UTILIZATION OF COIR DUST TO PARTIALLY REPLACE SAND IN VERTICAL DRAINS FOR SOFT GROUND IMPROVEMENT

U.P. Nawagamuwa[1*] and G.H.A.J.J. Kumara[2*]

[1]Department of Civil Engineering, University of Moratuwa, Moratuwa, Sri Lanka

[2]Department of Civil Engineering, Yokohama National University, Japan

*Formerly, Department of Civil and Environmental Engineering, University of Ruhuna, Galle, Sri Lanka

Abstract
During recent decades, ground improvements using waste materials have been encouraged in many countries as a cost effective way. This paper discusses application of coir wastes in vertical drains as a substitution material to sand.

The permeability behaviours of the combined material of sea sand and coir waste were studied and they were sufficient for vertical drains. The inclusion of vertical drains in the soft clay was physically modeled and the drains were filled by the mixed material. This study showed that consolidation rate of soft clay increased largely with the vertical drains. Finally, an optimum coir percentage was proposed.

Keywords: *coir waste, consolidation, permeability, sea sand, vertical drain*

1. Introduction

During recent decades, ground improvements using waste materials have been encouraged in many countries to solve mainly two problems at the same time. The usage of waste materials solve some environmental and economical problems caused by wastes itself as waste disposal needs a large budget. Ground improvements too need some materials, mostly expensive materials. Therefore, in many ways, the concept of using waste materials for ground improvements seems to be cost effective and reasonable especially for developing countries like Sri Lanka.

This paper discusses application of coir wastes in vertical drains as a substitution material to sand, the traditionally used material. The sand drains are used as a ground improvement technique to accelerate settlements of soft ground. The sand, normally taken from rivers also had been a major environmental issue. Therefore, in this research, sea sand was used. It was previously reported that Sri Lanka produces over 0.5 million tons of coir wastes annually [1]. In some part of Sri Lanka, especially along coastal areas, coir waste dumping have become a serious environmental issue as the waste are dumped as open dumps as shown in Figure 1. Hence, in this research, application of coir wastes to partially replace sand for vertical drains was studied.

As the main function of vertical drain is to flow water quickly, permeability behaviours of the combined material of sea sand and coir waste were studied. The constant head permeability tests were conducted to study permeability characteristics. The materials were mixed with certain percentage by weight. The consolidation behaviour of soft clays, collected from a section of Southern expressway was also studied using consolidation tests. The inclusion of vertical drains in the soft clay was physically modeled. The consolidation tests were done as three cases, where effects of vertical drains in soft clay and then as a separate case, the effects of sand and combined material in vertical drains were studied.

The permeability and consolidation characteristics as well as some data of cost of the materials and environmental issues were considered to decide how much coir wastes would be mixed for the combined material. Finally, a model was proposed to determine a percentage of coir waste to use for vertical drains.

2. Material and methods

As mentioned above, sea sand and coir wastes were mixed to make a combine material which was used as a filling material for vertical drains.

2.1 Coir wastes

The coir wastes were collected at a dumping site, located in Nugaduwa, Galle and Figure 2 shows the site. The brown colour coir is harvested from fully ripened coconuts. It has been reported that the coir are thick, strong and has high abrasion resistance [2]. Further, it was found that the coir fibres contain more lignin and less cellulose which made them resilient, strong and highly durable.

The content of fibres is important as they make the vertical drains more stable in soft grounds. The sieve analysis tests were done to evaluate particle distribution and percentage of fibres on the collected coir wastes.

Figure 1: *Coir wastes Hikkaduwa*

Figure 2: *Coir wastes dumping site at Nugaduwa*

2.2 Sea sand

As the research was done at University of Ruhuna, Galle, the sea sands were collected from the coast near to Galle fort area. The sieve analysis was done to evaluate particle size distribution.

2.3 Soft clay

The soft clays were collected from a section of Sothern expressway (CH: 15+000 from Kurundugaha Hetekma). There were many places along the expressway where soft clays were removed or structural measures were done for ground improvements. Figure 3 shows the soft clays collected area.

Atterberg limit tests were conducted to classify the soft clay collected. The liquid limit, plastic limit and plasticity index were evaluated with Atterberg limit test.

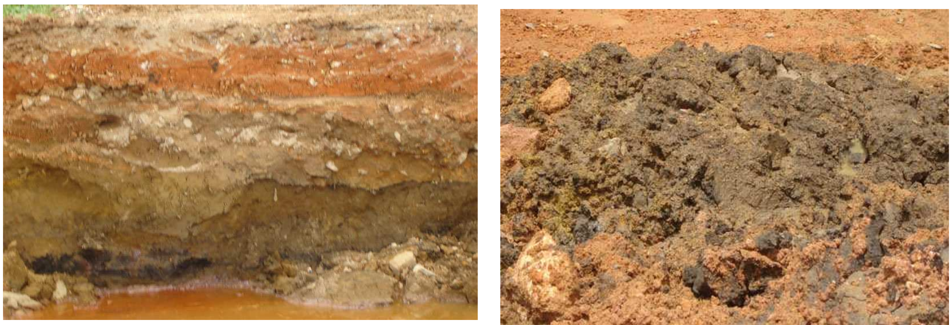

Figure 3: Soft clay collected area

2.4 Mixing of coir wastes and sea sand

The mixing of coir wastes and sea sand were done using the mixing machine shown in Figure 4 and Figure 5. The percentage of coir wastes for the mixture was changed from 0 to 100 (on weight based) as shown in Table 1.

The mixing time (5 mins) was kept constant for each sample as to keep same conditions for every sample.

Figure 4: *Material mixing machine*

Figure 5: *After mixing coir wastes and sand*

2.5 Permeability tests

The permeability characteristics were examined by Constant head permeability tests. The sample preparations were done slightly different to the standard as in some cases, coir fibres tend to separate from the sand during sample preparations. Therefore, as shown in Figure 6, constant number of blows from a small rod (5 blows) was applied while applying some water into the sample. The samples were prepared in three layers. Figure 7 shows a prepared sample.

Figure 6: *Sample preparation (a) application of small compaction and (b) addition of water*

Figure 7: *The prepared sample*

2.6 Consolidation tests

The laboratory one-dimensional consolidation tests were conducted for three cases, one is for the soft clay specimen without a vertical drain. The other two cases were done with vertical drains, at the centre of the specimen. The vertical drains were filled by sea sand and combined material respectively. As a typical case, the combined material was selected as 50% of coir wastes with 50% of sea sand by weight.

The specimens were prepared as 50mm in diameter and 20mm in thickness. The ratio of vertical drain diameter to sample diameter was selected as 1/10. Figure 8 shows the specimen prepared for consolidation tests.

Figure 8: *(a) Application of vertical drain and (b) vertical drain filled by combined material*

3. Results

The results of laboratory experiments are shown in graphical forms.

3.1 Particle size distribution

Figure 9 and Figure 10 show the particle size distribution curves of sea sand and coir wastes used for experiments.

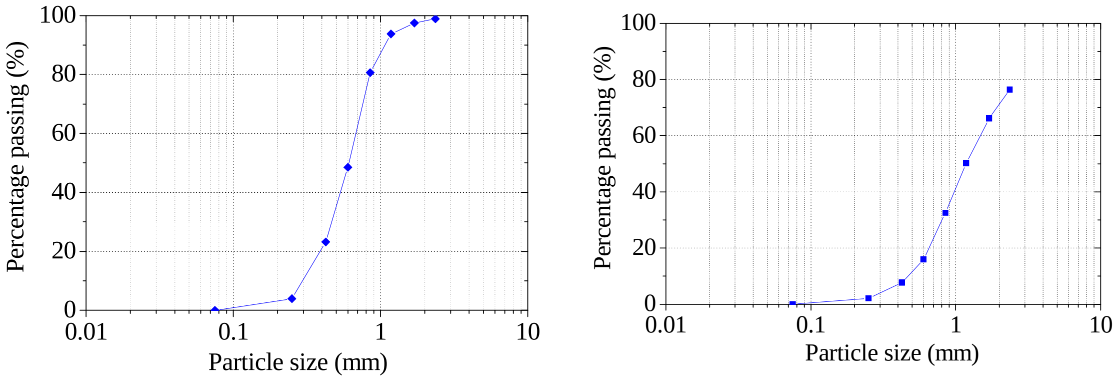

Figure 9: *Particle size distribution (a) sea sand and (b) coir wastes*

3.2 Permeability tests

The Constant head permeability tests were done for 8 cases, ranging coir wastes from 0% (sea sand) to 50% on weight based. As typical cases, only data from few tests are shown in figure 10 and Figure 11.

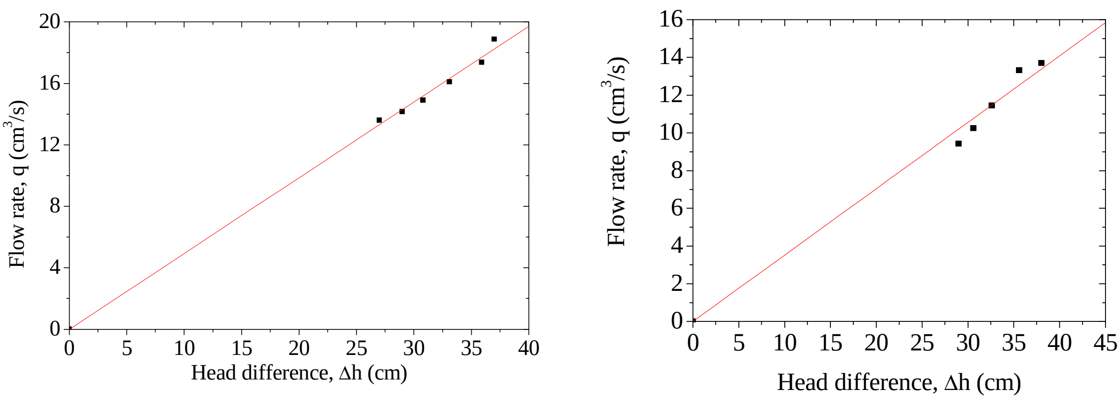

Figure 10: *The graph of q vs Δh for coir waste of (a) 5% and (b) 20%*

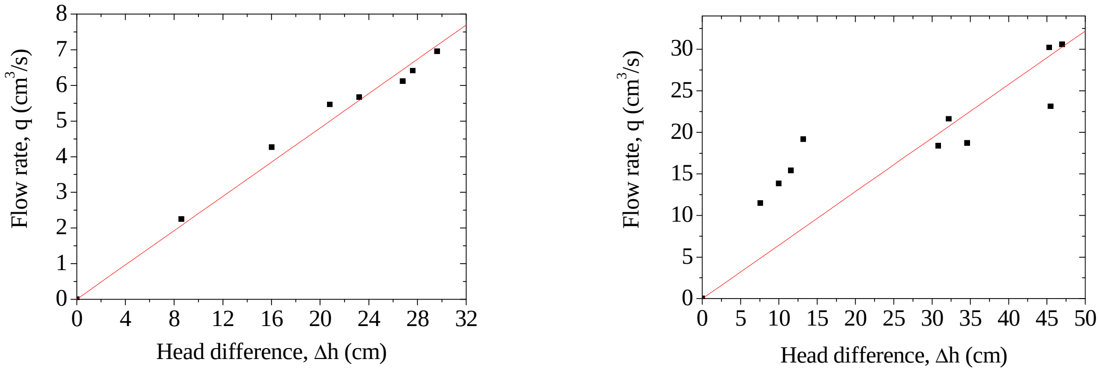

Figure 11: *The graph of q vs Δh for coir waste of (a) 50% and (b) 0% 9 sea sand sample)*

3.3 consolidation tests

The results of consolidation tests for three cases are shown in Figure 12.

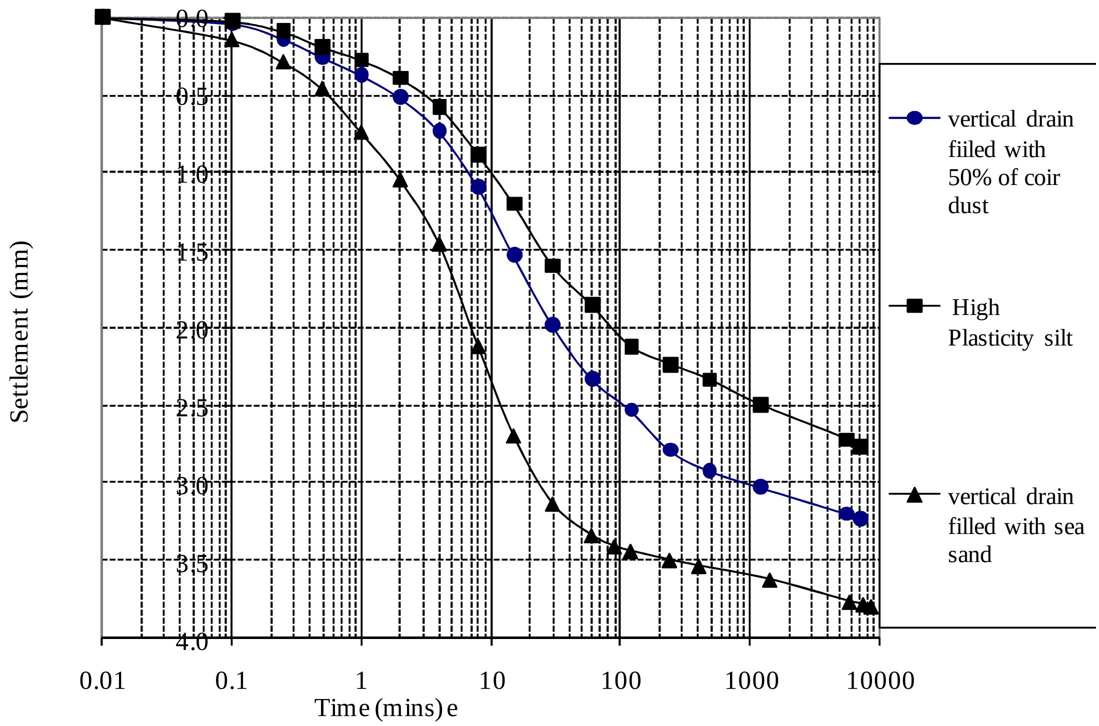

Figure 12: *The consolidation graphs for all cases*

4. Discussions

The permeability tests indicated that coefficient of permeability (*k*) reduces with amount of coir wastes added. The value of *k* for sea sand was 0.121 (cm/s) while that of combined material (50% of coir wastes) was 0.048 (cm/s) as shown in Table 1 and Figure 13. Therefore, it is clear that the reduction of *k* with 50% of coir wastes is about half of sea sand. The 50% coir wastes by weight based is equivalent to about 80% by volume. Therefore, with costs involved, the usage of coir wastes for vertical drains can be justified though it reduces permeability slightly.

As practical application will be based on volume, the coefficient of permeability was plotted against the coir percentage by volume as shown in Figure 14. A model to determine required k with coir percentage was also proposed as $k = 0.1173 - 0.00009c_v$ where c_v is coir percentage by volume.

Table 1: *The details of the samples*

Case No	Coir by weight (%)	Coir by volume (%)	*k* (cm/s)
1	0	0	0.121
2	5	18	0.098
3	10	32	0.091
4	15	43	0.077
5	20	52	0.070
6	30	65	0.064
7	40	74	0.052
8	50	81	0.048

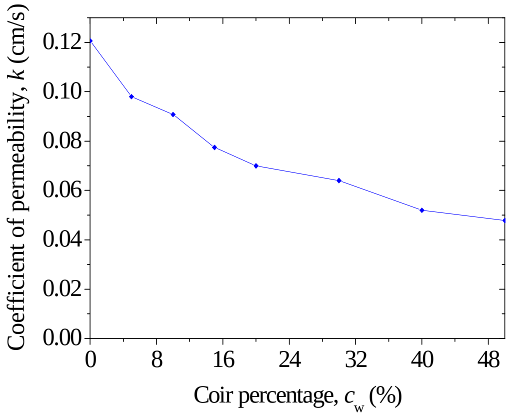

Figure 13: *The variation of k with % of coir*

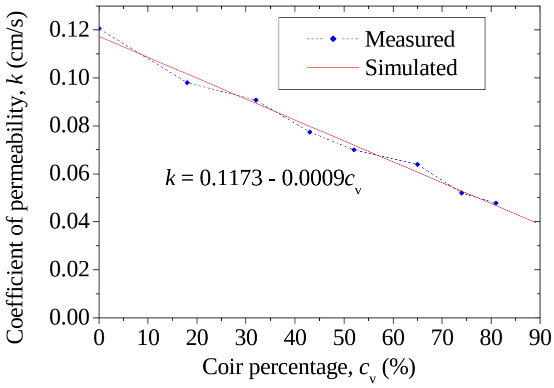

Figure 14: *The proposed model for k*

The consolidation tests showed that inclusion of vertical drains increased the coefficient of consolidations from 1.446 (mm^2/min) to 3.457 (mm^2/min) where vertical drains were filled by sea sand. However, the typical case of the combined material (50% of coir wastes) increased it only to 1.973 (mm^2/min).

The soft clay used was classified as high plasticity silt from the Atterberg limit tests where liquid limit, plastic limit and plasticity index read as 67, 40 and 27(%) respectively.

As shown in Figure 9 (b), the fibre (over 2mm in diameter) content is about 25%. It had been found in the literature that inclusion of fibres increase the strength of soil [2 and 3]. This high amount of fibres will increase the stability of the vertical drains.

5. Conclusions

Following conclusions could be made.

The permeability reduces slightly but even with 80% of coir wastes (on volume based), the combined material gives about half of permeability given by sea sand.

The coefficient of permeability gives a linear relation with percentage of coir wastes mixed. Therefore, once the value of *k* is determined based on site conditions, the required amount of coir wastes mixed can be determined (Figure 14).

Consolidation tests showed that inclusion of vertical drains increased the consolidation rate. Further, it was observed that addition of coir wastes as a filling material to vertical drains gives a reasonable consolidation rate.

As coir wastes make some environmental problems, here it is recommended to use them as filling material to vertical drains.

Based on the experimental results and some literature data on costs of materials [1], it is proposed to use coir percentage about 50% (on weight based) for filling materials. However, depending on *k*, the percentage can de determined as shown in Figure 14.

References

[1] Kumara, G.H.A.J.J. and Nawagamuwa, U. P., "Application of coir dusts in vertical drains for improvement of soft clay", Proceedings of 2nd International Symposium, Sabaragamuwa University of Sri Lanka, July 8th ~ 12th, 2008.

[2] Mwasha, A.P. (2009), Coir fibre: A sustainable engineering material for the Caribbean environment. The College of The Bahamas Research Journal, 15, 36-44.

[3] Prabakar, J. and Sridhar, R.S. (2002), Effects of random inclusion of sisal fibre on strength behaviour of soil, Construction and Building Materials, 16, 123-131.