**TSF015**

# The Thermal Conductivity Improvement for Mortar using Water Hyacinth

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***Abstract***

Water Hyacinth, aquatic weed, is one of plant species which grows and spreads rapidly. Therefore, the water hyacinth has extensively been studied in order to eliminate and make benefits. As an insulator property, water hyacinth was introduced to mortar development to investigate the thermal conductivity property. The study investigated an effect of the amount and length of water hyacinth fibers for mortar. In the study, the thermal conductivity was carried out at various amount and length of water hyacinth with sand replacement. In addition, compressive strength was experimentally observed for 28 days of sample age. As a flow standard test, the maximum amount of water hyacinth was 2%. The experimental results showed that the increasing amount of water hyacinth reduced the thermal conductivity and compressive strength of modified mortar compared with mortar without water hyacinth. Additionally, the 1% of sand replacement in modified mortar achieves Thai Industrial Standard (TIS) 1776-2542 and improves 27% of the thermal conductivity reduction.

***Keywords****:* Mortar, Thermal conductivity, Water hyacinth, Compressive strength.

## 1. Introduction

Recently, many countries around the world have been facing global warming due to the greenhouse effect. The environment and bio-organism has seriously confronted to this crisis such as flooding, drought, and rising sea level. According to the crisis, the increasing global temperature has severely influenced an overall heat through buildings. As the results, the rate of energy consumption in air conditioning system has been continuously increasing to maintain or improve comfort conditions in building. Therefore, many researchers and research laboratories have been looking for reducing the heat gain into building and finding alternative material that not only should be decrease energy consumption, but also environmentally friendly. In the past few decades, because the insulation material is one of the best choices for energy saving in building, alternative materials have been received a lot of attention from researchers and industries to diminish energy from environment through the buildings. Various types of material including concrete block, insulation roof, protective coating, and insulation ceiling as well as low thermal conductivity mortar, can generate a significant reducing energy into building and protect the environment at the same time. Furthermore, mortar also has been introduced by using bagasse ash, lime mud, oil palm fruit, tire crumb, nano-structured waste materials, phase change materials and rubber particles to reduce thermal conductivity by replacement of sand or cement. Moreover, the water hyacinth is promising for a good insulation and is also weed in our environment. As the world's worst aquatic weed for decades, only one water hyacinth can reproduce to three hundred in 20 days [1]. Additionally, temperature and water nutrient level are the important factors in growing [2]. Because of plentiful amount of water hyacinth, it has been studied not only for elimination, but also benefits from it. As the benefits, water hyacinth has been used for remove heavy metals and plant nutrients from wastewater [3-4], ethanol production [5], soil nutrient [6], and biogas [7]. In order to study the benefits, water hyacinth has been applied to be the insulation because of a low thermal conductivity property material.

There are many bio-materials such as clay, fly ash, rice hush ash, and epoxidized tall oil used in many applications especially insulation materials. These compositions were used to be one of layer of composite structure for external building wall. The variation ratios of composition gave different thermal conductivity values of insulation materials between 0.256-0.537 W/(m·K) [8]. In order to improve the thermal properties, mortar has been developed and applied using phase change materials (PCMs) and rubber particles as insulation mortar. The experimental results indicated that, in the same volume fraction of PCMs and rubbers, the thermal conductivity significantly reduced by using the smaller and more rubber particles in rubberized mortar, while the PCMs can improve heat capacity of the mortar. Moreover, the range of thermal conductivity is between 0.323-0.476 W/(m·K) [9-10]. To investigate the thermal conductivity of mortar, the industry wastes such as silica fume, class C fly ash, and blast furnace slag have been used to replace the cement with varied fraction. The experimental study showed that the thermal conductivity of mortar had decreased up to 39-46%. [11]. An electricity generating power plant waste, bagasse ash, as a partial replacement in mortar was used to replace sand and lime stone powder. The research revealed that the thermal conductivity was decreased when increasing the bagasse ash [12]. To improve mechanical properties of mortar, oil palm fruit fiber and tire crumb have been used to develop compressive strength, split tensile strength, and flexural strength of the mortar composites. The study showed that oil palm fruit fiber and tire crumb substitute for aggregates could significantly improve the mechanical properties of light weight mortar [13]. As an aquatic weed, water hyacinth was introduced to reduce heat gain into building as a composition of a non-load bearing concrete masonry unit. The study results illustrated that the thermal conductivity of a concrete block had a significant reduction and it was 0.111 W/(m·K) while the sample achieved the compressive strength criterion of TIS 58-2533 [14].

The purpose of this study is to investigate the modified mortar using water hyacinth to replace sand in order to improve the thermal conductivity. This work was done based on TIS 1776-2542 [15]. Moreover, the thermal conductivity and compressive strength were carried out under the various amount and length of water hyacinth fibers in modified mortar. In addition, the modified mortar was compared with the mortar without water hyacinth as a control sample.

## 2. Materials and Experimental procedure

In this study, water hyacinth fibers was used for sand replacement with varied length and ratio in order to investigate the thermal conductivity and compressive strength of mortar as shown in Fig. 1. There were three sizes of water hyacinth fibers used in the experimental study which are 3/8 mesh, 4 mesh, and 8 mesh. Furthermore, the sieve analysis based on ASTM C136-06 [16] had been conducted on water hyacinth fibers. As a replacement material, the maximum value of water hyacinth fibers was 2.0% because of the flow test standard. Moreover, the mortar was varied with the different ratios of sand, and water hyacinth. Each specimen has been mixing as a following table 1 and the control specimen is mortar without water hyacinth.

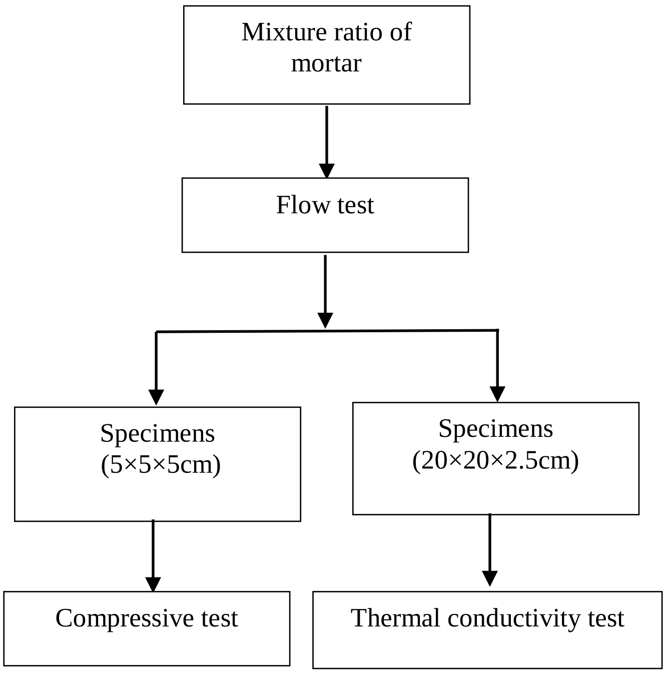



Fig.1 Diagram of experiment

Table1: The composition of samples

| Sample number | Mixture ratio (kg) | | | Sand replacement (%) | Length of Water hyacinth fiber (cm) |
|---|---|---|---|---|---|
| | Cement | Sand | Water hyacinth fiber | | |
| 1 | 1 | 3.000 | - | - | - |
| 2 | 1 | 2.985 | 0.015 | 0.5 | 1 |
| 3 | 1 | 2.970 | 0.030 | 1.0 | 1 |
| 4 | 1 | 2.955 | 0.045 | 1.5 | 1 |
| 5 | 1 | 2.940 | 0.060 | 2.0 | 1 |
| 6 | 1 | 2.985 | 0.015 | 0.5 | 2 |
| 7 | 1 | 2.970 | 0.030 | 1.0 | 2 |
| 8 | 1 | 2.955 | 0.045 | 1.5 | 2 |
| 9 | 1 | 2.940 | 0.060 | 2.0 | 2 |
| 10 | 1 | 2.985 | 0.015 | 0.5 | 3 |
| 11 | 1 | 2.970 | 0.030 | 1.0 | 3 |
| 12 | 1 | 2.955 | 0.045 | 1.5 | 3 |
| 13 | 1 | 2.940 | 0.060 | 2.0 | 3 |

## 3. Standard and testing methods

The compressive strength, flow test and thermal conductivity were investigated in this study.

### 3.1 Compressive test

This experiment was done based on TIS 1776-2542 using Universal Testing Machine (UTM) model Hualong WEW-1000B. Moreover, the mortar must have a compressive strength not less than 5 MPa (50ksc). The specimen dimensions of 5 cm×5 cm×5cm were prepared for each sample and compressive test was investigated at 7 days, and 28 days of age.

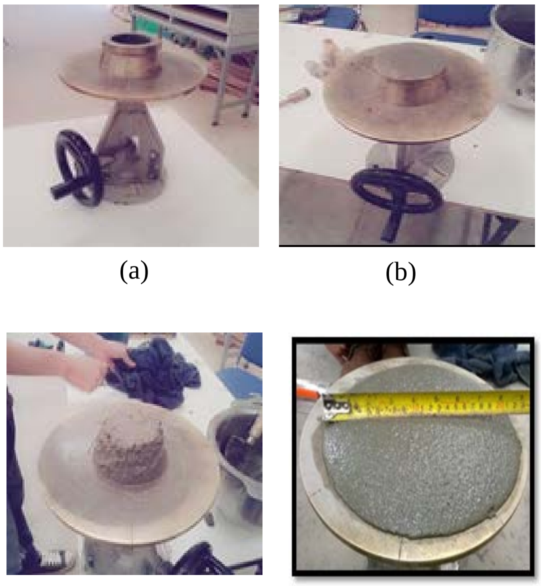
### 3.2 Flow test

The flow test was conducted for limit the amount of water hyacinth fiber to replace sand. The flow test was done based on ASTM C91. As a standard, the flow test of the mortar mixture has to be accept for 110±5%. According to the flow test, the amount of water hyacinth had been used less than 2%. The flow test can be determined using the eq. (1):

$$\text{Flow test (\%)} = \frac{D_{out} - D_{in}}{D_{in}} \times 100 \qquad (1)$$

In which $D_{out}$ is diameter of the mortar that flow over the tester (cm), and $D_{in}$ is the diameter of the tester which is 10 cm.

The flow test was investigated using device Fig. 2(a) and the mixture of mortar was fill in Fig. 2(b). In the test, the plate was lifted for 13 mm and released it to free fall for 25 times in 15 second. Finally, the mortar was showed in Fig. 2(d) and measured the diameter. The flow test was calculated from eq. (1) and the percentile of flow test has to be 110 ±5 % for the standard.



(a) (b)

(c) (d)

Fig. 2 Flow test

### 3.3 Thermal conductivity test

The thermal conductivity test was examined based on the Guard Hot Plate with standard ASTM C177. The specimen dimensions of 20 cm×20cm×2.5cm were prepared for each sample and samples were investigated 28 days of age. The thermal conductivity of mortar is determined using the eq. (2):

$$k = \frac{Q \cdot L}{A(T_{hot} - T_{cold})} \qquad (2)$$

In which k is the thermal conductivity (W/m·K), Q is a heat from power supply (W), L is a thickness of mortar sample (m), A is an area that has the heat transfer passing through in one direction ($m^2$), and the temperature difference, $T_{hot} - T_{cold}$, is the temperature difference between the hot side and cold side that gives into the sample (K). Moreover, the hot side has been used the operating temperature condition of mortar between 60-70°C.

## 4. Experimental Results and Discussions

In this section, the study found that the length and amount of water hyacinth replaced sand have a significant effect on compressive strength and thermal conductivity. These results are detailed below.

### 4.1 The compressive test

The experimental results of compressive test were investigated at 7 days and 28 days as show in following figure 3. The compressive strength depended on age of mortar. As expected, the mortar at 28 days had more compressive strength than 7 days and the compressive strength was reduced when the amount of water hyacinth fibers was increased.

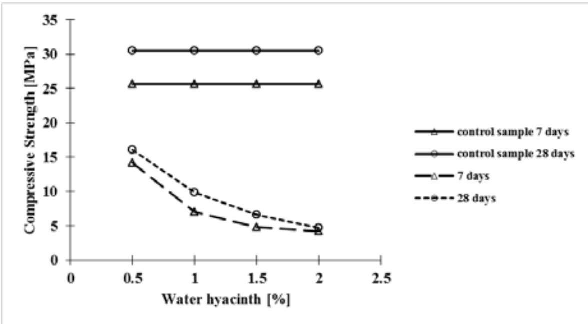



Fig. 3 The compressive strength comparison between 7 days and 28 days using 3-cm water hyacinth length

In Fig.4, the length and amount of water hyacinth have significantly affected on the compressive strength when compared with a control sample, mortar without water hyacinth. Moreover, the compressive strength was dramatically reduced when the amount of water hyacinth fibers has been increased. The results showed that the shorter fiber gives the more compressive strength than the longer one. Moreover, the more amount of water hyacinth gives less compressive strength. Then, the amount of water hyacinth should be less than 1.5% because of the standard, TIS 1776-2542.

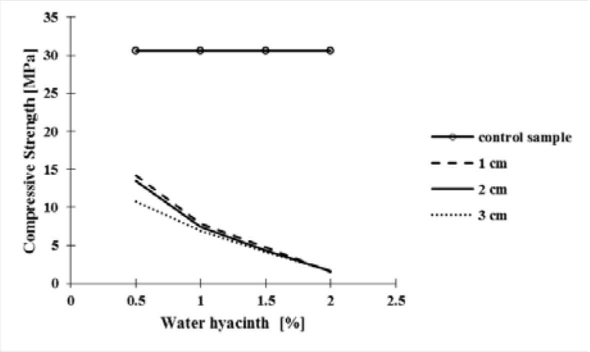



Fig. 4 water hycinth percent versus compressive strength at 28 days

### 4.2 Thermal conductivity test

The experimental setup was based on Guard Hot Plate, ASTM C177, according to thermal conductivity test. The amount and length of water hyacinth were varied as the following figure 5. The experimental results showed the amount and length of water hyacinth also had significantly influenced of the thermal conductivity of modified mortar in fig.5. To illustrate, as compared with a control sample, the thermal conductivity had significantly decreased when the amount of water hyacinth was increased. As the results, the more amount of water hyacinth gave the more insulation property of modified mortar. However, the maximum replacement of sand was 2% as a standard of flow test. In addition, the length of water hyacinth fibers at 3 cm gave the lowest thermal conductivity. Moreover, the 1 cm and 2 cm were almost the same and did not have any significantly in thermal conductivity value.

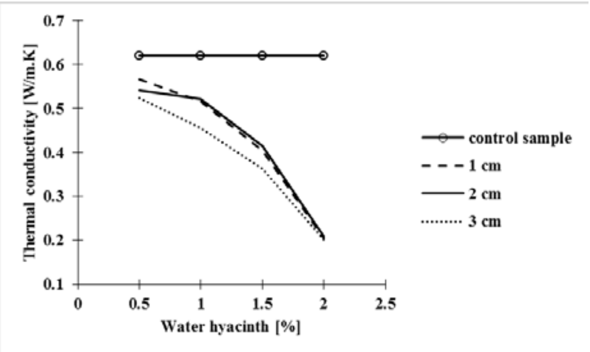



Fig. 5 The thermal conductivity versus water hycinth percent at 28 days

### 4.3 Thermal conductivity and density

In the study, the relationship between thermal conductivity and density were observed in mortar. The amount and length of water hyacinth can reduce the density of mortar. Therefore, the modified mortar gives low density and thermal conductivity compared with conventional mortar. The results have been shown in table 2

Table 2: The density and thermal conductivity of modified mortar

| Sample number | Length of Water hyacinth fiber (cm) | Water hyacinth (%) | Density (kg/m$^3$) | Thermal conductivity (W/m.K) |
|---|---|---|---|---|
| 1 | - | - | 1852.4 | 0.6918 |
| 2 | 1 | 0.5 | 1712.1 | 0.5685 |
| 3 | 1 | 1.0 | 1489.6 | 0.5469 |
| 4 | 1 | 1.5 | 1293.1 | 0.5056 |
| 5 | 1 | 2.0 | 1177.5 | 0.1640 |
| 6 | 2 | 0.5 | 1589.9 | 0.6672 |
| 7 | 2 | 1.0 | 1549.2 | 0.6112 |
| 8 | 2 | 1.5 | 1319.3 | 0.5174 |
| 9 | 2 | 2.0 | 1166.6 | 0.3441 |
| 10 | 3 | 0.5 | 1658.3 | 0.5617 |
| 11 | 3 | 1.0 | 1491.1 | 0.3550 |
| 12 | 3 | 1.5 | 1277.3 | 0.3284 |
| 13 | 3 | 2.0 | 1138.3 | 0.2234 |

## 5. Conclusions

The mortar was modified using water hyacinth fibers in order to reduce the thermal conductivity. Dependence of thermal conductivity on length and amount of water hyacinth was verified. The experimental results found that the amount of water hyacinth had significantly influenced on thermal conductivity of mortar. To illustrate, the more amount of water hyacinth gave the less thermal conductivity. However, the compressive strength was decreased when the amount of water hyacinth fibers was increased. Moreover, the 3-cm length and 1% sand replacement was used to be the mixture of mortar because it meets the flow and compression standard test, TIS 1776-2542. Additionally, the thermal conductivity reduced by 27% in modified mortar.

## 6. References

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