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A SIMPLE MODEL FOR THE LONG TERM SWELL-SETTLEMENT VALUES OF TRINIDAD CLAYS

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ABSTRACT

Expansive soils occupy a major portion of Trinidad. Their swelling nature and settlement behaviour have an important bearing on foundation design. The long term values of swell and settlement include secondary effects, the determination of which is time-consuming and complex. A simpler method of obtaining these quantities quickly and accurately will greatly help in the preliminary design of foundations. This paper is an attempt to fit the hyperbolic model to the test data. The results have adequately validated the applicability of this simple model to represent the long term swell-settlement characteristics of local soils.

1.0 INTRODUCTION

Settlement computation is a basic criterion for foundation design. The settlement behaviour of clays is a time dependent phenomenon and hence has to be studied with respect to both load and time. Neglecting the immediate settlement, the long term settlement of clays is the sum of the primary and secondary consolidation settlements. The primary consolidation settlement is computed using Terzaghi's theory. The computation of the secondary component is complex and cumbersome. As a result, in normal design practice, the secondary consolidation is ignored, being a small fraction of the primary component. However, it has been observed that [6] the seconxdary component may be significant especially in plastic clays, water softened clays, clays with organic content and expansive clays. Hence, ignoring its impact on the foundation behaviour may lead to erroneous results.

Another basic criterion of foundation design deals with soils exhibiting volume changes with variation in moisture content. Such soils have to be first identified, based on the degree of potential swell, and appropriate techniques of stabilising them or of designing and constructing suitable foundations should then be adopted. As there is ample evidence of extensive structural damage to buildings and pavements due to the expansive nature of the clays in Trinidad, this aspect of evaluating their potential swell assumes special importance. The potential swell of soils can also be treated as consisting of a primary part and a secondary part as illustrated in Figure 1. Separation of these parts is achieved by Casagrande's logarithm of time method (also shown in the figure).

If the probable magnitudes of the long-term, or the ultimate, values of these swell and settlement characteristics of the foundation soils are known in advance, appropriate design and construction criteria can be established for the foundation and the structural components of the structure. Determination of these values using oedometer tests is a time-consuming and difficult procedure. Thus, there is need for a simple model to predict these values to aid preliminary foundation and structural design.

In this paper a simple hyperbolic relationship is presented for the quantitative determination of the ultimate values of swell-settlement characteristics of Trinidad clays.

2.0 HYPERBOLIC MODEL

The hyperbolic relationship is used to represent stress-strain and other soil characteristics [3,7,8]. The expression used relates to a rectangular hyperbola with two constants. In this paper its application is extended to the swell-settlement behaviour of clays. The swell and settlement values, for any given pressure intensity, are measured against time and these quantities are related using the hyperbolic relation as follows:

$$S = (t/a+bt) \quad (1)$$

where s = swell or settlement

t = time

a,b are the two constants

Transposing this equation as,

$$(t/s) = a+bt \quad (2)$$

indicates that the ratio (t/s) is a linear function of t. If values of (t/s) are plotted against t, the resulting plot would be a straight line. This type of plot is known as the transformed plot. The constant, a, represents the intercept on the y-axis while, b, represents the slope of the straight line. In the above equation, if t is equal to infinity (long term) it reduces to:

$$s_{ult} = (1/b) \quad (3)$$

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which means that the ultimate value of swell or settlement is given by the reciprocal of slope of the transformed plot.

3.0 SOIL TESTS

Three clays from central and southern regions of Trinidad were used in the present investigation. All are overconsolidated silty clays exhibiting high plasticity. Some of the engineering properties of these soils are shown in Table 1. Consolidation and swell tests were performed on undisturbed samples extracted from a depth of 1m below ground level, which is the normal depth for shallow foundations. A fixed-ring oedometer of dimensions: 606 mm dia. and 19 mm height was used for this purpose. In the case of consolidation tests, the soil sample was subjected to an initial load of 16 kN/m^2 before saturating it to simulate in-situ overburden effects. After the sample was inundated, load increments were applied in the order of 64, 128, 256 and 512 kN/m^2, and the settlement dial gauge readings were recorded for each of these loads at predetermined time intervals. The load increments were applied and sustained over a considerable time until most of the secondary consolidation was complete.

In the swell tests, the soil sample was subjected to an initial load of 16 kN/m^2 and when the sample was fully compressed under this load, it was saturated with distilled water. The swell of the sample was measured, using a dial gauge reading to 0.0025mm (0.0001 in.), at predetermined time intervals until there was no further swell. The results of these swell/settlement tests are presented in Figures 3 to 5 along with the corresponding transformed plots.

4.0 ANALYSIS OF TEST RESULTS

From the time-settlement and time-swell curves and their transformed plots for the three soils, presented in Figure 3 to Figure 5, it may be clearly observed that the straight line variation is well exhibited in the transformed plots except at low values of time. This shows that the swell-settlement characteristics of the soils investigated are adequately represented by the hyperbolic relationship.

Using the slopes (b values) of the transformed plots for various applied pressures and equation (3), the ultimate values of swell and settlement were predicted and compared with the corresponding measured values. The results are tabulated in Table 2. The comparison showed a very close agreement between the predicted and experimentally measured values.

5.0 CONCLUSIONS

A simple hyperbolic model was used to represent the time-settlement and time-swell curves of local soils to predict their long-term values. The results confirmed the usefulness and validity of the hyperbolic model to predict the long-term swell and settlement of these soils.

The merits of the model are that (i) these values can be predicted fairly accurately and (ii) the tedious and time consuming oedometer tests can be made quick tests since only a few readings in the early phase of the test are needed to establish the two parameters of the transformed plots.

6.0 ACKNOWLEDGEMENTS

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TABLE 1
PROPERTIES OF SOILS TESTED

Silty Clays:

No.	Location	Soil Series	γ (kN/m^2)	w %	LL %	PL %	P_c (kN/m^2)
1.	GRAN COUVA (Telephone Exchange) Central Trinidad	575	18.2	26	93	65	88
2.	TABAQUITE (Senior Comp.) Central Trinidad	177	17.1	43	106	67	128
3.	BARRACKPORE (Senior Comp.) Central Trinidad	177	17.1	39	84	56	106

TABLE 2
PREDICTED AND MEASURED VALUES OF ULTIMATE SWELL AND SETTLEMENT

No.	Soil	NMC %	Pressure (kN/m^2)	b (mm^{-1})	Predicted value (mm)	Measured Value (mm)	Error %
			A. SWELL				
1	GRAN COUVA	17	16	0.21	4.76	4.70	+1.3
		21	16	0.30	3.33	3.15	+5.8
		26	16	0.64	1.56	1.60	-2.5
2	TABAQUITE	43	16	1.64	0.61	0.58	+5.2
3	BARRACKPORE	38	16	2.33	0.43	0.41	+4.9
			B. SETTLEMENT				
1	GRAN COUVA	26	64	6.00	0.17	0.20	-15.0
			128	2.22	0.45	0.48	-6.2
			256	1.17	0.86	0.85	+1.2
			512	0.75	1.33	1.32	+0.8
2	TABAQUITE	43	64	8.70	0.12	0.14	-14.3
			128	2.43	0.41	0.42	-1.9
			256	1.46	0.69	0.72	-4.2
			512	0.71	1.41	1.43	-1.4
3	BARRACKPORE	38	64	5.30	0.19	0.20	-5.0
			128	1.92	0.52	0.53	-1.9
			256	0.97	1.03	1.15	-10.4
			512	0.51	1.96	2.01	-2.5

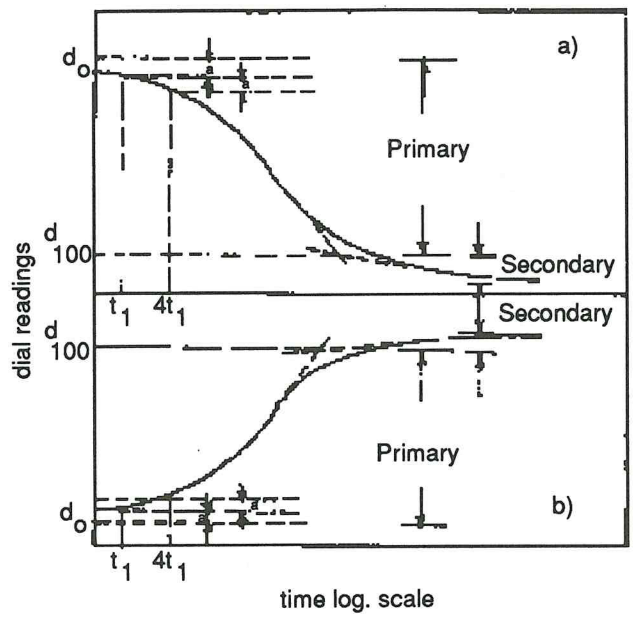

Figure 1. a) settlement b) swell curves

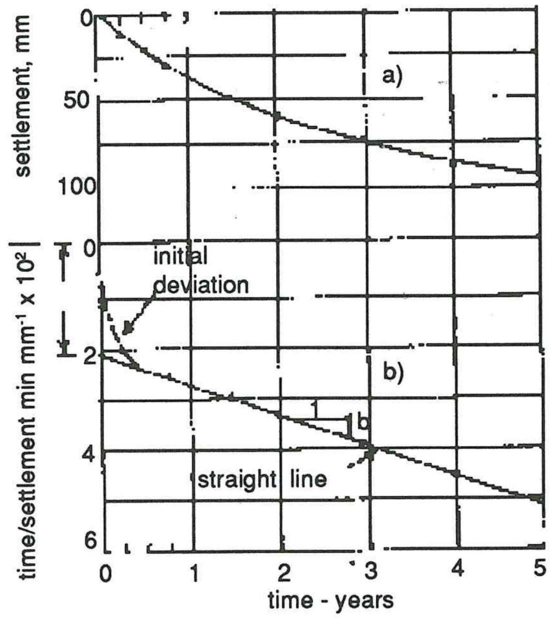

Figure 2 a) typical consolidation c
b) transformed plot

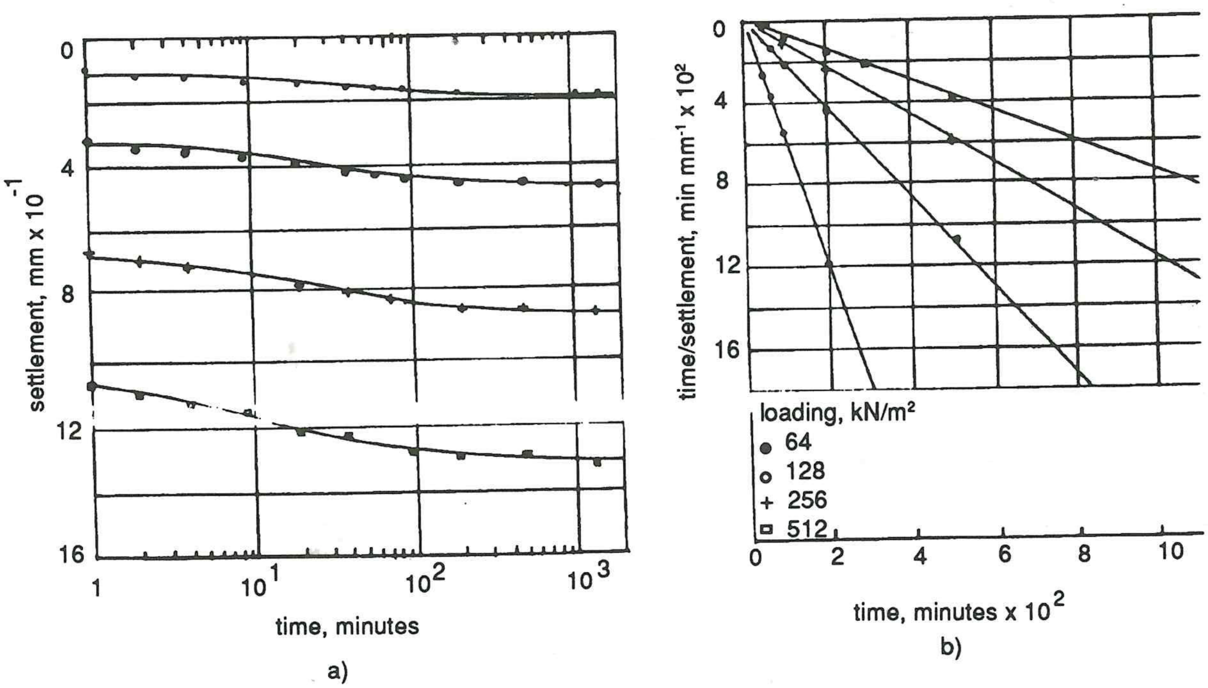

Figure 3: a) Time-Settlement b) Transformed plots of GRAN COUVA silty clays

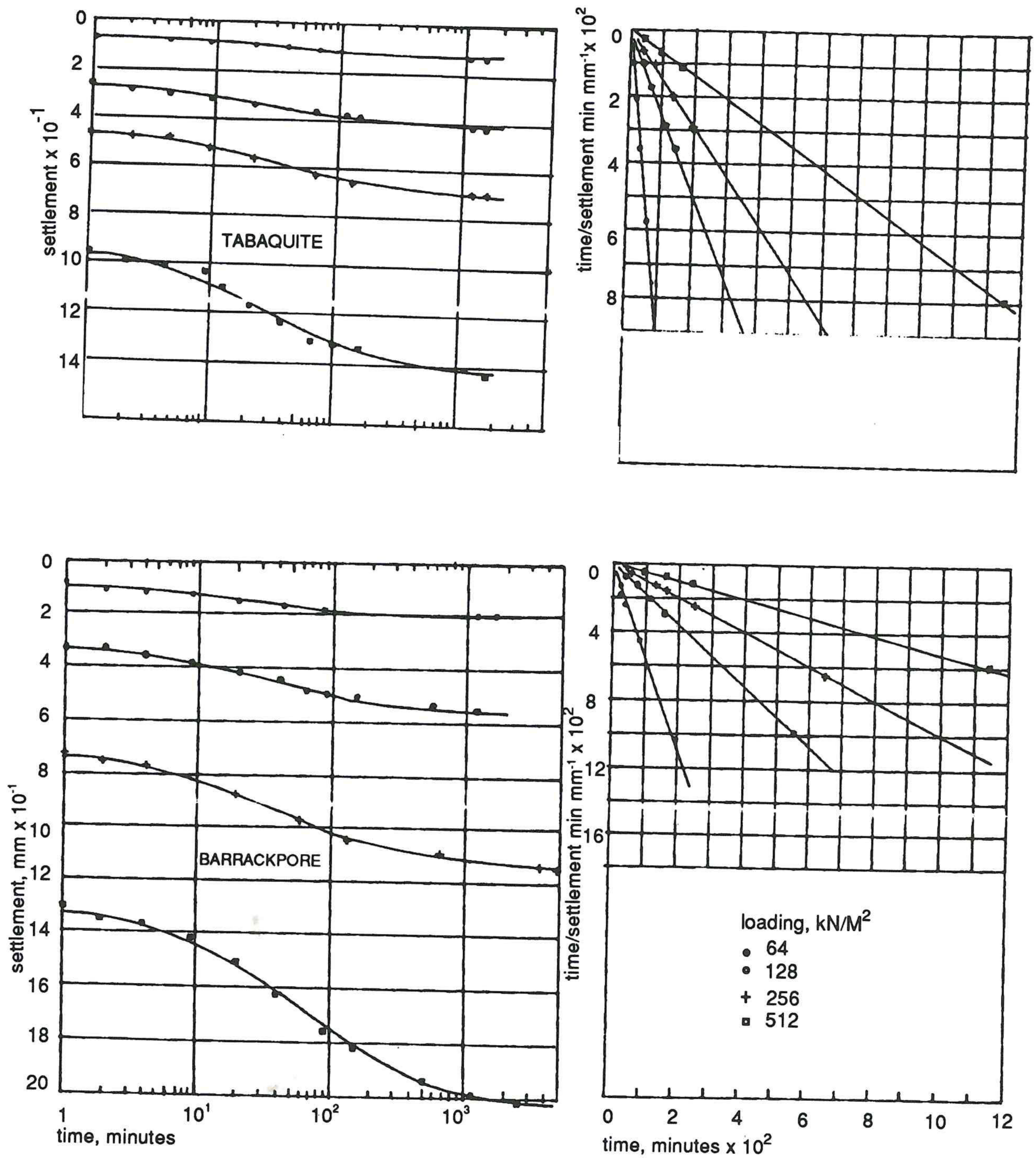

Fig. 4: Time-Settlement and transformed plots for

TABAQUITE and BARRACKPORE Silty clays

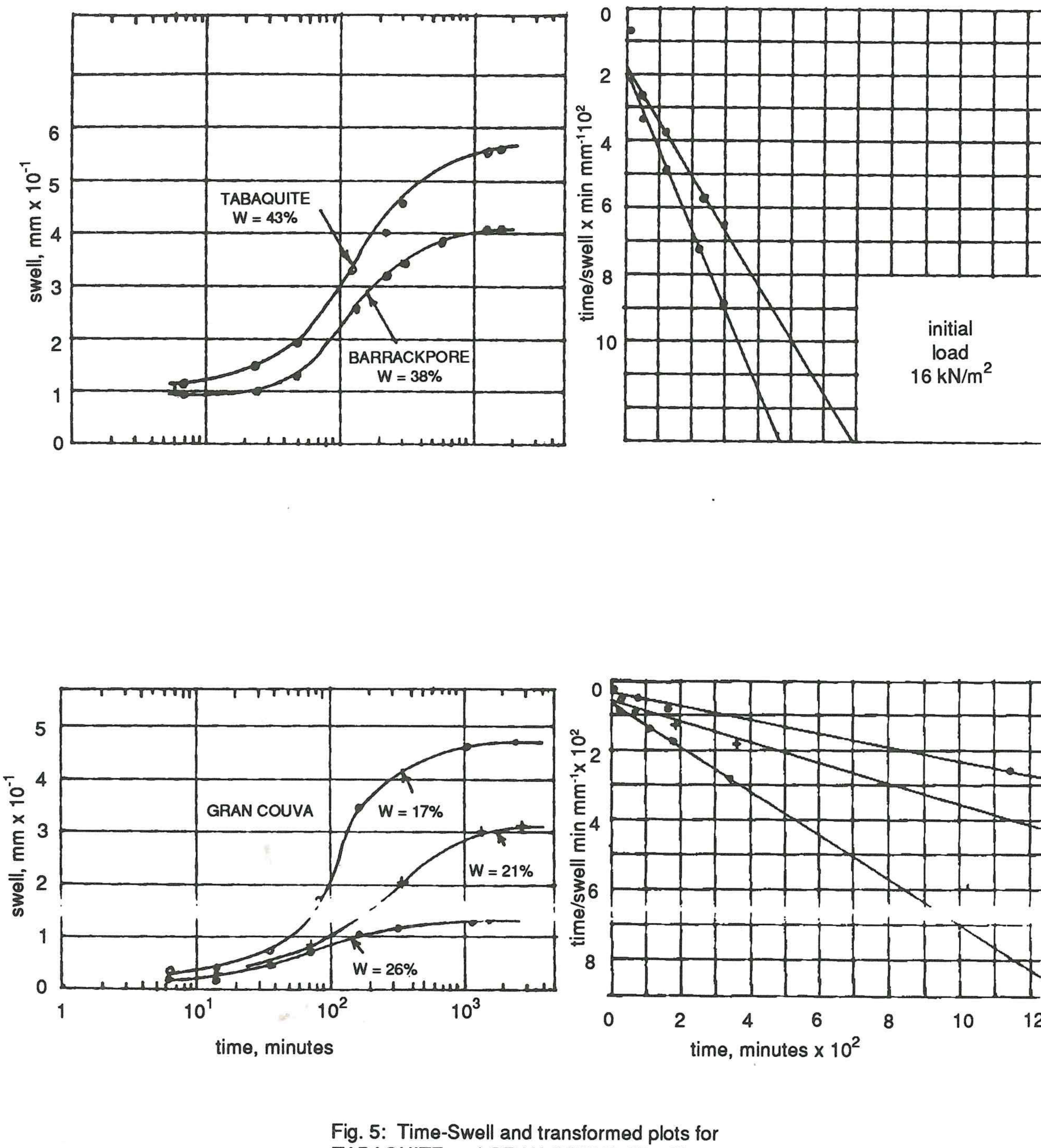

Fig. 5: Time-Swell and transformed plots for TABAQUITE and GRAN COUVA Silty Clays