KKU ENGINEERING JOURNAL 2016;43(S2):187-191 Research Article

KKU Engineering Journal

https://www.tci-thaijo.org/index.php/kkuenj/index

# Utilisation of discarded motorcycle inner tubes as the reinforcement for embankments

Panu Promputthangkoon*[1)] and Bancherd Karnchanachetanee[2)]

[1)]Department of Civil Engineering, Faculty of Engineering Rajamangala University of Technology Srivijaya, Songkhla 90000, Thailand.
[2)]Department of Civil Engineering, College of Industrial Technology and Management Rajamangala University of Technology Srivijaya, Nakhonsithammarat 80210, Thailand.

Received April 2016
Accepted June 2016

**Abstract**

This study attempted to address the two problems of embankment stability and a growing number of discarded tyres and their associated parts such as motorcycle inner tubes. It was done by introducing woven motorcycle inner tube as reinforcement in an embankment with the aims at reducing the construction cost as well as conserving the environment. To achieve the purposes of this research the loading tests on model embankments having various configurations of reinforcement constructed under 1-G condition were conducted. The loading test results revealed that the plain embankment has the highest displacement as initially predicted. When one-layer of woven inner tubes was introduced, however, the stability was evidently improved. Furthermore, the stability was even better when two-layer of woven motorcycle inner tubes was included. Nonetheless, when three-layer of motorcycle woven inner tubes was included the displacements were very similar to those of the embankment reinforced with two-layer of woven inner tubes. This suggests that the three-layer of reinforcement is no better than those of the two-layer of reinforcement. From the test results and analyses, it may be concluded that woven motorcycle inner tubes could be employed as reinforcement to increase the stability of an embankment thereby reducing the overall construction cost as well as improving the environment.

**Keywords:** Embankment, Slop failure, Motorcycle inner tube, 1-G condition

## 1. Introduction

The failure of both natural and man-made slopes is a natural disaster. Examples of the causes of the slope failure are erosion, heavy rainfall [1], and low shear strength of slope material. When a failure has occurred, the obvious damage is the financial loss due to repairing and even rebuilding. Most importantly, there may be casualties that are invaluable. Note that it is possible to totally prevent the failure of a slope provided with unlimited budget and resources. Examples of countermeasure methods are cement and lime columns, soil nailing, rock anchor, chemical grouting, and reinforcing with geogrids, geomembranes, and geotextiles. Recently, the geotextiles have been the material mostly employed for slope protection because of their properties as well as low cost compared to other methods. Details of embankments reinforced with geosynthetic and similar products can be found in [2-4].

At the end of 16 February 2016 the total number of vehicles registered in Thailand is approximately 37 million. It consists of 14.6 million cars, 20.6 million motorcycles, any other vehicles of about 0.6 million, and 1.2 million vehicles under the land transport act [5]. It may be said that each year there will be huge amounts of discarded tyres and their associated parts such as motorcycle inner tubes. In addition, it should be emphasised herein that disposing of them in open areas is a danger to the environment. For example, if huge amounts of the discarded tyres caught fire either accidently or intentionally, it would be very difficult to cease. The consequence is that when there is rainfall, the rainwater could carry the burnt tyres into underground thereby contaminating the groundwater. Then, it may require over hundreds of years for the groundwater to become clean again. Therefore, it is vital for Thailand to sensibly consider this problem. Notice that recently there has been a study incorporated between Worcester Polytechnic Institute and Chulalongkorn University to address this particular problem [6].

This paper presents the study related to making use of discarded motorcycle inner tubes (MT) as reinforcement for embankments. To achieve the purpose a model plain-embankment and MT-reinforced embankments were constructed. Then, loading tests under 1-G condition were carried out to obtain the effectiveness of the MT in terms of reinforcing material.

## 2. Materials and equipment

### *2.1 Tested sand*

The model embankments were constructed using sand

*Corresponding author. Tel.: +6689 502 4964
Email address: panu_pptk@hotmail.com
doi: 10.14456/kkuenj.2016.85

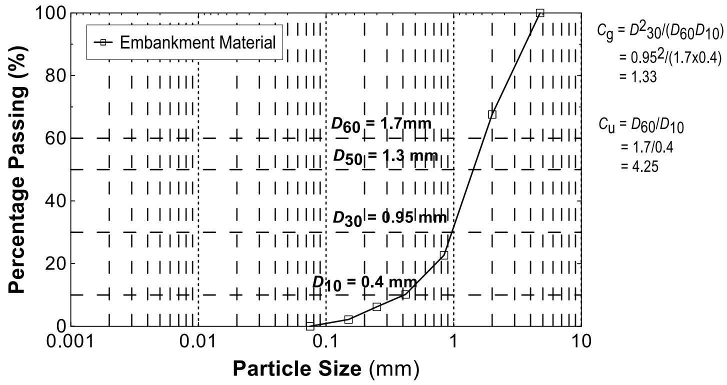


**Figure 1** Particle size distribution of the tested sand

**Table 1** Some properties of the bentonite

| **Concentration Bentonil® CF (kg/m$^3$) (kg/m$^3$)** | **40** | **45** | **50** | **55** | **60** |
|---|---|---|---|---|---|
| Mud density (t/m$^3$) | 1.020 | 1.023 | 1.026 | 1.029 | 1.032 |
| Marsh-funnel time (s) | 32 | 34 | 36 | 39 | 42 |

because it is easier to conduct the loading test under 1-G condition. In other words, it needs not to be consolidated. The grain size distribution curve for the sand is illustrated by Figure 1. The average and effective diameters of the sand were 1.3 mm and 0.4 mm, respectively, resulting in the coefficients of uniformity and curvature of 4.25 and 1.33, respectively. According to the Unified Soil Classification System the sand was classified as SP, or poorly-graded sand.

*2.2 Kaolin and bentonite*

The foundation layer was a mixture of two clays, kaolinite and bentonite. The kaolinite was obtained from Mineral Resource Development. Its main compositions are SiO2 and Al2O3 as usually found in the kaolin, consisting of 82% kaolin, 2% quartz, 11% mica, and 5% gibbsite. The bentonite was obtained from Süd-Chemie (Thai). Some properties for both clays are shown in Table 1, including mud density and marsh-funnel time.

*2.3 Motorcycle inner tube*

This study sought MT for reinforcing an embankment because huge amounts of discarded MT are annually generated. Thus, making use of them is definitely sensible considering the environmental impacts if disposed in open areas. Also, they may be obtained at virtually no cost thereby reducing overall construction cost. A single MT was prepared by simply cutting a whole MT to have the dimensions of 1.5 and 4.0 mm with respect to thickness and width. This corresponded to the cross sectional area of 6 mm$^2$. For the case of woven MT, it was prepared by meshing the MTs into 5 by 5 cm. Note that a small piece of wire was employed for interlocking the MTs into mesh by simply punching and tightening. By performing common tension test, the elastic modulus of the MT was found to be 5625 kPa. Figure 2 (a) illustrates the preparation of the woven MT to be installed in the model embankments.

*2.4 Chamber for model embankments*

As the experiment was done on the model embankment a chamber was required. It was designed and built using a steel frame, artificial plastic-wood, and acrylic, as shown in Figure 2 (b) and (c). The frame was built to be strong enough to maintain the embankment shape during loading test. The acrylic was employed in order to be able to visually observe the deformation behaviour.

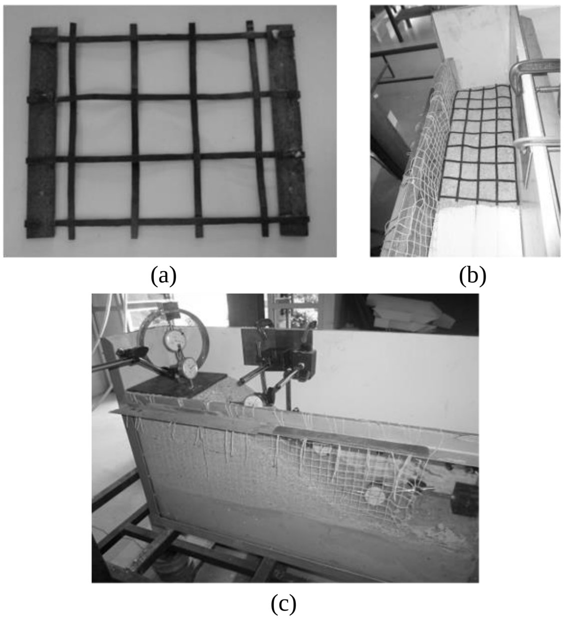


**Figure 2** Woven MT (a) woven MT during embankment construction (b) chamber (c)

*2.5 Device for applying load*

The most important part of this investigation was the device for applying load on the model embankment. It was designed and built from the ground up using a specially-made slow-speed actuator. The pneumatic type was chosen because it is much cheaper compared to the hydraulic and electric types. It comprised a steel frame, custom-ordered pneumatic actuator, and control box, as can be seen in Figure 3. Attached to the steel frame was a movable cross beam that was designed to be adjustable to suit any test configurations.

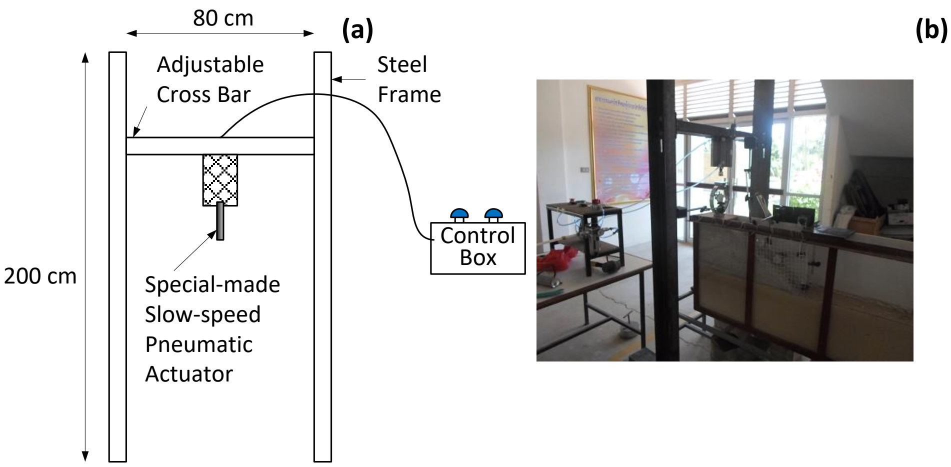


**Figure 3** Diagram of the loading device (a) the loading device applying test load (b)

## 3. Test programmes and procedures

### *3.1 Test set-up and programmes*

In this research, four test configurations were prepared, including plain embankment, one-layer MT-reinforced embankment, two-layer MT-reinforced embankment, and three-layer MT-reinforced embankment, corresponding to cases I, II, III, and IV, respectively. These are illustrated in Figure 4 and also described in Table 2. To be able to compare the results, all of the embankments were constructed by maintaining the density of around 1,346 kg/m$^3$. Notice that this was quite low because little effort was made for densifying the embankments as it might disturb the foundation soil and the chamber. After the embankment, with or without reinforcement, prepared the vertical stress was applied by means of the actuator connected with a proving ring. In the meantime, the displacements were read and recorded by employing five dial gauges as depicted in Figure 4. Please be noted that the dial numbers 1 – 4 were horizontally installed for measuring lateral displacement; while the dial number 5 was vertically installed to measure vertical displacement.

## 4. Results and discussion

The deformation behaviour of all of the embankments when loaded is displayed in Figure 5 (a), (b), (c), and (d), with respect to the cases I, II, III, and IV. It was observed that for all of the embankments, at the same stress level the displacement at the dial gauge number 1 is the maximum; and, the displacement at the dial gauge number 4 is the minimum. This is, however, predictable as the locations for the dial gauges number 1 and 4 were at the top and the bottom of the embankment, respectively.

Considering the applied load, the maximum stress that the case I can sustain was about 50 kPa. For the case II, however, it increased to 60 kPa, of which is as much as 20% improvement. For the cases III and IV, the maximum stress that both embankments can sustain was about 70 kPa at which is the highest. This indicates that an embankment reinforced with three-layer MT is no better than an embankment having two-layer woven inner tubes as reinforcement in terms of the level of withstanding applied stress.

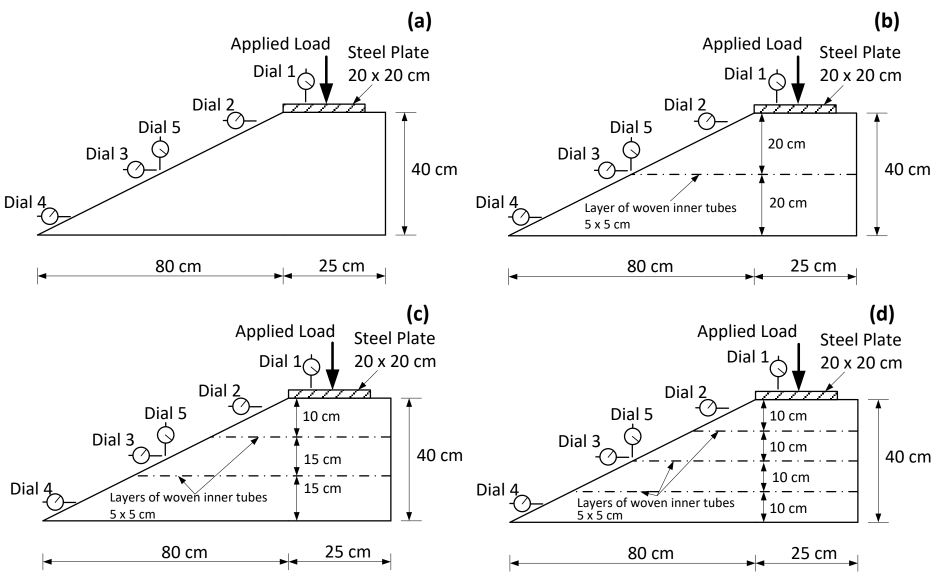


**Figure 4** Test set-up for cases I (a) II (b) III (c) IV (d)

**Table 2** Test configurations

| No | Case | Type of reinforcement | Note |
|---|---|---|---|
| 1 | I | None | Plain embankment |
| 2 | II | One layer of woven MT | At the mid-height of the embankment |
| 3 | III | Two layers of woven MT | At 10 cm and 25 cm from the top |
| 4 | IV | Three layers of woven MT | At 10 cm vertically interval |

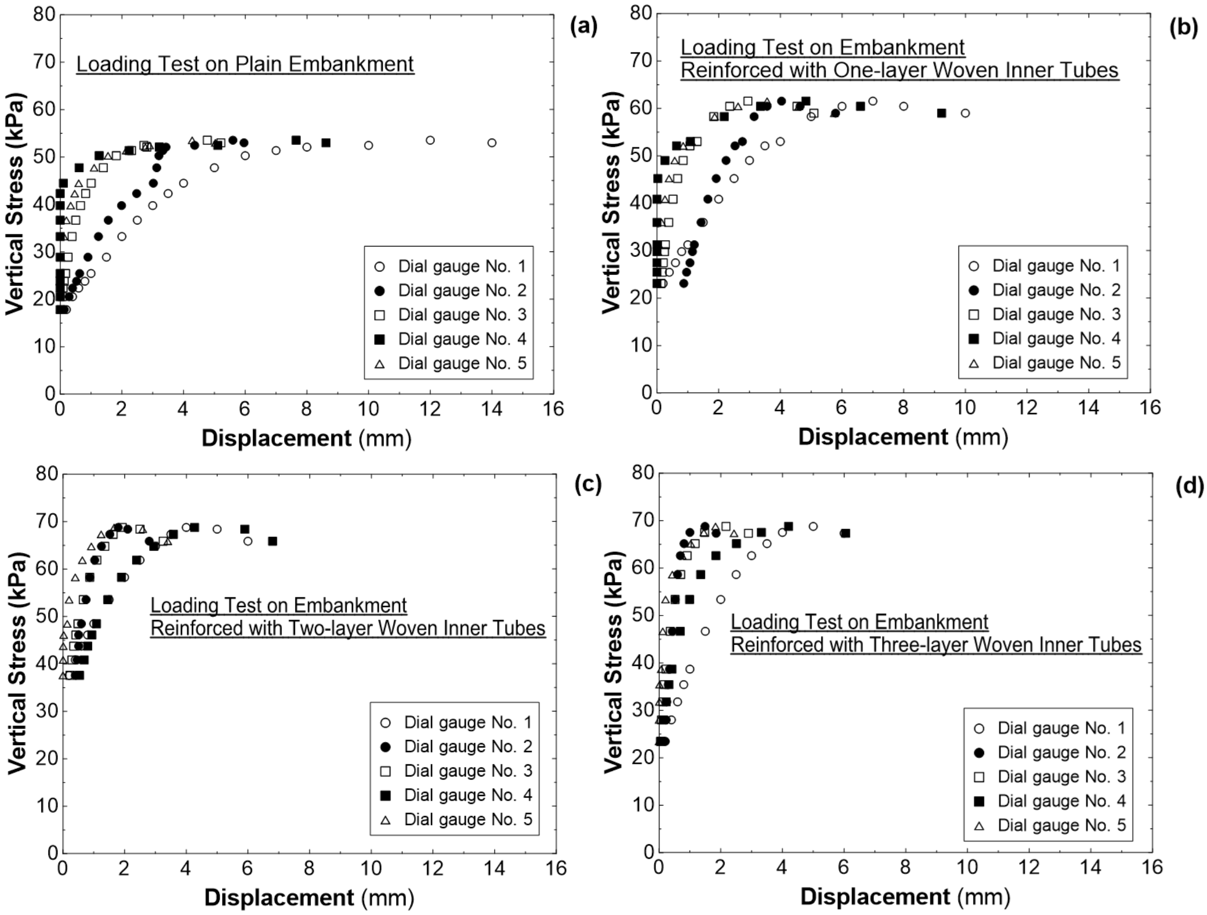


**Figure 5** Vertical stress-displacement relationships for the cases I (a) II (b) III (c) IV (d)

When considering the displacements at the dial gauge number 1 for all embankments, it was obvious that the embankment that has the lowest stability is the case I, i.e., at the same level of stress applied the displacement is the greatest. When a one-layer woven inner tube was introduced, however, it was observed that the stability is pretty much improved, as evident in Figure 5 (b) – (d). Another point should be considered is that for the case I the displacement was observed when the stress was around 18 kPa. For the cases II, III, and IV, however, it was observed when the stresses were 22, 37, and 23 kPa, respectively. This observation clearly indicates that the reinforced embankments are better than the plain embankment in terms of stability, i.e., they can sustain higher load.

In addition, it was observed that the cases I and II have somewhat ductile displacement behaviour, e.g., the displacement is gradually curved with the gradual increase of the applied stress. The peak stress was reached at around 2 – 3 mm; then, the embankments undergone the displacement of 10 – 14 mm without any increase of stress. This is quite contrary to the cases III and IV as their displacement behaviour is rather brittle. For instance, at the beginning the stress increased sharply to the maximum displacement of 2 mm; then the failure was observed at the displacement of about 6 mm at which is much lower than those observed in the cases I and II.

## 5. Conclusions

The growing number of discarded tyres and their associated wastes is increasingly becoming problematic concerning the environment. This study attempted to make use of motorcycle inner tubes (MT) as reinforcement for embankments in order to reduce the construction cost as well as conserve the environment. It was achieved by performing the loading tests on four model embankments: (1) case I, plain embankment, (2) case II, one-layer MT-reinforced embankment, (3) case III, two-layer MT-reinforced

embankment, and (4) case IV, three-layer MT-reinforced embankment. A loading device was also specifically developed for this study. Based on the experiments, test results and analyses, the below conclusions have been drawn:
(1) For all of the embankments, at the same stress level the displacement obtained from the dial gauge number 1 is the maximum; while the minimum was observed at the dial gauge number 4. Note that the dial gauges number 1 and 4 were installed with respect to the top and toe of the embankment.
(2) The maximum stresses at failure for the cases I-IV were about 50, 60, 70, and 70 kPa, respectively.
(3) In terms of overall stability, case III was the most effective. It should be noted that even though the case IV could also sustain the same stress applied to the case III, but it was reinforced with more MT.
(4) The cases I, II, III, and IV began to move when the applied stress levels of 18, 22, 37, and 23 kPa were reached, indicating that the case III has the most stability. This point clearly supports the conclusion given in (3).
(5) The cases I and II had ductile displacement behaviour. In the meantime, brittle displacement behaviour was observed for the cases III and IV.

## 6. Acknowledgements

The authors wish to thank Rajamangala University of Technology Srivijaya for financial aid and support throughout. In addition, help and support obtained during the research provided by the people at the Research and Development Institute, Trang Campus, is kindly acknowledged.

## 7. References

[1] Soralump S. Geotechnical approach for the warning of rainfall-triggered landslide in Thailand considering antecedent rainfall data. International Conference on Slope 2010, Geotechnique and Geosynthetics for Slopes; 2010 July 27-30; Chiang Mai, Thailand. Bangkok: Department of Highways Ministry of Transport, Thailand; 2010.

[2] Indian Roads Congress. Guidelines for the design and construction of geosynthetic reinforced embankments on soft subsoils. New Delhi: Indian roads congress; 2013.

[3] Christopher BR, Gill SA, Giroud JP, Juran L, Mitchell JK, Schlosser F, et al. Reinforced soil structures: Volume II summary of research and systems information. New Jersey: US Department of Transportation; 1989. Report No. FHWA-RD-89-043.

[4] Koerner RM. Designing with geosynthetics. 5th ed. New Jersey: Prentice hall; 2005.

[5] DLT. Number of vehicle registered in Thailand as of 16 February 2016 [Internet]. 2016 [cited 2016 March 31]. Transport Statistics Sub-Division. Planning Division. Department of Transport. Available from: http://apps.dlt.go.th/statistics_web/statistics.html

[6] NSTDA. Developing a sustainable waste tire management strategy for Thailand. Bangkok: National Science and Technology Development Agency; 2013.