International Congress on Computational Methods in Engineering
May 2 - 6 1993
School of Engineering
Shiraz University

بسمه تعالی

کنگره بین‌المللی روشهای محاسباتی
در مهندسی
۱۲ الی ۱۶ اردیبهشت ۷۲
دانشکده مهندسی
دانشگاه شیراز

COMPUTERIZED STATIC AND DYNAMIC PASSIVE EARTH PRESSURES BY THE METHOD OF ASSOCIATED FIELDS

PART I

L. Behpoor and A. Ghahramani
Faculty Members, School of Engineering
Shiraz University, Shiraz, Iran
and
A. Fakhimi
Shiraz University, Shiraz, Iran

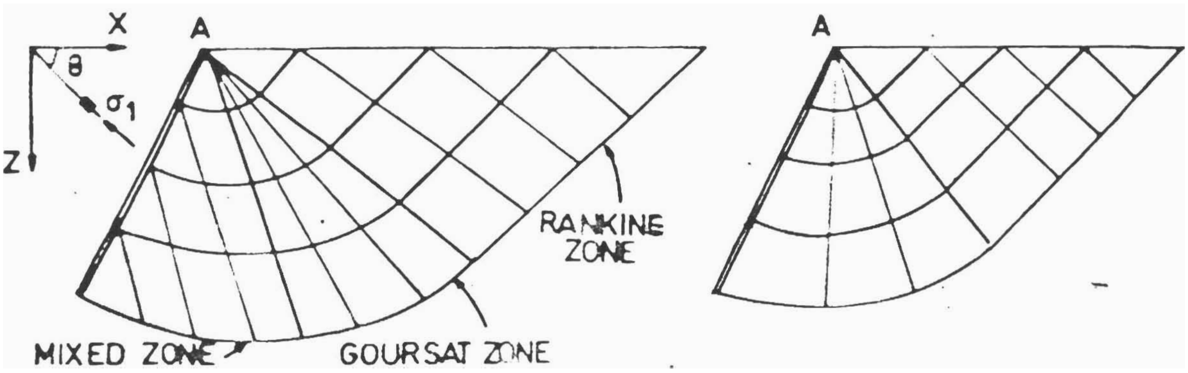
The method of associated fields relating the field of stress characteristics to the field of strain characteristics by using soil properties and boundary conditions has been computerized. This computerized scheme makes possible the evaluation of the static and dynamic passive earth pressures on retaining walls of various shapes. Furthermore the computerized solution makes possible the evaluation of the pressure as a function of wall movements. The computation difficulties of using radial acceleration and the instability problem of characteristics fields have been removed. The results of computations compare favorably with the experimental earth pressure measurements. In part I the theoretical basis is discussed, and in part II results and discussion are presented.

INTRODUCTION

The method of associated fields was first proposed by Roscoe [1] in the solution of earth pressure problems of sandy soils. Given a retaining wall and its friction angle with the soil, an initial stress field is evaluated using the soil parameter ϕ (the angle of internal friction). Then boundary displacements are introduced and field of strain characteristics or zero extension lines (lines with linear strain equal to zero) are evaluated. By using the strain field, the angle of dilation ν and new angle of internal friction ϕ are evaluated. The name of associated fields stems from stress characteristics field and zero extension line field and their association through the angle of friction ϕ and angle of dilation ν. The calculations of these fields are iterated until convergence is achieved. Now new displacements will be given to the wall and through iteration of associated fields, the response is further evaluated. Thus the method is capable of evaluating both static and dynamic earth pressures.

REVIEW OF PREVIOUS WORKS

The associated fields method was used by Serrano [2], James, Smith and Bransby [3] to solve static earth pressure problems. The extension of the method to dynamic problems was carried out by Sabzevari and Ghahramani [4]. Later the simplified method of zero extension line was extensively developed by the authors [5, 6 and 7]. The present paper deals with the theory of static and dynamic passive earth pressure problems. In part II the results and discussion will be presented.



(a) (b)

Fig. 1. (a) Stress characteristics and (b) Strain characteristics

THEORY

Given a retaining wall shown in Fig. 1, there are two stress characteristics directions:

$$\frac{dz}{dx} = \tan(\theta - \mu) \tag{1}$$

and

$$\frac{dz}{dx} = \tan(\theta + \mu) \tag{2}$$

where

$$\mu = \frac{\pi}{4} - \frac{\phi}{2} \tag{3}$$

and θ is the angle of direction of major principal stress with x-axis. If S is $(\sigma_1 + \sigma_3)/2$ and X and Z are body forces (which can be gravity or inertia force in the dynamic case) in the x and z directions, it can be written:

$$dS - 2S\tan\phi d\theta = (X - Z\tan\phi - S\frac{\partial\phi}{\partial z})dx + (Z + X\tan\phi + S\frac{\partial\phi}{\partial x})dz \tag{4}$$

$$dS + 2S \tan\phi d\theta = (X + Z \tan\phi + S \frac{\partial\phi}{\partial z})dx$$

$$+ (Z - X \tan\phi - S \frac{\partial\phi}{\partial x})dz \quad (5)$$

It is clear that if the boundary stresses are given then the field of stress can be calculated behind the retaining wall.

For the displacement field again there are two directions:

$$\frac{dz}{dx} = \tan(\theta - \xi) \quad (6)$$

$$\frac{dz}{dx} = \tan(\theta + \xi) \quad (7)$$

where

$$\xi = \frac{\pi}{4} - \frac{\nu}{2} \quad (8)$$

and ν is the angle of dilation.

$$\sin\nu = - \frac{\delta V}{\delta \gamma} \quad (9)$$

where δV is volumetric change and $\delta\gamma$ is shear strain increment. Along the lines we will have:

$$du\, dx + dv\, dz = 0 \quad (10)$$

where u and v are displacements along x and z axes respectively. It is agian clear that if boundary displacements of the wall are given, u and v can be calculated throughout the field.

The displacement field can be used to calculate strains and using the relations for ϕ and ν[8]:

$$\sin\phi = \frac{18\gamma + 0.4}{30\gamma + 1} \quad \text{(loose sand)} \quad (11)$$

$$\sin\phi = 0.56 + \frac{4.61\gamma - 0.11}{193\gamma^2 + 1} \quad \text{(dense sand)} \quad (12)$$

$$\sin\nu = \sin\phi - 0.58 \quad \text{(loose sand)} \quad (13)$$

$$\sin\phi = 0.53 + 0.536 \sin\nu \quad \text{(dense sand)} \quad (14)$$

the two fields can be associated with each other.

For dynamic problems

$$X = \rho\ddot{u} \quad (15)$$

$$7 = -\gamma + \rho v \qquad (16)$$

where ρ is density and γ is the unit weight and during each increment of time the acceleration is assumed to be constant.

THE COMPUTER PROGRAM DEVELOPED

The computer program for evaluation of static and dynamic earth pressures is composed of three basic routines:
Routine X, Routine Zero and Routine Displ2.

Routine X

The program uses the information: angle of internal friction $\phi(x,z)$, soil density $\gamma(x,z)$, and the inertial forces $\rho\ddot{u}$ and $\rho\ddot{v}$ to calculate the stress field. At the beginning of the program, the values of ϕ, γ, $\ddot{u}$ and $\ddot{v}$ are specified at the grid coordinates (DELTAX and DELTAZ). The grid coordinates were chosen to facilitate the transfer of information between stress characteristics and strain characteristics. Because these fields in general do not coincide, the grid coordinates are used to avoid lengthy interpolation. Furthermore because partial derivaties such as $\partial\phi/\partial x$ and $\partial\phi/\partial z$ are needed in calculations, the grid assignment makes evaluation of these partial derivaties simple. Thus for a point such as M inside the grid, ϕ is linearly interpolated from the known values of ϕ at surrounding triangle rpq and partial derivatives are also evaluated as constants in this triangle (Fig. 2).

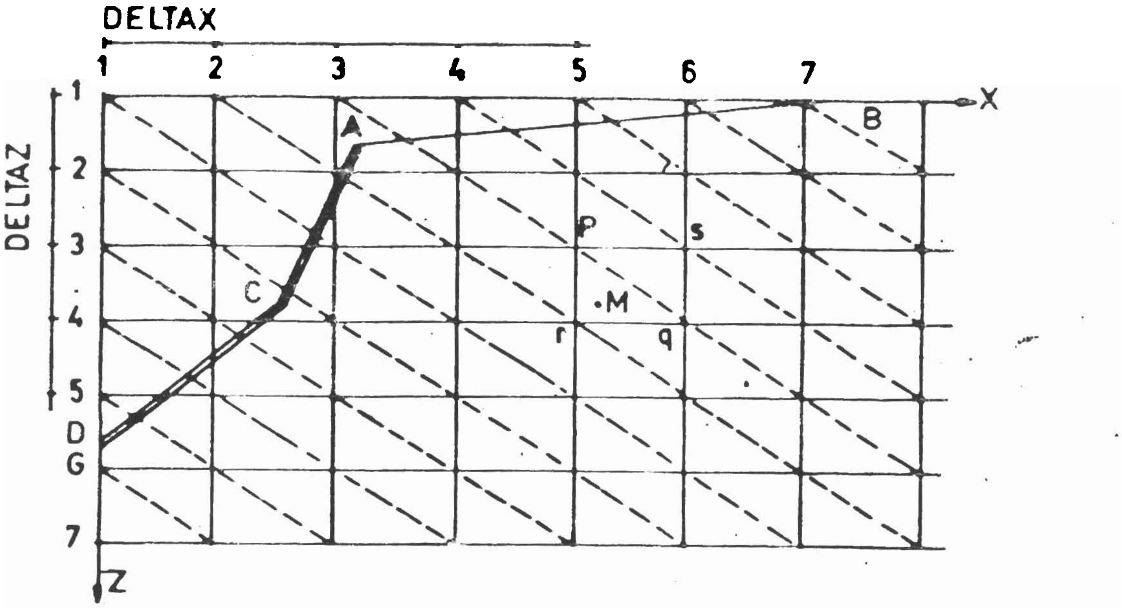


Fig. 2. Grid coordinates

The known boundary condition on free surface AB can be used to evaluate the stresses at Rankine, Goursat and mixed zones. At each point such as M located at the intersection of two characteristics, using Equations 1 to 5, the quantities $\theta(M)$, $S(M)$, $x(M)$ and $z(M)$ are calculated. For better accuracy, modified Euler method is used. After evaluating θ, the quantities θ_1 and θ_2 are computed using:

$$\theta_1 = \frac{\theta + \theta_1}{2} \tag{17}$$

$$\theta_2 = \frac{\theta + \theta_2}{2} \tag{18}$$

in order to evaluate x, z, θ and S more accurately. To propagate the information at point M, such as θ, to the grid, each quantity at point M is equally distributed to the nodes r, p and q and the number of θ's referred to a point is determined. Finally θ is calculated at node as sum of total θ's referred to the point divided by the number of referals.

Thus at the end of X Routine, in addition to evaluation of state of stress, θ is calculated at the the grid points.

The angle of friction between the wall and the soil δ can be taken as a fraction of φ. For quite rough wall δ= (2/3)φ and for normal wall δ= (1/3)φ.

Routine Zero

This routine calculates the zero extension line net. The angle of dilation ν at the grid points should be known. Thus the zero extension line net can be calculated starting from the wall assuming in rough cases that the wall itself is a zero extension line.

Routine Displ2

This routine is used to calculate the displacement, velocity and acceleration at the field of zero extension line. Using the wall boundary conditions of u, v, $\dot{u}$, $\dot{v}$, $\ddot{u}$ and $\ddot{v}$, these quantities are calculated at the nodes of zero extension line and eventually propagated to the grid nodes.

Thus at the end of this routine, the increment shear strain δγ and volumetirc strain δV can be calculated at the grid points yielding the values of ν, angle of dilation, at the grid points.

Furthermore since total shear strain is also evaluated at the grid points using the values of γ and ν, the friction angle φ at the grid points can be evaluated.

The routines are used successively until convergence is achieved.

The program is capable of solving simple vertical or brocken back retaining walls (Fig. 3).

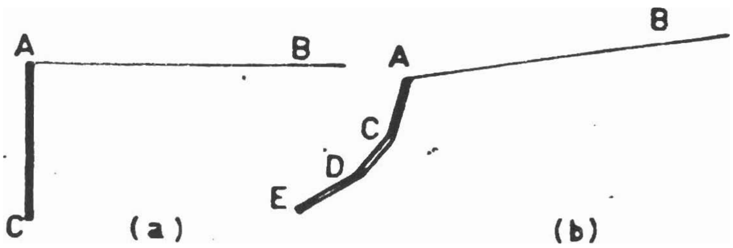


Fig. 3. (a) Vertical and (b) Brocken back walls

ACKNOWLEDGEMENT

The authors wisn to thank Mrs.Z. Sarmadi for her fine effort in typing the manuscript and Mr. Bodnam for drawing the figures.

REFERENCES

1. Roscoe, K.H., The influence of strains in Soil Mechanics, Geotechnique, Vol. 20, No. 2, 1970.

2. Serrano, A.A., The method of associated fields of stress and velocity and it application to earth pressure problems, Proc. 5th European Conf. on Soil Mech. and Foundation Eng., Vol. 1, pp. 71-84, Madrid, 1972.

3. James, R.G., Smith, I.A.A. and Bransby, P.L., The prediction of stresses and deformations in a sand mass adjacent to a retaining wall, Proc. 5th European Conf. on Soil Mech. and Foundation Eng., Vol. 1, pp. 39-66, Madrid, 1972.

4. Sabzevari, A. and Ghahramani, A., Dynamic passive earth pressure problem, Geotechnical Eng. Division, ASCE, Vol. 100, No. GT1, pp. 15-30, 1974.

5. Behpoor, L. and Ghahramani, A., Zero extension line theory of static and dynamic bearing capacity, proc. 8th Asian Regional Conf. on Soil Mech. and Foundation Eng., pp. 341-346, Kyoto, 1987.

6. Jahanandish, M., Behpoor, L. and Ghahramani, A., Load-displacement characteristics of retaining walls, Proc. 12th International Conf. on Soil Mech. and Foundation Eng., pp. 243-246, Rio de Janeiro, 1989.

7. Behpoor, L. and Ghahramani, A., Application of zero extension line in bearing capacity, Proc. 9th Asian Regional Conf. on Soil Mech and Foundation Eng., Vol. 1, pp. 19-22, Bangkok, 1991.

8. Fakhimi, A., The associated field method and its application in Soil Mechanics, M.S. thesis, Shiraz University, Shiraz, 1987.