

Flat Dilatometer and Lateral Soil Modulus

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ABSTRACT

Changes in the lateral stress condition in soil in the immediate vicinity of the blade of the flat dilatometer during the penetration of the device were experimentally investigated in a laboratory study. Lateral separation that takes place during the penetration of the blade was simulated by horizontally advancing a rectangular aluminum block instrumented with a dilatometer diaphragm against sand specimens prepared in a testing tank at different relative densities. A cantilever beam-type deflection transducer mounted in the chamber behind the diaphragm made it possible to obtain a continuous record of pressure-diaphragm center deflection. For purposes of comparison, a standard flat dilatometer was used in a series of penetration tests conducted concurrently with the lateral separation study. Also, the effect of repeatedly expanding the diaphragm on the pressure-diaphragm center deflection curve was considered. The results of the study point out factors that are thought to be of importance in a meaningful interpretation of the dilatometer data and the assessment of the lateral soil modulus.

An extensive array of penetration devices has been developed during the last half-century as a result of a need to profile subsoil conditions more accurately than conventional methods of drilling and intermittent sampling allow. Some of these devices, such as the standard penetration and cone penetration tests, have been widely accepted and used in a range of geotechnical and highway engineering problems. In highway engineering, in addition to their use in solving typical foundation soil bearing capacity problems, penetrometers have been used as quality control tools during the construction of compacted embankments.

The flat dilatometer, first introduced in this country in the mid-1970s (1) is basically a penetrometer that is also capable of measuring the soil stiffness with the help of an expandable, circular steel diaphragm attached on a stainless steel blade 14 mm (0.550 in.) thick. The blade is jacked into the soil using a penetrometer rig. A nylon tube that runs through the penetrometer rods connects the dilatometer control unit with a chamber behind the diaphragm. A steel wire passing through the nylon tube completes the electrical circuit that is used to detect specific positions of the diaphragm center as it is expanded against the soil. A spring-loaded displacement sensor mounted inside the pressure chamber behind the diaphragm is adjusted to close the circuit and keep a buzzer on the dilatometer control unit activated when the diaphragm center is at two specific positions: (a) flush with the blade surface and (b) deflected by 1 mm against the soil. During penetration of the blade, the diaphragm is kept flush with the surface of the blade by the lateral soil pressure acting on it. As soon as the desired depth is reached, the diaphragm is inflated by pressurized gas. The first pressure reading is taken at the instant the outward movement of the diaphragm is initiated. This is indicated by the silencing of the buzzer on the control unit. The second pressure reading is taken when the diaphragm center has deflected by 1 mm (0.039 in.), at which instant the buzzer is activated again. These readings, which must be corrected for diaphragm stiffness, are used to compute soil index parameters that correlate with in situ soil type and characteristics.

Previous applications of the flat dilatometer include profiling of subsoil conditions and estimation of a number of soil parameters such as at-rest lateral earth pressure; overconsolidation ratio; coefficient of volume compressibility; and, in saturated sands, assessment of liquefaction susceptibility (2-4). By virtue of its construction, the flat dilatometer is capable of obtaining lateral soil stiffness data in a nearly continuous manner in both cohesive and cohesionless soils. It can, therefore, be employed as an alternative to the methods currently used in assessing soil response during lateral loading of pile foundations.

Differences in the soil strains resulting from dilatometer penetration and pile driving, however, present difficulties in extrapolating the dilatometer data for use in the analysis of laterally loaded pile behavior. This study was designed to

1. Obtain the soil response against the expansion of the diaphragm in the form of a continuous pressure-diaphragm deflection curve and evaluate the significance of such a relationship and
2. Investigate the changes in the lateral pressure in the immediate vicinity of the dilatometer in response to penetration of the dilatometer blade.

The scope of the work presented covers the possible use of flat dilatometer data in estimating the stiffness of cohesionless soils for laterally loaded pile analyses. The results presented are of a preliminary nature. However, the data obtained, which should be substantiated by calibration studies on laterally loaded full-scale piles, indicate a potential for effective use of the flat dilatometer in securing field data for such analyses.

LATERAL SOIL STIFFNESS

A number of techniques and related equipment are available for the evaluation of lateral soil stiffness. These include, in addition to the flat dilatometer, full-scale lateral pile loading tests (5-9), plate-loading tests (10,11), triaxial testing (12,13), consolidation test (14), pressuremeter

(15,16), Iowa stepped blade (17), standard penetration test (18,19), and empirical correlations with other soil properties (10,20,21). A primary source of difficulty in interpreting the test results--with the exception of full-scale pile load testing--has been the significant differences in deformation modes imposed on soil during the tests and those that occur as a result of pile installation and subsequent lateral loading. Therefore, the majority of the techniques listed previously will not work satisfactorily under all circumstances. Also, discontinuous profiling of the soil, in relation to the lateral stiffness parameters, has a tendency to increase the statistical margin of uncertainty of the analysis. Therefore, short of conducting in-place full-scale lateral loading tests on prototype piles, much remains to the judgment of the engineer in extrapolating the field data, which are often obtained in the form of standard or cone penetration test results, far enough to make reasonable estimates of the lateral soil stiffness parameters.

During a dilatometer test the lateral stresses acting on the blade are measured at approximately 20-cm intervals as the blade penetrates the soil under static or impact loading. The mode of deformation imposed on the soil is similar to that resulting from the penetration of a driven pile, and dilatometer data may be used in a subgrade reaction type of analysis of piles under lateral loading. Because of the difference in the lateral soil separation that results from dilatometer and pile penetration, however, the soil disturbance condition, at which the soil stiffness is obtained by the dilatometer, is intermediate between undisturbed state and remolded conditions as imposed by the cross-sectional dimensions of the driven pile and the pile-soil friction. This leaves the task of extrapolating the dilatometer data backward to zero lateral strain condition to obtain the undisturbed soil stiffness and forward, within reason, to estimate the pressure-displacement relations for driven piles of substantially larger cross sections than that of the dilatometer blade. Another factor to be remembered in the analysis is the dependence of the subgrade reaction coefficient on the dimensions of the loaded area.

Marchetti (3), assuming linear elasticity, defined a "dilatometer modulus" ($E/(1 - \mu^2)$) that can be calculated with the data obtained during the expansion of the diaphragm against soil:

$$E/(1 - \mu^2) = (2\Delta p)/(\pi S_0) \quad (1)$$

where

- E = elastic modulus of soil,
- μ = Poisson's ratio of soil,
- D = diaphragm diameter,
- S_0 = deflection of the diaphragm center, and
- Δp = difference between two pressure readings corrected for diaphragm rigidity: the first reading is taken immediately after the outward movement of the diaphragm has been initiated (p_0), and the second at 1-mm lateral deflection of the diaphragm center (p_1).

The dilatometer modulus correlates with the soil compressibility and the lateral soil stiffness. If the generally nonlinear stress-strain response of soils is considered, however, the dilatometer modulus in Equation 1 is actually a secant modulus. In this study, a suitably placed deflection transducer mounted to be in contact with the inside surface of the diaphragm was used to obtain a continuous record of the deflection of the diaphragm center as a function of inflation pressure.

Ideally, a field calibration test can be conducted on a driven pile instrumented with a number of stress cells or dilatometer blades mounted flush with the surface (S. Marchetti, personal communication, 1982). Another dilatometer can be used to profile the soil in the vicinity of the pile and to establish correspondence with the pile response observed under lateral loading. However, by most standards, this technique is time consuming and relatively cost prohibitive to implement as a routine field test.

EXPERIMENTAL STUDY

The laboratory study to be described was carried out under controlled conditions and concentrated primarily on (a) the form of the pressure-diaphragm deflection curve when the diaphragm is inflated against soil and (b) the effect of the wedging action, which takes place as a result of dilatometer penetration, on the lateral soil pressure conditions in the immediate vicinity of the blade.

The present design of the flat dilatometer yields two pressure readings that necessarily require the assumption of ideally elastic soil behavior in calculating the dilatometer modulus. With a standard dilatometer, however, a gradually decreasing p_1 obtained by repeated pressurizing of the diaphragm and the fact that on the release of the pressure following the first inflation of the membrane the buzzer is not activated again are indicative of inelastic behavior as well as permanent soil deformations effected by previous pressurizing.

To obtain the pressure-deflection curve in a continuous form, a leaf-type cantilever beam deflection sensor, instrumented with a half-bridge strain gauge arrangement, was used behind the dilatometer diaphragm. The cantilever deflection sensor had a maximum tip travel of approximately 1.13 mm (0.044 in.). No significant creep was observed in deflection readings during the experimental program. Both the deflection sensor and the diaphragm were mounted on an aluminum block, 150 mm (6 in.) long, 100 mm (4 in.) wide, and 25 mm (1 in.) thick. Experimental work was carried out in a steel bin (Figure 1). A pipe section 25 mm (1 in.) in diameter was attached to the backside of the block and was extended out through a hole on the short side of the bin. Dilatometer pressure line and deflection sensor wires were taken out through the pipe. A sand composed of angular particles was used during the experiments, and the test specimens were prepared at initial relative densities of 15, 30, and 45 percent.

Increasing lateral separation of soil as a result of dilatometer penetration was simulated by laterally forcing the aluminum block against the soil using a trailer jack mounted rigidly on a steel frame that, in turn, was welded to the short side of the bin. Overburden stress was simulated by applying a vertical force through a hydraulic jack on a rigid steel plate placed on the sand surface. The steel plate was purposely not extended over the aluminum block in order to avoid damaging the block as the vertical pressure was applied. The vertical force was measured by a load cell mounted between the steel plate and the hydraulic jack. Before the start of each test, overburden load was applied, and, through a hole cut in the steel plate, a standard dilatometer was introduced to the same depth as the aluminum block, diaphragms facing each other. Readings of p_0 and p_1 were taken by the standard dilatometer after 7 mm (0.275 in.) lateral movement of the aluminum block. The inflation pressure was measured by an electronic pressure transducer mounted on the dilatometer control box at a distance of approxi-

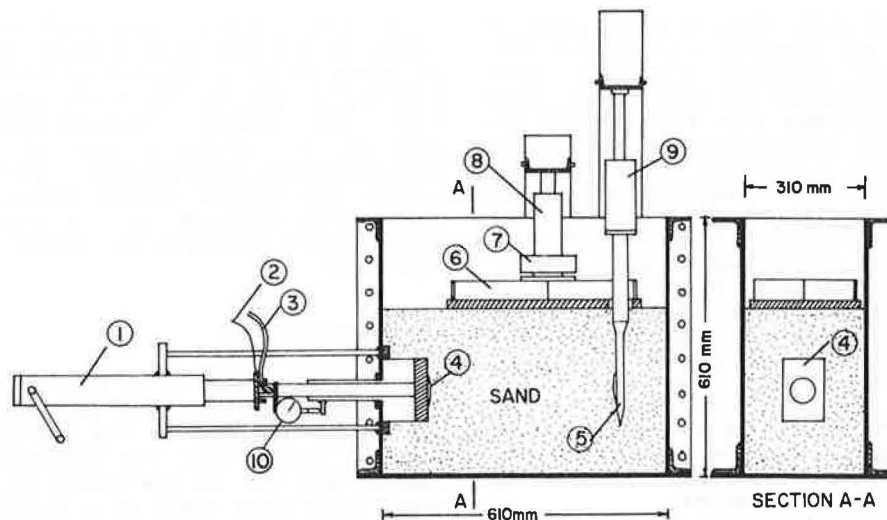


FIGURE 1 Experimental setup: 1, trailer jack; 2, deflection sensor leads; 3, pressure line; 4, aluminum block; 5, flat dilatometer; 6, pressure plate; 7, load cell; 8 and 9, hydraulic jacks; and 10, dial gauge.

mately 750 mm (30 in.) from the dilatometer block along the pressure line.

Initially, the pressure versus diaphragm center deflection curves were taken at 0-, 2-, 4-, and 7-mm lateral movement of the aluminum block. One such group of curves (a) is shown in Figure 2, which was redrawn by tracing over experimental curves. However, it was later discovered that inflating the diaphragm at 2- and 4-mm lateral penetration substantially decreased p_1 taken at 7-mm penetration. Therefore, a new series of experiments was performed in which the full inflation curves were obtained at 0- and 7-mm lateral penetration values only. At intermediate penetration values of 2, 3, 4, and 5 mm, only the p_0 readings were taken. Repeated pressurizing of the diaphragm (five times) was performed in the majority of tests at 7-mm lateral movement of the block (Curve b in Figure 2). The diaphragm cali-

bration curves were taken several times during the experimental study by inflating the diaphragm against atmospheric pressure before the sand specimens were prepared inside the bin (Curve c in Figure 2). The net pressure-diaphragm deflection curves can subsequently be obtained with reference to this calibration curve.

EXPERIMENTAL RESULTS AND DISCUSSION

Pressure-Diaphragm Deflection Curves

An increasingly nonlinear relationship between the pressure and the diaphragm center deflection was observed as the aluminum block was gradually forced horizontally against the soil. Curve family (a) in Figure 2 illustrates this behavior. The full inflation curves at intermediate lateral penetrations of 2 and 4 mm were taken during the first series of experiments only. At all three initial relative densities, however, within the 0- to 1-mm deflection range of the diaphragm center, no significant nonlinearity was observed on the pressure-deflection curves taken before the lateral movement of the aluminum block. This indicates that, if the diaphragm inflation were to be started at at-rest earth pressure condition, the deflection range of the diaphragm would be inadequate to detect the nonlinearity in the pressure-diaphragm deflection curve that would definitely occur at larger deflections.

If, however, the point of interest is specifically the soil stiffness for the small-strain lateral response analysis of cast-in-place piles, a relationship to be obtained between the dilatometer modulus and the modulus corresponding to lateral loading beginning with at-rest earth pressure conditions will be convenient. One such relation, shown in Figure 3, indicates linear dependence between the two modulus values. The resulting relationship is evidently independent of the relative density and overburden stress conditions. A relation of this nature should be useful in estimating the Young's modulus of the soil for possible use in formulas relating the modulus of elasticity of the soil to the lateral coefficient of subgrade reaction (12). Further testing is presently under way to investigate whether the slope of the line in Figure 3 is significantly dependent on soil type. Also, for

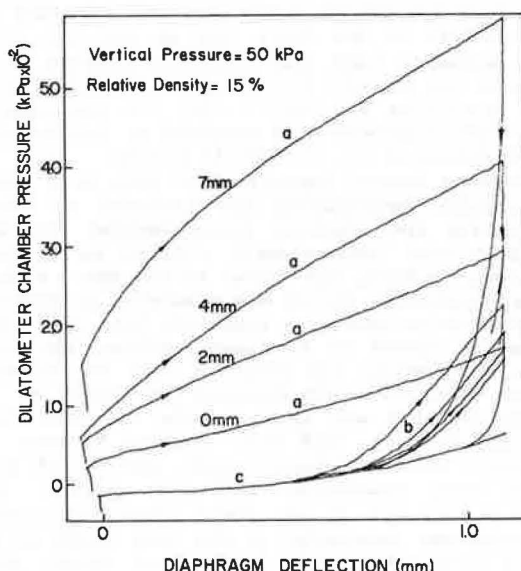


FIGURE 2 Block dilatometer chamber pressure-diaphragm center deflection curves: a, initial inflation curves; b, repeated pressurizing curves; and c, diaphragm calibration curve.

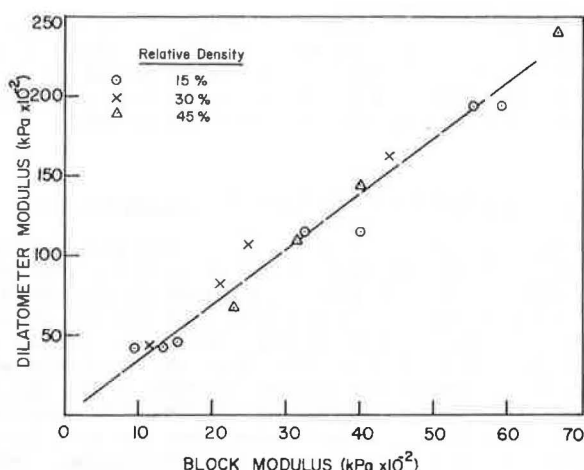


FIGURE 3 Standard dilatometer modulus versus at-rest condition block dilatometer modulus.

seismic analyses, a plot of this type is expected to yield reasonably accurate values for the small-strain shear modulus of the soil in situ if a reasonable assumption about the Poisson's ratio can be made. If the shear modulus at still smaller strains were needed, the continuous pressure-diaphragm de-

flection curve obtained by the cantilever beam attachment would have to be used.

In the majority of the experiments, the secant value of the dilatometer modulus calculated from the pressure-deflection curve using Equation 1 yielded reasonable average values for the modulus within the 0- to 1-mm range of lateral soil displacements. However, the tests also indicated that the initial tangent dilatometer modulus can be as much as 50 percent higher than the secant modulus. This points to the possibility of a substantially lower actual modulus value if the inflation curve is extrapolated significantly beyond the 1-mm point, or a substantially greater modulus at lateral displacements of less than 1 mm.

During the experiments, p_0 and p_1 values obtained with a standard dilatometer blade were found to be consistently less than the corresponding values obtained after laterally penetrating the aluminum block 7 mm toward the soil. Figure 4 shows the difference for 30-kPa vertical pressure at initial relative densities of 15, 30, and 45 percent. This is interpreted as reflective of the effect of vertical shear deformations accompanying lateral separation of soil during the penetration of the standard dilatometer. No such action took place as the aluminum block was forced against the soil laterally. Table 1 gives a comparison of these readings for the second test series.

Because of the lack of a provision for continu-

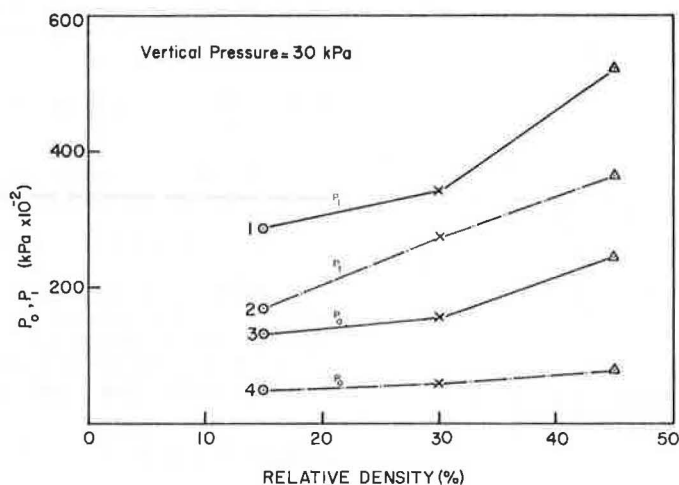


FIGURE 4 Values of p_0 and p_1 obtained by standard dilatometer and the dilatometer block as a function of the initial relative density: Lines 1 and 3, aluminum block; Lines 2 and 4, standard dilatometer.

TABLE 1 Dilatometer Block and Standard Dilatometer Diaphragm Inflation Data

Initial Relative Density (%)	Vertical Pressure (kPa) ^a	Dilatometer Block (at rest)		Dilatometer Block (7 mm)		Standard Dilatometer	
		p_0 (kPa)	p_1 (kPa)	p_0 (kPa)	p_1 (kPa)	p_0 (kPa)	p_1 (kPa)
15	12.5	10	35	80	190	38	147
	30	10	50	130	285	48	167
	50	75	180	350	610	93	393
	100	110	255	460	820	133	638
30	12.5	20	50	100	265	38	152
	27	30	85	155	340	58	273
	50	45	110	235	475	78	358
	100	80	195	395	695	148	572
45	12.5	5	65	145	375	68	243
	30	27.5	110	245	520	78	363
	50	45	150	300	625	123	498
	100	85	260	445	1050	218	843

^a 1 kPa = 0.145 lb/in.².

ously recording the movement of the diaphragm on the standard flat dilatometer, it is not possible to assess the effects of repeated pressurizing of the diaphragm on the lateral soil stiffness. The pressure to reach 1-mm deflection gradually decreases with successive cyclings of pressure. However, because the exact position of the diaphragm cannot be determined when the pressure is reduced to zero, the term S_0 in Equation 1 is unknown and a new value of the dilatometer modulus cannot be determined. Continuous measurement of pressure and diaphragm deflection, however, indicated increased soil stiffness for repeated cyclings of pressure (curve group b in Figure 2), although beyond the second cycling of the pressure the change observed in the dilatometer modulus was minimal (Figure 5). Residual deformation, however, continued to build up with continued cycling of pressure. The initial upward curvature recorded on the cycling curves is thought to be due to the receding of the diaphragm by a small amount from the soil following the depressurizing of the chamber. On repressurizing, when the diaphragm-soil contact was established, the curves became significantly steeper.

It is thought that the cycling curves can be used

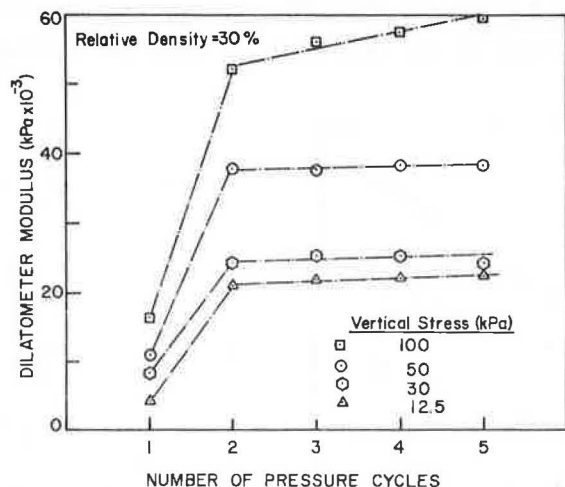


FIGURE 5 Dilatometer modulus values obtained as a function of the number of pressurizing cycles of the diaphragm.

in estimating the buildup of permanent deformations in soil surrounding piles laterally loaded in a repetitive manner. However, a viable method of establishing correspondence between the test data and the actual pile response has yet to be devised.

Lateral Pressure as a Function of Soil Separation

The lateral pressure necessary to start the outward movement of the diaphragm on the block (p_0), plotted as a function of the lateral movement of the block, yielded approximately a straight line for all three relative densities and vertical pressures. Figure 6 shows two such curves. The slope of a continuous curve of p_0 versus the lateral movement of the block should indicate the coefficient of subgrade reaction of the soil for an object separating the soil laterally—in this case, the flat dilatometer. The present flat dilatometer design does not allow for obtaining such relationships in field applications. However, it would be enlightening to see if the diaphragm pressurization data taken after 7 mm of lateral deflection might be of any use in determining the value of the slope of this curve. For this, consider the curves in Figure 6. If linearity is assumed, between 0- and 7-mm lateral separation values the lateral coefficient of subgrade reaction would be

$$k_h = [(p_0(7)) - (p_0(0))] / d \quad (2)$$

In Equation 2, d is the half-thickness of the dilatometer blade. The numerical data in Figure 6 yield, for the upper curve,

$$k_h = [(245 - 27.5) / 0.007] = 31\,070 \text{ kN/m}^3 \text{ (114.3 lb/in.}^3\text{)}$$

With the block width of 100 mm (4 in.), the subgrade reaction modulus becomes

$$k = 31\,070 \times 0.1 = 3\,107 \text{ kN/m}^3 \text{ (450 lb/in.}^3\text{)}$$

A "diaphragm subgrade reaction coefficient" was defined for the purpose of comparing the soil stiffness values obtained by Equation 2 and during the inflation of the dilatometer diaphragm through Equation 1. Rearranging Equation 1 in the form

$$\Delta p / S_0 = (\pi / 2D) [E / (1 - \mu^2)] \quad (3)$$

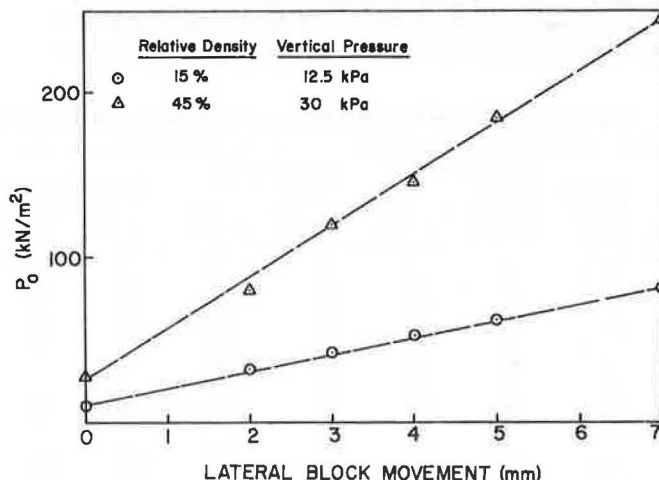


FIGURE 6 p_0 versus lateral block movement curves obtained by the aluminum block.

yields the ratio of the difference between two corrected pressure readings to the diaphragm center deflection and has the same units as the subgrade reaction coefficient. Both Δp and S_0 are quantities measured during a dilatometer test, and the ratio $\Delta p/S_0$ can be calculated without knowledge of the terms on the right-hand side. The data obtained by a standard dilatometer for this particular test yielded approximately $285\,000\text{ kN/m}^3$ ($1,046\text{ lb/in.}^3$) for the diaphragm subgrade reaction coefficient. A comparison indicates that this value is an order of magnitude greater than the lateral coefficient of subgrade reaction obtained previously.

One possible way of interpreting the difference is that, as the block penetrates laterally, yielding of the soil in the vicinity of the edges takes place, whereas, when the diaphragm is inflated, it is forced against the part of the soil that was densified by the wedging action of the dilatometer blade without yielding significantly. The difference is also believed to be partly a typical display of the dependence of the subgrade reaction on the contact area and the difference in the modes of deformation imposed by the blade, in the form of lateral penetration of a rectangular object, and by the diaphragm, as essentially axisymmetric loading of a thin plate.

A first-approximation value of the lateral subgrade reaction modulus can be computed with Equation 2 using p_0 obtained by a standard dilatometer and assuming zero in situ lateral stress. For the same initial relative density (45 percent) and the simulated overburden pressure (30 kPa) conditions considered previously, the data yielded

$$k_n = (78/0.007) = 11\,142\text{ kN/m}^3\text{ (41.0 lb/in.}^3\text{)}$$

This value, also, is substantially lower than the dilatometer subgrade reaction coefficient calculated on the basis of the diaphragm inflation data.

Because of the soil disturbance resulting from the penetration of the blade, the values of the average coefficient of subgrade reaction obtained by the standard dilatometer were substantially different from those obtained by the block. Given that the lateral subgrade reaction obtained by the block will be more representative as a design value in the case of cast-in-place piles, it is interesting to

note that these two values plot approximately as a straight line at small overburden pressures with evidently little dependence on relative density (Figure 7). The slope of this line is defined here as the "disturbance index" and represents the correction factor by which the standard dilatometer subgrade reaction coefficient value should be divided to obtain a disturbance-free lateral subgrade reaction coefficient. With increasing overburden pressure, however, the effect of relative density becomes more pronounced, and, also, the straight line approximation does not remain valid (Curves a, b, and c in Figure 7). At this point it is not known whether the relationship is significantly dependent on the type of sand. In the case of piles constructed in sand, a sample of the soil can be tested in the laboratory using a setup similar to that in Figure 1 to obtain, for subsequent analyses, an approximate value of the disturbance index and, if necessary, a complete group of curves similar to those of Figure 7.

Schmertmann (22) suggests that a first approximation of the value of the lateral subgrade reaction coefficient can be obtained as the ratio of the difference between the standard dilatometer p_0 reading and the at-rest lateral earth pressure to the half-thickness of the dilatometer blade (Line c in Figure 8). Here the at-rest lateral pressure is to be estimated through a statistical relationship presented by Marchetti (3). However, as discussed previously, because of the disturbance that results from the insertion of the dilatometer blade, the undisturbed p - y relationship (Curve a in Figure 8) may be significantly different from the value calculated as the slope of Line c in Figure 8. Nevertheless, this assumption may have merit in assessing the lateral stiffness of the soil around driven piles because of the significant soil disturbance associated with the pile installation techniques.

For cast-in-place piles constructed without substantial remolding of the soil in the vicinity of the pile, a better value of the lateral subgrade coefficient can probably be obtained by dropping the in situ lateral pressure term from the calculation scheme. Although theoretically incorrect, ignoring this term will have an improving effect on the calculated value of the subgrade reaction coefficient because the remolding of the soil around the dilatometer already results in too low a value for p_0 .

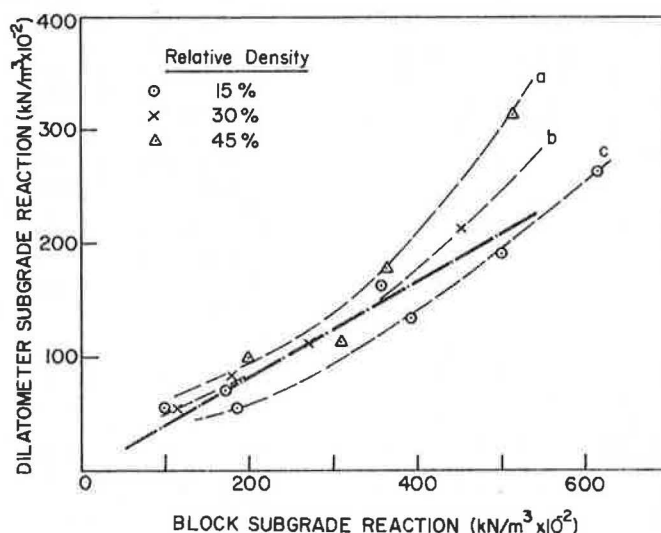


FIGURE 7 Relationship between average values of dilatometer and block subgrade reaction calculated over a separation distance of 7mm.

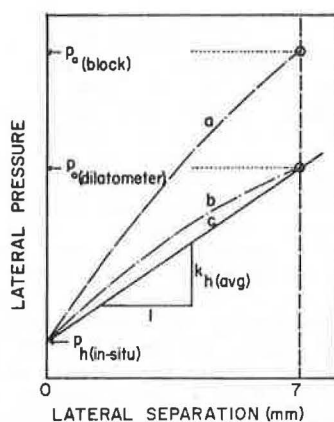


FIGURE 8 Qualitative comparison of the block and standard dilatometer lateral separation-pressure curves and the lateral subgrade reaction coefficient ($k_{h, avg}$) as suggested by Schmertmann (22); p_h is the at-rest lateral earth pressure.

This argument assumes that the p_0 value obtained by the dilatometer is always less than what it would be if lateral soil separation were not accompanied by vertical shear deformations around the blade during penetration, which implies contractive soil behavior. The effect of possible delative behavior is not known at present and further work is planned to clarify this point.

A case study on a pier foundation 1370 mm (4.5 ft) in diameter and 4500 mm (15 ft) long constructed in a silt soil yielded good agreement between the measured lateral pier-top displacement and the computed value obtained by using the subgrade reaction coefficient corrected according to Figure 7. In the analysis, the slope of the initial straight line portion of p - y curves (6) was computed on the basis of the corrected subgrade reaction coefficient. An extensive field calibration study, however, appears to be absolutely necessary to evaluate the potential of the flat dilatometer for securing data for use in pile analyses under lateral loading, especially if a strong nonlinearity is present in the lateral response characteristics of the soil.

The test results presented indicate that the direct use of the diaphragm subgrade reaction coefficient (as defined in Equation 3) in analyses will probably result in a substantial overestimation of the actual soil stiffness for the pile dimensions considered. It should, however, also be stressed that the laboratory study was conducted on a sand. At the present time, the writers do not have data on this aspect of the behavior of cohesive soils.

CONCLUSION

The results obtained, although preliminary in nature, point out some of the factors that have to be considered and the questions that need to be answered in order to realize the full potential of the flat dilatometer. The potential certainly exists for using dilatometer data in estimating the subgrade coefficient of soils for lateral loading. In its present form, the flat dilatometer is capable of yielding an average soil modulus instead of a complete description of the lateral stress-displacement (p - y) relationship, and the modulus value obtained

will probably reflect the soil stiffness within a small deflection range.

This study points out a viable procedure for obtaining representative values of soil stiffness for piles constructed in place with little disturbance to the soil in the immediate vicinity. The subgrade reaction modulus obtained by a standard dilatometer can be corrected for soil disturbance to give a representative value for the disturbance-free soil stiffness. However, the more general problem of relating the data to the actual soil stiffness as a function of the pile cross section and the method of pile installation is presently the primary obstacle that has to be removed through further study. Research should also address the question of whether the dilatometer modulus can effectively be combined with the subgrade reaction modulus obtained by Equation 2 to substantiate data on the lateral stiffness of a soil (e.g., evaluating nonlinear effects).

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Abridgment

Pavement Failure Investigation: Case Study

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ABSTRACT

An investigation of pavement distress occurring along a major two-lane roadway 5 years after its construction is presented. The primary objective of the study was to determine the probable cause or causes of the pavement distress. The investigation involved a condition survey and an examination of the pavement structure and subgrade through soil borings. The condition survey showed that outer wheel path rutting and associated cracks were severe on both lanes and covered about 68 percent of the overall length of the roadway. The soils investigation revealed that the bank gravel subbase was saturated and the bituminous base course had deteriorated to a virtually cohesionless material that could be easily removed with the fingers. Distinct rapid seepage of water was observed at the interface of the base and subbase layers and within the subbase. On the basis of the findings of the investigation, it was concluded that the major factor causing distress was free water trapped within the pavement structure. This water, it was reasoned, infiltrated the pavement through cracks and a porous surface but because of the poor drainability of the subbase was unable to leave the pavement through the shoulders. This situation resulted in the pavement existing in a "bathtub" condition.

Most, if not all, flexible pavement structures undergo some form of distress during their design life. Investigation of the cause or causes of distress is required for successful pavement rehabilitation and to provide data for improving or modifying design methods, construction techniques, and job specifications.

An investigation undertaken to determine the probable cause or causes of continually occurring

pavement distress along a major two-lane roadway is described.

BACKGROUND

The roadway investigated is located in Trinidad, West Indies, an island with a uniform average yearly temperature of 26° C (79° F) and annual rainfall of