EFFECT OF SOME SOIL AND GEOMETRIC PROPERTIES ON REINFORCEMENT IN CANTILEVER RETAINING WALLS

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Abstract

There are many variables affect the analysis and design of the cantilever retaining wall and it is including the properties of soil which is retained by the wall. Unit weight of the soil, backfill slope, coefficient of internal friction, and in addition to others are variables affecting the calculation of active lateral earth pressure on the retaining wall and then affect the design of the retaining wall parts (base and stem).

This research presents the results obtained from STAAD III computer program, which give the steel area for each part of the retaining wall and for both primary and secondary directions. The research studied different values of unit weight and different values of backfill slope.

A regression analysis was made to the data resulted from research, and an equation was resulted from the regression relates the studied properties together.

Symbols

H: retaining wall height
Wc: weight of concrete wall
Ws: weight of backfill soil
e: eccentricity
Pa: active lateral earth force
α: angle of backfill soil
γ : unit weight of backfill soil

1- GENERAL

Retaining walls are structure used to provide stability for earth or other material where conditions disallow the mass to assume its natural slope and are commonly used to hold back or support soil banks, piles, and water.

Retaining walls are classified, based on the method of achieving stability, into six principal types Fig. (1)[1]. The gravity wall depends upon its weight, as the name implies, for stability. The cantilever wall is a rein forced-concrete wall that utilizes cantilever action to retain the mass behind the wall from assuming a natural slope.

Stability of this wall is partially achieved from the weight of soil on the heel portion of the base slab. A counterfort retaining wall is similar to a cantilever retaining wall, except that it is used where the cantilever is long or for very high pressures behind the wall and has counterforts, which tie the wall and base together, built at intervals along the wall to increase the bending moments and shear capacity of the wall.

As indicated in Fig. (1c), the counterfort is behind the wall and subject [illegible] forces. A buttressed retaining wall is similar to a counterfort wall, except [illegible] bracing is in front of the wall and is in compression instead of tension.

Two other types of walls not considered further are crib walls, which [illegible] up members of pieces of precast concrete, metal, or timber and are supported [illegible] pieces embedded in the soil for stability, and semi-gravity walls, which [illegible] intermediate between a true gravity and a cantilever wall.

Retaining walls must be of adequate proportions to resist overturning (or excessive tilting) and sliding as well as being structurally adequate. Terms used in retaining-wall design are shown in Fig. (2)'.

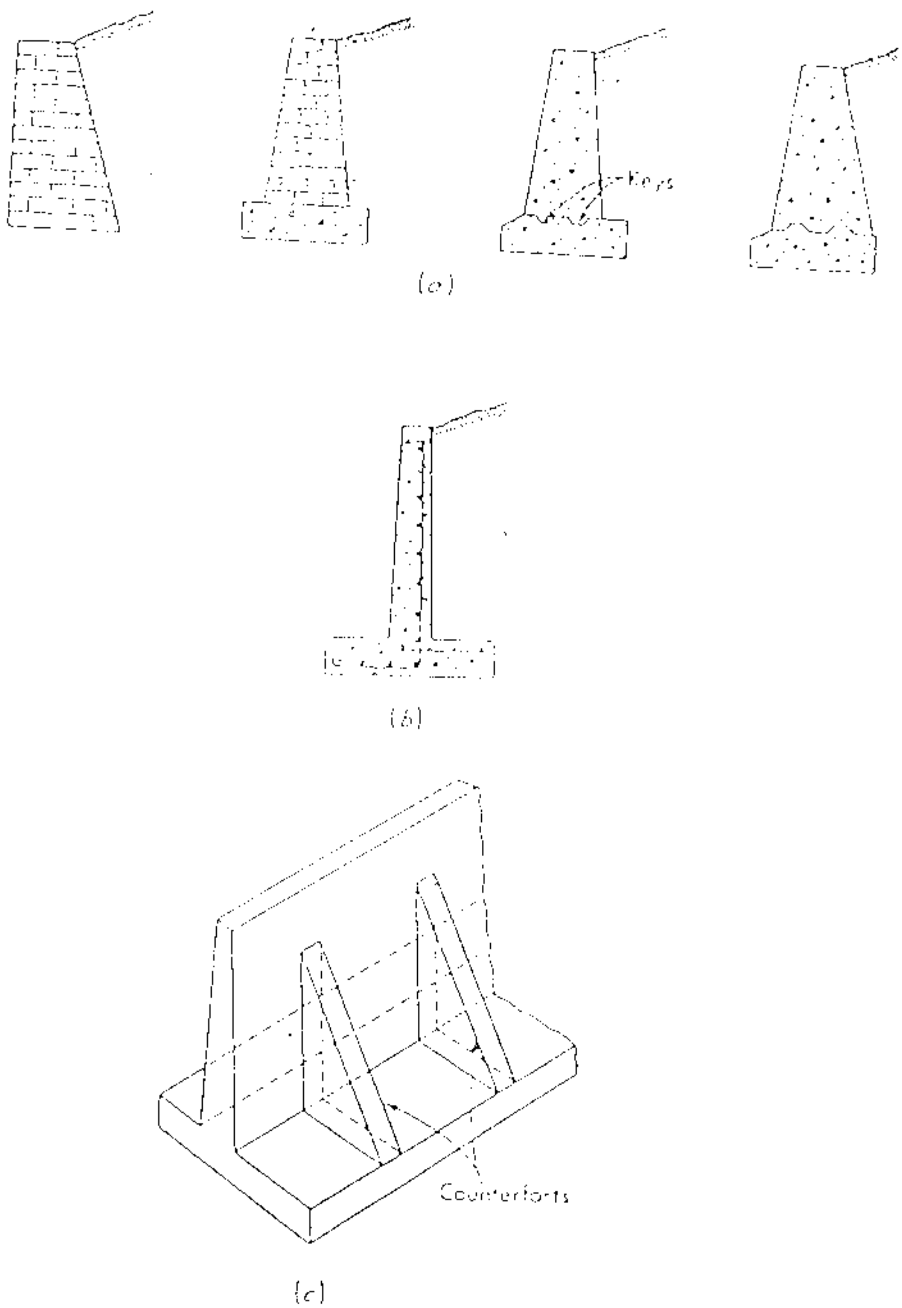

Figure (1): Types of Retaining Walls, a) Gravity Walls, b) Cantilever Wall, c) Counterforts

2- Introduction To Cantilever Retaining Wall

Dimensions for a retaining wall should be adequate for structural stability and to satisfy local building-code requirement.

The top of the stem should generally be not less than (200 mm) from a liberal interpretation of ACI Art. 14.2.7[2] and preferably not less than (300 mm), so that proper placement of concrete may be affected and, if part of the end spalls off or is broken off, a sufficient amount will remain to satisfy structural and aesthetic requirements.

The base-slab dimensions should be such that the resultant of the vertical loads falls within the middle one-third. If the resultant falls outside the middle one-third, the toe pressures will be excessively large, only a part of the footing will be effective[2].

A batter is usually used for cantilever retaining walls to affect some saving in material[3]. A front batter is preferable so that the forward wall movement to develop active pressure is not noticeable. Most highway retaining walls and nearly all bridge abutments have the exposed face vertical. A slight increase in stability is usually obtained when the batter is on the back face. Low walls of under 3 m in height walls are often built with constant thickness to save on forming costs"[1].

3- Forces On Cantilever Retaining - Walls

The forces acting on a retaining wall are customarily taken per unit of length for both gravity and cantilever walls. Counterforted walls may be considered as a unit between joints, or as a unit centered on two buttresses.

forces on a cantilever wall are shown in Fig. (3)[1]. Because of difficulty in evaluating wall friction, it is usual practice to use the Rankine active pressure (i.e., taking $\delta = 0$) for wall height less than 6 to 7 m[1].

For walls over about 7 m in height the Coulomb equation is more economical[1]. It should be noted that the wall height H for use in determining the maximum shear and bending moment acting on the stem is not the same as that used to find the driving forces for sliding computations. The designer must also make a decision on whether to use passive pressure from the soil in front of the toe and whether the soil covering the toe portion will be available for resisting overturning moments and sliding. Most times this soil is neglected for a conservative solution.

The use of the differential equation enables rapid computation of the cutoff points for the reinforcing steel, since it is uneconomical to use a constant amount of reinforcing for the entire wall height.

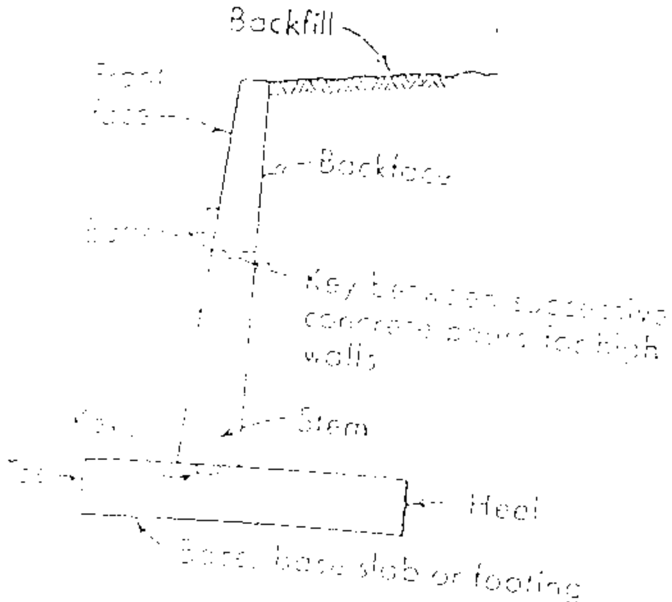

Figure (2): Principal Terms Used with Retaining walls.

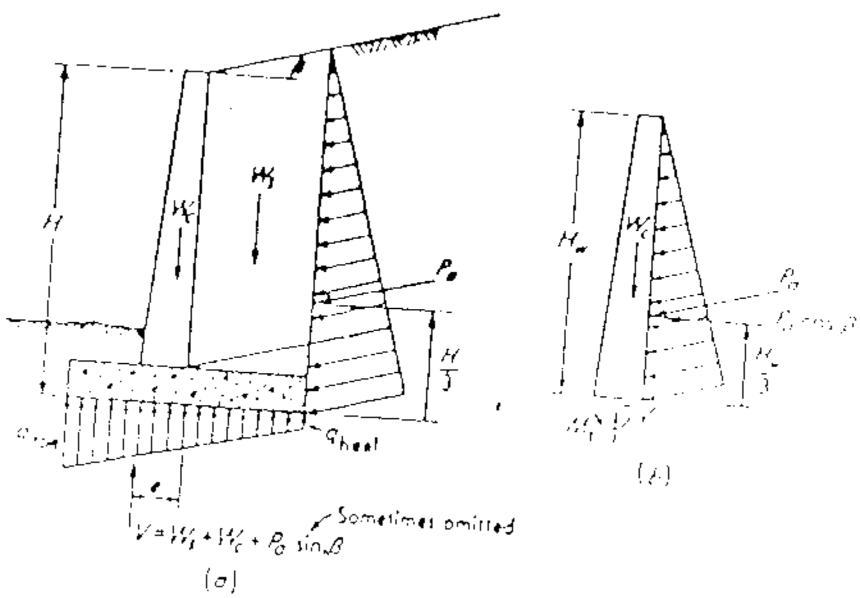

Figure (3): Forces on Cantilever Walls.

4- Presentation Of Results

The results were obtained from STAAD III computer program. The results were checked with results of by hand solution.

The investigated parameters are tabulated in Table (1).

Table (1); The Investigated Parameters.

Trial No.	Soil Unit Weight (γ), kN/m^3	Backfill Angle(α), °	Wall Height, m	Water Table, m	Surcharge, kN/m
1	12	0	7	0	0
2	16	0	7	0	0
3	20	0	7	0	0
4	12	2.5	7	0	0
5	16	2.5	7	0	0
6	20	2.5	7	0	0
7	12	5	7	0	0
8	16	5	7	0	0
9	20	5	7	0	0
10	12	10	7	0	0
11	16	10	7	0	0
12	20	10	7	0	0

The resulted factor of safety against sliding is (2.0) and against overturning is (6-7)

4-1- Effect of (α) and (γ) on Primary Wall Reinf.

As shown in figure (4), we can say that there is a clear relationship between angle of backfill and primary steel reinforcement in wall especially with high soil unit weight, the increase in backfill angle increases the steel area in wall. There is no effect of backfill angle in low unit weight on wall reinforcement.

Also in low backfill angles, the effect on wall reinforcement is little and not clears.

There are clear trend of results as a straight line between these variables indicated above.

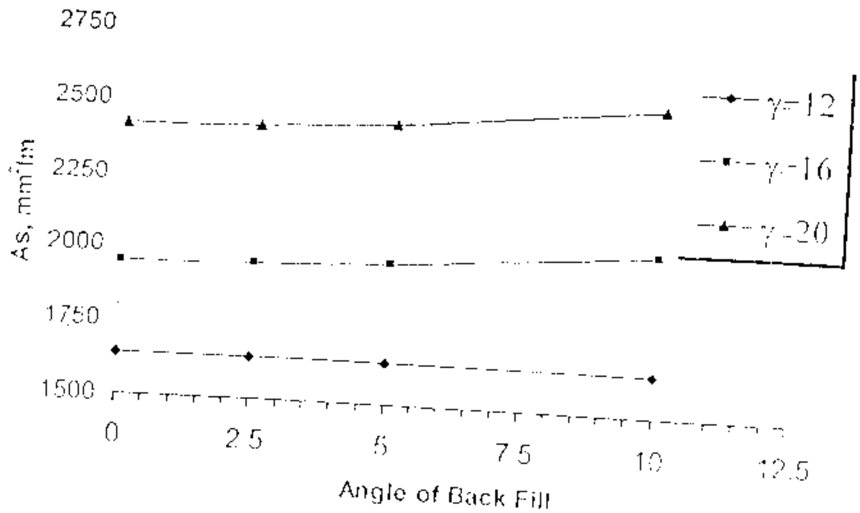

Figure (4): Relationship between Angle of backfill and Primary Steel Area of Wall.

4-2- Effect of (α) and (γ) on Primary Slab Reinf.

As in figure (5), there are no effects of angle of backfill and unit weight on primary reinforcement of retaining wall slab. Same certain value of steel area for all studied conditions.

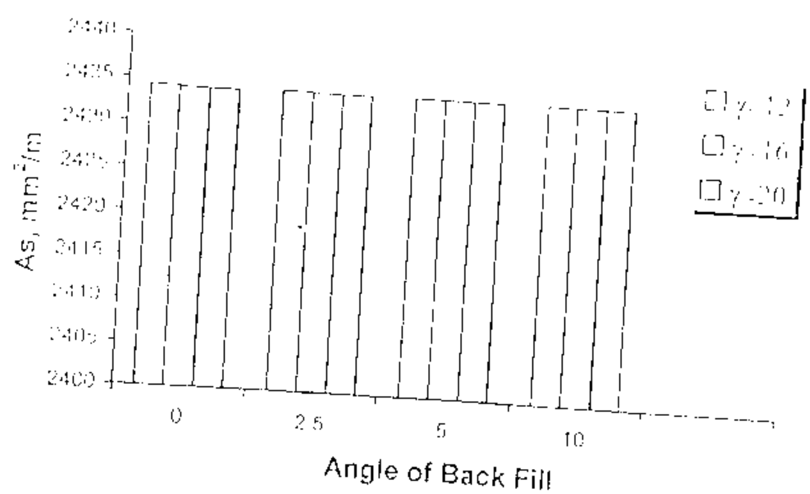

Figure (5): Relationship between Angle of Backfill and Primary Steel Area of Slab.

4-3- Effect of (α) and (γ) on Secondary Wall Reinf.

As shown in figure (6), there are no effects of angle of backfill and unit weight on secondary reinforcement of wall. Same certain value of steel area for all studied conditions.

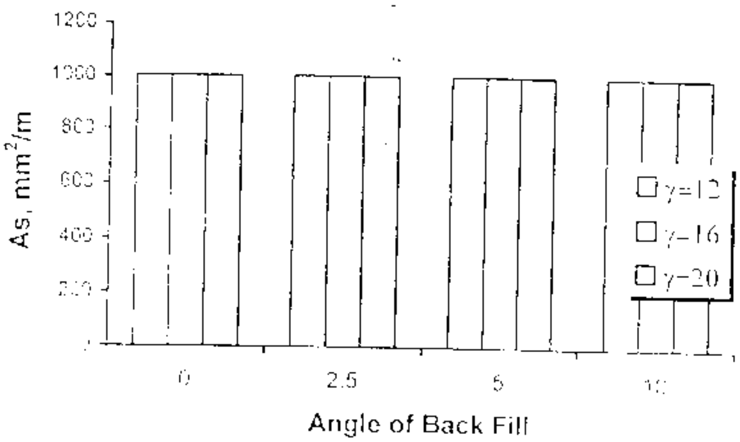

Figure (6): Relationship between Angle of Backfill and Secondary Steel Area of Wall.

4-4- Effect of (α) and (γ) on Secondary Slab Reinf.

As shown in figure (7), there are no effects of angle of backfill and unit weight on secondary reinforcement of retaining wall slab. Same certain value of steel area for all studied conditions.

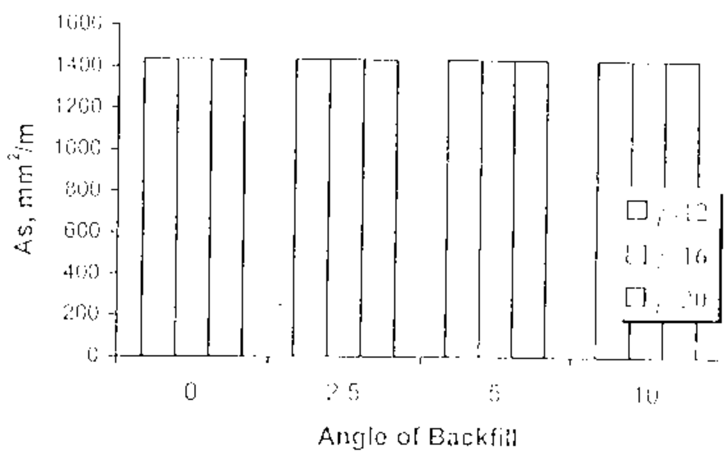

Figure (7): Relationship between Angle of Backfill and Secondary Steel Area of Slab.

4-5- Investigation of Minimum Batter

The batter is usually used for cantilever retaining walls to affect some saving in material. Minimum value for the batter to ensure safety is investigated to be (1:47) and it is closing to the standard minimum batter (1:48), as shown in Fig. (2) after Bowles. Figure (8) shows the relationship between primary steel area of the wall and wall base width to wall top width ratio, from minimum value of that ratio calculate the minimum batter and it is very close to that in specifications of retaining wall.

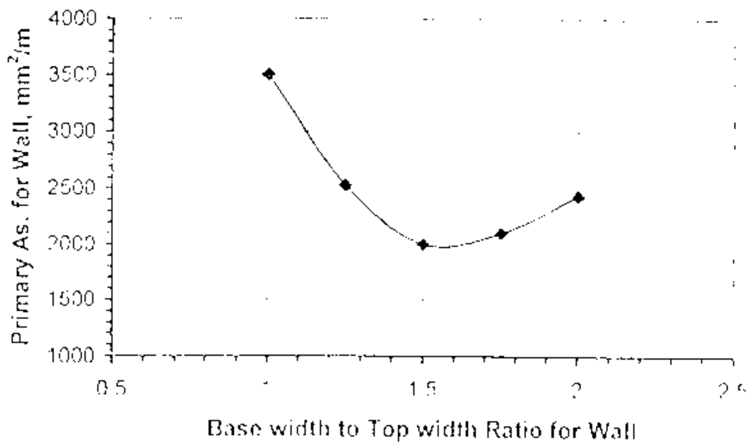

Figure (8): Relationship between Primary Steel Area of Wall and Base Width to Top Width Ratio.

5- Regression Analysis

A regression analysis was made to the data obtained from the research, Eq. (1), resulted from regression, correlated the studied variables together to estimate the suitable primary steel area for the stem.

$$As, mm^2/m = 353.743 + 7.135 \cdot \alpha + 102.372 \cdot \gamma \quad \ldots (1)$$

Fig. (9) shows the results of Eq. (1) for different values of different variables.

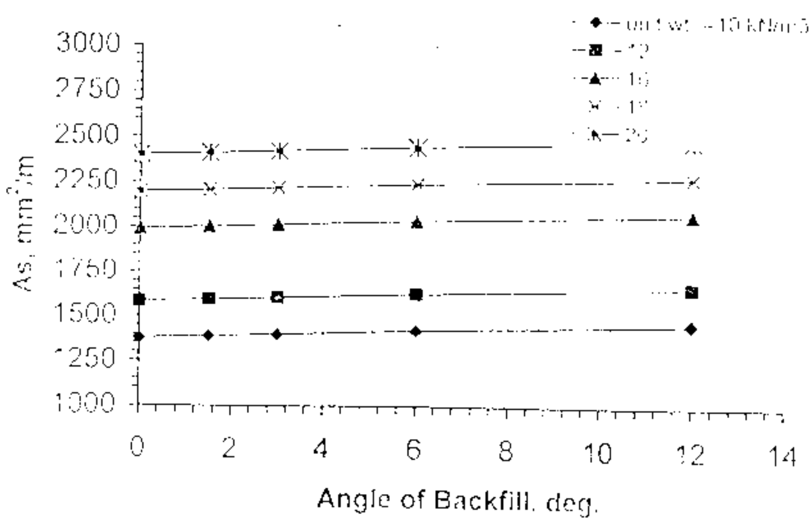

Figure (9): Results of Eq. (1)

6- Conclusions

From the results, one can states the followings: -

1-The effect of unit weight on primary steel area in wall be clear in high value of unit weight (> 18 kN/m^3).

2-The effect of backfill angle on primary steel area in wall be considerable in large angle value (> 5°).

3-Primary steel area of slab and secondary steel area for both wall and slab have a certain value for each case, i. e., unit weight and backfill angle have no effect on steel area in primary and secondary slab reinforcement and secondary wall reinforcement.

4-The minimum batter investigate in the research was close to standard (1:48).

5-The results in primary (As) for wall have an approximate parallel straight trend.

7- Recommendations

In future work we suggest the following recommendations: -1 - Consider other variables, such as coefficient of internal friction, water table variation in both back and front of the retaining wall and application of surcharge load on backfill, in the design.

2- Make a regression analysis for the data obtained from research to find an equation correlates the variables to be using in design.

3- Study other types of the retaining walls.

8- Acknowledgment

Special thanks to engineer Ali Abdul Shaheed for his help to complete this research.

9- References

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تأثير بعض خواص التربة والشكل الهندسي

على تسليح الجدار الساند

الخلاصة

هناك عدة متغيرات تؤثر على تحليل وتصميم الجدار الساند وبضمنها خصائص التربة التي يسندها الجدار. فالكثافة الوزنية للتربة، ميل تربة الإملاء خلف الجدار، معامل الاحتكاك الداخلي، وإضافة إلى متغيرات أخرى كلها تدخل في حساب ضغط التراب الجانبي على الجدار وبالتالي تؤثر على تصميم أجزائه (البلاطة الأرضية والجدار الذي يستند عليها).

يقدم هذا البحث النتائج المستحصلة من برنامج الحاسبة STAAD III والمتمثلة بكمية التسليح لكل من جزئي الجدار الساند وبالاتجاهين الرئيسي والثانوي. في هذا البحث، درسنا قيم مختلفة من الكثافة الوزنية للتربة وقيم مختلفة لميل التربة خلف الجدار.

تم إجراء تحليل إحصائي للبيانات المستحصلة من البحث، وتم الحصول على معادلة تربط الخصائص المدروسة في هذا البحث.