FIELD STRENGTH OF SOILS IN RELATION TO TEXTURE AND MOISTURE CONTENT

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Strength profiles of *in situ* soils representing different textural groups except silt have been established by measuring cone index values at the surface and thereafter at successive depth intervals of 3 inch upto a maximum depth of 24 inches at 92 sites during dry and wet seasons. In wet state, clayey and silty soils lose nearly half of their original strength. Most soil types show a progressive increase in strength with increase in depth in both dry and wet states.

In nature, ground strength varies not only from place to place but from season to season. The field strength of soil is dependent on its topography, moisture regime and the prevailing climate with respect to its location. Intrinsically the strength of soil is largely determined by its density, texture and moisture content.

An attempt has been made to evaluate the *in situ* strength of surface soils both in dry and wet seasons by employing a probe type instrument called the Cone penetrometer in this paper. The aim is to establish the influence of texture and moisture content on the magnitude and variation of strength characteristics of different soils.

EXPERIMENTAL PROCEDURE

Ninetytwo sites in plains of Punjab and Bihar were selected for the study. A large number of soil samples were collected from surface layers (0–6 in.) and subjected to mechanical analyses by Pipette method[1]. The textural types representing these sites, were established by comparing the experimental results with ranges of sand, silt and clay fixed for different textural groups by Feret Triangle[2] and are given below :

Textural Type	Symbol	Textural Type	Symbol
Sand	S	Clay Loam	CL
Loamy Sand	LS	Clay	C
Sandy Loam	SL	Silt Clay	SiC
Sandy Clay Loam	SCL	Silt Clay Loam	SiCL
Sandy Clay	SC	Silt Loam	SiL
Loam	L	Silt	Si

The moisture content of these samples was determined by 'oven dry' method during dry season and by 'Rapid Soil Moisture Tester' (employing Calcium Carbide), in wet season.

The sites were visited in April-May during dry season and August-September during wet season for determining resistance to penetration (cone index) of layers of soils at depths of 0, 3, 6, 9, 12, 18 and 24 inches. A mean of 3 readings for each layer was recorded. The accuracy of the cone penetrometer, which gives Cone Index (CI) values, is within $\pm$ 5%. The instrument and its operation is described below.

Cone Penetrometer

The cone penetrometer has a spring that deflects under load thereby actuating the needle on the graduated drum (Fig. 1). The compression of the spring rotates the drum through a rack and pinion arrangement. The spring and the drum is housed in an aluminium casting, attached with folding handles. The shaft is in 6 inches, detachable pieces with male and female screwed ends. Each piece is marked at 3 in. interval. At capacity load of 150 lbs, the drum rotates through 360°.

The dial has a graduated scale which indicates C I values in the range 0 to 300. The 30° cone having 0·5 sq in. base area is attached to the lower end of the shaft when CI values are to be measured.

The instrument is assembled by attaching the cone to the lower end of the shaft, the upper end of which is then screwed to the head assembly. The handles are held firmly with both hands and keeping the instrument vertical, force is gradually applied on the handles so that a steady downward movement occurs. First reading is taken just when the base of the cone is flush with the ground surface. The steady downward movement is continued at the rate of 1 in./sec and successive readings are taken at 3 in. intervals.

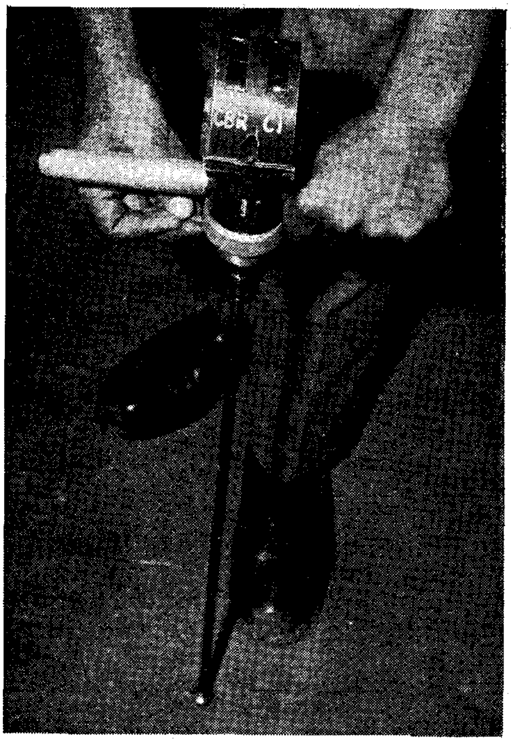

Fig. 1—Cone penetrometer.

On soft and saturated soils, the operator is able to penetrate the cone right upto 24 in. On hard and compact soils, continuous penetration by the application of manual pressure is seldom possible, therefore penetration has to be interrupted and carried out in stages by making bore holes with a soil auger.

Cone Index

Cone Index measured by Cone penetrometer is a measure of the shearing strength of soil. Although a dimensionless number, it actually represents force in pounds on the handle divided by the area of the cone.

TABLE 1

PERCENTAGE OF DIFFERENT FRACTIONS IN THE SOILS STUDIED (0–6 in.)

Textural type	No. of samples studied	Fraction (%)					
		Sand		Silt		Clay	
		Range	Mean	Range	Mean	Range	Mean
S	6	86–94	89·4	4–10	7·2	2–6	3·4
LS	8	59–82	71·8	8–33	17·6	6–16	10·6
SL	13	50–72	61·3	8–33	21·6	12–20	17·1
SCL	11	50–63	56·5	10–28	17·8	21–29	25·7
SC	6	47–62	53·7	2–14	9·2	35–41	37·1
L	13	31–53	45·0	22–49	32·1	16–28	22·9
CL	7	27–41	36·9	21–36	30·1	29–37	33·0
C	7	13–45	27·4	12–37	23·9	41–57	48·7
SiC	6	2–12	5·2	43–53	46·3	42–56	48·5
SiCL	6	12–20	16·5	46–57	50·2	28–39	33·3
SiL	9	15–48	28·0	30–60	49·5	16–26	22·5
Si	Not found in any sample						

RESULTS

Results of the study are presented in Tables 1–3 and Fig. 2.

DISCUSSION

Variation of Soil Strength with Moisture Content and Texture

Upon ingress of water, all soils suffer loss of strength. The magnitude of loss suffered however, varies with different soils having different porosity and permeability characteristics—properties which are essentially controlled by soil texture. Thus soil texture and moisture content are two significant factors influencing strength of soils.

The textural types representing the 92 sites studied conform to 11 types (USDA) as shown in Table 1. That the sites chosen are free from the influence of rising water table, is amply borne out by the moisture content data in dry season of all soil types reported in Table 2. Similarly the moisture content data in the wet season reflects moisture contribution from rainfall alone. From the magnitude of moisture contained in all soils during wet season, it is reasonable to assume that most soils are either close to or at field capacity level and possess comparable degree of wetness.

Though CI measurements have been made on all sites representing different textural types upto a total depth of 24 in. in both dry and wet seasons, for comparison of strengths,

TABLE 2

MOISTURE CONTENT IN SOIL DURING DRY AND WET SEASONS (0–6 in.)

Textural type	Moisture content (%)			
	Dry season		Wet season	
	Range	Mean	Range	Mean
S	0·5–2·2	1·2	6·6–11·8	8·8
LS	0·8–1·8	1·4	8·5–14·6	12·2
SL	1·2–2·4	1·8	10·4–16·8	14·4
SCL	1·8–3·0	2·4	9·8–18·2	15·5
SC	2·5–3·5	3·2	14·4–22·5	18·8
L	2·4–4·6	3·5	18·2–24·4	22·4
CL	2·8–5·8	4·2	19·4–26·8	23·6
C	6·5–9·6	8·2	28·6–36·8	33·2
SiC	3·8–8·4	6·6	21·4–30·5	27·6
SiCL	3·5–5·9	4·6	19·5–28·6	25·4
SiL	3·3–5·6	4·4	18·0–28·2	24·1

TABLE 3

AVERAGE CONE INDEX STRENGTH (0–6 in.) OF SOILS DURING DRY AND WET SEASONS

Textural type	Cone Index				Loss in mean strength (%)	Strength reduction factor
	Dry season		Wet season			
	Range	Mean	Range	Mean		
S	138–222	175	107–168	144	17·7	0·82
LS	162–228	200	147–177	162	19·0	0·81
SL	150–257	216	145–193	166	23·1	0·77
SCL	122–215	173	113–185	149	13·9	0·86
SC	127–232	198	112–208	160	19·2	0·80
L	161–260	214	140–163	155	27·6	0·72
CL	113–197	154	83–115	96	37·7	0·62
C	92–245	184	50–152	108	41·3	0·59
SiC	159–240	195	80–158	107	45·1	0·55
SiCL	128–227	185	71–125	102	45·0	0·55
SiL	107–217	160	47–130	87	45·6	0·54

an average strength of surface layers (0–6 in.) is considered alone (Table 3). This is in correspondence with the mechanical analyses made only for the surface soils (0–6 in.). From a scrutiny of Table 3, the order or strength of different soil types in dry season has been found to be as follows :

SL > L > LS > SC > SiC > SiCL > C > S > SCL > SiL > CL.

Soil strengths in the CI range of 150–300 are considered adequate and viewed in this context, the strengths displayed by all soils are satisfactory. However in wet season clayey and silty soils (fine-grained soils) display poor strengths as CL, C, SiC, SiCL and SiL show a CI value of 96, 108, 107, 102 and 87 respectively. The order of uniformly decreased strengths in these soils during wet season is :

SL > LS > SC > L > SCL > S > C > SiC > SiCL > CL > SiL.

Magnitude of Loss of Soil Strength in Wet Season

Table 3 also gives reduction in soil strength brought about by moisture accretion during wet season. The various textural types suffer loss in strength in the order :

SiL > SiC > SiCL > C > CL > L > SL > SC > LS > S > SCL.

This clearly shows that coarse-grained soils and true loams are water stable whereas clayey, silty soils and their combinations are highly water unstable. In other words, soils deriving their strength from friction and mechanical interlocking of particles (sandy and coarse-grained soils) and soils that derive their strength partly by cohesion and partly by friction[3] (loams and sand-clay combinations) are far superior to soils that drive their strength chiefly from cohesion (fine-grained soils and combinations of clays and silts).

Variation of Soil Strength with Depth

The area of study being in the alluvial zone, the texture of soils does not show any marked variation upto a depth of 24 in. from the surface in which CI measurements have been made. In every case, it is not necessary to examine the nature of variation of soil strength upto this depth, however, typical CI profiles of soils are shown graphically for four distinct groups namely, Sand, Loam, Clay and Silt Loam in Fig. 2. There is a tendency for strength to increase progressively with increase in depth for soils typified by S, LS, SL SCL, and SC, CL and C groups in both dry and wet seasons. In Fig. 2 (i), the two curves showing continuous increase of strength with depth during dry and wet seasons strength for a sand are running closer and parallel upto a depth of 24 in. With decrease in sand content and increase of either clay or silt in soils, the two curves representing dry season and wet season strengths are markedly displaced from each other [Fig. 2 (ii), (iii) and (iv)]. This displacement is due to greater water imbibing capacity by virtue of preponderance of finer fractions (silt and clay) over sand in the textural types of Loam, Clay and Silt Loam respectively and accounts for the tremendous decrease in strength of these types in the wet season. Another notable feature of the types represented by SiC, SiCL and SiL groups [Fig. 2 (iii)] is their peculiar behaviour which shows marked fluctuations, i.e., increase or decrease in strength with depth instead of a continuous increase in strength with depth in both dry and wet states as displayed by most textural types. The cause of this anomaly is probably due to differential wetting of the layers of these poorly drained soils which even on drying retain weaker pockets here and there.

CONCLUSION

Concluding some of the significant findings from the study are as follows:

(a) In dry state all textural types possess adequate field strength.

(b) In wet state clayey and silty soils typified by CL, C, SiC, SiCL and SiL display poor strengths and only retain nearly half of the original strength of the dry state.

(c) Most soils show a progressive increase in strength with increase in depth in both dry and wet states, the exception to this rule being the types represented by SiC, SiCL and SiL.

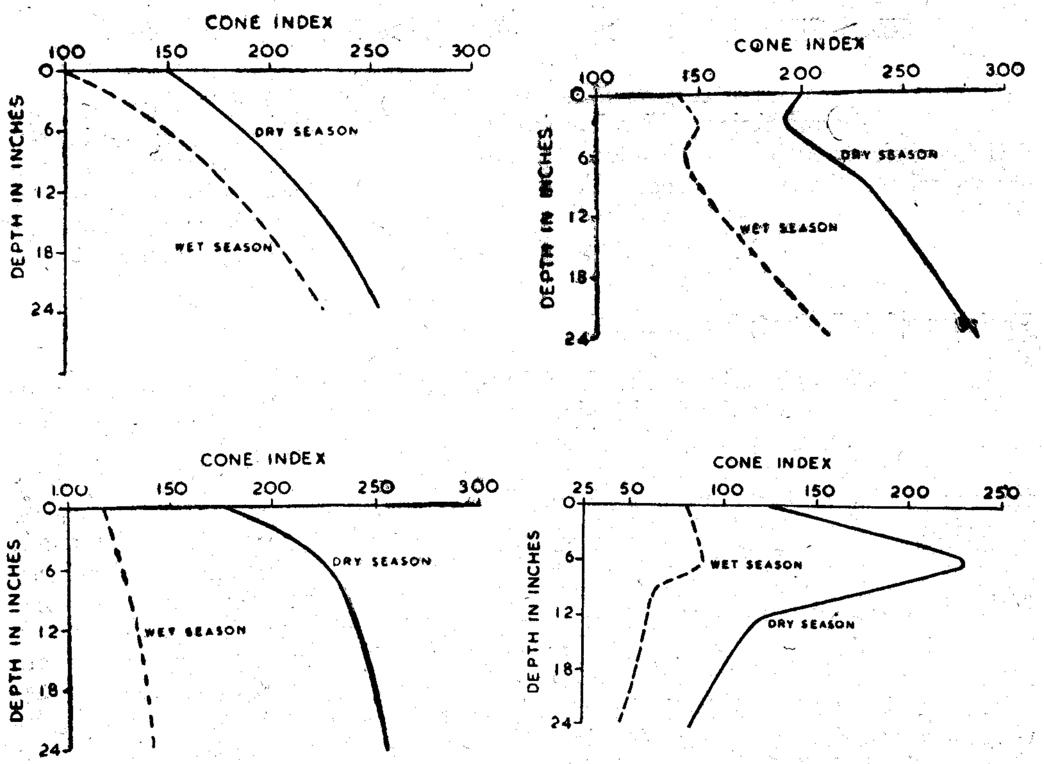

Fig. 2—Typical cone index profiles of soils for four distinct groups viz., (i) Sand, (ii) Loam, (iii) Clay, an . (iv) Silt Loam.

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