Identification of Petrifaction in Soils

Identification de la pétrification dans les sols

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SUMMARY

It is recalled that in geotechnique the distinction between soils and rocks is that the former disintegrate in water whereas the latter do not. The authors point out the frequent occurrence in civil engineering of many materials which do not fit well into one or the other of these extreme situations: disintegration or non-disintegration. Certain soils disintegrate less completely than others, or do not disintegrate at all. Such behaviour is ascribed to the presence of water-resisting or "petrous" bonds in these soils. Water-absorption tests enabling a quantitative identification of the "petrifaction degree" of soils are presented in this paper. Some results obtained in lateritic soils and in Lisbon Tertiary clays are also presented.

SOMMAIRE

Les auteurs rappellent que ce qui en géotechnique distingue les sols des roches est la désagrégation des premiers et la non-désagrégation des secondes dans l'eau. Ils soulignent, cependant, la présence fréquente dans les travaux de génie civil de plusieurs matériaux ne satisfaisant nettement ni à l'une ni à l'autre des deux positions extrêmes: désagrégation ou non-désagrégation. Certains sols se désagrègent plus que d'autres ou ne se désagrègent même pas du tout. Ce comportement est attribué aux liaisons résistantes à l'eau ou liaisons pétrées. On présente des essais d'absorption qui permettent l'identification quantitative du "degré de pétrification" des sols. On présente aussi des résultats obtenus sur des sols latéritiques et sur des argiles tertiaires de Lisbonne.

THE CONCEPTS EXPRESSED by the Portuguese words *solo* (soil), *rocha* (rock), and *terreno* (which corresponds to the French *terrain*), commonly used in geotechnique are defined as follows in the *Vocabulário de Estradas e Aeródromos* (1962):

Soil, a natural assembly of mineral particles which can be separated by agitation in water. The voids among the particles contain water and air, together or separately (p. 39).

Rock, material resulting from a given geologic process . . . distinguished from soils because as a rule it does not disintegrate if agitated in water (p. 36).

Terreno, a portion of the earth's crust, whether a soil or a rock (p. 39).

However, not all the materials present in the crust can be sharply separated into soils or rocks: between these two extremes lie soils which resist the disintegrating action of water better than others and so are closer to the rocks, whereas some rocks do not withstand the disintegrating action of water very well and so more nearly approach soils. The former is true of some lateritic soils, the behaviour of which is better in road construction than their Atterberg limits would lead us to expect, and of some Tertiary clays of the Lisbon area which can remain for long periods of time in very steep cliffs more than 10 m in height. The latter case is illustrated by some shales and granites so weathered that they behave almost as soils.

The difference between soils and rocks lies in the way their cohesion resists the action of water. In what could be called pure soils, bonds in the solid phase are such that they cannot withstand the free absorption of water; in rocks, on the contrary, bonds in the solid phase can resist the disintegrating action of water. As these water-resisting bonds are typical of petrous materials, they could be called "petrous bonds", and the corresponding agglomerating action, "petrifaction".

Although these more or less petrified materials are frequent in civil engineering, no simple methods are available for the quantitative interpretation of petrifaction, which would be the first step towards putting this knowledge into practical use. In this paper, the authors present methods of identification of petrifaction developed at the Laboratório Nacional de Engenharia Civil, first in disturbed samples of lateritic soils, and more recently in both disturbed and undisturbed samples of Tertiary clays.

IDENTIFICATION OF PETRIFACTION OF SOILS

In a former study on lateritic soils (Nascimento, de Castro, and Rodrigues, 1963) the "petrifaction degree" of soil was

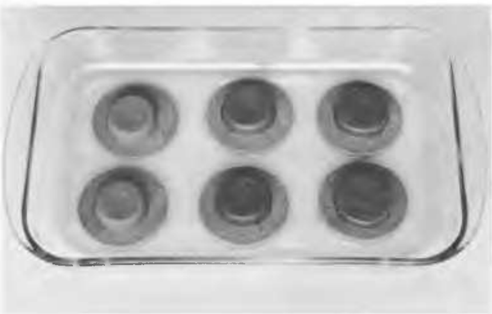

FIG. 1. Absorption test on the pats used in the shrinkage limit tests.

TABLE I. IDENTIFICATION AND ABSORPTION DEGREE OF SOME LATERITIC ($SiO_2/R_2O_3 < 2$) AND NON-LATERITIC SOILS

Sample	$\frac{SiO_2}{R_2O_3}$	w_L per cent	w_P per cent	I_P per cent	w_S per cent	AL per cent	Absorption degree $\frac{AL}{w_S}$	Petrifaction degree $\frac{w_S}{AL}$
2348	1.49	53	29	24	20	50	2.50	0.40
2351	1.60	69	31	38	18	61	3.39	0.30
2353	1.58	32	20	12	16	26	1.63	0.62
2355	1.53	41	25	16	21	39	1.86	0.54
2359	1.50	34	18	16	17	20	1.18	0.85
2360	1.20	37	21	16	19	20	1.05	0.95
552–2	2.76	37	21	16	24	65	2.71	0.37
2592	—	36	18	18	17	40	2.35	0.43

defined as the ratio of the shrinkage limit (w_S) to the absorption limit (AL) of the soil:

$$\text{petrifaction degree} = w_S/\text{AL} \qquad (1)$$

and the inverse of this ratio was designated the absorption degree

$$\text{absorption degree} = \text{AL}/w_S. \qquad (2)$$

The absorption limit was defined as the moisture content of a sample pat used in the determination of the shrinkage limit, when placed so as to absorb water from a porous plate in the position shown in Fig. 1.

This definition of petrifaction degree is justified as follows: if the oven-dried pat were a stone (i.e., entirely petrified) it would absorb water in the conditions of the absorption test (Fig. 1) only until its water content reached the shrinkage limit. Its petrifaction degree would then be the unit. In the absence of petrifaction, the pat would absorb water until its moisture content is much above the shrinkage limit, attaining or even exceeding the liquid limit. Thus, the petrifaction degree of a soil will have as an upper limit the unit for petrified soils, and will be correspondingly lower for less petrified soil. In Table I some results obtained in our study are presented in which the absorption degree ranges from 1.05 (sample 2360) to 3.39 (sample 2351). The corresponding petrifaction degrees will be 0.95 and 0.30 respectively.

Undisturbed Samples

Petrifaction of *in situ* soils cannot be identified on disturbed samples as petrous bonds are destroyed during the preparation of the samples. Consequently, the concept of petrifaction degree must be extended so as to enable the identification of petrifaction in undisturbed samples.

If w_0 is the moisture content theoretically corresponding to the undisturbed soil assumed saturated without volume change, and w_a the final moisture content of a pat cut from the ground and subjected to the absorption test of the preceding article (Fig. 1), the ratio

$$w_0/w_a = \text{petrifaction degree} \qquad (3)$$

and the ratio

$$w_a/w_0 = \text{absorption degree}. \qquad (4)$$

The moisture content (w_0) is calculated from the volume, the weight, the moisture content of the sample, and the specific gravity of the particles. The final moisture content (w_a), assumed to saturate the sample, is directly determined in the oven-dried sample.

As the determination of the petrifaction degree can be influenced by the moisture content of the undisturbed sample *in situ* (w_i), this is always recorded for further reference. It should be noted that the petrifaction degree obtained applies to the tested sample alone in the initial moisture conditions in which it was tested. It is also important to note that the concept of petrifaction loses its meaning for soft soils or soils with high initial moisture contents.

Compacted Samples

Petrifaction can be identified in compacted samples by one of the two following methods: either, as in the case of undisturbed samples, by testing a sample from a soil compacted in the site or in a mould in the laboratory; or, by preparing in a suitable mould a pat analogous to those used in shrinkage limit tests.

Some results obtained in Tertiary clays from the southern bank of the Tagus in front of Lisbon are presented in Table II, where the petrifaction degrees determined in undisturbed samples are compared with the values obtained in samples compacted to approximately the same void ratio and pats of shrinkage limit tests. According to these results, the petrifaction degree was found to be very high *in situ* (0.94) but fell to less than half its value (0.41) when the soil was disturbed, even if it was subsequently compacted so as to reach about the same bulk density. In the pats of shrinkage limit tests, the petrifaction degree did not exceed 0.37.

TABLE II. PETRIFACTION DEGREE OF UNDISTURBED AND COMPACTED SAMPLES OF A TERTIARY CLAY FROM THE SOUTHERN BANK OF THE TAGUS IN FRONT OF LISBON

Initial conditions	w_0 per cent	w_a per cent	Absorption degree w_a/w_0	Petrifaction degree w_0/w_a
Undisturbed sample	22.0	23.3	1.06	0.94
Compacted sample	23.3	56.4	2.42	0.41
Pat of shrinkage limit tests	22.3	60.9	2.73	0.37

REFERENCES

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