Torsion Hydrometer for Mechanical Analysis of Soils

Hydromètre à torsion pour déterminer la granulométrie des sols

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Summary

A simple torsion hydrometer for the quick determination of mechanical analysis of soils has been devised and standardised.

Sommaire

Un hydromètre à torsion pour la détermination rapide de la granulométrie des sols a été inventé et standardisé.

The use of the hydrometer for the mechanical analysis of soils has been investigated by *Bouyoucos* (1927, 1928a, 1928b) and perfected by *Puri* (1939).

Keen (1928) vehemently criticised this method. He stated "The determination was essentially qualitative, since an appreciable density differences must exist in the suspension between the top and the bottom of the long hydrometer bulb after so short a period as 15 minutes". Further he has discussed "Hence in physical terms, the hydrometer technique consists in measuring at an arbitrary time the average density of a layer of suspension several centimeters in length, whose density is continually changing both in depth and time. The statement that the method is essentially qualitative is not a matter of personal opinion, but of fact."

Puri (1939) devised a chaino-hydrometer, with a chainometric arrangement whose immersion could be reproduced to the fraction of a millimeter. A total weight of 100 mg/m could be added by the chainometric arrangement. Larger weights were added directly. From an examination of the density gradients in suspensions of 150 soils and comparing the results with the pipette method, it was concluded that the hydrometer method could replace the pipette method for the routine analysis of soils in the laboratory. *Puri* (1939) further pointed out that there was nothing arbitrary or empirical in the use of the chaino-hydrometer as was remarked by *Keen* (1928). His main argument was based on the fact that the settling times of the particles of various sizes were calculated from Stokes' Law to a depth corresponding to the middle point of the hydrometer bulb. If the bulb was not symmetrical about the middle point, then the mean density point corresponded to the centre of gravity of the surface of the bulb, which could easily be calculated. The mean density points were determined in these cases and pipetting was carried out at these points.

The present investigation was prompted with a desire to devise some simple hydrometer, which could even be manufactured in the field laboratories for the routine mechanical analysis of soils.

Torsion Hydrometer

The principle of the hydrometer is embodied in the well known *Nicholson*'s hydrometer but the fundamental basis of the hydrometer method rests on the assumption that the average density of any section of a sedimenting column is equal to the density at its middle point i.e., centre of gravity. It is made of brass and is chromium plated. They can also be made from the bulbs of 50 cm^3 and 100 cm^3 pipettes and are to be weighted with mercury.

The hydrometer is suspended preferably by a quartz fibre or horse hair. Its movements are counterpoised through a fine wire of invar metal, by rotating the graduated disc. The invar metal is not affected by the fluctuations of temperature and for this reason it was preferred to other metal wires.

The hydrometer readings are taken both in the distilled water and the soil suspension and the percentage of the size particles is calculated from the difference between the two readings. The relation between the percentage of the particles and the torsion of the hydrometer is first determined before using the hydrometer for routine analysis.

The detailed parts of the hydrometers are schematically shown in Fig. 1. The adjusting needle is set at the dead point every time by looking through the small mirror attached vertically against it. The torsion needed by the rotation of the graduated disc for bringing the adjusting needle to the dead point is then read and the distilled water reading is subtracted through it. The bottles are placed on a railing which can be easily moved and bring the bottles in turn for hydrometer reading.

This type of hydrometer can also work vertically on the principle of *Jolly*'s Balance, where a spring of invar metal wire may be used. There is a mirror attached behind the spring and the torsion is given from the top by rotating the graduated disc gradually in order to bring the adjusting needle every time to the same mark. The reading in both types are comparable. Fig. 2 shows the relation between the concentration of sodium chloride and torsion of the hydrometer.

A number of soils were examined both with the torsion hydrometer and the pipette method. The results are given in Table 1 and are diagrammatically represented in Fig. 3. The results emphasize the close agreement between the hydrometer and the pipette method.

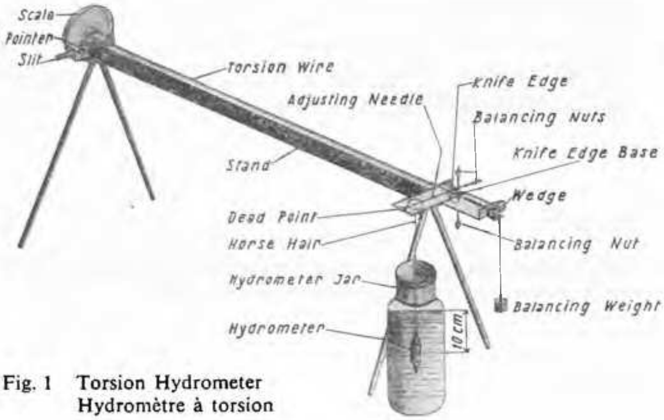

Fig. 1 Torsion Hydrometer
Hydromètre à torsion

Table 1 Reproducibility of Results by Torsion-Hydrometer and Pipette Method

Sr. No.	*Torsion*	*Calculated % from Torsion*	*Determined % by Pipette Method*
1	108.5	30.76	28.75
2	79.5	22.44	22.90
3	73.5	21.4	21.35
4	79.5	22.44	22.55
5	86.0	24.38	24.15
6	68.5	19.42	19.35
7	106.0	30.1	28.5
8	111.5	31.61	31.80
9	12.0	3.4	3.60
10	119.5	33.88	33.80
11	106.5	30.05	31.30
12	140.0	39.69	40.4
13	156.0	44.22	42.8
14	139.0	39.4	39.2
15	101.0	28.63	26.4
16	85.0	24.76	24.7
17	132.0	37.42	38.25
18	143.0	40.54	39.90
19	77.0	21.8	21.05
20	14.0	3.97	4.0
21	122.0	34.58	33.4
22	154.0	43.65	44.8
23	67.0	19.0	19.8
24	93.0	26.37	24.8
25	52.0	14.76	14.65
26	55.0	15.60	15.06
27	88.0	25.04	25.35

Temperature Correction

Fig. 4 shows the relation between temperature and torsion. Hydrometers are usually calibrated at a particular temperature in the laboratory and if the suspension is not at this temperature, a correction is essential for the change in the density of the liquid. The correction is to be added or substracted if the temperature is above or below the temperature of calibration.

Knowing the coefficient of expansion of water with temperature and the coefficient of cubical expansion of the material

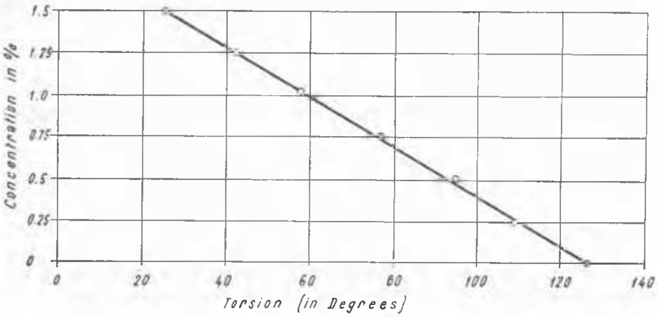

Fig. 2 Effect of Varying Sodium Chloride Solutions on the Torsion Hydrometer (Temperature 29.6° C)
Influence de différentes solutions de chlorure de sodium sur l'hydromètre à torsion (température 29,6° C)

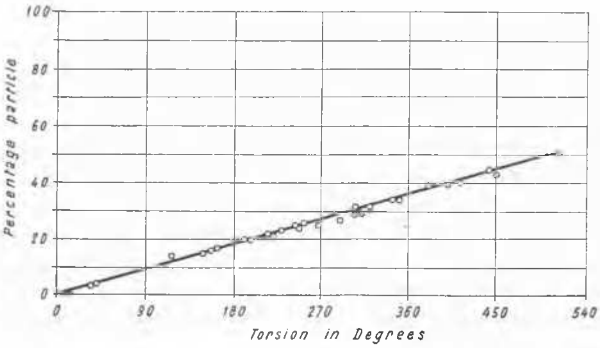

Fig. 3 Relation between Torsion and Percentage Particles
Rapport entre la torsion et le pourcentage des particules

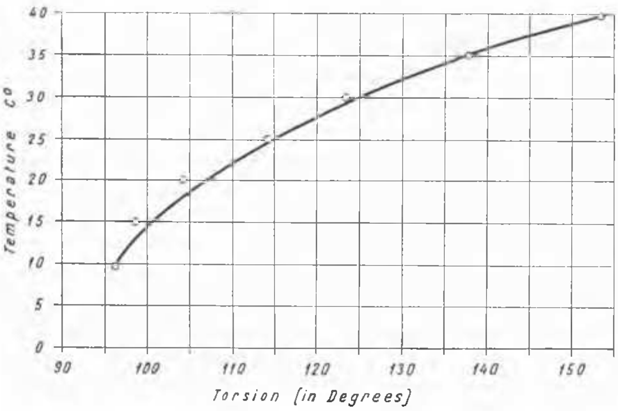

Fig. 4 Effect of Temperature on the Torsion Hydrometer in Destilled Water
Influence de la température sur l'hydromètre à torsion immergé dans de l'eau distillée

forming the hydrometer, a complete temperature correction chart can be prepared from the following formula:—

$W + w_t = V_t \cdot dt$

where W = weight of the hydrometer

w_t = additional weight needed to bring the hydrometer to the point of equilibrium at temperature, t °C

V_t = volume of the hydrometer at temperature, t °C

dt = density of water at temperature, t °C.

In this type of hydrometer, the weights are equivalent to the torsion given by the graduated disc fixed at the end. By taking 3 or 4 readings, a temperature correction chart can be prepared. But it has been argued by *Puri* (1939) and also confirmed in the laboratory by taking a number of readings that the correction required for the change in the temperature cannot affect substantially the accuracy of the mechanical analysis of soil.

Dispersing Agent Correction

The addition of the dispersing agent increases the specific gravity of the liquid. Therefore a correction has to be subtracted. But, as discussed under Temperature Correction, the increase in density with the addition of the dispersing agent does not materially affect the results.

Acknowledgment

The authors express their heart-felt thanks to Dr. *H. L. Uppal*, M.Sc., Ph.D., Director, Irrigation Research Institute, Punjab, India, for his helpful suggestions.

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