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Bamboo Crosswind Barrier

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Abstract: Crosswind is one of the contributing factors of road accidents along highways. The high-speed wind that passes through or across the highway area is causing the moving vehicles to experience a reluctant change in driving direction that may contribute to a single-vehicle collision. This study tends to explore the use of bamboo as an alternative to replace the existing wind barriers to reduce the risk of crosswinds effect along the highways. This study includes reviews of the past research projects related to the problem of crosswind in obtaining accurate and authentic information and facts. Interview with bamboo expert was also carried out to obtain more information about bamboo. The bamboo that has been considered as the most suitable for crosswind barrier is Oldhamii Bamboo. The preliminary study shows the promising result on the potential usage of bamboo as crosswind barrier. Nevertheless, a subsequent study is needed before it can be use.

Keywords: Bamboo, Crosswind, Highway, Malaysia

1. Introduction

Crosswinds are the winds that move in the perpendicular direction to the line or direction of the travelling unit such as vehicles and occur on areas that have strong wind currents such as valleys, high places such as highlands and places that are located near the oceans such as area that are near to the beaches. Various locations of highways in Malaysia also have strong wind currents or crosswinds such as Kilometer 197- Kilometer 212 of North-South Expressway [1]. Crosswinds can cause vehicles to move to lose stability and move to the vertical direction causing them to crash to other objects nearby. During the year 1992 there were an amount of 17 accidents that causes 4 death that occur at the North-south expressway that are caused by crosswind [1]. Based on the studies conducted by the Universiti Teknologi Malaysia in 1998, the highest wind velocity recorded on kilometer-212 of North-South Expressways is 13.5 m/s (48.6 km/j) with 100% of the wind directions recorded to be crosswind [1]. Based on the research made by The Transport and Road Research Laboratory, the velocity required to cause accidents on traffic is 15 m/s which is recorded on the high of 10 meters from ground level. Using "Power Law" the velocity required for the height of 5 meters from ground level (which was the ground

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level used when the researchers made this research) is 12.35 m/s [1]. To counter these situations, many companies have invented different type of wind barriers throughout the years. The usage of common wind barriers which are made with steels or plastic may solve the crosswind problems, but they are not economical, require constant maintenance as the Malaysian tropical climate which consists of wet and dry seasons would cause the materials to rust and deteriorate, the costs for removing it is also high. Natures also have their own wind breaker mechanisms which are made from various kinds of plants or trees such as bamboo. The objectives for this study are to identify the properties of bamboos and their advantages as potential crosswind barrier and to validate the properties of bamboos and their advantages as potential crosswind barrier. This paper consists of four sections namely Introduction, Materials and Methods, Results and Discussion as well as Conclusion.

2. Materials and Methods

Table 1 shows the method of study applied.

Table 1: Method of study

No.	Objectives	Method	Outcome
1	To identify the properties of bamboos and their advantages as potential crosswind barrier	Literature review analysis	Table of comparison between several bamboo types, Design of the Oldhamii Bamboo used On the Highway
2	To validate the properties of bamboos and their advantages as potential crosswind barrier	Expert interview session	Quotation marks of responses from the expert

In this study, more than 30 journal articles of previous case studies which are related to the usage of bamboo as wind barrier were reviewed. The information is important to be used for ideas and references in this project. An interview with a bamboo expert, Ts Salman Bin Salim was conducted to obtain more ideas and inspirations to complete the study of bamboo crosswind barrier. Among questions that were asked are as follows:

i. Could you explain about bamboo in general?
ii. What is the type of bamboos that are suitable to be used as crosswind barrier?
iii. How to identify the suitable bamboo to become the crosswind barrier?

3. Results and Discussion

3.1 Literature Review Analysis

Three types of different bamboo were compared to propose the most suitable bamboo to be used as wind barrier namely the Blumeana Bamboo, Gracilis Bamboo, and Oldhamii Bamboo. Table 2 shows the comparison of these bamboo types based on five aspects which are physical properties, strength, durability, suitability, and safety of bamboo as wind barrier.

Table 2: Comparison of three types of bamboo

Bamboo Type	Blumeana Bamboo	Gracilis Bamboo	Oldhamii Bamboo
Physical properties of Bamboo	Can grow to the height of 15 to 25 meters. Have the diameter of 8 to 15 cm. Usually, can be found in Southeast Asia commonly planted in medium and low attitude areas.	Very popular for landscaping architects, have 1 inch diameter and can grows to 30 ft tall. It can find at Southern China. It depends on climate. [2]	Reaching up 17-20 m, up to 10 cm diameter and can be found from Taiwan to Southern China. [3]
Strength of Bamboo	Usually used in construction as scaffolding and raw materials in low-rise constructions. Based on the other studies, the compressive strength of the bamboo is 20 MPa and the tensile strength is 95 MPa. [4]	It has hard on physical but weaker than Blumeana Bamboo and Oldhamii Bamboo.	The Oldhamii Bamboo is considered as a common structural bamboo with medium quality. The compressive strength of the Oldhamii Bamboo is 56.1 MPa while the tensile strength of the bamboo is 273.3 MPa. [5]
Durability of Bamboo	Unless the bamboo to be treated properly, the natural durability of the bamboo culm is very low causing the bamboo to only last for 1-3 years outdoor [6]. Effective bamboo treatment and protection by design is needed to ensure durable result. This bamboo cannot withstand cold climate.[4]	This bamboo can tolerate cold to 12 degrees, very dense hedge. [7]	While this bamboo suited in tropical climate, this bamboo can also withstand cold climate. [8]
Suitability of Bamboo as Wind Barrier	Used as wind breaker around farmhouses [6]. Have features such as rhizomes which acted as anchors which help to withstand wind load.[9]	It can be use as wind barrier in farm but more to use as landscaping. [7]	Usually used as wind breakers. Have features such as rhizomes which acted as anchors which help to withstand wind load. The strong mechanical properties of the bamboo also help to withstand strong wind loads. [9]
Safety of Using the Bamboo	The branches which are located at the lower nodes of the bamboo are solitaire and densely intertwine with sharp and curved thorns which can endanger the workers which are maintaining the bamboo. [10]	It is tall, thin, and safe to use but not effective for strong crosswind. [2]	Safe to use because their maximum height is 20 m, not danger people and have low amount of damage or bending from strong crosswind. [8]

3.2 Interview Outcome

Table 3 shows the summary of interview session outcome. The questions are not limited to the list given; random questions were also asked to obtain comprehensive idea for this project.

Table 3: Summary of Several Questions asked in the Interview Session with Ts. Salman Salim

Questions	Answers
1. Could you explain about bamboo in general?	*"bamboo terdiri daripada banyak jenis spesies,ada beribu spesies.Ia terbahagi kepada tiga komponen iaitu yang pertama, bamboo yang digunakan untuk construction iaitu digunakan sebagai material untuk construction…….yang kedua adalah bamboo untuk makanan dan juga untuk kegunaan tradisional seperti penyapu……yang ketiga adalah bamboo landskap……"*
2. What is the type of bamboos that are suitable to be used as crosswind barrier?	*"sebenarnya banyak pun kalau kita tengok bamboo-bamboo yang berada di tepi jalan, di tempat-tempat yang jenis bamboo kuning yang digunakan untuk landskap yang ditanam di kawasan taman bunga dan sebagainya. Jadi itu lebih sesuai untuk wind barrier di samping dia boleh menambah ecstatic value….."*
3. How to identify the suitable bamboo to become the crosswind barrier.	*"pemilihan jenis buluh ini bergantung kepada spesifikasi lalulintas jalan raya. Dia ada jarak penglihatan yang sesuai, tinggi sangat pun tidak sesuai dan dia diletakkan di kawasan mana. Kalau kawasan -kawasan yang telah dikenalpasti memang angin kuat, mungkin jenis buluh yang yang digunakan berbeza……"*

In summary, based on the answers given by Ts. Salman, there are many species of bamboo in this world, and it is divided into three category which are bamboo for construction purposes, bamboo for consumption and traditional uses and bamboo for landscape purposes. Of these, the type of bamboo suitable to be used as crosswind barrier are bamboo that is used for landscaping purposes. Besides that, the types of bamboo used for crosswind barrier also depends on the location were said crosswind barrier to be setup.

3.3 Recommended Bamboo and its properties

Based on the literature study and interview outcomes, it can be concluded that the most suitable type of bamboo to be used as a possible crosswind barrier is the Oldhamii Bamboo. Bambusa Oldhamii, often known as Oldhamii Bamboo or gigantic woody bamboo, is a huge bamboo species. This bamboo is recommended for this study. In the United States, this is the most common and commonly grown bamboo, and it has been introduced into agriculture all over the world. Figure 2 shows the picture of Oldhamii Bamboo.

Figure 2: Oldhamii Bamboo

The foliage of Oldham bamboo is dense, reaching up to 17–20 m (56–66 ft) in height in good condition and with green shoots up to 10 cm in diameter (4 in) [11]. Oldhamii Bamboo can be found from Taiwan to Southern China (Fujian, Guangdong, Guangxi, Hainan, Zhejiang). It was widely planted and is now native in some locations, including Ryukyu Island, New Zealand, Chiapas, Honduras, Peru, and others [3].

This bamboo is primarily used for building, but it may also be utilized as a green screen, a windbreaker, and a woven product. Bamboo has a modulus of elasticity under compression (24.6 GPa), allowing it to bend but not break in heavy winds. Windbreaks are frequently employed to cover cash crops [12]. To optimize this benefit, however, efficient clump management is required, as congested clumps offer a more solid barrier and are significantly more prone to succumb to strong winds. Clumping bamboos come in a variety of shapes and sizes, and they make excellent windbreaks. Oldhamii Bamboo is a tall, slender windbreak and boundary plant that looks great. This species escaped cyclonic winds with the least amount of damage (bending and breakage) of the seven species tested in Fiji, although more research is needed. Bambusa multiplex is a dense low screening hedge and windbreak that is frequently grown in Fiji [8].

The Oldhamii Bamboo needs a rich, wet soil and full sun to moderate shade to thrive. It has a low water requirement, but if provided water on a regular basis, it will produce the best results. This plant grows best in tropical climates with warm weather and is hardy to 15-20 degrees Fahrenheit. This plant only blooms at periods of the year, and when it does, it can perish. On the other hand, the plant will normally recover if you leave it alone [13].

3.4 Advantages of Oldhamii Bamboo as Crosswind Barrier

a. The thickness of the groove of the bamboos can be controlled.

Oldhamii Bamboo the same as other bamboo grew from their rhizomes. This phenomenon helped them to be one of the fastest growing plants in the world [1]. However, this phenomenon caused the bamboos to grow wildly as the rhizomes spread to other areas of the nearby soil causing the bamboos to spread further than the intended area. However, this situation can be avoided by installing rhizome barrier in the area where the bamboos will be planted. By installing rhizome barrier, the rhizome will not be able to penetrate the barrier which will restrict the area of growth of the bamboos [14]. This

situation will be useful to areas which has difference average crosswind velocities as engineers can plant the right amount of thickness needed for groove of the bamboos in these areas [15][16].

b. The design of the bamboo is suitable for wind load resistance.

In countries like China, the Oldhamii Bamboo is also known for its ability to act as a wind breaker for orchards, gardens, and crops. The Oldhamii Bamboo has the average height of 10-12 meter with the maximum height being 17-20 meter [17] meaning the area that will be protected from the crosswind will be higher [18]. Due to the rhizomes of the bamboos spreading and growing horizontally in linked fashion, the bamboos are connected by a long rhizome which acted as a strong anchor for the bamboos which supported the in-resisting wind loads, external forces and gravitational forces [9]. The positioning of the Oldhamii Bamboos which are in an erect culms state and grew near to each other also help to break the air flow of the crosswind [16]. The Oldhamii Bamboo is also known for having resistance to cold climate and being a type of structural bamboo with medium quality. This means that the mechanical properties of the Oldhamii Bamboo include having great strength, density, and durability as it can be used for structural uses such as building houses, bridges and even can be used as scaffolding [19].

c. High resistance and high strength bamboo

The resistance of six bamboo species planted in Hawaii to attack by Subterranean Termites. The American Wood Protection Association's standard E1-09 was used to conduct four-week laboratory feeding trials. Each of the six bamboo species was exposed to 200 termites individually. Oldhamii Bamboo was shown to be the most resistant bamboo after a four-week feeding trial [20]. Furthermore, the maximum compressive strength of 60 mPa found in Oldhamii Bamboo would be equal to a high-strength concrete [13].

d. Temperature and weather

The ideal temperature for Oldhamii Bamboo is a subtropical climate like Taiwan. Furthermore, the climate in Europe and North America is suitable to produce Oldhamii Bamboo, which can survive in temperatures ranging from -6 to -9 degrees Celsius. Malaysia is also a good site to grow Oldhamii Bamboo, which can be used as a windbreak on the side of the road to keep crosswinds at bay [20].

e. Dense foliage

Oldham bamboo is not only tall and strong, but it also has a lot of attractive greens in the form of long and wide leaves that grow densely between the bamboo stems. Furthermore, Oldhamii Bamboo has beautiful leaves and can be utilized as a landscaping plant [20].

3.5 Design of the Oldhamii Bamboo used on the Highway

Using the AutoCAD, three cross section drawings of the highway were produced which represented the positioning of the Oldhamii Bamboos beside the highways based on the Guidelines for Planting within Highway Right-of-Way prepared by the North Carolina Department of Transportation [21]. Figure 3 shows the design layout of the Oldhamii Bamboos used in an actual highway.

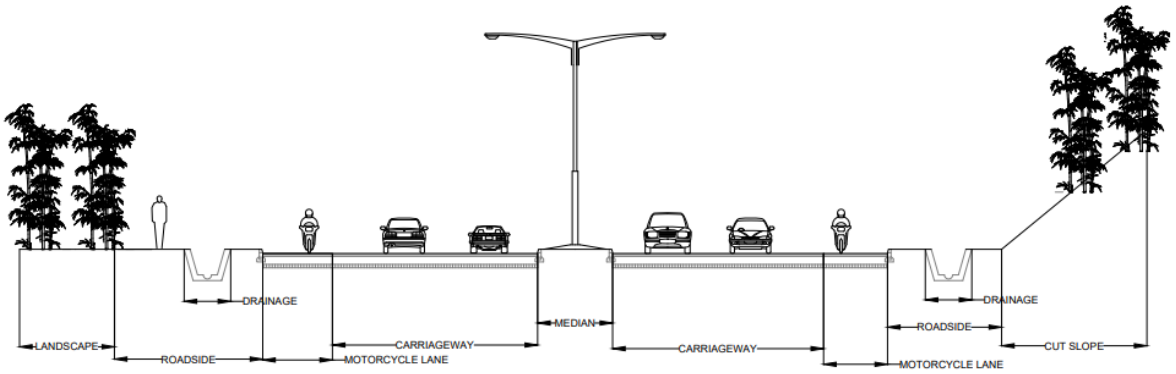


Figure 3: The design of the Oldhamii Bamboos used in an actual highway

Referring to Figure 3, the Oldhamii Bamboos are strictly positioned beside the highways based on the guidelines. Some of the guidelines that were followed in the positioning of the bamboos are the plants are:

a. The plants are in the condition of not endangering both vehicular and pedestrian traffic.
b. The plants must follow the specific distance between the plants and the travel lane.
c. Selection of the plants must not be a tall-growing trees and wide spreading trees unless width of the planting area is sufficient.
d. The trees planted must have the minimum vertical clearance of 16 feet above the entire pavement and 7 feet above pedestrian spaces.

In addition, the distance of the position of the bamboos and the curb and gutter. Based on the guidelines produced by the North Carolina Department of Transportation, the distance between the plants and the curb and gutter are based on a lot of factors such as the topography of the highway and the speed limit of the highway which is greater than 45 mph or 72.42 km/h [21]. Due to the speed limit, the ideal distance between the curb and gutter with the bamboos are 25 feet or 7.62 m for the topography of ground level as shown in Figure 4. While the ideal distance of between the bamboos with the curb and gutter for cut slope, topography is 30 feet or 9.14 m as shown in Figure 5. The Oldhamii Bamboo are considered a large tree due to the single stem being greater than 4 inches in diameter during maturity.

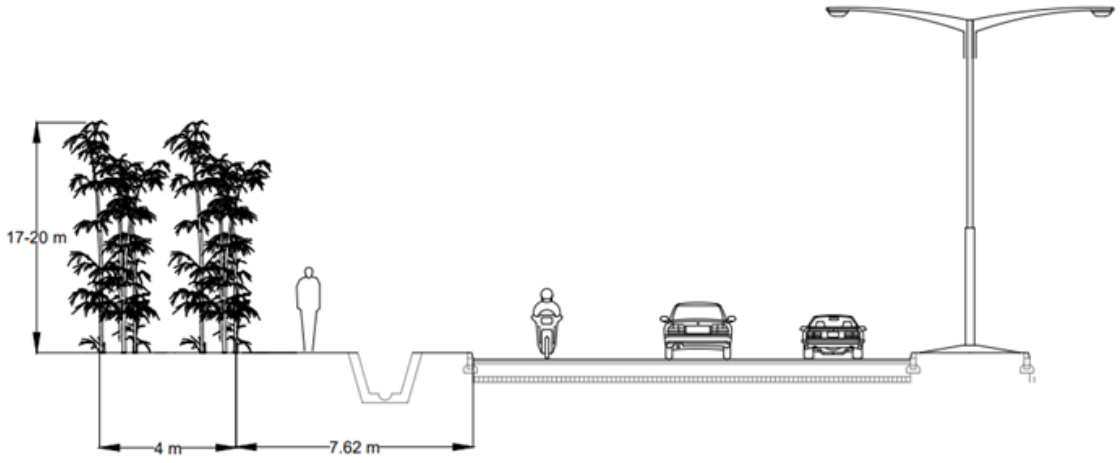


Figure 4: The distance between the curb and gutter with the bamboos on a ground level topography

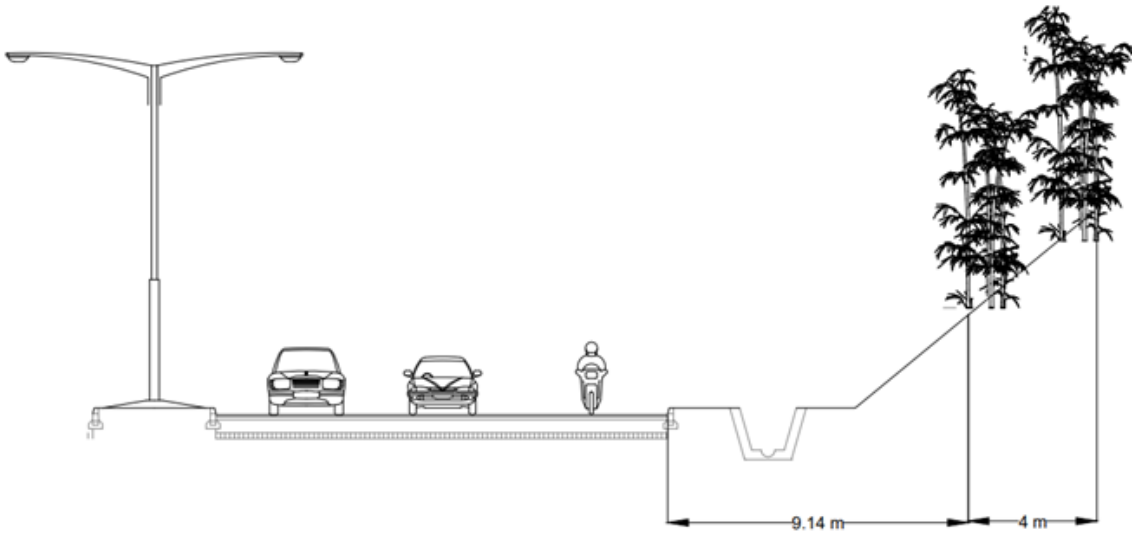
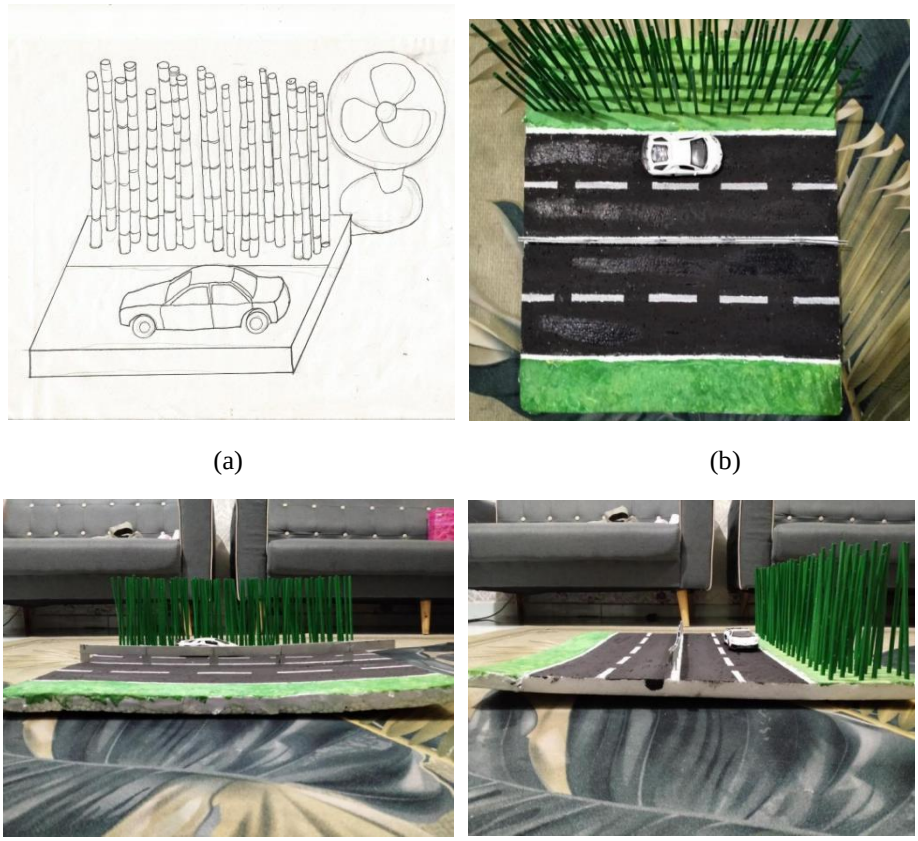


Figure 5: The distance between the curb and gutter with the bamboos on a cut slope topography

A mini model was developed in effort to present a general idea on the concept of bamboo as crosswind barrier. The model was not-to-scale model as it is only used as a visual representation only. Figure 6 shows the early sketch, the plan view, side view and front view of our model.



(a) (b)

(c) (d)

Figure 6: Model views - (a) early sketch; (b) plan view; (c) side view; (d) front view

4. Conclusion

In fulfilling the first objective, the properties of bamboos and their advantages as potential crosswind barrier were identified through literature study. The comparison of Blumeana Bamboo, Gracilis bamboo and Oldhamii Bamboo was presented in Table 2 in the previous section. The elements that were compared are the physical properties and the mechanical properties of the bamboo which are strength, durability, suitability, and safeness of the bamboo to be used as crosswind barrier. While for the second objective, the advantages of bamboo as potential crosswind barrier were validated through interview session with a bamboo expert, which is Ts. Salman Salim. Therefore, it can be concluded from the outcome of the literature study and interview, that the most suitable type of bamboo to be proposed as a potential crosswind barrier is Oldhamii Bamboo. There are several recommendations to be taken into consideration in future research such as conducting laboratory testing for thorough information of the Oldhamii Bamboo properties and identifying a specific study location to test the ability of this bamboo to negate the crosswind. It is hoped that this study will enhance the attraction to the use of bamboo in construction, especially the construction of roads in addressing the crosswinds problem.

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