Collapsible and suffosion deformations of gypsy soils

Les déformations d'effondrement et de suffosion des sols gypseux

V.P.PETRUKHIN, All-Union Research Institute of Bases and Underground Structures, Moscow, USSR

SYNOPRIS: Collapsible and suffosion deformations of gypsy soils have been studied in laboratory by means of compression-filtering tests.It has been received that loams are always collapsible ones with short-term moistening, but sandy loams have collapsibility properties only with considerable content of gypsum. The peculiarities of suffosion compression of gypsy soils have been investigated under the conditions of long-term water filtrating and leaching out.Multi-staged character of developing the suffosion compression of loams while dissalining was stated for the first time as well as the dependence of loams and sandy loams suffosion deformations on pressure.Empiric formula for defining the suffosion compression of gypsy loams and sandy loams has been proposed.

Like-loess,preloess-pastloess and loess gypsy soils are widely spread in the South regions of the Soviet Union.These soils are also met in the other countries.During last years gypsy soils are widely used as natural and artificial bases of buildings and structures.Not taking into account of these soils special properties in surveying and designing leads to the considerable deformations of structures (Petrukhin I980).In this connection a great attention has been given to the study of mechanical properties of gypsy soils in the USSR.At the same time such works do not take place abroad, and this fact complicates the construction in arid and semiarid zones.

Loams and sandy loams,consisting of gypsum in the amounts d_g=0-50%,easily solutable salts d_e < I,5% were investigated.Physical properties of loams: density in dried state ρ_d =I,24-I,62 g/cm³, density of particles ρ_s =2,59 - 2,72 g/cm³, porosity coefficient e =0,7 -I,08, humidity w < 0,I. Properties of sandy loams : ρ_d = I,38-I,47 g/cm³ , ρ_s =2,76-2,78 g/cm³ , e = 0,88-I,0 , w < 0,I.

The investigations showed that the deformations of sandy loams with natural humidity were very little due to the presence of gypsum casing (carcass).The relative compression of samples ε_{np} with natural humidity in the interval of pressures p=0,I-0,4 MPa did not exceed 0,008.

When we have short-term moistening of loams then the subsidence takes place.Relative subsidence of loams ε_{sl} with any content of gypsum exceeds 0,0I,and this makes possible considering of these soils to be collapsible. Subsidence of sandy loams is occaisoned by partial destruction of cementation links owing to the softening and dissolving of gypsum in the places of it contact with insoluble particles of soil and owing to the moving apart action of water as well. Under the other equal conditions (pressure,porosity,humidity) relative subsidence of sandy loams depends on the content of gypsum in the soil (the more content of gypsum,the less relative subsidence),Table I.

Table I. Values $\varepsilon_{sl}, \varepsilon_{sf}, p_{sl}$ and p_{sf} of gypsy sandy loams.

Content of gypsum,%	Pressure p,MPa	ε_{sl}	p_{sl},MPa	ε_{sf}	p_{sf},MPa
5	0,3	0,I3	0,08	0,0I	-
7	0,2	0,08	0,I0	0,03	0,06
	0,4	0,I4		0,02	
I5	0,2	0,05	0,I2	0,09	0,04
	0,4	0,I0		0,06	
25	0,2	0,03	0,I5	0,I6	0,02
	0,4	0,07		0,I3	
35	0,3	0,03	0,I7	0,20	0,0I

The data of relative subsidence ε_{sl} ,relative suffosion compression ε_{sf} ,initial subsidential pressure p_{sl} and initial pressure of suffosion compression p_{sf} were given in the Table. The term "initial pressure of suffosion compression" was suggested by the specialists of our institute ,and this term corresponds to the pressure,when ε_{sf} of the sample is 0,0I. From Table I one can see that the more d_g the less p_{sf} ,and it becomes considerably less than p_{sl} .

Later on after the conditional stabilization of subsidence and the definite density of soil the suffosion compression of sandy loams takes place while filtering due to leaching out and dissalining of soil.The generalized dependences of relative suffosion compression ε_{sf} of sandy loams on β (the degree of leaching out) with p=0,3 MPa are given in Fig.I. It follows from this Fig. that the diagram $\varepsilon_{sf}=f(\beta)$ has curvilinear character in all cases irrespective of the initial content of gypsum.

In the process of filtration the density of samples firstly increases a little,then it begins to decrease and at the end of experiment

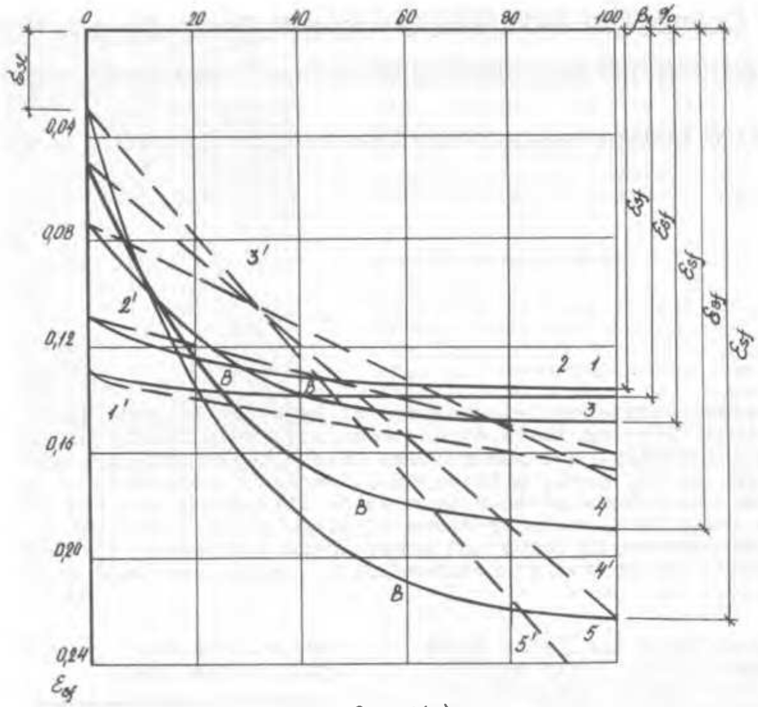

Figure I. Diagrams $\mathcal{E}_{sf}=f(\beta)$ for sandy loams: I- $d_0 < 5\%$; 2- $d_0=7\%$; 3- $d_0=15\%$; 4- $d_0=25\%$; 5- $d_0=35\%$ (dotted lines-theoretical curves of suffosion compression, calculated from the formula $\mathcal{E}_{sf}=0,66 d_0 \cdot \beta$)

the porosity coefficient e exceeds the theoretical value e' corresponding to the full replacement of the leached out gypsum with the soil particles (see Fig.I).

For the first time we have the generalized dependence of final values of sandy loams $\mathcal{E}_{sf}$ and $\mathcal{E}_{sl}$ on d_0 and p (Fig.2).

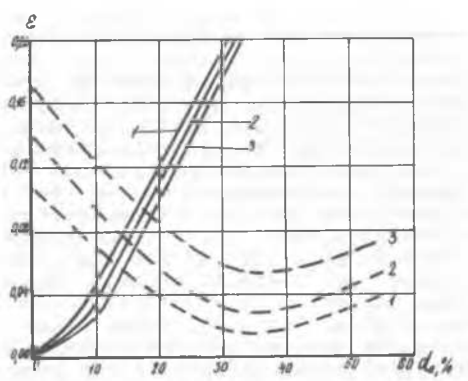

Figure 2. Dependence $\mathcal{E}_{sl}$ (dotted line) and $\mathcal{E}_{sf}$ (full line) on the initial gypsuming of sandy loams with the pressure: I-0,2 MPa; 2-0,3 MPa; 3-0,4 MPa.

With this we have the regularity when the increase of pressure gives the decrease of $\mathcal{E}_{sf}$.

In the natural humidity the compressibility of sandy loams is negligible, because $\mathcal{E}_{zp}<0,005$. With the short-term moistening of samples, containing of gypsum less than 35%, $\mathcal{E}_{sl}<0,01$, that is the soils are noncollapsible. Absence of collapsibility even with the high porosity (e =0,9) is explained by the increased density of sandy loams due to the cementing action of gypsum (Terletskaya I955).

Sandy loams with $d_0 \geqslant 35\%$ are collapsible soils (Table II) that is explained by the peculiarities of its composition and by the increased porosity (e =I,I).

Table II. Average values of $\mathcal{E}_{sl}$, $\mathcal{E}_{sf}$, P_{sl} and P_{sf} of gypsy sandy loams.

Content of gypsum d_0,%	Pressure p, MPa	$\mathcal{E}_{sl}$	P_{sl}, MPa	$\mathcal{E}_{sf}$	P_{sf}, MPa
I0	0,3	0,006	-	0,0I	0,45
I5	0,3	0,004	-	0,04	0,20
25	0,2	0,003	-	0,08	0,05
35	0,2	0,0I0	0,I5	0,I8	-
45	0,2	0,025	0,I0	0,32	-

Table II shows that P_{sl} is decreased with the increase of gypsum content in sandy loams, that is explained by the increase of porosity and decrease of structural density (with $d_0 \geqslant 35\%$).

With long-term filtration of water through the sandy loams the suffosion compression takes place (Fig.3). In this case quantative and qualitative regularities of suffosion compression depend considerably on the initial content of gypsum.

With d_o<10% the relative suffosion compression of sandy loams does not exceed 0,01, and the diagram $\varepsilon_{sf}=f(\beta)$ has rectilinear character. With d_o=10-35% three-stage suffosion compression, firstly mentioned in our investigations, was observed in all experiments.

The presence of two points of change is the peculiarity of the diagram $\varepsilon_{sf}=f(\beta)$ for these soils. Point A, after which intensive suffosion compression begins, corresponds to "critical" degree of leaching out β_c. Sharp decrease and stabilization of deformations takes place after point B, corresponding to β_e.

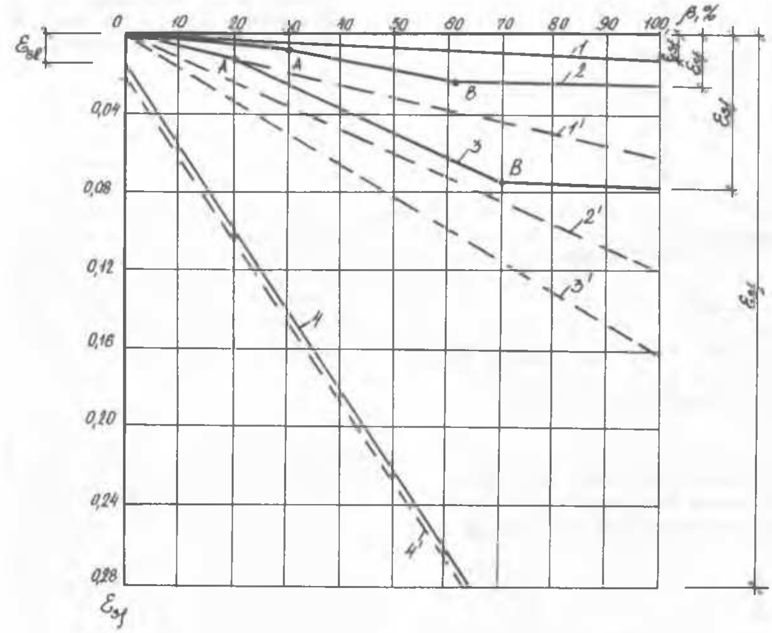

Figure 3. Diagrams $\varepsilon_{sf}-f(\beta)$ for loams with p=0,2MPa 1- d_o < 10%; 2- d_o=10-20%; 3- d_o=20-35% ;4- d_o > 35% (dotted lines-theoretical curves of suffosion compression).

The value β_c depends on the initial content of gypsum and pressure. With equal content of gypsum the value β_c less,the more the pressure. With equal pressure β_c the more, the less the content of gypsum. As for the value β_e the inverse dependence is observed.

The regularities of developing the suffosion compression of sandy loams were defined subject to the pressure (Fig.4). Suffosion compression depends a little on the pressure in the soils with a little content of gypsum (d_o=10-15%) and with p=0,3 MPa it does not change almost. In the soils with $d_o \simeq 30\%$ the compression is proportial to the applied pressure in the interval 0,1-0,4 MPa. The soils with high content of gypsum have the considerable deformation with small pressure, and even with p=0,1 MPa they have rather high density. The further increase of pressure gives less intensive compression.

In majority of cases when leaching out of gypsum under the loading the full replacement of the salt washed out by soil particles does not occur. Theoretically calculated curves do not coincide with the experimental ones(see Fig.1 and Fig.3). In this connection relative suffosion subsidence can not be equated with the relative volume of the washed out gypsum, as it is given in some papers.

The investigations showed that in common case the dependence ε_{sf} of loams and sandy loams on the degree of leaching out β is expressed by the power function

$$\varepsilon_{sf} = m\beta^{n} \qquad (1),$$

where m -coefficient, defined from the condition β=1, numerically equalled to the final relative suffosion compression; β -degree of leaching out in fractions of unit; n -empiric coefficient equalled to 1,0 for loams and sandy loams with d_o > 40% and 0,33 for sandy loams with d_o < 40%.

In the given dependence the correlation coefficients r are not identical for thevarious groups of sandy-clay soils ,and they depend on the initial content of gypsum. The correlation coefficient for sandy loams changes from r=0,88 (d_o=40%) to r=0,97(d_o=10%). For loams the maximum value r=0,95-0,97 corresponds to d_o > 40%. The intermediate values of the correlation coefficient were determined for the soils with d_o= 10-20% (r=0,91). The minimum values of r=0,74-0,88 correspond to the loams with d_o = 20-40%, that is connected with the points of change on the diagram $\varepsilon_{sf}-f(\beta)$. Therefore the use of the formula (1) for calculating ε_{sf} of the soils with average content of gypsum may lead to some errors in calculations. However to symplify engineering calculations in many cases the dependence $\varepsilon_{sf}=f(\beta)$ may be taken as rectilinear one for sandy loams as well with d_o=20-40%. If the higher accuracy of ε_{sf}

is needed then the dependence $\varepsilon_{sf} = f(p)$ should be taken as piece-linear for the soils with average content of gypsum.

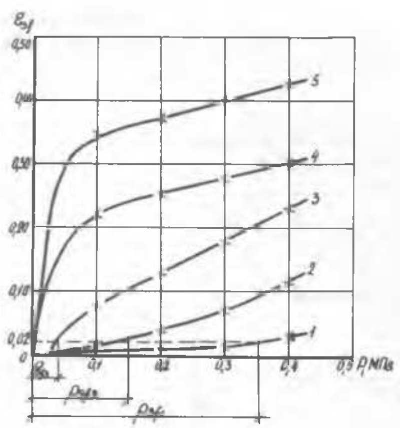

Figure 4. Diagram $\varepsilon_{sf} = f(p)$ for the loams with different content of gypsum d_o : I- d_o=I0%; 2- d_o=20%; 3- d_o=30%; 4- d_o=40%; 5- d_o=50%.

Basing on the investigations carried out the empiric formula was deduced by means of which the relative suffosion compression may be defined:

$$\varepsilon_{sf} = K_1 \cdot d_o \cdot \frac{\rho_d}{\rho_{sg}} \cdot p^n \qquad \text{(II)},$$

where K_I -empiric coefficient, defined from Table III;
d_o -initial content of gypsum in the soil, fractions of unit;
ρ_d -initial density of dry soil, g/cm^3;
ρ_{sg} -density of gypsum particles, g/cm^3.

The given formula makes it possible to define the value ε_{sf} without labour-consuming and long-term compression-filtration tests.

Laboratory results coincide well with in-situ data (Petrukhin I987) and they may be used to forecast collapsible and suffosion deformations of gypsy loams and sandy loams, being utilized as bases of buildings and structures.

Table III. Coefficient K_I

Type of soil	Content of gypsum, %	Values of coef. K_I with pressure, MPa			
		0,I	0,2	0,3	0,4
Loams	I0	0,86	0,70	0,52	0,43
	20	0,95	0,90	0,83	0,76
	30	0,97	0,95	0,90	0,85
Sandy loams	I0	0,08	0,I5	0,30	0,46
	20	0,I5	0,27	0,50	0,84
	30	0,45	0,60	0,80	I,I0
	40	0,85	0,96	I,07	I,30
	50	I,08	I,I5	I,22	I,38

REFERENCES

Petrukhin, V.P. (I980). Building properties of saline and gypsy soils, Stroiizdat, Moscow.
Terletskaya, M.V. (I955). Deformations of gypsum-bearing soil with filtration. Pochvovedenie. 9.
Petrukhin, V.P. (I987). Calculation of suffosion settlements of bases taking into account the diagram of percolation flow. Proceedings IX European Conf. on Soil Mechanics and Found. Eng., Balkema, Rotterdam.