ROLE OF SHEAR KEYS IN CANTILEVER RETAINING WALL

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ABSTRACT: In this paper, the earth pressure distribution generated behind a retaining wall supporting sand, is estimated by the finite element method (using the finite element Plaxis program) and compared with those obtained from classical earth pressure theories like the ones proposed by Rankine (1857) and Coulomb (1776). In this analysis the behaviour of soil is assumed to be elasto-plastic with Mohr-Coulomb failure criterion. The concrete wall is represented by linear elastic model. The performance of the cantilever retaining wall with the shear key in various positions is also being studied analytically. The active and passive lateral earth pressures acting on the wall stem, obtained from the three approaches, are compared and discussed. Good agreement is found especially in the case of active earth pressures.

INTRODUCTION
Retaining walls are structures that are used to retain earth (or any other material) in a position where the ground level changes abruptly. They can be of many types such as gravity wall, cantilever wall, counterfort wall and buttress wall among others.

Shear Key in Retaining Wall
Since the cantilevered retaining wall is by far the most common type of retaining wall used, it is important to achieve as much efficiency in its design as possible. In general, the width (B) of the footing should range from 0.40 to 0.60 times the height (H) of the wall above the top of the footing. Retaining walls must provide adequate resistance against sliding. The resisting forces against sliding are mainly due to friction of wall base and the foundation materials and partly due to the passive earth pressure of the soil which may develop in front of the retaining wall as the wall tends to slide towards it.

If the wall is found to be unsafe against sliding, shear key below the base is provided. Such a key develops passive pressure which resists completely the sliding tendency of the wall. Safety factor may be defined as the ratio of resisting forces or moments to the forces or moments which tend to instabilize the wall. To insure proper functioning of the wall during its lifetime, adequate safety factors should be adopted. The safety factor against sliding should be at least 1.5 for cohesionless and about 2.0 for cohesive backfill. Where sufficient sliding stability is not possible—usually for walls with large H—a base key, has been used. There are different opinions on the best location for a key and on its value. It was common practice to put the key beneath the stem. This approach was convenient from the view of simply extending the stem reinforcement through the base and into the key.

In this paper, shear key has been considered in three locations, i.e., below heel, stem, and toe. The dimension of the shear key considered are width of 0.5m and depth of 0.5m, 1m, 1.5m, and 2m.

Description of the Problem
A cantilever retaining wall with the dimension shown in the Figure 1 is being analysed. The finite element mesh is as shown in Figure 2, while the material properties are given in Tables 1 and 2.

In this paper, the earth pressure distribution generated behind a retaining wall supporting sand, is estimated by the finite element method (using the finite element Plaxis program) and compared with those obtained from classical earth pressure theories like the ones proposed by Rankine (1857) and Coulomb (1776). For Rankine’s analysis five different cases are considered with \( \theta = 25^\circ, 30^\circ, 35^\circ, 40^\circ \) and \( 45^\circ \). For Coulomb’s analysis each of this case with wall friction, \( \delta = 0.5 \theta, 0.67\theta, 0.75\theta \), \( \theta \) is considered. Finally finite element analysis is carried out using commercial software PLAXIS version 8.2 for all cases mentioned above. For all the cases retaining wall without shear key and with shear key at the heel, stem, and toe are considered separately.
For the analysis, active case and passive case have been considered with loads of 100 KN and 400KN respectively.

**Table 1** Properties of Concrete (Linear Elastic)

<table>
<thead>
<tr>
<th>γ_unsat [kN/m³]</th>
<th>γ_sat [kN/m³]</th>
<th>k_x [m/day]</th>
<th>k_y [m/day]</th>
<th>E_ref [kN/m²]</th>
<th>ν</th>
</tr>
</thead>
<tbody>
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<td>24</td>
<td>0</td>
<td>0</td>
<td>3E7</td>
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</table>

**Table 2** Properties of Soil (Mohr – Coulomb)

<table>
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<th>γ_sat [kN/m³]</th>
<th>k_x [m/day]</th>
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<td>0.1</td>
<td>0.1</td>
<td>40000</td>
<td>0.3</td>
</tr>
</tbody>
</table>

**Figure 2.** Deformed mesh for a Passive load of 400KN

**Figure 3.** Maximum active earth pressure for δ = 0.5Φ

**Results without shear key**

**Figure 4.** Maximum passive earth pressure for δ = 0.5Φ

**Results with Shear Key**

**Figure 5.** Pa max for δ = 0.67Φ and Shear Key at Toe

**Figure 6.** Pp max for δ = 0.67Φ and Shear key at Toe

**Figure 7.** Pa max for δ = 0.75Φ and Shear Key at Stem
Below are the graphs showing depth of shear key v/s Factor of safety against sliding for different Φ. From the graphs it can be observed that factor of safety against sliding increases as the depth of the shear key increases. In any case, depth of shear key should not be more than half the base width.

In order to have an idea on the quantity of material for shear key, graphs showing percentage increase of Factor of safety v/s depth to breadth ratio for various angle of friction has been drawn.
CONCLUSIONS
From the above graphs and results following points can be recorded.
1. For active case, results obtained from finite element analysis are in good agreement with Rankine’s and Coulomb’s equation.
2. For passive case, results are close to Rankine’s equation. The value of wall friction angle (when greater than zero), which is considered in case of Coulomb’s equation, will not that affect the values of pressure distribution behind the retaining wall.
3. When comparing the location of shear key at heel, below the stem and toe, earth pressure is comparatively lesser in the case of heel, which in turn results in greater factor of safety against sliding. So the best location of shear key in a cantilever retaining wall is under the heel.
4. By increasing the depth of shear key from 0.5m to 2m, it shows an increase in factor of safety against sliding.
5. All the analyses performed in the study assume that the retaining wall founded on well treated or sound foundation in the present study. Therefore, ground movement only causes the minimum effect on wall deformation. In fact, study is needed to investigate the deformation behaviour of retaining wall on poor foundation.
6. All the analyses performed in this study assume that the retaining wall behaves in 2 – D plane strain condition. Therefore, it is necessary to perform the analyses in 3-D direction to verify the 2-D numerical analyses.

REFERENCES