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ANALYSIS & DESIGN OF COUNTERFORT RETAINING WALL

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ABSTRACT

Retaining walls are relatively rigid walls used for supporting soil laterally so that it can be retained at different levels on the two sides. Retaining walls are structures designed to restrain soil to a slope that it would not naturally keep to (typically a steep, near-vertical or vertical slope). They are used to bound soils between two different elevations often in areas of terrain possessing undesirable slopes or in areas where the landscape needs to be shaped severely and engineered for more specific purposes like hillside farming or roadway overpasses. A retaining wall that retains soil on the backside and water on the front side is called a seawall or a bulkhead. Every retaining wall supports a "wedge" of soil. The wedge is defined as the soil which extends beyond the failure plane of the soil type present at the wall site, and can be calculated once the soil friction angle is known. As the setback of the wall increases, the size of the sliding wedge is reduced. This reduction lowers the pressure on the retaining wall.Lateral earth pressures are zero at the top of the wall and – in homogenous ground – increase proportionally to a maximum value at the lowest depth. Earth pressures will push the wall forward or overturn it if not properly addressed. Also, any groundwater behind the wall that is not dissipated by a drainage system causes hydrostatic pressure on the wall. The total pressure or thrust may be assumed to act at one-third from the lowest depth for lengthwise stretches of uniform height.

INTRODUCTION

A counter fort retaining wall is a cantilever wall with counter forts , or buttresses, attached to the inside face of the wall to further resist lateral thrust. Some common materials used for retaining walls are treated lumber, concrete block systems, poured concrete, stone, and brick. Counter fort retaining walls are similar to cantilever walls except they have thin vertical concrete webs at regular intervals along the backside of the wall. These webs are known as counter forts. The counter forts tie the slab and base together, and the purpose of them is to reduce the shear forces and bending moments imposed on the wall by the soil. A secondary effect is to increase the weight of the wall from the added concrete. Can be precast or formed on site. Counter fort retaining walls are more economical than cantilever walls for heights above 25 ft. The present study deals with the optimization of counterfort earth retaining wall, to improve the resistance against the lateral loads acting on them; Introducing transverse support to the walls reduces the bending moment of the structure. The counter fort earth retaining wall divides the vertical walls into rectangular panels and thus supports them on two sides and behaves them as vertical cantilever beam. Below are the some of the research works conducted on the retaining walls

PROBLEM STATEMENT

In the present study a counterfort earth retaining wall of 8 m height is considered for the analysis by soft computing technique in comparison with conventional one. Parameters like position of pressure relief shelf, width of pressure relief shelf and soil of different safe bearing capacity are considered to decide the optimum parameters of counterfort earth retaining wall. Under each condition a counterfort earth retaining wall with pressure relief shelf yielded high performance compared to conventional one. Analysis of counterfort earth retaining wall with pressure relief shelf by manual approach is very tedious compared to soft computing technique. Hence in the present an attempt is made to analyze counterfort earth retaining wall with pressure relief shelf by using finite element package (SAP-2000). Usage of SAP-2000 for analysis reduces the complexities like huge manual involvement and complex iterative procedure to fix the optimum parameters compared to tedious manual design procedure. This approach is very useful for new less experienced civil engineers for optimum design of counterfort earth retaining wall.

PROBLEM MOTIVATION

When it comes to a retaining wall design, the points in counter fort are extremely important. Unfortunately this is not something that many people are aware of when they are building and they could potentially save you from a serious headache down the road. They typically are important because they will ensure that the wall does not collapse, giving you a peace of mind knowing that it is sturdy. Here are a few things to think about for your next project.

LITERATURE SURVEY

2.1 Design and analysis of Counter fort

2.1.1 Introduction

Wall used to retain soil of height more than 6.0 meter is often provided with counterforts to economize its design. Behavior of such stiffened wall under earthquake forces is still uncertain and practically no solution exists till date in terms of their dynamic behavior except the dynamic pressure concept proposed by Mononobe and Okabe (1924) based on pseudo static analysis. The seismic coefficient method that forms the backbone of M-O method has though been obsolete for other type of structures (where more rational techniques like modal and time history analysis have been in vogue) has however continued to be in practice for the last 86 years, though found to give a considerable lower bound solution to the problem (Ostadan 2004, Chowdhury et al 2007). The present paper is an attempt to re-visit this long standing practical problem and proposes a more realistic analysis based on modal response technique considering a generalized back filled soil having both c and φ value with overburden- an oft faced condition in practice for which again M-O method is deficient

2.1.2 APPLICATION OF COULOMB'S THEORY FOR RETAINING WALL WITH PRESSURE RELIEF SHELF

To realize the effect of pressure relief shelf on the retaining wall, assumption has to make by deducting the weight of soil mass above the pressure relief shelf from the portion of failure wedge. In the case of non-cohesive soils, stability of soil mass from different wedges of failure plane will be considered for the determination of active earth pressure on the retaining wall. When the value of rupture surface makes an angle of $45^{o} + \phi/2$, it is considered to be the maximum value of failure plane.

2.1.3 ABOUT SAP-2000

SAP-2000 is a FEA package used for the analysis and design of any civil engineering structural system. In SAP2000 we can model a basic and advanced system ranging from 2D to 3D and of simple or complex geometry. The fire analysis engine is integrated to the SAP-2000; it converts the object based model in to a finite element model by meshing the material domain in to a network of quadrilaterals and triangles. It contains effective engineering features for those engineers who engage in state of art practical with linear, non-linear and dynamic loading considerations

2.1.4 TYPICAL COUNTERFORT RETAINING WALLS

Guidelines for design of counter fort retaining walls (Pillai and Menon, 2009) are available for arriving at optimal proportions of typical counter fort retaining walls. The counterfort retaining wall adopted in the present study is based on such guidelines which will ensure the required deterministic factor of safety suggested by national codes of various countries. The objective of the present study is to check whether the proposed deterministic factor of safety is sufficient to quantify the uncertainties associated with the design variables. The dimensions of the counterfort retaining walls in the present study are arrived at based on such de-

sign guidelines which aim to achieve the prescribed minimum factor of safety of '1.5' against various failure modes. The typical cross section of the selected counterfort retaining wall

2.1.5 Objectives

After studying this unit, you should be able to

1. Describe various types of retaining wall,
2. Explain forces acting on retaining walls
3. Design centilever walls and counterfort walls.

III. FORCES ON RETAINING WALLS

The two forces which act on a retaining wall are:

(a) Gravity loads due to the weight of the materials, and

(b) Lateral force due to earth pressure.

The usual gravity loads due to the weights of the materials do not present great problems with respect to retaining walls. The lateral force due to earth pressure constitutes the main force acting on the retaining wall. The determination of the magnitude and direction of the earth pressure is based on the principles of soil mechanics. Under confinement, the soil has a tendency to slide and thereby exerts pressure on the wall. If the wall is absolutely rigid, earth pressure at rest will develop. If the wall deflects or moves a very small amount away from the earth, active earth pressure will develop. If the wall moves towards the earth, passive earth pressure will develop

The magnitude of earth pressure at rest lies at some value between active and passive earth Dressier. Under normal conditions earth pressure at rest is so intense that the wall deflects, relieving itself of this type of pressure, and active pressure results. For this reason, most retaining walls are designed for active pressure due to the retained soil.

3.1. STABILITY REQUIREMENTS

The factors of safety (FS) against overturning and sliding should not be less than 1.4. The 2 stabilising forces (due to dead loads) should be factored by a value of 0.9 for calculating the factor of satety. stabilising force or moment) FS = 0.9 X (2 1.4 destabilizing force or moment

Overturning In case of overturning of retaining wall, the toe will act as the centre of rotation. Overturning moment, Mo, and the stabilising (restoring) moment, Mr ,depend on the lateral earth pressure and the geometry of the retaining wall. For sloping backfill

3.2 TYPES OF WTAINING WALL

Gravity Wall

Retaining walls can be broadly classified into two categories:

(i) Free standing retaining walls, and

(ii) Walls which form part of structures.

Gravity wall, cantilever wall, counterfort wall and buttress wall are the most common examples of free standing retaining walls. Basement wall, wall-type bridge abutments, and side walls of box culvert are the examples of retaining walls which form part of a bigger structure. Various types of retaining wall are described below. 21.2.1 Gravity Wall The gravity wall provides stability by virtue of its own weight, and therefore, is rather massive in size. It is usually built in stone masonry and occasionally in plain concrete. The thickness of the wall is governed by the need to eliminate or limit the resulting tensile stress to its permissible limit. For obvious economic reasons, plain concrete gravity walls are not used for heights exceeding about 3 m.

CANTILEVER WALL

It is the most common type of retaining structure and is generally economical for heights up to about 7 m. It consists of a vertical arm (called as stem) which retains the earth and a base slab. Base slab is made up of two distinct regions, viz. a heel slab and a toe slab. These three components behave as one-way cantilever slabs : the, 'stem' acts as a vertical cantilever under the action of lateral earth pressure; the 'heel slab acts as a horizontal cantilever under the action of the weight of the retained earth (minus soil pressure acting upwards from below); and the 'toe slab' also acts as a horizontal cantilever under the action of the resulting soil pressure (acting upward). Reinforcement is provided on the flexural tension faces. The stability of the wall is maintained essentially by the weight of the earth on the heel slab plus the self weight of the structure

COUNTERFORT WALL

For the large heights, in a cantilever retaining wall, the bending moments developed in the stem, heel slab and toe slab become very large and require large thickness, thereby making the structure uneconomical. The bending moments (and hence the thickness of stem and slab) can be considerably reduced by introducing transverse supports, called counterforts. These counterforts are spaced at regular intervals of about one-third to one-half of the wall height and interconnect the stem with the heel slab. The counterforts are concealed within the retained earth (on the rear side of the wall). Such a retaining wall structure is called the 'counterfort wall' and is economical for heights above 7 m approximately. The counterforts subdivide the vertical slab (stem) into rectangular panels and support them on two sides (suspender-style), and themselves behave as vertical cantilever beams of T-section and varying depth. The stem and heel slab panels between the counterforts are now effectively 'fixed' on three sides (free at one edge), and for the stem the predominant direction of bending and flexural reinforcement is now horizontal (spanning between counterforts), rather than vertical as in the case of cantilever wall.

BUTTRESS WALL

When the counterforts are provided on the front of the wall and not on the soil side, it is known as 'buttress wall'. Buttress wall is similar to the counterfort wall, except that the transverse stem supports called buttresses, are located in the front side, interconnecting the stem with the toe slab (not with the heel slab as in case of counterfort wall). Although buttresses are structurally more efficient (and more economical) than counterforts, the counterfort wall is generally preferred to the buttress wall as it provides free usable space (and better aesthetics) in front of the wall.

COULOMB THEORY

The Coulomb‟s theory is conveniently adopted when the plane of failure extending diagonally upward and backward through the backfill. The sliding wedge is a triangular mass of soil between this plane of failure and the back face of retaining wall. The soil within the sliding wedge would slump down when the retaining wall is suddenly removed. If a plane of failure makes an angle ϕ with the horizontal, the forces acting on the sliding wedge are as shown in figure 1. Forces acting on failure plane these forces consist of weight of the soil within the wedge W which acts through the centroid of the triangle, a thrust normal to the plane of failure N which exerted by the soil to the right of the failure plane. N = N tan ϕ will be at the limit of equilibrium. These forces must be balanced by the thrust P which is assumed to act horizontally and to be concurrent with W, N and S. The equal and opposite reaction to P is the lateral force to withstand which the wall is to be designed. The forces N and S may be replaced by the resultant R to derive the value of P. S acts along a line making the angle ϕ with the normal to the failure plane. Since W, P and R are three concurrent forces which are in equilibrium, when the failure is about to take place along the failure plane, they may be represented by the triangle of forces

LOFT THEORY

For non-cohesive soils the active earth pressure on a retaining wall can be computed by considering the stabilities of different wedges of soil mass. It attains a maximum value when the rupture plane makes an angle of 45o + ϕ/2 with the horizontal, where ϕ is the angle of internal friction of the non-cohesive soil. Fig 3 shows cross section of retaining wall with one horizontal shelf of width „b‟ and thickness „t‟ at a height „H-h‟ from the base. When b= H-T-h tan [45o + ϕ/2], the rupture plane originating at the intersection of base and stem on the backfill side meets the horizontal shelf. According to Jumikies the earth pressure distribution diagram below the shelf would be as shown in the fig.3, as if a free surface existed at the shelf level. If b is greater than H-T-h tan [45o + ϕ/2], the rupture plane which gives the maximum value of lateral earth pressure, i.e. the plane inclined at 45o + ϕ/2 with the horizontal, cannot develop, as it has to go through the shelf. The total active earth pressure at any level can be obtained by stability analysis of wedge, assuming that by providing a horizontal shelf, the weight of the earth over the shelf is born by the shelf and the weight of this soil mass is not effective to cause sliding.

CONCLUSION

In the present study comparison of conventional counter fort earth retaining wall with pressure relief shelf attached counter fort earth retaining wall is studied. Positions of pressure relief shelves are varied H/3, H/2, 2H/3 positions to analyze the behavior of retaining wall. The moments developed by the retaining earth in the counter fort earth retaining wall with pressure relief shelf are always less compared to conventional retaining wall. During the absence of relief shelves, 12 % reduced moment are recorded by SAP-2000 analysis in comparison with manual (conventional) method of analysis of counter fort earth retaining wall. 33%, 50.5% and 61.53% of reduction of moments are recorded when there is adoption of relief shelves at H/3, H/2 and 2H/3 positions of the stem in comparison to the moments of counterfort earth retaining wall without the pressure relief shelf. Due to the reduction moments, stability of the counterfort earth retaining wall is increased against sliding and overturning. Computation of displacement of stem at top of the wall can be effortlessly done by using SAP-2000. This cannot be possible by manual approach. About 122, 99 and 86.7 mm displacement of stem at top were recorded at (H/3, H/2, 2H/3 positions) respectively

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