THE STRENGTH OF GYPSUM SANDY SILTS
RESISTANCE DES LIMON SABLEUX PLATRE

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SYNOPSIS: Strength properties of gypsum sandy silts are investigated in natural state and after desolving. Special experimental methods and test equipment were developed. It was found out that angle of internal friction increases by 2-3° after desolving. Sandy silts are characterized as a result of leaching process by practical absence of cohesion.

In 50-60 th intensive construction begun in the arid and semiarid regions of the former USSR. It was connected with rising of land reclamation works, elaboration of cosmic explorations, opening and developing of wraniwm, gold, non-ferrous metals deposits, oil-and gas-fields. In most cases particular forms of arid soils were used as base of structures, but at that time little was known on mechanical properties of such soils. Gypsum soils are one of this type of arid soils.

Site investigation and experimental research of mechanical properties of gypsum soils were carried out using standard methods developed for the usual soils. This led to selection of wrong basic parameters during foundation design. As a result numerous cases of deformations of tens and hundreds of structures took place.

First investigations of gupsum soils, Lomize (1953), Terleckaya (1951), permitted to determine specific character of suffosion compression and change of physico-mechanical properties during salts leaching.

It was established that soil strength changes during long term filtration of water and desolving of the soil. But these results were mainly quantative character due to limited number of experiments. This limited volume of researches was connected with absence of special equipment and also with high labour-consumings and methodical complexity of determination strength parameters of gypsum soils during leaching.

In investigation of gypsum soils strength it is necessary to make preliminary desolving of samples, so samples with stated physico-mechanical properties must be prepared. Preparing of such samples can be made by modelling process of filtration desolving and, desirably, stress state. But known standard equipment is not adapted for desolving of soil and consequent determination of its strength.

It is necessary to desolve and test in triaxial and shear plane devices tenth and hundreds of samples for determination of dependence of angle of internal friction φ' and cohesion intercept C' changes depending on degree of salts leaching β and initial gypsum content d_o.

Preliminary desolving of samples, according to method worked out by author and E.A.Arakelian (1984), is carried out in triaxial or uniaxial stress state and also in absence of pressure on the sample. Special methods and equipment were worked out for this purpose, that permit to get samples with any given degree of salts leaching, Petruknin (1989) .

Up to now general dependences of changing strength during desolving were received for sandy clays only, Petrukhin (1989), but for sandy silts such dependences were absent. In this work sandy silts are classified as soils with plasticity index I_p = 1,0 - 7,0 and sandy clays as soils with I_p = 7,0 - 17,0.

In this connection multiyears research of proluvial - deluvial gypsum sandy silts was carried out. All experiments were made with soils of natural (undisturbed) structure. Initial gypsum content was d_o = 0 - 50 %, density of dry soil ρ_d = 1,35 - 1,50 g/cm^3, density of solid particles ρ_s = 2,60 - 2,74 g/cm^3, initial water content w= 2 - 5 %, plasticity index I_p = 3,0 - 6,5. Sandy silts degree of leaching was during samples prepairing from β = 27 % to β = 80 %. 180 experiments were carried out. The duration of leaching of one sample took 2 - 15 months.

It was established that sandy silts, in contrary to sandy clays, are characterizied by considerable deformation during desolving. The relative volumetric deformation ε_{sf} reaches 0,25 and more. The diagram ε_{sfv} =f(β) has rectilinear form.

The coefficient of permeability of sandy silts decreases during desolving under pressure by 2 - 8 times in interval β = 0-20 %. This is connected with intensive compuction of samples decreasing of void ratio (Fig. 1).

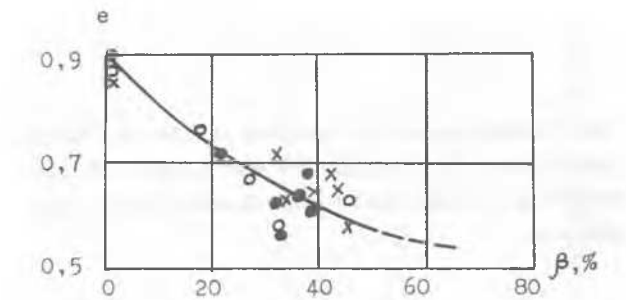

Fig. 1. Void ratio e dependence on the degree of leaching β for the sandy silt with d_o = 26 % at different values of compressive stresses:
o - σ_2' = 0,1 MPa,
x - σ_2' = 0,2 MPa,
• - σ_2' = 0,3 MPa.

Above β = 20 % the coefficient of permeability changes insignificantly during further desolving of soil (Fig. 2).

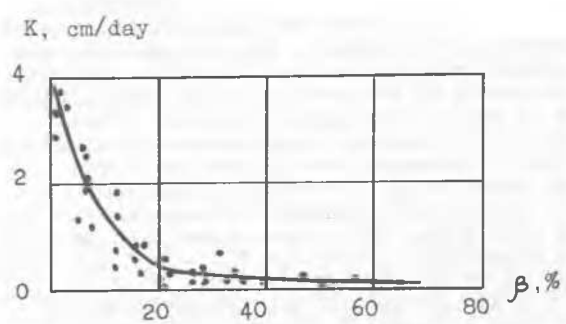

Fig. 2. Coefficient of permeability K dependence on the degree of leaching β at compressive stress σ_2' =0,1 MPa for the sandy silt with d_o = 26 %.

In most experiments with sandy silts, containing gypsum less 35 %, filtration practicaly stops above β = 60 - 70 %. So desolving of sandy silts with β> 70 % is practicaly absent and consequently it is possible to neglect the changes of strength.

Theoretically it is necessary to test several groups of soils with different initial content of gypsum and degree od salts leaching for obtaining data on possible changes of the strength during desolving. For each of this group it can be established change of the angle of internal friction φ and cohesion C depending on d_o and β .

But it is very difficult to realize this practically. So special methods of tests and treatment of data were carried out. According to this method, the diagrams of dependence σ_1' on β and σ_2' (Fig. 3) are constructed firstly, then on the base of these diagrams graphs of dependence of φ' and C' on d_o and β are constucted (Fig. 4).

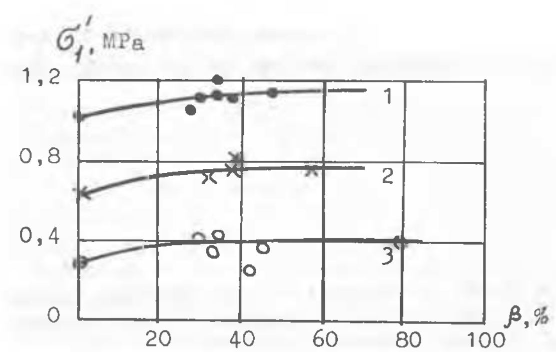

Fig. 3. Limited principal effective stresses σ_1' change dependence on the degree of leaching β and compessive stress σ_2' (curve 1 - σ_2' = 0,3 MPa, curve 2 - σ_2' = 0,2 MPa, curve 3 - σ_2' = 0,1 MPa) at initial gypsum content d_o = 26 %.

Small dispersion of ultimate principal stresses values (Fig. 3) indicates sufficient homogeneity of sandy silts both before desolving and after salts leaching. Besides, the diagrams analys shows that main change of values σ_1' takes place under the degree of salts leaching β = 40 %. Consequent desolving of soil don't depend on the value σ_1' .

Fig. 5 shows generalised diagrams of the internal friction angle and cohesion intercept of sandy silts dependence on gypsum content in natural state (β = 0) and in condition of limiting desolving (β = 70 %). The curves in the Fig. 5 were received using data of the Fig. 3 and 4. So each point in the Fig. 5 corresponds to mean value and was received on the results of many samples tests.

For the sandy silts at β = 0 (in water-saturated condition) porosity increases with rising of the initial gypsum content, that is connected with absence of initial (before cristalls formation) cohesion in these soils. Active cristallyzation of gypsum at contacts

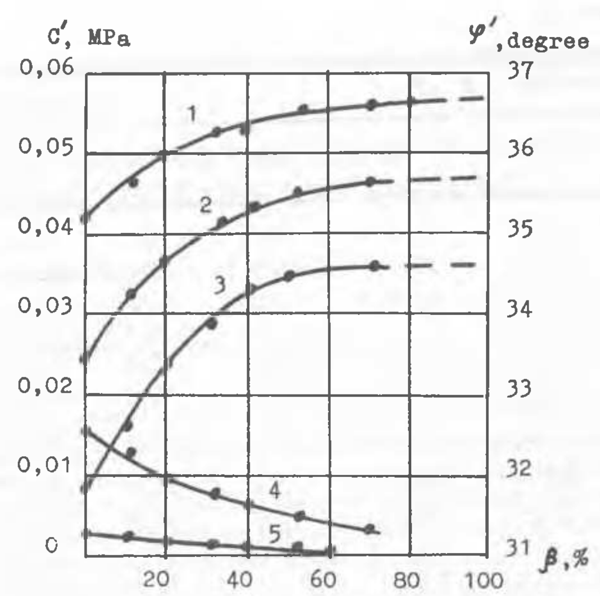

Fig. 4 . Angle of internal friction φ' (curves 1 - 3) and cohesion intercept C' (curves 4 - 5) change dependence on the degree of leaching β and initial gypsum content d_o. (Curves 1 and 5 - d_o = 16 %, curve 2 - d_o = 26 %, curves 3 and 4 - d_o = 48 %).

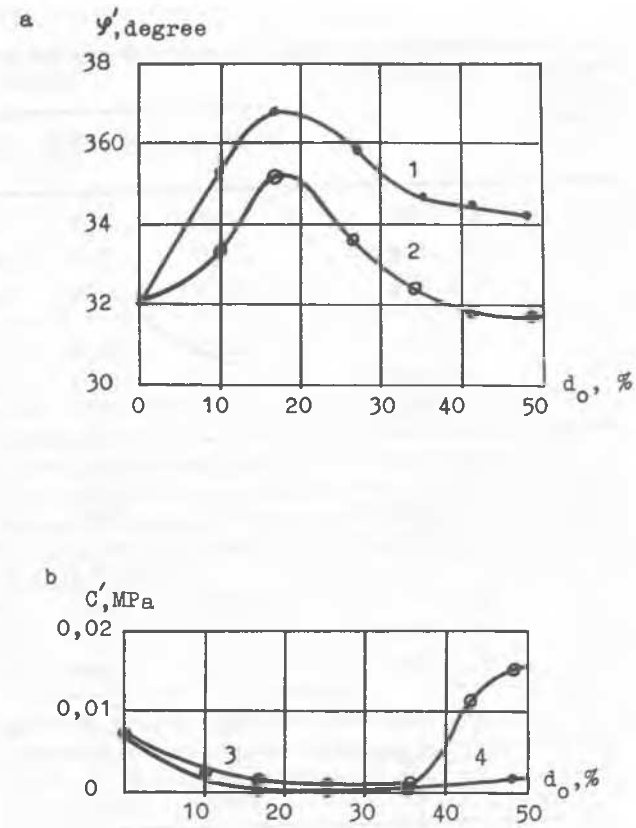

Fig. 5. Angle of internal friction φ' (a) and cohesion intercept C' (b) dependence on the initial gypsum content d_o for the sandy silts at the nature state (β =0, curves 2 and 3) and at the limiting state of desolving (β = 70 %, curves 1 and 4).

between particles move apart the latter. As a result the structure with higher porosity is generated and it is destroyed easely even during watersatturating at small stresses. Larger cristalls are formed with increasing initial gypsum content ($d_o > 35$ %) and their mutual jointing leads to generation of higher cohesion (Fig.5 , curve 3).

Continious increasing of gypsum sandy silts porosity under raisieng d_o leads to some decreasing of the angle of internal friction. Similtaneously mineral friction (tg φ_m') increases due to high coefficient of friction of gypsum crystals. The value of the angle of internal friction increases for soils with $d_o < 17$ % (Fig. 5, curve 2) as the result of interaction with both factors and predomination of tg φ_m .

On the contrary the porosity raise plays decisive role for the soils with $d_o > 17$ % so the angle of internal friction decreases. But it is necessary to note,that the angle of internal friction of sandy silts remains high and exceeds 31° at any value of the initial gypsum content. This is connected with the genesis as well as structural and mineralogical peculiarities of gypsum sandy silts.

Noticeable closeness in values of the angle of internal friction of gypsum sandy clays and sandy silts at $d_o > 35$ % was established. This conformity is connected with the nature of physical properties change and structural peculiarities of these soils. Sandy clays and sandy silts are characterizied by the same structure at $d_o > 35$ % and the distribution of gypsum inclusions is uniform. Besides at d_o = 35 - 50 % the density of sandy clays and sandy silts differs insignificantly.

The mechanizm of the strength change of the gypsum sandy silts during desolving is more simple than in case of the gypsum sandy clays because sandy silts are characterized by practical absence of cohesion.

Compression of sandy silts takes place abruptly at the initial stage of desolving under pressure. As a result (Fig. 4, curves 1 - 3) the angle of internal friction increases by 2 - 3° due to raise of total area of interaction between mineral particles and increase of their interlocking. Then change of φ' stops as consequent gypsum removing leads to decreasing tg φ_m' . But soil becomes more

Table 1. Dependens of Strength Parameters on d_o and β

Initial gypsum content d_o, %	Parameters	Degree of leaching β, %							
		0	10	20	30	40	50	60	70
10	d_t, %	10,0	9,1	8,2	7,2	6,3	5,3	4,3	3,2
	φ', degree	33,0	35,5	34,0	34,5	35,0	35,0	35,0	35,5
	c', MPa	0,003	0,003	0,003	0,0025	0,0025	0,002	0,002	0,002
20	d_t, %	20,0	18,4	16,7	14,9	13,1	11,1	8,2	7,0
	φ', degree	34,0	34,5	34,5	35,0	35,0	35,5	35,5	36,0
	c', MPa	0	0	0	0	0	0	0	0
30	d_t, %	30,0	27,8	25,6	23,1	20,4	17,6	14,6	11,4
	φ', degree	33,0	33,5	34,0	34,5	35,0	35,0	35,0	35,0
	c', MPa	0	0	0	0	0	0	0	0
40	d_t, %	40,0	37,5	34,8	31,8	28,6	25,0	21,3	16,7
	φ', degree	31,5	32,5	33,5	34,0	34,0	34,5	34,5	34,5
	c', MPa	0,008	0,006	0,005	0,004	0,003	0,002	0,001	0,001
50	d_t, %	50,0	47,5	44,5	41,2	37,5	33,2	28,5	23,0
	φ', degree	31,5	32,5	33,5	34,0	34,0	34,5	34,5	34,5
	c', MPa	0,015	0,013	0,010	0,007	0,005	0,004	0,003	0,002

compact and as a result negative influence of mineral friction decrease is compensated.

In can be seen from the general curve in Fig. 5,a that the angle of internal friction of sandy silts increases under limiting value of leaching (β = 70 %) all over interval d_o= 0 - 50 %.

Sandy silts with gypsum content d_o = 15 - 35 % are characterized by very low values of cohesion intercept (Fig. 5,b) in the natural state (β = 0) and at limiting level of desolving (β= 70 %).

The cohesion intercept of sandy silts with gypsum content d_o > 35 % decreases with rising β and approaches to zero at β = 70 %. Both negligible cohesion of sandy silts and its decrease during desolving depend on the presence of large crystals of gypsum inside srtucture of soil. These crystals are forming weak contacts and increase the interlocking during shear.

On the base of carried investigations the Table 1 was developed with value of the angle of internal friction and cohesion intercept depending on d_o and β .

Established peculiarities of the angle of internal friction and the cohesion intercept change during leaching process must be taken into consideration during design of soil bases, embankments and retaining walls.

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