Effectiveness of geogrid reinforced embankment with cushion layer as a rockfall protective structure

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Introduction

Rockfall protection structures (RPE) such as an embankment wall, bridge abutments play a significant role in engineering fields. In many civil engineering infrastructures projects, these structures are being used and are often subjected to different impact forces caused by rockfall. Type of filling materials acts as the main factor for the performance of embankment wall under static and dynamic loading conditions. For better stability of protective structures, various types of reinforcements are used in the embankment wall. In recent years, geogrid has obtained significant importance as soil reinforcement materials in civil applications due to their high tensile strength and acceptable extensibility. Nowadays, they are widely used in such applications as roads, embankment structure and retaining walls, since they possess several advantages over existing methods regarding cost-effectiveness, stability. On the other hand, the sand cushion is often used in rockfall protection structures as a shock absorber. Impact by rock fall is considered one of the most important variable loads for protection structures. However, the geosynthetic reinforcement and the cushion layer acts as a cover or layer to absorb the impact force. The objective of this study is to investigate the effect of impact load, geogrid reinforcement and cushion material on vertical pressure against the embankment wall.

Experimental Setup

Fig 1.shows the details of the experimental apparatus, which consist of several parts - Vertical falling impact test device & Angular falling impact test device. The chamber soil for the drop weight falling impact test is made of acrylic plate, which is 60 cm in length, 30 cm in height and 10 cm in width. A total three load cells (LC) for impact force measurement, are connected to the bottom of the embankment between the impact plate and the base plate. Figure.1 shows the layout of the LC. The guide rails that are used to control steel weight which is installed vertically on the apparatus the lenght is 2 m.

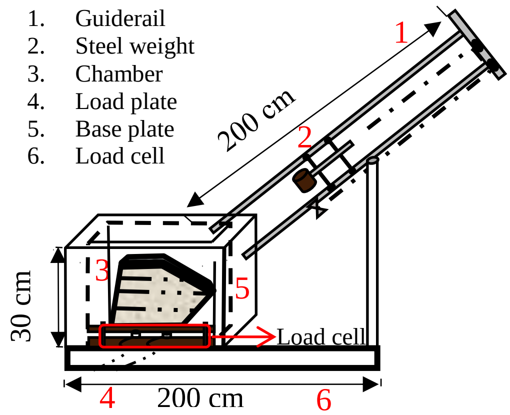


Fig1. Drop weight falling impact test

Testing materials and methodology

The Physical Properties of Masado soil which is used in this study, as follow; the specific gravity Gs=2.721, maximum dry density ρ_{dmax}= 1.56 (g/cm^3), minimum dry density $\rho_{d_{min}}$ =1.42 (g/cm^3), maximum void ratio e_{max} = 1.711, minimum void ratio e_{min} = 1.121 and angle of internal friction φ = (38°). The properties of Toyoura Sand which are used for cushion layer in this study are as follows; maximum dry density $\rho_{d_{max}}$ = 1.47 (gr/cm^3), minimum dry density $\rho_{d_{min}}$= 1.12 (g/cm^3), gravity Gs= 2.656, maximum void ratio e_{max} = 0.953, minimum void ratio e_{min} = 0.612 and angle of internal friction φ = (36 °). Many of the physical properties of geogrid including the type of structure, rib dimensions, junction type, aperture size, and thickness were measured directly which is shown in Table 1. The Masado soil was used as main filler material for embankment wall. The Masado soil was compacted to the optimum water content, in three layers of 10 cm thickness. Each layer was compacted with high and low compaction. High compaction density was 1.56 g/cm3 and low compaction density was1.42 g/cm3 as shown in figure 2To absorb the impact load energy from the rockfall, the sand cushion was used as amplification layers. And, for the stability of the embankment wall, from geogrid reinforcement materials was used as horizontal layers. To get better results, different parameters such as weight and drop height on embankment walls were used.

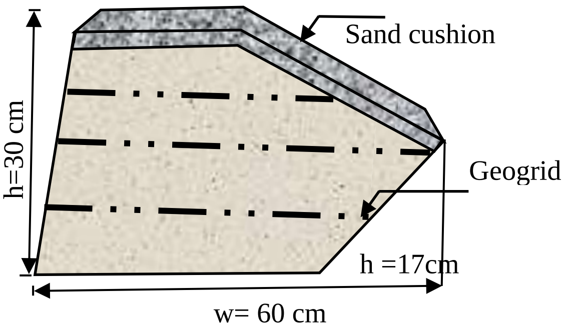
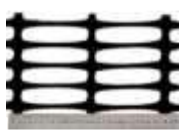


Fig2. Schematic embankment model

Table1. Physical properties of geogrid

Properties	Values
Mesh type	Black
Aperture size (MD), (mm)	20
Aperture size (XMD),	6
Rib thickness, (mm)	4.5/3
Rib width (mm)	1.6/1.2
Thickness of Junction, (t$_j$	1.5



Keywords: rockfall, embankment, geogrid, sand cushion and experiment.
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Results and descussions

1.1 Effect of impact force and incident angle

Figs. 3, 4, and 5 illustrate the reaction impact force as a function of height, density and its maximum point as a function of weights. Based on those figures, increasing the heights of dropping the impact load has a significant increase in the reaction force, which is measured by the load cell that was connected at the bottom of the embankment model. The obtained results show that the impact force increases with steep slope regardless with increasing weight (w) and drop height (h). However, the higher density soil provides greater impact strength, thereby guaranteeing greater energy absorption compared with low density. In the case of geogrid reinforcement; it can be observed that the increased loads are absorbed by the tensile strength of the reinforcements. At the same time, the compacted soil can resist the compression stresses linked with the vertical loads. However, the cushion layer exhibits the strongest reduction effect due to high energy absorption capacity among the non-reinforced and reinforced materials.

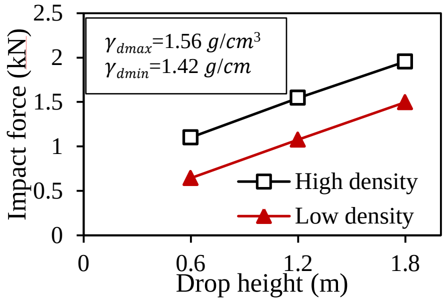

Fig3. Impact force with drop height and different density

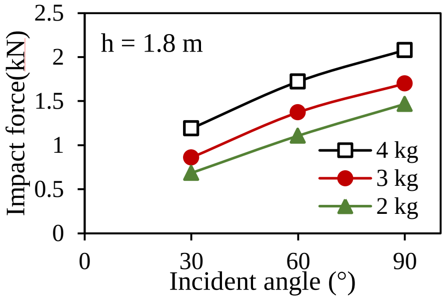

Fig4 .Impact force drop height with Incident angle and different weights

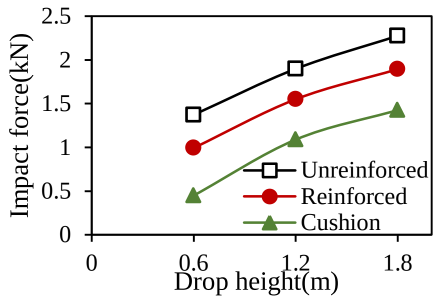

Fig 5.Impact force drop height for reinforced and cushion with different weight

1.2 Influence of cushion layer

A layer of cushion material on the protection measures reduce the impact force to a greater extent. The reduction effects are dominated by the cushion material and the thickness of the cushion layer. The thicker the cushion layer, the greater the reduction effect and therefore the less the impact force. As shown in Figure 6and 7. The measured impact force after reduction by the 4 cm thickness cushion layer is about half of that after reduction by the 2 cm thickness cushion layer.

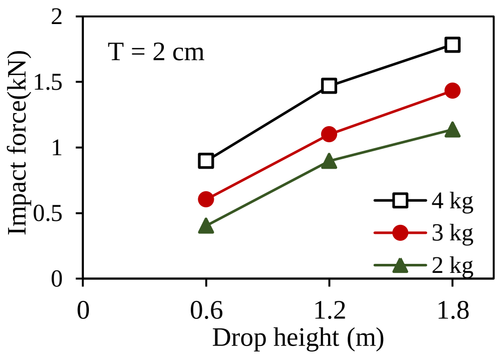

Fig 6. Influence of cushion layer with 2 cm thickness

Conclusion

It can be observed the higher density soil provides greater impact strength, thereby guaranteeing greater energy absorption compared with low density. A layer of cushion made of sand significantly reduces the impact force, and the thicker the cushion layer, the greater the extent of reduction. In the case of geogrid reinforcement, it can be observed that the increased loads are absorbed by the tensile strength of the reinforcements. At the same time, the compacted soil can resist the compression stresses linked with the vertical loads.

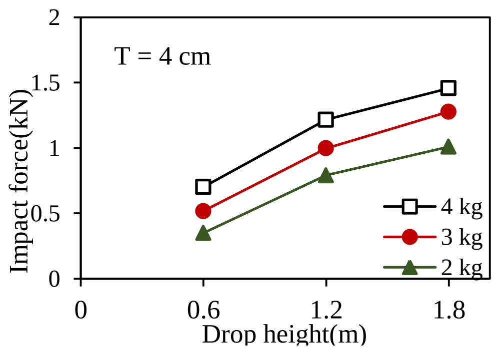

Fig 7. Influence of cushion layer with 4 cm thickness

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