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Rheological Behaviour in a Clayey Soils

Clara Magda Tudor 1, Gh. Rogobete 1, Adia Grozav 1

1 Politehnica University Timisoara, Hydrotechnical Engineering Department, George
Enescu 1A, Romania

clara_tudor_magda@yahoo.com

Abstract. Soils are the basis for production of the overwhelming majority of food, natural
filers and wood. Most civil engineering operations are founded in the soil. Soil consists of three
phases, that is, solids, water and air. It is important to understand the nature of the soil and the
rheological properties. Site investigations for structures are focused on the mechanical
properties of the subsoil at foundation levels and the corrosiveness of the groundwater. The
type of foundation needed for a major structure is directly related to the strength of the
underlying soils. Detailed site exploration may be required even at the preliminary design
stage. The analytical data offer some values on particle size distribution, compaction,
compression, consistence, lower and upper plastic limit, shrinkage limit, resistance to
penetration, shearing strength, deformation resistance, and conventional pressure. The paper
also presents some analytical data obtained in an experimental field, situated on a similar type
of soil, relative to the draft requirement for plowing and the influence of the degree compaction
on the level of agricultural production. The type of external force applied, time dependency
and number of ploughings, scarifying’s or settlings and rolling’s can change properties down to
deeper depths. The survey of soil indexes established for the foundation indicated a normal
consolidation, the building plot, a plastic-viscous consistence and a great plasticity. The
consequences of soil deformation and agricultural production are minimum in the variant with
a double scarifying at 80 cm depth. The main rheological characteristics in the clayey soil from
the area of locality Sânnicolau are: clay content varies between 39.8 to 45.9%, lower plastic
limit 22.2-23.5%, upper plastic limit 48.9-55.0%, plastic limit 25.4-34.6%, void ratio (e) 0.85-
1.00%, resistance to penetration 10-18kg/cm², consistency index 0.98-1.14, activity index
0.64-0.75%, shrinkage limit 22.7-15.4, deformation module 12.9-17.2 dan/cm², shrinkage-
swelling index 0.78-1.01%.

1. Introduction

Soil is the foundation for buildings, roads, technical and industrial structures and also building
materials. They also play a major role in the functioning of the urban ecosystem. The development
of the city consumes large surface areas of farmland which are irreversibly transformed for construction
of buildings and infrastructures.

Today 2.3% of the European Union’s territory were actually sealed an equivalent of 200 m² for
each citizen [1]. Until now, 35 percent of the agricultural land in the European Union show signs of
compaction, and 17 percent is degraded – with soils significantly damaged or even completely
destroyed [2].

Most civil engineering operations are founded in the uppermost layers of the ground and are
therefore generally carried out in soil. Poor soil conditions in terms of engineering increase the cost of
construction by necessitating special foundation structures and mean that some type of engineering soil treatment is required [3].

Soil mechanics is a branch of science studying the mechanical properties and processes of soils. Soil mechanics can be divided in two branches: mechanical properties and rheological properties.

Mechanical properties include properties such as grain size descriptions, density, bulk density, pore space, void ratio, packing, permeability. Rheological properties include consistency, plasticity, deformation, resistance to shearing, stress – strain compression, resistance to penetration, compaction, swelling and shrinking, elastic modulus, plastic flow and displacement, pressure [4].

The soil – water complex does not exhibit constant properties or conditions 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 [5].

Theories for soil mechanics originated around the middle of the eighteenth century. Coulomb was concerned with calculating loads on soil on masonry retaining walls [6].

Rheology is a physics branch which focuses on analysing the material deformation under the effect of strain stress.

In order to study the rheological phenomenon there are two physical aspects [7]:

- Creep phenomenon, $\varepsilon(t) = (\varepsilon_0; t)$, namely the deformation goes on under a constant burden,
- Relaxation phenomenon, $\sigma(t) = (\varepsilon_0; t)$, namely a continuous decrease of efforts for a constant deformation.

The time-deformation curve can be expressed by:

$$\varepsilon = \varepsilon_0 + \varepsilon_1(t) + V \cdot t + \varepsilon_3(t)$$

in which: $\varepsilon_0$ - instantaneous elastic deformation;
$\varepsilon_1(t)$ – primary creep, Ith domain of deformation;
$V \cdot t$ - permanent creep, IIth domain of deformation;
$\varepsilon_3(t)$ - Tertiary creep or accelerated creep, IIIth domain of deformation

Depending on behaviour, the rocks can be with various rheological behaviour: perfect elastic, perfect viscous, perfect plastic, viscous – elastic, firm – viscous.

2. Material and methods
The scientific considerations have been obtained on the basis of the field attempts and physical and rheological analysis of disturbed and undisturbed samples, effectuated in the soil mechanics laboratory from the Civil Engineering Faculty.

The analytical methods used were those from Romanian Standards. In this paper, we present the soil rheological data from a drilling of Bruznic – Arad county.

The present geotechnical study was carried out for the purpose of establishing the foundation parameters for a construction “Metallic Tower – GSM Telecommunications Mast” of 15 metres high. The drilling of 3.00 metres in depth was made in a clayey deposit in order to establish the lithological stratification on undisturbed samples and disturbed samples. The results of the analyses are presented as average values. The location is in a uniform land at an altitude of 320 metres with a natural insured stability.

3. Results and discussions
The results, obtained in the soil science laboratory, are expressed in the table 1.
Table 1. Particle – size and pH analyses

| Depth, cm | 60-100 | 130-150 | 180-200 | 200-250 | 250-300 |
|-----------|--------|---------|---------|---------|---------|
| Coarse sand (2-0.2 mm), % | 2.3 | 1.9 | 0.2 | 0.1 | 0.2 |
| Fine sand, (0.2-0.02 mm), % | 28.3 | 27.8 | 40.1 | 15.8 | 13.8 |
| Silt (0.02-0.002 mm), % | 23.2 | 21.3 | 23.5 | 32.1 | 26.2 |
| Clay (<0.002 mm), % | 46.2 | 49.0 | 36.2 | 52.0 | 59.8 |
| Soil texture class | loamy | loamy | medium | silty | loamy |
| pH<sub>H<sub>2</sub>O</sub> | 5.44 | 7.50 | 8.35 | 8.47 | 8.25 |
| CaCO₃, % | - | 0.42 | 24.7 | 43.0 | 4.94 |

These terrace deposits, with <60% clay, belong to Pliocene age and can be of 800 – 1600 m thickness consisting in a succession of clayey – sandy, clay and marl layers. At the Bruznic perimeter, these layers were penetrated by the quaternary magmatic rock such as basalt and diabase. In the contact with basaltic lava, the piocone deposits suffered a weak thermal metamorphism. Some mineralogical analysis effectuated nearby [8] revealed the presence of smectites which explains the vertic behaviour smectites shrink upon drying and swell upon wetting. This shrink – swell behaviour is most pronounced in the Vertisol order and in vertic subgroups of other soil orders. These properties lead to cracking and shifting problems when house roads and other structures are built on smectitic soils. The main results of the rheological behaviour are presented in the table 2.

Table 2. Rheological properties - Bruznic

| Conventional altitude, 0.0 m | 0.0-1.0 | 1.0-2.0 | 2.0-3.0 |
|----------------------------|---------|---------|---------|
| Lower plastic limit, w<sub>p</sub>, % | 26.8 | 29.6 | 26.6 |
| Upper plastic limit, w<sub>L</sub>, % | 50.3 | 51.8 | 55.1 |
| Plasticity index, I<sub>p</sub>, % | 23.5 | 22.2 | 28.5 |
| Bulk density, t/cubic meter | 1.44 | 1.39 | 1.50 |
| Total soil porosity, % | 44.0 | 45.9 | 41.6 |
| Void ratio, e, % | 0.78 | 0.85 | 0.71 |
| Resistance of penetration, R<sub>p</sub>, kg.cm⁻² | 20.2 | 21.4 | 18.9 |
| Consistency index, I<sub>c</sub>, % | 0.82 | 1.12 | 0.94 |
| Present moisture content, % | 31.2 | 26.8 | 28.3 |
| Optimum Proctor moisture for compaction, % | 14.1 | 13.6 | 13.9 |
| Volume contraction, C<sub>v</sub>, % | 30.6 | 28.4 | 36.4 |
| Deformation modulus, E<sub>kPa</sub> | 14300 | 13500 | 16900 |
| Angle of internal friction, Φ | 18.8 | 18.0 | 19.5 |
| Cohesion, c, daN/cm² | 0.091 | 0.085 | 0.100 |
| Admissible pressure, t/m² | 22.90 | 20.01 | 26.40 |

4. Conclusions

The foundation land a loamy clay, with a hard consistency to plastic – viscous, stickiness and plasticity with shrinkage and swelling. The minimum foundation depth must be 2.50 m. For various calculations, the following geotechnical indexes will be taken into consideration:

- For the foundation layer between 1.80 – 2.50 m:
  \[ \gamma = 1.39 \text{ t/cubic meter}; c=0.085 \text{ daN/cm}^2; \Phi=180^0; E=13500 \text{ kPa}; p_{adm}=20.01 \text{ t/m}^2 \]

- For the foundation layer between 2.50-3.00 m:
  \[ \gamma = 1.50 \text{ t/cubic meter}; c=0.10 \text{ daN/cm}^2; \Phi=19.5^0; E=16900 \text{ kPa}; p_{adm}=26.40 \text{ t/m}^2 \]
The ground water is at 7-8 m depth and does not influence the foundation. For digs deeper there is necessary a support. In order to avoid the foundation layer weathering, shortly before the cast concrete introduction in the foundation, it is necessary to eliminate a thin layer of soil, of about 0.10-0.15m.

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