Reduced Soil Strength and Stiffness at the Top of Tube Samples

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SUMMARY.- An investigation is described designed to assess which part of a tube sample gives the more reliable estimate of the original soil properties in the ground. A decomposed granite and a decomposed mudstone were sampled with a 3 in. Auger Core Soil Sampler. In one set of tests at each site, each sample was long enough to permit an upper and lower test specimen to be cut, while in the other set the advance of the sampler was shorter, permitting only one test specimen per tube sample. Subsequently an immediate undrained triaxial compression test was made on the specimens in the laboratory.

Secant modulus values for the single specimens were found to match closely those for the lower specimens, even though the sampling forces required to obtain the latter were much higher. The influence of these forces, and of soil disturbance arising from the sampling procedures, on variations in tube sample properties is discussed. It is concluded that the lower part of a sample should give a more reliable indication of actual soil ground conditions than the upper part.

I.- INTRODUCTION

Even though care is taken in obtaining intact soil samples, some disturbance is inevitable. While attempting to minimize disturbance to that acceptable for the proposed tests, a practical approach is to recognize that disturbance will occur, and to make allowance for its influence on the properties measured in the laboratories. Disturbance can be considered to be present when variations in the values of soil properties measured at points along the length of a sample exceed variations to be expected from natural causes. Experimental evidence of variations along the length of tube samples has been reported (Ref. 1, 2 and 3).

The author reported (Ref. 4) that when two test specimens were cut from the same tube sample, the lower specimen had significantly greater strength and stiffness than the upper specimen. The next question to be answered is which values give the better indication of the properties of the undisturbed material in place. For example, it could be argued that depressed values were obtained for upper specimens due to loosening of the sample during sampling, or alternatively that high values for the lower specimens were caused by compaction. Since in some cases, the forces applied to the sampler during the latter stages of the advance of the sampler were quite large, it was decided to investigate the significance of this factor.

II.- BASIS OF EXPERIMENTATION

A method involving the comparison of two sampling procedures or patterns was used. Pattern A (Fig.1(a)) followed that used previously (Ref. 4), the advance of the sampler being sufficient to permit two test specimens (upper and lower) to be cut from each tube of sample obtained. In Pattern B (Fig. 1(b)) the possibility of large forces was reduced by limiting the length of sample taken with each advance of the

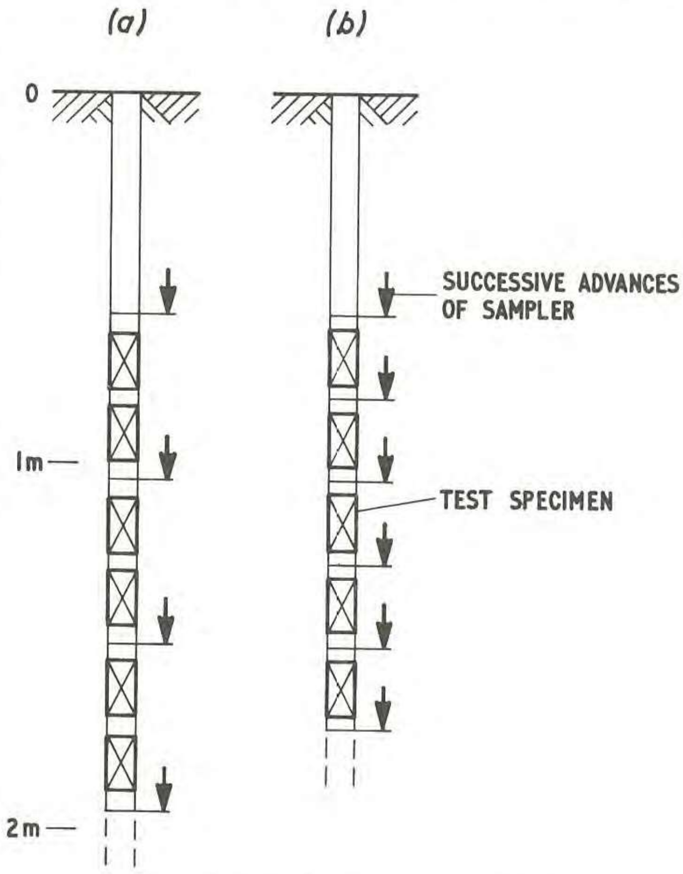

Fig. 1.- (a) Sampling Pattern A;
(b) Sampling Pattern B.

sampler. From these short samples only a single test specimen could be prepared.

The secant modulus of elasticity was adopted as the principal criterion for assessing variations of disturbance. The superiority of this variable over soil strength had been predicted (Ref. 1), and demonstrated experimentally (Ref. 4 and 5). The greater sensitivity of the modulus of elasticity is due to this property being related to that part of a test where little strain has occurred. The greater strain and distortion of the specimen before peak stress is reached will tend to mask any disturbance caused by the sampling operation.

III.- TEST SITES

The soils at the two sites were residual, having been formed from decomposed granite at Greenvale and decomposed mudstone at Syndal. Features of the two sites are compared in Table I. The soil at Greenvale was chosen for test sampling because it was expected that any excessive sampling forces would tend to destroy the structure of the residual soil and that this would be readily apparent in laboratory test results. In contrast it is known that some soils can take a good deal of ill treatment without showing undue distress. Such soils are quite unsuitable for investigating sampling procedures as test results obtained will not show any difference between one sampling procedure and another.

The tests made at Syndal enabled comparison with earlier work done on this site.

IV.- SAMPLING PROCEDURE

All sampling operations were carried out with a 3 in. Auger Core Soil Sampler (Ref. 6 and 7). In this sampler the sample tube does not rotate but is forced axially downward while the annular space outside the sample tube is cleared by cutters and

TABLE I

TYPICAL PROPERTIES AT TEST SITES

Site	GREENVALE	SYNDAL
Location (from City of Melbourne, Victoria)	22 km (13 miles) NNE	18 km (11 miles) ESE
Soil	Decomposed Granite	Decomposed Mudstone
Clay size, under 0.002 mm (%)	15	35
Silt size, 0.002 - 0.060 mm (%)	20	35
Sand size, 0.060 - 2.000 mm (%)	50	30
Gravel size, over 2.000 mm (%)	15	0
Dry Density (kg/m^3)	1800	1730
Moisture content (%)	13	19
Degree of saturation (%)	72	91
Strength (σ_1-σ_3 at σ_3 = 70) (kN/m^2)	360	390

auger flight fixed to the outer rotating barrel. The sampler was operated from a truck-mounted drill (Mobile B-40 Explorer) using hydraulic power for both feed and drill shaft rotation. For experimental purposes this machine is fitted with instruments developed to measure the principal parameters of the sampling operation, such as position, thrust, torque, rotational speed, and sample displacement. The instruments have been described elsewhere (Ref. 8).

In Pattern A the sampler was advanced 450 or 600 mm (1.5 ft or 2.0 ft), to obtain a sample long enough to cut two test specimens. Each sampling began from the depth to which the sampler had advanced previously, that is, the sampling was *continuous*. The machine was anchored to the ground and the designated advance of the sampler obtained, even though this meant that large forces had to be applied and that less than complete recoveries were obtained. Thus at Greenvale the axial forces applied to the sampler rose to the region of 16 kN (3500 lbf.), while the torque reached 270 Nm (200 lbf. ft). Gross recoveries for this pattern at Greenvale were low, generally about 70 per cent. Examination of record made showed that usually in these cases, the specific recovery ratio was 100 per cent for 70 per cent of the total advance; then jamming occurred quite suddenly and no further sample entered the tube. At Syndal forces were less and recoveries better, but still often less than 100 per cent.

In Pattern B the advance of the sampler was about 210 mm (0.70 ft). Again the sampling was *continuous* but with this pattern recovery ratios were generally 100 per cent while applied forces were a good deal less, averaging in the case of Greenvale about half the values of Pattern A. (This seems reasonable as the advances were approximately halved.)

At each site several bores were made spaced about 1 m apart. At Greenvale, samples were taken from four bores using Pattern A and two bores using Pattern B, while for Syndal there were seven bores using A and two bores using B. There was no free water in any of the bores.

V.- LABORATORY TESTING

In the laboratory an immediate undrained triaxial compression test was made on specimens 6 in. (152.4 mm) long and the full 3 in. (76.2 mm) diameter as sampled. All tests reported were made at a lateral pressure of 70 kN/m^2 (10 p.s.i.). The secant modulus values are determined from the stress-strain origin (with the strain origin corrected if necessary for bedding-in effects) to a point where the stress is one-third of the peak value reached.

VI. DISCUSSION OF RESULTS

For the Greenvale samples both peak deviator stress and secant modulus values obtained from the triaxial tests were generally higher for the lower specimens than for the upper specimens of pairs cut from the same tube sample (Fig. 2). Similar results were reported previously for a site at Syndal (Ref. 4). No explanation can be found for the one notable exception in Fig. 2(b).

Fig. 3 and 4 show for Greenvale and Syndal respectively, the peak deviator stress and secant modulus

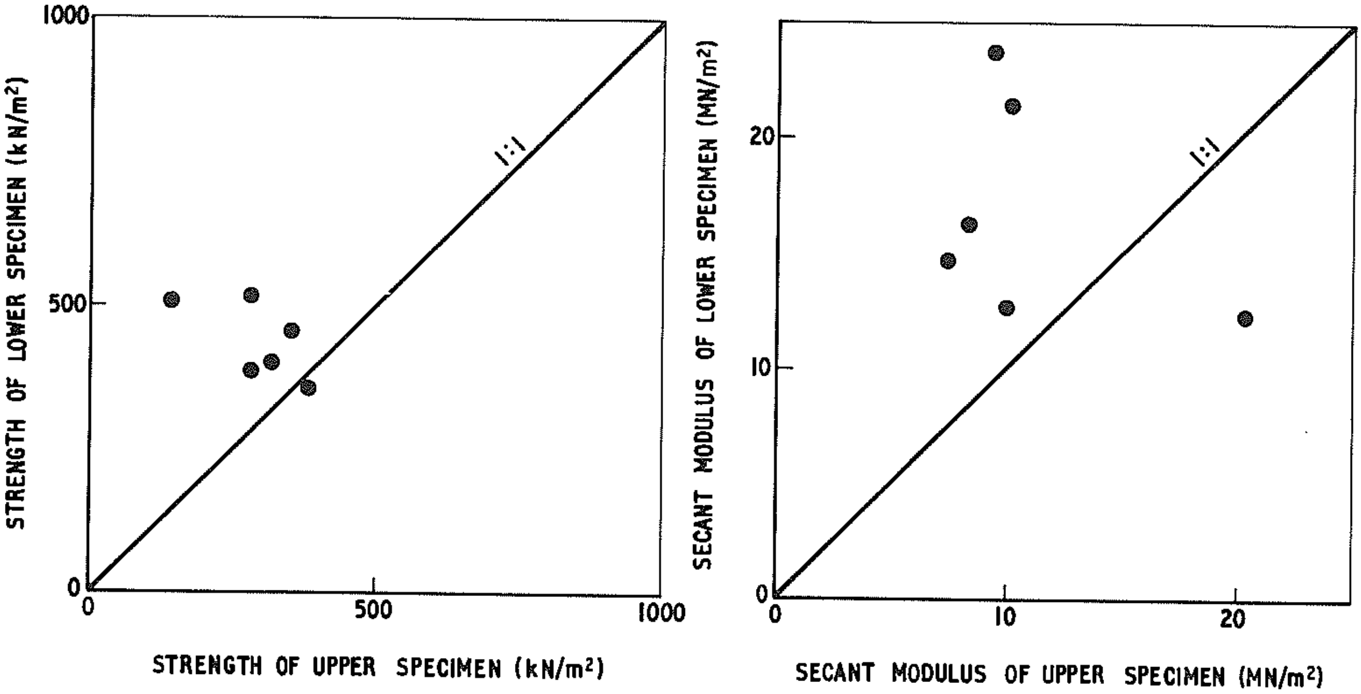

Fig. 2.- Greenvale Site: Comparison of peak deviator strength and secant modulus of elasticity for upper and lower specimens from same sample tube.

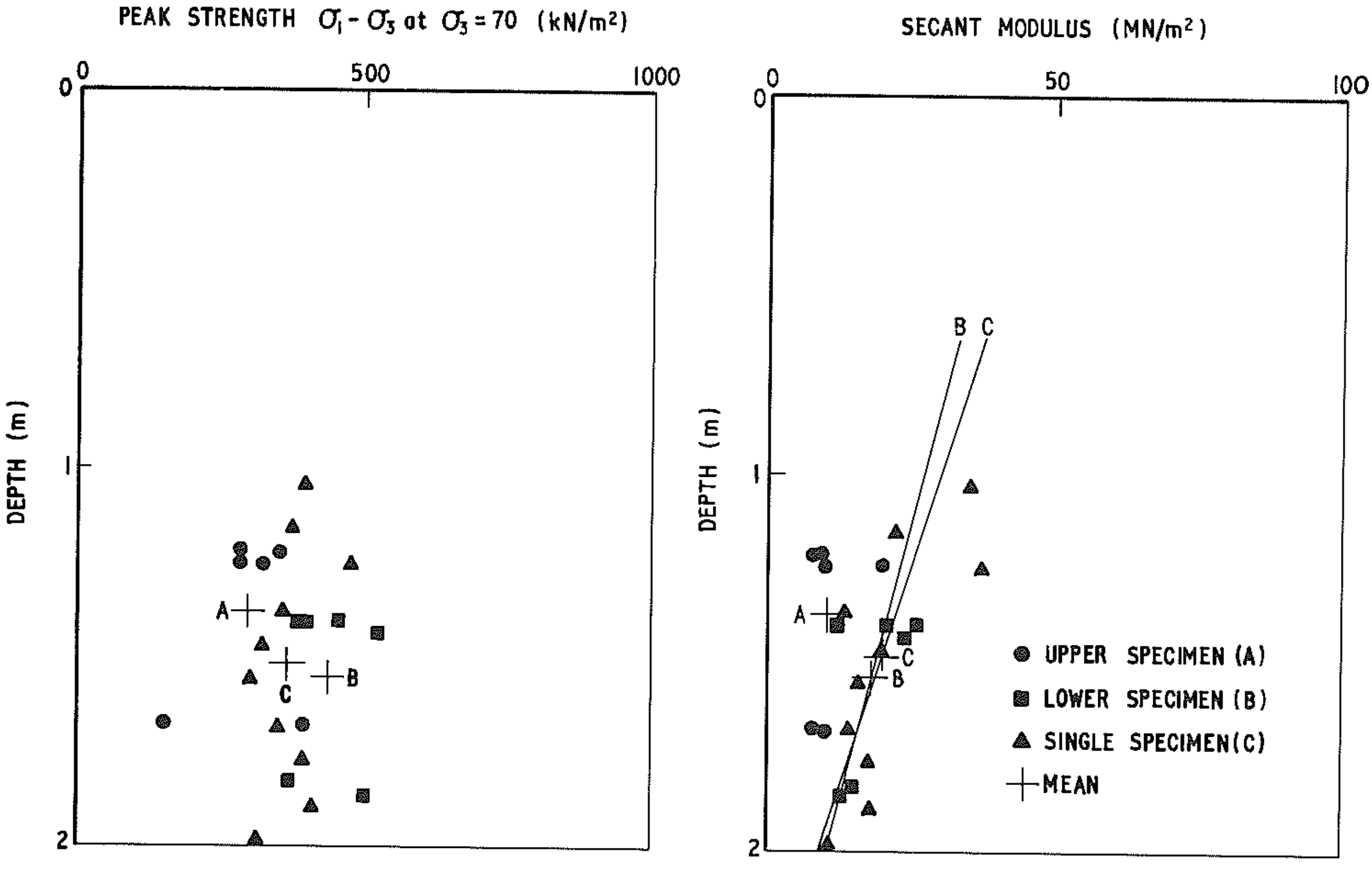

Fig. 3.- Greenvale Site: Peak strength and secant modulus of elasticity for different types of specimen against depth.

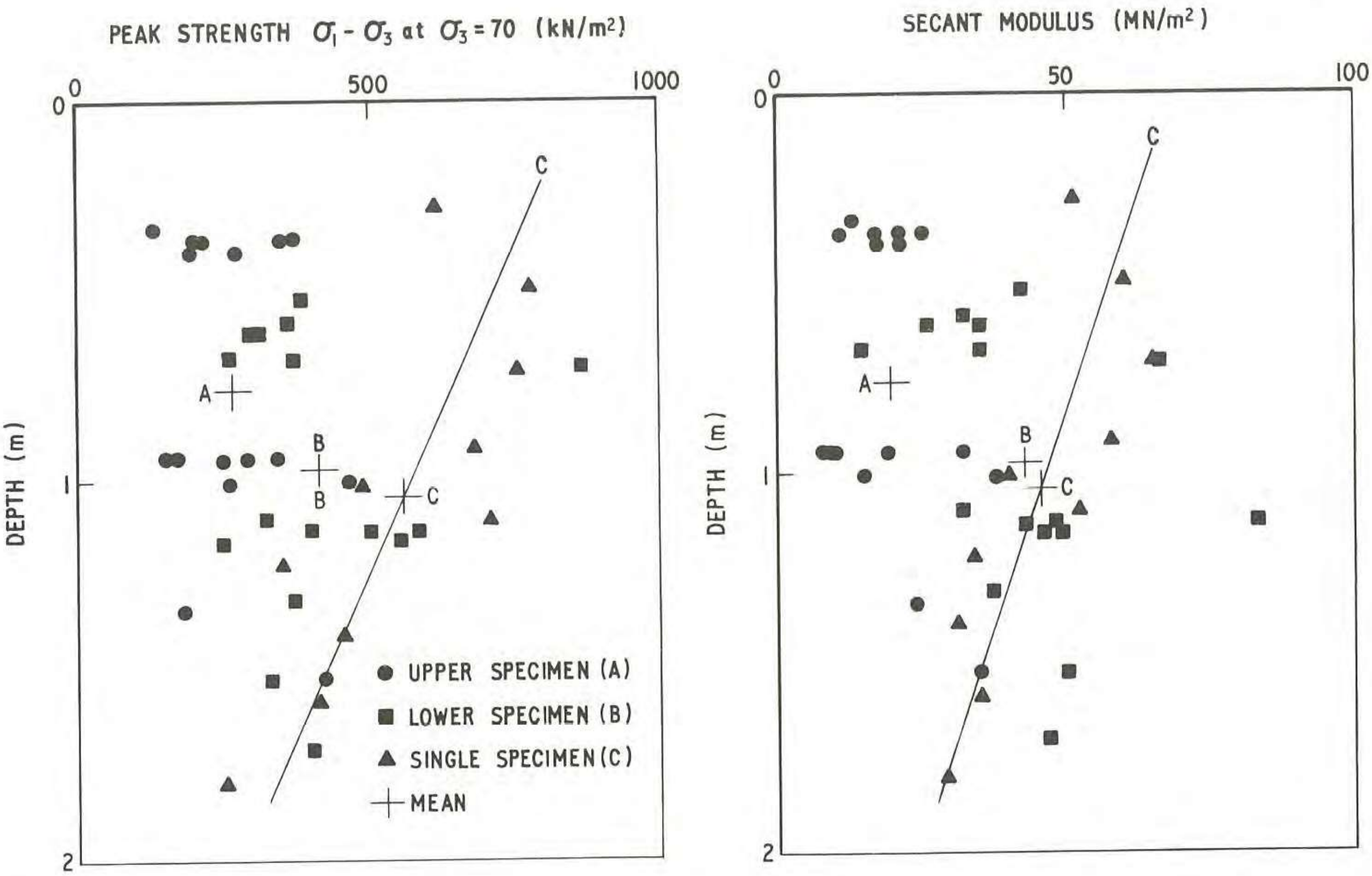

Fig. 4.- Syndal Site: Peak strength and secant modulus of elasticity for different types of specimen against depth.

plotted against depth. In these figures the points for the upper specimens, lower specimens or single specimens are differentiated. Mean points for each set are marked and when the correlation is statistically significant, the regression line for a set of values against depth is also shown.

From the records obtained during the sampling operations at Greenvale, the peak axial forces applied to the sampler during the intervals that the upper and lower parts of a sample were entering the sample tube have been determined. In Fig. 5 the secant modulus of test specimens is shown against the force applied while the sample was entering the sample tube. It is seen that there is no correlation between these variables. However, when the secant modulus is plotted, as in Fig. 6, against the force applied in the interval immediately before the sampling of the part of the sample being considered, then a significant, negative correlation is found, with the secant modulus decreasing as the force increases. Apparently, the application of high forces during the time that a particular part of a sample was being cut did not affect *that* part of the sample, but after a sample jammed in the sample tube the soil zone below the sampler was subjected to shear failure as the sampler was forced down to the designated sampling depth. Because the sampling was *continuous*, this shear failure zone would lie in the material from which the upper part of the next sample would be cut and would account for the lower values of the corresponding test specimens. Thus the variations within a tube sample were not influenced very much by what happened during the taking of a sample, but were influenced considerably by what had happened during the previous sampling operation. For sampling Pattern B (short samples), there would have been less prior disturbance of this nature because the forces applied were lower. While the possibility of this prior disturbance mechanism has been recognized previously (Ref. 1), this present experimental work provides some positive evidence of its significance.

The relationship of the single specimens to the pairs is not consistent for peak strength. For Syndal clay, the single specimen mean is higher than that of upper or lower specimens of pairs, but for Greenvale the single specimen mean lies about midway between the other two.

VII.- CONCLUSION

The results of the experimental investigation are generalized and consolidated in Table II.

This table shows a negative association between secant modulus and force applied *prior* to sampling, but no association between secant modulus and force during sampling.

This result is contrary to initial expectation and suggests that prior disturbance of a soil sample was the dominant cause for the difference in values obtained for upper and lower specimens, particularly

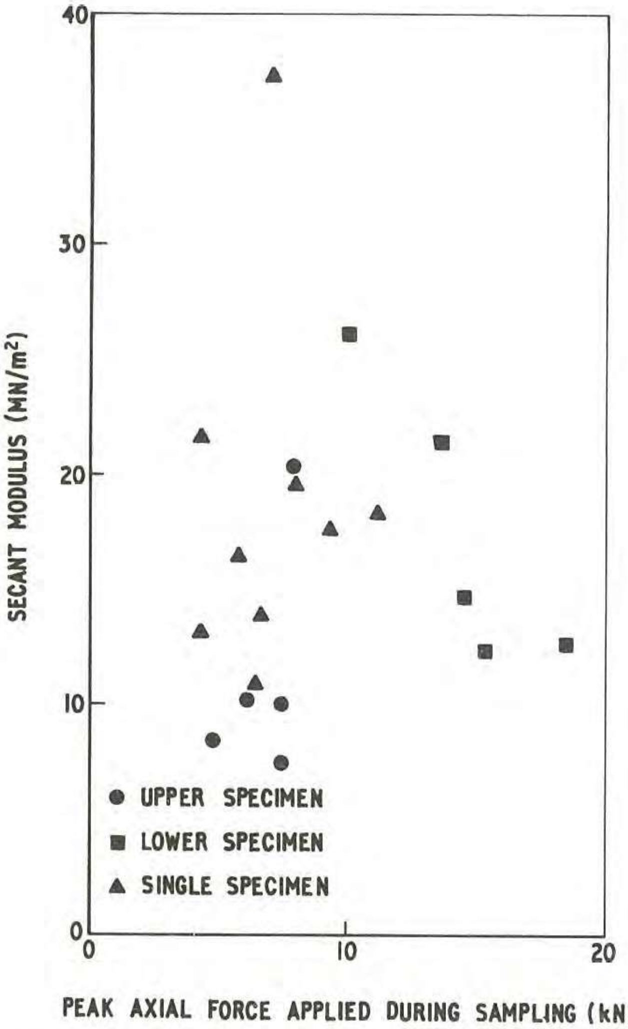

Fig. 5.- Influence of force applied during sampling on secant modulus of elasticity of specimens.

in view of the fact that *continuous* sampling was used in all the tests. Before a sample was taken, the upper zone of the depth to be sampled had already, in some cases, been disturbed by the final stages of the previous sampling operation.

TABLE II

CONSOLIDATION OF RESULTS

Type of Specimen	Forces Applied to Sampler		Secant Modulus
	During Sampling	Prior to Sampling	
A. Upper	Low	High	Low
B. Lower	High	Low	High
C. Single	Low	Low	High

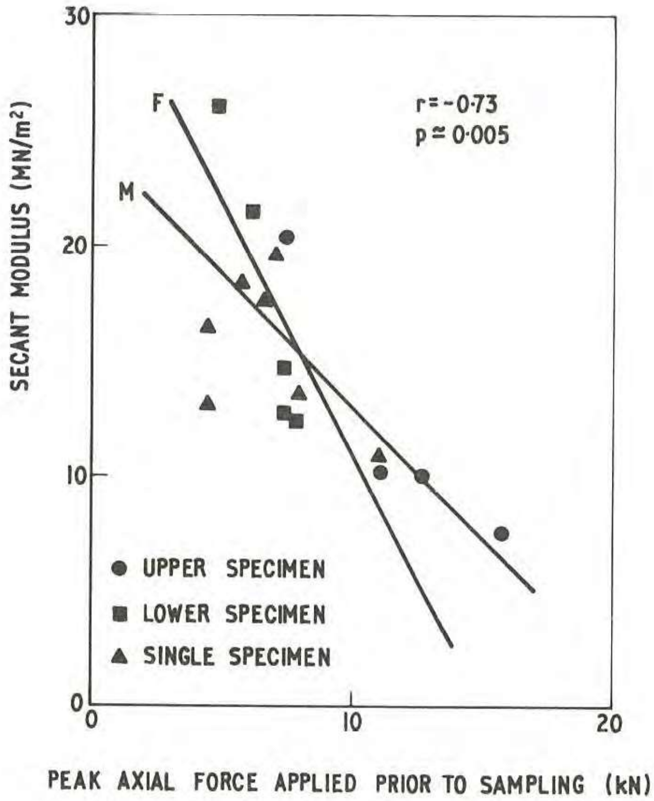

Fig. 6.- Influence of force applied prior to sampling on secant modulus of elasticity of specimens. (F is regression line for force, M for modulus.)

In the present work the influence of prior disturbance has not been investigated directly. A possible extension would be to use a pattern similar to Pattern A (long samples) but to space the samples and carefully remove the potentially disturbed material from below one sample before taking the next sample. This next sample would then be from ground not subjected to prior sampling forces.

On the basis of the results obtained, and the suggested cause, it follows that the test results from lower specimens of pairs, cut from the same tube sample, give a better indication of the true conditions in the ground, particularly when secant modulus of elasticity is the property being examined. For peak strength, the position has not been so well defined, but in the absence of other evidence, it is considered that the same conclusion may reasonably be applied for practical purposes.

VIII.- ACKNOWLEDGEMENT

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