Short Communication

Evaluation of Modulus of Deformation in Cohesive Soils During Shear

by

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Introduction

The growing application of finite element techniques to problems in soil mechanics in recent years has placed a greater emphasis on the accurate prediction of elastic parameters of soil from laboratory tests. It is well known that the modulus of deformation and poisson's ratio of soil do not remain constant, but are functions of many factors such as density, degree of over-consolidation, the magnitude of octahedral effective normal and shear stress, time, temperature, etc. (Ladd, 1964, Brown and Pell, 1967, Clough and Woodward, 1967). A survey of literature reveals the paucity of investigations on the variation in the values of the elastic constants of cohesive soils with different factors, especially level of the shear stress. In the present study, the decrease of deformation modulus of remoulded saturated clay with increase in shear stress during triaxial testing is investigated.

Experimental Work

The investigation was carried out on commercially available kaolinite ($LL = 63\%$, $PL = 33\%$). Saturated clay samples were obtained by consolidating the clay water slurry with water content twice that at liquid limit in a $305 \times 305 \times 305$ mm perforated brass mould. The final consolidation pressure reached was about 40 kPa. Isotropically consolidated triaxial compression and extension (drained and undrained) tests were conducted on samples of 38.1 mm diameter and 76.2 mm height. All testing procedures correspond to the methods detailed by Bishop and Henkel (1962). Tests carried out on specimens are listed below.

(*a*) Drained compression test, keeping σ_r' constant and increasing σ_a'

(*b*) Drained compression test, keeping octahedral effective normal stress, p, constant

(*c*) Drained extension test, keeping σ_r' constant and decreasing σ_a'

(*d*) Undrained compression test, keeping σ_r constant and increasing σ_a

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The paper is open for discussion till the end of May 1976.

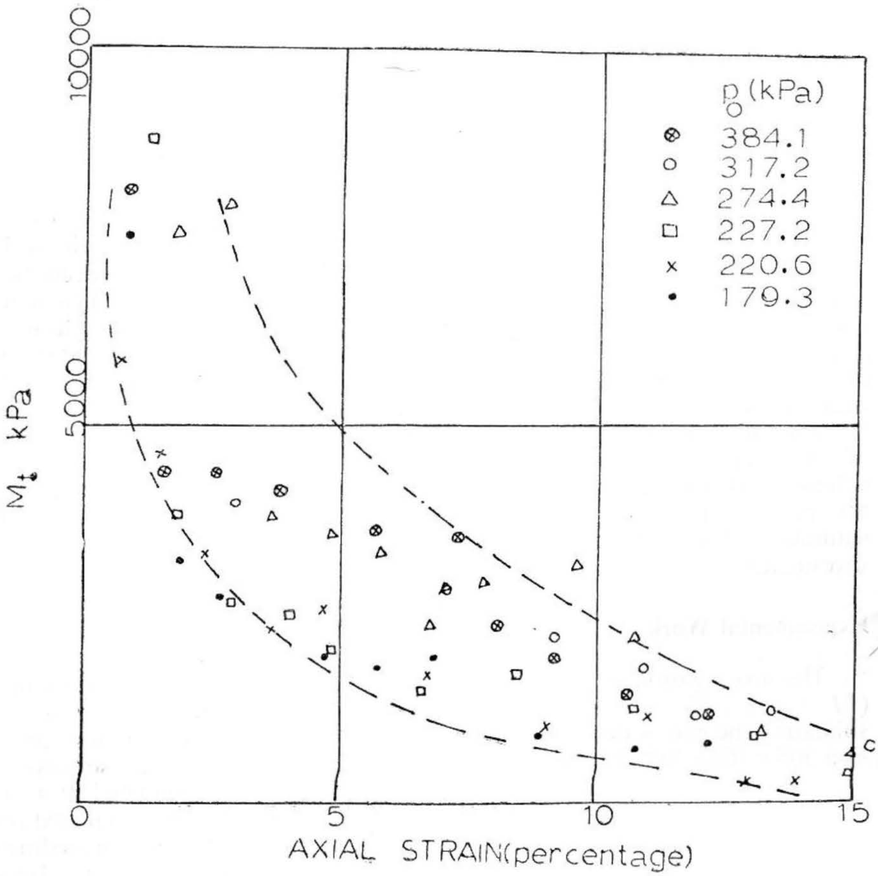

FIGURE 1. Variation of stress-strain modulus with axial strain, normally consolidated Kaolinite, $\frac{\Delta p}{\Delta q} = 0.33$

(*e*) Undrained compression test, keeping octahedral total normal stress, σ_m, constant.

Tests have been conducted on normally consolidated and overconsolidated kaolinite. Overconsolidation of the soil was achieved by consolidating the trimmed sample in the triaxial cell to a pressure of 456 kPa and then allowing to rebound to a pressure of 76 kPa. The samples were then recompressed to different cell pressures lower than 456 kPa before they were sheared. The shearing of the samples was done at a constant rate of strain.

Test Results

In the triaxial test conditions it can be shown from the three-dimensional stress-strain relationships that :

$$\epsilon_1 = \frac{1}{E}\left[\sigma_1 - 2v\sigma_3 \right] = \frac{\sigma_1 - \sigma_3}{E} + \frac{\sigma_3\,(1-2v)}{E}$$

where ϵ_1 = major principal strain

σ_1, σ_3 = major, minor principal stress

v = poisson's ratio

E = modulus of linear deformation

Except in case of confining stress held constant, the value of E is a function of deviator stress change as well as changes in cell pressure and poisson's ratio. Hence, because of the uncertainity in the determination of poisson's ratio (Jakobson, 1957), the stress-strain modulus, M_t

$$\left[= \frac{d\,(\sigma_1 - \sigma_3)}{d\,\epsilon_a},\ \epsilon_a \text{ is the axial strain} \right]$$

has been computed for all stress paths.

Figure 1 reports a typical variation of the stress-strain modulus, calculated at each value of the axial strain, with the axial strain. In an attempt to linearise the $M_t - \epsilon_a$ curve empirically a relation of the form $\frac{P_o}{M_t} = a + b\epsilon_a$ has been found to be suitable. ($p_o = p$ at the commencement of shear). Figures 2(a) to 2(b) report the linearised plots for different test conditions. It has been seen that, up to 83 to 98 percentage of axial strain at failure, the relation holds good with a maximum error of +50% and −30%. The values of the constants a and b along with the values of the slopes of the stress paths, $\frac{\triangle p}{\triangle q}$, ($q = \sigma_1 - \sigma_3$) are reported in Table 1. Further studies are required to investigate the influence of factors such as rate of strain during shear, type and duration of consolidation, temperature, etc. on the constants a and b.

The applicability of the suggested relation for soils other than remoulded kaolinite also has to be investigated.

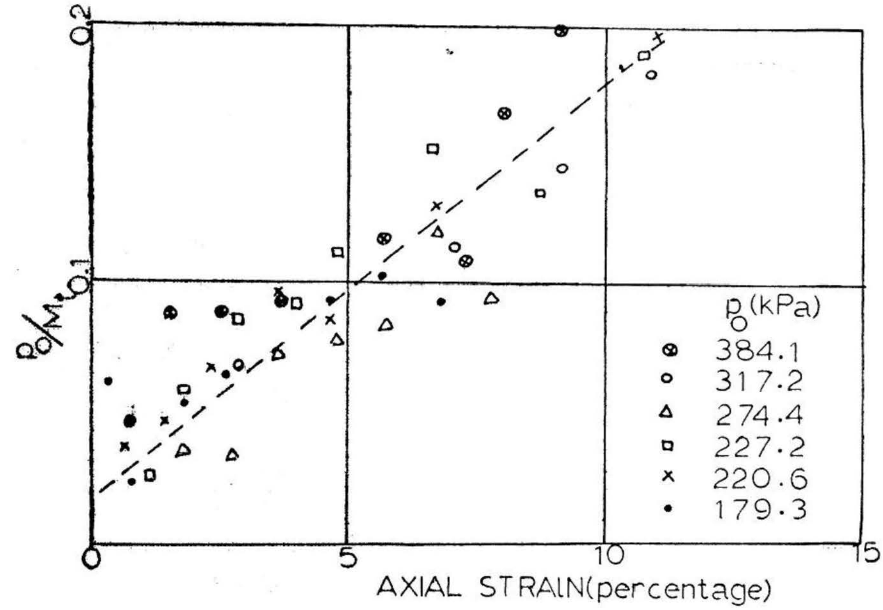

FIGURE 2a. **Linearised plot of stress-strain modulus and axial strain, normally consolidated Kaolinite,** $\frac{\Delta p}{\Delta q} = 0.33$

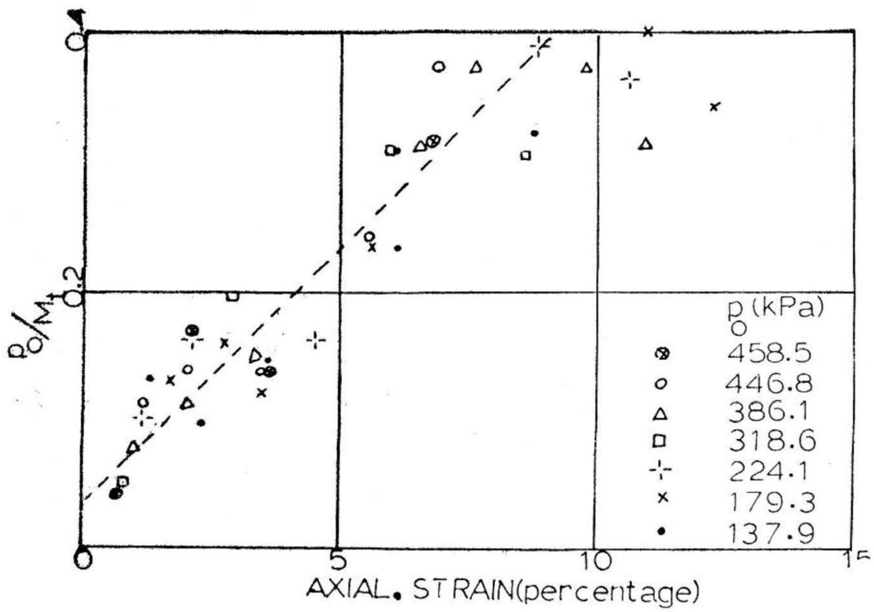

FIGURE 2b. **Linearised plot of stress-strain modulus and axial strain, normally consolidated Kaolinite,** $\frac{\Delta p}{\Delta q} = 0$

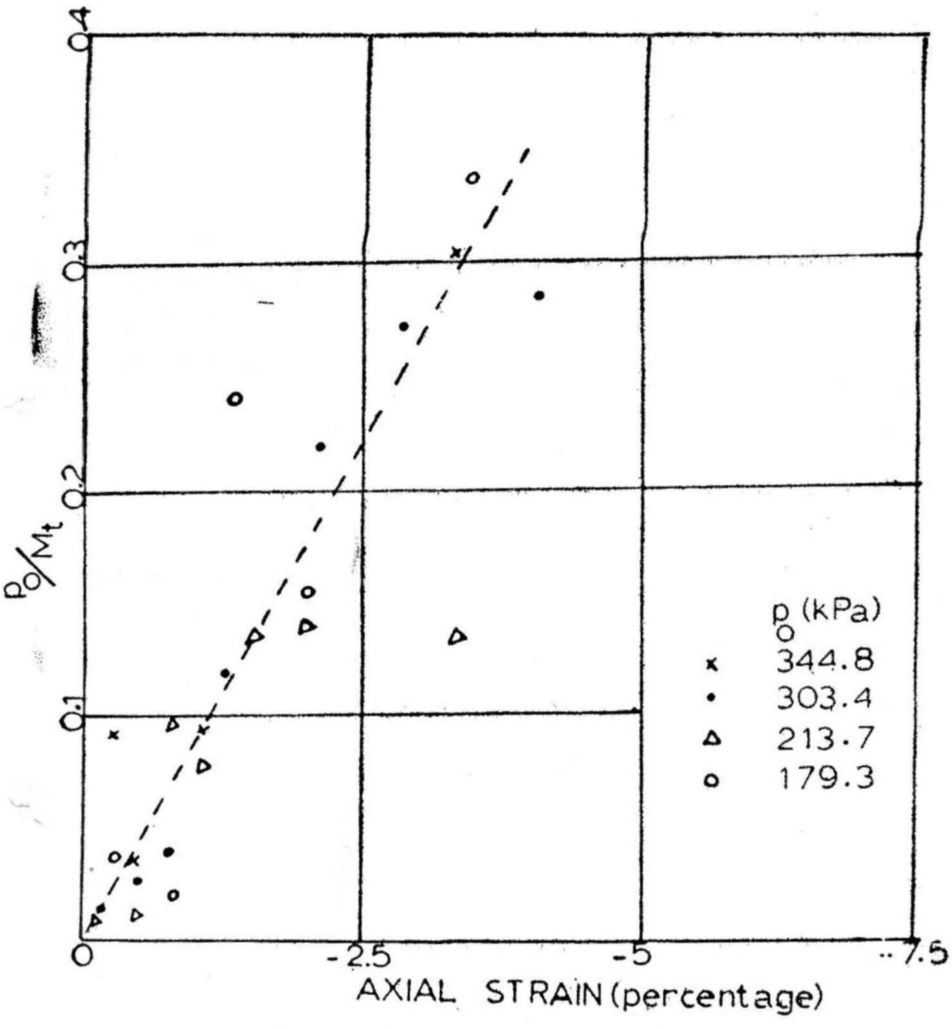

FIGURE 2c. Linearised plot of stress-strain modulus and axial strain, normally consolidated Kaolinite, $\frac{\Delta p}{\Delta q} = -0.33$ (Extension test)

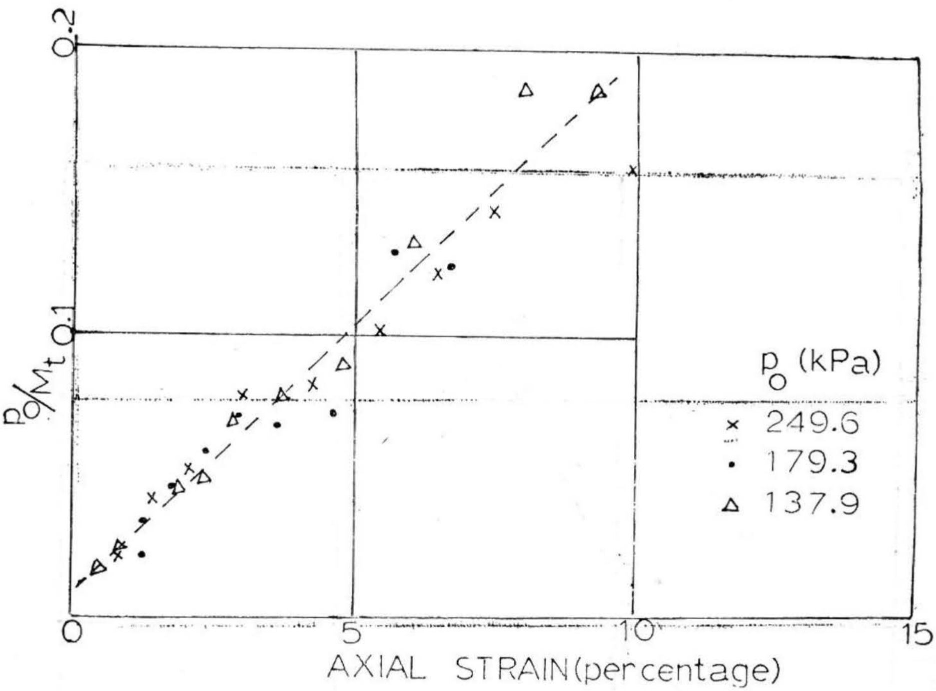

FIGURE 2d. Linearised plot of stress-strain modulus and axial strain, over consolidated Kaolinite, $\frac{\triangle p}{\triangle q} = 0.33$

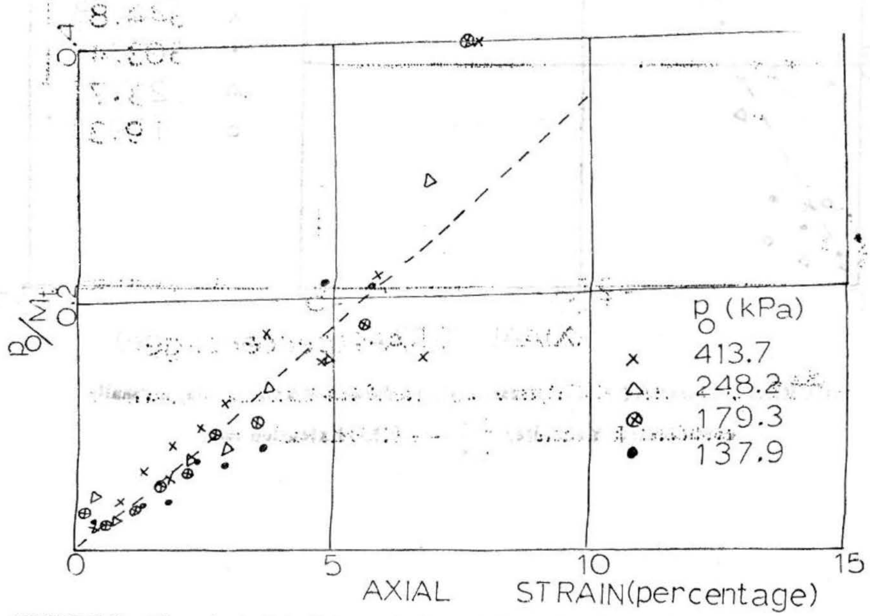

FIGURE 2e. Linearised plot of stress-strain modulus and axial strain, over consolidated Kaolinite, $\frac{\triangle p}{\triangle q} = 0$

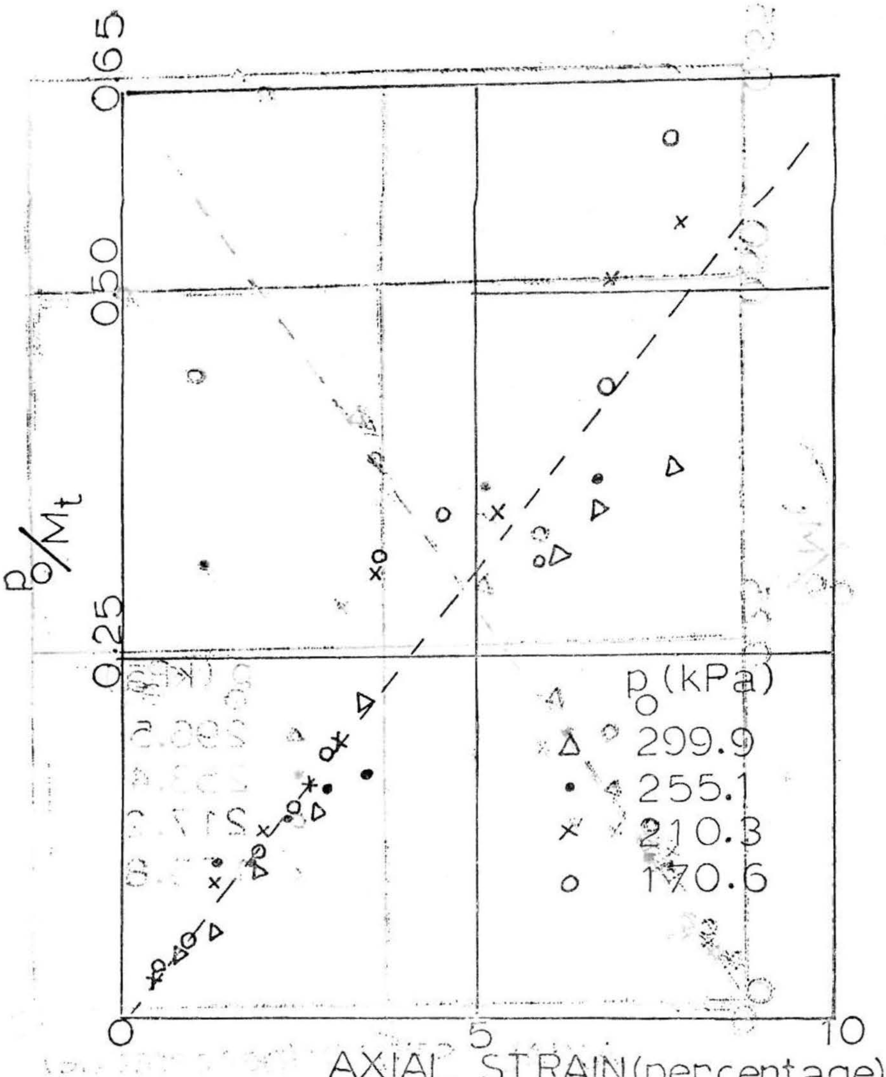

FIGURE 2f. Linearised plot of stress-strain modulus and axial strain, normally consolidated Kaolinite, $\frac{\Delta\sigma_m}{\Delta q} = 0.33$

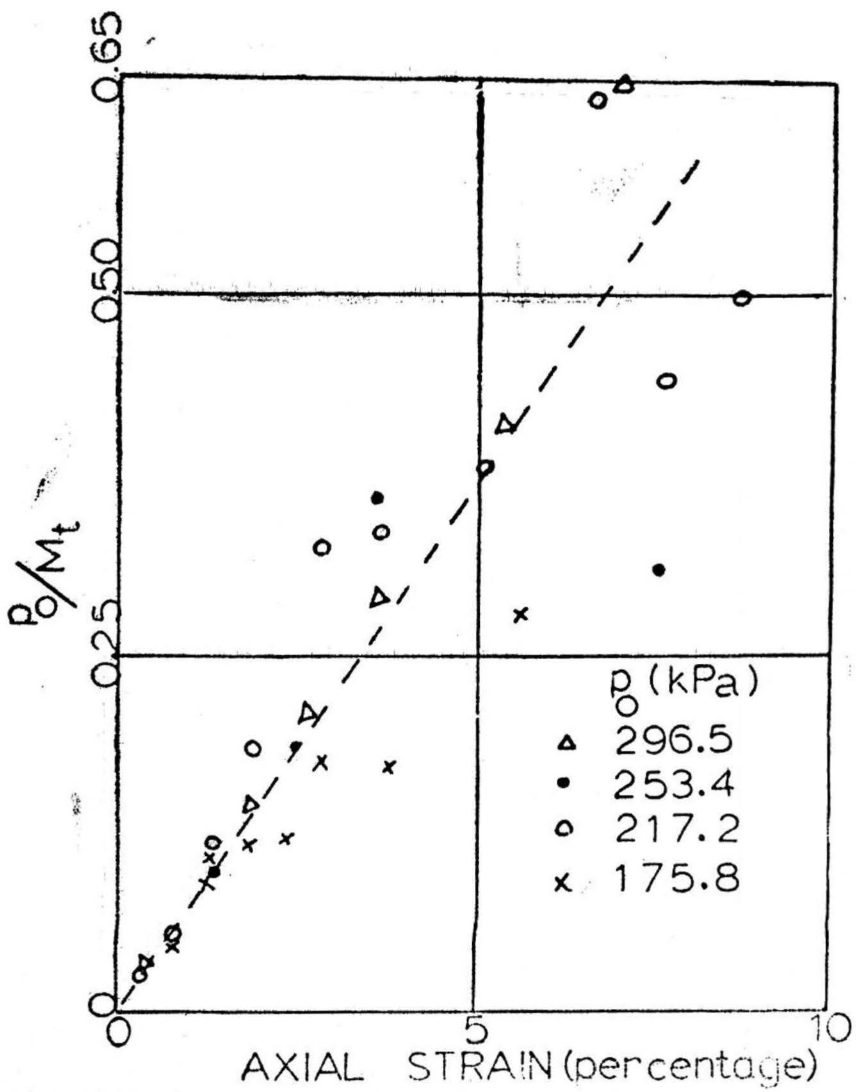

FIGURE 2g. Linearised plot of stress-strain modulus and axial strain, normally consolidated Kaolinite, $\frac{\Delta\sigma_m}{\Delta q} = 0$

TABLE 1

Soil-kaolinite

Stress history	Type of test	$\frac{\Delta p}{\Delta q}$ or $\frac{\Delta \sigma_m}{\Delta q}$	a	b
Normally consolidated	undrained	0.33	0	6.3
Normally consolidated	undrained	0	0	7.4
Normally consolidated	drained	0.33	0.016	1.6
Normally consolidated	drained	0	0.032	4.0
Normally consolidated	drained	—0.33 *(Extension)*	0	8.6
Overconsolidated	drained	0.33	0.008	1.9
Overconsolidated	drained	0	0	3.56

Acknowledgement

The experiments connected with this investigation were done at Indian Institute of Science, Bangalore, India. The manuscript of this paper was prepared at the Department of Civil Engineering, Queen's University of Belfast. Thanks are due to Professor A.A. Wells and Dr J.G. Stuart for their continuous support and encouragement.

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