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A research on the tensile resistance of wired rope anchor

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ABSTRACT: This research is an attempt to propose a new method of stabilizing soil using wired rope anchor as tension reinforcement embedded in soil mass. The proposal is supported by experiments involving the pulling of wired ropes placed in sand. Resistance against pull was measured experimentally using ropes and rods separately. Currently steel rods are usually being used for this purpose. However, during this research, comparative experiments using the conventional steel rods and wired rope were conducted. It was found that wired ropes were more effective than their conventional counterparts.

1 INTRODUCTION

In civil construction, anchors of various forms and material are in use for various purposes such as strengthening of retaining walls, supporting cut slopes, stabilizing weak soils etc. It is important to consider the effectiveness of the anchor type and materials selected for a particular application. Studies on the use of wired rope anchor as reinforcement in embankments are almost non-existent. This study tries to fill this gap.

Laboratory experiments were conducted to examine the effectiveness and safety of using wired rope anchors as reinforcement in soil embankment. The experiment was conducted in sand. Separate sets of tests were performed with wired ropes and steel rods as soil reinforcement. Parameters describing the wired ropes or rods were their number, arrangement, size and shape of cross-section, and material properties; and the parameter varied for sand was its density.

In one case, experiments were conducted by using wire ropes or rods, and in another case, ropes or rods were tied together with a wire-netted frame (Figure 1). This wire frame was 38 mm by 60 mm in dimensions, and two types of frame, one with 7mm by 7mm mesh and the other with 9mm by 9mm mesh, were used. During the experiment, a constant surcharge load was applied at top of reinforced sand layer, and tensile force applied at the end of reinforcement bars. Displacement, δ, and pull out force needed to pull out the reinforcement, P_t were measured.

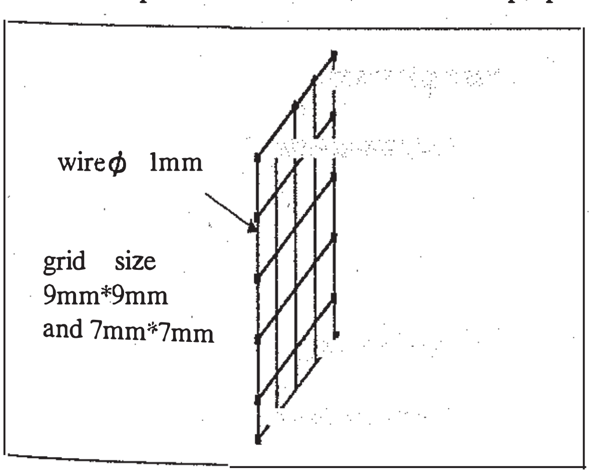

Figure1. Anchor structure.

2 METHODOLOGY

2.1 *Experiment set up*

Sand was placed in a container, made of acrylic acid resin, with inside dimension 570 mm long, 200 mm high and 50 mm wide. After placing sand to about half of container depth in case of using ropes/rods (Figure 3(a), 3(b)), or one-third of container depth in case of using wire frame, the rope/rod or frame was placed over sand and more sand poured to fill up the container. Sand was poured into the container in three layers of equal depth, each layer being compacted by 20 blows of 660 g hammer before another layer was poured. Wire ropes were placed in sand mass as shown in Figure 2.

Figure 3 shows the schematic layout of the experiment set up. Initialy,the embedded length of rope or rod was 50cm. In case (a), a single rope; in case (b), three ropes; and in case (c), four ropes in two layers were placed.

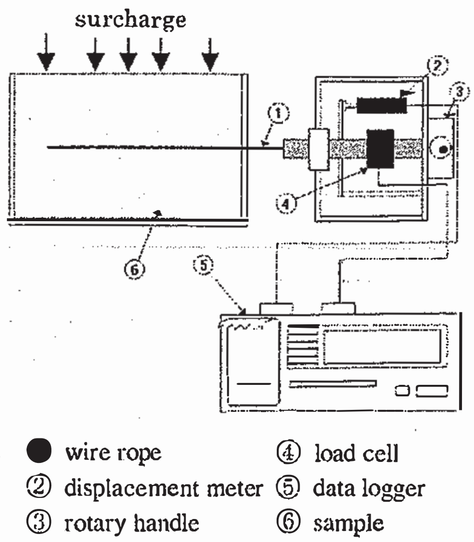

Figure 2. Experiment layout.

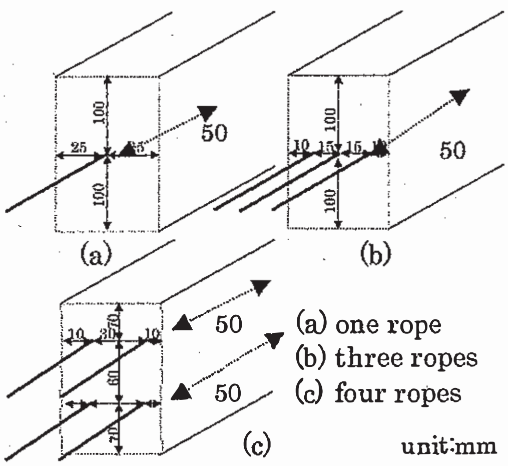

Figure 3. Rope layout.

2.2 *Loading and measurement*

A 5 kg constant surcharge load was applied to sand mass through a plate placed on top. Under this loading, tensile force was applied to ropes or rods through rotary handle, resulting in the gradual pulling out of the rope at a rate of 2.0 mm/min. Displacement (δ) and the corresponding tensile force (P_t) were measured during the interval of pulling out. The measurement were taken at a maximum pull-out length of 20 mm. These measurements were auto recorded at data logger.

Similar measurements were taken with varying sand density of 1.60g/cm^3 and 1.71g/cm^3, and with varying diameters of 1.0, 1.5, and 2.0 mm of ropes and rods.

2.3 *Physical properties of material*

Sand used in the experiment was sampled at Tottori sand dune. Its physical properties are shown in table 1 below.

Table 1. Properties of sand.

Sample	Max.grain.size	Unit weight
Tottori sand dune	0.85mm	23.2kN/m^3

D50	U_c	
0.32mm	2.00	

Grain size distribution is shown in Figure 4.

The tensile load vs elongation relations for wire rope of different diameter used in this experiment are shown in Figure 5. The relationship is linear up to a load of around 23.8N.

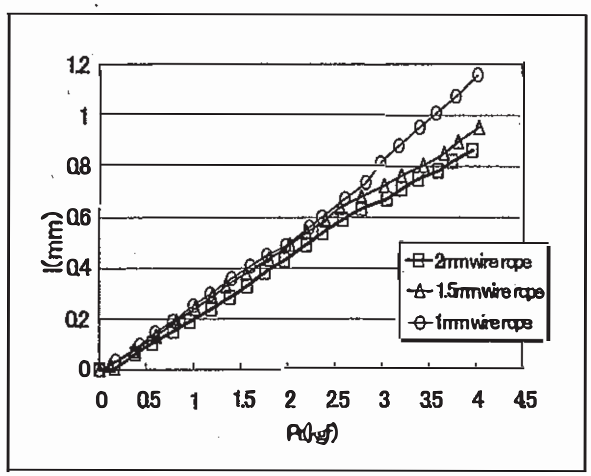

Figure 4. Particle size distribution curve.

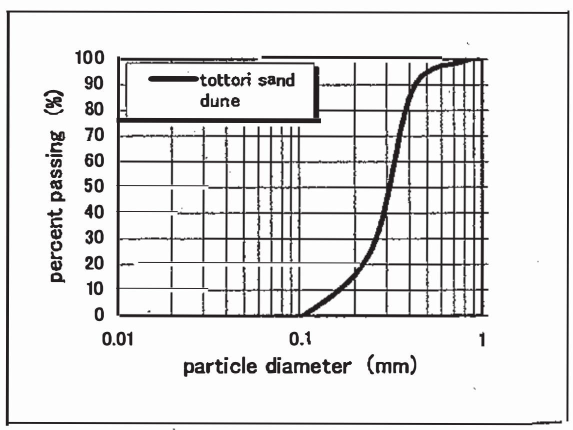

Figure 5. Elongation property of wire undertension.

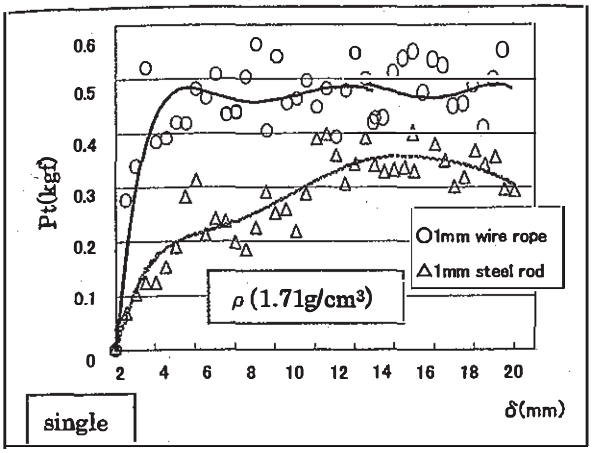

Figure 6. Relation between displacement of rope and tensile load.

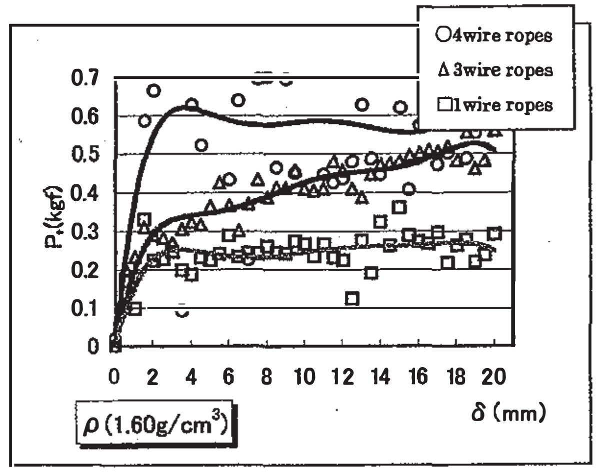

Figure 7. Relationship between displacement of wire/steel rods and tensile load, for varying number of ropes/rods.

3 RESULTS AND DISCUSSION

Experiment results obtained with different cases were compared as follows.

3.1 *Comparison with respect to reinforcement type*

Case a) Single rope/rod: In this case, pull out resistance was higher with wire rope than that with steel rod, and this difference was higher for larger diameter ropes/rods and for denser sand. This is shown in Figure 6.
Case b): Three ropes/rods: As in case (a), resistance was higher for rope. However, this pattern was found only for a rope/rod diameter of 1 mm. For 1.5 and 2.0 mm diameter wire ropes, there was no difference in resistance with variation in sand density.
Case c): Four ropes/rods (in two layers):The result in this case was almost similar to case (b) mentioned above.

The reason for the difference in resistance behavior between wire rope and steel rod is the difference in surface friction. Compared to steel rod, surface roughness is high in wire rope due to the twisting of rope strands.

Coefficient of form unevenness (FU) was calculated for rope and rod, using the relation:

$$FU = 4\pi a / l^2$$

Where, a: cross-section area
l: cross-section perimeter.

This coefficient, FU, will have a value of 1.0 for a perfectly even one, and less than 1.0 for uneven cross-section. A smaller value would mean higher degree of unevenness FU values of wire rope and steel rod were obtained as 0.56 and 1.0 respectively. This difference in FU values has a direct influence upon the difference in pull out resistance mentioned above.

3.2 *Comparison with respect to number of ropes/rods*

In this case, for a sand density of 15.7 kN/m^3 and for all diameters, wire rope exhibited an increasing resis-tance with increasing number of ropes. In the case of steel rod, the resistance was smaller when four rods were used than with only three rods.This pattern in the case of steel rods is thought to have been due to the difference in rod spacing (see Figure 3) in the two cases. Figure 7.

3.3 *Comparison with respect to diameter*

Case a): Single rope/rod: In case of wire rope, resistance was higher for larger diameter. On the other hand, no difference in resistance was noted with varying diameter.
Case b): Three ropes/rod: In this case, resistance pattern for wire rope was same as in case (a). However, for steel rod, resistance was higher with larger diameter.
Case c): Four ropes/rod: In this case, resistance was higher with larger diameter for wire rope as well as steel rod.

This pattern can be explained by the fact that larger diameter ropes/rods will result in bigger surface area in contact with sand. This would mean stronger friction. Figure 8.

3.4 *Comparison with respect to use of anchor net*

When anchor net was used, the resistance was higher which is obvious i.e. ropes/rods would get anchored at the net making them difficult to pull out. However, the effect of grid size of the anchor net was observed. Resistance was higher when mesh size was smaller. As shown in Figure 9 when anchor net was used, resistance increased continuously with is placement. When it was not used, there was a peak after which resistance stayed almost uniform.

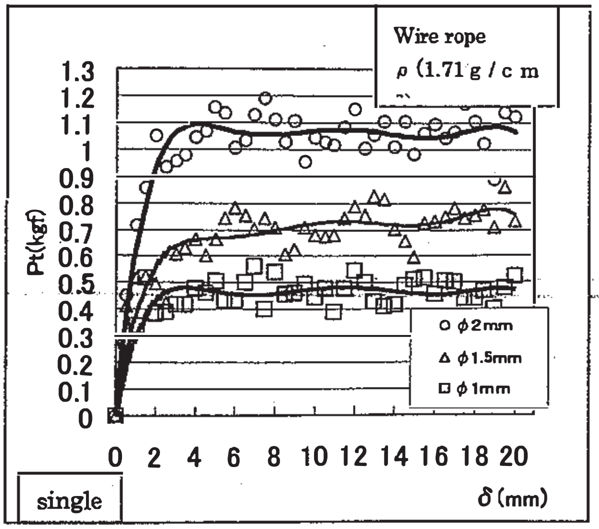

Figure 8. Relation between displacement of steel rod and tensile load.

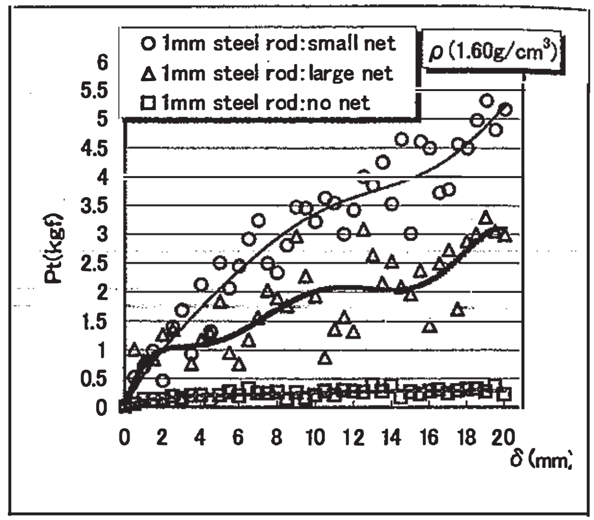

Figure 9. Relation between displacement and tensile load using/not using anchor net

3.5 *Comparison with respect to sand density*

In all cases, stronger resistance was observed when a denser sand was used in the experiment.

4 CONCLUSION

1) Compared to steel rod, resistance against pulling was higher in case of rope.
2) Resistance was higher for larger diameter of rope as well as rod.
3) In general, resistance was higher for larger number of ropes or rods. However, in case of steel rods, resistance was higher with three rods than with four rods.
4) Resistance was higher when an anchor net was attached to the ropes or rods.

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