

Lateral Pressure on Rigid Retaining Walls without Lateral Movement

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Keywords:	Abstract
Lateral earth pressure, Rigid wall, Numerical method, Finite element.	There is a direct relationship between lateral pressure on retaining walls due to surface charges and the rigidity of the wall. According to Spangler theory if the wall is rigid without horizontal displacement the lateral pressure is equal to double amount of added horizontal stress by overload that is calculated by the Boussinesq formula. However, recently Bowles opposed to the theory and considers Renman studies on the effect of Poisson's ratio and soil density correct. This study aims at making a comparison between the two theories using elastic finite element software. Vertical stress distribution in the vicinity of a surface perpendicular to the fixed horizontal position that models rigid retaining walls behavior has been investigated. The results have been compared with the recent studies findings and the theory of elasticity and the shortcomings of existing computational power have been analyzed, as well.

1. Introduction

Lateral pressure from overloads and soil density effects on lateral pressure of rigid walls with prevented lateral movement is an issue that lacks enough research by geo-technical scientists with different opinions on it. Terzaghi [1] conducted studies on the effects of soil density on the lateral pressure and found that the more density increase during bulwark the more lateral pressure is. Rowe [2] and Sowers et al. [3] conducted studies in this field and believed that wall motion should also be considered in density. Several analyses have been performed based on hysteretic loading some models have been offered [4, 5]. Duncan expanded his studies using finite element program called EPCOMP2 and concluded that the lateral pressure increases as the density increases. Duncan and Williams [6] carried out practical experiments with different rollers and presented their results on the amounts of lateral pressure at the table's dependant on the rollers types and the amount of density. Boussinesq in 1883 [7] have solved the problem of the lateral pressure generated due to the overload on the surface and presented relationships with Poisson ratio ν is involved. Also Westergaard in 1938

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[8], offered a similar relation for the stress distribution caused by overload. This was tested by Gerber (1929) [9] and Spangler (1938)[10] through large scale experiments and Spangler, according to their arguments, found the amounts double to that of found by Boussinesq relation for the reality in rigid walls without lateral movement caused by lateral over load. And Rehman and Broms (1972) [11] conducted studies on the effect of Poisson's ratio and soil density in rigid walls lateral pressure without lateral movements that rejects Spangler ratio 2. Bowles (1996) [12] agrees with Renman studies without offered certain factors with respect to the Poisson ratio and soil density. However, in these studies attempts have been made to make a comparison between the theories using elastic finite element software and also compare the recent studies results with the theory of elasticity to evaluate the shortcomings of existing computational power [13].

2. Numerical and Analytical Approach

FEM is already the most powerful tool in the analysis with extensive role in engineering problems. Given the importance and the accuracy of the finite element, in the studies attempts have been made to make a comparison between the theories using elastic finite element software. The applied model has 3599 elements and 3720 nodes. Tetrahedral elements are used to model and Plane Strain modes are considered. A rigid wall with no lateral movement is modeled and the bulwark behind the wall is free to move in vertical and horizontal directions. Bulwark weight is ignored and only the effect of the overload due to soil Poisson ratio is studied. Figure (1) depicts the corresponding model.

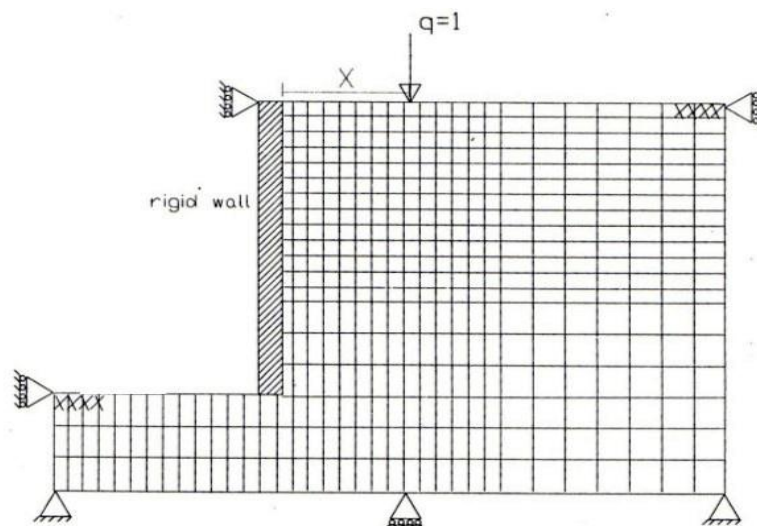


Figure 1. Corresponding model

Boussinesq offered tension generated by point overload for each point of an elastic-homogenous-isotropic and semi-infinite environment in accordance with the following general equation:

$$OX = \frac{3Q}{2\pi} \left[\frac{X^2 Z}{R^5} + \frac{1-2\theta}{3} \left[\frac{1}{R(R+Z)} - \frac{(2R+Z)X^2}{R^3(R+Z)^2} - \frac{Z}{R^3} \right] \right] \&R = \sqrt{X^2 + Y^2 + Z^2} \quad (1)$$

But for convenience, if we consider the Poisson ratio $\nu = 0.5$ in the above equation, we will have summarized well-known lateral pressure relations under various overloads. Next, Spangler considered a series of practical horizontal pressure caused by overload on with no movement rigid walls tests twice that of Boussinesq in his studies, and announced that the reason is that the loading is like that a same size and the same distance from the wall load is located in front of the wall.

According to calculation on Figure 2 a strip load with unit width and unit intensity is applied parallel to the wall. To obtain the lateral pressure caused by it, the strip load is converted to elements of the unit dimensions with the force of each element in the center of it as a point load. Strip load sum of all elements effects for each depth of the wall is obtained by equation (1). However, in this technique it is possible to sketch lateral pressure in depth for strip load with a different Poisson ratio based on Boussinesq relation. Now, in this study attempts have been made to compare the results of obtained lateral pressures with Boussinesq relation, and to examine them on a factor of 2 with respect to the Poisson ratio of soil. In conducted studies, the strip load is applied in different intervals from rigid wall on bulwark with different Poisson ratio considered for soil.

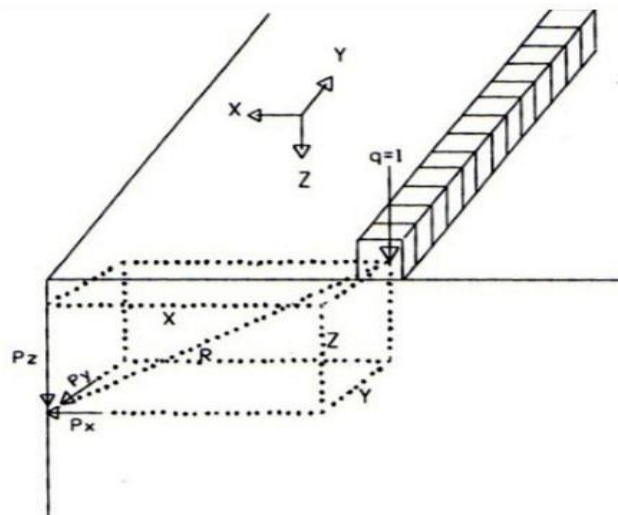


Figure 2. Strip load with unit width and intensity

Figure 3 shows that according to conducted studies, lateral pressure and its peak value increases by increased Poisson ratio. The results are higher than that of Boussinesq relations. Moreover, according to Figure 4 the lateral pressure is reduced for a constant Poisson ratio with increasing load distance from the wall, and it is observed that with increasing load distance from the wall, the diagram peak point gain in depth.

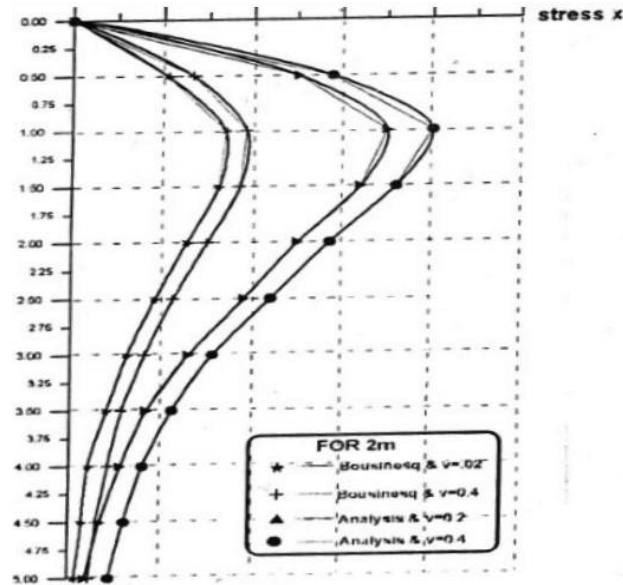


Figure 3. Lateral Pressure for different Poisson ratios

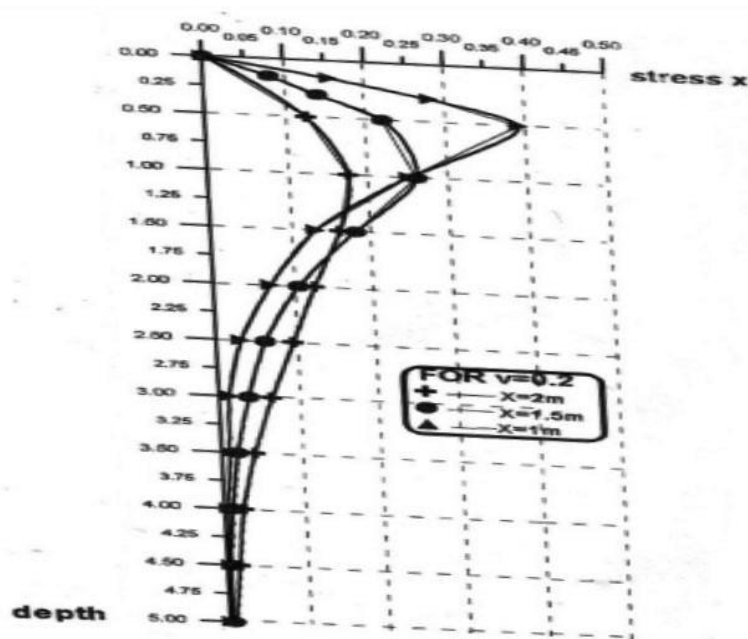


Figure 4. Lateral pressure to different load distances from the wall

According to Figure 5, a linear load within a distance of 1 meter, to Figure 6, a linear load within a distance of 1.5 meters and to Figure 7, a linear load within a distance of 2 meters from the wall, for Poisson ratios are 0.3-0.2-0.5-0.4, the stresses were compared to that of Boussinesq relation.

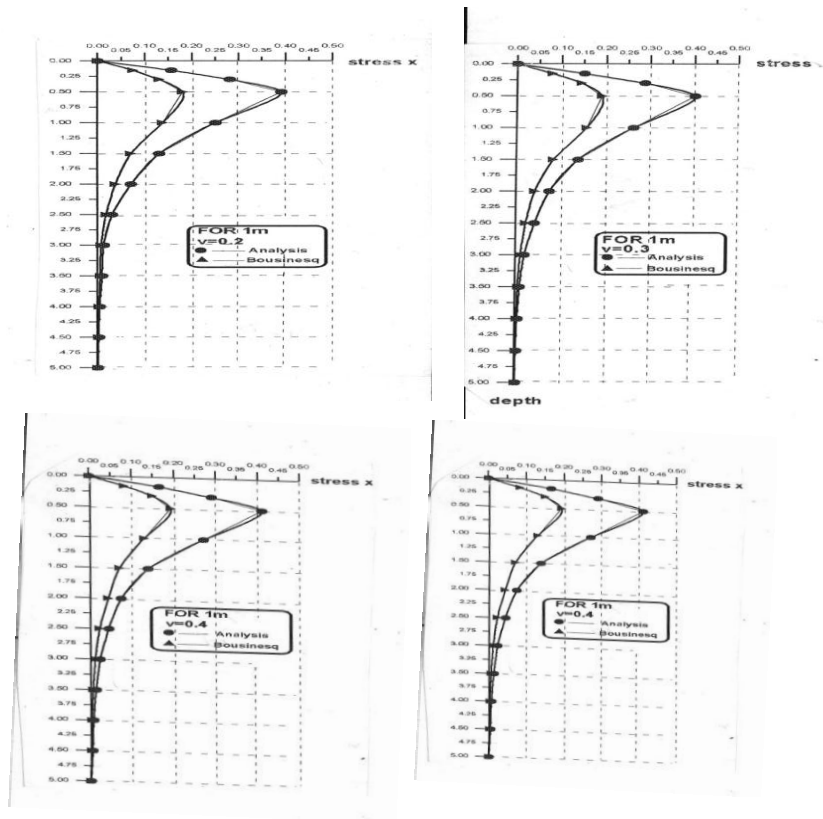


Figure 5. Profile of stress for linear load within a distance of 1 meter

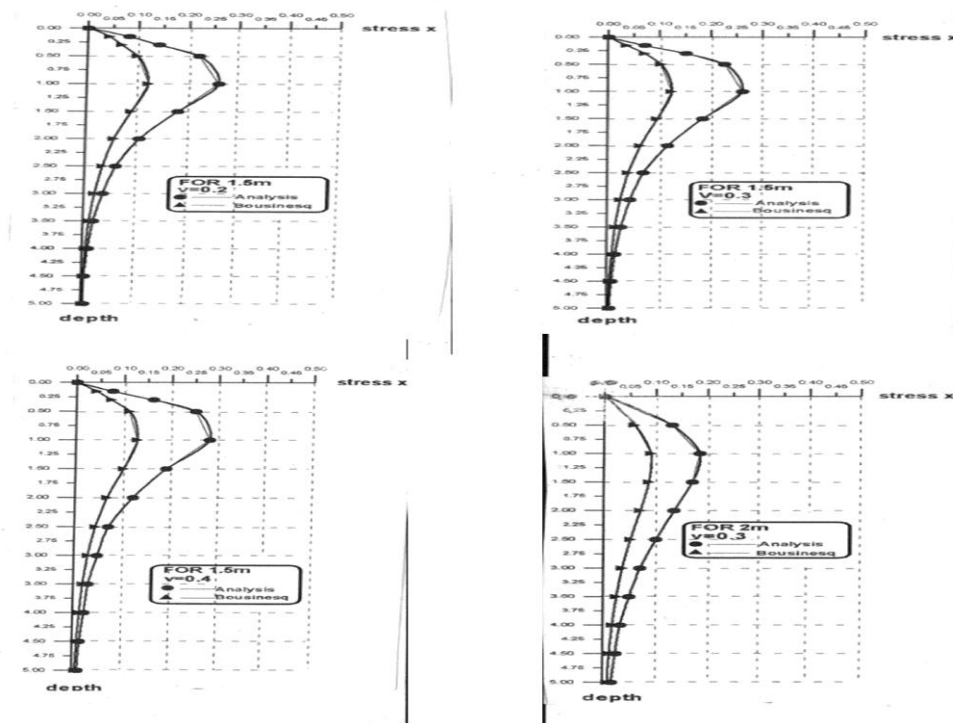


Figure 6. Profile of stress for linear load within a distance of 1.5 meters

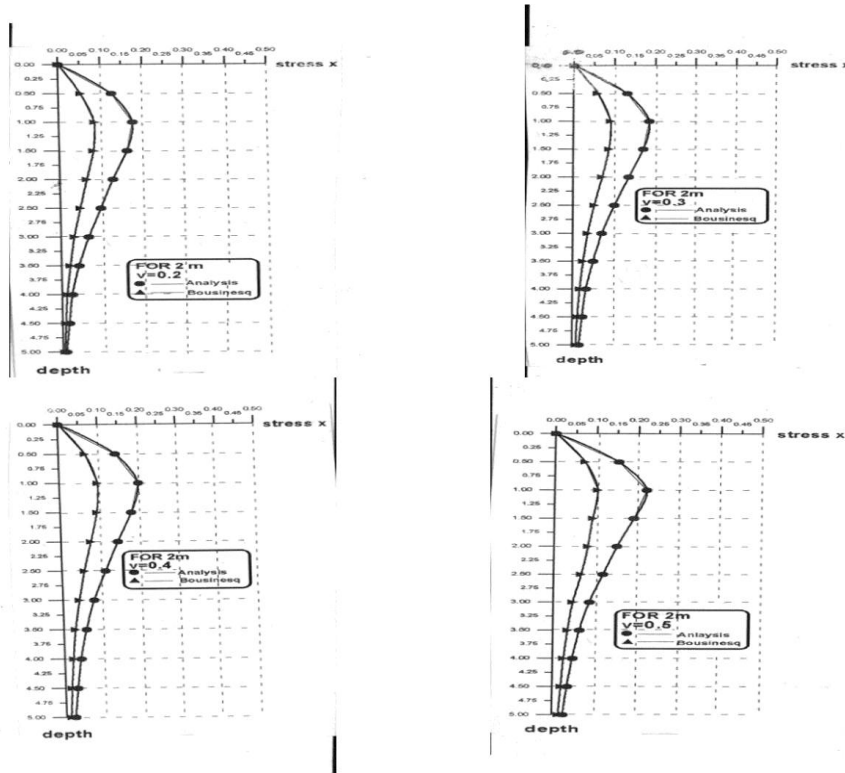


Figure 7. Profile of stress for linear load within a distance of 2 meters

These figures were compared in two ways, first, as the ratio of the area under each curve and second, in term of the mean ratio of pressure at any depth. According to the above comparison, we can see that the ratio applied on Boussinesq relation is less than 2 for different soil Poisson ratios, and with increased soil Poisson ratio the corresponding ratio decreases. Also, the applied load factor increases with increased load distance from the wall until at about 2 meters away from the wall, reaches to the value of 2 for Poisson's ratio equal to 0.2.

Figure 8 shows the ratio applied to Boussinesq relation in term of the load distance from the wall and different Poisson ratios. The resulting diagrams can present a relation for applied ratio on Boussinesq relation dependent on the Poisson ratio and the load distance from the wall. Also, we find that with increased the load distance from the wall, the lateral force effect increases from the surface; also, by increased soil Poisson ratio, the lateral force effect center increases in depth. The comparison between Boussinesq results and the analysis shows that the lateral force effect centers are higher than that of the analysis.

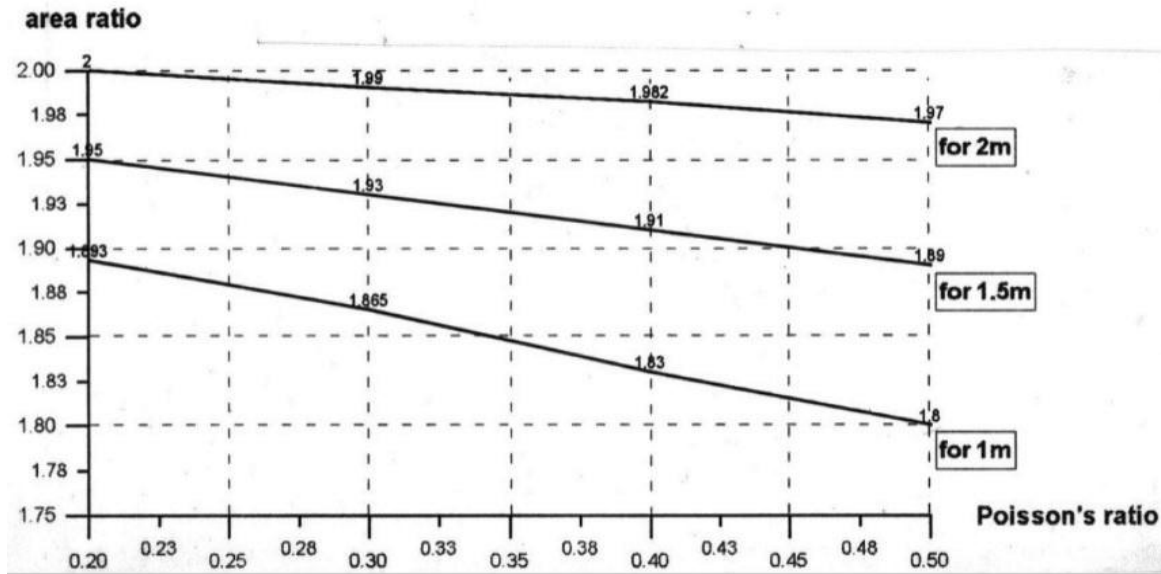


Figure 8. Incurred ratio in Boussinesq relation for different v, and x

According to Figure 8, using the regression line, we can convert available diagrams to straight lines. Then, we have a first-degree equation for any load distance from the wall as follows:

For 1 meter Area ratio = -0.314v + 1.957 (2)

For 1.5 meter Area ratio = -0.200v + 1.990 (3)

For 2 meter Area ratio = -2.020v + 0.098 (4)

Where, the following general equation can be used for different load distances from the wall:

$$\text{Area ratio} = b \cdot v + a \tag{5}$$

Where a and b are dependent on the distance of the load from the wall, and by increased distance of load from the wall, the negative slope value decreases. Figures 9 and 10 show the amount of slope and constant coefficients of line listed to the load distance from the wall, given the regression line we obtain the following equations:

$$b \text{ (Line slope)} = 0.216 \times (\text{the load distance from the wall}) - 0.528 \tag{6}$$

$$a = (\text{the load distance from the wall}) \times 1.8945 + 0.063 \text{ (constant coefficient)} \tag{7}$$

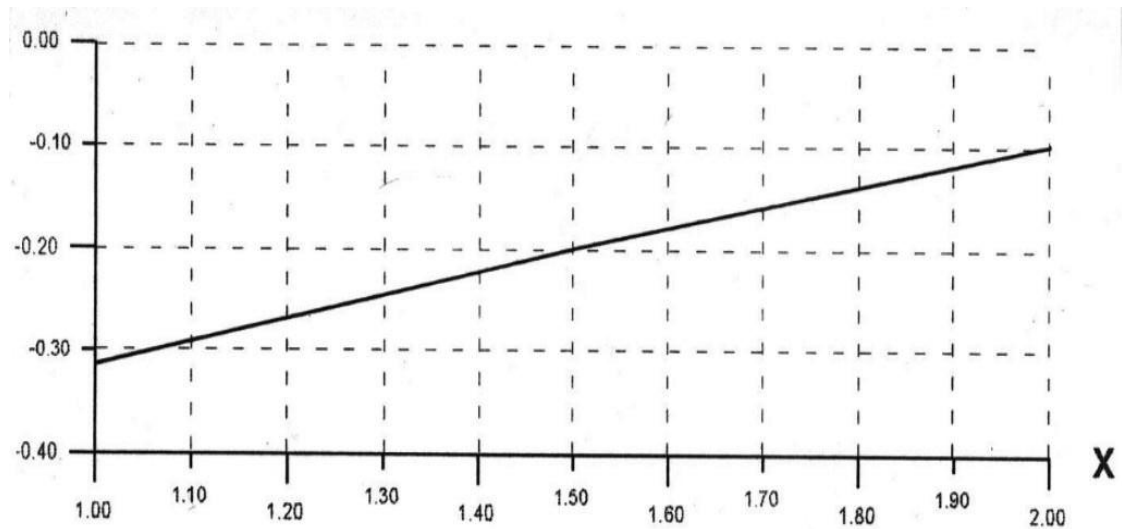


Figure 9. Slope of the line equation 5 for different load distances from the wall

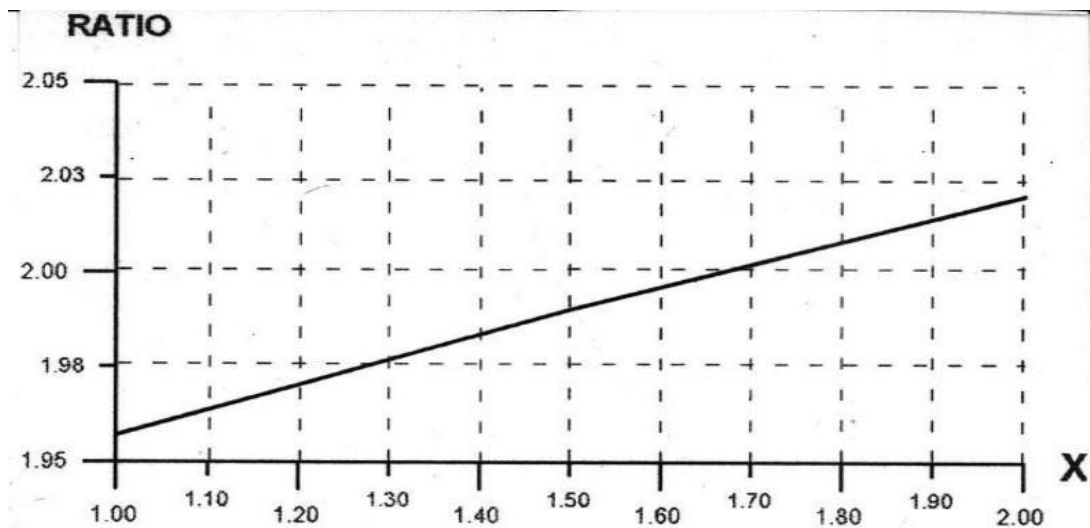


Figure 10. Constant parameter in the line equation 5 for different load distances from the wall

Finally, the equation (5) may be used to apply the ratio on the Boussinesq relation for lateral pressure due to the overload on rigid retaining walls with prevented movement. The relationship depends on the soil Poisson ratio and the load distance from the wall.

3. Conclusions

The present study led to the following conclusions:

1. The applied ratio on Boussinesq relation results depends on the amount of (x-y-z) load density and soil Poisson ratio and decreases with the Poisson ratio increase, while increases by increased load distance from the wall and reaches to 2.
2. The depth of the lateral pressure effect center increases by the increased load distance from the wall and for a fixed distance from the wall with increased soil Poisson ratio this depth increases.
3. Increased density while embankment leads to increase the soil lateral pressure.
4. Soils with more natural density have less ν and less lateral pressure due to overload compared to led dense soils.

5. The following equation can be used to apply ratios to Boussinesq relation for lateral loads due to overload in rigid walls without lateral movement with obtained ratios:
Areas ratios = $b \times (v) + a$

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