In-situ Stress States in Soils

In geotechnical modeling problems, determination of in-situ stresses is of fundamental importance. For soils, vertical stresses can be readily determined, while horizontal stresses are much more difficult to establish.

The ratio of horizontal to vertical effective stresses in soil is known as the coefficient of earth pressure at rest, K_o:

$$K_o = \frac{\sigma_h'}{\sigma_v'}.$$

Coefficient of Earth Pressure at Rest for Normally Consolidated Soils

It has been established empirically that the value of K_o during one-dimensional normal compression (consolidation under which no lateral deformation occurs), known as $K_{o,nc}$, is constant for a given soil. Some of the most widely used relationships for estimating $K_{o,nc}$ are provided below:

Jaky (1944)

$$K_{o,nc} = \left(1 + \frac{2}{3}\sin\varphi'_{crit}\right)\left(\frac{1-\sin\varphi'_{crit}}{1+\sin\varphi'_{crit}}\right)$$

This can be approximated by the equation

$$K_{o,nc} = 1 - \sin\varphi'_{crit}$$

Brooker & Ireland (1965)

$$K_{o,nc} = 0.95 - \sin\varphi'_{crit}$$

Bolton (1991)

$$K_{o,nc} = \frac{1-\sin\left(\varphi'_{crit} - 11.5^\circ\right)}{1+\sin\left(\varphi'_{crit} - 11.5^\circ\right)}$$

Brick model

$$K_{o,nc} = \frac{\sqrt{2} - \sin\varphi'_{crit}}{\sqrt{2} + \sin\varphi'_{crit}}$$

Coefficient of Earth Pressure at Rest for Overconsolidated Soils

For overconsolidated soils K_o can be calculated from known values of $K_{o,nc}$ and OCR. Widely accepted formulas for calculating K_o include:

Wroth (1965)

$$K_o = OCR \cdot K_{o,nc} - \frac{\mu}{1-\mu}(OCR-1)$$

Schmidt (1966) (K_o for clays on unloading)

$K_o = K_{o,nc}(OCR)^{\alpha}$, where $\alpha = \sin(1.2 \cdot \varphi'_{crit})$

Meyerhof (1976) suggests $\alpha = 0.5$ is suitable for most soils for most practical purposes

Mayne and Kulhawy (1982) suggest $\alpha = \sin\varphi'_{crit}$

Pruska (1973)

$K_o = \frac{\sqrt{K_a} \cdot OCR}{1 - K_a \cdot (1-OCR)}$, where K_a is the Rankine active earth pressure coefficient

$K_a = \frac{1-\sin\varphi'}{1+\sin\varphi'}$, where φ' is the angle of internal friction

Typical Values of Coefficient of Earth Pressure at Rest, K_o

No.	Soil Type	K_o
1	Dense sand	0.35
2	Loose sand	0.6
3	Normally consolidated clays	0.5 – 0.6
4	Lightly overconsolidated clays	1.0
5	Heavily overconsolidated clays	3.0

References

Bolton, M.D. (1991). *A Guide to Soil Mechanics*. MD & K Bolton.

Brooker, E.W. and Ireland, H.O. (1965), "Earth pressures at rest related to stress history," Canadian Geotechnical Journal, Vol. 2, No. 1, pp 1-15.

Jâky, J. (1944), "A nyugalmi nyomâs tényezöje (The coefficient of earth pressure at rest)," Magyar Mérnok és Epitész Egylet Közlönye (Journal for Society of Hungarian Architects and Engineers), October, pp. 355-358.

Mayne, P.W. and Kulhawy, F.H. (1982), "K_o-OCR relationships in soil," Journal of the Geotechnical Engineering Division, ASCE, Vol. 108, GT6, pp. 851-872.

Meyerhof, G. G. (1976), "Bearing capacity and settlement of pile foundations," Journal of Geotechnical Engineering, ASCE, Vol. 102, GT3, pp. 197-228.

Prŭska, M.J. (1973), "Effect of initial stress on the stress-strain relation," Proceedings of the 8th International Conference on Soil Mechanics and Foundation Engineering, Moscow, Vol. 4, pp. 26-28.

Schmidt, B. (1966), "Discussion of 'Earth pressures at rest related to stress history' by Brooker & Ireland (1965)," Canadian Geotechnical Journal, Vol. 3, No. 4, pp. 239-242.

Wroth, C.P. (1975), "In situ measurement of initial stresses and deformation characteristics," Proceedings, In Situ Stress Measurement of Soil Properties, North Carolina State University, Geotechnical Engineering Division, pp. 181-230.