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Failure Mechanism Evaluation of Plate Anchor Retaining Walls containing Crumb Rubbers by using PIV Technique

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ABSTRACT: Traditional techniques such as burning leads to some highly durable non-degradable synthetic materials that cause unrepairable environmental damages by releasing heavy metals such as arsenic, chromium, lead, manganese, and nickel. Today, scrap tires are used as lightweight alternative materials in many applications such as retaining wall backfilling. In the present study, several laboratory models were carried out to evaluate the stability of retaining walls reinforced with plate anchors. Then, the effect of adding different contents (10 and 20 wt.%) of crumb rubber to fill of a mechanically stabilized retaining wall with plate anchors were investigated including its effect on bearing capacity and wall horizontal displacements during static loading. To visualize the critical slip surface of the wall, particle image velocimetry (PIV) technique was employed. The results showed that the circular anchor plates provide a higher bearing capacity and wall stability in comparison to square plates. Also, it was found that the backfill with 10 wt.% crumb rubber provides the wall with the maximum bearing capacity. In addition, increasing the weight percentage of crumb rubber to 20 wt.% resulted in a significant reduction in bearing capacity and horizontal displacement of the wall, which occurred due to a decrease in lateral pressure against the whole walls. Moreover, an increase in weight percent of crumb rubber results in a decrease in failure wedge formation and expansion of wall slip surface while the failure wedge is not formed in mix of sand-20 wt.% crumb rubber.

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1- Introduction

Simultaneous use of plate anchors as retaining walls reinforcement and recycled tires as lightweight filler material could be a suitably combined method in terms of economic, environmental and safety aspects of wall stability under static and dynamic loadings. Plate anchors with one or multiple buried plates in soil have high pull-out capacity. Unlike metal strips and geogrids, which their bearing is caused by surface friction and locking with soil particles, the presence of recycled tires separately or mixed with soil has no devastating impact on the pullout capacity of plate anchors because of their direct relation to the end plate. The present research is conducted to investigate the effect of adding different weight percentages (10 and 20 wt.%) of crumb rubber to fill material of a retaining wall and effect of plate anchors geometry, dimensions and reinforcement configuration on bearing capacity of the wall. To observe the critical slip surface during each experiment, particle image velocimetry (PIV) technique was employed as a technique for detecting soil particles displacement in a laboratory setting. This method, being originally applied in fluid mechanics and tracing gas and soil particles flow, was initially put into practice by White et al. (2003) in laboratory modeling in geotechnical problems [1-5].

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2- Methodology

To carry out tests at a laboratory scale, a dimensionality reduction ratio of 1/10 was applied. Thus, all dimension of the designed retaining wall were divided by 10. As a result, a retaining wall with a height and length of 3000 mm was reduced to a wall with 300×300 mm2 dimensions.

To construct permanent retaining wall facing, prefabricated or precast concrete blocks were used. Wood (2003) conducted a dimensional analysis and introduced different types of material with different thicknesses for a 300 mm concrete facing in laboratory modeling. Hence, a 0.9 mm thick aluminum plate was used in the experiments conducted in the present work [6].

The soil used in all tests was the dry sand from Sufian (in Eastern Azerbaijan, Iran). According to the Unified Soil Classification System (USCS), the soil is classified as poorly graded sand with letter symbol 'SP'.

Three square and circular anchor plates with different areas are typically used in retaining wall construction as mechanical plate anchor reinforcements (16.9, 22.5 and 28.2 mm of circular plates diameter and 30, 40 and 50 mm square plates side length). The length and diameter of applied tie rods were respectively 300 mm and 4 mm, which are their scaled 3000 mm and 40 mm actual dimensions.

The horizontal and vertical distances of passive reinforcements (no post-tensioned), such as grouted and helical (screw) soil nails, and active reinforcements (post-tensioned), such as grouted and helical (screw) soil anchors, were reported between 1000 mm and maximum 3000 mm [7-9]. Because no post-tensioning occurs in these plate anchors, the horizontal and vertical distances were both selected as 1500 mm. By applying a dimensionality reduction coefficient of 1/10, a 150 mm center-to-center distance was obtained for reinforcements in the wall. Accordingly, three applied reinforcement configurations including 5-anchor, diamond, and square configurations are presented in Figure 1.

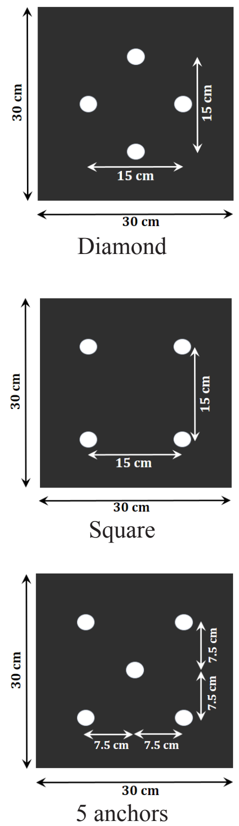

Figure 1. Reinforcement configuration

All crumb rubbers were screened and those passed from sieve #4 (4.75 mm) and remained on sieve #6 (3.35 mm) were added to the soil mixture. Because of implementing particle image velocimetry (PIV) tests, using particles with larger sizes was not possible.

3- Results and Discussion

The maximum bearing capacity for walls is related to the large, medium, and small anchor plates in the order of their appearance. Also, the small plates not only give the minimum bearing capacity but also show the maximum horizontal displacements. The minimum horizontal displacements are for the large, medium, and small anchor plates in the order of their appearance; indicating the suitable anchorage of active zone (failure wedge) to the passive zone through medium and large plates.

Among all configurations shown in this Figure 1, the 5-anchor configuration provides a higher wall stability because of having one more reinforcement. In this regard, in all tests, the diamond configuration gives a higher bearing capacity compared to the square configuration.

The minimum horizontal displacement is for the 5-anchor configuration, with the diamond configuration being in the next position. The noteworthy point here is the small difference between wall displacements for diamond and 5-acnhor configurations despite one less reinforcement for the former configuration. In addition to the minimum bearing capacity of the square configuration, the maximum wall horizontal displacements (with a high difference) is for this configuration that implies its lower efficiency compared to other two configurations.

4- Conclusion

The maximum footing bearing capacity and the minimum wall displacement is for the large, average, and small plate anchors in the order of their appearance. Significant increases in bearing capacity with changing the plates dimensions from small to medium and fewer increases in the value with changing the plates dimensions from medium to large are achieved, which shows the low strength and limited locking of small plates against lateral soil pressure.

Circular plates show better performance in terms of bearing capacity and wall horizontal displacement compared to square plates.

The 5-anchor configuration shows a higher bearing capacity because of an extra reinforcement. Followed by this configuration, diamond and square configurations have the larger bearing capacity, in the order of their appearance. In square configurations, the maximum displacement is observed at middle wall height due to the large meshes (30 cm^2) of zones without reinforcement in the middle wall height.

Fills made using 10 wt.% of crumb rubber indicate the maximum bearing capacity. A descending trend of the wall horizontal displacement occurs by increasing the crumb rubber content. The minimum wall horizontal displacement occurs on fills with 20 wt.% crumb rubber.

The PIV analysis images indicate that formation of failure wedge in 5-anchor and diamond configurations is less distinct compared to that in a square configuration, with the large circular plate anchors having the maximum performance. Also, addition of crumb rubbers, especially at 20 wt.%, leads to a considerable decrease in slip surface propagation.

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