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Performance Analysis of Introjected Backfill Retaining Wall

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Abstract. Earth retaining structures can endure lateral stresses from the held soil as well as additional pressure from neighboring structures foundation, moving vehicles, or any other dynamic movement. While designing retaining walls, the amount and distribution of soil earth pressures are critical. The economy of retaining wall structure is depends on amount of earth pressure developed. Many techniques have been developed in the past to reduce soil lateral earth pressure on wall in order to create a cost-effective design. Provision of pressure relief shelves, use of light weight backfill, and inclusion of compressible geofoam etc are a few of approaches used. One of the least explores solution for reducing lateral earth pressure on retaining walls is Introjected backfill retaining wall. Introjected backfill wall consist of pressure relief shelves projected towards backfill side. Static load i.e., pressure load is applied on backfill soil for numerical simulation. The objective of the present study is to find out how effective relief shelves are at reducing retaining wall deflection and settlement of the backfill under various static loading conditions. A 14m high retaining wall with and without relief shelves by varying width is analyzed using finite element code ABAQUS2020.
Keywords: Rigid Retaining Wall, Relief Shelf, ABAQUS, Lateral Earth Pressure.

1 Introduction

A retaining wall is a structure that is built to withstand the lateral pressure exerted by the earth behind it and additional pressure due to foundations, moving vehicles or any other dynamic movements. It protects a steep faced slope of an earth mass from sliding down. The sectional design of a retaining wall is governed by the magnitude and distribution of earth pressure. This earth pressure on the retaining wall depends on the factors like soil cohesion value, angle of internal friction, and the magnitude and direction of retaining wall movement. Generally, it is assumed that earth pressure distribution follows the hydrostatic pressure distribution. However, multiple tests have proven that the above assumption is true in a specific instance when the wall is absolutely smooth and vertical. A pressure relief shelf is a horizontal cantilever platform of limited width that runs along the length of the wall, extending into the backfill at right angles, and it is built monolithically with the stem of the retaining wall. A number of similar shelves are built at regular interval along the length of the wall. A specific sort of retaining wall is a cantilever retaining wall with pressure relief shelves. The purpose of adding Relief shelves on the backfill side of a retaining wall is to decrease overall earth pressure on the wall, resulting in a thinner wall, increase retaining wall stability and a more cost-effective cantilever wall design. Literatures and other reported studies related to introjected wall can be found out in the studies by Chauhan et al. [1–5], Rizwan et al. [1], Shehata et al. [6], Chaudhuri[7], Moon et al. [8], Liu and Chen [9], Adonkar and Savoikar [10], Yoo et al.[11], and Djireb et al. [12, 13]. The present study uses ABAQUS2020 [14] to do a finite element analysis of retaining wall.

2 Numerical Modelling

The ABAQUS finite element code has been used for numerical analysis. Numerical simulations have been carried out for a 14m high retaining wall with three relief shelves of different width and situated at different positions to investigate the impact of relief shelves along the wall. The relief shelf thickness is kept constant as 0.5m. the material properties used in the study has been shown in Table 1.

Table 1. Material properties used in numerical modeling.

Properties	Units	Concrete	Backfill soil	Foundation soil
Unit weight (γ)	kN/m^3	25	16.5	16
Young's modulus(E)	MPa	2.75E4	13	34
Angle of internal friction (Φ)	(^{0})	-	39	30
Poisson's ratio (μ)	-	0.15	0.3	0.33
Dilation angle(Ψ)	(^{0})	-	0	0
Cohesion(c)	kN/m^2	-	30	30

The RCC concrete wall has been modeled using linearly elastic isotropic model. The backfill soil and foundation soil have been modeled as elasto-plastic with Mohr coulomb failure criteria. Surface to surface contact interaction was used for various surfaces of the structure. A tangential behavior with coefficient of friction as 0.37 and normal hard contact has been given between all the surfaces of the model. For the purposes of this study, self-weight and static loading have been taken into account. The surcharge loading has been applied on backfill soil. The outline and dimensions of the Introjected backfill retaining wall are shown in the below Fig. 1.

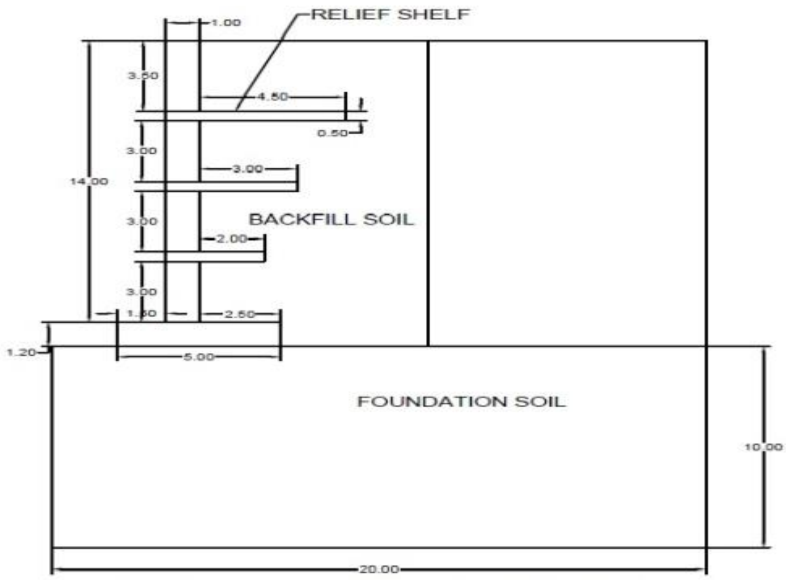

Fig. 1. Outline and dimensions of numerical model.

A numerical model of Introjected backfill retaining wall has been developed with height of 14 m. it is demonstrated in below figure. The introjected backfill retaining wall consist of pressure relief shelves which are projected into the backfill soil. The width of the relief shelf was varied from top to bottom in such a way that it should cut the active zone in 45+ϕ/2 angle with the base. The number of relief shelves have been determined based on the height and location of failure plane. In the present study optimum three numbers of shelf have been considered for the analyses. To check the effectiveness of the relief shelves, the length of the relief shelf was varied. A maximum of three pressure relief shelves are provided because three relief shelves are more effective in reducing earth pressure. Providing a greater number of relief shelves cause of excess development of stress on stem and it will cause for failure of retaining wall. The numerical model developed using ABAQUS has been shown in Fig. 2.

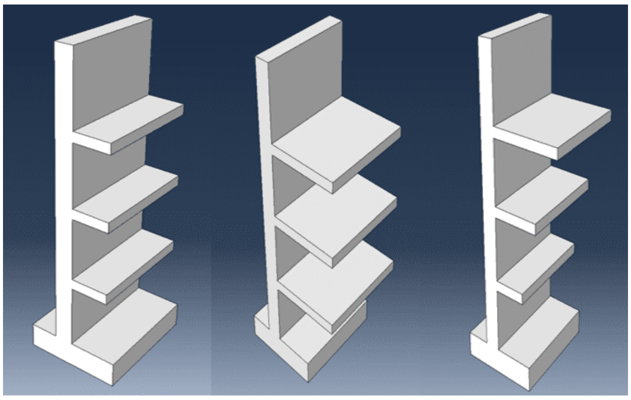

Fig. 2. Numerical model of introjected backfill wall.

2.1 Loading and Boundary Conditions

Generally, a retaining wall is subjected to a different type of loads like static pressure load, vehicle movement loads, seismic loads etc. In the present study only gravity loading and static pressure loading on backfill soil have been considered. These two loads have been given in two steps in [14]. In the first step, gravity loading has been given to whole structure which is the self-weight of the structure. After completion of analysis of the first step, Geostatic stresses have been generated due to gravity loading. In the next subsequent step static surcharge loading were given on backfill soil. There are three types of boundary conditions were given. At the bottom of base soil, fixed support condition (U=V=W=0) were provided to restrain horizontal and vertical movements. The side surfaces of soil i.e., in X and Z-directions roller support were provided. Two backfills are created, one separate backfill is for relief shelves, these two backfills have been connected with a tie constrain to act as one part backfill.

2.2 Mesh Discretization

All the parts of the numerical model have been meshed with free type of meshing with 10-node quadratic tetrahedron reduced integration, and hourglass control (C3D10). Global seed size of 1 is used with a free mesh type. Reduced integration is used due to counter the computational problems and time insufficiency. The discretized domain with boundary conditions have been shown in Fig. 3.

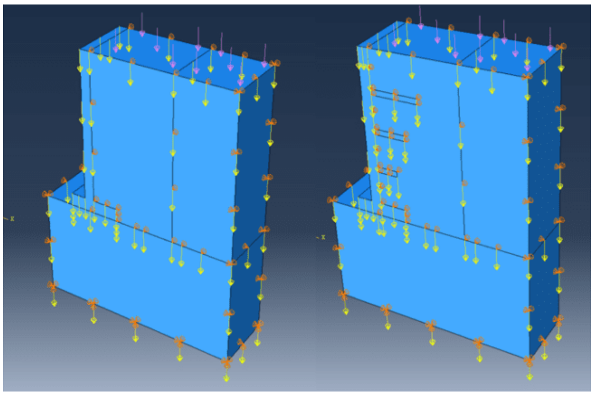

Fig. 3. Discretized domain with boundary conditions.

3 Results and Discussions

3.1 Model Validation

A 6m high non-yielding retaining wall with a single relief shelf has been modeled and validated as shown in Fig. 4. The deflection of relief shelf by varying its width and thickness has been compared with reported results of Khan et al. [1] as shown in Fig. 5 and Fig. 6. The deviation of results may be inherent limitations of numerical modeling and various assumption made in modeling.

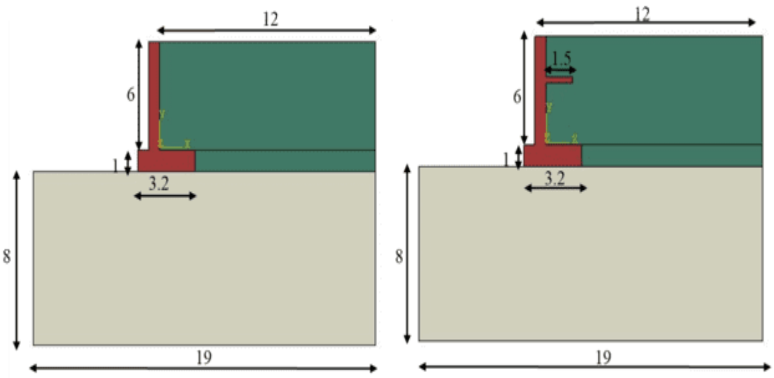

Fig. 4. Outline of the numerical model.

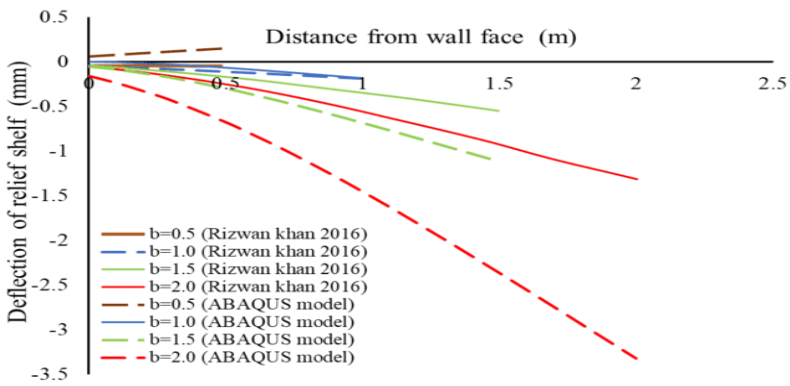

Fig. 5. The comparison of variation of deflection of shelf for different values of width of shelf.

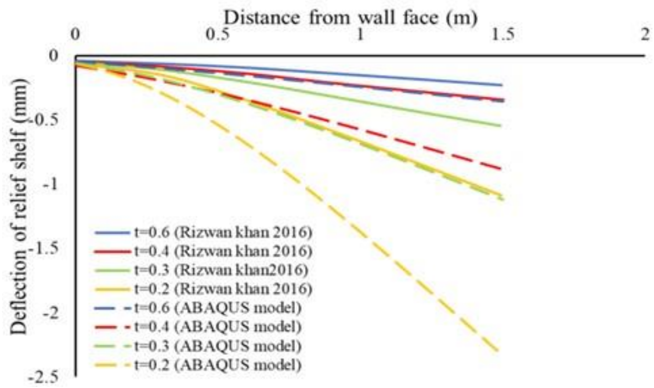

Fig. 6. The comparison of deflection profile of shelf for different values of shelf thickness.

3.2 Influence of Length of Releif Shelf

The performance of Introjected backfill retaining wall has been checked under various parameters like length of relief shelf and by varying soil properties. The efficiency of the wall has been determined based on the amount of reduction in wall deflection, backfill settlement and earth pressure. In the present study, three different shelves have been analyzed and the results are compared with conventional retaining wall. The deflection of retaining wall has been significantly reduced by providing curtailed length relief shelves shown in Fig. 7. The main reason behind the reduction in deflection of retaining wall is major part of soil load and surcharge load carried by relief shelves. The total deflection of wall is reduced by providing curtail length of relief shelves are 80%. By providing relief shelf the reduction in backfill settlement has been observed compared to conventional retaining wall but by varying the length of relief shelves there is no significant reduction in backfill settlement has been observed as shown in Fig. 7.

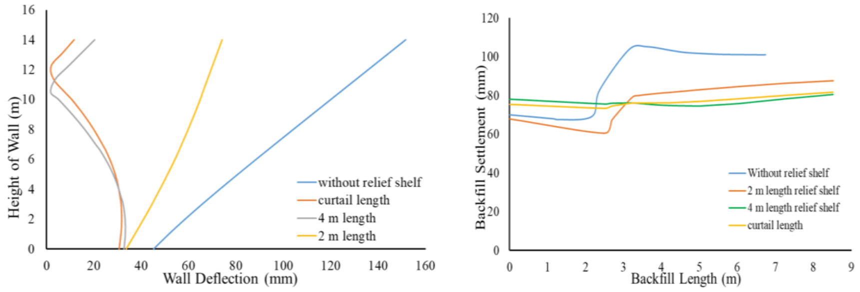

Fig. 7. The performance of releif shelf in terms of wall deflection and backfill settlement in different conditions.

3.3 Influence of Position of Releif Shelf

It has been seen that the topmost relief shelf is more effective in reducing settlement of backfill. The topmost relief shelf position has been varied from 1m to 4m from the top level of the wall and evaluated backfill settlement. From the **Fig. *8***, it has been seen that the relief shelf position at 4m from the top level of wall is reduce the backfill settlement compared to other positions.

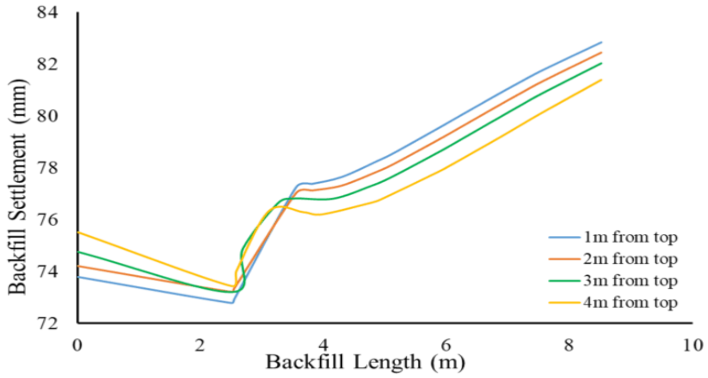

Fig. 8. The variation of backfill settlement due to various location of relief shelf.

3.4 Influence of Backfill Soil Strength Parameters

The cohesion of backfill soil has been varied from 10 kPa to 4 0kPa to check the variation in settlement of backfill soil, retaining wall deflection and earth pressure on Introjected backfill retaining wall. It has been observed that there is no significant change in backfill settlement by increasing in the cohesion value. Therefore, settlement of backfill soil was nearly same for both cohesive and cohesion less soil by providing shelves as shown in Fig. 9. It has been observed that by increase the cohesion of backfill soil the earth pressure increases. The variation of earth pressure and wall deflection are shown in Fig. 10.

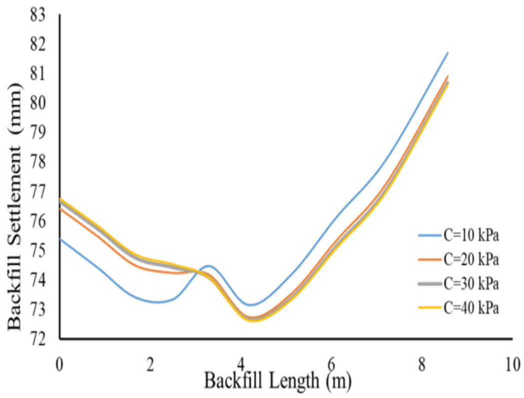

Fig. 9. The variation of backfill settlement due to different value of cohesion.

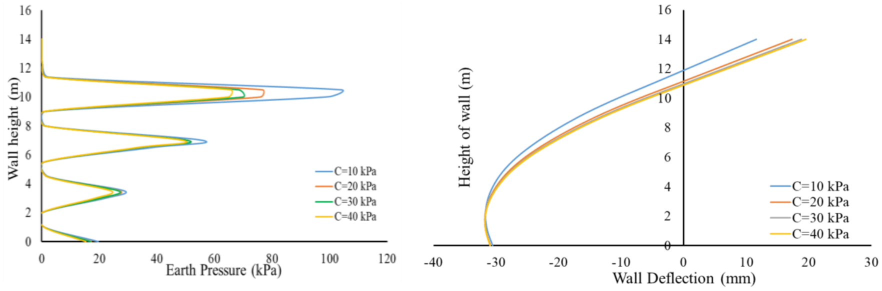

Fig. 10. The variation of earth pressure and wall deflection due to different cohesion value.

3.5 Influence of Surcharge Loading

The magnitude of surcharge load on the backfill side has been varied from 40 kPa to 70 kPa. The settlement of backfill soil has been evaluated. From the Fig. 11, it has been observed that if the magnitude of surcharge increases then backfill settlement has been enhanced.

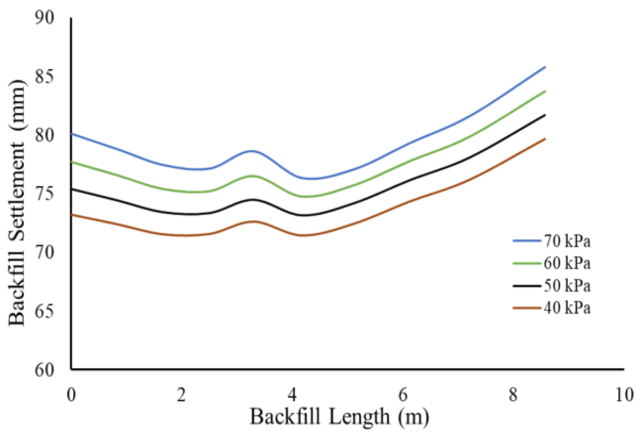

Fig. 11. The variation of backfill settlement due to various surcharge.

4 Conclusions

In the present study, the performance of introjected backfill wall has been evaluated. The effect of different geometric properties of retaining wall and relief shelves have been explored. Based on the results of the present FE model the following conclusions can be done.

- The maximum reduction in wall defection has been achieved by providing relief shelf with curtailed length, which is nearby 80.2%.
- Relief shelves with curtail length has been reduced the backfill settlement significantly.
- The present investigation reveals that by increasing the length of the relief shelf, the stresses at the junction of wall stem and relief shelf increase.

• The earth pressure reduction mainly depends on the length of the relief shelf. The present study reveals that with a 2m length of relief shelf the earth pressure is reduced by 74% compared to other lengths.
• The top relief shelf plays a significant role in the reduction of backfill settlement.
• The parametric study by varying cohesion and angle of internal friction, with retaining wall with relief shelf the earth pressure decreases for cohesive soil. The maximum reduction of earth pressure was revealed as 38%.
• Only the length of relief shelf is a major governing factor in the reduction of earth pressure on the retaining wall.
• The present investigations reveal that relief shelves with 2 m length are more effective in reducing earth pressure and relief shelves with curtail length reduce wall deflection and minimize stresses on the stem.

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