THE DESIGN OF SHALLOW FOOTINGS ON EXPANSIVE SOIL

BY

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SUMMARY

A method of analysis for the prediction of soil movement and the design of shallow footings on expansive soil is developed from fundamental principles which define the nature of expansive soil and the soil-footing interaction. The developed concepts are modified by field observations of distorted footings, and a simple design table is presented.

A review of the commonly used methods of shallow footing design indicates a large variation in the bending moment calculated by each method. The variation is primarily a result of the assumed loading configuration and initial distorted soil shape.

The prediction of the magnitude of expansive soil movements is developed from fundamental concepts in terms of three constants; an Instability Index, defining the expansiveness of the soil; a Swelling Stiffness, defining the suppression of swell under load; and the Diffusion Coefficient, defining the movement of moisture through the soil. Laboratory methods are suggested to determine the Instability Index and Diffusion Coefficient. The effects of common causes of moisture change (such as garden watering, subfloor ventilation, tree root influence, expansive soil movements under a cover) can thus be predicted more confidently than previously possible. Observations of the behaviour of expansive soil under seasonal conditions support the developed concepts, though the prediction of water infiltration through fissures remains intractable.

The soil-footing interaction is examined by integration of the beam equation, and algebraic expressions for the bending moment and required stiffness in centre and edge heave are developed. A parametric study indicates that each of the design variables (i.e footing length, building loads, soil movement, structure flexibility, swell stiffness and shape of the initial distorted soil surface) affects the bending moment and required footing stiffness. Charts are developed from the algebraic expressions, and these are correlated with the observed behaviour of thirty-one problem raft footings. Modifications to the theoretical analysis, made in the light of the field observations, are incorporated into a simple design table for practical use.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university, and to the best of my knowledge and belief, contains no material previously published or written by another person, except when due reference is made in the text.

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PRINCIPAL NOTATION

A_o Rate of water uptake by tree roots

B Breadth footing area

C Support ratio

D Depth of raft subbeam

E Young's Modulus, footing material

G_s Specific Gravity

I Moment of inertia, footing

I_{pt} Instability Index

L Length of footing or covered area

M′ Effective ultimate moment capacity

M_u Ultimate moment capacity

M^- Hogging Bending Moment

M^+ Sagging Bending Moment

M_x Bending Moment about a point x on footing due to superstructure loads.

W Perimeter loads

W_L Perimeter Loads in long direction

W_B Perimeter loads in short direction

P Soil pressure; Perimeter load in PTI-Wray Method.

T Internal line loads at footing centre; Non-dimensional parameter $\alpha t/\ell^2$

T_L Internal line loads in long direction

T_B Internal line loads in short direction

Y Differential free soil heave across unloaded flexible structure

a Depth of soil over which suction varies (the active depth)

b Breadth of raft subbeam

c Moisture characteristic

d Soil displacement

e Void ratio; edge distance in Walsh, Swinburne & PTI-Wray Methods

h_t Total suction in cms water

h_m Matrix suction in cms water

h_s Solute suction in cms water

f Compressibility factor

g Lateral restraint factor

k Swelling stiffness

ℓ Length of a soil sample

m Exponent in equation defining soil surface under covered area (the shape factor)

p Unsaturated permeability

t Exponent in equation defining deflected shape of footing; time

u Total suction expressed as a pF

w Superstructural loads excluding perimeter and centre line loads per unit area footing; moisture content of soil

α Diffusion coefficient

δ Footing deflection

δ_o Displacement of origin footing profile from origin soil profile

Δ Maximum differential footing deflection

ω Superstructural loads per unit area footing

γ_d Dry density

ε_{vert} Vertical strain