An alternative model of retaining walls on sandy area to prevent landslides

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Abstract. Landslide is one of the potential disasters that can take life and material. A way to reduce disaster risk in slopes is to improve slope stability. A challenge in improving slope stability is how to make soil retaining walls that are simple, quickly built, and workable in the process. This research focuses on laboratory tests of gravity, segmental, and pre-cast retaining walls in sands. The tested models are slopes with different segmental, pre-cast, gravity walls made of un-reinforced concrete for static loads. The slope failure patterns were observed with their load variations. There are two wall models segmental. Each segmental wall observed a collapse pattern that occurred behind the wall. Static loading is carried out step by step until collapse occurs in the segmental wall. Observations and defects are carried out during the load process until the segmental wall collapses. This research shows that segmental pre-cast retaining walls with specific models and sizes can be selected to support certainly given loads to prevent slope failure.

1 Introduction

Landslides often occur on sloping surfaces or hilly areas. The gravitational field of the earth draws soil down from a higher area to a lower one. One way to prevent this happening is to construct retaining walls be they gravity, semi gravity, cantilever, Counterfourt, Gabion, Embedded, Soil Nailing, Crib, Reinforced, or segmental Retaining Walls. This research focused on segmental retaining walls (SRW).

At present, SRW is commonly used to stabilize the soil around main road bridges, embankments. SRW is cheap, easy, and quick to construct, does not require much labor, and can be made attractive [1]. Another advantage of using SRW is that water can flow between its segments, and hydrostatic pressure decreases [1][2][3]. The resulting force is parallel to the backfill. This construction method is also a flexible and adaptable way to increase the stability of a roadbed, and so is a common feature of modern highway construction [4].

It was initially known as conventional retaining walls such as gravity, semi gravity, and cantilever retaining walls that were built using masonry or concrete pairs. In 1969, Vidal discovered a retaining wall with the concept of reinforced soil using geosynthetic sheets or steel reinforcement. In 1984 found the retaining wall of the soil by arranging a pile of segmental elements made of concrete. The composition varies so that it can adjust to the existing contours with an attractive appearance (artistic) and become famous in various countries. However, this lack of segmental walls cannot be built for higher walls ([5].

The risk of SRW collapse can be analyzed from the construction design [6]. A wall must be designed to be safe against sliding, overturning, and not overload the carrying capacity of the soil it is built. Forensic failure studies inform engineers so they can avoid repeating mistakes and build safer and more efficient constructions. Any retaining wall should meet internal, external, and local stability requirements so that it has a long life.

Annisa's research results state that relative density, dynamic sinusoidal acceleration, and type of retaining wall affect the area of movement of material behind the retaining wall. The relative density will affect the area and shape of the grain movement field. The relative density will be inversely proportional to the area of grain movement. When the density value is relatively high, the area of grain movement that occurs is quite small. Furthermore, when the density value is relatively low, it is getting wider and in the form of grain movement [7].

In analyzing the stability of a retaining wall, assumptions are needed in calculating the landslides that occur behind the retaining wall. For this reason, a method or method is required in designing the construction of retaining walls by considering the shape of collapse or landslides that occur. This study is to look for any parameters that contribute to the movement of sand grains due to static loads.

The study of collapsed model walls looking at the load that produced the collapse and the extent of the collapse that occurred can inform future construction. In this study, modeling was constructed in a laboratory scale to compare empirical results with a commonly used retaining wall design tool, Rankine's theory. This study focuses on landslide patterns in the sand and compares it with those predicted by Rankine's theory.

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2 Rankine Theory

The Rankine Method (1857) examines stresses in the soil that vary with conditions of plastic balance. Plastic or plastic equilibrium balance in the soil is a condition where the mass points of the soil are undergoing a process of collapse. The concept of the Rankine method is useful for estimating the amount of lateral pressure occurring behind a retaining wall. The modified Rankine theory can be used to calculate the value of soil cohesion and slope. Equations of Rankine's theory are simple and conservative compared to Coulomb's theory. On the other hand, Rankine's theory also has a weakness because it assumes there is no friction between the ground behind the wall and the retaining structure.

Rankine (1857) proposed the following assumptions about soil pressure on retaining walls:

- There is no adhesion or friction between the wall and the ground (friction is so small that it is ignored.
- Lateral pressure is limited to vertical walls of 90 °.
- Landslides (in the fill) that occur as a result of soil displacement are determined by the ground shear angle (ϕ′).
- Lateral pressure varies linearly with depth, and the resultant pressure is that at one-third of the height of the wall, measured from the bottom of the wall.
- The resultant force is parallel to the surface of the fill.
- The surface of the soil behind the retaining wall is horizontal.

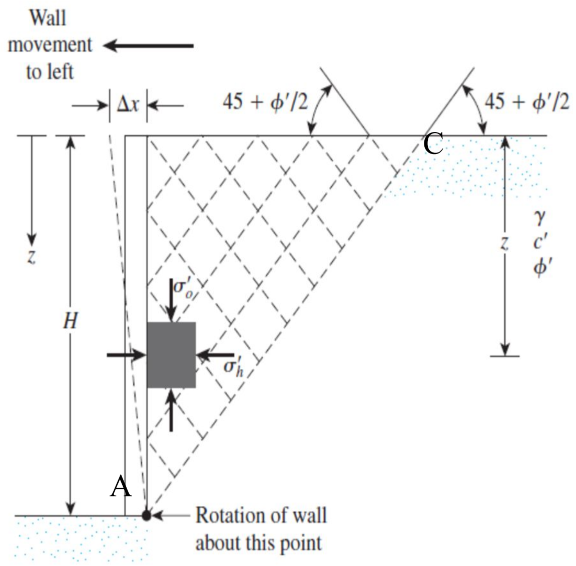

Fig. 1. Rankine Active Pressure (Source: Braja M. Das, Principle of Foundation Engineering)

Fig. 1 shows the assumptions used in the Rankine theory. When the wall moves to the left due to lateral earth pressure behind the wall, the soil mass will collapse along the AC surface. This surface is slightly curved. If the slide surface is assumed to be a flat AC surface, the analysis will show that the slide surface will form a 45 ° + ϕ / 2 angle with the horizontal plane. In this research, experimental landslide experiments compared the theoretical model based on these assumptions with what is observed in the laboratory.

3 Laboratory Experiment

Laboratory experiments used sand soil that passed sieve number 40. The model was built in an 80cm x 40cm x 10cm glass box so that results could be analyzed visually. Each layer of sand soil was dropping into the glass box from a constant height to ensure uniform density. A colored mark was made each 2.5 cm on the side of the glass to help identify traces of landslide sand. A 5 cm x 5 cm x 9.9 cm model SRW was arranged, as shown in Fig. 2a and Fig. 2b.

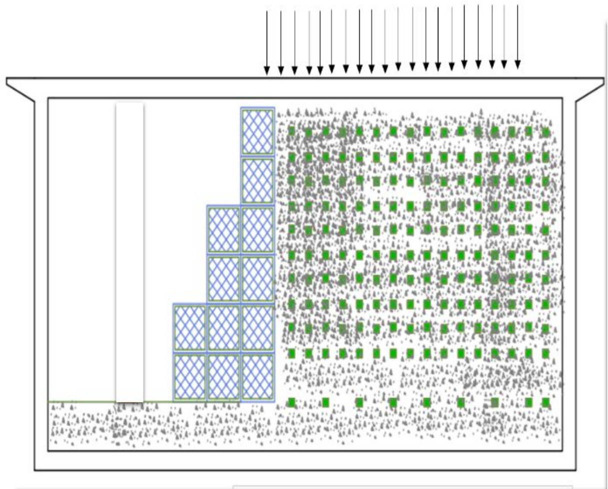

Fig. 2. Laboratory scale model (first model SRW1)

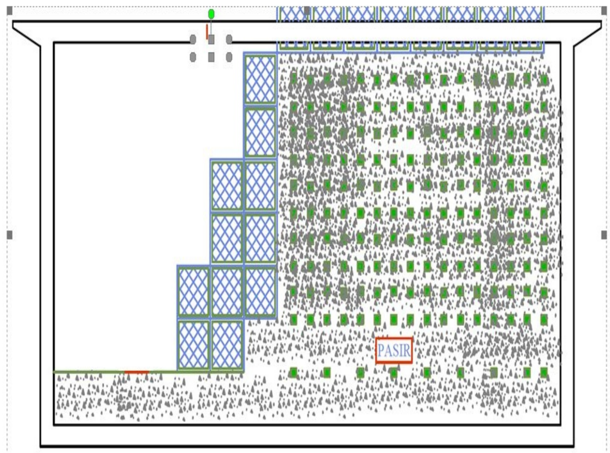

Fig. 3. Laboratory scale model (Model SRW2)

Laboratory experiments used sand soil that passed sieve number 40. The model was built in an 80cm x 40cm x 10cm glass box so that results could be analyzed visually. Each layer of sand soil was dropping into the glass box from a constant height to ensure uniform density. A colored mark was made each 2.5 cm on the side of the glass to help identify traces of landslide sand. A 5 cm x 5 cm x 9.9 cm model SRW was arranged, as shown in Fig. 2a and Fig. 2b.

Literature values for the sand soil properties that were used in calculations are recorded in Table 1.

Table 1. Soil properties of soil

Type of Parameter	Value
Total Unit Weight (γ)	1,472 gram/cm^3
The cohesion of soil (**c**)	0 gram/cm^2
The angle of internal friction of soil (ϕ)	31,699^o
Sieve analysis of soil	96,067 % (sand)

The material the SRW was made of concrete using sand, cement, and water in a ratio of 2: 1: 1 without reinforcement and had a total unit weight (γ_c) of 220 kg / cm3. Loading was applied in steps observing the movement patterns of the sand and SRW after each step until the SRW collapsed (at a certain loading) using image analysis with a camera to take pictures and videos at each stage of construction and loading.

4 Results and Discussion

4.1. Model SRW1

In the laboratory, static loads were applied in stages to several model SRW. During the test, displacement of sand and SRW was observed and recorded, so that known the shape of the movement of sand grains occurred behind the SRW. In order to record the movement of sand grains, each distance of 2,5 cm (vertical and horizontal direction) is given a colored mark placed on the side of the glass. Fig. 3 shows the movement of soil grains during initial loading. Fig. 4 shows the movement of the grains as the soil began to slide. At the end of the slide, the pattern of sand grain movement could be identified, as illustrated in Fig. 5

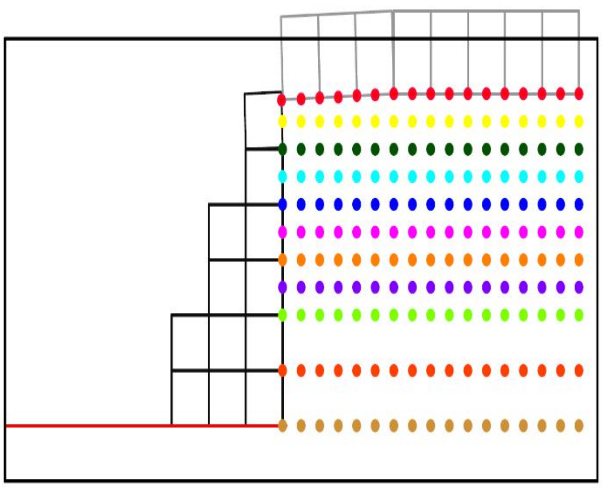

Fig. 4. Position of sand and SRW1 on initial position

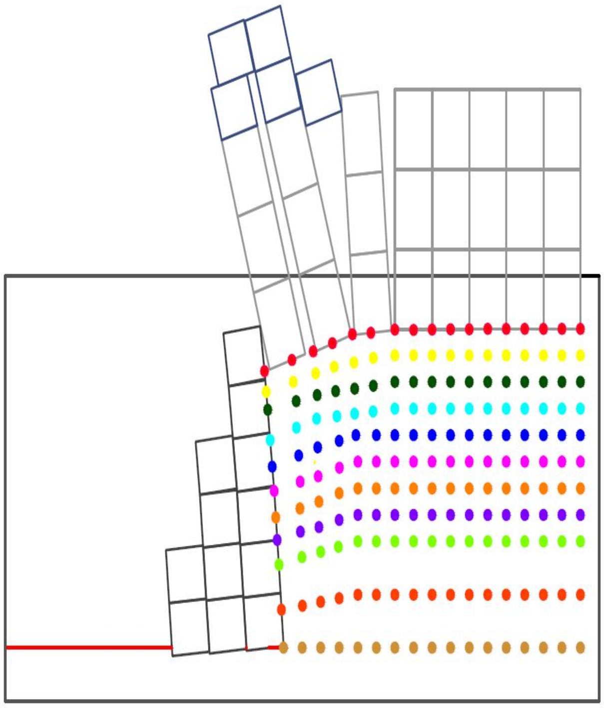

Fig. 5. Position of sand and SRW1 at the beginning of failure

At the end of the slide, the pattern of sand grain movement could be identified, as illustrated in Fig. 5.

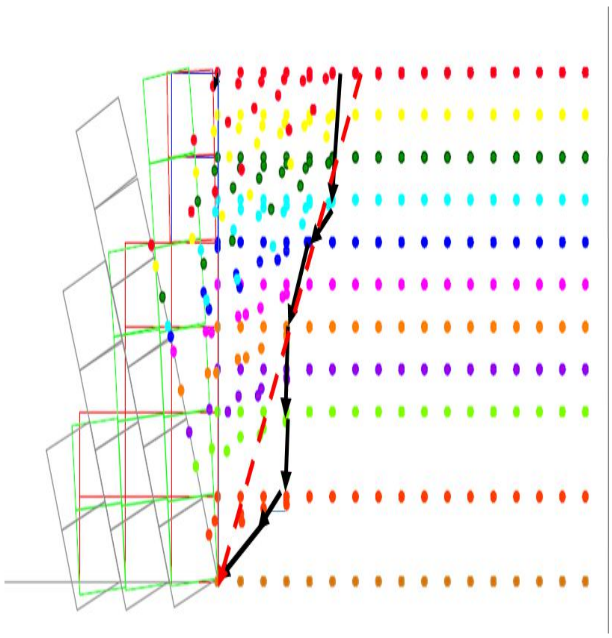

Fig. 6. The pattern of sand grain movement (SRW1)

The black line (Fig. 5) shows the pattern of sand soil collapse with the model SRW1, and the dashed red line shows the theoretical collapse pattern based on the Rankine assumptions with a sliding angle of 60.84950. It can see that the shape of the surface collapse is not a smooth curve or straight line but almost like the letter S or the scribble curve. The angle of collapse that occurred was smaller than the angle of collapse predicted in the Rankine Theory.

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4.2. Model SRW2

As with the model SRW1, in the model SRW2, the loading was also done in stages while looking at the movement of the grains of sand. Fig. 6 shows the model SRW2 in position at the start of loading. A slight decline or movement of sand is visible due to loading. Fig. 7 shows the movement of sand grains at the beginning of the slide and Fig. 8, at the end of the collapse, the pattern of collapse is evident.

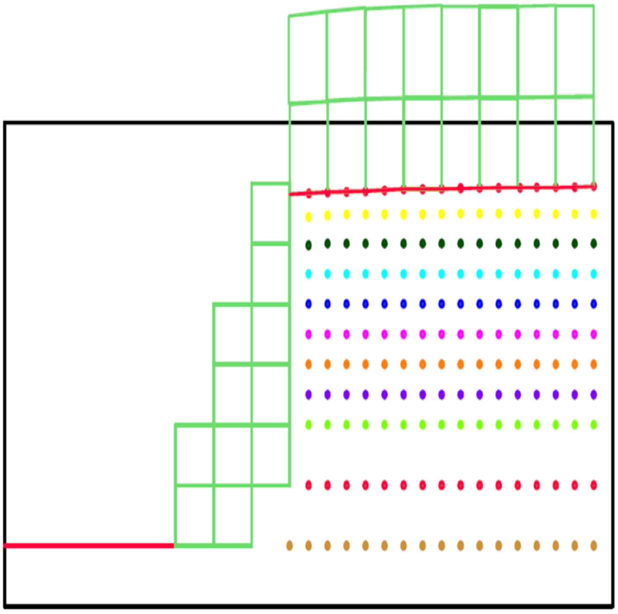

Fig. 7. Position of sand and SRW2 on initial position

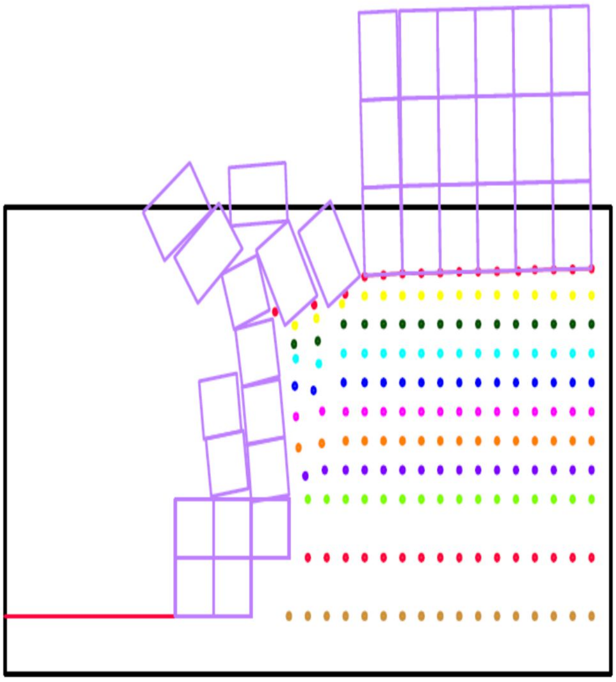

Fig. 8. Position of sand and SRW2 at the beginning of failure

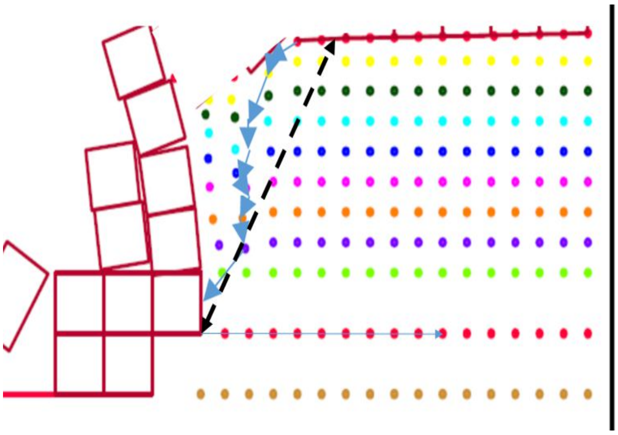

Fig. 9. Pola The pattern of sand grain movement (SRW2)

The gray arrow indicates the pattern of collapse that occurred in the model SRW2. The dashed black line is the estimated collapse according to Theory Rankine with a slope angle of 60.84950. As with the model SRW1, the pattern of collapse or movement of grains of sand resembles a letter S. In Fig. 8 also shows that the angle of collapse in the horizontal plane is also smaller than the estimated angle of collapse in the Rankine Theory.

5 Conclusion

- This laboratory experimental has shown a different pattern of failure surface for sand backfill compare to Rankine theory.
- The angle of failure surface at the bottom wall is likely less than 45° + ϕ/2 and the distance of the failure on the backfill surface also less than the backfill surface of Rankine theory.
- These experiments provide an opportunity for further research in understanding the failure of segmental barrier walls

References

1. H. Bui, J. A. Kodikara, R. Pathegama, A. Bouazza, and A. Haque,. ICSMGE 2013 **1** 687–690, (2013).
2. NCMA, *Design Manual for Segmental Retaining Wall*, 5th ed. Herndon, VA: NCMA Publication Number TR 127B.
3. R. Tiwari, N. T. K. Lam, and E. Lumantarna, *Aust. Earthq. Eng. Soc. 2017 Conf. Nov 24-26, Canberra, ACT*, (2017)
4. X. Jia, J. Xu, and Y. Sun, Discret. Dyn. Nat. Soc., (2018).
5. Moch. Sholeh; Yunaefi, J. Tek. Sipil **10** (2) 120–126.
6. A. Haddad and G. Shafabakhsh, *Geosynth. Civ. Environ. Eng. - Geosynth. Asia 2008 Proc. 4th Asian Reg. Conf. Geosynth.* 852–856, (2008).
7. A. M. Hidayati, *J. Rek. Sipil* **8** (1) (2012).