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How to build on difficult foundation soils in Iasi County area

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Summary

Romania is a medium-sized country (23.83 millions ha), located in the south-eastern part of Europe. Geographically, plains and tablelands occupy 49.3 percent of the country area, hills occupy 30.2 percent, and mountains 20.5 percent.

Being the second largest city of Romania by number of inhabitants (after Bucharest), through its numerous historical, cultural and economic sites, also called "the museum-city", but also as an educational and business centre, Iaşi is the city of "Gh. Asachi" Technical University, we come from.

During the past decade, damage due to swelling action of swell-shrinking clays from Iaşi area, Romania, has been observed more clearly in some parts of Iaşi where rapid expansion of the city led to the construction of various kinds of structures.

In this study, a research program has been conducted to investigate the effect of remoulding and desiccation on the swelling behaviour of swell-shrinking clay and its swelling anisotropy, to estimate depth of active zone, to develop a simple technique in determining the magnitude of swelling based on water content of the soaked specimen after 24 and 72 h, and to produce predictive models which could be used to estimate the swelling potential of swell-shrinking clays from its mineralogical and simply measured engineering characteristics. A laboratory testing program was carried out using both undisturbed, and remoulded and desiccated samples selected from different locations.

KEYWORDS: difficult foundation soils, building.

1. INTRODUCTION

The relief of Romania varies from high mountains to low plains: these categories are represented by the Carpathian Mountains, the lower basin of the River Danube and the Western coast of the Black Sea with the most important wetland of Europe – the Danube Delta. Various natural resources and a large agricultural potential characterize the territory of Romania. After the Second World War and particularly under the communist government, the economic and industrial development of the

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country took place without any concern for environmental protection and sustainable use of mineral and human resources. Consequently, Romania faces at present numerous difficult environmental problems, which require urgent actions for rehabilitating the quality of the environment and for improving the quality of life. Solving or mitigating these problems is a large scientific and technological endeavour, which needs up-to-date know-how. Such efforts are surpassing the national capacity of Romania and thus can only be achieved by an efficient international co-operative programme.

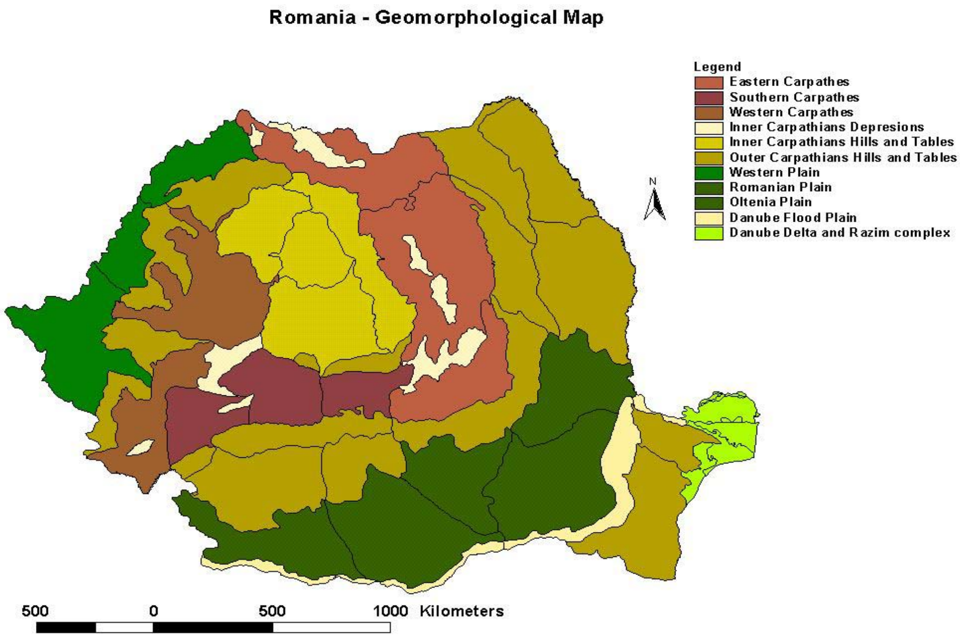

Fig.1 – Map of Romania and geomorphological map of Romania

Iaşi is placed in north-eastern Romania, more exactly where the 47^{o} 10' N parallel meets the 27^{o} 35' E meridian. Seated on seven hillock covering 3770 ha, its altitude varies between 40 m in the Bahlui Meadow, and 407 m in Păun Hill. It is the capital of Iaşi County, with a total area of 5,470 square kilometres, and an average altitude of less than 250 meters. On the eastern side, Iaşi County is neighbouring the Republic of Moldova.

From the point of view of the relief, the area of the town of Iaşi lies at the contact of two big geographical sub-units of the Moldavian Plateau: The Moldavian Plain and the Central Moldavian Plateau.

The landscape is dominated by plains, with very good agricultural potential, and by low hills, whose elevation increase going west, where they are to meet the Eastern

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Carpathians mountain chain. Generally, the vegetation and wild animals are quite typical to those of Central Europe.

The county is especially rich in building materials (sand, gravel, and limestone), pottery clay, as well as mineral waters well-known for their medical properties.

The capital city is crossed by Bahlui River, one of the county's four main rivers.

The general climate is temperate continental, with hot summers and freezing winters. Here are some characteristic values:

- Annual absolute maximum: 37 Celsius degrees
- Annual absolute minimum: -19.5 Celsius degrees
- Rainfall: is about 600 millimetres per year

The analyzed area is characterized by preponderance of two categories of difficult soils: contractive soils and macroporous soils. These two categories of soils complicate the selection of the locations and also complicate the design, the execution and the exploitation of all the buildings of the zone.

2. THE GENESIS AND STRUCTURE OF ALLUVIAL DEPOSITS FROM IAŞI AND CLIMATE FACTORS

To the geologic formation of the studied area take place deposits from Quaternary, Miocene, Cretacic, Silurian and crystalline beds. The zone’s relief belongs to the category of fluvial and deluvial deposits of accumulation of Quaternary age.

Climatologically, Iaşi City and its surroundings belong to the temperate – continental climate. Atmosphere’s dynamic is characterized by the preponderance of the influence of Europe’s north – west and north air – masses, with abundant precipitations, those from south – east and east creating dryness weather and great differences between winter’s and summer’s temperatures. The thickness of the snow - bed is different every year and the storms and hailstones are constant meteorological phenomena in the area of Iaşi City, especially in July and August months.

3. PHYSICAL AND MECHANICAL PROPERTIES OF BAHLUI CLAYS

The observations made in the open holes of the studied zone in the summer time indicate that foundation soil is structured from brown plastic clay with thin zones of bluish and yellow colour. Until -1.10m depth the plastic clay is stiff and it can be digged. From this level to -1.90m the colour become darker, with ferruginous zones, with concretions of limestone, the clay is very stiff and is digged hard. This section allows the influence of the compressive process, realised by repeated drying and wetting tests of a clay soil. Between -1.90 and -2.40 meters the colour gets brown – black with ferruginous and bluish zones. Between -2.40 and -3.20 meters the water content of the soil keeps almost constant, the plastic clay has plastic consistency, is stiff and the colour is yellow with bluish – ferruginous zones. The natural water content varies from 28% to 43%. The results of the classification in function of geotechnical index are presented in Table 1.

Table 1 – Geotechnical index

Bore	Sample	Level	w_{nat}	Plasticity			Grain-size				γs		Physical index				
				Wf	Ip	Wc	2 µ	5 µ	1 mm	2 mm	Pic	Gr	γg	γu	n	e	S
		m	%	%			%				g/cm³		g/cm³		%		
S1	1	1.0	28.0	23.8	59.7	83.5	45	21	32	-	2.75	2.69	1.69	1.31	52.4	1.10	0.701
	2	1.5	30.0	27.0	46.8	73.6	3	18	33	-	2.72	2.69	1.74	1.40	51.1	1.04	0.783
	3	2.0	40.0	36.4	52.5	88.9	41	21	30	-	2.83	2.69	1.74	1.24	56.3	1.29	0.880
	4	2.5	35.4	26.5	55.5	82.0	46	23	30	-	2.76	2.69	1.76	1.30	52.7	1.11	0.875
	5	3.0	36.4	30.4	53.4	83.8	56	13	29	-	2.74	2.69	1.89	1.23	55.2	1.23	0.810
S2	1	1.0	40.7	29.7	55.2	84.9	54	18	24	-	2.74	2.70	1.76	1.25	54.4	1.19	0.936
	2	1.5	36.6	26.3	59.1	854	49	18	30	-	2.76	2.70	1.82	1.33	51.8	1.07	0.937
	3	2.0	36.7	25.8	58.0	83.8	44	22	31	-	2.77	2.70	1.82	1.35	51.4	1.05	0.962
	4	2.5	35.9	24.4	65.7	90.1	46	24	27	-	2.79	2.70	1.82	1.33	52.5	1.10	0.912
	5	3.0	33.7	22.5	59.5	82.0	47	22	30	-	2.81	2.70	1.87	1.40	50.3	1.01	0.936
S3	1	1.0	42.9	34.3	61.6	95.9	46	26	25	-	2.83	2.70	1.77	1.25	55.9	1.27	0.959
	2	1.5	42.3	31.5	74.7	106	55	22	20	-	2.80	2.70	1.78	1.26	54.6	1.20	0.984
	3	2.0	43.0	32.6	60.5	93.1	44	23	29	-	2.76	2.70	1.75	1.23	55.6	1.25	0.948
	4	2.5	39.8	26.2	76.3	103	40	24	30	-	2.74	2.70	1.78	127	53.4	1.15	0.949
	5	3.0	38.8	31.7	60.0	91.7	46	22	29	-	2.77	2.70	1.82	1.33	52.0	1.09	0.982

Taking into account the plasticity (Cassagrande line A), the Iaşi clay is in the category of inorganic clay soils with high plasticity.

The grain - size composition and distribution classifies the soil in plastic clay, the clay fraction being between 61% and 82%. This classification is also verified by the ternary diagram, which places it in the zone of plastic clays.

Natural unit weight is 1.67 g/cm³ – 1.69 g/cm³ ;

Dry unit weight is 1.23 g/cm³ – 1.35 g/cm³ ;

Porosity, n, has a great variation: 50.3% – 56.3% :

Degree of saturation is 0.701 – 0.984.

Swelling processes being a consequence of wetting processes, the water absorbed by the hydrophilic swelling body is followed by heat of absorption. Taking into account the amounts of the heat of wetting used as index for the recognition of the very active clays (which presents volume changes at water content changes) the soil activity may be classified.

Thus, for heats of wetting of more then 7 cal/g the soils are considered active and very active.

Knowing the amounts of the total heat of swelling, we calculated the water content which corresponds to the adsorbed water. We also calculated the amount of specific surface, which is between 343mp/g and 270.5 mp/g. Experimentally testing the total heat of wetting as geotechnical index, we drew up the conclusion that the clays from Bahlui Plain are placed in the very active soils category and from the point of view of shrinkage and swelling in the category of very swell – shrinking soils.

4. THE STUDY OF SWELL – SHRINKING SOILS

4.1. The study of shrinkage phenomena

Many researchers analyzed the shrinkage and swelling behaviour of the clay soils. The number of joints or cracks per volume and their dimensions increase accordingly to the proximity of the soil's upper surface. Therefore, the most adequate geotechnical index, which characterise the properties of these clays are the shrinkage coefficients. There are three shrinkage coefficients: α_l , α_s , α_v . The graph water content versus geometrical dimensions before and after drying (dimensions of length, surface and volume) marks some straight lines which slope is precisely the shrinkage coefficient (fig.2, fig.3 and fig.4). The montmorillonitical clay of Iaşi we obtained the following values: $\alpha_l = 0.52$, $\alpha_s = 1.17$, $\alpha_v = 2.03$.

4.2. The study of swelling phenomena

In certain conditions, absorbing water, the shrinkage clays present volume expansions. If the volume expansions are limited, they produce remarkable swelling pressures. The experimental tests realised on undisturbed clays draw curves like those shown in fig.2, fig.3 and fig.4 which represent the line between pressure p, water content w and volume V. These curves propose a variable moisture index depending on water content.

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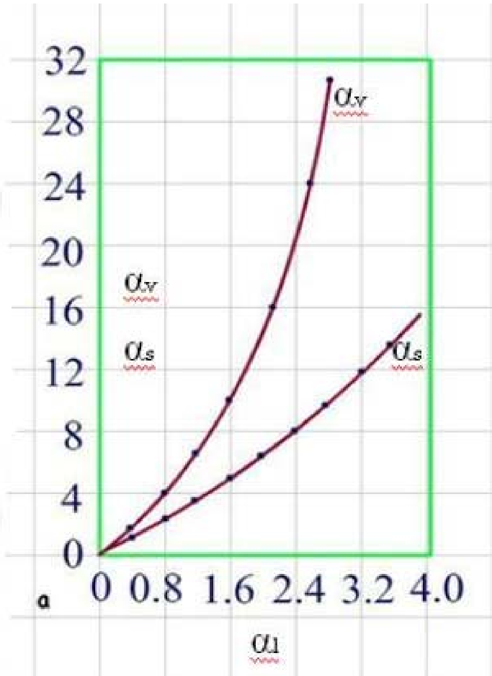

Fig.2 – The influence between shrinkage indexes

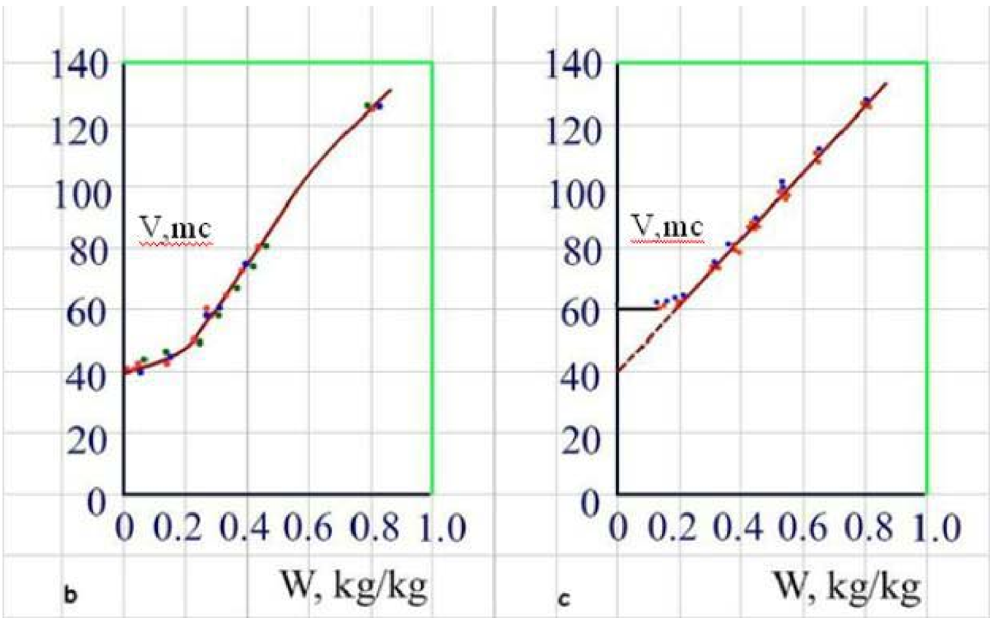

Fig.3 and 4 – Volume variation in function of water content, at continuous drying and at repeated dryings.

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Experimental tests for establishing the swelling pressure are made in triaxial apparatus or in special adapted odometers. Like in the study of shrinkage, the swelling at higher water content must be a preoccupation of those who place structures on such soils. Experimental results and the observations made indicate that the clay from this area produces volume changes, movements of the ground, respectively, which are in connection with the transmitted pressure and with water content.

In conclusion, on Bahlui clays we can admit:

- The plasticity index, the grain – size composition and analysis, consistency index, activity index place these soils in the category of active and very active soils.
- The chemical – mineralogical study of foundation course from the plain Bahlui River, colour's reactions, the studies on electron microscope and the thermodynamics analysis led to the conclusion that most clay minerals are from the groups of montmorillonite and hydrated mica.
- The heat of wetting places the clay in the category of the swell – shrinking soils.
- The experimental research allows an improvement of the method for establishing the shrinkage coefficient. The elimination of the water content must be done slowly because the water content must be uniformity distributed in the sample. The increase of water content leads to important increases of the volume. The swelling depends on water content and pressure.
- The use of remolded and desiccated specimens seems to be a better approach in swelling tests for achieving more reliable swelling parameters. The swell pressures obtained from the remoulded samples showed better correlations with mineralogical, index and physical properties when compared to swelling percent and swell indices, such as free swell and modified free swell index.
- On this basis and considering its use in design, it can be concluded that the swell pressure is a better parameter for quantifying the swell potential.
- On the basis of the experimental results, we compute the swelling volumetric coefficient. In the field of 1 – 20 daN/cm^2 the values of the volumetric coefficient vary between -0.2 and 1.0 .

A hazard map showing the area distribution of high and very high expansive soils for the city of Iaşi is considered to be a very important tool. It is hoped that this map will be a useful tool for planners and engineers in their efforts to achieve better land use planning and to decide necessary remedial measures. Preparation of

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such a map based on swelling pressure or swelling percent, which are determined through expensive laboratory tests, takes long time. Therefore, the use of the predicted models seems to be more practical tools for this purpose. A study by the authors for the preparation of a map of swell potential for Iaşi City by considering the predictive models is in progress.

4.3. Recommendations regarding foundation execution

- The depth of foundation must be established in order that the variations of the water content have no influence upon the swell – shrinking phenomena. Thus, in the area of Bahlui Meadow this depth of foundation must be at least 2m.

- The execution of tree – plantations and the public utility equipment in the areas with shrinking soils must be realized taking into account the amplitude of ground movements caused by water content variations.

- When the depth of foundation of 2m cannot be respected, for the swell – shrinking soils of the area we must study the transmission to the ground of the effective pressure, in function of foundation pressure.

5. THE STUDY OF MACROPOROUS SOILS (LOESSOIDAL SOILS)

5.1. Conditions of loessoidal soils

Iaşi City is at contact of two areas, different from geomorphologic point of view – The Jijia Depression, The Bahlui Depression and The Moldavian Plateau. Iaşi City develops and extends on the cliffs and on the Valley of Bahlui River. The loessoidal deposits are on the upper cliff and on the medium cliff, which include areas of Copou Hill, Şorogari Hill and Ciric Hill.

The loess deposits from Iaşi area have the follow stratification: the surface is formed by a vegetable layer with fill here and there. It follows passing beds to the form bed of the deposit, with sand layers and transition silty clay between Quaternary and Sarmatian. The loessoidal underlay is sarmatian's clay marl.

The plasticity of the loess of Iaşi is medium with yield limit between 30 and 50. The thickness of loess layer varies between 8 m and 11 m, with a peak value of 24 m in the north – west of the city.

The level of underground water presents variations: 11 – 16 m in the upper cliffs and 5 - 12 m in the medium cliffs with low rate flow. The loesses from Iaşi area and from the basin Jijia – Bahlui are alluviums transported and deposited in Pleistocene over the clay marls from Sarmatian.

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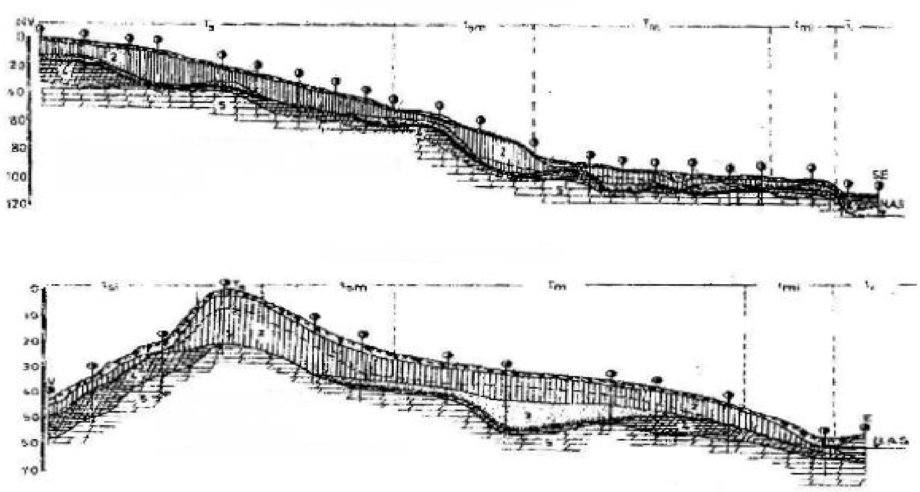

Fig.5: Extension of macroporous soils from Iaşi area

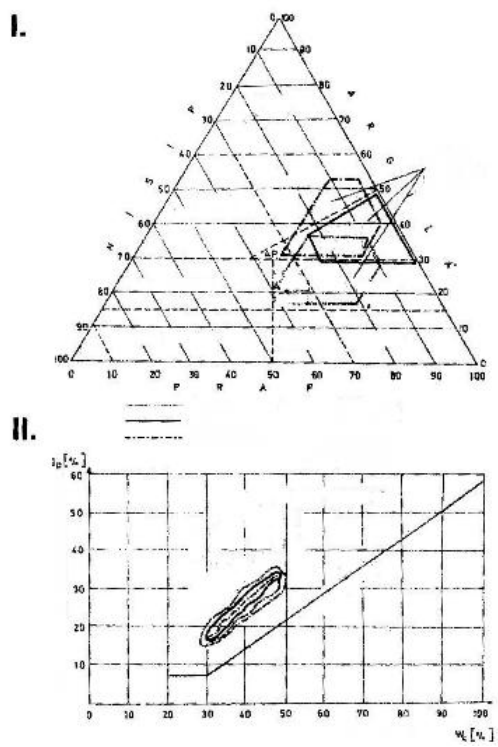

Fig.6 From the grain – size point of view the loess of Iaşi is represented in the ternary diagram

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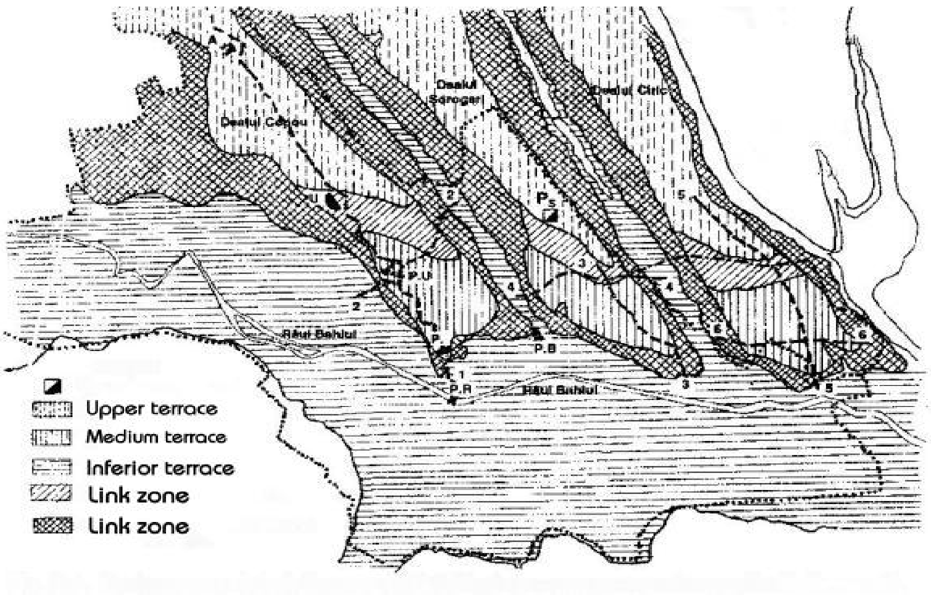

Fig.7: The loess of Iaşi presents more amounts of clay in the zone of Copou Hill

The specific properties of loessoidal rocks (high porosity, flocculated structure, accumulations of calcium carbonate, yellow – brown colour) formed due to a specific process of macroporous soils.

5.2. Foundation conditions

- The necessity of improvement of the macroporous soils.
- The compulsory check of constructions built on these soils at the effects of the complementary loads induced by the non – homogeneous settlements.
- The diminution of the length of the constructions built on these soils (settlement joints) especially for the soils capable of important total settlements.
- The checking of the systems of soils consolidation taking into account the analysis of relative bending and the analysis of average settlement.
- The limitation of non – homogeneous settlements taking into account the structure's configuration.
- The utilization of computational methods to establish the soil's deformations, different from the structure's deformation.

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- The ensuring of the stiffness and of the solidity of the substructure allowing the computations of the unequal settlements.

Building on locations with difficult foundation soils requires a distinct attention (in design, execution and exploitation) in order to choose the right structure and foundation and to pursue and keep in time these buildings.

Analyzing the geologic column from different locations we observe the nature and the properties of the layers and the expected sliding or some others geologic phenomena which would lead to the building's collapse.

Analyzing the different methods used in order to know the depth of active zone, we must grant a distinct attention to the macroporous soils, to the shrinking soils, to laboratory and in situ tests, in order to elaborate accurate solutions for foundations and for the co – operation soil – foundation – structure.

For these soils we must do more complex studies, in order to establish some properties which may influence the strength, the stability and the costs of the building (compressibility, swelling pressures, shrinking pressures, flood settlement).

The costs of the analysis of the soil's properties may lead to the decrease of the properties of these soils.

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