

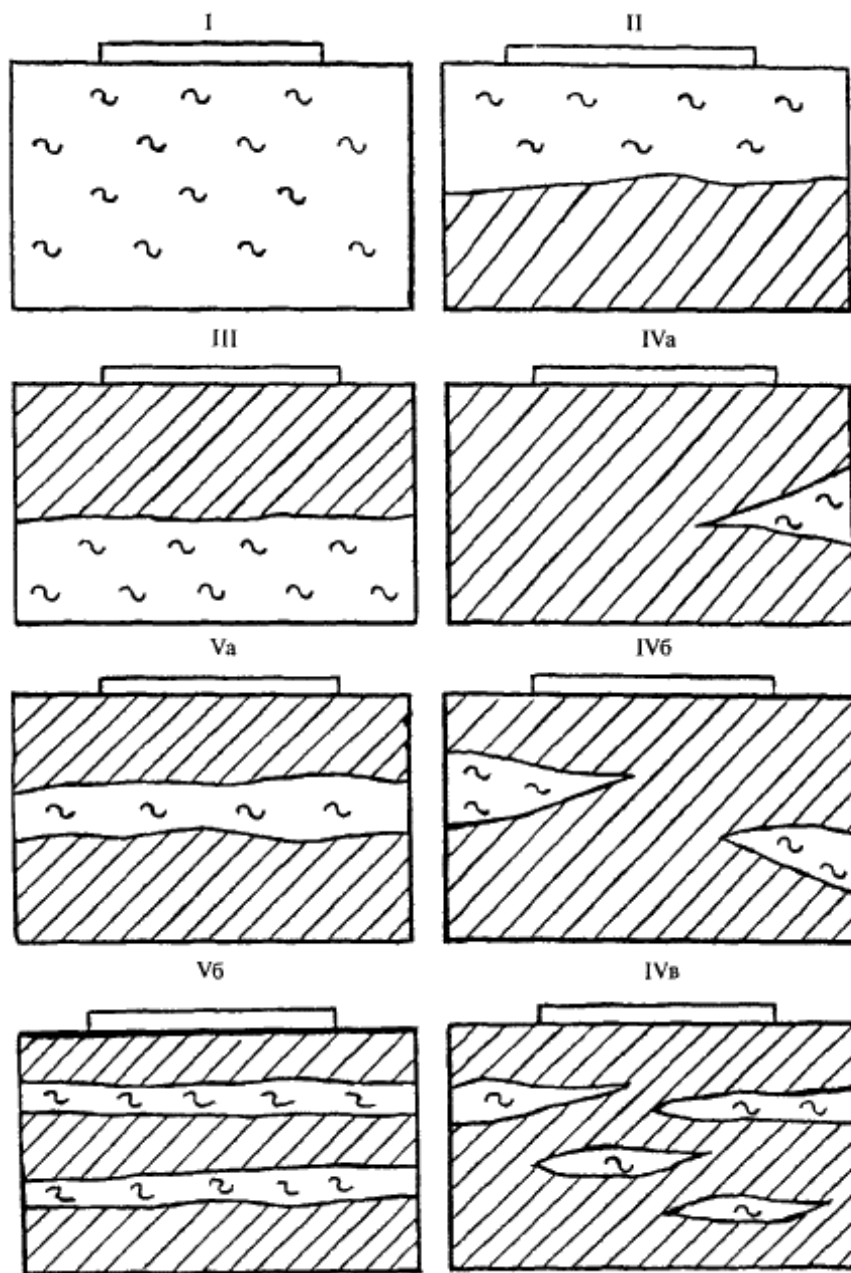
**TOPIC 6. FOUNDATIONS ON ALLUVIAL AND  
EMBANKMENT SOILS.  
FOUNDATIONS ON WEAK SOILS**

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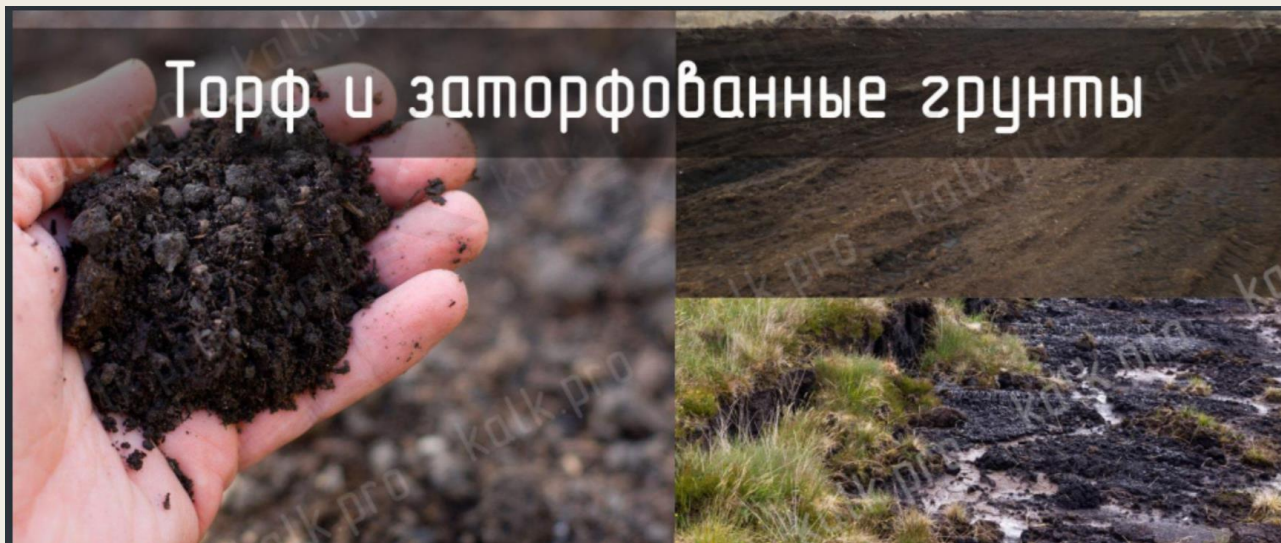
## ***SOILS WITH WEAK STRUCTURAL BONDS***

Weak water-saturated soils include highly compressible soils saturated with water, which at normal speeds of application of loads to the base lose their strength, as a result of which their shear resistance decreases and compressibility increases. These usually include silts, peaty soils, strip clays, water-saturated loess soils, and some other types of clay soils.



**Typical schemes of bases containing organo-mineral and organic soils**

I - within the entire compressible layer of the base, organo-mineral or organic soils are located; II - a layer of organo-mineral or organic soil lies in the upper part of the compressible layer of the base; III - organo-mineral or organic soils lie in the lower part of the compressible layer of the base; IV – the compressible layer within the construction of the building includes one-sided (IVa), two-sided (IVb) wedging of lenses or contains many lenses (IV century) of organo-mineral or organic soils; V - within the depth of the compressible layer, there is one (Va) or several layers (Vb) of organo-mineral or organic soil, the boundaries of which in the plan go beyond the boundaries of the spot where the building was built



Peat soils



Sapropels

Peat soils and sapropels

When designing shallow foundations, it is necessary to limit:

- average settlement with limiting values;
- relative differences in settlement of adjacent foundations with limiting values;
- settlement flow rates are acceptable.

When the calculated deformations of the base composed of organic-mineral and organic soils are greater than the maximum or the bearing capacity of the base is insufficient, the following measures must be taken:

- complete or partial cutting through layers of organomineral and organic soils by foundations;
- complete or partial replacement of organomineral and organic soil with sand, gravel, crushed stone, etc.;
- compaction of soils by temporary or permanent loading of the foundation of a structure or the entire construction site with bulk (alluvial) soil or other material (with the installation of a filter layer or drains, if necessary, to accelerate the process of consolidation of the foundation);
- fixation of peats using the drill-mixing method.

*Foundations composed of water-saturated organic-mineral and organic soils must be calculated according to their bearing capacity.*

In these calculations, the ultimate resistance force of the base  $n_u$ , kN/m, under the action of a vertical load for a strip foundation can be determined by the formula

$$n_u = b'(q + 5,14c_I),$$

where  $b'$  is the reduced width of the foundation.

$q$  - load, kPa;

$c_I$  - calculated value of specific soil cohesion, kPa.

*The final settlement of a layer of organomineral and organic soil in a stabilized state  $s$ , m, caused by a washed or poured layer of sand, is determined by the formula*

$$s = 3ph/(3E + 4p)$$

where  $p$  is the pressure from the sand embankment on the surface of organic-mineral and organic soil, kPa;

$h$  - thickness of the layer of organic-mineral and organic soil, m;

$E$  - deformation modulus of organo-mineral and organic soil at full moisture capacity, kPa.

The size of the embankment in plan must be at least  $5h$ .

## ***METHODS FOR COMPACTING FOUNDATIONS.***

**Filter loading.** Effective pre-construction compaction of weak water-saturated soils. For this purpose, a filter load is arranged. The compaction time of water-saturated soil is almost directly proportional to the square of the distance to the drainage surface. To reduce the distance of movement of the squeezed water, vertical sand drains with a diameter of 0.4 ... 0.6 m are installed with a distance of 2.5 m from each other. The vertical drains on top are combined with a sand filtration bed 0.6 ... 1 m thick.

*The final settlement* of a layer of biogenic soil or silt in a stabilized state, due to the washed and poured layer of sand, is calculated using the formula

$$s = 3ph / (3E + 4p), \quad (3.1)$$

where  $p$  is the pressure from sandy soil on the surface of weak water-saturated biogenic soil or silt, kPa;

$h$  – thickness of the layer of biogenic soil or silt;

$E$  – deformation modulus of biogenic soil or sludge at full moisture capacity, kPa.

The settlement of highly compressible soil depends on the timing of consolidation and on the drainage of the base. Settlement of an undrained base loaded with a filter embankment at a given point in time.

**Sand cushions.** In practice, to reduce the size and unevenness of foundation settlements, sand cushions up to five meters thick are often installed. With their help, it is possible to reduce the depth of foundations and distribute pressure over a larger area, reducing the size of foundations. Sand cushions are made from medium- and coarse-grained sand, crushed stone, gravel, and gravel-sand mixture.

Sand cushions, arranged under foundations in order to replace organic-mineral and organic soils, reduce pressure on the underlying layers, increase, if necessary, the level of the base of the foundations, accelerate the process of consolidation (compaction) of underlying soils, are usually made from coarse and medium size. In some cases, the use of crushed stone, gravel, slag or gravel-sand mixture is allowed. Fine sands are not recommended for making cushions. The density of dry soil in coarse and medium-sized sand cushions is recommended to be at least 1.65 t/m<sup>3</sup>.

**Lime piles.** In some cases, it is advisable to use lime piles. Wells with a diameter of 30...50 cm are drilled into the soil under the protection of casing pipes. They are filled with a layer of about one meter of quicklime. A tamper weighing 300...400 kg is lowered into the casing and compaction is performed. A layer of lime is poured again and compacted, etc.

The soil is compacted when the pipe is immersed and after compacting the lime. When quicklime interacts with pore water, slaking occurs. As a result, the diameter of the lime pile increases by 60 ... 80% and the soil around the pile is further compacted. In addition, when slaking lime, a large amount of heat is released. The temperature rises to 200 °C. As a result, the humidity of the surrounding soil decreases, and the strength characteristics increase. Next, surface compaction of the soil is carried out using heavy tampers.

Sand piles are constructed by driving a metal pipe with a closed end into the ground. The cavity is filled with sand and thoroughly compacted. A compacted zone of soft soil with a diameter of up to one and a half meters is formed around the pile shaft (with a pile diameter of 0.4 ... 0.5 m).

**Electrochemical processing.** In practice, electrochemical soil treatment is sometimes used to increase the load-bearing capacity of the foundations bases of structures, create barriers when digging pits and trenches, and combat frost heaving and landslides. They are used to strengthen all types of soils with a filtration coefficient of less than 0.5 m/day (fine and silty sands, sandy loams, loams, clays, silts, decomposed peat). Electrochemical processing is divided into: electro drying, electrolytic processing and electrosilicatization. Long-term irreversible hardening can be achieved by introducing chemical additives.

Soil strengthening occurs due to electrochemical and structure-forming processes occurring in clay soil when a direct electric current is passed through and electrolytes are introduced.

**Pile foundations.** They are used with a relatively small thickness of weak soils (up to 12 m), underlain by strong ones. The piles completely cut through the weak soil with support on the strong one. When driving a pile, the pore pressure increases sharply, as a result of which the bearing capacity of the pile decreases. Over time, the pore pressure decreases almost to zero, and the bearing capacity of the pile increases.

In the conditions of a weak clay base, the manifestation of negative friction is possible. The soil settling around the pile loads it. The amount of negative friction can reach 500 kN.

*The reasons for this can be:*

- layout of the area with filling;
- loading of the surface with long-lasting useful loads;
- loading of weak soils within driveways and streets with periodic backfilling during the repair of road surfaces;
- change in soil density as a result of lowering the groundwater level;
- dynamic effects on the soil of heavy transport and industrial installations;
- manifestations of processes leading to constant compaction of young weak soils.

Negative friction forces are taken into account up to the depth at which the values of the settlement of the surrounding soil exceed half of the limit value of the foundation settlement. Calculated soil resistance  $f_i$  is accepted for peat, silt, sapropel  $f_i = 5 \text{ kPa}$ .

## ***ARTIFICIAL SOILS AND TOPSOILS***

Artificial soils are called rocks and soils that have undergone displacement as a result of the production and economic activities of people, or purposely changed by man in solving various engineering and construction problems.

Depending on the main processes of their formation, they are divided into two subgroups.

*The first subgroup* combines artificial soils, which were formed in cases where special conditions for their creation were not required. This group includes *cultural layer* – that spontaneously arises on territories of populated areas, *bulk and artificial washed soils* – which are created by man during production activities, but without an aim of improving their engineering and geological properties.

This subgroup of artificial soils also includes *degraded soils* – those natural soils in which the engineering and geological properties have changed in an unfavorable direction as a result of human exposure.

*The second subgroup* of artificial soils combines rocks and soils that are purposely modified by human being in order to improve their engineering and geological properties. These are *improved soils*.

According to standards, such soils are called *technologically altered* – that is, natural soils that have been deliberately subjected to technogenic effects of different nature (chemical, physical, physic-chemical, biological) at their place of occurrence. Issues of improving the engineering and geological characteristics of soils are handled by a special branch of soil science – *technical soil reclamation*.

# CULTURAL LAYERS



сир. рикта змента з  
битою цаллою па  
лишню атрапачому

тмкн-  
коричневй шар

сод

алана

ауапа

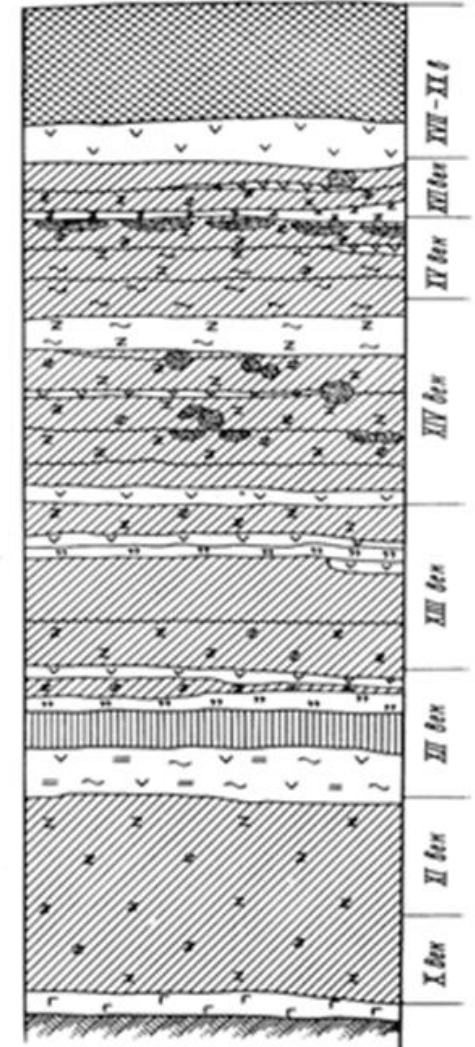
сод

сод

трона

березина

похаванй  
зрунт



The cultural layer in Veliky Novgorod: a – thickness of section; b – composition and age of sediments



Cultural layer in Kosice

## ***DESIGN BASES ON BULK SOILS***

- **Bulk soils include:**
- – soils with disturbed natural structure;
- – waste dumps from various industries;
- – landfills of all kinds of materials, the layers of which were formed as a result of filling ravines, pits, quarries, local depressions during the planning of territories with soils obtained during the development of pits, trenches, land planning by cutting, stripping operations during open-pit mining, etc., as well as waste from various industries.

# ***CLASSIFICATION OF BULK SOILS***

## **According to the method of laying**

- Dumped by road or rail transport, scrapers, bulldozers, etc.
- Planarly erected embankments (backfills) and cushions, which are characterized by an almost uniform composition and uniform compressibility.

## **By the uniformity of the composition**

Dumps of soils and industrial wastes, which have an almost uniform composition, but uneven density and compressibility

Landfills of soils, industrial waste and household waste, which are characterized by heterogeneous composition, uneven density and compressibility, as well as the content of organic inclusions

## **According to the type of source material that makes up the main part of the embankment**

Natural soils: large-clastic, sandy, clayey

Production waste: slags, ashes, molding soil, tailings from enrichment factories, etc.

Household waste

## **According to the degree of compaction from its own weight**

They have settled - the process of compaction from its own weight has ended

Do not settle - the process of compaction from its own weight continues

The approximate periods of time for self-compaction of bulk soils from their own weight, after which the soils can be classified as compacted

| Types of soils                                                                                                                  | Time period, years          |
|---------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| Planarly erected embankments (with insufficient compaction):<br>from sandy soils<br>from clay soils                             | 0,5—2<br>2—5                |
| Dumps of soil and industrial waste:<br>from sandy soils<br>from clay soils<br>from slag, forming soil<br>from ash, furnace dust | 2—5<br>10—15<br>2—5<br>5—10 |
| Landfills of soil and industrial waste:<br>from sandy soils, slag<br>from clay soils                                            | 5—10<br>10—30               |

The process of self-compaction is considered complete, and the soil layer is called *stacked*, if sufficient time has passed after its stacking. In the case of non-planar embankments, the compaction period increases: up to 5 years for large-clastic and sandy soils, 10 years for dusty-clay soils lying above the groundwater level, and 30 years for such soils below the groundwater level.

Uneven compressibility of bases composed of bulk soils is usually caused by:

- by changing the composition of bulk soils in plan and in depth;
- uneven density of bulk soils;
- changes in humidity, especially for clay soils;
- a layer of bulk soils of different thickness at the base;
- the presence of highly compressible layers and interlayers in bulk soils;
- increased content of organic inclusions;
- by laying highly compressible underlying soils below the bulk soils and changing their thickness on the built-up area;
- the presence of large inclusions or voids in bulk soils, commensurate with the width of foundations.

## ***CALCULATION OF BASES ON BULK SOILS***

The bases and foundations of buildings and structures on bulk soils are calculated based by deformations based on the fact that the total settlement of the foundation on bulk soil does not exceed the maximum permissible for the building or structure being designed. In this case, the total settlement  $s_f$  of the foundation is calculated as the sum of settlements caused by its load and additional factors:

$$s_f = s + s_{f1} + s_{f2} + s_{f3} + s_{f4},$$

where  $s$  is the settlement of the foundation due to its load, determined according to the DBN. 5;  $s_{f1}$  - additional settlement of the base due to self-compaction of bulk soils due to its own weight;  $s_{f2}$  - the same, due to soaking, lowering the groundwater level;  $s_{f3}$  - the same, during the decomposition of organic inclusions;  $s_{f4}$  - the same, due to the compaction of the underlying soils from the weight of the embankment.

The main methods of preparing bases on bulk soils are:

- surface compaction with heavy tampers to a depth of 3-4 m;
- compacting pits;
- arrangement of sand and other cushions;
- surface compaction with vibrating machines and vibrators;
- deep compaction by drilling wells;
- hydraulic vibration compaction with deep vibrators.

Surface compaction with heavy tampers is used in construction;

- on systematically constructed embankments, filled with insufficiently high density;
- on dumps of soil and industrial waste containing various inclusions no larger than the diameter of the rammer;
- in landfills of soils and industrial wastes containing organic inclusions of no more than 0.05;
- in areas located at a distance of at least 10 m from existing buildings and structures;
- on soils with a humidity level of no more than 0.7.

Cutting through bulk soils is carried out using driven or bored piles in the following cases:

- if, when using bulk soils as bases (including using bases preparation methods), acceptable foundation settlements are not ensured, both in absolute value and in the degree of their unevenness;
- in the absence of technical and practical capabilities to compact sandy soils to the required depth;
- when bulk soils (landfills of soil and industrial waste) contain a large amount (more than 0.05-0.1) of organic inclusions;
- with a high bearing capacity of natural soils underlying the embankment;
- if in bulk soils there are no large strong inclusions (goats in slag, metal, concrete, reinforced concrete, etc.) and it is possible to drive piles or drill wells under them to the underlying load-bearing layer;
- with a more appropriate (compared to methods of compacting bulk soils) use of pile foundations in terms of technical and economic indicators.

Constructive measures when designing on bulk soils are taken in cases where, when using bulk soils as a natural foundation or preparing the foundation using the compaction methods discussed above, acceptable precipitation in its absolute value or degree of unevenness is not ensured. Structural measures are intended to increase the strength and overall spatial rigidity of buildings, adapt them to uneven deformations of soils at the base and thereby increase the permissible settlements of the designed buildings.

The complex of constructive measures usually includes:

cutting buildings and foundations with sedimentary seams;

installation of reinforced belts in foundations and buildings;

increasing the strength of butt joints between individual prefabricated elements;

increasing the areas of support of load-bearing elements of coatings and floors on walls and columns, etc.

Structural measures are prescribed, as a rule, based on the calculation of the structures of foundations and buildings for possible uneven settlement of soils at the base.

# WASHED SOILS



Washed soils are dispersed material, loose, finely fragmented waste from industrial and economic activities, as well as low-value minerals laid by hydro-mechanical methods – using various dredging mechanisms. The difference between washed soils from the original soils of natural occurrence and from bulk soils lies in the changed granulometric composition due to the removal (washing out with the hydraulic process) of some of the smallest fractions. The physic-mechanical properties of such soils can vary significantly over time: under the influence of natural compaction processes, the density of dry soil, the general strain modulus, specific adhesion, the angle of internal friction and so on.



Artificially washed islands in the Persian Gulf, UAE