Short Communication

Free-Swell Index of Soils : A Need for Redefinition

by

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Introduction

Free-swell of a soil is defined (Indian Standard Code, 1977) as the increase in volume of a soil, without any external constraint, on submergence in water. The test procedure comprises of weighing two 10g specimens of an oven dry soil passing through 425 micron IS sieve. Each soil specimen is poured in a 100 ml graduated cylinder respectively. One cylinder is filled with water and the other with kerosene upto the 100 ml mark. After removal of the entrapped air (by gentle shaking or stirring the soils) the soils in both the cylinders are allowed to settle. The final volume of the soil in each of the cylinders is noted. The level of the soil in kerosene is read as the original volume of the soil sample, kerosene being a nonpolar solvent is considered not to cause any swelling of the soil. The level of the soil in water is read as its free-swell level. The percent free-swell index is calculated as :

$$\text{Free-swell index, percent} = \frac{V_d - V_k}{V_k} \times 100 \qquad \text{...(1)}$$

where, V_d = the volume of the soil specimen read from the graduated cylinder containing distilled water and

V_k = the volume of the soil specimen read from the graduated cylinder containing kerosene.

In this paper, results of free swell tests on a number of natural soils are examined and the limitations of the present definition are brought out. A new definition which is simple, requires less time to determine, and gives a more realistic picture of the soil swelling potential, is proposed. Based on the new definition, a new classification of sewelling potential of soils is suggested.

Experimental Results and Discussion

Free-swell tests were performed with nine natural soils. They were from Indian Institute of Science Campus, Gas Turbine Research Establishment, Domalur Market Complex (DMC) (Bangalore District, Karnataka),

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TABLE 1

Some Relevant Physical Properties of the Soils Studied

Soil	*Depth (m)*	*Principal clay mineral*	*Organic carbon %*	*Liquid limit %*	*Plastic limit %*	*Plasticity index %*	*Percent passing 0.075 mm*	*I.S. classification*
Kaolinite	—	kaolinite	0.00	47.0	29.7	17.3	100	MI
G.T.R.E. campus	3.5	kaolinite	0.00	53.0	20.0	33.0	100	CH
Mangalore marine	13.5	kaolinite, montmorillonite	3.30	72.6	40.4	32.2	98	MH
I.I.Sc. campus	1.2	kaolinite, montmorillonite	0.44	75.0	33.8	41.2	100	CH
Domalur	1.8	kaolinite, montmorillonite	0.00	75.0	36.3	38.7	61	MH
Narayanpur	7.0	montmorillonite	0.44	100.0	45.2	54.8	100	MH
Benihalla-I	2.5	montmorillonite	0.47	84.0	41.7	42.3	100	MH
Benihalla-II	9.2	montmorillonite	0.06	106.4	44.1	62.3	100	MH
Bentonite+Sand	—	montmorillonite	0.00	100.0	30.97	69.03	20.57	SC
Renigunta	2.5	montmorillonite	0.18	124.2	23.2	101.0	100	CH

Mangalore Coast (Mangalore District, Karnataka), Narayanpur Dam Site (Bijapur District, Karnataka), Benihalla (Dharwar District, Karnataka) and Renigunta (Chitoor District, Andhra Pradesh) The soils were repeatedly washed with distillled water, air dried and ground to pass a 75 micron IS sieve. Some of the relevant physical properties of the soils are listed in Table 1.

The sediment volumes of the soils in water and kerosene respectively and their per cent free-swell values are presented in Table 2. With the exception of G.T.R.E. campus soil which occupied a higher sediment volume in kerosene than in water, all other soils gave a positive free-swell value. X-ray diffraction spectra of the Mg-saturated, glycerol solvated clay fractions of the soil samples indicated the presence of only kaolinite in the G.T.R.E. soil, kaolinite and montmorillonite in the I.I.Sc. campus, D.M.C. and Mangalore marine soils and only montmorillonite in the Narayanpur, Benihalla and Renigunta soils. The free-swell test conducted with pure kaolinite mineral gave a higher sediment volume in kerosene than in water, similar to that observed with G.T.R.E. soil (Table 2). The behaviour of kaolinite occupying a higher sediment volume in a nonpolar solvent than in a polar solvent has been reported by Sridharan et al (1984), and Rao and Sridharan (1984). The free-swell test conducted with a bentonite (20.57 per cent)+sand (79.53 per cent) mixture (sand was added to reduce the free-swell level of bentonite to a measurable value) gave a higher sediment volume in water than in kerosene as observed with the remaining soils (Table 2).

TABLE 2

Sediment Volumes of Clays and Soils in Kerosene and Water and their Free-Swell Values

Clay/Soil	*Sediment volume in kerosene (cm^3)*	*Sediment volume in water (cm^3)*	*Free-swell index % (from Eqn. 1)*	*Free-swell index per unit soil weight (from Eqn. 2)*
Kaolinite	28.0	14.5	−48.21	1.45
G.T.R.E. campus	19.0	14.0	−26.32	1.40
Mangalore Marine	17.0	19.75	16.17	1.975
I.I.Sc. campus	14.0	17.75	26.78	1.775
Domalur	14.5	19.0	31.03	1.90
Narayanpur	10.5	21.0	100.00	2.10
Benihalla-I	11.0	21.0	90.90	2.10
Benihalla-II	10.5	33.0	214.28	3.30
Bentonite+Sand	10.0	67.0	570.00	6.70
Renigunta	11.0	80.0	627.27	8.00

The above results point out that the presence of only kaolinite in a soil leads to the latter occupying a higher sediment volume in kerosene than in water while the presence of an expansive clay results in the soil occupying a higher sediment volume in water than in kerosene as expected. The assumption, that the level of a soil in kerosene graduated cylinder may be read as its original volume, used in calculating the percent free-swell index does not hold good for soils containing kaolinite alone. The existing definition of percent free-swell index gives a negative value for such soils (Table 2) and is hence ineffective in predicting their expansiveness in water. Further, the presence of kaolinite in the I.I.Sc., D.M.C. and Mangalore marine soils results in their occupying a markedly higher sediment volume in kerosene in comparison to other soils (Figure 1) and thus suppressing their percent free-swell values.

With a view to overcome the above shortcomings, it is proposed that free-swell index may be calculated as :

$$\text{Free-swell index} = \frac{V_d}{10} \text{ cc/g} \qquad \ldots(2)$$

where V_d = the volume of 10g of soil specimen read from the graduated cylinder containing distilled water and determined by the procedure detailed in the code.

The proposed definition eliminates the determination of sediment volume of a soil in kerosene as it leads to anomalous results for soils containing kaolinite as a predominant mineral. Free-swell is then defined as the volume occupied by a unit weight of soil in the water without any external constraints.

The free-swell index per unit soil weight as calculated from equation (2) for different soils is presented in Table 2. The values range from 1.40 for G.T.R.E. soil to 8.0 for Renigunta soil. A free-swell index of < 1.5 would indicate the soil swelling to be negligible. A system of classification of the soil's swelling potential based on the new definition is proposed.

Free-Swell Index (cc/g)	*Swelling Potential*
<1.50	Negligible
1.5 to 2.0	Slight
2.0 to 5.0	Moderate
5.0 to 10.0	High
>10.0	Very high

Conclusions

The existing definition of free-swell index gives a negative value for soils containing kaolinite alone and leads to a supressed free-swell value for soils containing a mixture of kaolinite and an expansive clay. Hence a need to redefine the free-swell index of soils is felt. Consequently free-swell index is proposed to be defined as the volume occupied by an unit

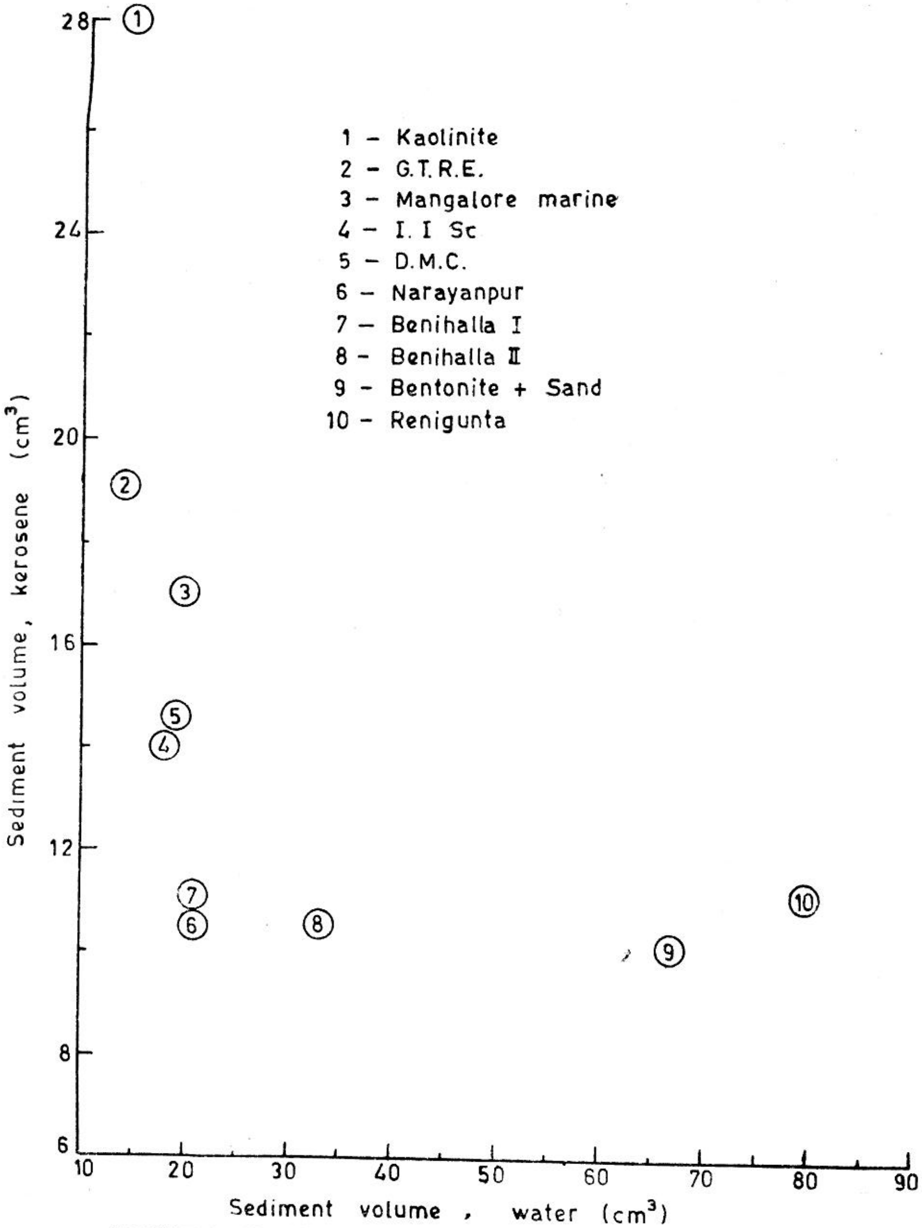

FIGURE 1 **Plot of Sediment Volume in Water *versus* Sediment Volume in Kerosene of Clays and Soils.**

weight of oven dry soil in water, under no external constraint. The proposed definition eliminates the determination of free-swell of the soil in kerosene. A classification identifying a soil's swelling potential based on the new definition of free-swell index has been proposed.

Reference

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