SOIL MECHANICS

R. BERTICI[1], Gh. ROGOBETE[2], Adia GROZAV[2], Laura SMULEAC[1]

[1]Banat's University of Agricultural Sciences and Veterinary Medicine, Faculty of Agricultural Sciences, Timisoara, Aradului, 119
[2]Politehnica University of Timisoara, Civil Engineering Faculty, George Enescu 1/A
E-mail: adiagrozav@yahoo.com

Abstract: *Mechanical behavior covers strength, shear strain, resistance to shearing, shrinking, swelling, compaction, volumetric compressibility, deformation, permeability and seepage of water. The clay is stronger than the sand because it can sustain larger suctions: otherwise their behavior is fundamentally the same. The solid phase interacts whit the fluids which permeate soil pores. Models are best expressed in the concise and terse language of mathematics. Theories for soil mechanics originated around the middle of the eighteenth century. The theories of soil mechanics apply equally to sands and clays. Soil mechanics can be divided in two branches: mechanical properties and rheological properties. The scientific considerations relied on a lot of field and laboratory geotechnical studies effectuated in Banat region. Because water is relatively incompressible, volume changes in soil can occur only if water can flow or out from the pore spaces. If soil is loaded undrained the resulting pore pressures will not be in equilibrium with the long – term, groundwater pressures. As the excess pore pressures dissipate under constant total stress there will be change of effective stress and volume changes. This process is known as consolidation. Swelling or shrinking accompanying soil water content change results in vertical displacement of the wet soil, which involves gravitational work and contributes an overburden component to the total potential of the soil water. For a better recognition of vertic and pelic horizons, it can be used the next index values: u_L – free swelling (vertic horizon: >140%, pelic horizon: 100 - 140%); I_p – plasticity index (vertic horizon: >35%, pelic horizon: 25 - 35%), I_A – activity index (vertic horizon: > 1.25%pelic horizon: 1.0 - 1.25%). The simple theories presented above form the basis for analysis and design of engineering works. It must be determined some properties and index as: compressibility mechanical properties, rheological properties (strength, shearing strength, penetration resistance, permeability, plasticity, consistency, plastic deformation, shear stress consolidation).*

Key words**:** *compressibility, strength, compaction, consistence, soil*

INTRODUCTION

Soil mechanics is a branch of science studying in civil engineering and agricultural engineering, the mechanical properties and processes of soils. Mechanical behavior covers strength, shear strain, resistance to shearing, shrinking, swelling, compaction, volumetric compressibility, deformation, permeability and seepage of water. The theories of soil mechanics apply equally to sands and clays. In each case the strength arises from suctions in the pore water. The clay is stronger than the sand because it can sustain larger suctions: otherwise their behavior is fundamentally the same. The soil consists of numerous solid components irregularly fragmented and variously associated and arranged. Some of the solid material consists crystalline particles, while some consists of amorphous gels which may coat the crystals and modify their behavior. The solid phase interacts whit the fluids which permeate soil pores. The soil – water complex does not exhibit constant properties or conditions of stable, equilibrium, as it alternately wets and dries, saturates and desaturates, swells and shrinks, disperses and flocculates, cracks, aggregates, compacts, and undergoes chemical changes and structural rearrangements (ATKINSON I., 1993).

In many cases, the theories and mathematical equations employed in soil physics do not describe the soil itself, but an ideal and well – defined model by which we simulate the soil.

We tend to describe the system macroscopically rather than microscopically. Models are best expressed in the concise and terse language of mathematics. We set an equation which describes the model's behavior. We can transform the equation to anticipate how the model should behave under different conditions, and the model serves to predict what we still do not know. Then, we check our prediction by experiment and we have a working model. Thus, theory cannot advance without experimentation. As physics deals with the state and movement of matter and with the fluxes and transformations of energy in the soil.

Theories for soil mechanics originated around the middle of the eighteenth century. Coulomb was concerned with calculating soil loads on masonry retaining walls. (ATKINSON J., 2005). Acording to the Coulomb equation shearing strength of soils has two components, cohesion and internal friction. It is partially represented by a Coulomb line. Shear stress (τ_f, Pa) is related to the normal stress (σ_n, Pa) according to:

$$\tau_f = c + \sigma_n (tg\phi)$$

where c is the cohesion (Pa), and ϕ is the shear or internal friction angle (Pa), both characteristic for a given soil (CANARACHE and, 2006).

An extension of Coulomb law is Coulomb – Terzaghi law:

$$\tau_f = c + (\sigma_n - u)(tg\phi)$$

where τ_f is the shear stress (Pa), c is the cohesion (Pa), σ_n is the normal stress (Pa), u is the pore – water pressure (Pa) and ϕ is the internal friction angle (Pa).

One dimesional flow of water in soils that change volume with water content was first analyzed in a modern context by Terzaghi, who sought to describe soil consolidation following the imposition of loads associated with built stuctures. The outcome was a linear diffusion equation that Terzaghi solved using Fourier series.

In the 1960s Andrew Schofield and Peter Wroth from Cambridge University applied the then relatively new theories of plastic flow to frictional materials and created the model Cam Clay, a complete stress – strain theory for soils. These theories of frictional strength effective stress and plastic flow are the basic building blocks for modern soil mechanics (ATKINSON, 2005).

Soil mechanics can be divided in two branches: mechanical properties and rheological properties. **Mechanical properties** include some properties like grain size descriptions, Atterbery limits, density, bulk density, structure and size distribution of microaggregates, pore space, void ratio, packing, permeability. **Rheological properties** include: consistency, plasticity, deformation, resistance to shearing, stress – strain compression, resistance to penetration, compaction consolidation, swelling and shrinking, elastic modulus, plastic flow, and displacement, pressure (ROGOBETE, 2005).

MATERIAL AND METHODS

The scientific considerations relied on a lot of field and laboratory geotechnical studies effectuated in Banat region. It were made field trials and sampling. There are use methods predicted in Romanian Standards like STAS 1913/12-82, STAS 193/9 – 76, STAS 9180/73, STAS 8942 – 82, STAS 8942/5 – 75, STAS 8942 – 71. In this paper, we present the soil mechanics data from a drilling of Gătaia – Timiș county.

RESULTS AND DISCUSSIONS

The main results obtained in test of soil sampled in a drilling with 3.60m depth are presented in table 1:

Table 1

Rheological properties, Gătaia

Conventional altitude, 0,00m	-0.50	-2.20	-3.50
Coarse sand, %	2.95	2.25	2.35
Fine sand, %	38.05	27.07	26.67
Silt, %	38.3	24.8	24.6
Clay, %	39.8	45.9	45.4
Lower plastic limit, $w_{p,}$%	23.50	22.24	20.28
Upper plastic limit, $w_{L,}$%	48.95	55	54.97
Plasticity index, I_p, %	25.45	32.76	34.69
Bulk density, $t \cdot m^{-3}$	1.35	1.44	1.53
Total soil porosity, %	50.0	46.2	46.0
Void ratio, e, %	1.0	0.86	0.85
Resistance to penetration, R_p, kg/cm^{-2}	10	17	18
Consistency index, I_c, %	0.98	1.01	1.14
Activity index, I_A, %	0.64	0.71	0.75
Volume contraction, C_v, %	42.97	41.95	64.03
Contraction limit, w_s, %	22.79	21.72	15.43
Optimum Proctor moisture for compaction, %	12.42	11.99	17.14
Deformation module, E, $daN \cdot cm^{-2}$	12.9	15.6	17.2
Cohesion, c, $daN \cdot cm^{-2}$	116	125	148
Angle of internal friction, ϕ^o	25	40	45
Critical pressure, P_{crit}, $t \cdot m^{-2}$	21	20	17
Conventional pressure, P_{conv}, $t \cdot m^{-2}$	23.41	26.94	20.17
Admissible pressure, P_{adm}, kPa	-	425	380
Shrinkage – swelling index, I_{cu}, %	1.01	0.78	0.85

In order to evaluat the intensity of the swelling and shrinking phenomena and the presence of the "active layer", we present in table 2, the limits for the main rheological properties (Dron, 1984)

Table 2

Evaluation of the soil rheological properties

Activity	**Clay %**	**I_p %**	**I_A %**	**U_L, % - free swelling**	**Ws %**	**P_u-MPa swelling pressure**	**Cv, %**	
							natur str.	**modif str**
very active	>35	>35	>1.25	>140	<10	>0.4	>100	>35
active	18-35	25-35	1.0-1.25	100-140	14-10	0.1-0.4	75-100	25-35
less active	15-25	20-30	0.75-1.00	70-100	16-14	0.05-0.1	55-75	15-25

Because water is relatively incompressible, volume changes in soil can occur only if water can flow or out from the pore spaces. If water cannot drain from the soil it is said to be undrained. If water has time to drain freely from the soil it is said to be drained:

- Undrained loading: $\delta V = 0$ and u changes;
- Drained loading: $\delta_u = 0$ and volume V, changes.

If soil is loaded undrained the resulting pore pressures will not be in equilibrium with the long – term, groundwater pressures. As the excess pore pressures dissipate under constant total stress there will be change of effective stress and volume changes. This process is known as consolidation.

Consolidation

The basic theories for consolidation are for one – dimensional loading and drainage, illustrated in figure 1, in which all movements of soil and water are vertical. Solutions for the rate of sonsolidation are given in Terzaghi equation (1923), in which the deformations remains small.

Terzaghi equation consolidation index, Cv:

$$C_v \frac{\partial^2 u}{\partial z^2} = \frac{\partial u}{\partial t}$$

Methods for soil consolidation:

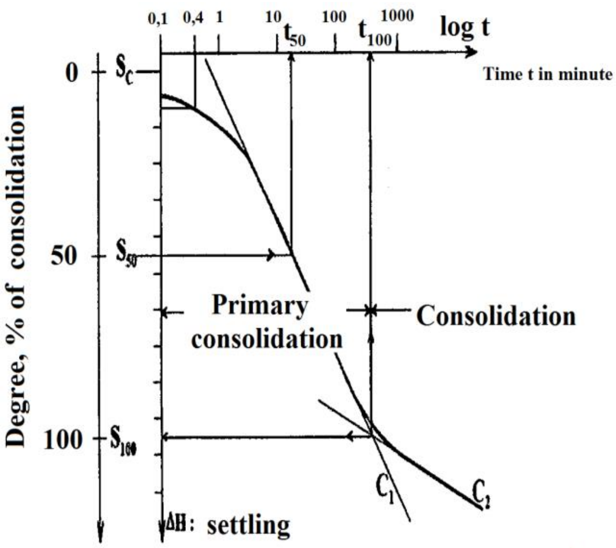

Figure 1 Casagrande method for C_v determination

Consolidation is the principal cause of the settlement of foundations and embankments on clays long after construction is complete.

Behavior in swelling and shrinking

Swelling or shrinking accompanying soil water content change results in vertical displacement of the wet soil, which involves gravitational work and contributes an overburden component to the total potential of the soil water. In addition, the total flux of the water has a component advected with the moving solid as well as the water potential – driven darcian flux relative to the solid. Finally, many swelling soils crack and the network of cracks provides alternative, preferential pathways for rapid flow of water which prejudice application of theory simply based on darcian flow. One dimensional flow of water in a swelling system requires material balance equations for both the aqueous and solid phases:

$$\frac{\partial \theta_w}{\partial t} = \frac{\partial F_w}{\partial z} \, and \, \frac{\partial \theta_s}{\partial t} = \frac{\partial F_s}{\partial z}$$

where z is a distance coordinate, t is the time, F_w and F_s are the volume flux densities of the water and of the solid relative to the observer, and θ_w and θ_s are the volume fractions of the water and solid.

The total potential, Φ, is defined by the equation:

$$\Phi = z + \psi + \Omega = z + \psi + \alpha(\int_z^T \gamma dz + P)$$

in which, γ, is the wet specific gravity of the soil, ψ is the capillary potential, and P is any static load on the soil surface; in a saturated soil, α =1, in an unsaturated soil, 1≥ α , and in a nonswelling soil, α =0.

The overburden, Ω, is related to the civil engineers' **effective stress** according to the equation:

$$\Omega = \sigma' + p_w \text{ and } \sigma' = -\psi$$

Proposals for vertic and pelic horizons

For a better recognition of vertic and pelic horizons, it can be used the next index values:

1. u_L – free swelling:
   - vertic horizon: >140%
   - pelic horizon: 100-140%
2. I_p – plasticity index:
   - vertic horizon: >35%
   - pelic horizon: 25-35%
3. I_A – activity index:
   - vertic horizon: >1.25%
   - pelic horizon: 1.0-1.25%

Vertisols are deep clayey soils, more than 45% clay, dominated by clay minerals, such as smectites, that expand upon wetting and shrink upon drying.

CONCLUSIONS

Soil mechanics describes the mechanical behavior of granular materials. The theories of soil mechanics apply equally to sands, clays and rocks. In describing theories for the behavior of soil materials some mathematics is unavoidable. It must be determined some properties and index as: compressibility mechanical properties, rheological properties (strength, shearing strength, penetration resistance, permeability, plasticity, consistency, plastic deformation, shear stress consolidation). The simple theories presented above form the basis for analysis and design of engineering works. For soil science, we proposed index for the vertic and pelic horizons, to recognize and for a clear separation.

BIBLIOGRAPHY

1. AKKER VAN DEN I., SOANE B., 2005, "Compaction" Encycloped. of Soils, Elsevier, Edit. Hillel D., vol.1;
2. ATKINSON J., 1993, "The Mechanics of Soils and Foundations", London, Mc Graw - Hill;
3. ATKINSON J., 2005, "Soil Mechanics" Encycloped. of Geology, vol.5, Elsevier, Academic Press;
4. BERTICI R., 2007, "Vertisolurile din Banat si efectul variației de volum asupra unor elemente constructive din amenajările funciare" Teza de doctorat, Edit. Politehnica Timisoara;
5. BERTICI R., GROZAV A., ROGOBETE GH., ȚĂRĂU D., 2012, "Experimental research of vertic phenomena during of 45th years in Cheglevici - Romania" Analele Univ. din Craiova, Edit. Universitară;
6. CANARACHE A., VINTILĂ I., MUNTEANU I., 2006, "Elsevier's Dictionary of Soil Science", Elsevier;
7. DRON A., 1984, "Geotehnica pentru hidroamelioraţii" Edit.Ceres, Bucureşti;
8. ROGOBETE GH., 1993, "Stiinta Solului", Edit. Mirton, Timisoara;
9. ROGOBETE GH., BERTICI R., BEUTURĂ D., 2005, "Comportament reologic în Vertisolul de la Cheglevici – Timiş", Ştiinţa Solului, SNRSS, vol.XXXIX;
10. ROGOBETE GH., GROZAV A., ȚĂRĂU D., 2011, "Solute transport, swelling and shrinking in salt – affected soils", Research H. of Agric. Science, Ed. Agroprint, Timișoara;
11. SMILES D., RAATS P., 2005, "Swelling and shrinking". Encyclop. Of Soils, Elsevier, vol.4;
12. ***Sistemul Român de Taxonomie a Solurilor (SRTS - 2012), Edit. Sitech, Craiova.