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# Evaluation of subsoil properties by pressuremeter test

## L'évaluation des propriétés du sous-sol par l'essai pressiométrique

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**SYNOPSIS :** The prediction of behaviour of subsoil and hence of structural element founded on it or embeded into is a fundamental and prime work for Geotechnical engineer. It is a practice to drill a hole, to collect samples in their natural and disturbed condition and to test them in laboratories, for getting various parameters. Based on these the required properties can be predicted and type of structural element for such soil can be decided. With the rapid and diverse development in construction techniques, the ways of subsurface investigation have also made strides. Pressuremeter test is recently practiced method of knowing load - deformation characteristics at required depth.

Attempts are made by the author to conduct the series of the tests with Pressuremeter by Ax and Bx probes between 2.0 to 4.5 m depth which is a depth of foundation in the region of South Gujarat for normal structures. The sample collected in disturbed and undisturbed condition for the same subsoil and depth were also tested to know fundamental Geotechnical parameters like consistency limits; particle size distribution, compaction characteristics, and shear parameters by Triaxial test. The other in situ tests like static cone penetration dynamic probing, standard penetration test were also carried in the vicinity of the pressuremeter test site.

The deformation modulus E and limit pressure  $p_l$  are important parameters those defines qualitative and quantitative properties of soil in load deformation behaviour. The deformation modulus E is measured in deviatric stress field.

It is determined for the pseudo-elastic phase of the test.

By knowing these characteristics namely E and  $p_l$ , the behaviour of various kind of foundation like raft, pad, and bored pile and their load carrying capacity can be found out. Different nomograms are availbale relating these parameters. It can be summerized as:

- 1 As the ratio  $E/p_l$  is a characteristics of the type of the soil, the soil can be classified in the different range of value of ratio  $E/p_l$ .
- 2 It can be used for computing settelment of the foundation resting or embeded in the soil.
- 3 For the problem of skin friction for caisson, bored piles and bearing capacity computation with different geometric configuration.

### 1.0 INTRODUCTION

The design and construction of foundations require a thorough knowledge of behaviour of soils and rocks in the field. Since even elaborate laboratory tests on large subsurface can at best only approximate the field condition, in situ tests are often preferable. Various insitu direct and indirect tests to investigate subsoil are in practice in our country. The aim for the test is to predict behaviour of structural element founded or embeded in the soil strata. To establish confidence on the test and to arrive at certain decision about the behaviour of the structural elements, the varification of the test by the actual examination in laboratory is a must. The variation in the result will lead about the improvement in the test itself. The pressuremeter test is probably the most versatile insitu testing device available for investigating static and cyclic strength-deformation properties of soil and rock at required depth. The behaviour of subsoil in load-settelment can be observed in very short time by pressuremeter test and the test is also cheaper. Attempts are made by the author to conduct test series in South Gujarat region of alluvium deposite. Various laboratory tests and insitu tests in the vicinity of the bore hole were also carried and this has lead to confirmation of geotechnical properties of subsoil.

### 2.0 THE PRESSUREMETER TEST

The basic principle behind the pressuremeter test is the expansion of a cylindrical cavity formed in the ground in order to measure the relationship

between pressure and deformation for the soil. As the soil is represented by a linear elastic isotropic homogenous mass it is also characterised by both fundamental parameters, Elastic constant and Poisson's ratio. The rheological properties of elasto plastic soil by considering stress strain behaviour of the soil can be studied and the pressuremeter curve for incompressible soil can be attempted. The deformation by applying known magnitude of pressure of infinitely long cylinder will take place in pseudo-elastic stage and the analysis to arrive to obtain two fundamental parameters, the deformation modulus E and limit pressure  $p_l$ .

A probe of the type Ax and Bx with diameter 44 and 55 mm respectively, which contains baloon and can be inflated by injecting fluid, are lowered in prebored hole at the required depth where, the soil properties are to be measured. It is pressurised with fluid and thus deformation of the surrounding soil can be known. A curve relating pressure and volume is plotted as shown in fig. 2. The deformation modulus E and limit pressure  $p_l$  are important parameters by which, the stress-strain characteristics, plastic behaviour of soil mass, and thus shear strength properties can be predicted.

E is related as

$$E = (1 + \mu) \cdot r \frac{\Delta p}{\Delta r}$$

Where  $\mu$  = Poisson's ratio  
 $r$  = radius of cavity  
 at instant  
 when increse of pressure occurs.

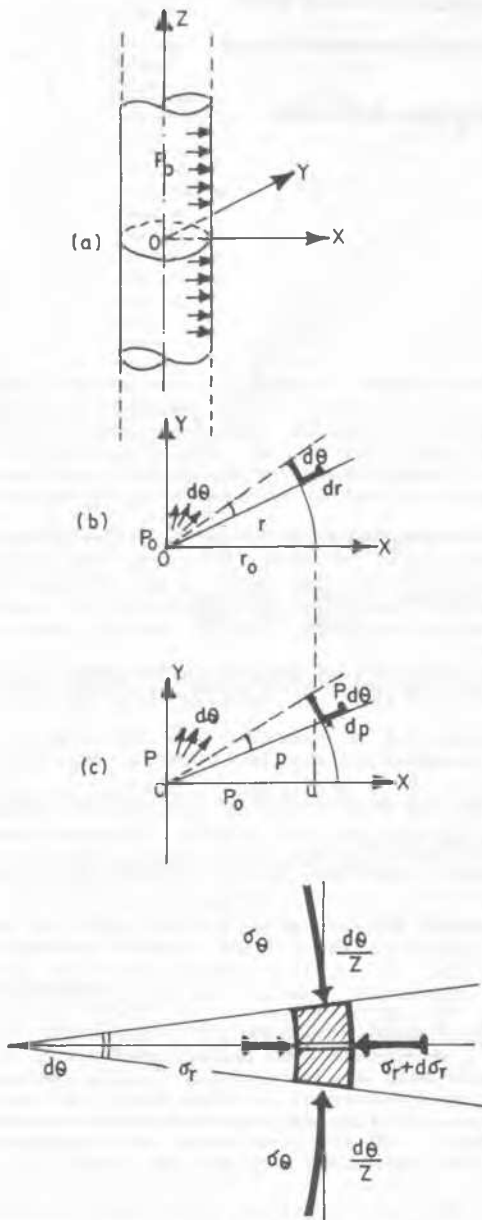


Fig. 1 Basic fundamentals of Pressuremeter test

Tests with Ax and Bx probe were carried out in bore hole 1 & 2 at 2.0, 3.0, and 4.0 mts respectively. The disturbed samples at these depth were also collected for laboratory varification of the result. Also insitu tests like static cone penetration test, dynamic probing were also carried in the vicinity of the pressuremeter test site.

2.1 The Pressuremeter test result

By conducting series of test with Ax and Bx probe upto 4.0 m depth which is normal foundation depth of the region for the common structure the graph of all cycles are plotted as shown in fig. 2.1 to 2.4. The various values of deformation modulus E, limit pressure  $p_l$ , and the ratio  $E/p_l$  is shown in table 1.

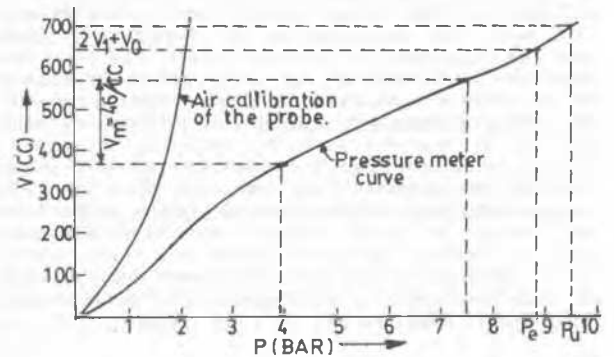
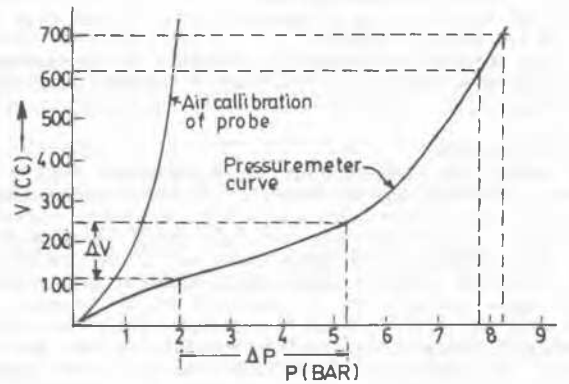
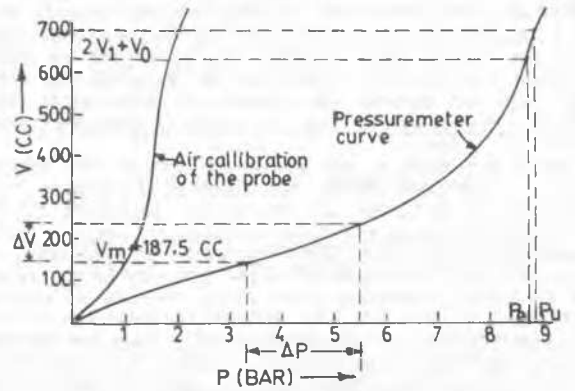
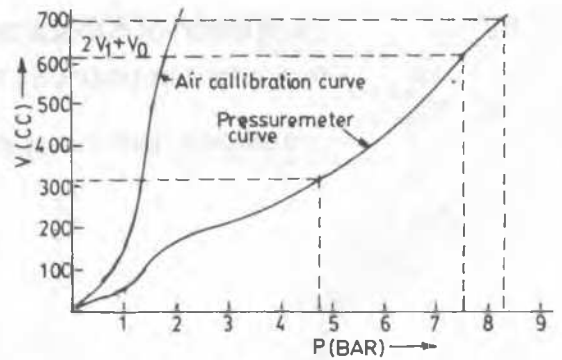


fig. 2.1 to 2.4, PMT curves at 2.0, 3.0, and 4.0 m depth

Table 1 The values of E, pl and ratio E/pl at various depth.

Sr.No.	Depth m	Deformation modulus E in Bars	Limit pressure pl in bars	E/pl ratio
1	2.0	42.75 By Graph	5.8	5.30 to 7.37
2	2.0	42.00 By nomogram	7.5	
3	3.0	56.37	7.1	5.23 to 7.94
4	3.0	53.30	9.10	
5	4.0	49.11	6.4	
6	4.0	48.00	7.3	6.17

### 3.0 USE OF PRESSUREMETER TEST RESULT

The basic strength characteristics of soil that is to say load-deformation behaviour which is very important for foundation design can be evaluated by pressuremeter test. Based on the different values of limit pressure, the soil is categorized with different range. Different charts and nomograms can be used to design foundation.

Table 2 Categorization of soil strata based on limit pressure range.

Range of limit pressure pl in bars	Nature of soil	Soil categories
0-12	Clay	Category I
0-07	Silt	
18-40	Firm Clay	Category II
12-30	Compact Silt	
04-08	Compressible Sand	
10-30	Soft or Weathered rock	
10-20	Sand and Gravel	Category III
40-100	Rock	
30-60	Very Compact Sand and Gravel	Category III A

There are various uses of pressuremeter tests. The deformation modulus plays an important role in the calculation of the settlement of the foundation. The PMT result are useful in computing settlement of foundation resting on or embeded in the soil, bearing capacity computation with different geometric configuration and for deep foundation problem like skin friction of casisson, bored piles etc. The type of soil based on E/pl ratio can also be predicted as shown in recommended table.

Table 3 Classification of soil based on E/pl ratio

Soil type	E/pl values
Very loose to loose sand	4 to 7
Compact to dense sand	7 to 10
Peat soft to firm clay	8 to 10
Stiff to hard clay	10 to 20
loess	12 to 15

### 4.0 VARIFICATION OF RESULT BY ROUTINE TESTS

Various laboratory tests like triaxial test, compactibility characteristics study of fundamental physical properties were conducted with the samples collected at the same depth the result of the various tests are tabulated in table 4

Table 4 various laboratory tests results

Sr.No.	Laboratory Tests	Soil Characteristics	Values
1	Triaxial Test	Plasticity Modulus at Lateral Pressure	
		0.5 Kg/cm <sup>2</sup>	123 bar
		1.0 Kg/cm <sup>2</sup>	106 bar
		1.5 Kg/cm <sup>2</sup>	120 bar
		Cohesion	0.359 Kg/cm <sup>2</sup>
		Ø	8°.20'
2	Sp. Gr. Test	Specific Gravity	2.6
3	Consistency limit	Liquid limit	49.33%
		Plastic limit	24.07%
		Plasticity Index	25.26%
		Consistency Index	0.037
4	Light Compaction test	OMC	24%
		MDD	1.5gm/cc

### 4.1 The discussion of the result.

Based on these results of Triaxial test, the soil samples were classified as well graded silty clay. The triaxial test gives the compression modulus such as young's modulus, and the values of c' and Ø also. The pressuremeter test gives values of deformation modulus 'E' say 'Em' where as the elastic behaviour of soil gives young's modulus 'E' from triaxial test. The results obtained after carrying out the test respectively lead to certain conclusion. The values of Em at various depth of 2.0 m, 3.0 m and 4.0 m and E at these depth are given in the table 5. Their ratios Em/E are also mentioned.

Table 5 The ratio Em/E at different depth.

Depth m	Deformation modulus Em bars	Young's modulus E bars	Em/E
2.0	42.75	123.0	2.87
3.0	53.3	106	1.98
4.0	48.0	120	2.50

### 5.0 THE CORRELATION WITH OTHER FIELD TEST

The static cone penetration test was conducted in the vicinity of Pressuremeter test site. The skin friction and cone resistance, the principal factors for design of pile foundation are plotted with variation of depth. The cone resistance  $q_c$  gives limiting value of shear resistance of soil mass as limit pressure gives in case of Pressuremeter tests. The  $E/q_c$  and  $q_c/pl$  ratio defines the soil type. Table 6 gives the value of ratios at various depth and in fig. 3 the values are plotted with variation in depth.

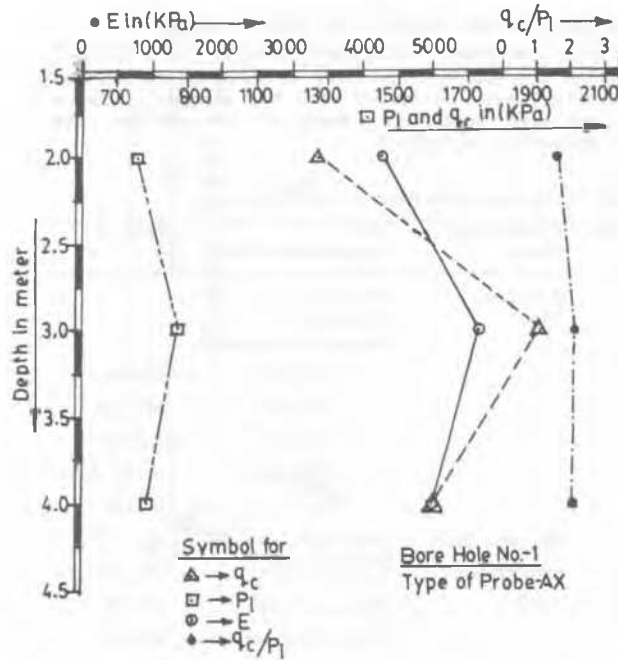


Fig. 3 PMT and CPT at the same depth.

Table 6 The correlation between CPT and PMT result

Depth m	E KPa	$p_l$ KPa	$q_c$ KPa	$E/q_c$ ratio	$q_c/p_l$ ratio
2.0	4275	760	1271	3.36	1.67
3.0	5637	870	1910	2.96	2.20
4.0	5000	780	1600	3.12	2.05

#### 6.0 CONCLUSION

Pressuremeter test is more reliable compare to other field tests. It gives actual behaviour in load-deformation characteristics by which analysis design and prediction of behaviour of foundation is possible. If deformation modulus and limit pressure are correlated to other geotechnical parameters, the evaluation of subsoil properties can be confidently predicted.

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