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Comparative Analysis of Lateral Earth Pressures from Surface Line Load

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Abstract - The lateral earth pressure acting on the stem of retaining wall by the application of line load surcharge over the backfill for concrete cantilever retaining walls are examined. These lateral pressures are of great significance as the design of structural components of retaining wall is governed by magnitude and nature of these lateral pressures. Two analytical methods and the finite element method (GEOSTUDIO) are used to analyze these lateral pressures. The values and nature of FEM results are also compared with previously done FEM analysis. The lateral pressures evaluated from conventional methods based on elastic theory differ from the pressures as predicted by finite element method. Moreover present FEM pressures also differ from FEM values which were more absurd compared to conventional method values. These differences can be attributed to the erroneous implication in elastic theory that any combination of effective principal stress ratio is possible for the backfill soil.

Key Words: GEOSTUDIO, FEM, Lateral pressure

1. INTRODUCTION

Over the decades there has been an immense research done on the retaining wall structures. Increase in the technology and software has allowed us to construct these structures with more safety. As retaining wall are the structures which are designed to retain the soil which laterally rest on them. Active and passive earth pressures are required for the designing of these structures. The design of retaining wall needs the determination of magnitude of lateral earth pressure and its point of action. Magnitude of these lateral pressures depends upon various factors such as the mode of the movement of the wall, properties of the soil, flexibility of the wall etc.

A study within each calculation method will be performed. A conceptual model will be constructed and the different methods will be used to calculate the lateral earth pressure in the model. The results from calculations will be the basis for the discussion. Different exercises and a literature study will be done to be able to apply GEOSTUDIO into the analysis.

The main focus of this analysis is on the horizontal stresses acting on the wall stem under practical working load conditions. These horizontal stresses are generally of importance for the structural design of the reinforced concrete wall. One general practice while designing the wall is to modify the lateral pressures acting on the wall stem by multiplying the pressure by a load factor which has usually a value greater than one.

This research will deal with the horizontal earth pressure which is coming on the face of the retaining wall for the line load conditions. Analytical method and finite element method will be used to evaluate these earth pressures. The difference in these pressures by two methods will be compared.

1. Lateral pressures given by Spangler and Boussinesq will be compared with FEM
2. Anthony T.C. Goh FEM results will be compared with our FEM results.

2. LITERATURE REVIEWS

2.1 The Boussinesq Equation

The trial wedge method seems to be too conservative in estimating the lateral force against a wall when there are surcharges (or loads) on the backfill particularly outside the Rankine zone. For this reason, this procedure does not seem to be much significant. The Theory of Elasticity method can be used to compute the lateral pressure profile against the wall from the surface surcharge (point, line, strip) loading. The Boussinesq equation or some variation of it is commonly used. The equation of Boussinesq is-

$$\sigma_r = \frac{P}{2\pi z^2}\left[3\sin^2\theta\cos^3\theta - \frac{(1-2\mu)\cos^2\theta}{1+\cos\theta}\right]$$

Goh Anthony T.C. (1994) has done a comparative study for determining retaining wall earth pressures from surface line load. He compared the lateral earth pressure calculated from elastic theory formula to the earth pressure calculated be FEM analysis.

The lateral pressure calculated by finite element method comes different from conventional elastic theory formula. He concluded that finite element allows for more realistic consideration of the soil-structure interaction, material non linearity and the construction sequence and lead to solutions which are near to actual condition than conventional design methods.

Since there was no experimental verification of numerical findings, the results should provide qualitative insight for further development of improved design methods.

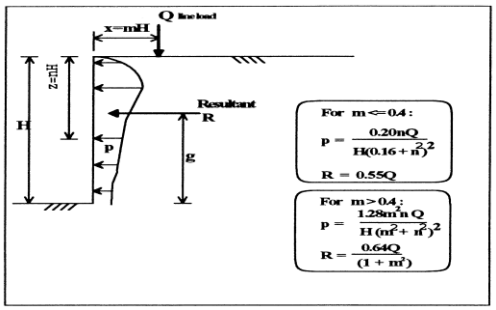


Fig- 1(a)

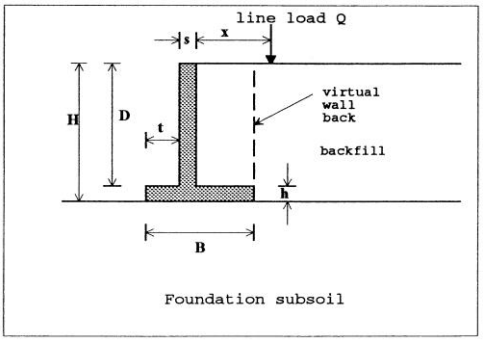
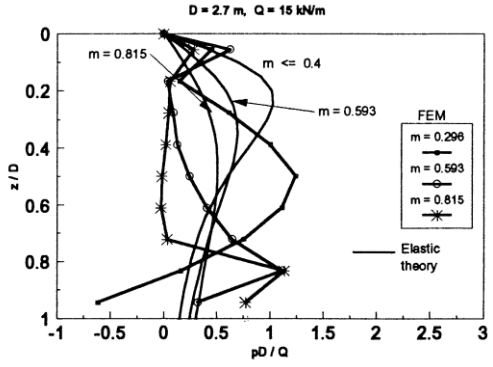


Fig- 1(b)



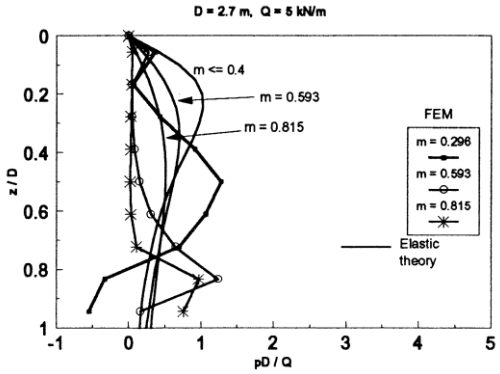


Fig- 2(a) & 2(b)

2.2 FEM Software

GEO-STUDIO provides several geotechnical and geo-environmental engineering software products. One of these products is "SIGMA/W" that is used in this work. SIGMA/W is a general finite element software product for stress and deformation analyses of geotechnical engineering structures. The followings are some typical cases that can be analyzed using SIGMA/W.

3. METHODLOGY

A concrete cantilever retaining wall was taken into consideration with a cohesionless backfill soil and different foundation subsoil. Different magnitude of line load Q and its variable distance x from the back of the wall was considered. Details are given in the following table

Table-1 Wall Properties

Property	*Symbol*	*Value*
Wall base width (m)	*B*	*1.7*
Wall toe width (m)	*T*	*0.4*
Wall stem thickness (m)	*S*	*0.3*
Wall heel thickness (m)	*H*	*0.3, 0.6*
Wall height (m)	*H*	*3.0, 6.0*
Wall stem height (m)	*D*	*2.7, 5.4*
Young's modulus	E_c	*25*

$(x10^3 MPa)$		
Poisson's ratio	ν_c	0.2
Unit weight (kN/m^3)	γ_c	22.0

3.1 Wall Configuration

A retaining wall of height 3m,6m and other dimensions as mentioned in the table 1 was modeled. Line load Q with different magnitude as 5kN, 15kN and 20 kN and with varying distance x from the back face of the wall as 0.8m, 1.6m and 2.2m were applied. So, there will be three cases for each set of line loading and for different height of wall.

Material model

Material model for wall was taken as **elasto plastic** and not as rigid or unyielding which provides the realistic condition and consequently allow the wall to deform and behave according to the lateral pressure variation along the depth of the wall. Backfill soil and foundation subsoil is taken as **hyperbolic** with all the properties.

3.2 GEOSTUDIO

FEM software GEOSTUDIO was used as the modeling tool to simulate the interaction between the retaining wall and the soil. SIGMA/W a component of GeoStudio is a finite element code that can be used to analyze the stress and deformation of earth structures due to surcharge.

4. RESULT AND DISCUSSION

4.1 GENERAL

Lateral pressures on the stem of wall were calculated for different sets. FEM calculated lateral pressures are shown in below figures, these pressures are expressed in the parameter PH/Q and are compared with the Spangler's and Boussinesq's pressures values with the same parameter.
Figure 3 shows the lateral pressures calculated with the FEM software with different sets of line loads, their point of application and heights of wall.

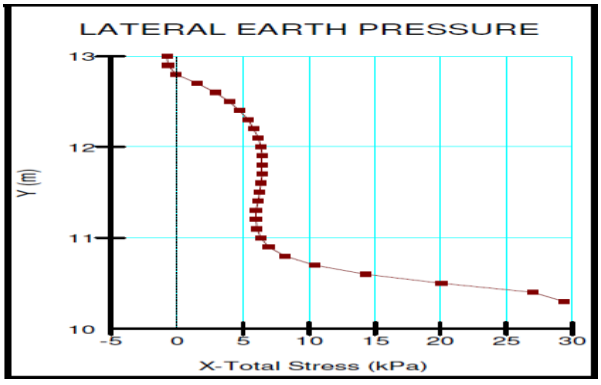


Fig-3

Fig-4 shows comparative graphs obtained using elastic theories results and software results for wall height of 3m and loads acting at a distance of 0.8m from the wall.

The FEM results clearly shows that the lateral earth pressures acting on the wall stem are affected by the magnitude of the line load and the point of application of the load.

The increase in the pressure P because of the application of line load is examined which was obtained by subtracting the lateral pressures acting when backfill was not subjected to the line load from the lateral pressures acting when the line load is applied to the backfill.

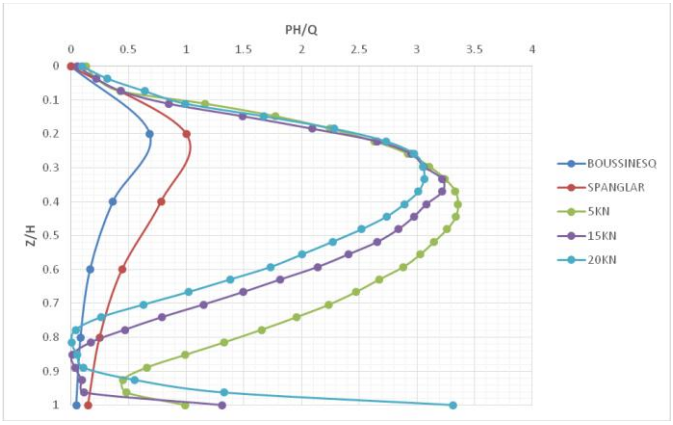


Fig-4

4.2DISCUSSION ON COMPARATIVE GRAPHS

- Graph shows that when the loads are applied at closer distance to wall, pressure intensity will be more and as these loads move away intensity of pressure decreased.

- Variations in the conventional methods graphs does not seems to be much significant as these values have less amount of changes for different sets.

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