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Consolidation technologies and protection of difficult soil foundations

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Summary

In the paper there are presented analysis regarding the consolidation of the difficult soils foundations using cushion of ballast and soil, following to be located on different constructions. Ballast or ground cushion distribute the pressures on a bigger surface than the foot foundation that is why the increasing of the pressure transmitted to the weak soil it will be smaller than the one beneath the foot foundation. These increase the foundations stability, because generally their characteristics of strength are superior to the strength characteristics of base soil. The substitution of difficult soil by ballast cushion , soil or other local materials consist in excavation of the weak layer, settlement and then compaction through rolling or puddling consecutively of the ballast or soil layers.

KEYWORDS: consolidation, ballast cushion, ground cushion.

1. INTRODUCTION

On the settlements where will be executed the future constructions, often appear foundation soils with physical – mechanical properties which are not corresponding as quality to the imposed requirements of the constructions that follows to be achieved on these settlements. The refore, it is possible that these physical – mechanical properties of the soils that the foundation soil is made of on these settlements, to deteriorate in time due to some natural or artificial factors that appeared after the construction is executed. These soils foundation were named difficult soils foundation. In the first category there are contained the shores, earthy brown coal, residual soils, padding's, dusts , soft clays, loose sands and loose sand saturated with water. On the second category there are the soils sensible to the moisture, the soils that are susceptible to the big expansions and contractions and saturated soils. No matter the category that they are included in, when the actual physical –mechanical properties are not corresponding to the requirements imposed by the building, they will be characterized by a carrying capacity reduced by a great and irregular compressibility or by some factors that proceed further.

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To eliminate the mentioned inconveniences, should be taken some actions to improve physical – mechanical properties to coincide actually and in the future to the requirements imposed by the construction, to ensure the resistance, stability and the best exploitation of it during the period of activity. To be in picture with the improvement of the properties of the foundation soils there is a chart of the improvement of foundation soil presented in figure 1:

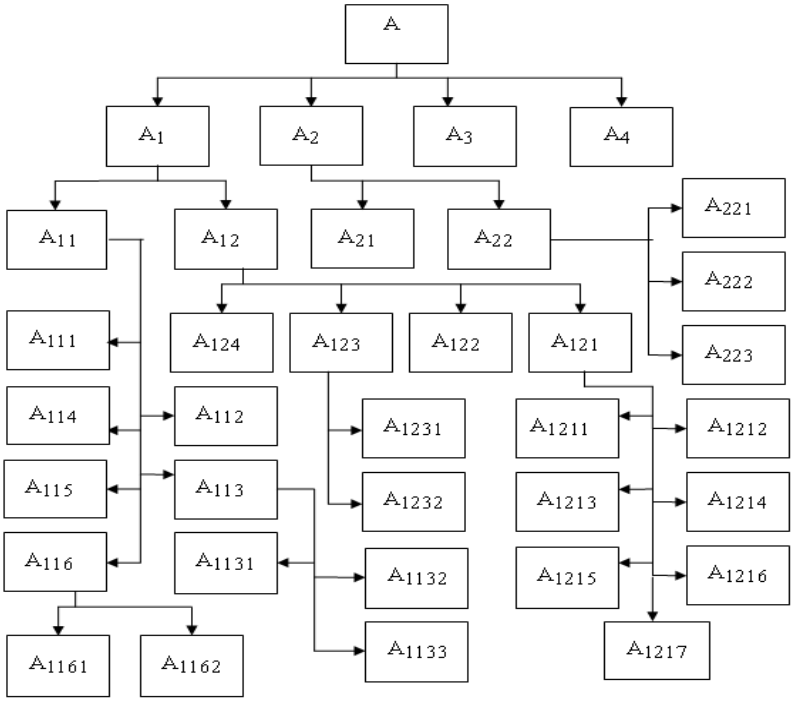

Figure 1. Chart of improvement of foundation soil.

A The improvement of foundation soil;

A_1 Consolidation in depth;

A_2 Methods of consolidation of surface (mechanical);

A_3 Consolidation by vibrosticking;

A_4 Consolidation through vibration;

A_{11} Consolidation through mechanical methodes ;

A_{111} Compactions with the heavy rammer of 5 tf and extra heavy of 10 tf ;

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A_{112} Ballast cushion or stabilised soil;

A_{113} Shaft of ballast or soil;

A_{114} Piles (cores, centres, kernels) of plain concrete with admixture of ash;

A_{115} Consolidation by pre-loading;

A_{116} Loesses compaction by explosion;

A_{1131} The construction of ballast or soil shafts through puddling;

A_{1132} The construction of ballast shafts by vibro-pressure;

A_{1133} The construction of ballast shafts through vibro-floating;

A_{1161} The inspissation through surface explosions in the water;

A_{1162} The inspissation by deep explosions through draw wells. The inspissation by deep explosions of the loose sands;

A_{12} Consolidations through methods of transformation of the soil structure;

A_{121} Chemical methods of artificial transformation;

A_{122} Thermal treatment of the soils (clinkering);

A_{123} Electric and electro- chemical methods;

A_{124} Directive flooding of the soils and the settling on its own weight;

A_{1211} the silification;

A_{1212} The cementation. Descendant, ascendant and total injection;

A_{1213} Consolidation by pre- damping;

A_{1214} Consolidation by the Jet Grouting method;

A_{1215} Consolidation by the lime pillars;

A_{1216} Claying;

A_{1217} Bituminization;

A_{1231} Electro-osmosis;

A_{1232} Electro- drilling;

A_{21} Consolidation by rolling;

A_{22} Consolidation by beating;

A_{221} Consolidation by special shape pounding

A_{222} Compaction with the heavy tamper;

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A_{223} Compaction with the dropping plate;

From all this foundation methods, on the study will be discussed two methods that regard the consolidation of difficult foundation soil: ballast cushion or stabilised soil. Placing the construction on such soils means constant searching of solutions which should satisfy from technical point of view, on low prices. The performance of this desideratum has great importance, because in our country (in fact as in other countries) frequently appear solutions of indirect foundations (piles, caissons, shafts etc.). Indirect foundation procedures, generally solves the problem of foundation on difficult soils, but with high discharge of materials (cement, steel etc.) and on superior prices, therefore it appeals for finding some methods that lead to improvement of weak soils, growing up their mechanical strength, improving the geotechnical properties, becoming proper for the direct foundation. To obtain direct foundation systems on difficult soils conditions, it is applied either the method of replacing them with cushions of soil, ballast or other local materials (procedure used for surface compaction when the thickness of the difficult layer is not big), or deep improving of the weak layer all over the thickness, or only partially, when that is quite big. Ballast or soil cushions are distributing the pressures on a bigger surface than the foundation pad, therefore the magnitude of the pressure transmitted to the weak soil it will be smaller than the one beneath the pad foundation. They increase the stability of foundations, since in most of the cases they have strength characteristics superior to the base soil characteristics. The utilizations of cushions contribute to the reduction of the foundations settlings, increasing the general modulus of deformation of the soils beneath the foundation that exceed few times the modulus of deformation of the base layer. Ballast cushions with big and medium granulation, with not a great content of dust and clay particles, permit reduction of the foundation depth, since the clay soil sensitive to frost is replaced with sandy soil unsusceptible to frost. The cushions made by compacted soil, intend to reduce or eliminate the sensibility on the soil humidification, that constitute the foundation soil in the area that is felt the effect of the transmitted loadings of the constructions pad foundations. These cushions could be realised by applying three technologies: The cushion of deposited soil, spread in the digging on thicknesses that assure good compaction and compacted to the optimum compaction moisture. The compaction of the foundation soil so that it should not present moisture sensitivity; The mixture of these two technologies through a compaction of the soil from the settlement, beyond which, further is performed the cushion of deposited soil that is compacted too. Whatever the adopted solution, the design suppose setting of the following characteristics referring to the cushion: the normalized pressure applied to the surface of the cushion, the thickness of the cushion, its extension on the plane, the material inspissations' from cushion and the rammed soil nature (optimum moisture of compaction for this soil and the necessary mechanisms of pudding. The normalized pressure applied on the superior part of a cushion is determined

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considering the physical- mechanical properties of the cushion soil. That is determined for the complete state of flooded of the cushion. In our country the normalised pressure in case of a loess cushion for foundations centrically loaded is p=2 daN/ cm^2. For foundations loaded eccentrically it is raised with 15% and in case of extraordinary grouping with 30%. When the thickness of the cushion is initially imposed, the normalised pressure on the cushion will be taken so the carrying capacity of the unimproved soil under the cushion not to exceed the limit pressure (until it exist the linear dependence between pressure and settling). For determining the thickness of the cushion it is considered that the distribution of the lateral pressures of foundation is made on an area equal to half of the cushion thickness. The thickness of the cushion is determined from the condition that on its base should not exceed the value of the structural strength of the saturated soil.

By the term structural resistance (noted with p_o) of a loess soil it is realised the sum between the tension generated by the exterior load and the one from its own weight on which it starts the redundant settling on the state of its total saturation.

Hence: $$p_o^n = p_o(b + h_p)$$

Where: b- foundation width

Hp- thickness of the cushion

From here it can be assumed the thickness of the cushion:

$$h_p = \frac{p_o^n}{p_o} b$$

If the cushion is executed only to avoid the supplementary settling through moistening, it should have only a baffle function. When the thickness of the cushion is imposed, the normalized strength from the superior side can be calculated from its thickness and structural strength of the soil under the cushion:

$$p^n b = p_o + 2p_c \frac{h_p}{2}$$

$$p^n = p_o(1 + \frac{h_p}{b})$$

From practice results that the relation is valid for foundations having the width until 2m. The thickness of the cushion can be determinate with abacus, being equal with $h_p=K_1 b$.

K_1- is taken from abacus according to the ratio of the foundation side and the ratio between the pressure that is applied on the superior side of the cushion and the

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structural strength of the soil beneath it. In our country the procedure of consolidation of the weak soil foundation through soil cushions is popular, especially for the sensitive soils on moisture. Thus, most of the constructions from the area of Iasi and Constanta municipality –where are popular the soils sensitive to moisture belonging to class A, were settled on the loess cushion compacted by rolling. Soil cushions can be adopted with good results on others soils types, except the sensitive soils to moisture, respectively to those with a muddy character or of lower consistency, but especially through their substitution on a certain depth from surface. A precise execution of the ground cushions can lead to the achievement in surface of a reduced permeability layer, that oppose to the penetration beneath the construction of surface waters. Must be avoided the execution of the ground cushions on rainy seasons because, in these situations is difficult to respect the optimum moisture of compaction: On their measuring is necessary to solve the following problems: the thickness of the cushion must be determined such as to its base the transmitted pressure, not to exceed the carrying capacity of the foundation soil. Also, the cushion settlements and of the soil beneath it can not be greater than the admissible settlements for the structure on which it is used this foundation procedure; carrying capacity of the cushion to assure preparation of the load transmitted by the construction; the dimensions in plane of the cushion not to permit the recourse of the material from the cushion unto the bordering foundation soil, unsettled. The material cushion compacted on the desired thickness can be realised through hard pounding of the land in situ , or by execution of the cushion with material brought from other side and compacted with different resources, or by stamping the hole with a rammer of a special shape. In these cases it should be assured for the cushion material, the mechanical work and optimum moisture of corresponding compaction. The compaction equipments for the ballast or quarry stone cushion are the soft compression cylinders, vibrating cylinders, vibrating plates, but for the cohesive soils the clip bolt cylinders, explosion rammers, compression cylinders smooth or with tires. Every device used for compaction is characterised by a certain compaction depth, a certain static and dynamic depth, a certain surface action. According to the proposed aim, their choosing it will be done having in mind the compaction that can realise acting on the compaction parameters that are demanded. Most of the cases are using mixed methods that contain two of these compaction procedures at the same time being supporting of the environment.

2. CONCLUSIONS

Following the realised study, can be observed that the ground cushions might be utilised having good results through P.S.U. consolidation from A class for the direct foundation of constructions subjected to precise dimensioning especially of

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their thickness, that must be chosen from the condition that the pressure transmitted to the base of the cushion to be almost equal with the structural strength of the soaked loess. Ballast cushions contribute to the decreasing of the settling foundations. These cushions with a medium and big granulation, with a great content of dust and clayey particles are decreasing the foundation depth because the clayey soil sensitive to the frost. Ballast cushions have an important function as a drainage layer, resulting the water drainage from the pores of clayey ground, saturated, situated beneath. Ground cushions will adjust also to the soils with muddy character or of lower consistency, but especially through their substitution on a certain depth from the surface. An accurate execution of the soil cushions may lead to the performance on surface of a waterproof layer that opposes penetration beneath the construction of the surface waters. Must be avoided the execution of the soil cushions in the rainy seasons, because in these situations is difficult to maintain the optimum moisture of compaction.

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