International Journal Of Engineering Research And Development
e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 19, Issue 6 (Nov.-Dec. 2023), PP. 94-99

Mechanical Properties Of Pre-Wet Soils Compacted With A Heavy Rammer

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Abstract. *In the case when the value of the calculated settlement according to the II limit state of subsidence and loose soils exceeds the maximum permissible value or the bearing capacity of the foundation soil is insufficient, one of the main methods for improving the calculated values of the soil is the compaction method with heavy compaction. The method of compacting loose soil with heavy tamping has been used for a long time; over time, equipment, methods of structural calculations and technology have developed, and it has become possible to compact soils up to 12.0 m thick and using tampers weighing up to 100...200 tons. The essence of this method is to increase the mechanical properties of the soil by transferring the energy of dynamic action to the internal structure of subsidence soils with low bearing capacity. This article discusses the results of compaction of pre-moistened loess-like sandy loam soil, common in the city of Darkhan, Mongolia.*
Keywords. *loess-like soil, optimal humidity, relative subsidence index, deformation modulus, adhesion force, angle of internal friction*

Date of Submission: 08-12-2023 Date of Acceptance: 23-12-2023

I. INTRODUCTION

The value of the calculated settlement according to the II limit state of subsidence and loose soils exceeds the maximum permissible value or the bearing capacity of the foundation soil is insufficient; one of the main methods for improving the calculated values of soil is the method of compaction with heavy compaction

Abelev Yu.M. [1], Mustafaev A. A. [2], Tsytovich N. A. [3], Yodecke H. I. [4], Brandl H. et al [5], Rouaiguia A. et al [6], Tan E. et al [7], Hamidi B., et al [8], Klebanyuk D.N.[9], Holger Pankratha, et al [10], Minaev O.P.[11] and other researchers have developed a theoretical and methodological basis for the method of compacting subsidence soils with heavy compaction and which form the basis of international building codes for soil compaction of the foundations of buildings and structures.

V. A. Ilyichev and Yu. A. Bagdasarov [12] conducted tests on loess soils in Western Siberia with similar conditions in the territory bordering Mongolia, using an 80-ton heavy rammer. And G.I. Shvetsov [13] and other scientists conducted experiments on compacting subsidence soil with heavy tampers in order to prepare high-strength compacted foundation soil in the cities of Barnaul and Novosibirsk.

Further development of research on soil compaction with heavy tamping was continued from the late 1960s by the French company LOUIS MANERD (Menard L. [14]) and began to use compacting tampers with a mass of 10...20 tons and from a height of 25 m, and installed , that it is possible to compact subsidence soil with a thickness of 8...10 m. It is written that to compact the soil of the runway of the French Nice airport using a special pneumatic wheeled excavator crane, a heavy rammer with a mass of 200 tons was used. In addition, there are research results and information on the successful use of 50-ton rammers in England and Sweden, and also 150-ton rammers in Japan.

On the territory of Mongolia, subsidence clay soils are common, with a thickness of 4.5...9 m, in rare cases more or less thick, usually type I, less often type II in terms of subsidence, with low natural humidity. When moistened and subject to additional loading, and even in conditions of small thickness, there is a very high probability of subsidence exceeding the permissible value. Based on this, an accelerated method of soaking the soil to optimal humidity (W_{opt}) is effective, after which it is lengthened with heavy compaction, while it is necessary to comply with the additional distance conditions, at least 30 m from deformed buildings to some extent, and at least 15 m from non-deformed buildings and underground networks of engineering communications (V.I. Krutov [15]).

II. METHODS AND MATERIALS

The effectiveness of using the compaction method with heavy tamping is confirmed by the results of the above-cited and other numerous scientific and industrial experiments due to the simplicity of the equipment and production technology, cost-effectiveness, and achievement of compaction quality. Currently, rammers with diameters of 1.5...2.0 m and a weight of 5.0...7.5 tons are widely used, while compaction of subsiding loess soils reaches a depth of 3.0...4.5 m with preliminary soaking of the soil to optimal humidity (W_{opt}). In Fig. Figure 1 shows changes in the microstructure of loess subsidence soil before and after compaction with heavy compaction.

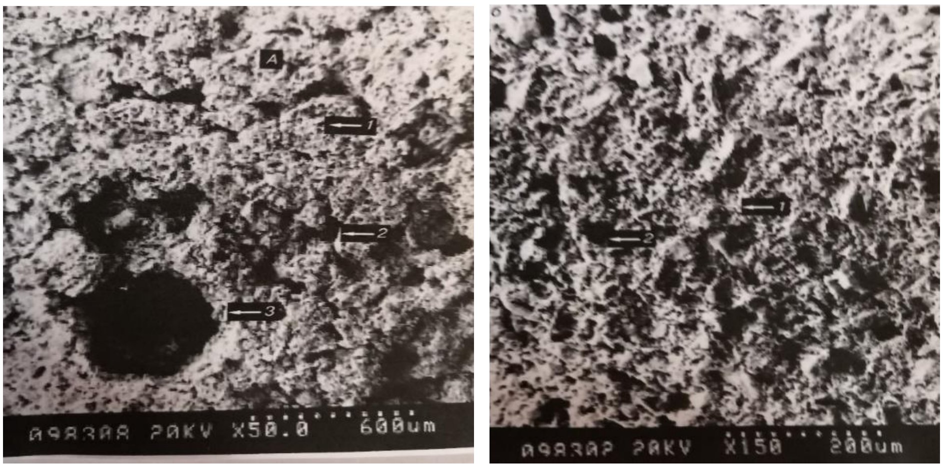

Figure 1. Microstructure of loess soil after and before compaction. a - state of the natural structure, c - microaggregate after compaction (x600). 1-micro-unit; 2-micropores; 3-macropores (Sokolov, 1996).

The number of impacts required at one point on the surface of the compacted soil is determined by calculating the possible conditions for soil compaction with optimal moisture (W_{opt}) to the specific gravity of dry soil $\gamma_d = 1.65 \ldots 1{,}85 ton/m^3$.

III. RESEARCH METHODOLOGY

The methodology for field field testing, modeling and calculation models of a two-layer base to determine the bearing capacity are presented (Nyamdorj S. [16]). The results of field tests and analytical calculations for the compaction of subsidence soil in the city of Darkhan using heavy compaction provided that the soil is pre-soaked to optimal moisture content (W_{opt}) are presented. Currently, a large number of civil buildings and industrial facilities are being built in Mongolia, some of them with wet technological processes, in such conditions the use of the heavy compaction method can be highly effective. Based on this situation, field tests were carried out on compaction using the heavy compaction method. Figure-1 shows a photo of the heavy rammer used for the test.

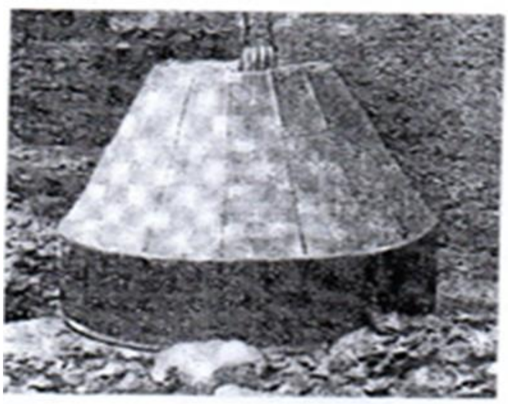

Figure 2. Heavy rammer with a weight of 5.0 tons and a diameter of 1.5 meters.

Table 1 shows the indicators determined from the results of the field test. The subsidence soil was compacted with 10, 15 and 18 blows of a heavy rammer with a diameter of 1.5 m, weighing 5.0 tons in a pre-wetted state

Table 1. Compaction characteristics of subsidence soil

Test option	Number of impacts	Tamper diameter, m, м	Tamper mass, ton,	Tamper drop height, m,	Impact energy, kJ	Effective compaction D_{max}, m	Depth location D_{max}, m местоположение D_{max} , м
I	10	1,5	5,0	7,0	3,22	2,68	1,48
II	15	1,5	5,0	7,0	4,75	3,52	1,85
III	18	1,5	5,0	7,0	5,10	3,80	2,06

After completion of the compaction test, samples are taken every 0.5 m from the surface to a depth of 6.0 m and the following parameters are determined in the laboratory: W = 0.27...0.32 or degree of moisture 0,94 ≥ S_r ≥0,8, soil density ρ_d= 1.73...1.87 g/cm3, and the change in surface level was 37...42 cm. Based on the amount of surface reduction depending on the number of impacts for soil compaction, a graph of the dependence Δh=f(n) was constructed and shown in Figure 3.

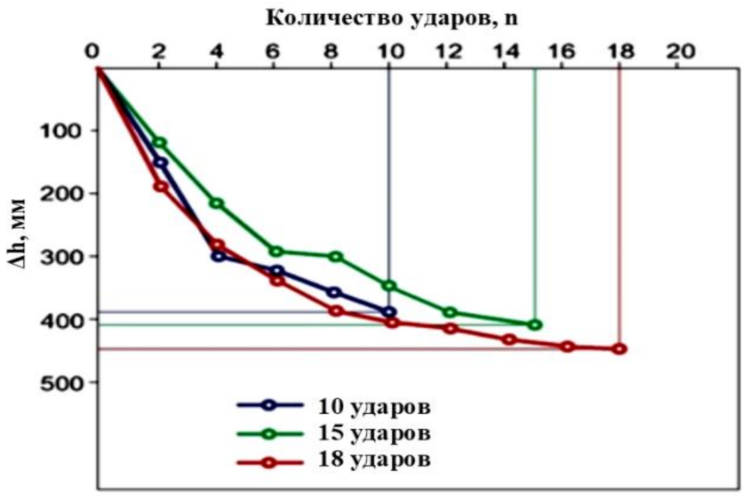

Figure 3. Curves of dependence Δh=f(n) for determining the value (Δh) from the number of blows (10, 15 and 18)

A comparative analysis of the results of compaction of subsiding sandy loam soil by heavy compaction after soaking revealed the following growth patterns for a number of calculated characteristics.

A. Analysis of relative subsidence ε_{sl}. Figure 4 shows a comparative diagram of the relative subsidence of compacted soil for 10, 15 and 18 impacts, determined from laboratory tests of a sample at a pressure P = 0.3 MPa.

Figure 4. Diagram of the average value of the relative subsidence $\varepsilon_{sl} = f(n, W_{opt})$ of compacted soil at different numbers of impacts

B. Adhesion force C. Based on the results of the compaction test, a diagram was constructed of the average value of the adhesion force C=f (n, W_i) of compacted soil at different numbers of impacts and different humidity (Figure 5).

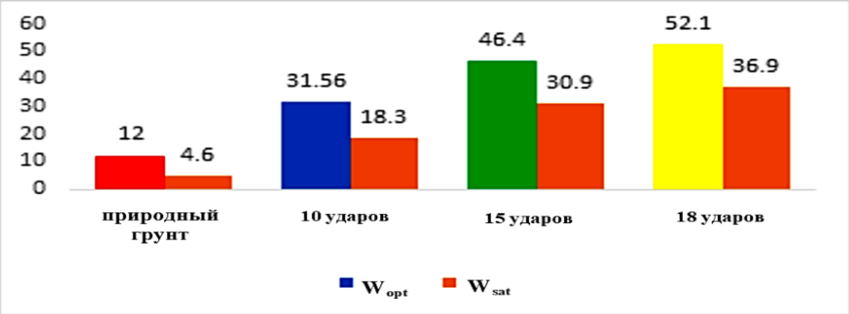

Figure 5. Diagram of the average value of adhesion force C=f(n, W_i) of compacted soil at different numbers of impacts and different humidity

C. Angle of internal frictionφ^n_{opt}. Based on the results of the compaction test, a diagram was constructed of the average value of the adhesion force $\varphi = f(n, W_i)$ of compacted soil at different numbers of impacts and different humidity (Figure 6).

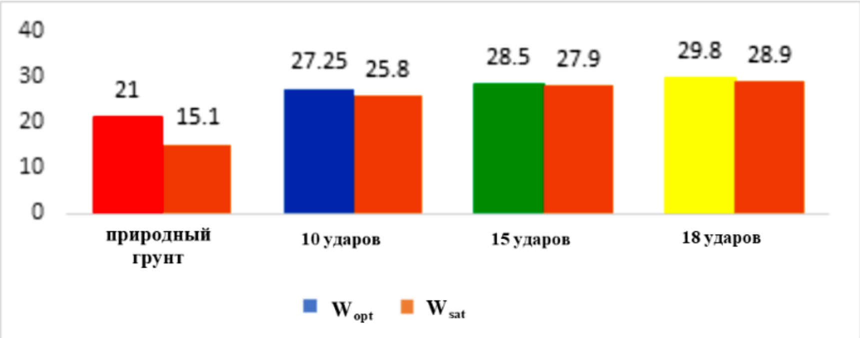

Figure 6. Diagram of the average value of the angle of internal friction $\varphi = f(n, W_i)$ of compacted soil at different numbers of impacts and different humidity

D. Deformation modulus E. Based on the results of the compaction test, a diagram was constructed of the average value of the deformation modulus $E = f(n, W_i)$ of compacted subsidence soil at different numbers of impacts and different humidity (Figure 7).

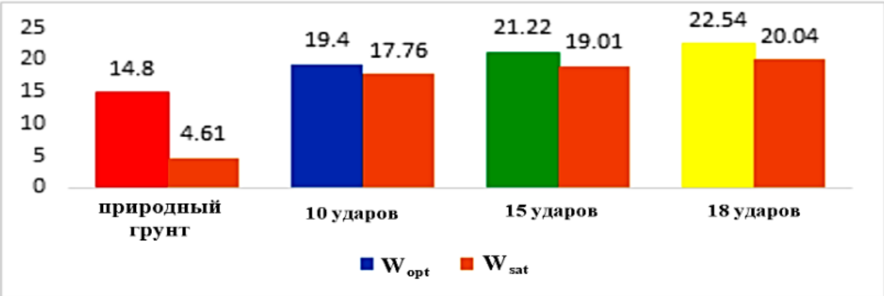

Figure 7. Diagram of the average value of the deformation modulus E=$f(n, W_i)$ of compactedsoil at different numbers of impacts and different humidity levels

The values of the deformation modulus of subsidence soil after compaction with heavy compaction of 10, 15 and 18 blows were increased by 3.85…4.50.

D. Analysis of the compaction result. Table 2 shows the indicators of subsidence soil compacted with heavy compaction after 10, 15 and 18 impacts.

Table 2. Results of compaction of subsidence soil using heavy compaction

Number of blowsударов	Density on the surface of compacted soil, t/m3	Standard Density Initial Depth 1.65 t/m3, m	Density reduction depth t/m3 to	Initial depth where the density reached $\rho^n_{d.max}$	Maximum density $\rho^n_{d.max}$, ton/m3
10	1,53	0,33	3,15	2,00	1,740
15	1,52	0,45	4,30	2,00	1,825
18	1,58	0,55	4,65	2,00	1,835

IV. CONCLUSIONS

1. With an increase in the moisture content of soil with a natural structure to water saturation, the adhesion force decreased by 2.61 times, after preliminary soaking to moisture $\boldsymbol{W_{opt}}$, the relative subsidence index, density, adhesion force, angle of internal friction and the calculated value of the soil deformation modulus improved by 1.23.. .4.35 times.
2. When the humidity of compacted subsidence soil increases to the state of water saturation ($\boldsymbol{W_{sat}}$), the values of the calculated mechanical parameters change relatively little, which indicates that the newly formed soil structures are relatively well preserved, the latter being a very important property.
3. The pattern of growth in the mechanical indicators of compacted pre-moistened soil using the heavy tamping method is explained by the transition of the natural contact structure and cementation-crystallization of structural bonds to relaxation to a certain extent as a result of an increase in humidity and the action of the impact dynamic energy of heavy tamping. And the processes of primary consolidation caused by incomplete displacement of pore water and relaxation after quasi-liquefaction formed by the dynamic action of the impact also influence.
4. Using the method of soil compaction with heavy tamping is more effective for preparing the foundations of industrial buildings with wet technological conditions, such as mining and processing plants and processing plants for agricultural and livestock products.

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