SUB-SECTION IIc

CONSOLIDATION TESTS

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SECONDARY TIME EFFECT IN THE COMPRESSION OF UNCONSOLIDATED SEDIMENTS OF VOLCANIC ORIGIN

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INTRODUCTION

The foundation soils of broad areas of Italian Peninsula consist mainly of volcanic non-cemented or slightly cemented materials.

These materials, ejected in cenozoic era or in the present one by the many volcanoes along the Thyrrenian coast, were often carried by the wing in lands very far from their origin. Sometimes the running water worked on the deposits so formed and, mixing volcanic materials with other kind of products, made them settling as soon as the water speed went slowing down.

Important built-up areas, as ROME and NAPLES, mostly lay on soils of this kind.

Similar conditions occurred in other lands of the globe and, hence, similar foundation problems must arise there. That is why we believe it could be useful to expose to the Congress some observations on the behaviour of such materials which, as far as we know, have not yet been observed from the mechanical point of view.

Our observations have been done by studying the foundation soils of the town of NAPLES which, as is known, lays between the two important volcanic districts of VESUVIUS and CAMPI PLEGREI.

The cohesionless volcanic materials, which can be found in this area, are composed by grains of very different size. However, they have two common characteristics:

1) The main part consists of isotropic substance (volcanic glass);
2) this isotropic substance has a spongy texture particularly notable in pumices. Consequently grains may be easily broken.

The various deposits formed by such materials differentiate in particle-size distribution and in the rate of porosity of the volcanic glass. Furthermore, it may happen that the material has undergone rock decay; but in the volcanic district we are speaking of, material is generally unaltered or altered at a very low rate. At last we can find in the above materials a certain amount of organic substances.

Difficulties may arise in studying foundation problems in such soils, owing to the fact that only in few cases we find homogeneous beds of a notable thickness; but very often the soil consists of a series of very thin beds (some centimeter). Constituent materials have a different particle-size distribution and sometimes they did suffer a high rate of diagenesis until they reached a remarkable stage of lithification.

While carrying on our researches in order to have an almost large view of the behaviour of such materials under the load of buildings, we believe interesting to call attention on a peculiar phenomenon we have repeatedly observed either on undisturbed or on disturbed samples of different origin.

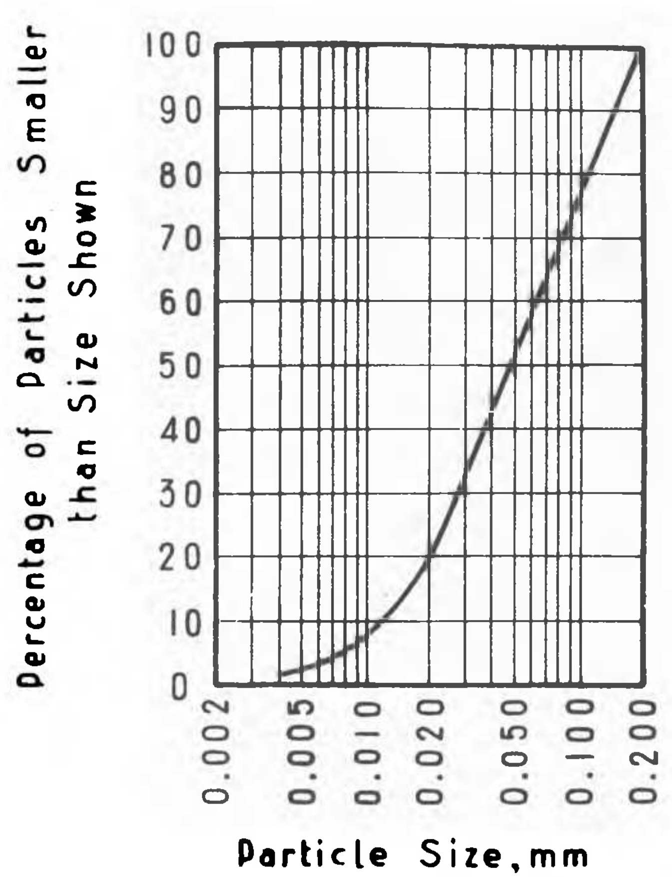
DESCRIPTION OF TESTS

In order to facilitate comparisons, we will expose results of a confined compression test on a typical volcanic material, the so called "pozzolana di BACOLI". The tests have been performed on the fraction passing the 0,2 mm sieve.

The particle-size distribution is shown in fig. 1. The mechanical analysis has been done with sieves down to 0,07 mm diameter. For smaller fractions Andreasen pipette has been used, distilled water being the dispersion medium.

As shown, the grain size accumulation curve mainly develops in the fine sand fraction.

The grains composing the material under test are fragments of angular volcanic glass (fig. 2) sometimes compact and clear, more often porous for holes caused by the expansion and escape of gases from the interior of the magma piece, while this late was rapidly cooling. These holes are variously shaped; often they are considerably long and minute and have



Grain size acumulation curve

FIG. 1

Photomicrograph showing different textures of grains.

FIG.2

no external outlets. The texture is more or less spongious, according to the frequency and dimensions of the holes.

On the basis of the particle-size distribution and microscopic analysis, it can be rejected that in the tested material there was any appreciable content of clay substance.

The confined compression test has been done on a test sample of 56,2 mm diameter and 20 mm initial thickness, fitted upside and downside with drainage porous stones. The used extensometer permitted to evaluate settlements until 1/500 mm. The successive applied loads were in Kg/cm^2:

0,04; 0,015; 0,19; 0,50; 1,00; 2,01; 4,02

The settlements s and the time t are plotted in fig. 3 for some values of the applied ed pressure p; either time and settlement have been measured from time-moment in which the last load increment was applied. Drawings show that:

1) About one half of the settlement occurs in a very short time, less than 30 sec.
2) Consecutively the settlement proceeds approximately straight with the ln.t.
3) Lately this straight development shows a trend to change in slope towards the final setting (see the last points of graph).

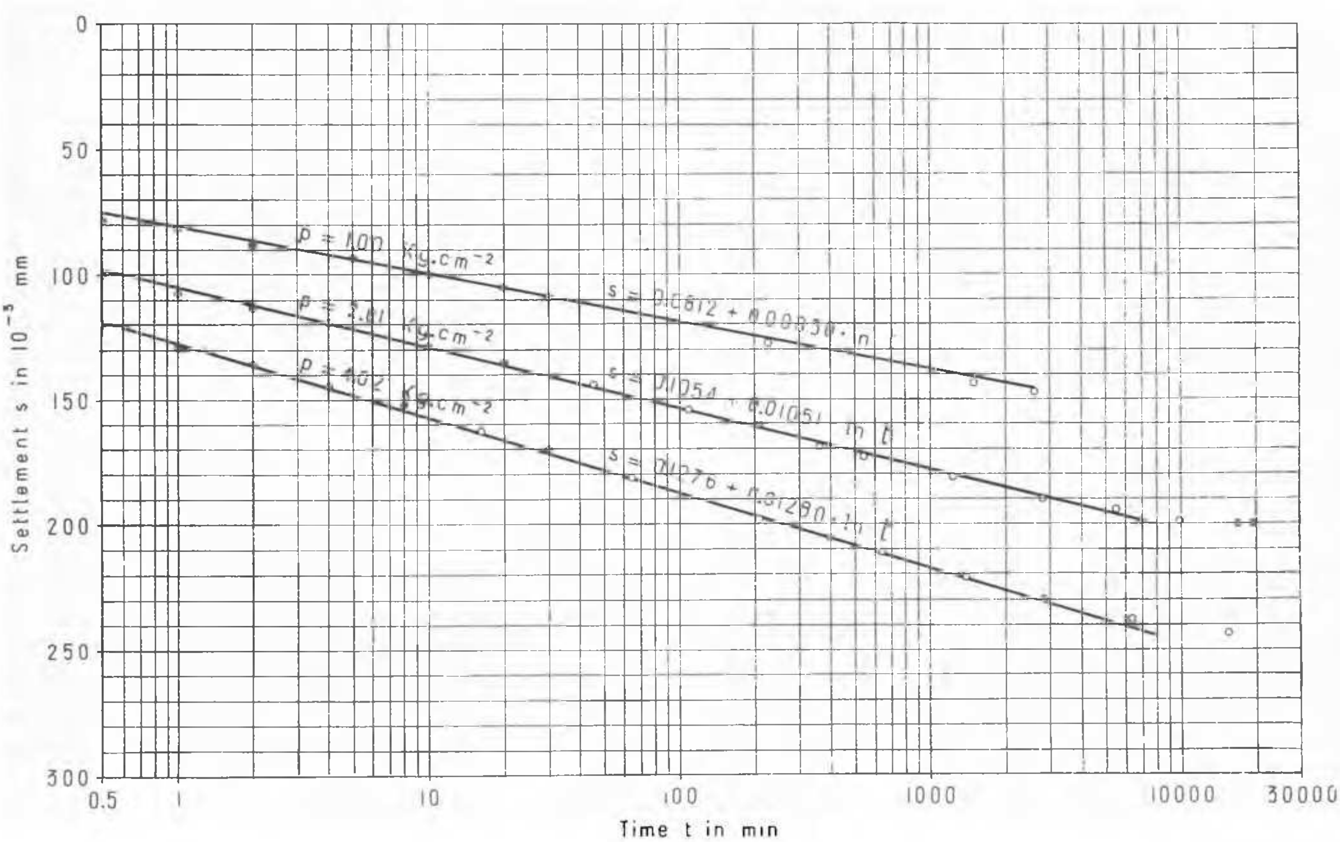
The phenomenon described in 1 and 2 can be expressed by the relationship:

$$s = a + b \cdot \ln t$$

Coefficients a and b have been calculated by the method of least squares and following results obtained:

applied load Kg/cm^2	a mm	b mm	probable error mm
1,00	0,0812	0,00830	0,0009
2,01	0,1054	0,01051	0,0010
4,02	0,1276	0,01280	0,0009

With the falling head permeameter the permeability coefficient k has been measured at various loads. Values of k are shown in the following table, together with inverse values



Time - settlement curves.

FIG.3

of moisture specific loss v, reckoned according to the final settlement observed.

applied load Kg/cm^2	k cm/min	1/v Kg/cm^2
1,00	3,72 x 10^{-4}	63
2,01	2,47 x 10^{-4}	91
4,02	1,60 x 10^{-4}	147

DISCUSSION

According to our present knowledge on the progressive settlement of soil samples subjected to a constant load in a consolidation device, two typical schemes are usually distinguished:

1) Sand The necessary time for the final adjustement of grains is very short and can be generally neglected.
2) Clay The time, required for reaching the test sample equilibrium under the applied load, is quite long. Up to the first half of yelding, the time-settlement curve has a typical trend that, with much approximation, is explained by the well known TERZAGHI's theory of consolidation. This part of the phenomenon is called primary time effect. Beyond this, the time settlement curve is almost straight, when time is plotted on logarithmic scale. This is called secondary time effect and was particularly observed in clays with a certain amount of organic substances.

Volcanic material, we have tested, certainly is not a clayey material, for its grain size distribution, as for its mineralogical composition. Yet, under constant load, it reaches the final settlement with a remarkable slowness and, for this respect, behaves like a clay.

Since TERZAGHI's theory of consolidation is applicable both to sands and clays, it is interesting to ascertain if the observed phenomenon of compression could be a primary time effect and then interpreted by such theory. The fact that the actual settlement s is a linear function of ln t shows immediately that the theory of consolidation is not applicable to the observed process. In order to illustrate this point, we have plotted in Fig. 4 the theoretical consolidation curve, expressed by means of the dimensionless variables:

$$\begin{cases} \sigma = \frac{s}{s_1} & \text{(degree of consolidation)} \\ T = \frac{c}{H^2} t & \text{(time factor)} \end{cases}$$

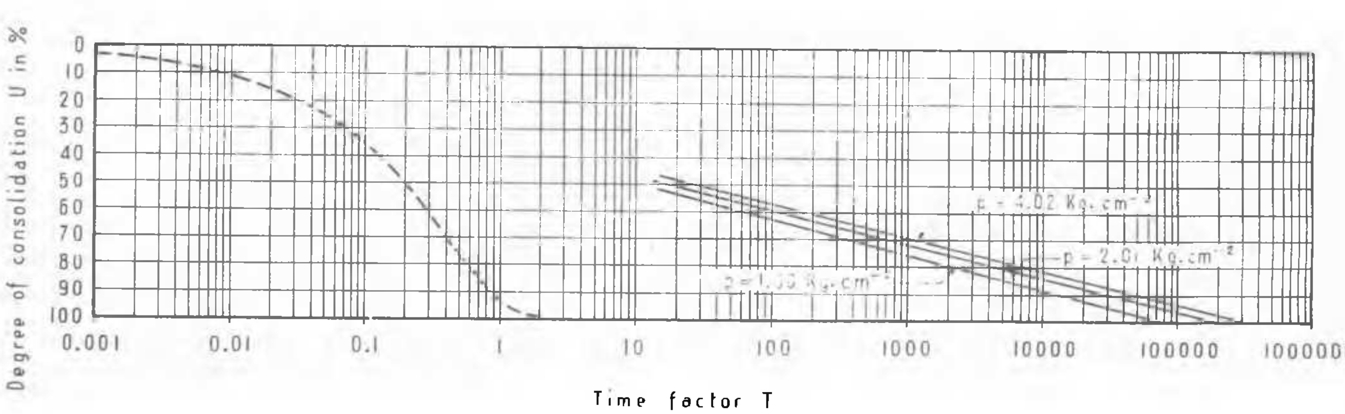
where: s_1 indicates the final settlement produced by the load increment;
c the coefficient of consolidation given by $\frac{k}{\gamma v}$, where γ is the unit weight of water;
H the half thickness of the test sample.

If we express the empirical relationship we have found for our volcanic material through the above dimensionless variables, we obtain the straight lines of fig. 4. The observed phenomenon develops whithin an interval of values of the time factor T, which is clearly subsequent to the range of values of T, which limits the primary time effect. We believe, therefore, that the process of compression, we have experimentally noticed, must be considered as a secondary time effect. Likely, a primary time effect, as conceived in the theory of consolidation, took place in our test in a time inferior to 30 sec.

CONCLUSIONS

Our observations lead us into the opinion that unconsolidated sediments of volcanic origin, although they have, when unaltered, no petrographic characteristic in common with clayey materials display a secondary time effect like that of clays. Furthermore, it is possible that in the compression of volcanic materials a primary time effect takes place also. Nevertheless, some peculiarities for these materials have to be emphasised:
the primary time effect, owing to the high permeability of such materials, occurs in a negligeable time and is difficult to reveal by observation. Probably it could agree with the theory of consolidation. From technical standpoint this effect is of small importance on account of its quickhappening:
the secondary time effect develops slowly in time and can be easily noticed by way of experiments. The settlement due to this part of the compression process may not be disregarded in comparison to the settlement corresponding to the primary time effect.

Some other experiments have been undertaken to throw more light on the subject. Since the laws, that rule the moisture movements, can also decisively influence soils accomodation process, as the theory of consolidation has clearly shown for clays, we intend to mea-



Observed time curves and theoretical primary time effect (dotted curve)

FIG. 4

sure the pore water pressures in function of time.

More over, remounting to causes of the phenomenon now called secondary time effect, it seems that material's nature should be of peculiar importance, and precisely its brittleness and the fact that possibly, on account of breaking of single grains, the volume of solid constituents of the soil may be no more considered as constant.

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CONSOLIDATION TESTS ON SOILS CONTAINING STONES

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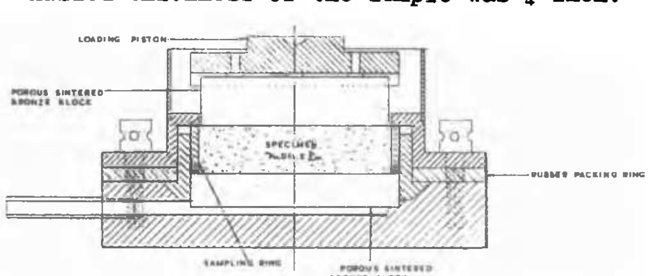
The test normally adopted in the determination of the consolidation characteristics of a soil, utilises a specimen of 3 inch diameter and approximately $\frac{3}{4}$ inch thick. This thin specimen is used and drainage allowed both from the top and the bottom, in order to shorten the time required for the test.

Soils containing stones, e.g., boulder clays, are common to many parts of the world and estimates of settlement under load can only be made from consolidation tests on thin specimens (1) by selection of a portion of the main sample free from stones, (2) by patching, if only an odd stone needs removal, or (3) by removal of the stones and remoulding. None of these methods can be considered satisfactory, especially when the high cost entailed in taking the sample, is considered. Investigations were, therefore, made to determine the effect of the presence of stones and the possibility of using larger test specimens, or other methods of testing.

Consolidation Apparatus.

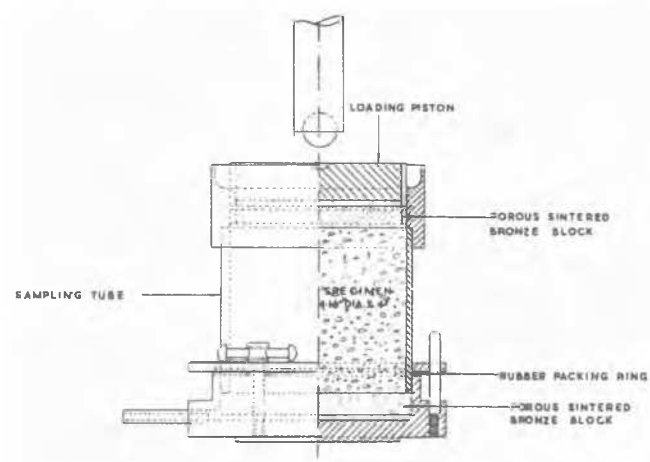
Specimens of 3 in., 4 in., and 6 in. diameter were tested by the conventional method, using a cylindrical mould with porous stones at each end, and the load applied vertically through a piston. The apparatus used for the 3 in. diameter specimens was not materially different from that used by other investigators, and is illustrated in Fig. 1. The method adopted to obtain the sample was to press the sampling ring into the soil being extruded from a 4 in. diameter sampling tube normally used for obtaining undisturbed samples in the field, and then to trim off the two ends. The finished thickness of the sample was $\frac{3}{4}$ inch.



Consolidation box 3in. Dia.

FIG.1

The apparatus for the 4 in. diameter specimen is illustrated in Fig. 2. In this case the sample was pushed direct into the 4 in. nominal bore sampling tube from another longer tube of the same diameter. The ends were then trimmed to give a finished thickness of approximately 4 in., and the load applied through porous blocks in the usual way.



Consolidation box 4in. Dia.

FIG. 2

In view of the difficulties described later in connection with the use of the 4 in. apparatus, only one 6 in. diameter specimen was tried. The sample was contained in a mould normally used for C.B.R. tests. A piston was used for the vertical load in the usual way, and porous stones made from brick dust and cement provided drainage.

The effects of friction in the 4 in. diameter apparatus were found to be serious and the following methods of overcoming this were considered:

1) coating the inside of the tube with glue or other similar material to reduce friction.
2) pouring molten paraffin wax round the soil specimen placed inside a sampling tube of larger diameter, the object being to provide an incompressible container, but with comparatively low side friction. This method was not effective.
3) the use of the triaxial compression testing machine utilising the water pressure to maintain a specimen of constant diameter. The object of this arrangement was to eliminate friction entirely, while still obtaining one dimensional compression.
4) the use of the triaxial compression testing machine with fixed end pistons, and an ar-