Hosking - Column Type Foundations

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Column type foundations are often adopted to support cantilevered posts subject to permanent and transient loadings, such as uprights for a sleeper retaining wall, or cantilever posts supporting a roof. Structural Toolkit offers two design modules that include methods to aid in the design these types of structures, being the Sleeper Walls and Post Footing modules.

This document outlines the Hosking method of column type foundation design for cohesive and cohesionless soils used in these modules, discusses possible criticisms of the methods, and additional options now incorporated into the design modules.

There is a range of technical publications and textbooks which present information specifically on pile type foundations subject to lateral loading including short piles (with an embedment on diameter ratio of less than 10-12), deep piles, fixed and free head. These include Broms (1964-1965), MJ Tomlinson (Pile Design and Construction Practice), Reese and van Imple (Single Pile and Pile Groups under lateral loading), and Brinch-Hansen (1961), amongst many others. Their applicability for small embedments and specifically long-term loadings may be the subject of further discussion depending on feedback.

Column Type Foundations

Hosking Approach

Applied Structural Design by Alan Hosking published in 1993 outlines a method for determining the ultimate overturning resistance of column type footing in cohesionless soil (c=0) and cohesive soil (ø=0°).

APPLIED STRUCTURAL DESIGN

by

A. K. Hosking

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The two methods are presented below:

For a "c - ϕ" soil, the equation becomes

$$\frac{\gamma h^2}{2}\left(\frac{1 + \sin\phi}{1 - \sin\phi}\right) + 2hc\tan\left(45° + \frac{\phi}{2}\right) \text{ kN/m run of face}$$

for footings which go to the surface of the soil.

The resultant of this resistance would be considered as acting at approximately 1/2 depth.

(b) The friction between the footing and the underlying earth, may, if desired, be regarded as assisting to resist horizontal displacement. This frictional force can be regarded as having an effective working value of

$$\frac{\text{net vertical reaction} \times \tan\phi}{4}$$

(Tan ϕ = μ is commonly taken as 0.45)

COLUMN TYPE FOUNDATIONS

Two cases occur:

(i) Non-cohesive soil.

(ii) Cohesive soil.

Case (i) Fig. 24(a)

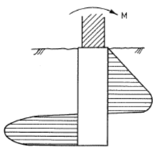

FIG. 24(a)

Assumptions:

(a) Soil is non-cohesive, unsubmerged, granular such that,

active pressure = $K_a \gamma h$

passive pressure = $K_p \gamma h$

(b) Soil movement is sufficient to fully mobilise earth pressure to oppose motion so that

effective net pressure = $(K_p - K_a)\gamma h$

(c) A pure moment is applied to the foundation; the shear force being ignored.

Deductions Refer to Fig. 24(b)

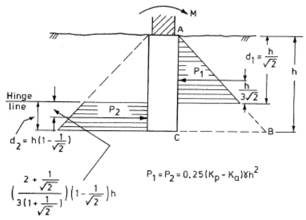

FIG. 24(b)

Since the applied horizontal force is assumed as negligible (zero shear)

$$P_1 = P_2 = \frac{1}{2} \text{ area of triangle ABC}$$

$$= \frac{1}{2} \times \frac{h}{2}(K_p - K_a)\gamma h$$

$$= 0.25(K_p - K_a)\gamma h^2 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

If depth to hinge line = d_1

$$P_1 = \frac{d_1}{2}(K_p - K_a)\gamma d_1 = 0.5(K_p - K_a)d_1^2\gamma \quad \ldots\ldots\ldots (2)$$

Equating equations (1) and (2) gives

$$d_1 = \frac{h}{\sqrt{2}}$$

and $d_2 = h - d_1 = \left(1 - \frac{1}{\sqrt{2}}\right)h$

Hence the distance of the centroids of pressure areas from the hinge line on each side of the foundation are:

$$\frac{h}{3\sqrt{2}} \text{ and } \frac{2 + \frac{1}{\sqrt{2}}}{3\left(1 + \frac{1}{\sqrt{2}}\right)}\left(1 - \frac{1}{\sqrt{2}}\right)h$$

$$= 0.236h \text{ and } 0.155h$$

The ultimate resisting moment against overturning will be

$$0.25(K_p - K_a)\gamma h^2(0.236h + 0.155h)$$

$$= \frac{(K_p - K_a)\gamma h^3}{10} \text{ kN.m/m width of foundation}$$

Case (ii) Refer to Fig. 25.

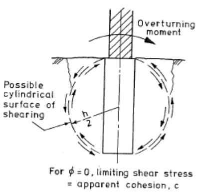

FIG. 25

Where the column foundation is into cohesive soil, Fig. 25 shows one possible type of failure. The overturning moment is resisted predominantly by the shearing resistance of the soil.

Based on this assumed failure pattern, ultimate resisting moment of soil

$$= b \times (\text{somewhat less than } \pi) \times h \times c \times \frac{h}{2}$$

$$= b \times (2.5 \text{ say}) \times h \times c \times \frac{h}{2}$$

$$= 1.25\, bh^2c \text{ kN.m}$$

Reinforcement

All concrete footings should be considered for steel reinforcement requirements. The appropriate theory is discussed in Chapter 4.

Stability

The following is a summary on the required calculations on design action effects for stability as set down in AS 1170.1.

A structure as a whole (or any part of it) shall be designed to prevent instability due to overturning, uplift and sliding as follows:

$$1.25G + 1.5Q < 0.8G^R$$

$$1.25G + \Psi_c Q + W_u < 0.8G^R$$

where G, Q and W_u (= 1.5W) are those parts of the nominal dead, live and wind loads that tend to cause instability.

G^R is the part of the dead load tending to resist instability.

This means that for wind load alone (in most design cases wind load is the only load causing instability) the 'effective' stability factor = 1.5/0.8 = 1.875 (or rounded off to 1.88).

These methods have been adopted in the Sleeper Wall and Post Footing modules pre-dating Version 4 of Structural Toolkit released in October 2010.

Below is a summary outlining the key points/assumptions of each method, and aspects that are not covered or unclear.

Cohesionless model

The following are stated:
- "A pure moment is applied to the foundation [with] the shear force being ignored.".
- "Soil movement is sufficient to fully mobilise earth pressure".
- The equation yields an ultimate resisting moment.

The following are not discussed:
- No slenderness (embedment to width) limitations are imposed on the model.
- No amount of surface material is considered as being ignored.
- The amount of deflection/rotation of the footing is not stated to reach a fully mobilised assumption.

Cohesive model

The following are stated:
- "Shows one type of possible failure.".
- The equation yields an ultimate resisting moment.

The following are not discussed:
- Whether the statement "A pure moment is applied to the foundation [with] the shear force being ignored." In the cohesionless model also applies to this model.
- No amount of surface material is considered as being ignored.
- The amount of deflection/rotation of the footing is not stated to reach the cylindrical shearing failure.
- Whether other failure modes may occur prior to ultimate failure ie. excessive rotation

Validity of the Hoskin's Models

We have recently been made aware of some criticisms surrounding Hosking's method, questioning the validity of the approach.

These criticisms focus on the following:
- That applying a pure moment to the footing but neglecting shear cannot be correct
- Whether the cohesive model also has the same assumption of ignoring the shear force
- Whether the cylindrical shear failure plane for cohesive soils is an appropriate/applicable mode of failure.

It should be noted that the Hosking reference does not site any source references for the derivation of the formulas presented, or and discussion for the justification for ignoring shear.

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Changes to Structural Toolkit

Given the uncertainty of the origins of Hosking's method, and inability to contact the Author or publisher to address these criticisms, the following changes to the Sleeper Walls and Post Footing modules which utilise Hosking's models have been incorporated.

Neglected Shear Force

A new option has been added to the notes section of both modules that will resolve the ignored design shear force to the point of rotation. This option is defaulted to "Yes", therefore, to match designs of previous module versions, it will need to be changed to "No".

For cohesive soils (ø=0°), the shear force is now resolved to the centre of rotation of the footing.

> Footing Moment:
> Hosking's model states that shear force is ignored. To consider the effect of shear, V* can be resolved to the mid-height of the resisting soil, subsequently increasing the overturning moment M*o.
> Resolve V* to mid-height = Y (Y)es,(N)o

For cohesionless soils (c=0), the shear force is now resolved to the hinge point for the footing.

> Footing Moment:
> Hosking's model states that shear force is ignored. This may result in a highly unconservative footing moment. To consider the effect of shear, V* can be resolved to the hinge line of the resisting soil, subsequently increasing the overturning moment M*o.
> Resolve V* to hinge = Y (Y)es,(N)o

This option will result in a greater overturning design moment, and subsequently require a deeper/larger footing (which may be significant).

Soil Behind Retaining Wall (Cohesionless Only)

Hosking's approach provides equations for overturning resistance based on a level soil profile on both sides of the footing. As the equations for cohesionless design adopt Rankine theory, it can be extrapolated that the active and passive pressure factors on the soil side (Ka and Kp) will be affected by the soil behind the wall.

A new option has been added to the Sleeper Walls module in the notes section that will allow the soil behind the wall to be included in the cohesionless design model for overturning resistance. This option will increase the lateral soil pressure on the wall side that is applied to the footing and will typically result in a slightly deeper footing being required. This option is defaulted to "No".

Soil behind the wall (Cohesionless):
The soil behind the sleeper wall can affect the overturning force, resistance and hinge line for cohesionless design. Additional overturning forces are represented by P3* when footing moment is resolved to hinge.
Include soil behind wall = N (Y)es,(N)o

Summary

Given the uncertainty of the origins and validation of the Hosking models for cohesive and cohesionless footing resistance, changes have been incorporated in the Sleeper Walls and Post Footings modules which will result in the previously ignored shear force to be resolved to a centre of rotation/hinge point. Furthermore, for cohesionless soils, the active/passive resistance can be modified to consider the soil above the footing behind the wall.

These changes will result in deeper footings.

We recommend the Design Engineer discuss and familiarise themselves with the Hosking method presented and determine how they consider the applicability.

Feedback is encouraged.