Development of Eco-Guide Post for Traffic Safety in Rural Areas by Using Hybrid Vetiver-Clay Composites

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ABSTRACT

The study aims to develop the eco-guide post by using vetiver-clay composites and natural materials. The concepts of appropriate and uncomplicated technology, conserving environmental friendliness and ecology are applied to produce the eco-guide post in accordance with Thai's DOH standard. Design of bonding materials, optimum proportions, and molding techniques were investigated. The suitable molding technique and proportion of materials were determined by comparing the results of various experimental programs in terms of physical, mechanical, and durability properties. Based on the results obtained, it can be found that the hybrid between 2 layers of long fiber vetiver-clay bundles and 3 layers of short fiber vetiver-clay composites with optimum proportions of clay : sand : vetiver was the most suitable in producing of eco-guide post. Furthermore, the use of eco-guide post was found to be more economical than the use of reinforced concrete guide post when comparing in terms of cost and environmental impact. The use of eco-guide post can reduce cost, pollution, and enhance the traffic safety in local roads. It is an alternative development for the people to gain the fruitfulness from their surrounding resources with the native intellect which is the sustainable development approach for utilization in rural areas of developing countries. The guide posts developed have now been installed at roadside on road number 104 in Wangchao-Tak region and road number 1090 in Maesord-Umphang region, Tak Province, Thailand.

Keywords: Eco-Guide Post, Road Traffic Safety, and Vetiver-Clay Composites

1. Introduction

Guide post is the posts used to mark the edge of the road carriageway. It assists the road users by indicating the alignment of the road ahead, especially at horizontal and vertical curves, and under some circumstances, by providing a gauge with which to assess available sight distance. Almost all of guide posts in Thailand's highway are made from very stiff materials such as reinforced concrete which cannot protect vehicle occupants from injures upon impact. In addition, the production of reinforced concrete guide post caused environmental pollution such as green house gas from materials used as well as manufacturing process. Figure 1 shows the reinforced concrete guide post in accordance with department of highway (DOH) standard.

a) RC guide post before installation   b) RC guide post on Thai's highway

Figure 1 Reinforced concrete (RC) guide post in Thai's highway before and after installation

Clay brick or adobe is abundantly available around the world, and would not need a large amount of energy for its production and application, because it does not need heat treatment [1,2]. Thus, the material is very environmentally friendly and does not produce any CO_2 during its production, application, and lifetime process. Besides, the thermal, acoustic and fire resistant properties of these materials are very high [3]. They are used especially as walls in buildings. With these properties, today, the adobe is gaining importance again in developed countries [4–6]. Adobe is sensitive against shrinkage because its water content needed for workability is very high. In its conventional applications, it is common to use natural fiber ingredients to address this problem [6-8].

In Thailand, the utilization of vetiver has been emphasizing on soil and water conservation [9]. There is a need to cut down the leaves every few months to encourage tiller growth and to reduce the danger of fire in the dry season. The cut leaves and clumbs can be utilized in various ways, thereby providing extra income to the growers.

Recently, Nimityongskul and Hengsadeekul [10] proposed the utilization of vetiver as construction material for paddy storage silo. A budle of vetiver-clay composited is developed based on the local wisdom. The results showed that the vetiver-clay composite bundle has a suffice mechanical properties and low thermal conductivity which can be used as a construction material for storage of paddy.

Based on the results from Nimityongskul and Hengsadeekul [10] and Parichatprecha [11], it reveals that the vetiver leaves can also be efficiently used for stabilizing and reinforcing of clay bricks and building materials. The use of vetiver-clay composites and natural materials is a possible hybrid material for developing the eco-guide post. This seems to be suitable for Thailand where vetiver is plentiful. It is of interest to study some factors affecting the physical, mechanical, durability, and ecology of the guide post developed. These factors will be taken into account in the production and installation of the eco-guide post.

2. Objective and Scope

The main objective of this research is to develop the eco-guide post by using a hybrid vetiver-clay composites and natural materials. The concepts of appropriate and uncomplicated technology, conserving environmental friendliness and ecology are applied to produce the eco-guide post in accordance with Thai's DOH standard. To achieve the main objective the sub-objectives can be drawn as follows:

- To investigate the most suitable molding technique and optimum proportions of ingredients by comparing the results in terms of physical, mechanical, and durability properties from various experimental programs.

- To investigate the durability and apply the prototype of the eco-guide post developed for the real use by installation on the road side of rural area.

- To transfer the technology developed to the related communities and organizations and establishing cooperation between government organizations such as Department of Highway (DOH) and agriculturists in rural areas.

3. Methodology

The methodology of this research can be summarized into three main parts namely, 1) Development of eco-guide post, 2) Durability test and application, and 3) Contribution to the related organizations and communities. The details of each part are illustrated in the flow diagrams as shown in Figure 2.

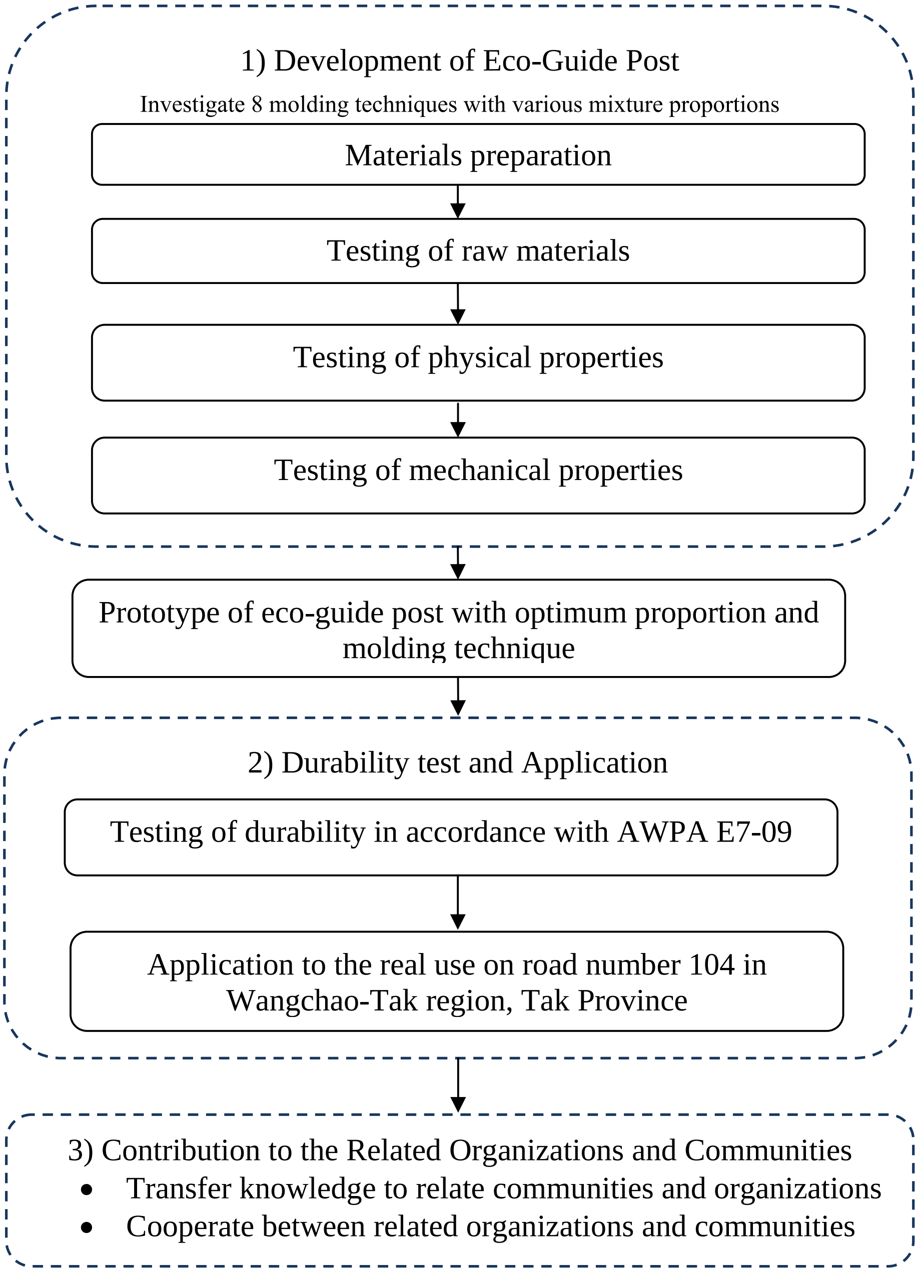


Figure 2 Flow diagrams of methodology

3.1 Materials Preparation

3.1.1 Vetiver

In this study, the fresh vetiver leaves from the same source and species were used as natural fibers reinforcement. Based on the results obtained from [6-8, and 9-11], the long fiber of vetiver leaves were used as fiber reinforcement to improve the mechanical properties of eco-guide post. Whereas, the 3-5 centimeter short fibers were used as fibers stabilizer for improving its physical properties. The vetiver leaves must be dried for seven to twenty-one days to reduce the water content and cut to the required length and then stored at the storage room with temperature of 28±3^{o}c. Figure 3 shows the preparation processes of vetiver.

a) Harvest

b) Drying

c) Cutting

d) Vetiver clay bundle

Figure 3 Preparation processes of vetiver

3.1.2 Clay

Cohesive clay with high plasticity was used as binder for fabrication of vetiver-clay composites. It should be fine, smooth and uniform, and free from impurities. It should be sun-dried for 4-5 days to reduce its water content. Then the sundried clay was soaked in water at a ratio of 1:1 (clay:water) for 24 hrs and mixed manually until a uniform slurry is achieved. The slurry clay was tested for its properties as follows.

- liquid limit (ASTM D 4318);

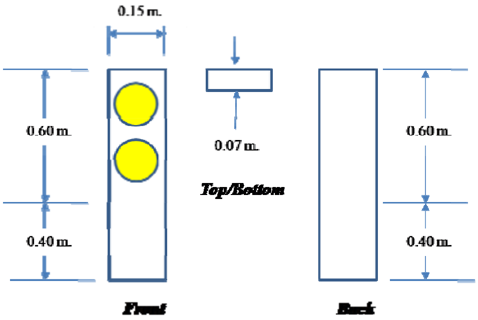
- plastic limit (ASTM D 4318);

3.1.3 Sand

Air dried natural river sand with passing ASTM sieve size No. 40 was used for stabilizing an eco-guide post.

3.2 Fabrication Process

In this study, the dimension of guide post (7.0 x 15.0 x 100.0 cm) in accordance with Thai's DOH standard was casted in the timber mold developed as shown in Figure 4. The fabrication process of eco-guide post can be summarized briefly as shown in Figure 5.



a) Dimension of guide post

b) Molds were made from wood

Figure 4 Dimension and mold of guide post developed in this study

a) Kneading

b) Blending

c) Vertiver-clay bundles

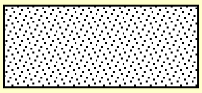
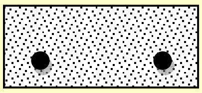
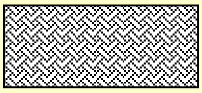
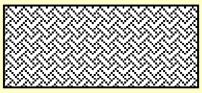
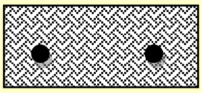
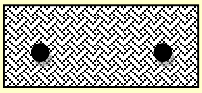
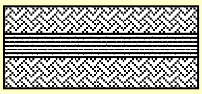
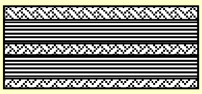
d) Fabrication and Finishing

Figure 5 Eco-guide post fabrication processes

3.3 Experimental Programs

To determine the suitable ingredients and molding technique for producing eco-guide post, the 8 moulding techniques with various mixture proportions were investigated as summarised on Table 1.

Table 1 Details of 8 molding techniques and various mixture proportions

Number	***Details of Molding Technique***	***Structural Model***	***Mixture Proportions clay:sand:3-5cm vetiver fibers (by volume)***
1	Control mixture without fibers.		1:0.15:0, 1:0.3:0
2	Bamboo reinforcement without fibers.		1:0.15:0, 1:0.3:0
3	Clay with 3-5 cm vetiver fibers reinforced and stabilized with 15% fine sand.		1:0.15:0.4, 1:0.15:0.6, 1:0.15:0.8, 1:0.15:1.0
4	Clay with 3-5 cm vetiver fibers reinforced and stabilized with 30% fine sand		1:0.3:0.4, 1:0.3:0.6, 1:0.3:0.8, 1:0.3:1.0
5	Hybrid bamboo and vetiver fibers reinforcement and stabilized with 15% fine sand.		1:0.15:0.4, 1:0.15:0.6, 1:0.15:0.8, 1:0.15:1.0
6	Hybrid bamboo and vetiver fibers reinforcement and stabilized with 30% fine sand.		1:0.3:0.4, 1:0.3:0.6, 1:0.3:0.8, 1:0.3:1.0
7	Hybrid 1 layer of vetiver clay bundle and 2 layers of vetiver fibers and stabilized with 30% fine sand.		1:0.3:0.4, 1:0.3:0.6, 1:0.3:0.8, 1:0.3:1.0
8	Hybrid 2 layers of vetiver clay bundle and 3 layers of vetiver fibers and stabilized with 30% fine sand.		1:0.3:0.4, 1:0.3:0.6, 1:0.3:0.8, 1:0.3:1.0

3.4 Tests of Eco-Guide Post

The details of testing for investigation the physical properties, mechanical property, and durability of eco-guide post are indicated as follows:

3.4.1 Physical Property

After 48 hours of drying process, all specimens of 8 molding techniques were inspected for cracking, shrinkage, and warping by visualization, and the best molding technique will be selected for further investigation.

3.4.2 Mechanical Property

To investigate the influence of drying period on the modulus of rupture, the samples were conducted based on the optimal result achieved from 3.4.1. After taking out the specimens from 48 hours drying at room temperature, the specimens were sun dried for 7, 14, and 21 days before testing of third point load test in accordance with ASTM C 78-94 as shown in Figure 6.

Figure 6 Complete test set up for third point load test in accordance with ASTM C 78-94

3.4.3 Durability Test

To evaluate the durability and performance of eco-guide post developed under the real environment. Standard of American Wood Protection Association (AWPA) E7-09 was applied to describe a procedure for testing the guide post specimens. The performance and preservative value can be determined from the rating grade of inspected area. The 20 test specimens were prepared by using the results obtained from 3.4.2. The specimens were treated by 2 layers coating with oil-color painted, and after-treatment specimens were also conducted by using the instructions as indicated in standard test method. The specimens will be observed every 2 weeks for 3 months. The grading system is shown in Tables 2-3.

Table 2 Decay Rating Scheme (AWPA E7-09)

Rating	Condition	Description
10	Sound	No sign or evidence of decay, wood softening or discoloration caused by microorganism attack.
9.5	Trace suspect	Some areas of discoloration and/or softening associated with superficial microorganism attack.
9	Slight Attack	Decay and wood softening is present. Up to 3% of the cross sectional area is affected.
8	Moderate	Similar to “9”, but more extensive attack with 3-10% of cross sectional area affected.
7	Moderate/Severe Attack	Sample has between 10-30% of cross sectional area decayed.
6	Severe Attack	Sample has between 30-50% of cross sectional area decayed.
4	Very Severe Attack	Sample has between 50-75% of cross sectional area decayed.
0	Failure	Sample has functionally failed. It can either be broken by hand due to decay, or the evaluation probe can penetrate through the sample.

Table 3 Termite Rating Scheme (AWPA E7-09)

Rating	Description Condition
10	Sound
9.5	Trace, surface nibbles permitted.
9	Slight Attack, up to 3% of cross sectional area affected.
8	Moderate attack, 3-10% of cross sectional area affected.
7	Moderate/severe attack and penetration, 10-30% of cross sectional area affected.
6	Severe attack, 30-50% of cross sectional area affected.
4	Very severe attack, 50-75% of cross sectional area affected.
0	Failure

4. Results and Discussion

4.1 Materials

4.1.1 Vetiver Grass

The physical and mechanical properties of vetiver are illustrated in Table 4 and Figure 7. Based on the results obtained from Figure 7, it reveals that the optimum sun dried period of vetiver grass was found to be 14 days.

Table 4 Physical and mechanical properties of vetiver

Testing	Average Value
Water Absorption (Oven-dried basis)	164.4%
Tensile Strength at 7, 14, and 28 days sun dried	59, 83, and 66 kg/cm^2

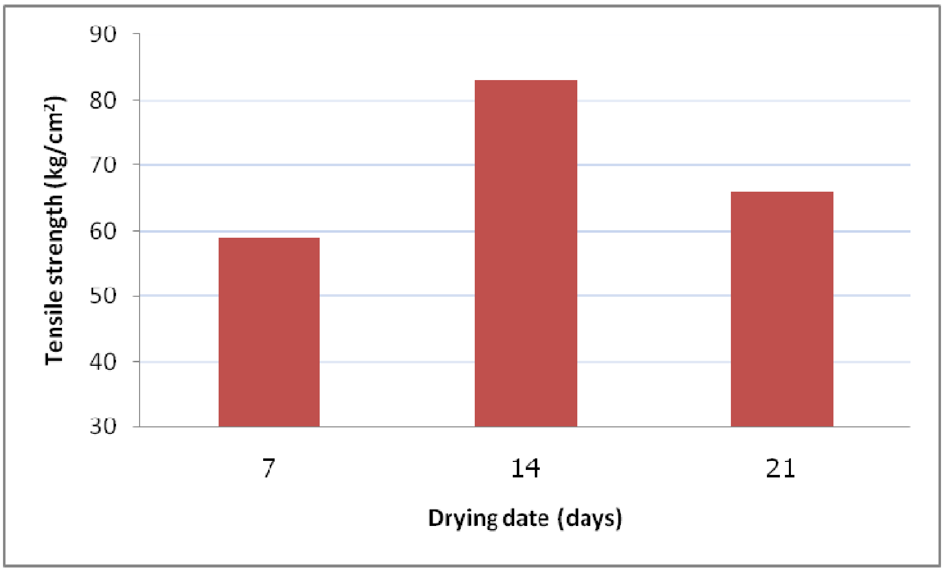


Figure 7 The relationships between drying date and average tensile strength of vetiver grass

4.1.2 Clay

The average liquid limit (LL), plastic limit (PL), and plastic index (PI) of clay was 60%, 23%, and 37%, respectively.

4.2 Visual Inspection

The results of visual inspection of 8 molding techniques were illustrated in Table 5.

Table 5 The results of visual inspection of 8 molding techniques

No.	Details of Molding Technique	Visualization			Related Figure
		Cracking	Shrinkage	Warping	
1	Control mixture without fibers.	Yes	Yes	Yes	
2	Bamboo reinforcement without fibers.	Yes	Yes	Yes	
3	Clay with 3-5 cm vetiver fibers reinforced and stabilized with 15% fine sand.	Yes	Yes	Yes	
4	Clay with 3-5 cm vetiver fibers reinforced and stabilized with 30% fine sand	No	Yes	No	
5	Hybrid between bamboo and vetiver fibers reinforcement and stabilized with 15% fine sand.	Yes	Yes	No	
6	Hybrid between bamboo and vetiver fibers reinforcement and stabilized with 30% fine sand.	Yes	Yes	No	
7	Hybrid between 1 layer of vetiver clay bundle and 2 layers vetiver fibers and stabilized with 30% fine sand.	Yes	No	No	
8	Hybrid between 2 layers of vetiver clay bundle and 3 layers of vetiver fibers and stabilized with 30% fine sand.	No	No	No	

Based on the results obtained from visual inspection as shown in Table 5, it can be summarized that the hybrid between 2 layers of vetiver clay bundle and 3 layers of vetiver fibers clay composite (Model 8) was the most suitable in molding of eco-guide post. This scheme and mixture proportion was used to re-construct specimens for further investigation.

4.3 Mechanical Property

To determine the optimum proportion of 3-5 cm vetiver grass in terms of mechanical property, the influence of volume fractions of vetiver grass and modulus of rupture were investigated. Furthermore, the optimum drying period was also examined. From Figure 8, it was found that the 60% vetiver grass at 21-day drying gave a highest modulus of rupture of 0.91 kg/cm^2. It was also found from Figure 8 that the suitable volume fraction of 3-5 cm. vetiver grass with more than 14-day drying period can be improved the flexural strength of eco-guide post.

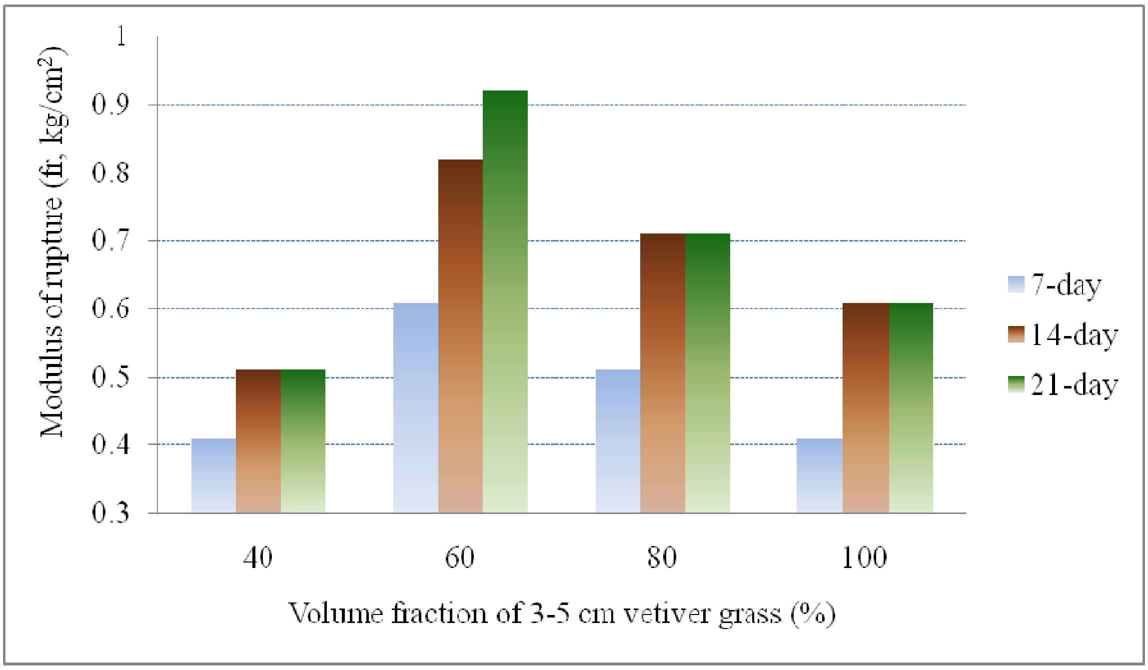


Figure 8 Relationship between modulus of rupture and volume fraction of 3-5 cm vetiver with different drying period

4.4 Durability

Figure 9 shows the summary of investigation processes for testing of durability in accordance with AWPA E 7-09. The three-month period of investigation was from September to December, 2010.

a) Samples test setup b) Withdrawal

c) Investigated decay rating d) Investigated termite rating

Figure 9 Investigation processes of durability testing in accordance with AWPA E7-09

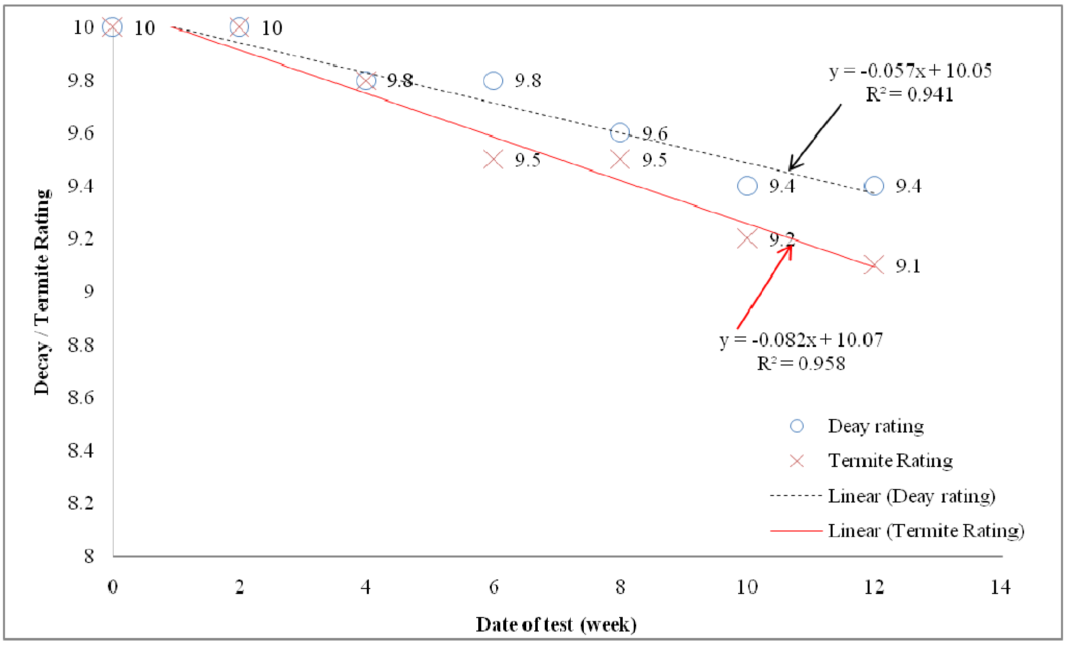


Figure 10 Relationships between decay and termite index versus date of test with linear best fit equations

4.4.1 Decay and Termite Rating Index

The results obtained from the investigation of decay and termite rating index of eco-guide post along three-month period were plotted as shown in Figure 10. It was found that the decay index at 3 months period was 9.4 and the condition was trace suspect. Whereas, the termite rating was 9.1 and the condition was trace. It can be summarized that the durability of eco-guide post in terms of decay and termite rating index along 3 months period was found to be sound condition.

4.4.2 Prediction of Service Life of Eco-Guide Post

To predict the service life of eco-guide post, the best fit equations of decay and termite rating index were determined as shown in Figure 10. The results of linear regressions analysis were given as follows:

Decay Index = -0.057(Date of test, weeks) + 10.05 (1)

Termite Index = -0.082(Date of test, weeks) + 10.07 (2)

According to the decay and rating condition of AWPA E7-09, the limited condition for serviceability of guide post was setting at 30-50% cross sectional area affected and the index for both rating was 6. By using this condition and best fit equations (equations 1 and 2), the service life of eco-guide post in this study was approximately found to be 12 months.

4.5 Cost Analysis

Costs of reinforced concrete guide post and eco-guide post were determined and the results were illustrated on Tables 6-7, respectively. It can be found that the unit cost of eco-guide post was approximately 9.15-10.50 Thai baht which was approximately 8 times cheaper than reinforced concrete guide post.

Table 6 Unit price of reinforce concrete guide post

No.	Materials	Unit price per piece of guide post* (Thai baht)
1	Concrete	25.0-29.0
2	Reinforcing bars	22.0-25.3
3	Steel plates and bolts	5.0-5.8
4	Labor	20.0-23.0
	Total	72.0-83.0

** Remark: 1) The unit price of all components was given from Profeel Co. Ltd. Thailand. 2) Finishing and installation costs excluded.*

Table 7 Unit price of eco-guide post

No.	Materials	Unit price per piece of guide post (Thai baht)
1	Clay	2.2-2.5
2	Vetiver grass included manufacturing processes	0.05-0.07
3	Sand	0.9-1.1
4	Labor*	6.0-7.0
	Total	9.15-10.5

**Remark : 1) Labor cost at Tak Province was approximately 300 Thai baht/person/day. 2) Finishing and installation costs excluded.*

5. Applications

The application of eco-guide post has been used since February 2011. Figures 11 shows the guide posts were being installed on the road number 104 in Wangchao-Tak region and road number 1090 in Maesord-Umphang region, Tak Province, Thailand. This seems to be a high potential approach for developing a Cooperate Social Responsibility (CSR) which government organization such as Department of Highway (DOH) can cooperate with agriculturists in rural areas. Furthermore, the new version of eco-guide posts replacing reflectors by used compact disk (CD) was also implemented as illustrated on Figure 12.

Figure 11 Application of eco-guide post on road number 104 in Wangchao-Tak region and road number 1090 in Maesord-Umphang region, Tak Province, Thailand.

Figure 12 Eco-guide post version 1.1 improved by replacing reflectors with used CD

6. Contribution to Related Communities and Organizations

Based on the results obtained, the use of eco-guide post was found to be much more economical than the use of reinforced concrete guide post in terms of cost and environmental impact. The use of eco-guide post can reduce pollution and enhance the traffic safety in local roads. To transfer the technology developed to the related communities and organizations includes establishing cooperation between them, the training programs were conducted and contributed to related communities and organizations as follows:

- Bureau of High Way Tak and Bureau of Highway Sakonnakorn, Department of Highway
- Department of Rural Roads at Sakonnakorn branch
- Sub district organizations at Sakonnakorn Province
- Faculty of Engineering and Faculty of Agricultural, Kasetsart Chalerm Phrakiat Sakonnakorn Campus, Kasetsart University
- Land Development Department at Tak Provinces
- Communities of vetiver growers in Phitsanuloke, Tak, and Sakonnakorn Provinces

Figure 13 shows the seminar and workshop for contribution of this research to the related communities and organizations at Sakonnakorn Province.


Figure 13 The seminar and workshop for contribution of this research to the related communities and organizations at Sakonnakorn Province

7. Conclusions

- The hybrid between 2 layers of vetiver clay bundle and 3 layers of 60% vetiver clay composite (Model 8) was the most suitable in molding of eco-guide post which cracking and warping disappeared. The short fibers of vetiver play an important role in stabilizing the matrix in the guide post developed. Whereas, the long fibers in terms of vetiver clay bundles were used as fiber reinforcement to enhance its mechanical property. The modulus of rupture of the best model was 0.91 kg/cm^2 at 21-day drying. The service life of eco-guide post in this study was approximately 12 months.

- The unit cost of eco-guide post developed was approximately 9.15-10.50 Thai baht which was approximately 8 times cheaper than reinforced concrete guide post.

- Based on the results obtained, the use of eco-guide post was found to be much more economical than the use of reinforced concrete guide post in terms of cost and environmental impact. The use of eco-guide post can reduce pollution and enhance the traffic safety in local roads. The Life Cycle Assessment (LCA) of eco-guide post induced very low pollution to the atmosphere in view of materials used, manufacturing processes, application, and decomposition. Furthermore, the guide posts developed have now been installed at roadside on road number 104 in Wangchao-Tak region and road number 1090 in Maesord-Umphang region, Tak Province, Thailand.

- The transferring technology of this research to the related communities has launched by conducting the training programs and distributed to the several areas on the northern and the northeast regions of Thailand. This seems to be a high potential approach for developing a Cooperate Social Responsibility (CSR) which government organization such as Department of Highway (DOH) can cooperate with agriculturists in rural areas.

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