H}{\partial x}\right) - \frac{\partial}{\partial y}\left(\rho k_y \frac{\partial H}{\partial y}\right) = \rho Q_p, \tag{1}$$

where: $Q_p(x,y,t)$ is the intensity of volumetric distributed source; ρ – water density; $H = p/\gamma + z$ – the total hydraulic load; $S_s = \rho g S_{op}$ – the specific storage coefficient, $k = \begin{vmatrix} k_x & 0 \\ 0 & k_y \end{vmatrix}$ – the hydraulic conductivity tensor.

The considered Ω domain is limited by eight frontiers. For $\Gamma^1_{1\ldots5}$ a Dirichlet type conditions applied,

$$H(x,y,t) = H_{\Gamma_i}(t),\ (x,y,t) \in \Gamma^1_i[t_I, t_F];\ \Gamma^1 = \bigcup_{i=1}^{5} \Gamma_i \tag{2}$$

and for $\Gamma^2 = \Gamma^2_6 \bigcup \Gamma^2_7$ a Newman condition is applied

$$kb\left(\frac{\partial H}{\partial x} n_x + \frac{\partial H}{\partial y} n_y\right) = q^{-R}_{\Gamma^2}(x,y,t),\ \text{for}\ (x,y,t) = \Gamma^2_x[t_I, t_F], \tag{3}$$

where b is the aquifer's thickness and $n_e = n(x,y,t)$ is the actual porosity.

The 3rd type of frontier condition (Cauchy) has the form

$$-\rho k_{ij} \frac{\partial H}{\partial x_j} n_i = -\Phi_{\Gamma^3}(H),\ (x,y,t) = \Gamma_x^3[t_I, t_F], \tag{4}$$

and defines the transfer rate with the neighboring underground area on the frontier Γ_8^3.

The initial conditions, having the form

$$H(x,y,t) = H_I(x,y,t), \tag{5}$$

are resulting from eq. (1) solved according to initial conditions

$$\frac{\partial}{\partial x}\left[k_x(H - z_b)\frac{\partial H}{\partial x}\right] + \frac{\partial}{\partial y}\left[k_y(H - z_b)\frac{\partial H}{\partial y}\right] + \bar{Q}_p, \tag{6}$$

where z_b is the level of the first grounwater layer.

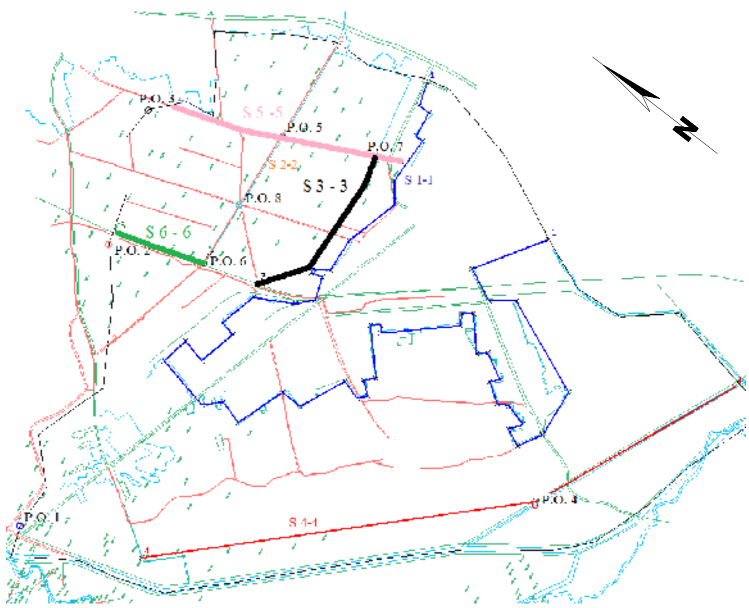
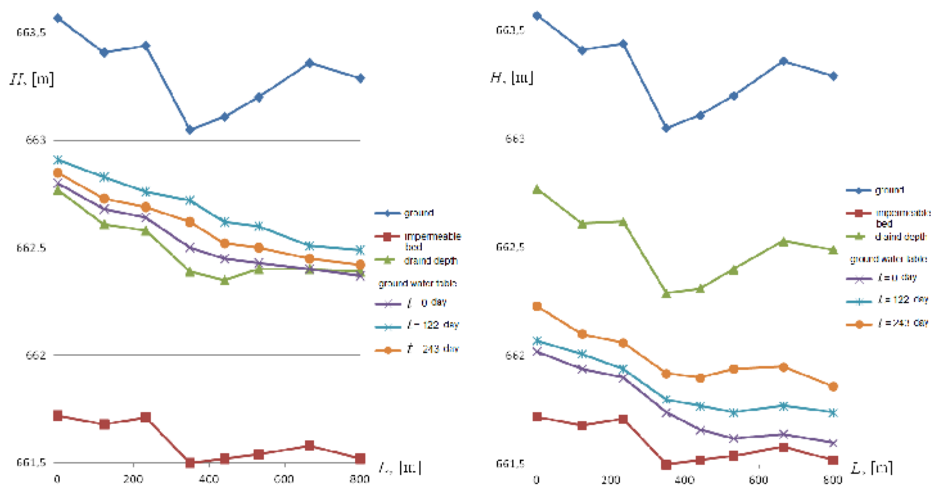


Fig. 13 – Analysis domain, defined as follows: at N-E – Topliţa District, at E – the high area, at S – Şumuleu creek, at W – regularized Olt River; eight observation points (1,2, ..., 8) and six sections (1-1, 2-2... 6-6) are marked.

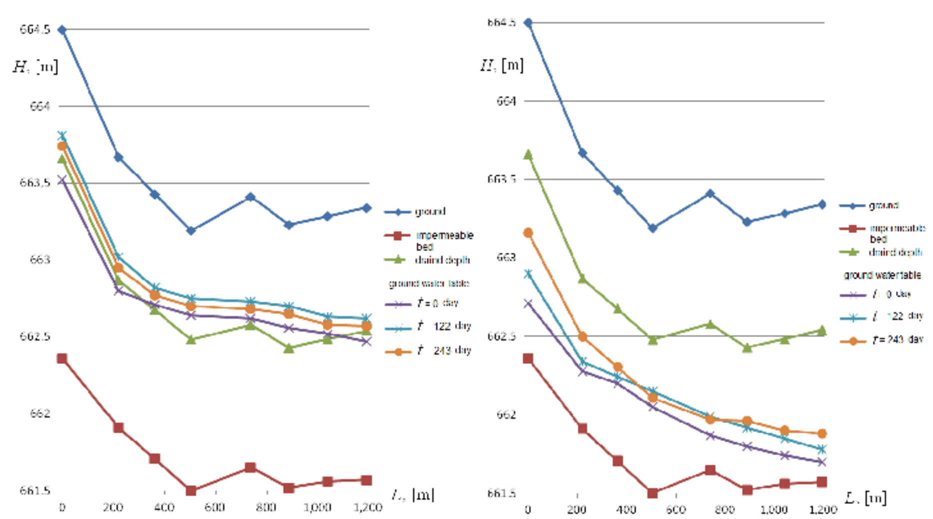
The processed data are in fact the input parameters for the FEFLOW software package (Diersch,2002) which generates the vector map (Fig. 13), which then is divided in finite elements and passed through the groundwater level changing scenarios, describing the water balances in eight observation points and six profiles.

The Şumuleu creek and the Olt River is the natural drainage network that has significant influence on the groundwater from that area. This effect can be studied with data extracted from processed data. Figs. 14 and 15 are showing



a *b*

Fig. 14 – Variation of characteristic levels and hydraulic loads along section 3-3; *a* – in 1985; *b* – in 2008.



a *b*

Fig. 15 – Variation of characteristic levels and hydraulic loads along section 5-5, *a* – in 1985; *b* – in 2008.

the ground elevation, the impermeable bed's position, the drain line position, the groundwater position at various moments, respectively, that is $t_1 = 0$, $t_2 =$ $= 122$ days and $t_3 = 245$ days in 1985 and 2008, for profiles 3 and 5.

It can be seen that in 1985 groundwater table, for both profiles, was above the channels drainage depth, which reaches 0.75 to 1.5 m, this meaning that channels were fulfilling the role for which they were designed. The numerical modeling shows, by means of water balance, the excess of 37 mm / year, in good agreement with data from studies (38 mm/year).

In 2008, the lowering of the Olt River's bed, and also of the Şumuleu tributary (lowering of the erosion base) by 0.26...2.94 m, created a new situation in which the drainage channels bottom are now above the water table (no longer serving for draining). The channels are also collecting and filtering all surface runoffs generated by heavy rains and melting snows. The lowering of water table by 0.40 to 0.70 m, due to beds' erosion (in Olt and Şumuleu) is cancelling the draining function in drainage systems. Further on, the lowering of groundwater table is altering the processes inside the peat layer by its drying (anaerobic process becomes aerobic ones). For this reason the final effect may be the peat's auto-ignition (Joseni, Remetea, Ciceu), phenomenon that is releasing gaseous pollutants, as CO_2 and others (Fig. 16). Dominant winds that blow from North–South direction are conveying the polluting clouds over Miercurea Ciuc town, the county residential city.

Fig.16 – Peat burning, Ciceu, November 2011.

4. Conclusions

The regularization of Olt River in Ciuc depression, with a new riverbed, partly with protective walls and bank protection, without a vertical strengthening of riverbed (ledgers, sills) has led to severe bottom erosion on the Mădăraş-Sâncrăieni sector and also significant mud sedimentations downstream, up to Tuşnad. These morphological changes are involving maintenance and reinforcement works (de-clogging, bank defenses, ledgers). Also the erosion base level of tributaries has been changed, this leading to implications related to erosion and sedimentation, and also an increased flood risk. On river sections with bed erosion the natural drainage network is modified and, hence, groundwater level is lowered in the adjacent flood plane. The drainage–evacuation systems (open or closed), inside the protected flood plane, completed in the same time with the river regulation, are losing their elementary drainage role, being now over the actual depth of groundwater table that has been lowered by riverbed erosion.

The drying of peat layer and the conversion of anaerobic biochemical processes in aerobic ones, together with the releasing of flammable gases, are increasing the possibility of peat auto-ignition and air pollution. The final regulation design must include reinforcement works for preserving the bed's stability (ledgers, thresholds, all installed at adequate inter-spaces).

The regulation and embankment works of rivers, respectively melioration arrangements within protected flood planes, must be designed in harmony and must be completed in a staged manner, otherwise there is a risk of failing to ensure their final functions. Even those drainage works, that do not regulate the groundwater levels (such solutions being applied in Romania), can lead to the above mentioned phenomena inside the peat layer, by excessive drainage. In order to prevent the uncontrolled drying of peat, the water level within channels must be strictly controlled by gates (weirs), installed at adequate inter-spaces, as to allow only a limited lowering of groundwater levels (strictly within the drainage admissible limits).

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EFECTUL EROZIUNII TALVEGULUI RÂULUI OLT AMONTE DE TUŞNAD ASUPRA HIDROLOGIEI LUNCII ŞI SISTEMELOR DE DESECARE

(Rezumat)

Regularizarea şi îndiguirea râului Olt între Mădăraş şi Tuşnad, din depresiunea Ciucului, a fost urmată de eroziuni şi depuneri în albie. Schimbările reţelei de drenaj natural au efecte majore asupra hidro-geologiei luncii, respectiv asupra pânzei freatice. Coborârea freaticului schimbă semnificativ funcționalitatea sistemelor de desecare–drenaj din lunca îndiguită.

Se studiază coborârea nivelului freaticului şi efectelor sale asupra funcționalității sistemelor de desecare prin observații directe şi prin modelare matematică a fenomenelor.

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EXPERIMENTAL STUDIES ON QUALITY ASSURANCE OF CONCRETE WITH ANTI-FREEZING AND SUPERPLASTICIZER ADDITIVES IN COLD WEATHER, BY OPTIMIZING OF ITS DELIVERY TEMPERATURE

BY

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Abstract. The laboratory investigations to estimate the influence of negative atmosphere temperature, wind, and time from the concrete delivery to pouring, on the concrete heat loss as well as the protective influence of the additives included in the concrete mix, are presented. Randomized controlled experiments were performed on C25/30 concrete prepared with a latest generation of additives (anti-freezing with superplasticizer). The major internal and external factors, active and reactive, involved in achieving quality from the concrete plant to site, and during cold weather, were considered. Thermal cycles for the concrete temperature at delivery (25º, 35º and 50ºC), in relation with the time (15, 30, 45 and 60 min) were performed. The temperature spectrum of the concrete at pouring in cold weather conditions was obtained, useful to choice correctly the concrete thermal regime at delivery.

Key words: concrete; additives; frost and wind action; transport duration.

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1. Introduction

A performant concrete will obtained if the quality is ensured at all stages of production, from preparing in the batching plant, then during transportation, placing and curing, especially in adverse weather conditions. The concreting in cold weather may become a common and necessary practice, in Romania, if, in every phase, the specific requirements would adopted. The number one rule is to avoid the concrete freezing at an early age, especially within first 24 h. Cold is a threat from the following considerations: the ordinary concrete gains strength more slowly at temperatures up to –5°C, very slowly under –5°C, and does not gain strength below –10°C, if the matrix of cement paste is not formed yet. In cold weather, the optimal conditions for the setting and hardening of the concrete may be ensured using various methods, separately or combined, such as: the use of cements releasing large heat of hydration, the heating of the fresh concrete or of its components, the introduction of additives in the concrete mix. The laboratory testing of concrete is performed at a controlled constant temperature, according to norms. The standard temperature is generally considered between 15°C and 23°C, and so a large part of basic data about the properties of fresh concrete and/or hardened concrete is based on behavior at this temperature. In practice, however, the concrete is prepared, delivered and used in an environment with a wide range of temperatures. In addition, during its service life, the concrete will be in an environment characterized by large variations of temperature, diurnal and seasonal, as well as by numerous thermal cycles. Therefore, knowledge of the effects of temperature on the concrete is of great importance.

2. Experimental Investigations

The experimental program focused to optimize the temperature at delivery of a concrete with additives, in correlation with the duration until concreting work, the air temperature, and the wind status.

The methodology of controlled experiments, in which the group of concrete subjected to treatment is compared with a control group (not subjected to treatment), was used. To reduce the risk of confusing the treatment effect, with the effect of other factors, randomized controlled experiments were applied, so that the subjects' assignment at the control group and the experimental group is done randomly.

The work schema has simulated the main internal and external factors, as well the actives and reactive ones, involved in achieving the concrete quality during transportation from the batching plant to site, in cold weather conditions.

In the performed experiments, thermal cycles as time function were performed, with the aim to establish and to quantify the effect of internal and external temperatures on the concrete quality at pouring.

The kind of the additives used in the concrete composition, the combinations of these additives, the concrete temperature at the output from the batching plant, the duration between the delivery until casting, and the atmospheric temperature were considered as controlling parameters. The atmospheric agitation was taken as secondary parameter.

The mixture corresponding to a C25/30 concrete class was prepared with ordinary Portland cement CEM I 42.5 R, releasing large heat of hydration, in 400 kg/m^3 dosage, water for W/C = 0.47, aggregates with nominal maximum size of 16 mm, coming from gravel pit, and a combination of two chemical additives. Two additives in combination were used *i.e.* 1% anti-freezing additive based on urea in aqueous solution, having a protective effect up to –10°C; 0.8% superplasticizer, HRWR, based on polyether–polycarboxylate, characterized by low content of chlorides and alkalis (the dosages are imposed by weight of cement).

The 36 fresh concrete samples were performed at 25, 35, respectively, 50°C and were kept in the environmental chamber, in which, they were exposed at three different temperatures, *i.e.* at 0°C, –5°C and, respectively, –10°C.

The time intervals between preparing and casting of the concrete were simulated by the keeping durations of the samples in the climate chamber, namely 15, 30, 45, respectively, 60 min. The minimum interval, of 15 min was considered in case the concrete provider is inside or in vicinity of construction site. For the maximum duration, the value of 60 min, according to norms (NE 012/2, 2010), has been chosen.

The values range of the independent parameter, "air temperature", was chosen between 0°C and –10°C, on the following reasons: the technological stages of preparation–transport–casting are carried out in the morning, when air temperature is increasing; the air temperatures below –10°C with / without wind are forecasted to the beneficiary of concrete, which, normally, ceases the concreting work, temporarily/permanently.

3. Results and Conclusions

A longitudinal study was performed on samples, at different times, the purpose being to assess the effect of the time passage on those quantitative variables of interest for the research objective.

The investigations were designed to optimize the temperature of concrete with additives, at delivery, in cold weather conditions, depending on the internal temperature, the duration between preparation and casting, air temperature, and wind.

The concrete temperature at the moment of put in work must be correlated with the agents of freezing and evaporation, as shown in Table 1 (Krylov, 1997).

Table 1
Proper Temperature of Concrete, Correlated with Atmospheric Temperature and Wind

Air temperature ºC	Minimum temperature of the concrete at pouring, [ºC]	
	calm weather	wind
0…–10	15	20
–11…–15	20	25

The experimental results, shown in Table 2, clearly show the situations when the use of anti-freezing & superplasticizer admixtures is a certainty for the cast concrete quality in cold weather conditions.

Table 2
Spectrum of Concrete Temperature under the Influence of Air Temperature, Transport Duration, Combination of Additives (*C25/30, W/C* = 0.47, D_{max}=16 mm)

Cement	Combination of additives	Concrete temperature at delivery ºC	Concrete temperature at pouring [ºC], after [min]				Environment temperature ºC
			15	30	45	60	
I 42.5 R 400 kg/m^3	Anti-freezing 1% (4 kg) Superplasticizer 0.8% (3.2 kg)	25	22	19	17	15	0
		35	31	28	24	21	
		50	46	42	38	31	
		25	20	18	16	13	–5
		35	30	26	22	19	
		50	44	39	35	28	
		25	19	16	14	9	–10
		35	27	24	20	16	
		50	40	36	31	23	

The analysis of the obtained results with concrete temperature at delivery as reference parameter leads to the following findings.

a) 50°C should not be used because, at pouring, the concrete temperature is much higher than the required temperature, as it is shown in the Figs. 1 and 2. The application of this procedure means a waste of energy and unnecessarily high costs. There is one exception, namely when it is cold and wind, and the time until the casting is long because of the difficult path to the construction site or due to difficulties arising from weather conditions.

b) 35°C is not recommended to use in cold weather, but quiet, when the time between preparation and casting is less than 60 min, because this combination of additives creates, in the fresh concrete, a higher temperature than necessary. The same reason as above, this temperature should not be used when it is cold and wind, and the duration is less than 45 min (Figs.1 and 2).

The temperature of 25°C requires a careful analysis of weather conditions and of the time of concrete transfer.

On windy cold weather, this solution is excluded, because the concrete temperature falls below that required.

On cold wheather without wind, the solution cannot be used for time exceeding 45 min, for the same reasons as above.

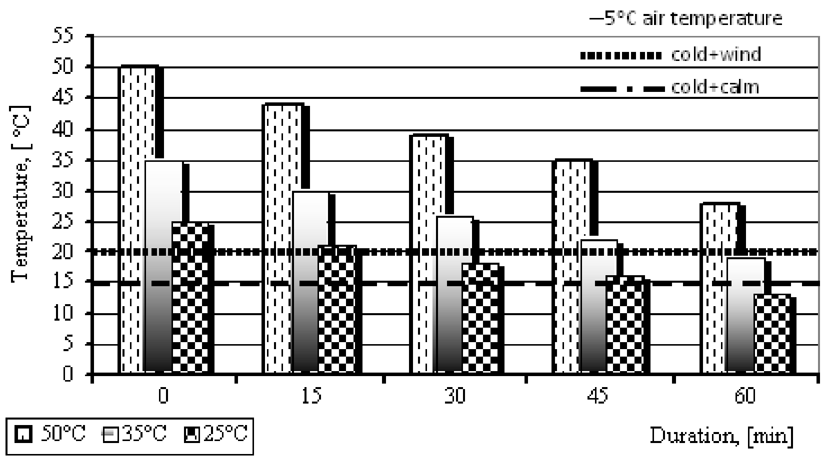

Fig. 1 – Influence of the transport duration, of the concrete temperature at delivery, and of the meteorological conditions, upon the concrete temperature at casting, when air temperature is –5 ºC.

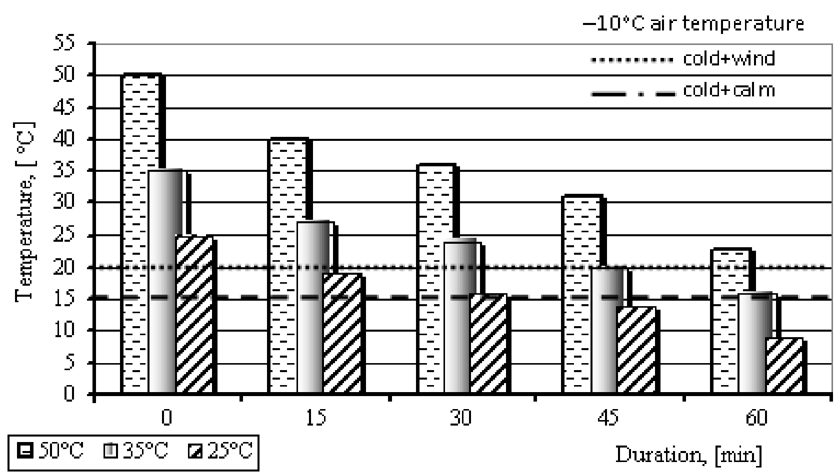

Fig. 2 – Influence of the transport duration, of the concrete temperature at delivery, and of the meteorological conditions, upon the concrete temperature at casting, when air temperature is –10 ºC.

The positive point of this thermal option is that in cold weather without wind, and for middle time, the chosen combination of additives is the most effective, economically and advantageous regarding the thermal conditions of hydration.

Finally, the spectrum of temperatures, at moment of casting fresh concrete, has been performed, as show the Figs. 1 and 2. This spectrum can be useful in practice in the management of temperatures, to choosing the thermal regime of the concrete delivery, properly.

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STUDII EXPERIMENTALE PRIVIND ASIGURAREA CALITĂŢII BETONULUI CU ADITIVI ANTI-ÎNGHEŢ ŞI SUPERPLASTIFIANŢI, PE TIMP FRIGUROS, PRIN OPTIMIZAREA TEMPERATURII DE LIVRARE A BETONULUI

(Rezumat)

Se prezintă rezultatele cercetărilor de laborator realizate pentru a elucida influenţa pe care o au temperatura atmosferică negativă, vântul şi durata de la livrarea betonului până la turnare, asupra pierderii de căldură din beton dar şi influenţa protectoare a aditivilor din compoziţia betonului. S-au efectuat studii experimentale randomizate pe beton C25/30 preparat cu o combinaţie de aditivi (anti-îngheţ cu superplastifiant) de ultimă generaţie. Domeniul de valori ale parametrului independent „temperatura aerului", a fost ales între 0°C şi –10°C. Schema de lucru a simulat principalii factori interni şi externi, activi şi reactivi, care intervin în obţinerea calităţii betonului pe traseul staţie de preparare–construcţie, pe timp friguros. Au fost realizate cicluri termice (pentru temperatura betonului la livrare de 25°, 35°, 50°C) variabile în funcţie de timp (15, 30, 45, 60 min). S-a obţinut spectrul temperaturii betonului la turnare, util în practică, pentru a alege corect regimul termic de livrare a betonului.

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EXPERIMENTAL STUDIES ON THE CONTRIBUTION OF ANTI-FREEZING ADDITIVES AND SUPERPLASTICIZERS TO ASSURE THE CONCRETE QUALITY IN COLD WEATHER

BY

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Abstract. The experimental investigations on the additives ability to manage the concretes’ properties designed to prolong the concreting work, in cold weather conditions, in Romania, are presented. From our experimental program wider we present the effect of a combination of anti-freezing additive with superplasticizer, on the evolution of concretes cast in cold weather. The tests has been performed on a concrete mix containing ordinary Portland cement CEM I 42.5 R; W/C = 0.47; aggregates with a nominal maximum size of 16 mm; anti-freezing additive based on calcium nitrate with the dosage 1%; superplasticizer high-range water-reducer, based on polyether–polycarboxylate with the dosage 0.8%. Three sets of batches have been prepared in accordance with three different dosages: mixture blank (MB) containing 400 kg cement/m^3 and additives in doses above mentioned, MB+7%, and MB–7%. After 7 days and 28 days, respectively, the compressive tests were performed. The followed main purpose was the effect of admixtures kind, taken in combination, as well as the dosage effect on strength gain during the concrete hardening.

Key words: concrete; cold; anti-freezing additive; superplasticizer.

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1. Introduction

The development of quality issues, which are dominant in the field of concrete and its components, is motivated by: the very large share of concretes and reinforced concretes in constructions for various destinations; the dependence of the safety and security of a construction, as well as of its beneficiaries, of concrete quality; the decreasing of long-term cost through the increasing of building longevity; the improvement of energy consumptions.

One of the troubles in the construction industry is damaging interruption of concreting process in cold weather. The strategy of concreting in cold weather conditions must cope to the numerous, diverse and unexpected challenges, during production, transportation, pouring, and maturation of concrete. These difficulties directly affect the quality of concrete during the time between preparing and casting, and, indirectly, the physical and mechanical properties of hardened concrete.

The management of concrete temperature, in cold weather, is very different than for normal temperatures or hot weather. Frost protection is needed, so that, the concrete temperature to be at least 10°C, to ensure the development of resistance. In this respect, the current rules provide, for the management of the temperature, only a few rules, and those relating to prevent freezing are heterogeneous and inconsistent. Regarding the use of anti-freezing additives, current rules make no mention.

2. Experimental Studies

2.1. Concept of Equivalent Performance

The concept of equivalent performance of the concrete properties was the basis for testing, because this concept guarantees that quality of concrete with additives is at least equal to that of reference concrete, evaluated as the average of the tests.

The reference concrete contains: a type of cement in accordance with the rules (SR EN 197.1, 2002; A3, 2007), constituents corresponding to the combination of cement with additives, and, in addition, the concrete complies with the requirements for the appropriate exposure class. The performed tests were based on normal Portland cement CEM I 42.5 R. The verification of concrete compliance with the specifications, was done passing through all the stages, after rules, for a normal density concrete, of strength class C25/30.

2.2. Sampling Process

The samples manufacturing operation is a link between the measurements on freshly mixed concrete and those on the hardened concrete, because the manufacturing is done with freshly concrete specimens and their testing is done after the concrete has hardened.

The storage and operating of the materials components were made so as not to be altered or their characteristics significantly, by mixture, contamination or climate conditions. Before preparation of concrete, all materials were kept in climate chamber for 72 h, during which they were subjected to a normal climatic cycle.

The materials, ingredients, and their proportions, which were used in the study of the concretes mixture, are presented below.

Ordinary Portland cement, CEM I 42.5 R type, was preferred because it has a high compressive strength, releases a large amount of heat of hydration and so is insensitive to cold. The dose was of 400 kg/m^3 cement and was kept constant in all studied recipes and in all variations of other parameters.

Water/cement ratio (W/C) was of 0.47 and water effective/cement of 0.39.

The aggregates, obtained from the "Frasin" river gravel pit, were used in three sorts: 0…4 mm (35%), 4…8 mm (25%), and 8…16 mm (40%) with continuous granulosity, having the nominal maximum size of 16 mm.

The multifunctional admixtures used are products approved, frequently used in the concrete industry, and comply with EN 934-2:2009, SIKA class, namely

a) Anti-freezing additive, based on urea in aqueous solution (Frostschutz FS 1); this additive is able to speed up the silicates dissolution so to develop the earlier heat of hydration, in addition has the property of lowering the freezing point to –20 °C, thus maintaining the liquid phase in concrete. The dose used was of 1% by weight of cement, as recommended in the material datasheet. The dose of liquid additive was added in the mixing water, and then was stirred rapidly. In calculating the ratio W/C was taken into account the contribution of additive.

b) Additive superplasticizer, HRWR, based on polyether–polycarboxylate, (ViscoCrete 1040), with low content of chlorides and alkalis (Na_2O equiv. $\leq$ 0.5%), used in ratio of 0.8% by weight of cement; this additive has the ability to maintain a prolonged workability of concrete, so it is suitable for transport concrete over long distances. The recommended dose is of 0.2…2.5% by weight of cement, and, in trials, was used a dose of 0.8%. The dose of additive was introduced into the mixing water, and then, the stirring was carried out min. 45 min.

The time from mixing until casting, in winter, may be of maximum 70 min, so, in experiments, we took maximum of 60 min. Download time and/or transfer were considered less than 30 min.

The concrete maturation, named *the concrete aging* too, begins immediately after pouring and compacting, being the decisive final phase in obtaining a performant concrete.

2.3. Laboratory Trials

Cross-sectional studies were organized in lab, to pursue three main objectives, namely: the impact of the kind of additives (not individually but in combination) on the evolution of compressive strength in the short term and normal term; the influence of dose value on the resistance gain over time until the concrete hardens; the comparative analysis of the concrete quality, depending on the nature and amount of additives, in cold weather conditions.

For each test of a batch of concrete three mixtures were made and, from each mixture, three specimens were manufactured and subjected to tests. The three sets of batches were prepared in accordance with three different dosages: mix blank (MB) containing 400 kg cement/m^3 and additives in doses above mentioned, MB + 7%, and MB – 7%.

Until the test age, the concrete specimens have been preserved in climate chamber, under the specified conditions, for 7 days, respectively, 28 days, and then were tested in compression.

3. Results and Conclusions

3.1. 7-day Strength Test Results

The 7-day strength test results are used to monitor early strength gain and are, often, estimated to be about 75% of the 28-day strength. These results are useful to the contractor and concrete producer as an early warning signal (Kosmatka *et al*., 2002). With today's fast-track concrete-placement schedules, it is essential for the contractor and concrete producer to know when 7-day test results are low. Then, suitable steps can be taken promptly to adjust batch quantities, improve quality control procedures at the job site, and ensure that sampling, molding, and testing of the cylinders are being done in accordance with applicable standards (ACI 318, 2005). As regards the concrete with special additives, produced in cold conditions, the evolution of compressive strength at 7 days shall be monitored highly strict, because there are no rules or regulations in this domain.

Fig. 1 presents the concrete quality, depending on the conditions of maturity, and the dosages, expressed by the values of 7-day compressive strength. It was found that the concrete kept in cold, acquires, with great difficulty, compressive strength at early age, the phenomenon being observed at all dosages. The recorded strength deficit, comparatively with specimens kept in thermal normal conditions, was of 37.61% ... 50.98%. Even the *prima facie* shows that the early development of compressive strength of concrete is found under the influence of additive dose. The analysis of the doses' effect on the resistance, within each thermal cycle, led to several conclusions.

Under normal conditions of hardening, the effect of additive amount is not significant, the differences from the control sample varying between –5.87%

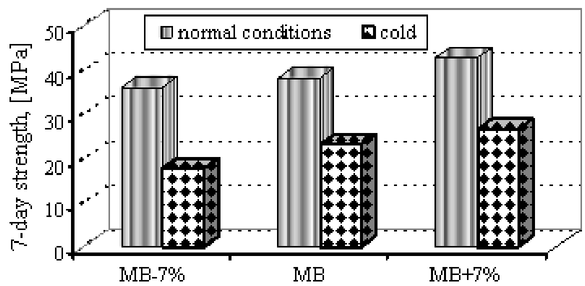

Fig. 1 – Influence of dosages and thermal conditions on 7-day strength development, at a C25/30 concrete prepared with CEM I42.5 R cement, polyfunctional additives of type anti-freezing 1% & superplasticizer 0.8%; MB (CEM I 42.5R - 400 kg/m^3; anti-freezing additive Frostschutz FS 1 - 4 kg/m^3; superplasticizer ViscoCrete 1040 – 3.2 kg/m^3).

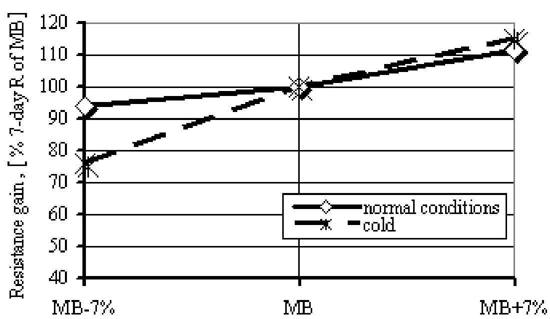

Fig. 2 – Compressive strength gain of concrete at 7 days, reported to basis dose, during normal maturation, respectively, in cold conditions; MB (CEM I 42.5R - 400 kg/m^3; anti-freezing additive Frostschutz FS 1 - 4 kg/m^3; superplasticizer ViscoCrete 1040 – 3.2 kg/m^3).

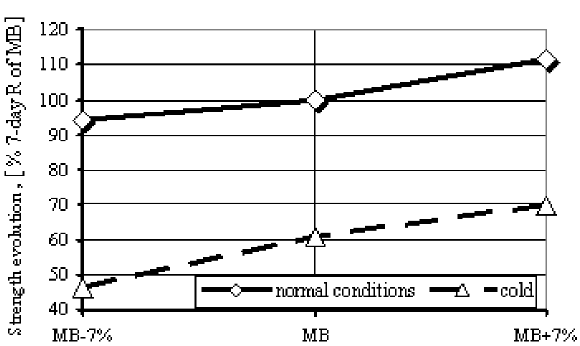

Fig. 3 – Compressive strength gain of concrete at 7 days, reported to blank specimen, under normal conditions, respectively, in cold; MB (CEM I 42.5R - 400 kg/m^3; anti-freezing additive Frostschutz FS 1 - 4 kg/m^3; superplasticizer ViscoCrete 1040 – 3.2 kg/m^3).

and +11.65%, as shown in Fig. 2. Not the same event occurs in cold conditions, the decreasing in the additive dose will delay much the hydration and the training of resistance structures. Reduce dose by 7%, the 7-day resistance was smaller with 23.92%, compared to the blank specimen resistance, kept in cold conditions (Fig. 2). The dosage effect on the strength gain is much stronger if the strength of specimen kept in cold is reported to blank specimen strength kept under normal conditions. The compressive strength of these represents 46.14%...60.64% of blank sample strength, kept under normal conditions (Fig. 3).

3.2. 28-day Strength Test Results

The values of compressive strength after 28 days of maturation in normal thermal conditions and cold weather conditions are illustrated in Fig. 4.

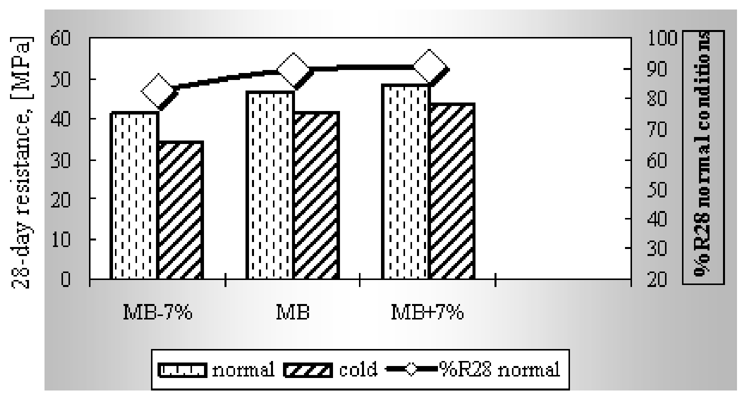

Fig. 4 – Evolution of 28-day compressive strength depending on the value of dosages and thermal conditions, at a C25/30 concrete prepared with CEM I 42.5 R cement, polyfunctional additives of type anti-freezing 1% & superplasticizer 0.8%; MB (CEM I 42.5R - 400 kg/m^3; anti-freezing additive Frostschutz FS 1 - 4 kg/m^3; superplasticizer ViscoCrete 1040 – 3.2 kg/m^3).

The loss of resistance has a similar spread, regarding extension, with that of the 7-day resistance, but the values are much smaller, ranging between 17.31% and 9.84%.

In normal thermal conditions, low levels of additives is harmful, and the concrete quite reaches only 88.71% of the blank strength (Fig. 4), and an increase in dosage of the same percentage brings no visible benefit. The same event occurs and in cold conditions, because the reducing of the additive amount delays the achievement of specified strength.

In cold weather conditions, the 28-day strength, having values of

73.35% … 93.73% of the control group strength in normal conditions, is particularly promising to sustain the use opportunity of additives studied.

3.3. Conclusions on the Concrete Quality Cast in Cold Weather Conditions, Using an Anti-Freezing and Superplasticizer Combination

The combination of additives studied prints a slow evolution of the resistance in early age respectively to 7 days, followed by a spectacular progress in the gain of strength until the age of 28 days. These results can be explained on the basis of the *crossover effect*, name given by Alexander & Taplin (1962), to the phenomenon whereby, a concrete subjected to low temperature has a low resistance, at early age, but reaches a very good resistance in high age.

This combination of additives represents the best solution of achieving the concrete buildings, during cold season, when the charging with loads will be done at 28 days.

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STUDII EXPERIMENTALE PRIVIND CONTRIBUŢIA ADITIVILOR ANTI-ÎNGHEŢ ŞI SUPERPLASTIFIANŢI LA ASIGURAREA CALITĂŢII BETONULUI, PE TIMP FRIGUROS

(Rezumat)

Se prezintă rezultatele investigaţiilor experimentale referitoare la capacitatea aditivilor de a gestiona proprietăţile betoanelor pentru a prelungi activitatea de betoane, pe timp friguros, în România. Din programul experimental adoptat, mai larg, se prezintă efectul unei combinaţii de aditiv anti-îngheţ cu aditiv superplastifiant, asupra evoluţiei betoanelor turnate pe vreme rece. Testele au fost efectuate pe un amestec de beton care conţine: ciment Portland obişnuit CEM I 42,5 R; raportul A/C = 0,47; agregate cu dimensiunea nominală maximă de 16 mm; aditiv anti-îngheţ pe bază de azotat de calciu în doză de 1%; aditiv superfluidizant pe bază pe polieter–policarboxilat în doză de 0,8%. Trei seturi de loturi au fost întocmite în conformitate cu trei dozaje diferite:

proba-martor (MB), care conţin 400 kg ciment/m^3 şi aditivi în dozele de mai sus, MB+7%, MB–7%. După 7 zile şi 28 zile, respectiv, au fost efectuate încercările la compresiune. Scopul principal al testelor a fost de a stabili efectul pe care îl are natura aditivilor, administraţi în combinaţie, precum şi efectul dozelor asupra câştigului de rezistenţă pe durata de întărire.

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ASPECTS CONCERNING THE ACHIEVEMENT OF THE DIGITAL CADASTRAL PLAN OF A ROAD

BY

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Abstract. The purpose for the Roads Cadastral Informational System (SINCAD) consists in the achievement of a data base and the inventory performing for real estates, administrated by the Roads National Company (CNADNR) or owned by different owners, under technical, economic or legal respect, comprising, in an unitary format, the regulations, ways, and methods for its execution and organizing. It provides the data for the roads technical Data Base development, as well as the correlation of this cadastre with the works needed to be recorded into the general cadastre technical documents and into the real estate publicity documents. The Data Bases, comprising the geographical information destined for the plans and maps development, are represented by an ensemble of layers, that shall be created for a road sector analysis. Certain aspects concerning the achievement of the digital cadastral plan for a road, are presented in this paper.

Key words: cadastre; mapping; data base; digital.

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1. Introduction

The Cadastre, as a system of inventory performing and evidencing of the real estates from the society, has a decisive role in seizing and presenting the evolution of these exchanges, concerning their shape, the size and their belonging (the Law of Cadastre and Real Estate Publicity, no. *7*/1996). Through this law, the technical, economic and legal tools, contributing to the protection of the ownership right over the real estates, have been established. The cadastre progressed toward a modern one, up to the extent where a data base cadastral information, represents the support for developing informational systems, on activity domains, with a priority role in management, planning and decisions taking. In the phase of passing to the market economy in Romania and of the accessing, with whole rights, to the European Union, the social role of the multi-functional cadastre has been increased, being a significant item, that the building of the new type of society is based on.

The Roads Cadastral Informational System (SINCAD) is defined as being a sub-system of the overall cadastre, through which the evidence and systematical inventory performing of the real estates administrated by the Romanian National Highways and Roads Company (CNADNR) or belonging to different owners, under technical, economic and legal respect.

The object of SINCAD is represented by public roads, therein: the bridges, the viaducts, uneven passages, tunnels, protection and strengthening buildings, sidewalks, bicycle tracks, parking and stationing places, road plantations, road signs, are integrated part. The lands that are part of road area, the lands that are safety areas, service buildings and any other buildings, arrangements or installations destined to road protection and operation, are also included.

Besides the above-quoted legislation, when introducing the cadastre for the funds from the transports field, the Order of the Ministry of Transports no. *399*/1999, concerning the approval of the methodology for the cadastral works performance for the roads fund and agreed by the National Agency of Cadastre and Real Estate Publicity (ANCPI) is mentioned.

The SINCAD is achieved in several phases, the volume of necessary works being assessed, depending on the fact of introducing or not the overall cadastre within the respective area. Whereas the cadastre introducing is generally performed, in this case, on the county territories, it cannot benefit of this information over the whole territory, but only within the zones where the routes go through the communal, town and municipal territories. In the opposite case, the roads cadastral works are performed before introducing the overall cadastre, beginning with the operations of delimiting the real estates belonging to the roads, the works volume being significantly larger.

The technical design for achieving the SINCAD, will be compulsorily drawn up, for all the works going to be performed in view of introducing the cadastre on road routes, on the whole county administrative territory or on a district territory. This means that these works are found on the territory afferent to the Regional Direction of Roads and Bridges, that is part of CNADNR.

For a comprehensive and systematic acknowledgement of the real estates, for their studying and inventory performing, the cadastre comprises three functions (sides), namely

a) Technical/quantitative function, for achieving the technical documentation, consisting in: the dossier with delimiting works, cadastral plans and maps and the cadastral registers and sheets, as well the synthesis statements.

b) Economic/qualitative function, for acknowledging the quality of the lands, of the buildings, etc., representing an important tool for organizing, directing, planning and rational utilization.

c) Legal function, that provides the correct identification of the lands and buildings owners and their recording into the cadastral documents and land books, on the ground of legal rights and deeds, that the ownership is based on. Further, the aspects concerning the achievement of a road digital cadastral plan, basic component of the technical function of overall cadastre and Informational Systems, on activity fields, will be presented.

2. The Achievement of Digital Cadastral Plan

The topographical survey is the cartographical representation of a relatively reduced land surface, at the scale. The plan represents the decreased image and also the horizontal projection of the topographical surface that, through the details contained, allows a more accurate acknowledgment of the planimetry and of the ground level (the relief) (Nistor, 1982). Whereas the topographical survey is produced at larger scales (1:500...1:10,000), its content is rich in details, more accurately represented.

2.1 Classification of Topographical Surveys/Cadastral Plans

It is performed depending on several criteria, as follows:

A. *After the content*

a) 3-D, spatial representations, the most frequent of them containing the planimetry, as well as the relief;

b) 2-D, bi-dimensional representations, comprising only the planimetry, without benchmarks or contours (level curves), such as the cadastral plans;

c) one-dimensional representations, as level marked plans, with contours (level curves), or profiles, representing only the ground level, on the surface or on certain directions, with the points located in the plan.

B. *After the presentation modality*, the plans and the maps may be presented as

a) graphic or analogical format, on paper or plastic support, used before the computers utilization;

b) numeric or digital format, based on the coordinates acknowledged for all the points, obtained through site measurements, that may be stored in computer memory, may be displayed, studied and listed or delivered on a magnetic support.

C. *After origin and obtaining modality*, the plans may be obtained through one of the following methods:

a) through digitization or scanning – vectorization of certain existent plans;

b) through classical measurements, performed on site, using the modern equipment (total stations, electronic tachometers, electronic levels);

c) through site measurements, using the satellite technology GNSS (“stop and go” method, continuous cinematic measurements);

d) using the digital photogrammetry, with the orto-photo-plan vectorization and getting the restored plan.

D. *After the scale*

a) graphical/analogical plans, are achieved at larger scales (1:500, 1:1,000, 1:2,000, 1:5,000) or at very large scales (1:200; 1:250);

b) digital / digitized plans, where the scale size is useless, whereas their visualization and listing may be performed at any scale.

In case of certain comprehensive topographic surveys and depending on the practical requirements, the reporting is performed on thematic layers, therein, through synthesis, the topographic survey or cadastral ensemble is obtained and the representation on large areas is performed on sections, that are connected accordingly to the scheme for locating the sheets into the plan.

2.2. Works Automation

The automation, based on the Informatics development has also been extended into the topographical surveys field, having the trend to be generalized in all the site and office phases, with favourable effects concerning the quality and works economic efficiency. In the field of data processing and plans editing, the commencement being represented by the computer assisted design, through CAD (Computer Aided Design) systems, progressing up to the programs as desktop mapping type, enabling the automatic mapping.

Currently, the computer processing system is a complex of specialized modules, in order to solve the problems from the geo-topographic sector, as follows:

A. *Topographic calculation modules*, that together with the CAD applications, are the basis of any program, enabling the performance of

a) data bidirectional transfer, using the interface between the electronic equipment memory and the computer;

b) geo-topographic calculations performing;

c) geometric solutions concerning the alignments intersections, inter-polations, etc.

B. *CAD functions software*, therein the reporting of digital topographic survey or cadastral plan is achieved.

C. *Three-dimensional modelling program*, having as final object the ground digital model (Digital Terrain Model), the points benchmarks evaluation. The site digital model is used for drawing the contours (level curves), achieving the profiles, embankments calculation, etc.

D. *Models with functions*, allowing the solution of certain design issues within the transport, cadastre, road cadastre and real-estates –public utility cadastre, etc.

2.3. Legal and Technical Documentation

Before the measurements beginning, the legal documentation concerning the real estates belonging to the roads, is performed. The legal deeds and facts, through which they come in the public roads units' administrations, are identified: expropriation decrees, laws, Governmental decisions, legal decisions, extracts from land Register, etc.

In parallel, the documentation concerning the existing technical works in the area and partially or totally describing the real estates over the roads fund, as well as all the works performed by other economic agents, is performed. The technical documentation will comprise topographical surveys at different scales, drawn up in different development phases of a real estate, plans that the object designing, the sketches and the drawings from the building technical book, were based on. Technical information over the real estate belonging to the roads and comprised within the cadastral plans and registers, will also be requested from the Cadastre and Real-Estate Publicity Offices (OCPI) and from the Town Development and Territory Arrangement Departments.

2.4. Identification and Delimitation of Real Estates

The identification operation of a real-estate location is achieved before the measurement works, it is performed by the service-provider together with the beneficiary, on natural or conventional limits. For recognition and delimitation, the CNADNR representative, the service-provider and the OCPI delegate visit the site and identify the existing point, delimiting the road zone (land marks) or establish a new point on the limits, mutually agreed with the neighbours. In parallel, the real estate limits materialization is performed, in accordance with the property deeds, submitted by the owner.

2.5. The Performance of the Measures in Order to Draw up the Digital Cadastral Plan

All the topographical measurements performed on site, necessary for the digital cadastral plan achievement, must rely on the National Geodetic Network (RGN) points, achieved with satellite technique GPS (Global Positioning System), including on its density increasing points. Depending on the size and on the supporting network points position, against the road considered, the topographical surveying network points are designed (planymetric and surveying roads, with details topographical surveying methods).

a) *Support geodesic network*

Starting with 1951, Krasovsky 42 ellipsoid has been used as horizontal datum, in Romania and for the plans and maps production, Gauss - Kruger (1951-1970) cartographical projections have been used and then, for the national economy needs, the Stereographic projection on unique secant plan (Stereo 70). Since 2009, the European geocentric datum ETRS 89 has been adopted, under the indicative RO_ETRS 89, using the same Stereo 70 projection. For this reason, the point coordinates transformation from the European geocentric datum to Stereo 70 datum, must be performed, through Helmert transformation, with seven parameters. This way, the planimetric support geodetic network is represented by the points of the network of grade *A, B* and *C*, on the permanent network points (RGN – SGP). Increasing the support points, of *D* grade, is performed accordingly to the requirement of the detailed topographical survey, using the satellite technology GPS, Smart Station system, ROMPOS Service, poly-goniometric roads survey.

The vertical determination of the points/landmarks is performed within Black Sea benchmarks system 1975 (MN 75). For this reason, the country geodetic-geometric surveying network is used, of high accuracy orders *I* and *II*, of accuracy orders *III* and *IV*, or the geodetic trigonometric surveying network, from the very rough areas. In case of GPS (ϕ, λ, h) determinations, the ellipsoidal height, h, is the distance, normally measured, from the point from the topographical surface, up to the geocentric ellipsoid surface.

Accordingly to the observation we can make, if the relative accuracy of the points from the state geodetic network does not comply with the inner specifications, then a compensation of the network, as a free network, shall be performed, after which this being compliant with the state network.

The support network points must provide a density of one point/km of route; in practice, the points are planted along the route, at 2 km distance between them, in the plain areas, at 1 km distance between them in hill and mountain areas. The landmarks will be located near the road, within the protection area, preserving the stability, accessibility and visibility conditions. Aspects concerning the support points network at a road topographical surveying, are represented by Georgescu *et al*. (2011).

b) *Topographical surveying measurements performance*

The operation has as purpose the gathering of data from the site, necessary in order to achieve the digital cadastral plan, respectively the analogical/graphical cadastral plan.

For surveying the detail points belonging to the real estates from within the road fund, the planimetric and surveying traverses method is utilized, combined with topographic radiation, intersections, cross-profiles, etc. using the modern equipment (total stations, electronic levels) the topographical surveying may be performed also using GPS technology (stop and go and continuous cinematic measurements). In case of larger works, digital photogrammetry, using the orto-photo-plan vectorization brought to a given scale and getting the restored plan, may be utilized.

Through topographical measurements, the shape within the plan and the road territory position, occupied by the road constructive elements, are determined: carriageway, sidewalks, bicycle trays, gutters, trenches, verges, guard ditches, support walls and other benchmark works. In parallel, there are established

a) The safety zones represented by the land surface located on the both sides of the road territory, exclusively destined to the road signs or for the purposes related to the road maintenance and operation, to the traffic safety of to the protection of the properties located in the road neighbourhood. The safety areas are comprised at the road territory external limit, up to certain values, established through Governmental Ordinance no. *43*/1997.

b) The protection areas are comprized between the safety zones external edges and the road zone edges, at distances from the road axis, established depending on the road category, through the same Ordinance.

The road axis will be represented by a 3-D poly-line, described by X, Y, Z coordinates. It will be split into homogenous sections, from the point of view of cross profile, of traffic, of road area, of the speed in traffic and of slope. Associated to the axis, text information concerning the name and kilometric position of the sector beginning and end, will be presented.

The road real length is measured on the axis and the alignments will be resulted from the positions of the tops defining the line described. The angles between the alignments will be measured in direct direction, expressed in centesimal degrees, in upward sense to the mileage meter (Fig.1).

The alignments are connected through curves, that must be represented through geometric items; for this purpose, sufficient points are measured in order to determine and/or check the respective items (connection curve radius, inlet and outlet tangents, connection length, etc.).

For the purpose of conveying the landforms and the way vertical geometry, the measurements necessary to determine the road longitudinal profile and the cross-profiles, are performed. The last ones are performed in the longitudinal axis characteristic points: at the slope modifications, at the cross-profile shape modification, besides the hectometric and kilometric landmarks, near the artworks, etc. The cross-profiles will compulsorily include all the characteristic points.

The kilometric landmarks coordinates, the inscriptions borne therein, as well as the shape within the plan and the position of the afferent buildings (bridges, viaducts, tunnels, supporting walls, protected slopes, etc.) will be determined. The related arrangements, comprizing all types of works, such as: intersections with other roads, with railways, special lanes, parking, fuel supply stations, will also be determined. From the traffic safety arrangements, the hallmarks, the road signs, the signalling marks, the parapets and directing pillars, will be positioned. For the buildings, including the CNADNR building of any type, that through their destination do not belong to the road, but at least a part of them, is located at distance from the road axis, the position and contour are determined.

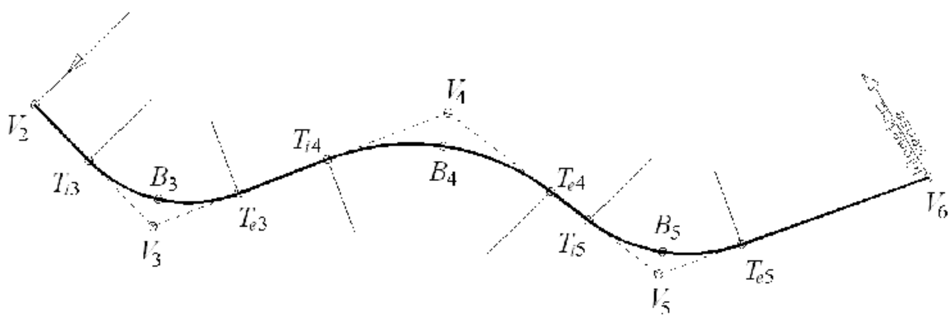

Fig. 1 – Alignments connected through curves; the road axis.

Finally, the roadway shall include the traffic lanes, the lanes for heavy vehicles, the acceleration/deceleration lanes, the turning left lane, the stopping lane, etc. The limits of the roadway shall be represented by: the separation line between the roadway and the side path, the border of the pavement, the border of the space between traffic lanes, as well as the platforms for the access to the tram, street refuges, monuments, etc. Besides the roadway, other elements forming the road platform shall be built: the side paths, the pavements, the parking spaces, the lanes reserved for tramways, bicycle lanes, tractor lanes, etc.

In the final part, after processing the field data, an inventory of coordinates for the support network points, the topographical surveying network and the details including the registration number, the code of the point and the coordinates *X, Y, Z* shall be drawn up.

The *Areas Synoptic Table* shall include the surfaces of the road lots (the road territory and the safety and protection areas), laid out on administrative territories and utilization categories: total, road territory, roadway, safety and protection areas.

c) *The drawing up of the cadastral digital plan of a road*

The digital cadastral plan must have the same content as the analogical/graphic plan, created in a classic way. It lays the technical foundation for creating the Informational Roads System. It is drawn up based on the locations coordinates, on a magnetic support, in an Auto CAD format, .dxf and .dwg, according to the CNADNR standards, regarding the structure of the cadastral plan and a database.

The content of the digital cadastral plan shall be drawn up on several layers, according to a certain structure. Conventional signs shall be used for rendering the details, for the scale of 1:500 from the conventional signs Atlas, for the scales 1:500…1:5,000, prepared by the General Direction of the Land Fund, Cadastre and Territory Organisation, Bucharest, 1978.

In the situation of topographical surveying through digital photo-grammetric methods, the digital plan/ map shall contain, in a .dwg format, the connection (link) with the images of the ortho-photo-plan of the areas crossed by the road, images used for the mapping and the checking of the details outlines, as well as layer (ortho-photo) of background, for ensuring the suggestive content of the map in the urban agglomerations.

The digital cadastral plan afferent to a road sector shall be drawn up as a multiple of the distance between the two kilometre stones (approx. 1 km), ensuring their connection. On the contrary, the division shall be performed by mutual agreement with the beneficiary, that the elements forming the road being able to be easily connected.

With regard to the digital plan of the road, the Auto CAD software gives the opportunity to create the Digital Model of the Field (DMF), to make it clear, the DMF is divided in two parts: the Situation Digital Model (SDM) and the Digital Relief Model (DRM). In order to create the DMF, two types of points are used namely

a) in order to draw up the SDM, situation/detail points, with or without the altitudes, are needed;

b) in order to draw up the DRM, surveying characteristic points and situation/detail points, with known altitudes are needed.

The SDM comprises a large number of conventional signs on the plan, helping to represent the topographical information. Its elements are represented on scale and without scale, as the cadastral plan is analogical or digital (Fig. 2). It comprises the surface items (building, forest), linear items (road axis) and location items (landmark, pillar).

The DRM represents a large number of triangular sides, built with the help of the spatial points (X, Y, Z) forming an Irregular Triangular Network (ITN). A surface area, approximated by the multitude of triangular sides, is bordered by the outline. The structural line connects the DRM points and univocally determines the triangulation of the area's surface.

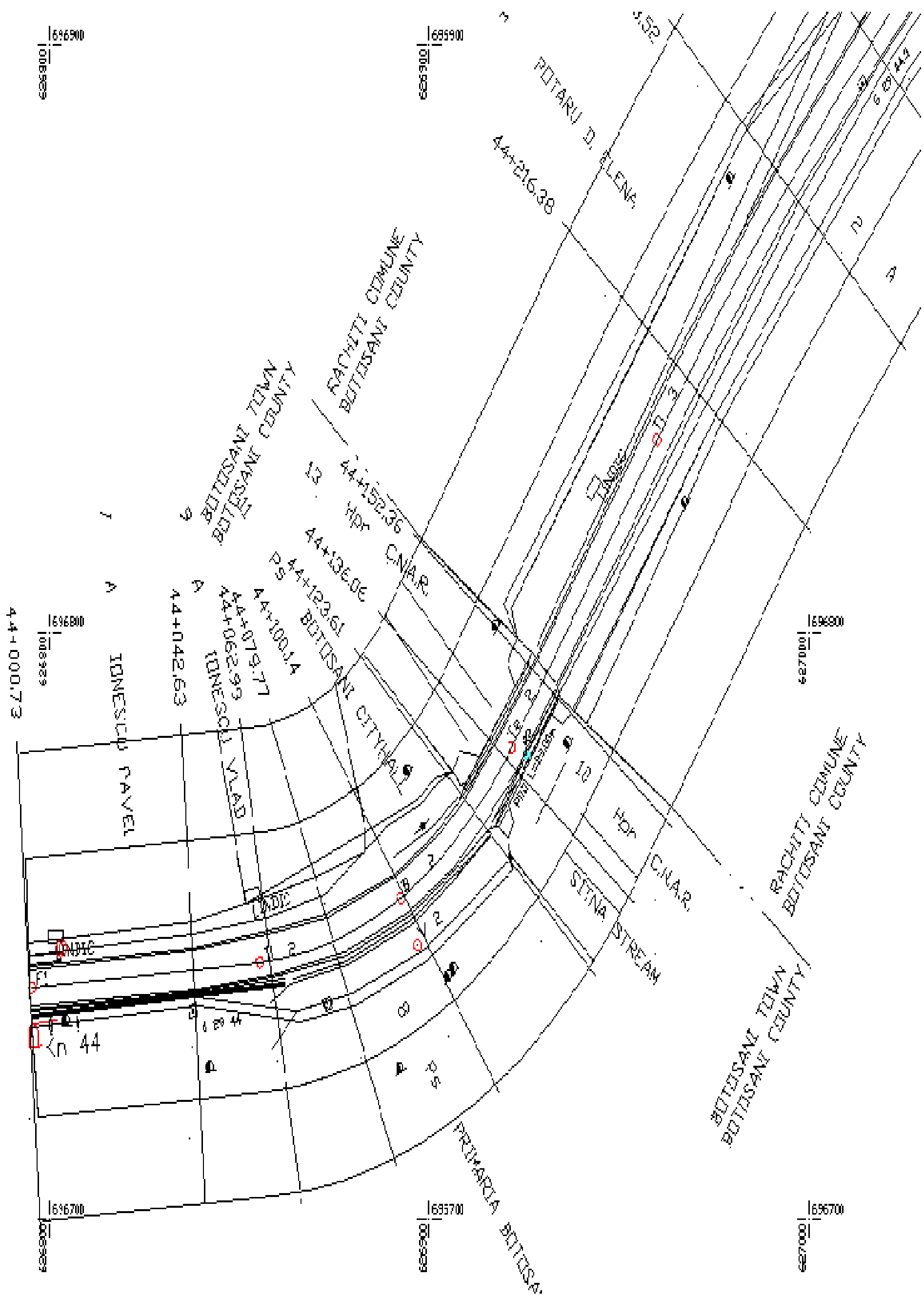

Fig. 2 – The Digital cadastral plan (SDM).

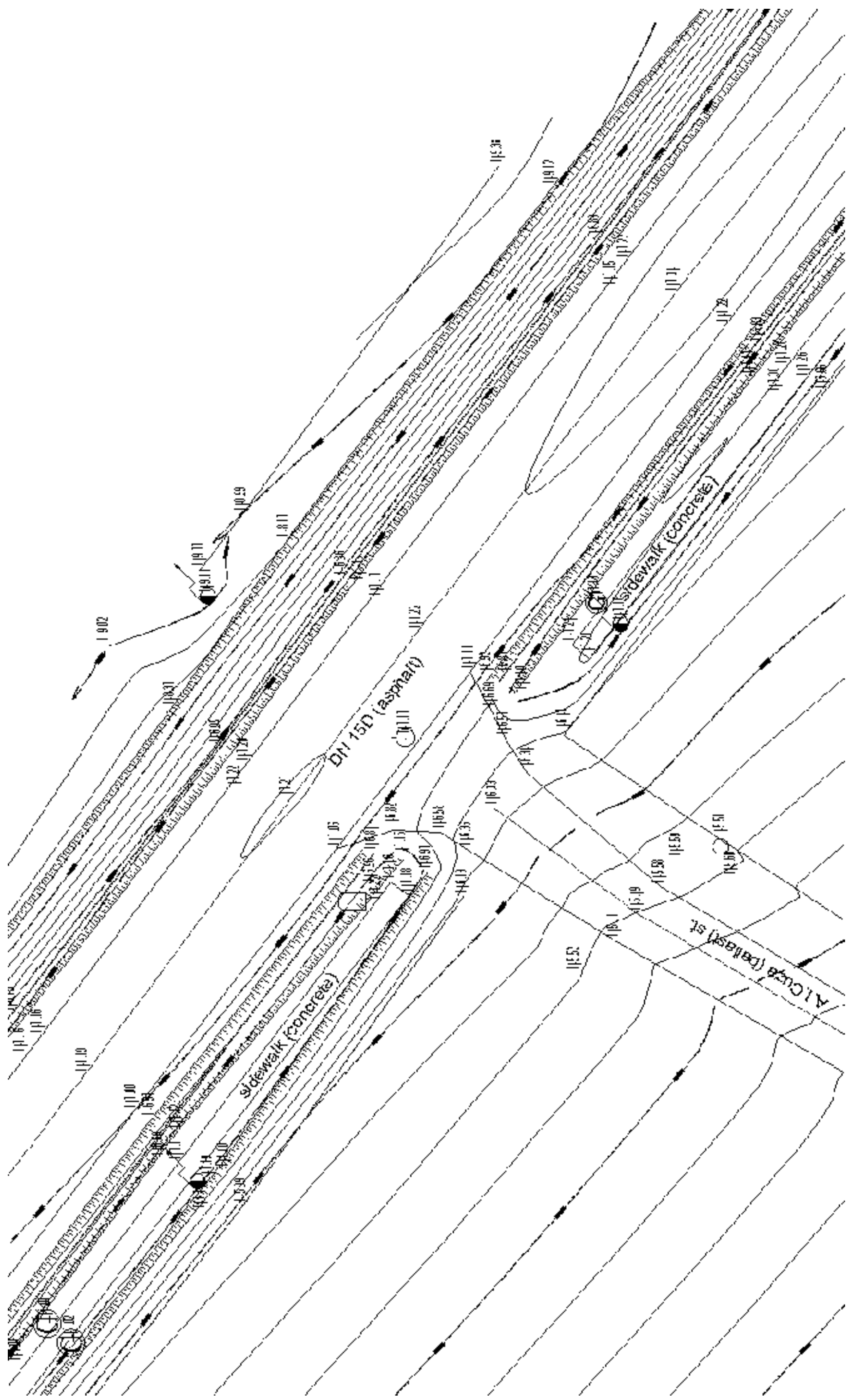

Fig. 3 – The generation of level curves.

The structural lines allow the univoque determination of the relief characteristic forms. The entire field surface is represented, created by the DRM, in several outlines. These allow the separation of the forms of relief, where the level curves are changed or ended (Fig. 3). Obtaining the Digital Field Model (DFM) shall allow the solving of many topographical and technical problems, of tracing the level curves, of creating the topographical profiles, of visualizing the field and most of all contribute to the database of the Cadastral Informational Road System.

3. Conclusions

The Digital Cadastral Plan represents the basic technical element for creating the Roads Cadastral Informational System (SINCAD), its drawing up being a complex operation. We can deduct the following conclusions from the above presentation:

1. The Digital Cadastral Plan allows the fast drawing up, on any scale, of the graphic/analogical plan, with accuracy and high execution speed.

2. The Digital Cadastral Plan allows a complete automation of the data processing, of processing and obtaining the graphical expression.

3. The Digital Cadastral Plan is a whole product, formed of spatial data and alphanumeric information, classified by their nature and affiliation in the folders, which may automatically provide the partial or total graphic expression of the space.

4. The scale of the digital plan is 1:1, being independent with respect to the classic graphic plan scale and refers only to the detail degree of the objects in the field; they must comply with the scale of 1:500 in urban area and 1:1,000 outside the urban area. Obtaining the graphic expression at a certain scale may be realized by changing the scale parameter.

5. The Digital Cadastral Plan is useful for performing certain studies and taking fast decisions, as it allows the fast selection of the information required and the drawing under the form of certain themed cadastral plans.

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ASPECTE PRIVIND REALIZAREA PLANULUI DIGITAL CADASTRAL AL UNUI DRUM

(Rezumat)

Scopul Sistemului Informațional al Cadastrului Drumurilor –SINCAD, îl constituie realizarea bazei de date şi inventarierea bunurilor imobile administrate de Compania Națională a Drumurilor (CNADNR) sau deținute de diferiți proprietari, sub aspect tehnic, economic şi juridic, cuprinzând într-o formă unitară reglementările, căile şi metodele de executare şi de organizare a acestuia. El furnizează datele pentru realizarea Bazei de Date Tehnice Rutiere, precum şi corelarea acestui cadastru cu lucrările necesare înscrierii în documentele tehnice ale cadastrului general şi în documentele de publicitate imobiliară. Bazele de date, cuprinzând informațiile geografice destinate crearii planurilor şi hărților, se constituie dintr-un ansamblu de straturi (layere), care vor fi create pentru analiza unui sector de drum.

Se prezintă unele aspecte privind realizarea planului cadastral digital al unui drum.

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CONTRIBUTIONS TO THE REHABILITATION AND MODERNIZATION OF GEODETIC NETWORK, IN ORDER TO ACHIEVE AND IMPLEMENT PUBLIC UTILITIES AND URBAN INFORMATIONAL SYSTEM

BY

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Abstract. In order to achieve digital cadastral plan of a city’s administrative territory and setting up the mapping database it is necessary the achievement and modernization of the geodetic support network. To this end it is required to respect European Union’s recommendations regarding terrestrial measurements. The adoption of ETRS’89 European geodetic datum and of a new map projection requires to be made the GPS satellite geodetic network and, for thickening, to be used traditional methods, using modern equipment. It is presented a case study, referring to the geodetic network for the administrative territory of a small town, for which is done public utilities and urban informational system.

Key words: digital cadastral plan; geodetic networks.

1. Introduction

To achieve urban and real-estate cadastre informational system it is necessary to consult town’s database and to analyse mapping and geodetic

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database of the City of Podu Iloaiei, county of Iaşi.

According to 4th article of Law No. *7*/1996 on cadastre and real estate advertising, specialized urban and real estate cadastre works will be executed according to the following standards and methodologies:

a) "Technical Standards on the Execution of General Survey" prepared by ONCGC under Order No. *186*/25.11.1997.

b) "Basic Technical Standards for the Preparation of Basic Topographic Plan" drawn up under Decree No. *305*/1971 and approved by order of the Ministry of Agriculture and Food Industry (MAFI) No. *147*/12.12.1980.

c) "Methodology for Execution of the Real Estate Cadastre Input Works in Localities" approved by the Ministry of Public Works and Territory Planning (MPWTP) by Order No. *90*/02.06.1997 and ONCGC by Order No. *911*/02.06.1997.

d) "Methodology for Execution of the Urban Networks Cadastre Input Works in Localities" approved by Order MPWTP ONCGC No. *91*/02.06.1997 and the Order No. *912*/02.06.1997.

The purpose of urban and real estate cadastre works is to set up databases for the localities management, having complete information on the existing building fund, utilities networks, capacities, possibilities of extension, etc., within inside of the city area.

2. Content of the Paper

2.1. Achievement of Thickening and Lifting Network by Triangulation–Trilateration

To achieve lifting network for the administrative territory of Podu Iloaiei City were determined the coordinates of two new unknown points by

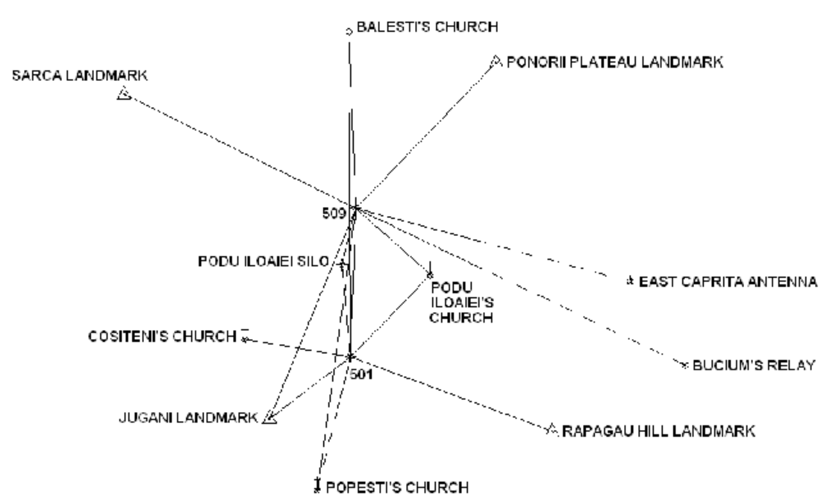

Fig. 1 – The outline of determination visas for the *501* and *509* points, using the method backwards intersection.

backwards intersection method and rigorously compensation of them in a triangulation–trilateration network (Fig. 1).

The existing cartographic and geodetic base regarding the execution of cadastre works for the administrative territory of the City of Podu Iloaiei consists in the topographic plan at scale 1:25,000, from the year 1984, and the orthophotomap made in the year 2005.

Further, it is shown the way of processing and compensation of the elements measured in the field, namely

a) The linear and angular elements measured on the field are processed, respectively, in Tables 1 and 2.

Table 1
Processing of Linear Elements Measured in the Field

Network side		Provisional distance, [m]	Reduced distance to the plane, [m]
Starting point	Arrival point		
501	*1002*	1872.4970	1872.6217
501	*509*	2740.5690	2740.3907
501	*1001*	3969.5840	3969.5796
509	*1003*	4753.1100	4752.9610
509	*1004*	3739.9760	3740.2737
509	*501*	2740.5990	2740.3907
509	*1002*	4194.4100	4194.3180

Table 2
Processing of Angular Elements Measured in the Field

Station point	Visa point	Meas. average direction g c cc	Corr. red. cc	Reduced direction g c cc	Provisional distance m	Provisional orientation g c cc
501	*2007*	14.712100	–	305.215400	5528.130	215.357157
	1002	57.353250	–	347.856550	1872.622	257.995418
	2001	109.496700	–	0.000000	1963.461	310.143068
	2003	199.092200	–	89.595500	6007.592	399.749182
	509	201.626450	–	92.129750	2740.391	2.267135
	2004	205.261200	–	95.764500	1804.750	5.905586
	1004	228.623250	–	119.126550	6063.899	29.264493
	2006	246.556900	–	137.060200	2199.197	47.204989
	1001	322.061950	–	212.565250	3969.580	122.698822
509	*1004*	71.558600	–	119.512800	3740.274	48.760423
	2008	139.403200	–	187.357400	15686.553	116.602014
	2009	151.157800	–	199.112000	33062.316	128.362091
	2006	165.938800	–	213.893000	1781.336	143.140514
	2004	218.108200	–	266.062400	944.232	195.302711
	501	225.073650	–	273.027850	2740.391	202.267135
	2007	233.822900	–	281.777100	8229.836	211.025717
	1002	247.343600	–	295.297800	4194.318	224.541550
	1003	352.045800	–	0.000000	4752.961	329.250197

The inventory of the coordinates of the geodetic points, belonging to the lifting network, is shown in Table 3.

Table 3
Old Points Coordinate Inventory

Point no.	Point name	Point order	STEREO '70 coordinates	
			X, [m]	*Y*, [m]
1001	Răpăgău Landmark	III	634244.966	674837.099
1002	Jugani Landmark	IV	634482.680	669637.604
1003	Sârca Landmark	I	640476.955	666954.714
1004	Ponorii Plateau Landmark	IV	641064.948	673807.531
2001	Cosițeni's Church	V	635942.040	669178.590
2003	Bălești's Church	V	641638.075	671093.514
2004	Podu Iloaiei Silo	V	637427.520	671284.360
2006	Podu Iloaiei's Church	V	637252.350	672602.500
2007	Popești's Church	V	630262.467	669796.530
2008	East Caprița Antenna	V	634324.594	686370.915
2009	Bucium Relay	V	624122.010	701049.880

b) The provisional coordinates calculation of new points *501* and *509* are presented in Tables 4 and 5.

Table 4
Provisional Coordinates of the Point 501 (*16-Combinations*)

Combination	Provisional coordinates of the point 501		Differences	
	X'501, [m]	*Y'501*, [m]	Δ*X*, [m]	Δ*Y*, [m]
2006-2004-2001	635630.444	671117.016	–0.176	–0.239
1002-2007-2004	635630.395	671117.151	–0.225	–0.104
2007-1004-2001	635630.654	671117.040	0.034	–0.214
...	…	…	…	…
1002-2004-2001	635630.697	671117.313	0.077	0.059
1002-1004-2001	635630.686	671117.315	0.066	0.061
1002-1004-2004	635630.671	671117.299	0.051	0.045
501	635630.620	671117.254	Ray = 9.8 cm	

Table 5
Provisional Coordinates of the Point 509 (*22-Combinations*)

Combination	Provisional coordinates of the point 509		Differences	
	X'509, [m]	*Y'509*, [m]	Δ*X*, [m]	Δ*Y*, [m]
1004-2006-2009	638369.338	671214.684	0.132	–0.249
1004-2006-2008	638368.971	671214.854	–0.235	–0.079
1003-1002-2006	638368.974	671215.141	–0.233	0.208
...	…	…	…	…
1003-2007-2006	638369.147	671214.898	–0.059	–0.036
1003-2004-2006	638369.148	671214.896	–0.058	–0.037
1003-2007-2004	638369.149	671214.896	–0.057	–0.037
509	638369.207	671214.933	Ray = 13.3 cm	

c) Rigorous compensation of the coordinates of the new points *501* and *509* and the results accuracy evaluation.

For complete evaluation of the weighted indirect measurements precision first is calculated the error unit of weight, with relation

$$s_0 = \pm\sqrt{\frac{[pvv]}{r-n}} = \pm 27.7815^{cc}.$$

Table 6
Error Ellipse Calculation Elements

Point no.	Coordinated errors		Semi-axes ellipse		Large ellipse axis orientation
	s_x, [m]	s_y, [m]	A, [m]	B, [m]	g c cc
501	0.107858	0.056281	0.10836	0.05532	192.893022
509	0.076664	0.074549	0.08798	0.06078	47.481058

The average square error of the offset distance will be calculated with the relation

$$s_{D_{ij}} = \pm s_0\sqrt{Q_{D_{ij}}} = \pm 0.2703 \text{ m}.$$

2.2. The Making of Geodetic Network by GPS Technologies

In order to create the thickening and lifting network made of two new points it was used the GPS measurement technology to determine the point's position in real time through the Romanian position determination system (ROMPOS).

ROMPOS system is based on a national network of permanent stations installed by Cadastre and Land Registration Office, which are base stations that operate continuously providing real time data, and at predetermined intervals (Dragomir *et al*., 2005).

To carry out observations the equipment used was (Nistor *et al*., 2005): GPS Spectra Precision Epoch 25 receiver, double frequency (L1/L2), rover RTK+PP, serial no. 0813J55676 (Tables 7,…, 10).

Table 7
Coordinates Inventory of ROMPOS RTK, Iaşi and VRS, Romania

Point no.	ROMPOS RTK Iași		ROMPOS RTK RO-VRS	
	X, [m]	Y, [m]	X, [m]	Y, [m]
501	635630.4105	671117.0560	635630.3975	671117.0375
509	638369.3395	671214.8815	638369.3365	671214.8700

Table 8
Calculation of the New Points Using Three Points to Determine the Trans-Calculation Parameters

Number / Point name	Geographic coordinates		STEREO '70 rectangular coordinates	
	φ	λ	*X*, [m]	*Y*, [m]
Răpăgău	47.110470	27.182042	634244.966000	674837.099000
JOGANI	47.111724	27.141388	634482.680000	669637.604000
Sârca DTM	47.143371	27.121446	640476.955000	666954.714000
501	47.115303	27.152569	635630.438844	671117.092303
509	47.132159	27.153407	638369.327453	671214.871016

Table 9
Calculation of the New Points Using Four Points to Determine the Trans-Calculation Parameters

Number / Point name	Geographic coordinates		STEREO '70 rectangular coordinates	
	φ	λ	*X*, [m]	*Y*, [m]
Răpăgău	47.110470	27.182042	634244.966000	674837.099000
JOGANI	47.111724	27.141388	634482.680000	669637.604000
POD PONORII	47.144641	27.174096	641065.948000	673807.531000
Sârca DTM	47.143371	27.121446	640476.955000	666954.714000
501	47.115303	27.152569	635630.578156	671117.173375
509	47.132159	27.153407	638369.595222	671214.903157

Table 10
Calculation of the New Points Using 28 Points to Determine the Trans-Calculation Parameters

Number / Point name	Geographic coordinates		STEREO '70 rectangular coordinates	
	φ	λ	*X*, [m]	*Y*, [m]
PG CERCU	–	–	624493.8567	697142.0401
PG DL HOLM	–	–	633189.0110	683396.1420
PG CUCUTENI	–	–	630182.6020	684285.6490
PG FOCURI	–	–	653503.6140	666033.2300
PG MOVILENI	–	–	633917.0480	644391.5470
PG CÂRPIȚI	–	–	645541.4420	697354.7310
ȚIBĂNEȘTI	–	–	604023.4960	679502.2470
IAȘI	–	–	630430.0780	693266.4860
PG SÂRCA	–	–	640476.9550	666954.7140
HÂRLĂU	–	–	662242.4960	644667.3380
RĂDUCĂNENI	–	–	607221.9860	729651.0850
PG MOV JORA	–	–	639034.3670	650995.7680
PG PROSELNICI	–	–	627921.8030	688720.3050
…	…	…	…	…
501	47.11530282	27.15256928	635630.4114	671117.0497
509	47.13215876	27.15340665	638369.3443	671214.8787

3. Results and Discussions

Following the measurements by GPS methods were obtained five sets of Stereo-graphical 1970 plane rectangular coordinates, presented in Tables 11 and 12 (Neuner *et al*., 2002; Nistor & Sălceanu, 2005).

For the comparative study were calculated the differences between new points coordinates obtained by the classical determination method and coordinates obtained from GPS measurements.

Table 11

Comparison Table Classic Measurements – Three Points Calibration GPS Control

Point no.	Determinations from classic measurements		Determinations with three control points for calibration		Differences		Vector
	X, [m]	Y, [m]	X, [m]	Y, [m]	ΔX, [m]	ΔY, [m]	
501	635630.537	671117.209	635630.4388	671117.0923	–0.0982	–0.1167	0.1525
509	638369.177	671214.886	638369.3275	671214.8710	0.1505	–0.0150	0.1512

Table 12

Comparison Table Classic Measurements – GPS ROMPOS RTK Iaşi

Point no.	Determinations from classic measurements		ROMPOS RTK Iaşi		Differences		Vector
	X, [m]	Y, [m]	X, [m]	Y, [m]	ΔX, [m]	ΔY, [m]	
501	635630.537	671117.209	635630.4105	671117.0560	–0.1265	–0.1530	0.1985
509	638369.177	671214.886	638369.3395	671214.8815	0.1625	–0.0045	0.1626

4. Conclusions

After the comparative study of determinations from the thickening and lifting network by triangulation–trilateration classical methods and GPS measurements, there were not found major differences. Thus we can say that in areas where support geodetic network exists and is easily accessible, it can be used to obtain a network of thickening and lifting of satisfactory accuracy, with minimal costs. In areas where the density of the points of support network does not provide opportunities for traditional measurements, GPS technology can achieve this by different measurement methods, obtaining new points with high precision.

The economic efficiency, defined by high productivity and low costs is higher then intersections whether GPS devices are their own or not, or if measurements are executed by custom by a specialized company. In addition, if the works that will be executed later will be continued with total stations, it can be counted on a lower density network, which greatly reduces the cost of works.

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CONTRIBUŢII LA REABILITAREA ŞI MODERNIZAREA REŢELEI GEODEZICE, ÎN SCOPUL REALIZĂRII ŞI IMPLEMENTĂRII SISTEMULUI INFORMAŢIONAL URBAN–EDILITAR

(Rezumat)

În scopul realizării planului cadastral digital al teritoriului administrativ al unui oraş şi constituirii bazei de date cartografice, este necesară operaţia de realizare şi modernizare a reţelei geodezice de sprijin. În acest scop se are în vedere respectarea recomandărilor Uniunii Europene privind măsurătorile terestre. Adoptarea datumului geodezic european ETRS '89 şi adoptarea unei noi proiecţii cartografice, impun realizarea reţelei geodezice satelitare GPS, iar pentru îndesire utilizarea unor metode clasice, cu folosirea aparaturii moderne. Se prezintă un studiu de caz, cu referire la reţeaua geodezică pentru teritoriul administrativ al unui oraş de mici dimensiuni, pentru care se realizează un sistem informaţional urban-edilitar.

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THE UPDATE OF THE CADASTRAL DATA FOR THE FORMER SAE COPOU, IAŞI, BASED ON GENERAL AND AGRICULTURE CADASTRAL WORKS

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Abstract. Getting vineyard cadastre database in the unitary system of technical, economical and legal will be done according to Law vine and wine No. *67*/1997, by identifying, recording, delineation and mapping of all land and cadastral plans of the national vineyard property and other real estate related.

This paper presents the update of the existing cartographic documents for the study area, necessary for observing changes in the situation of land parcels. The most obvious changes appeared by including the vineyard unit in the inside of the City of Iaşi, due to the process of urbanization of the area.

Key words: digital cadastral plan; cadastral parcels.

1. Introduction

According to the cadastral records of the City Hall of Iasi, in 1989, the built-up area of the City of Iaşi was of 3,679 ha, so that afterwards the territory of Iaşi Municipality was modified, in the following steps (Fig. 1):

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a) In 2005, the total area of the City of Iaşi was of 9,366 ha, following some changes of the outside and inside of the City of Iaşi limits, related to the year 1989.

b) In 2007, the inside of the City of Iaşi expanded with 2,382 ha, by creating 18 expansion areas, denoted by letters from *A* to *S*.

c) Until 2010, the buildable area of the inside of the City of Iaşi has increased with another 248 ha, by approving of 37 urban plans.

d) In 2010, the area of the expanded inside of the City of Iaşi has reached 6,309 ha, and the area of the outside of the City of Iaşi has reached 3,057 ha, dispersed in 14 areas.

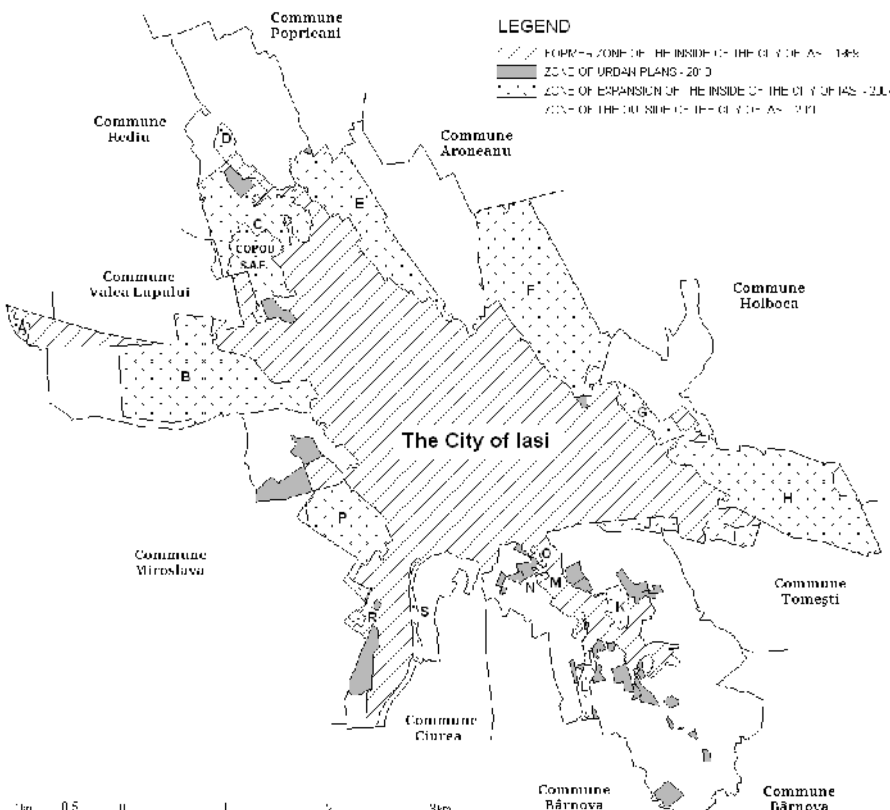


Fig. 1 – The map of the areas of the inside and the outside of the City of Iaşi.

By including the expansion areas and urban plans in the former inside of the city, the occupation degree has reached to 67.36% in 2010, related to 39.28% in 1989.

By making the General Technical Cadastre of the City of Iasi (Technical normative for general cadastre introduction, 2011), between 2005 and 2008, were accomplished the following measures:

a) Cadastral determination by materializing in the field of over 200 border points, noted *R*1, *R*2,…, which were determined by Stereo-70 Projection System flat rectangular coordinates and by Black Sea-1975 reference system bench marks.

b) The geodetic network of the Iaşi territory was determined by GPS technology and includes 84 main points, noted with *I*1, *I*2, …, materialized in the field and determined by *X*, *Y*, *Z* coordinates.

c) The thickening of the geodetic network up to approximately 5,000 points, which assures the density needed in the detailed execution of the topographic and cadastral measurements was made by polygonal networks.

The field work necessary for the lifting in plan of the vineyard unit were made with TC705 total station, by Leica Geosystems, with direction standard error of 15 cc and distance measurements precision of 2 mm + 2 ppm.

2. Content of the Paper

The thickening of the planimetrical support network included the determination of the new points *201* and *205* (Fig. 2), based on the old geodetic points of the 4th and 5th order, already existing in the triangulation network from the STEREO-70 Projection System of Iaşi territory (Huţanu & Nistor, 2010). By standing with the total station on the Jewish Cemetery Landmark (Patrici Hill Landmark) was checked the planimetric position, based on the method backwards intersection, by targeting the seven geodetic points of 5th order (Fig. 2), visible from this 4th order landmark.

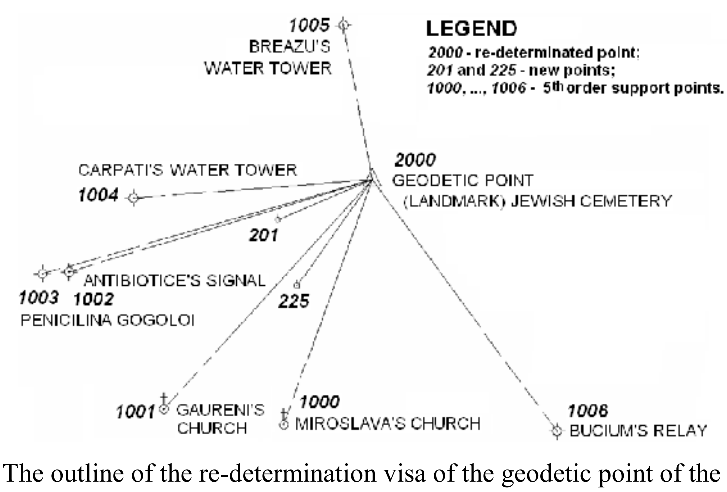


Fig. 2 – The outline of the re-determination visa of the geodetic point of the 4th order, Jewish Cemetery Landmark, through the backwards intersection and the determination of the new points *201* and *225*.

To the calculation of the position in plan of the landmark contributed the average of the 11th combinations remaining from a total of 35, obtaining the next plane rectangular coordinates: $X = 634886.578$ m; $Y = 692738.415$ m.

Due to the display of the geodetic points of 5th order in the three quadrants, the backwards intersection made by the processing program TOPOSYS is half rigorous and the average plan positioning error of the landmark is 4.9 cm. According to the coordinates inventory of the triangulation network in the STEREO-70 Projection System, made by O.C.P.I., Iaşi, for the territory of the Iaşi county , the plane rectangular coordinates of the Jewish Cemetery Landmark are: X = 634886.568 m; Y = 692738.436 m.

The measurements for the determination of the points from the realty perimeter and all the details of the plots included were made through the method of supported on the both ends traverse. The supported traverse included a number of 22 stations, from which a border landmark *R*31 and a GPS landmark from the main network of Iaşi, *I*84, with possibility of sighting towards the border landmark *R*30 and towards the GPS landmark *I*83 (Fig. 3).

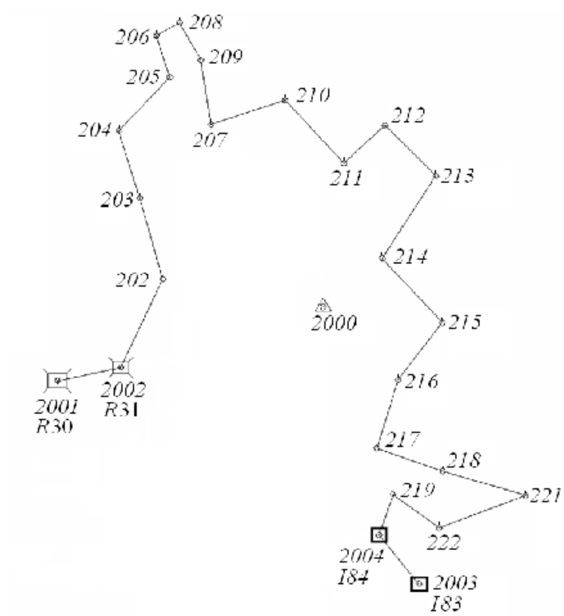


Fig. 3 – The outline of the supported traverse on the points *R*31 and *I*84.

3. Results and Discussions

Before making the processing of the topographic measurements obtained in the field work phase, because the processing program TOPOSYS allows us to do that, is recommended to be checked the distances between the traverse points. After the calculation it results the average error between forward – backward distances for the station points, which is of ±1.5 cm, and the biggest difference among the values of those distances is between the traverse points *208* and *209* and it has the value of ±2.4 cm.

By viewing the file where is presented the method of calculation and compensation of the supported traverse it is noted that the traverse has a total length of L = 4,031,718 m, an error of un-closure on directions $e_\beta = -0^g06^c85^{cc}$, respectively an error of un-closure on the axis OX, e_x = 0.217 m and on the axis OY, e_y = 0.164 m.

The plane adjustment of the supported traverse was made based on the distances. Still here are displayed for the traverse points, the values of the directions and distances measured and compensated with their corrections in seconds, respectively in centimeters. For all the 20 points of traverse which made the object of the compensation, the average error of direction is of $14^{cc}.3$ and the average error of distance is of 1.50 cm.

In the end, after the phase of compensation of the traverse, by the calculation version *Automatic Cancellation*, from the processing program, it results the position in plan of the traverse points, of the border points on the realty perimeter and of the corners of the plots (Fig. 4), (Huţanu & Nistor, 2010; Huţanu & Moca, 2010).

The emplacement and delimitation plans of the realty are executed for the next purposes:

a) registration with un-determinate character in the Cadastral Register of the judicial acts and facts regarding the lands and constructions located on a territorial administrative unit for which wasn't determinate the General Land Register's documents; for those will be elaborated documentation drawing instructions;

b) solving of the appeals regarding the fairness and the accuracy of the data on the realty;

c) advantaging the management, planning and forecast organizations from all national economy branches, by automatizing the cadastre works, in the taking decisions process, in case there is a large volume of data and information about real estate properties, provided by the Land Register;

d) for the elaboration of topographic and cadastral documentation, which are required by the public administration for the notices, certificates and licenses issuing and also for solving of all the aspects related on formation and reconstitution, after finalizing the general land register data processing of an administrative territorial unit;

e) updating this data and information, regarding the form, the area, the category of use, the owner and others is due to the dynamics of the real estate circulation in a society with a changing market economy.

The advantages of the digital cadastral plan consist in the fact that it permits

a) to the land register offices to identify on a graphic support the emplacement of the cadastre bodies and to assign them an unique identifier, in a low cost conditions; the cadastre must provide to the real estate market, when the realty is sold or mortgaged, not only elements which can prove the property right, but also the cadastral documentation necessary for localizing it;

b) to integrate the cadastral information to a different level of detailing;

c) to instantaneous updating the cadastral situation within certain territory;

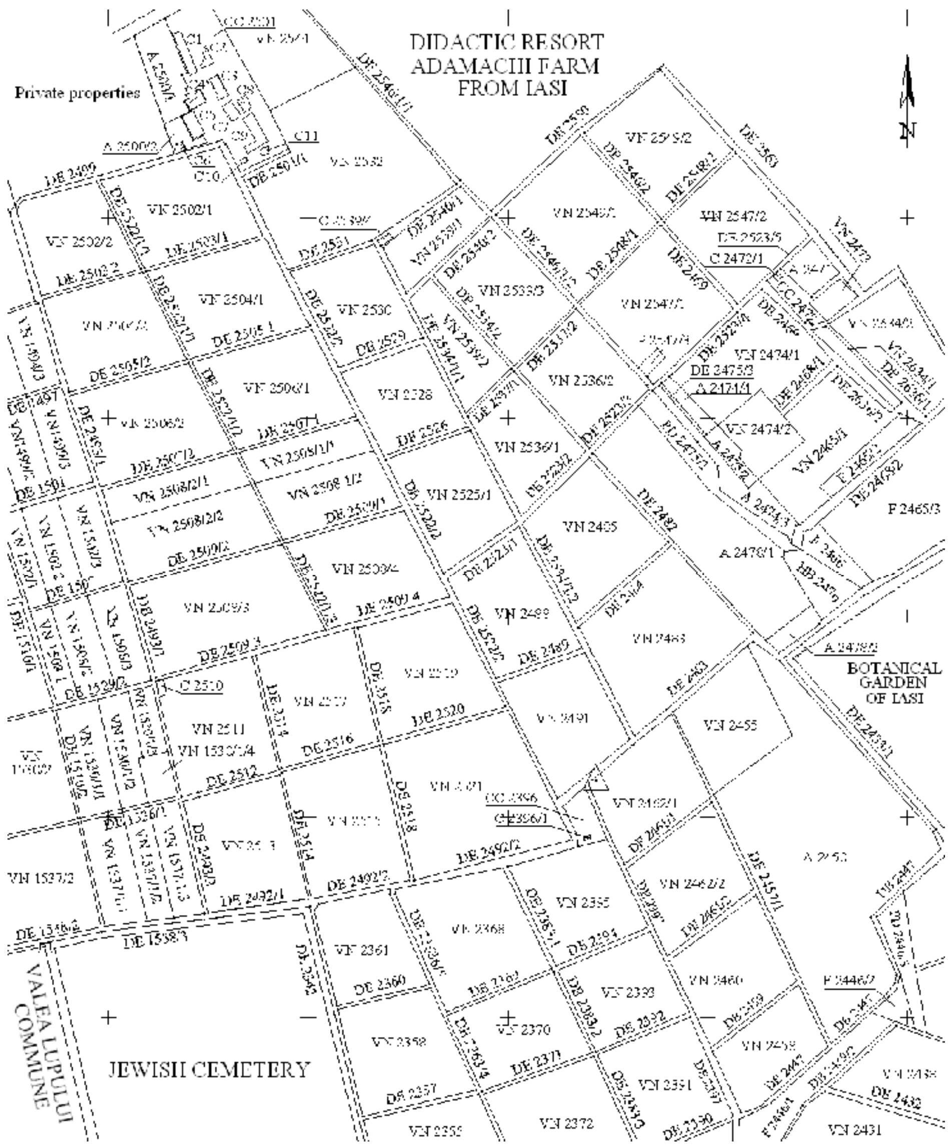


Fig. 4 – Drawing the location and cadastral delimitation plan for the vineyard unit.

d) to offer efficient cost solutions, especially in the urban areas where the request for cadastral data is more pronounced than in the rural areas;

e) to record systematically the cadastral documentations made within some territory, helping to realize a permanent update of the General Cadastre;

f) to correlate with the land register, becoming an interface in the process of cadastral noticing;

g) to connect with other geodetic data basis, especially the exchange of information with the Land Register System;

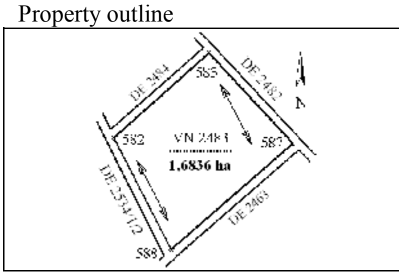
h) to ease up the access to the cadastral data, influencing in a positive way the development of the real estate market.

Table 1

The Summary of the Vineyard Real Estate

County: IAŞI	Nomenclature: L-35-32-A-c-3-IV-1-b
Administrative unit: IAŞI	No. field: T 63
Code SIRUTA: 95060	Nr. Plot: VN 2483
Code inside / outside city: 2	Nr. Cadastral register: 13263/2004

Property outline



Coordinates and surface inventory

No. point	Coordinates in Stereo-70 Projection System	
	X, [m]	Y, [m]
582	635,039.738	692,720.834
583	635,122.058	692,813.525
587	635,034.041	692,895.349
588	634,931.204	692,776.808
Surface, [m^2]		**16,836**

A. LAND VINE DATA BASE

Use Category	Use subcategory	Destination group code	Quality class	The zone inside territory
Vine (V)	Plantations of noble vine (VN)	Agriculture destination fields (TDA)	80 points	Patrici Hill

B. LANDOWNER DATA BASE

Landowner's name	S.C. Vinifruct Copou S.A. Iaşi
Landowner's Residence / Headquarter	No. 5 Viticultori Street, Iaşi
Landowners group code	DP – private domain
Ownership of the field	exclusive

C. PROPERTY'S CADASTRAL RECORDS DATA BASE

Type of soil	cambic chernozem
Suitability class	land with few restrictions
Favorability class	61…80 points of cadastral creditworthiness
Average slope of the plot	13.89% (slightly inclined)
Average altitude of the plot	110.1 m – Black Sea reference system, 1975
Slope exposure	Semi-shadowed (North-East and East)
Anti-erosion arrangements	Paralel rows with the direction of level curves
Type of vine culture	Pure culture
Soil and surface name	Aligoté = 16,836 m^2
Stock / variety	Berlandieri × Riparia Kober / Aligoté
Management way of the block	Semi-protected
Planting distances	2.20 m × 1.20 m
Current occupation degree	3,711 hubs (58.20%)
Current age of the plantation	35 years
Current stage of the plantation	Satisfactory

According to *Methodological Normative of Implementation and Maintenance of the Vineyard Cadastre* (Huțanu & Moca, 2010; Moca, 2009), the cadastral sheet of one plot must contain the basic and specialized data contained in Table 1.

Compared to the original cadastral situation, on the level of the year 1989, the update of the location and cadastral delimitation plan included the following steps.

3.1. First Stage of Updating the Cadastral Data (1989…2004)

Based on topographic measurements in 2004, have revealed changes in the application of Law No. *18*/1991, for the 111 ha remaining in the administration and operation of SAE-Copou, which later became the stock company Vinifruct Copou. In addition, *10 new roads* were established, for ensuring people's access to plots for which they were recognized property rights, under Law No.*18*/1991.

3.2. Second Stage of Updating the Cadastral Data (2004…2008)

By updating the cadastral data of the parcels, based on dismemberments registered at Cadastre and Land Registration Office, Iaşi, could be seen a faster growth of fragmentation of the parcels since the first year when the vineyard unit was included in the buildable area of the City of Iaşi. Then, for the first time, the fragmentation of the parcels was due to the desire of landowners to form, by dismemberment, lots for new buildings.

3.3. Third Stage of Updating the Cadastral Data (2008…2010)

At the last stage of updating cadastral data, according to the records of the *General Technical Cadastre* made for North-West area of the City of Iaşi, one of the changes in the cadastral situation of the parcels consists in the appearance of *three new categories of use*: shrubs and briers, green spaces and unproductive land. By comparing data, obtained in the three steps of updating the cadastral data (Table 2), by fragmentation the number of parcels, in 2010 compared to 1989, increased by 243.75% (468 plots), and from 2008 to 69.67% (271 plots).

The most significant changes that have taken place since the inclusion of this area in the inside of the City of Iaşi, consisted in fragmentation of land parcels in lots between 300…1,000 m^2 and removal from agricultural circuit, these operations being necessary to obtain building permits. This modifications, materialized in the last two years by the removal from the agricultural circuit of a number of 26 parcels and the tabulation of 27 new constructions, may lead to the conclusion that the process of urbanization of the area has begun (Huțanu, 2011).

Because initially, when was made a systematization plan of the area for the set up of the vineyard unit, access roads and paths of exploitation had widths of 2.5 m and 4 m, one of the conditions imposed by Law No. *50*/1991 is to insure in building areas pathways with minimum width of 6 m. After including the vineyard unit in the buildable area, this was the main reason which contributed to the growth of road surface with another 5.15% (0.5294 ha).

For an overview of the changes in time of the number of land parcels, they were summarized in Table 2.

Table 2

The Changes in the Number of Parcels of the Vineyard Unit, by Categories of Use of the Land, Between 1989-2010

Years	A	P	F	VN	L	PD	PDT	HB	HC	DS	CC	CP	N	Total
1989	20	5	7	67	1	4	0	1	2	77	8	0	0	192
2004	21	5	7	97	1	4	0	1	2	126	8	0	0	272
2008	21	5	7	209	1	4	0	1	2	131	8	0	0	389
2010	43	5	14	323	4	3	1	1	2	219	33	8	4	660

It may be noted that in this period of 21 years, the number of parcels of two categories of use (VN and DS) has greatly increased because of the fragmentation, since this area of North-West was caught in the extended inside of the City of Iaşi. This is illustrated in graphic statistical representation (Fig. 5).

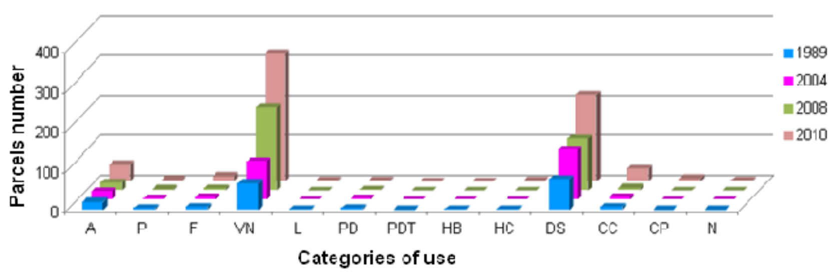


Fig. 5 – Evolution of the number of land parcels by categories of use (1989…2010).

By graphic representation of the increasing number of plots for each stage of cadastral data update can be seen how in the last stage, there is an upward trend, after inclusion of the study area in the inside of Iaşi City (Fig. 6).

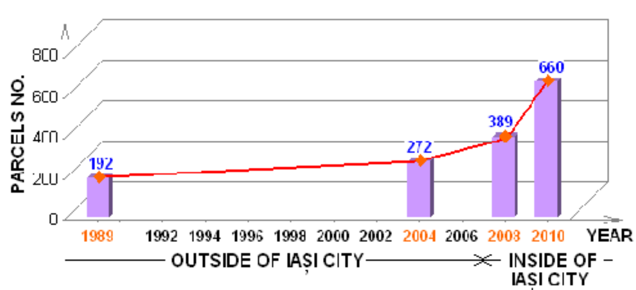


Fig. 6 – Evolution of number of land parcels (1989…2010).

For the future it is possible that, while the parcels fragmentation process stagnates, will increase the process of changing use categories, because of the owners who have not completed the documents for tabulation of the new buildings.

4. Conclusions

According to current technical standards, geodetic networks performed in the territory must be uniform and consistent, because they are a safe support for topographic and photogrammetric works, regardless of where is the work area.

The advantages of the digital cadastral plans consists in the fact that allows to land offices from the territory to verify and update the database, in a short time and at low cost, based on works done by authorized surveyors at the request of interested beneficiaries.

By fragmentation, the initial number of 192 plots increased by 45% (86 plots), while the vineyard unit was in the outside of the City of Iaşi (1989…2007) and in the next four years with 199% (382 plots), when the vineyard unit was included in the expanded inside of the City of Iaşi, due to urbanization process of the area.

In the upcoming years it exists the possibility that, while the parcels fragmentation process stagnates, to increase the process of changing use categories, especially for lots of land intended to future houses.

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ACTUALIZAREA DATELOR CADASTRALE PENTRU FOSTUL IAS COPOU IAŞI PE BAZA LUCRĂRILOR DE CADASTRU GENERAL ŞI AGRICOL

(Rezumat)

Obținerea bazei de date a Cadastrului viticol în sistemul unitar de evidență tehnică, economică şi juridică, se va realiza conform Legii viei şi vinului nr. *67*/1997, prin identificarea, înregistrarea, delimitarea şi reprezentarea pe hărți şi planuri cadastrale a tuturor terenurilor din patrimoniul viticol şi a celorlalte bunuri imobile aferente acestuia.

Se prezintă actualizarea documentelor cartografice existente pentru zona de studiu, necesară observării modificărilor survenite în timp referitoare la situația cadastrală a parcelelor. Transformările cele mai evidente au apărut prin includerea unității viticole în intravilanul Municipiului Iaşi, datorită procesului de urbanizare al zonei.

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PERMEABILITY FUNCTION FOR UNSATURATED SOILS

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Abstract. This paper describes the experimental studies, related to the soil permeability function, that were performed on unsaturated soil. The mechanical macroscopic theory developed by Brooks and Corey (1964) was used. Research was conducted on two types of samples (Tudor Vladimirescu and Copou), analysed so that the physical properties and pH could be identified. Analyses were performed in order to qualitatively and quantitatively evaluate the permeability and to account for all the elements that influence soil function as unsaturated environment. Sandbox method was used in the analysis of soil suction with a pressure ranging between pF = 0…1.8 (0.1…6.31 kPa). The concept of permeability function for unsaturated environments represents an important aspect, because natural and artificial soil processes lead to important changes on soil quality.

Key words: suction; hydraulic conductivity; porosity; permeability; texture.

1. Introduction

Permeability (Tang *et al*., 2011) of unsaturated soils is their property to allow fluids (including solid particles) circulation through their holes (Gerd *et al*., 2007). Soil permeability function is one of the most complex parameters in terms of unsaturated soils analysis (Jotisankasa *et al*., 2010). Unsaturated soils

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are spread throughout the world, especially at shallow depths (Khoury, 2010). There are many available permeability functions for unsaturated soils. Generally, the various permeability functions can be classified into three categories: empirical models, macroscopic and statistical (Leong & Rahardjo, 1997). The permeability function, in terms of suction and degree of saturation, is described in what follows, as a macroscopic model, according to Brook and Corey' theory (1964). The model is based on a mechanical theory according to which the porous space can be represented by a bundle of capillary tubes of different sizes (Brooks & Corey, 1964). To find out the function of the permeability of unsaturated soil, the degree of saturation was determined, expressed in terms of soil suction by means of the suction curve.

By suction one expresses the pressure deficit in relation to air pressure that occurs in water pores belonging to unsaturated hydrophilic materials. Suction is conditioned by factors that influence the interaction between water and solid phase, the nature and composition of the solid skeleton, water's salt content, thermal and electric status. The unsaturated zone, where the pores are partly filled with water partially filled with air, allows the coexistence of solid, liquid and gas phases. Liquids reaching the unsaturated zone usually travel following a downward vertical component (Gerscovich & Sayão, 2002). From this point of view one can talk about a quantitative permeability described by the vertical hydraulic conductivity term. This is determined based on Darcy's law.

To evaluate the soil's permeability, laboratory measurements, aimed at determining the physical parameters of soil, were performed on two types of soil samples (Tudor Vladimirescu and Copou). Research conducted in the laboratory pursued the analysis of soil permeability a well as its porosity, texture, structure, moisture, hydraulic conductivity, degree of saturation and pH. To determine soil suction curve the sandbox method was used with a pressure ranging between pF = 0,…,1.8.

2. Materials and Methods Used

Experimental method proposed in this paper is a common for measuring soil suction $S(\theta)$, where S is the analysed soil suction, and θ – the volumetric water content based on total porosity (TP) and the degree of saturation (S_e) according to the hydraulic gradient and hydraulic conductivity. According to Brook and Corey theory the analysed soil samples are considered as being unsaturated.

2.1. Soil Sampling

Research methodology includes several stages among which is the soil sampling. They were taken from two different natural locations, namely: Tudor Vladimirescu and Copou (Fig. 1). Using metallic cylinders four samples for each soil type were taken from a depth of 0…15 cm.

Fig. 1 – Soil sampling.

2.2. Sandbox Method *s*

This method is used to analyse suction for a pressures range of pF = 0 (saturation),…, 2.0 (Fig. 2 *a*). The sand in the box is used to transfer the suction from the desorption installation to the soil samples. Measurements results correspond to points on the samples drying curves and are associated with decreasing pressure. These pressure values are usually values of water standard potential. Wetting curve, on the other hand, is graphically determined by representing the water content at increasing values of pressure. This curve is not identical to drying one because the water content does not instantly respond to pressure changes (Hysteresis curve).

a *b*

Fig. 2 – Experimental setup used to determine the suction curve:
a – experimental setup; *b* – analysed samples.

"Water raising principle" is used when applying suction to the soil samples. Pressure difference represents the height difference between the suction regulator and soil samples centre. *H* pressure values between 0 and –100 cm can be applied. Suction regulator is adjusted so that to apply a pressure suction specific to each soil sample. Finally, samples are dried and weighed so that the water content can be deduced for each specific pressure. The laboratory temperature should be constant during experimental measurements. If a significant temperature variation occurs, waters viscosity can change and as a result water retention values can vary.

2.3. Determination of Soil Physical Parameters

Permeability function can be correlated using relations between volumetric water content, saturation degree and soil suction. When referring to the permeability of the soil in terms of quality, one refers to a ground that allows the water to pass through it. To determine the permeability degree of the two soil types firstly was analysed soil moisture using an oven (the samples were dried for 8 h at a temperature of 105°C). Calculation based on relations $W_g = (b - c/c - a)100$, [%], leads to a 24.89% soil moisture for Tudor Vladimirescu and a 23.85% for Copou soil. Soil porosity also depends on the apparent density (AD = $(m_2 - - m_1)/V_t$), [g/cm^3]), where m_1 is the empty cylinder mass, m_2 – the cylinder mass when filled soil dried at 105^{0}C and V_t – the total volume of the soil sample from the cylinder) (Fig. 3 *a*). Measurement revealed a 1.21 g/cm^3 apparent density (AD) for Tudor Vladimirescu soil and a 1.07 g/cm^3 for Copou soil. Soil density is used to assess the total porosity. Pycnometer method has been used to determine the soils density ($\rho = (m/m_1 + m + m_2)d$, [g/cm^3]), obtaining for Tudor soil ρ = 2.52 g/cm^3 and for the Copou one ρ = 2.39 g/cm^3 (Fig. 3 *b*).

a *b* *c*

Fig. 3 – Laboratory analysis of soil samples: *a* – analytical balance; *b* – pycnometer used to calculate soil density; *c* – pH analysed soil samples.

Porous space is often considered an artificial concept that allows its essential characteristics quantification (Sătescu & Pavel, 2011). *Total porosity* is a measure of the relative volume of soil pores. The value obtained (TP = $= (1 - \rho_a/\rho)100$, [%]) for Tudor Vladimirescu soil is of 52.05% and for Copou is of 55.14%. Transformation of total porosity in pore number and *vice versa* can be done using the following relations: e = PT/100 – PT or PT = $[e/(1 + + e)]100$. The results for Tudor Vadimirescu samples is e = 1.085 and PT = = 52.038 while for Copou e = 1.227, and PT = 55.096. Number of pores is generally a preferred index when dealing with soil engineering and soil mechanics problems, while soil porosity is a preferred for agricultural issues. Generally e varies between 0.3 and 2.0 (Stătescu, 2011).

The size distribution was determined by soil sieving. This method gives an overview of the degree of material's uniformity. The soil should not contain too much fine material, because of the risk that the material could easily be washed away by water, but neither too coarse, because it increases the permeability. The two types of analysed samples have a layered texture, laminar, inclined and shally, characterizing thin deposits of sand, dust and clay unconsolidated or consolidated through a diagenesis process.

Knowing the pH of a soil helps assess the state of fertility. Following the analysis, results indicate a pH = 6.8 for Tudor Vladimirescu soil and a pH = = 7 for Copou soil (Fig. 3 *c*).

3. Soil Water Content – Moisture Characteristic Curve

Moisture characteristic curve or suction curve (pF curve) is a function that describes the relationship between matrix suction and soil moisture based on its properties. Adsorption and pore geometry effects are often too complex to be described by a simple model (Sheng *et al.*, 2011). In the literature there are many proposed models and equations that can describe the suction curve.

This paper will follow Brook and Corey' mechanical macroscopic model that defines the relative permeability function in terms of effective degree of saturation, that can be expressed in terms of soil suction based on soil *vs*. water characteristic curve (Brooks & Corey, 1964).

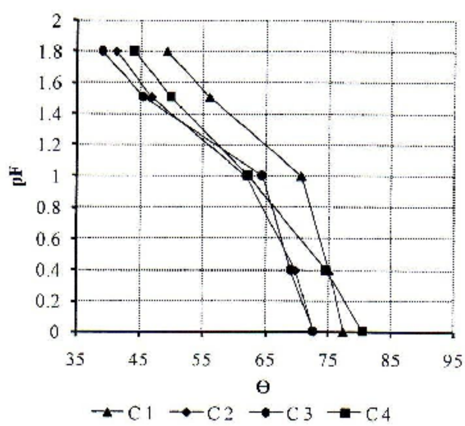
Table 1
Values Obtained from Measurements on the System

Soil sample no.	pF	Water column cm	Gravimetric water content, W		Apparent density, AD		Volumetric water content, θ	
			Tudor V.	Copou	Tudor V.	Copou	Tudor V.	Copou
1	0.0	1.0	63.88	54.23	1.21	1.07	77.29	58.02
2			60.03	59.09	1.21	1.07	72.63	63.22
3			60.05	54.70	1.21	1.07	72.66	58.52
4			66.35	58.55	1.21	1.07	80.28	62.64
1	0.4	2.5	62.03	50.00	1.21	1.07	75.05	53.5
2			57.54	56.36	1.21	1.07	69.62	60.30
3			56.88	49.57	1.21	1.07	68.82	53.03
4			61.68	57.65	1.21	1.07	74.63	61.68
1	1.0	10	58.33	48.30	1.21	1.07	70.57	51.68
2			50.94	49.09	1.21	1.07	61.63	52.52
3			53.21	47.00	1.21	1.07	64.38	50.29
4			51.40	51.35	1.21	1.07	62.19	54.94
1	1.5	31.6	46.29	38.98	1.21	1.07	56.01	41.70
2			38.67	39.09	1.21	1.07	46.79	41.82
3			37.61	40.17	1.21	1.07	45.50	42.98
4			41.12	44.14	1.21	1.07	49.75	47.22
1	1.8	63.1	40.74	37.28	1.21	1.07	49.29	39.88
2			33.96	37.27	1.21	1.07	41.09	39.87
3			32.11	36.75	1.21	1.07	38.85	39.32
4			36.44	40.54	1.21	1.07	44.09	43.37

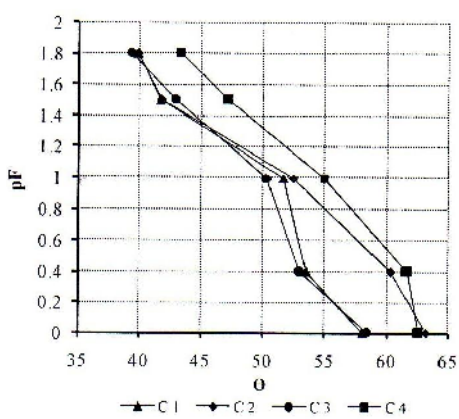
Different methods can be used to determine the suction curve. In this study the soil moisture curve was determined using the suction curve installation (Sandbox method). After soil sampling the samples were analysed for 10 days for each pressure domain, measurements being made every two days. Table 1 provides the values obtained using the Sandbox method. Volumetric moisture content was calculated as a percentage of total water content of soil. The relationship between volumetric and mass moisture is given by θ = *W*AD, where, *W*, [%], is the mass humidity and AD, [g/cm^3], the apparent density.

From Table 1, one can see that starting from pF = 1.0, the soil passes in the unsaturated area. The obtained results decrease as the pressure values increases, reaching a partial soil drying.

Experimental measured results were processed and curves that relate the volumetric water content and suction matrix were drawn (Fig. 4). Hydraulic gradient was computed only for unsaturated environment, that is between 1.0 and 1.8.



a



b

Fig. 4 – Suction curves for the two soil types: *a* – moisture characteristic curve for Tudor Vladimirescu soil; *b* – moisture characteristic curve for Copou soil.

Brook and Corey's theory, along with Poisseuille equation were used to describe flow through porous media.

To characterize the relationship between suction and the degree of saturation (Ψ *vs*. S_e relationship) experimentally determined suction curves were used. With the help of relation

$$S_e = \left(\frac{\Psi_{\text{ae}}}{\Psi}\right)^{\lambda}, \tag{1}$$

one was able to find out the degree of saturation varying the input for Ψ and Ψ_{ae}, where: λ is the suction curve slope, $\Delta\log \Psi/\Delta\log S_e$ using a double logarithmic scale.

Unsaturated soil hydraulic conductivity is defined using the relation

$$K_r = \left(\frac{\Psi_{ae}}{\Psi}\right)^{\eta}, \tag{2}$$

where $\eta = 2 + 3\lambda$, and is called *pore-size distribution coefficient*.

Soil moisture characteristic curve slope represents the change in water content at an elementary variation of matrix potential. This is an important property in relation to water retention in the soil and its availability to plants.

The total water capacity (TC) is the maximum amount of water that the soil contains when all pores (capillary + uncapillary) are filled with water. This depends on the total porosity, that can be calculated with relation

$$\mathrm{CT\%}=\frac{\mathrm{PT}}{\mathrm{DA}}\,. \tag{3}$$

Following calculations the values obtained for Tudor Vladimirescu soil is CT = 43.021% and for Copou soil CT = 51.539%. When humidity is at full capacity, anaerobic conditions are created in the soil (Stătescu & Măcîrescu,1997).

4. Results and Discussions

Using eq. (1), values between 2.5 and 4.2 were assigned to Ψ, the calculus was performed such as to find the degree of saturation (see Table 1). Afterwards the graphs were drawn based on matrix suction (Figs. 5 and 6).

The results obtained when analysing the soil samples have allowed the estimation of parameters necessary to describe the unsaturated hydraulic conductivity function (see Table 2 and Figs. 5 and 6).

Table 2

Values of Specific Parameters Studied Soils

Sample no.	Curve slope for suction, λ		Coefficient size of distribution soil, η		Soil suction, Ψ	Suction corresponding to the air inlet, Ψ_{ae}
	Copou	Tudor	Copou	Tudor		
1	8	3.8	26	13.4	2.5	1
2	6.15	4	20.45	14	3	1
3	5.15	3.8	17.45	13.4	3.5	1
4	3.52	1	12.56	5	4.2	1

One should note that for unsaturated soil, a third phase occurrs, the gaseous one, where rather complicated phenomena take place. An additional variable appears, that influences the development phenomena, namely water content.

Based on eqs. (1) and (2) the hydraulic conductivity and the degree of soil saturation have been computed. The results are presented in Table 3.

Assessment of soil permeability can be based on hydraulic conductivity, K_r. According to permeability classification (Buta & Arsenie, 2010) one can say that Tudor Vladimirescu soil has an excessively low, respectively very small permeability, and the Copou one has a very low, respectively small permeability. Excessively low permeability is not desired, since it causes the depletion of soil colloids and nutrients (Buta & Arsenie, 2010).

Table 3

Hydraulic Conductivity and Degree of Saturation

Curve no.	Hydraulic conductivity, K_r		Degree of saturation, S_e	
	Tudor V.	Copou	Tudor V.	Copou
	$\Psi = 2.5$	$\Psi = 2.5$	$\Psi = 2.5$	$\Psi = 2.5$
1	4.65162E-06	4.5036E-11	0.030749	0.00065536
2	4.0418E-07	3.93412E-13	0.015379	0.000152416
3	5.12257E-08	7.14876E-15	0.008561	4.44074E-05
4	4.45102E-09	6.2448E-17	0.004282	1.03277E-05
	$\Psi = 3$	$\Psi = 3$	$\Psi = 3$	$\Psi = 3$
1	2.68435E-06	7.27992E-09	0.0256	0.003570006
2	2.09075E-07	1.74932E-10	0.012346	0.001163334
3	2.41572E-08	7.4784E-12	0.006664	0.000450798
4	1.88152E-09	1.79702E-13	0.003214	0.000146898
	$\Psi = 3.5$	$\Psi = 3.5$	$\Psi = 3.5$	$\Psi = 3.5$
1	4.65162E-06	1.13749E-07	0.030749	0.008925015
2	4.0418E-07	4.72318E-09	0.015379	0.003490001
3	5.12257E-08	3.20636E-10	0.008561	0.001577791
4	4.45102E-09	1.33137E-11	0.004282	0.000616973
	$\Psi = 4.2$	$\Psi = 4.2$	$\Psi = 4.2$	$\Psi = 4.2$
1	0.01024	1.00432E-05	0.4	0.039742133
2	0.004115226	1.01708E-06	0.333333	0.020918627
3	0.001903969	1.46725E-07	0.285714	0.012158514
4	0.000765162	1.4859E-08	0.238095	0.006399742

Hydraulic conductivity represents the slope between the flow and the gradient curve. It is affected by total porosity and pore size distribution, water viscosity and density. Graphs presented in Figs. 5 and 6 show a decrease of the saturation degree to an unsaturated environment and slight dying due to desorbtion phenomenon.

Also apparent density strongly depends on hydraulic conductivity. Over an underground water the soil is unsaturated, and water is retained in the soil due to forces of attraction between solid matrix and water. Forces of adsorption of water molecules to solid surfaces, (the London-Van der Waals type) they are very strong but decreases with the sixth power of distance from solid wall. As a result, particles are surrounded by a thin film of liquid. Capillary forces are due to the existence of surface tensions. This water rises by capillary spaces looking porous matrix. Potential groundwater above matrix is negative, zero and positive corresponding to free surface under the canvas.

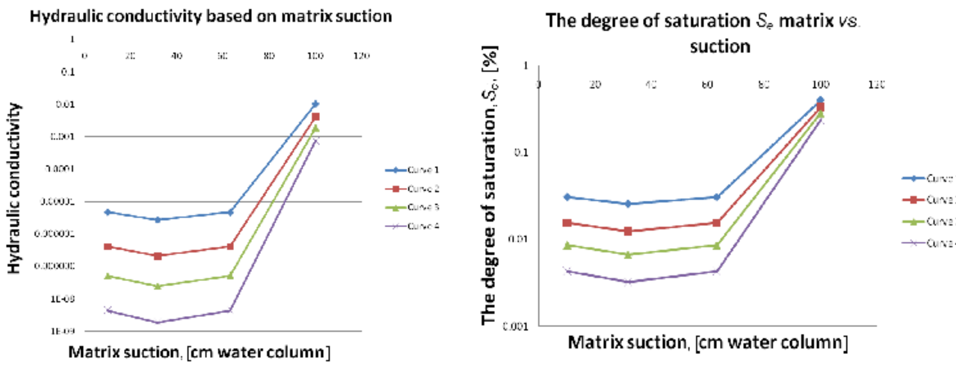


Fig. 5 – Graphical representation of soil soil suction curves, K_r and S_e, for Tudor Vladimirescu soil.

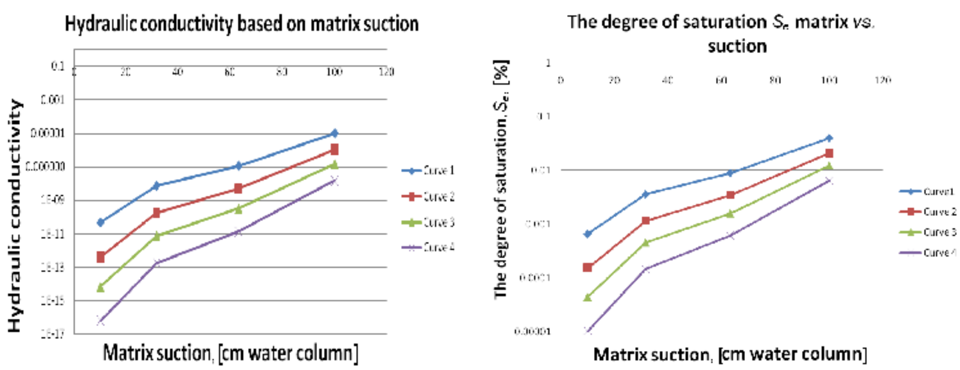


Fig. 6 – Graphical representation of soil suction curves, K_r and S_e, for Copou soil.

5. Conclusions

Knowledge of soil permeability presents a special importance both in the soil formation process and when related to applied hydroameliorative measures. In an unsaturated soil water is retained under the effect of absorption and capillary forces. Natural and artificial processes induce significant changes on soil porosity. If the soil is subjected to uniform pressure, it loses it’s macroporosity and gains microporosity. An uneven pressure exerts various effects on soil porosity, for example, fewer large pores, fine pores increase, closing pores, etc.

The permeability of unsaturated soil is difficult to interpret because it shows changes in physical and chemical environment continuously. This research method is very simple, convenient in engineering practice.

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FUNCȚIA PERMEABILITĂȚII SOLULUI NESATURAT

(Rezumat)

Se analizează funcția permeabilității solului nesaturat, pe baza metodei cutiei cu nisip, în evaluarea unui domeniu de presiuni pentru pF = 0 (la saturație) şi pF = 1.8. Cercetările s-au efectuat pe două tipuri de porbe de sol (Tudor Vladimirescu şi Copou), la care acesta a fost supus la analiza parametrilor fizici ai solului, urmând modelul mecanicist macroscopic după teoria lui Brook şi Corey (1964). Pe baza rezultatelor obținute s-au trasat curbele de sucțiune la scară dublu logaritmică, urmând apoi

calcularea pantei hidraulice în zona nesaturată. Gradul de saturaţie al celor două tipuri de sol demonstrează ca solul se află în zonă nesaturată. De asemenea conductivitatea hidraulică este un factor al permeabilităţii (din punct de vedere cantitativ) destul de important, care poate da informaţii despre gradul de permeabilitate. În mod clar este de recomandat să se efectueze cercetări asupra solului.