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МАЗМҰНЫ/ CONTENTS/ СОДЕРЖАНИЕ

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Water saturated foundation soil features

Abstract. *Water saturated soils are common for all cities of Kazakhstan without any exclusions, and oil regions on the coast of the Caspian Sea. Water-saturated soils are those whose pores are filled with water (more than 80%) and air in the form of bubbles and solutions in water. Therefore, water-saturated soil is a composite consisting of three phases, each of which has its own physical and mechanical properties. It is obvious that the quantitative ratio of these phases per unit volume largely determines the physical and mechanical properties of such a soil, and especially the nature of the formation of an array of such soil Water-deposited foundation soil with low deformational and mechanical properties requires detailed study for accident and defect prevention of buildings.*
Keywords: *Soil, loading, sediment, distribution, foundation, geology.*

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Introduction. Eluvial soils of quaternary system are the usual foundation for buildings and structures in Kazakhstan. SNiP 2.02.01-83 anticipates foundation design features erected on eluvial soils. Eluvial clayey soils composited from loose loamy soils and lesser out of clays. Eluvial foundations design must comply its specific features. Quaternary system soils are notable for their variability of physical conditions, complexity and mechanical diversity. Therefore, the quaternary water saturated clayey and sabulous soils were chosen as an object of the following research.

Regional characteristics of engineering-geological and hydrological conditions. For industrial and civil construction, for the first place it is necessary to take into account spreading and stratification of soils, which is going to be a foundation for the building and structures. The layout of tectonic zonation and division of Kazakhstan territory according to soil conditions construction were build up by geologists during the soil foundation research.In accordance with engineering-geological and hydrological conditions, the territory of Kazakhstan subdivided into the following regions:

- Central Kazakhstan (Central Kazakhstan Upland; Betpak-Dala Plateau; intermountain, piedmont lowlands and plains of Tengiz, Zhezkazghan, Balkhash and river valleys of Esil, Nura and Ertis);

Folded structures of South Kazakhstan (Tien-Shan; Zaisan; Altai; intermountain, piedmont lowlands and valleys of lake Alakol and river Ili);

- Russian platform and Scythian plateau (Caspian lowland and Obshchiy Syrt of Western Kazakhstan);
- Turan plateau (Aeolian sandy deserts of Myunkum, Kyzyl-Kum, Priaral; Alluvial, alluvial-diluvial plains of Turgay and Kostanai plateau; Piedmont valleys of Chu depression and plains of Shymkent and Karatau; valley and estuary, sea and lake-alluvial lowlands of Chu and Syrdariya rivers.

As a result of complex, regional engineering-geological research on the territory of Kazakhstan and the following generalization established that the primarily foundation of structures is continental the sedimentary loose soils of quaternary system by origin. Quaternary soil zonation of upper surface level lets scientists identify community of basic engineering-geological conditions of construction areas and implement typification. For sake of rational foundation type selection, beneficial way of compaction and foundation soil solidification. [Denisov N.Y. (1972), Amaryan L.S. (1990)].

For the quaternary sedimentary soil estimation in terms of building foundation, conditions of formation were revealed. According to genetic affiliation of soil, scientists identifying content, properties and changes in massif that allow separating them into engineering-geological elements. Genetic types of quaternary soils are marine, aeolian, alluvial, diluvial, lacustrine, eluvial.

Eluvial foundation design have to take into consideration its specific properties.

- Non uniform composition with considerable variation of strength and deformation characteristics;
- Sandy loams and sands under the saturation can transform into floating condition.
- Sandy loams and dusty sands under watering process show subsidence properties.
- Variability of clayey and loamy physical-mechanical properties under saturation.

During the design and erection, one of the most important factors is location and the fluctuations in the level of groundwater at the construction site. The choice of production techniques influenced by the groundwater such as excavation, and further strength and stability of structure foundation. Groundwater level and content always changes in time and in space during construction and building operation. There is a sudden fluctuation of ground water level of the Caspian depression. Following process influenced by several factors: impoundment, flooding, technogenic water level rise due to undermining, usage as water supply, freeze and thaw effect on soil above ground water level.

The North, Central and Eastern Kazakhstan having sharply continental climate with long lasting cold months and short, but hot summer. Temperature jumps from -380C up to+380C conditioning different depths of frost penetration. Following depth, for south part of Kazakhstan is 0.8 m, for the north, part is 2.1 m.

Construction on the water saturated foundations or situated in the area of capillary soil rise is getting more complex and expensive. Because of additional, civil works conduction (dewatering, moisture proofing and drainage installation).

Water exists in three states in soil - liquid, gaseous and solid. Furthermore, interact physically and chemically with solid mineral particles, and impacts divided into molecular, gravitational and capillary. Molecular water covering the mineral particles does not transmit hydrostatic pressure. Gravitational and capillary water percolate in all directions from the source through the soil pores. Gravitational water circulate inside the soil under gravity force or pressure head, while capillary water under capillary tension force. The main source of water-bearing formation is atmospheric precipitations (rain, snow, ice) and water condensation (condensation of water vapour in the air). According to conditions of bedding and features of state Savarenskyi F.P. (1972) classified underground water into – soilborne, swampy, top water, groundwater, karst, interstratal, fissure. Construction practise mainly faces with top water, ground water and interstratal water, which make difficulties for the process of building erection. Top water – closest to surface water-bearing horizon with feature of seasonality and concentration in sabulous lenses in the mass of loamy soil.

They well spread in steppe area. Investigation of foundation settlement of reservoir on Karachaganak condense gas deposit revealed to author the problem of negative effect of top water on physical-mechanical properties of soil in the mass of backfill.

Ground water is normally located on shallow depths and usually free-flow. Soil containing groundwater calls water-bearing deposit (horizon). The water level and fluctuation of water in seas, lakes, water reservoirs and rivers greatly influence on groundwater condition.

Groundwater level depends on the number of precipitations, vaporization, also on amount of technogenic water created by human activity. Groundwater level on Western Kazakhstan depends on the Caspian Sea and Volga, Ural rivers fluctuation. Groundwater level in Astana city depends on fluctuation of Esil River and Vyachaslavkii reservoir. Interstratal water usually interlay between two waterbearing layers and turn up to be under hydrostatic pressure. Therefore, during the construction process, violation of its state can lead to site flooding.

The analysis represents that majority of structures and buildings of industrially developed regions of Republic of Kazakhstan are constructed mainly on the quaternary soils. Quaternary soils have changeable physical condition, complexity and diversity of mechanical properties. Therefore, the object of research is quaternary water saturated clayey and sabulous soils of Western and Central Kazakhstan.

The main factors leading to the foundation soil saturation with water and its consequences.

Main factor leafing to the foundation soil saturation with water is first of all technogenic (technical and technological) and climatic (infiltration of atmospheric precipitations).

1. Technical factors linked to intensive construction process in Western Kazakhstan and in Astana city lead to the hydrogeological changes on the vast areas, consequently natural balance of ground water destroyed. In addition, processes of impoundment and groundwater level rise occurred. Construction and operation of high storey buildings (above 16th floor) destruct existing water balance of a territory and leading to the hydrogeological environment degradation.

2. Technological factors identified as well city is functioning. The city – complex multicomponent system, where geological and hydrological conditions within the territory of a city differ significantly in time and in space. Primal problem for the urban development is the hydrogeological model establishment with consideration of geological environment change (stress-strain conditions of watered foundations) and technogenic factors. Following model development requires broad and reliable information for the long period (years, decades of years) and hydrogeological studies of a city condition. However, this issue is problematic and literally unfeasible at this stage in Kazakhstan. Factors that are affect hydrogeological conditions on the territory of a city subdivided into two big groups: determined (backwater of groundwater from manmade reservoir, filtration losses from different canals etc.) and accidental (leakage in utilities, surface drainage run-off disruption).

If the first group can be taken into account at design stage and further construction, while the second is considered with undetermined probability or not considered at all. Thus, process of impoundment forecast of a city,territory by groundwater is a pure estimation. As an example, Degtyarev B.M., Dzacker Y.S., Muftakov A.Z. (1985) published diagram of an annual groundwater fluctuation in the borehole next to one trade centre (in Kazakhstan). The biggest groundwater rise snapped during summer season, when atmospheric precipitation is the smallest. Obviously, groundwater level rise is because of enormous utility leakage during the summer. Furthermore, observation of two more boreholes within the precincts of a city for the last 16 years took place. Borehole one represents groundwater rise for 9 m with permeability coefficient - 0.55 m/y, borehole two shows 5 m with permeability coefficient – 0.3 m/y. In case of constant observation after hydrogeological conditions of a city territory and having experimental results of groundwater measurement we are able to predict the time of stress-strain state change of a water saturated foundations, in order to avoid building's settlement and following accidents.

3. Climatic factors. Climatic factors primarily identified on the territory of Kazakhstan with long winter and massive snow mantle. Thickness is about one meter and frost penetration is up to 2.1 m. The summer is short, hot and rainless. Following climatic conditions represents that foundation soils within one calendar year work in dynamic regime "frost – thaw – saturation with water".

Just listed above factors lead to foundation soil saturation that creates decompaction and reorientation of solid mineral particles in the result of hydrostatic heave, porosity increases and permeability coefficient, soaking and loosing bonded clay soils and considerably changes in comparison with initial state. After foundation soil saturation, groundwater level drop causes hydrostatic soil compaction, and resulting in non-uniform foundation settlement.Changes in head gradient and seepage velocities in pore water cause permeability deformations and foundation soil destruction such as piping (mechanical or chemical), blow and colmatage. Piping – removal by seepage flow of pore water solid particles of soil under high gradient head and filtration rate. For every soil exists its own critical rate of percolation – VK, when mechanical piping occurs:

Abelev's M.U. (1983) studies revealed blow phenomenon not only in sandy soils but in clay soils as well.

Colmatage – compaction of fine particles mixed by seepage flow of pore water. Colmatage leads to seepage coefficient decrease that potentially produce local pore pressure and groundwater level rise.The following factors resulting in foundation soil saturation irreversible and strongly connected to engineering activity of humans, which have negative impact. Therefore, following factors' consideration directly affecting stress-strain soil condition and necessary for reliable saturated soil deformation forecast.

Features of water saturated foundations.

Unfortunately, up to now construction, further building operation and climatic territory conditions assist to sudden soil water saturation. In case of engineering survey, soil does not consider as loose one, later on it is becoming loose, mainly because of moisture rise. Primarily foundation soils are dispersive medium it is consist of solid particles and pores characterised by physical properties including moisture.

SNiP 25100-95 states that according to water saturation coefficient (Sr) soils divided into small, medium and full saturation. Soil foundations with saturation coefficient $Sr \geq 0{,}8$ is water saturated. Humidity characterised by saturation coefficient, which depends on moisture, soil density and porosity. Soil humidity identify consistency of dusty-clayey soils (loamy sand, loam, clay), which is characterising its plasticity (moisture on the edge of rolling and flow, plastic flow index, plasticity). In terms of sandy soils moisture content deviates in a low range and almost negligible to strength or deformation properties. High moisture content in dusty-clayey soils allows predicting sufficient impact on strength and deformation properties.

SNiP 1.02.07-87 attributes to loose soils: "very soft soil, flowable dusty and clayey soils with high values of porosity, because of piping porosity increases and soil deformation behavior decreases. Blow – soil loss due to seepage flow. There is a critical value for the JK gradient, exceeding this value leads to seepage flow. Critical value of gradient JK evaluated from this formula: and permeability properties during the natural state disturbance".

Water saturated soils having following physical-mechanical properties:

- Modulus of total deformation is not exceeding 5 MPa, which means high compressibility;

- Angle of internal friction for the dusty-clayey soils in saturated condition is 5-12 degrees, cohesion 0.01-0.03 where s – specific soil unit weight, kN/m3; w – unit weight of water, kN/m3; n – porosity; $\alpha = na/n$; na – active porosity: for sands $na \approx n$;

High coefficient values for the porosity e > 0.8 reveal porous structure with high ability of water accumulation.

Building settlement on water saturated foundations take long period of time (operation time), comparable to foundation consolidation.

Water saturated soils having relatively high structural strength in compression. Particles of clay soil bonded between each other with molecular force and film gel, which interacts through thin layers of water on the intersection of particles. Moreover, there is a cohesion hardening because of physiochemical processes. Strength and deformation properties of clay soils determined by cations as well. Loose saturated soils essentially have molecular bonds. Because of loading under structure's self-weight, mineral particles shift and pore water squeeze out take place. That leads to cementation and molecular bonds destruction. Following process governs the foundation settlement propagation within a time.

Water deposited soils well spread all over the territory of Kazakhstan, and even in oil-bearing regions of Caspian Sea coast. Water saturated foundations with low deformational

Abelev M.U. (1983) proposed that total deformation modulus of loose saturated soils depend on loading – P and following dependence can be expressed as (when E = 1.5 7 MPa)The duration of consolidation process depends on soil permeability characteristics changing with time. Abelev M.U.

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(1983) revealed logarithmic correlation between coefficient of permeability and porosity for strongly compressible soils: in case of applying following assumptions e0 >e, Kф0 >Kф.

Influence of mechanical and permeability properties of soil on foundation deformability.

Mechanical impact of groundwater upon the soil results primarily in soil saturation with water and simultaneously changes in stress-strain conditions of foundation. This effect modifies physical-mechanical properties of foundation soil leading into additional deformations (settlements, subsidence and swelling).

Usually foundations in non-saturated state maintain sufficient bearing capacity and relatively acceptable properties, however, change in moisture content notably reduce strength and deformation characteristics of soil.

Investigations carried out by Cytovich N.A. (1981), Abelev M.U. (1983), Zareckyi U.K. (1988), Ter-Martirosyan Z.G. (1981, 1988, 1990), Tatsuoka F., Shibuya S. (1991), Terzahgi K. (1961), Zhakulin A.S. (2015) reveal influence of mechanical and permeability soil properties in terms of changeability in stress-strain condition, also, complexity of compaction mechanism (consolidation) for saturated foundations. Study of deformation clayey water saturated soil should follow in such order:

- Description of consolidation process, following with phenomena as squeezing liquid out of soil pores under variable gradients of pore pressure;
- Description of soil skeleton deformation under effective stress with necessity in deformation character establishment (plastic, elastoplastic or viscoplastic).

Mechanical and permeability characteristics of saturated foundations usually investigate by experiment in laboratory or in field conditions for consolidation and deformation process description. Identifying the characteristics of deformability necessary to prove selection of a single one, out of plenty deformation modulus (total, volumetric, shift). Based on theoretically chosen approach of testing in laboratory (compression, triaxial, stamp, pressiometric etc.).

where *K0* – permeability coefficient of saturated soil before compaction, in other words porosity is *e = e0*; – coefficient for the saturated soils.

Shear strength of loose soils depends on the content, texture, moisture, porosity, structural strength etc. Shear strength indexes vary in the process of compaction that represents dependence on loading with nonlinear behavior.

Taking initial gradient of I0 is necessary during filtration through low permeable clays (*k* < 10-4 m/day.); usually hydrogeological calculations consider them as aquiclude. Research of silt soils pointed that initial gradient should be taken into account under loadings above 0.05 MPa and with pressure gradient *I0* >5.

It should be noted that correlation for highly compressible soils of *I0* to e is almost linear:

$$I0 = I'0 + aI\ (e0-e)$$

(where *I'0* – initial gradient before compaction with *e=e0*; *aI* ≈ 15 ,16). For dense clays, following correlation is parabolic.

Water-deposited loose soils characterized with compaction strength *pstr* – which is extreme pressure upon the soil and is almost incompressible. For ordinary clayey soils *pstr* ≈ 0.01,0.02 MPa, and for the silts and aeolian soils it can reach up to 0.05 MPa and more.

If the pressure is lower than *pstr* full loading sustain by soil skeleton, and pore pressure is absent. Therefore, usage theory of filtration consolidation requires consideration of pstr. In case of additional effective pressure upon the soil skeleton from buildings is *p0z* (where *p0z* > *pstr*), then at the initial moment of loading pore pressure - *pw* will not be equal to *p0z*, as it states in permeability consolidation theory of K. Terzaghi (1960), it will be at t = 0:

$$pw = p0z - pstr,$$

It is explained as the part of external loading equal to *pstr* directly transmits to the soil skeleton, i.e., at t = 0 equation is initial condition at all deformation calculation problems concerning permeable consolidation for loose saturated soils.

It is necessary to note that if *p0z* < *pstr* permeable consolidation will not occur, as whole loading is taken by soil skeleton.

As an active (compressible) zone *(Hc = z')* for the loose saturated soils advisable to take a depth where pressure p0z is equal to compression strength, i.e. *p pstr 0z'*. For potentially loose soils, identification of *Hc* should consider direction of soil saturation – upward (rise of groundwater), downward (percolation of different leakages and top water).

In the former case, straight after crossing border of active compressible non-saturated zone by groundwater, additional deformations take place. Since, soil saturation cause drastic drop in deformation modulus under total pressure *ptot* = *p0 z'* + *pz'*. Therefore, in this case instead of equation it is necessary to use ptot pstr or in accordance with SNiP 2.02.01-83, *ptot* 0.1 *pz'*.

In the second case, when edge of soaking *l (t)* will move down, in the upper zone clause (1.6) will be followed, while in the lower zone for the *z' (t)* identification at every moment essentially to follow these conditions:

na w l (t) 0.1 pz' ,

where *na* – active porosity of saturated layer soil; *w* – unit weight of water; *w* = 9,8 kN/m3; *pz'* – natural soil pressure on certain depth.

It should be noted that nowadays there is no any justified method for change in soil properties prediction under saturation (there are separate correlative dependencies for soils on the territory of Russia). Therefore, complex study of mechanical properties and its impact on deformability of Kazakhstan soils is actual problem.

Summary and Conclusions.

Analysis represents that majority of buildings and structures in industrially developed regions of Kazakhstan erected on quaternary system soils. Quaternary soils notable by diversity of physical state, complexity and variability of mechanical properties. Therefore, object of following research is quaternary water saturated loamy and sabulous soils of Western and Central Kazakhstan.

The influence factors resulting in foundation soil saturation irreversible and strongly connected to engineering activity of humans, which have negative impact. Therefore, following factors' consideration directly affecting stress-strain soil condition and necessary for reliable saturated soil deformation forecast.

Water saturated soils well spread on the territory of Kazakhstan and all over the cities without any exclusions, and in oil-bearing soil of Caspian Sea coast. Water saturated foundation soils with low deformational and strength characteristics require detailed investigation for accident and defects prevention of buildings.

It should be noted that nowadays there is no any justified method for change in soil properties prediction under saturation (there are separate correlative dependencies for soils on the territory of Russia). Therefore, complex study of mechanical properties and its impact on deformability of Kazakhstan soils is actual problem.

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Су қаныққан негіз топырақтарының сипаттамалары

Аңдатпа. Сумен қаныққан топырақ Қазақстанның барлық қалалары үшін, сондай-ақ, Каспий теңізінің жағалауындағы мұнай аудандары үшін ортақ болып табылады. Суға қаныққан топырақ - бұл кеуектер сумен (80% - дан астам) және судағы көпіршіктер мен ерітінділер түрінде ауамен толтырылған топырақтар. Сондықтан сумен қаныққан топырақ үш фазадан тұратын композит болып табылады, олардың әрқайсысы өзінің физикалық және механикалық қасиеттеріне ие. Көлем бірлігіндегі осы фазалардың сандық арақатынасы көбінесе мұндай топырақтың физика-механикалық қасиеттерін, әсіресе, топырақ массивінің пайда болу сипатын анықтайды, деформация-механикалық қасиеттері төмен су бар іргетас топырағы бұл ғимараттардың апаттылығы мен ақауларының алдын алу үшін егжей-тегжейлі зерттеуді қажет етеді.

Түйін сөздер: топырақ, жүктеме, тұнба, бөлу, іргетас, геология.

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Характеристики водонасыщенных грунтов основания

Аннотация. Водонасыщенные почвы являются общими для всех городов Казахстана без каких-либо исключений, а также для нефтяных районов на побережье Каспийского моря. Водонасыщенные почвы

- это те, поры которых заполнены водой (более 80%) и воздухом в виде пузырьков и растворов в воде. Поэтому водонасыщенный грунт представляет собой композит, состоящий из трех фаз, каждая из которых обладает своими физико-механическими свойствами. Очевидно, что количественное соотношение этих фаз в единице объема во многом определяет физико-механические свойства и особенно характер формирования массива такого грунта - водосодержащего грунта фундамента с низкими деформационно-механическими свойствами, требующего детального изучения для предупреждения аварийности и дефектности зданий.

Ключевые слова: грунт, нагрузка, осадка, распределение, фундамент, геология.

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