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EXPERIMENTAL MODELLING OF FLOATING DEBRIS BOOM

TAN JO EE

Thesis submitted in fulfilment of the requirements
for the award of the degree of
B.Eng (Hons.) Civil Engineering

Faculty of Civil Engineering and Earth Resources
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JUNE 2015

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Dedicated to my parents,

for their love and devotion

making me be who I am today

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ABSTRACT

Rivers play an important role in providing the water resources for human and ecosystem survival and health. Nowadays, most urban areas experience difficulties in solving water pollution in rivers and streams. Hence, a proper solution should be carried out to overcome this problem. The objective of this research is to study an effective floating debris boom which can be created with appropriate dimensions, as well as good level of effectiveness of material in various flow rates, in a rectangular open channel to reduce the river pollution. In this research, there are two types of connection, hinged or drilled hole that will be used to connect the piers and the booms. Three types of material were used which are Styrofoam, bamboo, and PVC. Total six booms were created and tested with five different flow rates. An amount of 200g of debris was put into the open channel to test the floating debris boom. The results indicated that hinged connection is stronger than drilled-hole connection to connect the piers and the booms as it provided a free movement for the boom to move. For the type of material, Styrofoam proved that it has the best effectiveness for capturing the debris due to its lighter weight among the three materials. Based on the data obtained, floating debris boom which is made from Styrofoam and connected by hinged connection has the best performance and effectiveness for capturing the debris in this experiment. Eventually, this finding may contribute toward the minimization of river pollution happening in Malaysia.

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ABSTRAK

Sungai memainkan peranan yang penting dalam membekalkan sumber air untuk manusia dan ekosistem secara langsung. Pada masa kini, kebanyakan kawasan bandar menghadapi kesukaran dalam mengatasi masalah pencemaran air di sungai dan anak sungai. Oleh hal yang demikian, solusi yang wajar perlu dilakukan untuk menyelesaikan masalah ini. Objektif penyelidikan ini adalah untuk menciptakan "floating debris boom" dengan dimensi yang sesuai dan mengkajikan tahap berkesanan bahan-bahan dengan pelbagai kadar aliran dalam saluran terbuka segi empat tepat untuk megurangkan pencemaran sungai. Dalam penyelidikan ini, dua jenis sambungan yang digunakan, "hinged connection" atau "drilled-hole connection", fungsi sambungan ini adalah untuk menyambung dermaga dan "boom". Tiga jenis bahan yang akan digunakan ialah "Styrofoam", buluh, dan "Polyvinyl Chloride (PVC)". Jumlah enam "boom" akan dicipta dan diuji dengan lima kadar aliran yang berbeza. Jumlah 200g sampah terapung akan dimasukkan ke dalam saluran terbuka untuk menguji "floating debris boom". Keputusan memnunjukkan bahawa "hinged connection" lebih kukuh dan kuat daripada "drilled-hole connection" untul menyambung dermaga dan "boom". Hal ini demikian kerana sambungan ini membekalkan pergerakkan bebas untuk "boom" bergerak dalam saluran terbuka. Manakala untuk bahan yang efektif adalah "Styrofoam" dan membuktikan bahawa bahan ini mempunyai keberkesanan yang terbaik untuk menangkap sampah terapung disebabkan berat bahan yang paling ringan antara ketiga-tiga jenis bahan ini. Berdasarkan data yang diperolehi, "floating debris boom" yang dibuat daripada "Styrofoam" dan "hinged connection" menunjukkan pretasi yang terbaik dan keberkesanan dalam menangkap sampah terapung dalam eksperimen ini. Akhirnya, penyelidikan ini dapat menyumbang kepada solusi mengurangkan pencemaran sungai yang sering berlaku di Malaysia

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LIST OF ABBREVIATIONS

PVC	Polyvinyl Chloride
HDPE	High Density Polyethylene

CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

This research contains information to create an experimental modelling of floating debris boom to reduce the river pollution. The content of this chapter would be the research problem background, problem statement, research objectives, scope of study, and research significance.

1.1 BACKGROUND

Most urban areas are experience difficulties in solving water pollution in rivers and streams. Polluted storm water runs off relatively fast in urban area, is then collected by collection systems (both open and closed) and finally discharged to rivers and streams (Ho, 2005). Some issues such as lower oxygen levels, increasing algae level, and over sedimentation are encountered by Environment Protection Authority in Australia which are the problems they are facing in their rivers (EPA, 2003). Some of the groups like Save Our Shores at the Monterey Bay region in California have started to promote funding for protecting and recovering water health. They noticed that the estuaries and streams that are being polluted were the places where many people have various types of recreational activities (Couch, 2007).

Pollution in rivers and streams has become a hot button issue for most of the state and federal regulators. The implementation and enforcement of some environmental organizations such as State Water Resources Control Board (SWRCB) implements the National Pollutant Discharge Elimination System (NPDES) permit program of the Clean Act, Section 402. They regulate discharges of pollutants in storm water and urban runoff (Miriam, 2006). In addition, development of educational and awareness programs has conducted to raise up the awareness such as "Save Our Seas" and "Waves, Wetlands, and Watersheds" (Mark, 2013).

Figure 1.1: Debris and trash thrown into the river has contributed significantly to river pollution.

Figure 1.2: Effect of river pollution – extinction of aquatic life.

Floating booms are one of the examples of cost effective tools which are effective in debris control as shown in Figure 1.3. These floating boom barriers are often installed in calm water, moving water, and fast moving water which can aid in the collection and disposal of debris such as containment as well as recovery of floating trash, debris, timber, urban waste or aquatic plants as shown in Figure 1.4. Besides that, floating booms can also be installed at the upstream of dam spillways to prevent blockage by debris during flood discharge. They might serve to prevent boaters from entering the spillway as well.

Figure 1.3: Floating boom was placed in the middle of the river or lake to block and capture the debris or trash.

Figure 1.4: Trash and disposable material that have been blocked by the floating debris boom.

Nevertheless, sometimes it will give a false sense of protection. For example, a boom may not prevent materials such as sticks or small sized debris from passing over or under the boom in narrow or shallow spillways during high wind events, which may eventually lead to blockages (Kerr, 1999).

Consequently, this research is conducted to examine the level of effectiveness of floating debris boom in reducing water pollution and debris control. Floating debris can be constructed in various designs and from various types of material. Through this research, we are able to determine the type of material most suitable for constructing the floating boom. Every water condition has different flow rates and indirectly it will affect the effectiveness of a floating boom. Hence, different flow rate conditions will be tested to find out the most suitable floating boom.

1.2 PROBLEM STATEMENT

Nowadays, river pollution has become a concern for everyone. This issue is getting more serious and it will lead to various bad impacts if it continues to spread. These impacts may affect human's health whether they come into contact with it indirectly or directly. Drinking contaminated water will cause diseases like cholera, hepatitis, typhoid, dysentery, and polio in humans (Alecia, 2012). Furthermore, it also brings negative effects to flora and fauna and their habitats.

There are many types of major pollutants that can be discovered in the river or ocean such as oil, sewage, chemical wastes, rubbish, eutrophication and plastics. Among these pollutants, rubbish and plastics seems to bring the most adverse effect to aquatic life and human health. It indicated that at least 267 species of animal endured entanglement and ingestion of floatable plastic debris (Claire, 2009).

In addition, National Oceanographic and Atmospheric Administration has reported before that plastic debris had killed an estimated value of 100,000 marine mammals every year, as well as millions of birds and fishes (Claire, 2009). This debris can also bring death to animals such as sea lions and seals through drowning, suffocation, strangulation, and injuries. The entangle rates has been recorded as it has been raised up to 7.9 %. An estimated 58% of seal and sea lion species that were affected includes Hawaiian monk seal, Australian sea lions, New Zealand fur seals and species in the Southern Ocean (Michelle et.al., 2006).

Besides foreign countries, Malaysia has also been suffering serious river pollutions in some states such as Selangor, Penang, Kuala Lumpur, and Negeri Sembilan. Juru River, which is located in Penang, has been classified by the Department of Environment (DOE) as the most polluted river in Malaysia (Zulkifly, 2008). From the on-site investigation, it was revealed that various kind of floating debris can found at the riverbank near the Juru dam such as mineral water bottles, Styrofoam, food waste, plastic materials, construction and household discard, and vehicle tyres.

Several past incidences has reported that thousands of dead fishes can be seen floating on the surface of Kuala Sungai Juru. Due to this impact, the livelihood of fishermen who stayed near the river mouth of Juru River has been affected also. Based on the feedbacks from two fishermen, it indicated that production of fish and cockles has decreased sharply. Compared to previous good times, they only have 5% of dead cockles on that time, but as of now, 60% of cockles harvested out from the coastal area off Kuala Sungai Juru are dead cockles. The main cause for this problem is due to water contamination and pollution. Besides that, the extinction of some species of fish is getting more serious when the flora and fauna have been endangered by the threats of floating debris (Imran, 2014).

Resulting from these impacts, it is important to seek for an alternative solution to solve this issue. Hence, engineers have done some researches and investigations to create a floating debris boom which can block and capture debris. An experimental modeling of floating debris booms can be created to reduce the river pollution.

1.3 RESEARCH OBJECTIVES

The objectives of this research are:

(i) To figure out which type of connection is best for connecting between the booms and the piers.

(ii) To determine the type of material to be used for the boom.

(iii) To obtain the data of floating boom performance in rectangular open channel over various flow rates.

1.4 RESEARCH SCOPE

The scopes of this study are limited to preparation, implementation, and evaluation of a prototype of floating debris boom which can block debris and hence can reduce river pollution.

In this research, a few scopes will be included. Firstly, methods of connection for floating debris booms will be tested with hinge and drilled hole. Secondly, the types of material that will be tested for floating debris boom is bamboo, PVC (Polyvinyl chloride), and Styrofoam. The choice of these materials is to determine which material can float well on the surface of water.

The test will be conducted in a rectangular flume (30cm width x 1000cm length) in the Hydraulics and Hydrology laboratory. Three flow rates such as 50 m^3/s , 100 m^3/s , and 150 m^3/s will be tested for the floating debris boom to find out which type of model are the most efficient prototype.

1.5 SIGNIFICANCE OF STUDY

Human health and a balanced ecosystem are the most important considerations that we take into account in this research. Based on the experimental result, an effective floating debris boom can be created with appropriate dimensions, as well as good level of effectiveness of material in various flow rates in a rectangular open channel. This effective floating debris boom is designed for capturing the debris, making the cleaning process easier as the floatable debris has been trapped in the floating boom. It can be used for short term or long term deployment in order to reduce the water pollutions.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

This chapter reviews relevant topics based on the research objectives. Information obtained was mainly from online resources such as ebooks, reports, articles and relevant websites. This chapter kicked start by viewing the methods of clearance and different types of boom. Then, focus will move to the discussion of design considerations, benefits, and limitations of floating debris boom. Next, effectiveness of boom in real life is discovered. Lastly, the last section in this chapter will relate and investigate the difference of my research compare to other research.

2.1 METHODS OF CLEARANCE

Recently, water pollution has become a global issue which many countries are facing this problem. As industrialization has spread around the globe, the water pollution has also spread with it. Organizations such as Greenpeace and World Wildlife Fund are seeking for the solution to solve it. Eventually, there is various methods has been revealed for handling this thorny problem.

Enforcement of laws and regulations is one of the ways to solve water pollution. Malaysia's government has implemented the Street, Drainage and Building Act 1974, which forbid those unauthorized connection of drains into public canals or streams;

discharges from toilets and trade effluent into canals, streams, ponds or drains into the rivers (Keng, 2013). Furthermore, cooperation across national and international borders can be an effective solution for this problem. For examples, the 1978 MARPOL International Convention for the Prevention of Pollution from Ships, the 1998 OSPAR Convention for the Protection of the Marine Environment of the North East Atlantic, and the 1982 UN Convention on the Law of the Sea have been used to govern the pollution in ocean (Chris, 2014).

In addition, World Wide Fun (WWF) in Malaysia had organized public awareness campaigns, business and industry engagement, environmental education as well as policy advocacy to rise up the awareness among residents (WWF, 2012). Through these campaigns, as a resident, we can take individual initiative to reduce the water pollution. For instance, we can use environmental friendly detergents, reduce the use of pesticides and fertilizers, and throw rubbish into the dustbin instead of river. There are some organizations and groups that help to educate people about the danger of pollution. It is good to join them as they will regularly encourage their members to have a better attitude towards the water.

Apart from that, there are some implementations of hardware has been discovered to solve the water pollution. It has divided into 5 categories which are drainage entrance treatments, in-line methods, self-cleaning screens, sediment traps, and floating traps (Victorian Committee, 1999). Each of this implementation has their own roles in handling different types of debris and trashes.

Examples of drainage entrance treatments is grate entrance system, side entry pit traps (SEPTs), and baffled pits. The installation of grate entrance system is cheap and easy to install. It can prevent blockage of drain. Disadvantages of this system are it only can trap large size of rubbish and floods will happen if the drain is blocked. Side entry pit traps can capture gross pollutants, coarse materials and fine contaminants at targeted specific areas such as school, parking lots, and shopping complex. This trap was installed underground which it can minimize the visual effect. It has been widely used in Europe and North Africa in storm water and combined sewer system (Victorian Committee, 1999).

However, there are some adverse effects may occur such as nutrients and heavy metals are release from sediments, regular maintenance has to be done due to the limited holding capacity, and large retaining capacity is needed to clean the pollutants effectively. Baffle pits is efficient for trapping highly buoyant contaminants and settlable solids (Victorian Committee, 1999).

In-line methods are using a direct screening to restrain gross solids by passing flow through the mesh barrier assembly. There are many types of tool can be used to retain the pollutants such as baskets, prongs, or perforated bags. It can be installed easily and can capture large amounts of litters. In-line methods include gross pollutant traps, litter collection baskets, boom diversion systems, trash racks, release nets, return flow litter baskets, and hydraulically operated trash racks (Victorian Committee, 1999).

Furthermore, according to the Sun Daily's news, Malaysia has implemented the gross pollutant trap (GPT) to stop rubbish from entering the river. (Aiezat, 2014). This devices mainly used for remove debris and coarse sediments after storm water happened. It also can act as a pretreatment for flow into a pond or wetland to confine the area of deposition of coarse sediments (Bridget, 2011). It can trap the coarse sediments before the flow enters and infiltration device. Gross Pollutant Trap can prevent clogging of inlet pipes. Nevertheless, the cost of construction is high and it is difficult and expensive for the cleaning process. The trash rack may cause blockage which will leads to the flooding of upstream.

Self-cleaning screens are created to improve the performance of in-line screen. There are two types of screen which are circular screen and downwardly inclined screen. Circular screen was developed in Victoria which used for separate the gross pollutants from the incoming storm water into the separation chamber. The floating solids will move continuously on the surface of water and the remaining heavy pollutant will settle into the containment sump. Despite that, the installation cost of this screen is very expensive and it required a large area for construction. Whereas downwardly inclined screen has been developed in New South Wales and South Africa (Victorian Committee, 1999). It has a trash rack which has an angle to allow the pollutants to flow to downstream.

Sediment traps include sediment settling basins and ponds, circular settling tank, and hydrodynamic separators. Sediments settling basins and ponds are normally used to capture coarse sediment that can utilize in isolation in the storm water. It has a simple design and can be easily constructed. It minimizes the coarse sediment load in storm water. Disadvantages of this sediment settling basin are there is limitation for the removal of fine sediments or soluble pollutants, large area of construction, and high potential for breaking down the collected wastes in wet sump.

Besides that, circular settling tank is designed for sediments and oil retention. This settling tank can collect high proportion of sediments, oil and grease. It protects the retained materials from scouring. But it required a high initial cost to construct and the inlet downpipe might block by those gross pollutants. For hydrodynamic separator, it results in producing high sediment removal rate and incorporates the return flows to sewers to minimize the cleaning process.

Last but not least, floating traps are purposely designed for highly buoyant and visible pollutants such as floating debris and trash, plastic bottles, and small timber. Examples of floating traps are flexible floating booms and floating debris booms.

The floating debris boom is installed across the middle of river or lake which can be used for long term and short term. It can be installed in calm, moving, and fast water location. Different types of water condition will have the different installation of floating boom. The floating debris boom can be model in many shapes and sizes, and it has different levels of effectiveness in different types of water condition. It also can generate by different materials such as steel, PVC (Polyvinyl chloride), and HDPE (High Density Polyethylene).

The installation of floating boom does not involve any construction. It can be manufactured off site and hauled into place by boats. As a result, the installation of this floating boom would not have any impact to the environment (U.S. Army Corps of Engineers, 2012).

The application of this floating boom is to act as a barrier for debris restriction or diversion. Normally, it is an ideal for trash, small timbers, aquatic plants, containers, and bottles. Once the debris is captured by the floating boom, the debris can then be collect where convenient for scheduled removal. It was an effective tool that can contribute in solving river pollution which is getting serious nowadays.

Maintenance of floating boom can be done by cleaning manually with vacuum truck or skimmer vessels (Allison, 1998). The cleaning process should be frequently clean every two to four weeks as recommended (Allison, 1998). After storm event, the floating boom must clean.

2.2 DIFFERENT TYPES OF BOOM

There are many types of boom can be produced for different requirements such as water condition, materials for manufacturing it, shapes, and sizes. Under this subtopic, I will discuss the types of boom that are using in some countries.

Firstly, for calm water condition, calm water and marina debris boom will be designed specifically for capture debris, garbage and even aquatic plants in limited water flow or calm area such as lakes, streams, and ponds. Normally, this boom will acts as a containment which collect the debris into the designated area. It was manufactured an impermeable PVC material, top flotation, bottom ballast chain and section connectors. This type of boom can use to limit the spread of debris and preventing seaweed from getting inside to the coastal areas.

Secondly, for moving water condition, moving water floating debris boom will be use. It was suitable for ports and rivers. Materials for making this boom is same with calm water and marina debris boom, but an additional tension cable will be added to stabilize the boom in moving water places. Hence, the boom can remain stable during strong wave and tidal influences. Application for this type of boom is acts as debris containment boom and plant control boom.

Thirdly, for faster moving water condition, fast water floating debris boom is purposely designed for high flow areas like offshore and coastline. It acts as a high strength barrier and produced from heavy duty tension cable which can support during tidal, waves, and strong moving water currents.

Trash net boom is one of the economic booms among other types of floating boom. It was installed for swim areas, debris locations, and protect intake from aquatic plants. This boom is constructed from a standard PVC material and built with a top floatation and freeboard. It was efficient for swimming area protection, intake protection, and aquatic plant control.

For controlling the spread of pollution, it was recommended that floating boom for debris control should install above and below the water. This type of floating debris boom is created by aluminum, galvanized steel or stainless steel panels. So that it is strong enough to adjust branches, leaves, and plastic containers from passing through the boom. It is suitable to be use in docking areas, around commercial properties or residential areas.

Instead of the water condition, floating boom can also be designed for capturing different pollutants. The most common floating boom was debris and trash boom. Oil contaminant boom is specifically designed for oil control and spilled materials that float on the marine during cleanup process (Sharda, 2011). The oil contaminant boom would be install at the location that dealing with oil contaminant in calm water or moving water area such as ponds, lakes, rivers, and marinas. Supplemental tension cable was added to the boom to keep the contaminant contained in moving water areas.

Offshore and coastline oil boom is a specific designed for location with demanding water conditions (Sharda, 2011). It is made from high grade of PVC material, dual tension cables, heavy bottom ballast, and high strength connectors. The reason for choosing these materials is it used for sturdy spills control and reliable oil spill containment.

Last but not least, floating silt and turbidity boom will be function at the place where silt, turbidity or displaced sediment needs to be contained. Applications of these barriers are roadside ditches and canals, dock contaminants, open water locations, bays and harbors, bridge construction, demolition or dredging jobs.

2.3 DESIGN CONSIDERATIONS FOR FLOATING DEBRIS BOOM

There are some design considerations that we should take into account are water conditions, types of pollutant, site condition, types of boom to be construct, budget, staging areas, ease of use, collection zones, frequency of recovery, available resources, and manpower (Granite Environmental, 2010).

Water condition is important because for high tidal areas, boom to be installed must have strong connector and heavier weight to withstand the high tides. If not, the debris will easily pass through the boom. Before we installed the floating debris boom, we have to determine the types of pollutant that can be found in that water location. This is because some pollutants such as plastic that is lighter weight than the floating boom is hardly to be trap. Hence, a lighter weight of material should be used in order to make the floating debris boom.

For types of pollutant, we have to estimate regarding the type of debris you are containing, as well as the quantity. In addition, site conditions may also need to consider. Site conditions include winds, storm patterns or other factors that may influence the way water flows in the area for installation of floating debris boom. However, the budget has to take into consideration because some of the material that used to construct a floating boom will expensive.

2.4 BENEFITS AND LIMITATIONS OF FLOATING DEBRIS BOOM

Applications of floating debris boom have brought many advantages to the environment. It improves the aesthetic and recreational potential of downstream waterways. Since the flow rate of the water is different, the floating boom is flexible to rise up and fall with the changes in flow or tide. Hence, floating debris and trash can be trap easily in rivers, lakes, ponds or oceans. Moreover, it collects the debris into a single location rather than a large area place. This will be more convenient for the person involved to do the cleaning and remove the debris from the water surface. It can save in term of time and energy.

Floating debris boom is mobile and can be place at any targeted specific areas (Ravikanth et. al., 2011). Different types of boom will be made for different flow rate of water conditions and types of pollutant found in that area. Types of pollutants can be oil and greases, small timber, aquatic plants, trash and litters. In addition, it enhances the retention of collected pollutants because those pollutants will be trap when they flow to the floating boom.

Nonetheless, gross pollutants may be swept past the boom by tide movement, wind or high flows. Knowledge of wind directions and flow paths for a reach of waterway is recommended prior to installation. Plus, booms can only capture floating pollutant load and the maintenance is difficult. Most boom assemblies have to be cleaned by boat.

Booms might break away from the banks during high flows. Some of the boom cannot withstand the high tides because the connection between them was not strong enough. Spanning of the entire waterway width may be difficult because of size and waterway traffic. The appearance of the boom and trapped litter can be aesthetically displeasing. This is because the pollutants were trapped in the booms, if those pollutants have not clean, it can be visible to the public and affect the aesthetic view of rivers or oceans.

2.5 EFFECTIVENESS OF BOOM IN REAL LIFE

In contrast, a Melbourne, Australia study used tagged litter items, released upstream of litter booms to determine the floating boom performance. The results varied from 12% to 50% recapture. These values were considered as preliminary because low number of items released in the boom catchments. Moreover, the items released in the study were highly floatable and do not represent the complete range of items found in urban storm water (McKay, 1993).

The County of Los Angeles Department of Public Works pilot tested a debris boom system at the mouth of Los Angeles River in Long Beach. During the first two years of the pilot testing, the debris boom system has trapped approximately 150 tons urban trash and litters. Historical trash collection data indicates a large variation in the volume of trash harvested after each storm event. 90% of trash harvested is vegetation whereas the remaining 10% is mostly Styrofoam and plastics (County of Los Angeles, 2003).

A research has been done to compare the effectiveness of floating debris boom by using different materials such as wooden, PVC (Polyvinyl chloride), and Styrofoam. Based on the results, it showed that Styrofoam was the most effective materials for designing a floating debris boom due to its light weight. It can trap the debris well because most of the part was float on the surface of water. The research has found out that hole drilled through boom was the best type of connection because it allowed a free and easier movement for the boom to float (Ho, 2005).

Alameda County installed a litter boom on the Oakland Slough in 1999. The City of Oakland Public Works Department removes debris an average eighteen times per year. This frequency was higher in the early years of installation. The result showed that a floating boom can remove pollutants, debris, trash, and litter effectively (Jackson, 2011).

2.6 CONTRIBUTION OF RESEARCH

The research that will be study is different with other researcher because a new material is proposed which is bamboo. Bamboo will replace the wood which was used by a researcher before. The reason for choosing this material is because the weight of bamboo is lighter than wood. The weight of bamboo is 300 – 400 kg/m^3 whereas the weight of American red wood is 450 kg/m^3. Hence, bamboo will have better performance compare to wooden. Compare to wood, bamboo has no rays or knots, thus allowing it to withstand more stress throughout the length of each stalk. Bamboo's sectional anatomy, both as a cane and on a microscopic fiber level, enhances its structural integrity. The high silica content in bamboo fibers which make it cannot be digested by termites and have a long durable life. As a result, bamboo has higher tensile strength compare to wood.

CHAPTER 3

RESEARCH METHODOLOGY

3.0 INTRODUCTION

This chapter explains the entire methodology of the research. Elements that will be discussed are the research experiment, flow chart, and procedures for carrying out the experiment.

3.1 RESEARCH EXPERIMENT

This experiment is conducted to determine the best combination of material and connection for the floating debris boom. In this experiment, total six booms will be created to test the effectiveness by using Styrofoam, bamboo, and PVC. There are two types of connection, hinged or drilled hole that will be used to connect the piers and the booms. Three booms will be using hinged connection whereas the other three booms will be using drilled-hole. Each type of boom with hinged connection will be tested with five different flow rates, and the same goes for the booms with drilled hole. The purpose of testing with different flow rates is to observe that when the water condition is calm or fast, the effectiveness of the floating debris boom will give a different result. The floating debris boom might capture more floating debris in calm water condition compare to fast water condition. This could be due to when placing a floating boom in fast water conditions, the debris can easily pass over it because of the higher flow rates.

Besides that, the weight of the materials used to create the floating debris boom can affect the performance of the boom. When a lighter weight of material is chosen, most body part of the floating boom will be floating on the surface of water, hence the debris cannot easily pass through it. Most of the debris can then be captured within the floating boom.

The test will be composed of varying floating boom experiments in a 30cm rectangular open channel. Total 30 tests will be conducted to test the effectiveness of floating debris boom as shown in Figure 3.1.

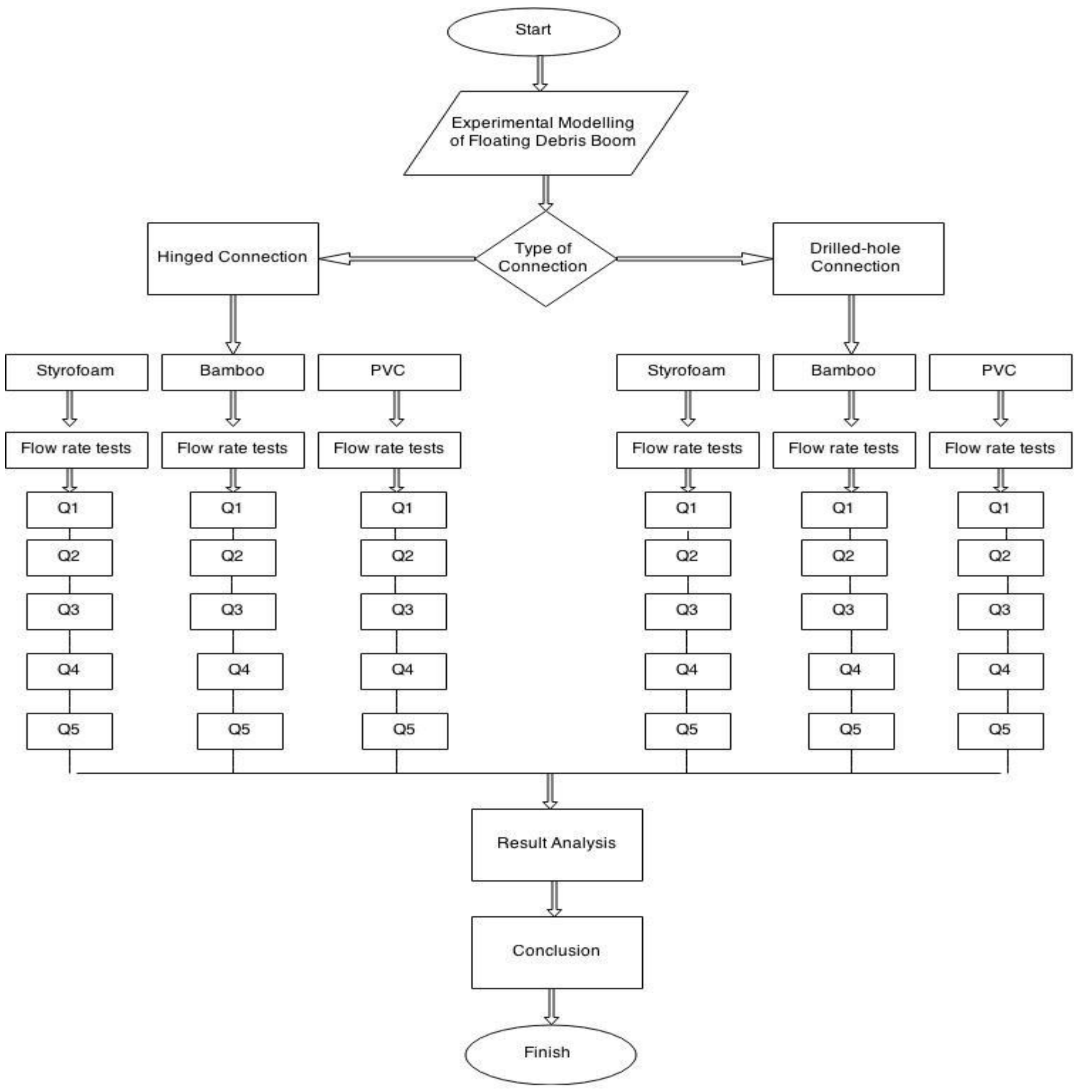


Figure 3.1: Flow chart of research experiment.

3.2 Apparatus and Materials

Apparatus of this experiment are rectangular open channel (30cm width) as shown in Figure 3.2, drill as shown in Figure 3.3, and steel base plate with screw as shown in Figure 3.4. Weighing machine is used to weigh the quantity of floating debris as shown in Figure 3.5.

For materials, 3 types of material such as Styrofoam with 1-inch thickness, 1-inch diameter of bamboo, and 1-inch diameter of PVC will be used to make the floating debris boom as shown in Figure 3.6, Figure 3.7, and Figure 3.8. Nylon rope is used as a connection to connect the section of floating debris boom. Debris such as 500ml crushed mineral water bottles, pieces of Styrofoam (2.5cm x 2.5cm x 2.5cm), and plastic bags is putting into the rectangular channel as floating debris.

APPARATUS

Figure 3.2: Rectangular open channel with 30cm width.

Figure 3.3: Drill is used to drill hole on the boom to make a connection.

Figure 3.4: Steel base plate with screw.

Figure 3.5: Weighing machine.

MATERIALS

Figure 3.6: Styrofoam board with 1-inch thickness.

Figure 3.7: Bamboo with 1-inch diameter.

Figure 3.8: 1-inch diameter PVC pipe will be used for making the boom.

Figure 3.9: 200g of floating debris.

3.3 PROCEDURE FOR EXPERIMENT

3.3.1 Hinged Connection

First, Styrofoam is cut into three sections with the length of 19.5cm, 19.5cm, and 18.5cm. The 3 sections will combined to make a floating debris boom. This step will be repeated by using bamboo and followed by PVC. For hinged connection, the boom is connected by nylon rope to tie the boom together as refer to Figure 3.9, Figure 3.11 and Figure 3.13. Steel base plate with screw is put into the rectangular open channel to hold and provide a small flexible movement for the floating boom to float on the surface of the water. 200g of floating debris is poured into the rectangular open channel to test the effectiveness of floating boom of capturing debris.

Five different water level, 20mm, 40mm, 60mm, 80mm, and 100mm are tested for each floating boom. Styrofoam floating boom with hinged connection is tested with five different flow rates. Each floating boom will be tested for 5 minutes, the performance of the boom is then observed and the weight of debris captured is weighed for comparing the result, then followed by bamboo and PVC floating boom with hinged connection as shown in Figure 3.10 and Figure 3.12. The floating debris should remove from the rectangular open channel after each boom was tested to prevent the excessive debris will affect the performance of next boom. The rectangular open channel was cleaned after all tests have been conducted.

Hinged Connection

PVC

Figure 3.10: Hinged connection was connected by nylon rope between each boom member.

Figure 3.11: Booms with hinged connection are placed in the rectangular open channel to test the effectiveness of the boom.

Styrofoam

Figure 3.12: Styrofoam boom with hinged connection.

Figure 3.13: Booms with hinged connection are placed in the rectangular open channel to test the effectiveness of the boom .

Bamboo

Figure 3.14: Bamboo boom with hinged connection.

3.3.2 Drilled-hole Connection

Styrofoam is cut into three sections with the length of 19.5cm, 19.5cm, and 18.5cm. The 3 sections will combined to make a floating debris boom. This step will be repeated by using bamboo and followed by PVC. For drilled-hole connection, the drill is used to make a hole on top of each section of the boom as refer to Figure 3.15. Steel base plate with screw is put into the rectangular open channel to hold and provide a small flexible movement for the floating boom to float on the surface of the water. The boom is then connected by placing the boom across the screw on the steel base plate as shown in Figure 3.14, Figure 3.16, and Figure 3.17. 200g of floating debris is poured into the rectangular open channel to test the effectiveness of floating boom of capturing debris.

Five different water level, 20mm, 40mm, 60mm, 80mm, and 100mm are tested for each floating boom. Styrofoam floating boom with drilled-hole connection is tested with five different flow rates. Each floating boom will be tested for 5 minutes, the performance of the boom is then observed and the weight of debris captured is weighed for comparing the result, then followed by bamboo and PVC floating boom with drilled-hole connection as shown in Figure 3.14, Figure 3.16, and Figure 3.17. The floating debris should remove from the rectangular open channel after each boom was tested to prevent the excessive debris will affect the performance of next boom. The rectangular open channel was cleaned after all tests have been conducted.

Drilled-hole Connection

PVC

Figure 3.15: Drilled-hole connection for PVC boom.

Styrofoam

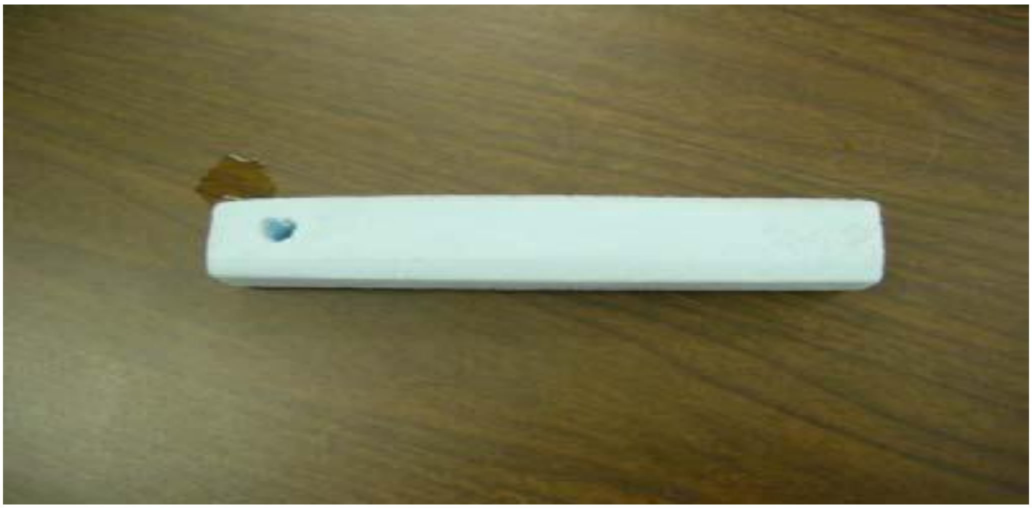


Figure 3.16: Drilled-hole through Styrofoam boom.

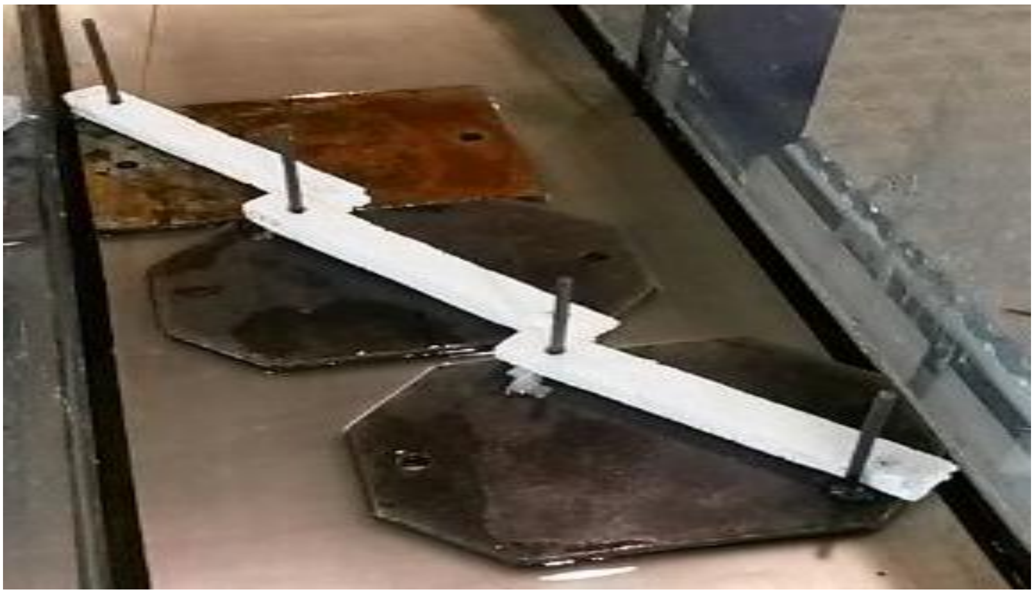


Figure 3.17: Drilled-hole connection for Styrofoam boom in rectangular open channel.

Bamboo

Figure 3.18: Drilled-hole connection for bamboo boom.

CHAPTER 4

DATA ANALYSIS AND DISCUSSIONS

4.0 INTRODUCTION

This chapter explains on the findings and results of the data collected through experimental by using the open channel in hydraulic laboratory. Eventually, the results of hypothesis testing are tabulated as a conclusion to this chapter. A summary of the entire analyses is presented.

4.1 RESULTS AND ANALYSIS

4.1.1 Hinged Connection

Table 4.1: Data for 3 different boom materials under hinged connection

Water Level (mm)	Flow Rate (l/s)	Weight of Rubbish (g)		
		Styrofoam	PVC	Bamboo
20	0.64	200.00	200.00	200.00
40	1.57	200.00	200.00	200.00
60	4.06	200.00	200.00	175.14
80	6.54	190.08	180.22	70.81
100	10.21	170.75	160.58	30.33

4.1.1.1 Bamboo Boom

Figure 4.1: Floating debris captured by bamboo boom when testing with water level 20mm, all the debris was blocked by the boom.

Figure 4.2: Floating debris captured by bamboo boom when testing with water level 60mm, debris started to pass through the boom.

Figure 4.3: Floating debris captured by bamboo boom when testing with water level 100mm, most of the debris passed through the boom.

4.1.1.2 PVC Boom

Figure 4.4: Floating debris captured by PVC boom when testing with water level 20mm, all the debris was blocked by the boom.

Figure 4.5: Floating debris captured by PVC boom when testing with water level 60mm,the boom was still able to block the debris, some of the debris started to pass through it.

Figure 4.6: Floating debris captured by PVC boom when testing with water level 100mm, half of the debris was blocked by the boom, half has been pass through it.

4.1.1.3 Styrofoam Boom

Figure 4.7: Floating debris captured by Styrofoam boom when testing with water level 20mm, all the debris was blocked by the boom.

Figure 4.8: Floating debris captured by Styrofoam boom when testing with water level 60mm, all the debris was still able to block by the boom.

Figure 4.9: Floating debris captured by Styrofoam boom when testing with water level 100mm, ¼ of debris has passed through the boom.

4.1.2 Drilled-hole Connection

Table 4.2: Data for 3 different boom materials under drilled-hole connection

Water Level (mm)	Flow Rate (l/s)	Weight of Rubbish (g)		
		Styrofoam	PVC	Bamboo
20	0.64	200.00	200.00	200.00
40	1.57	200.00	200.00	200.00
60	4.06	186.45	171.05	176.10
80	6.54	110.36	100.68	80.64
100	10.21	15.76	45.20	19.18

4.1.2.1 Bamboo Boom

Figure 4.10: Floating debris captured by bamboo boom when testing with water level 20mm, all the debris was blocked by the boom.

Figure 4.11: Floating debris captured by bamboo boom when testing with water level 60mm, half of the debris was blocked by the boom.

Figure 4.12: Floating debris captured by bamboo boom when testing with water level 100mm, few debris was blocked by the boom.

4.1.2.2 PVC Boom

Figure 4.13: Floating debris captured by PVC boom when testing with water level 20mm, all the debris was blocked by the boom.

Figure 4.14: Floating debris captured by PVC boom when testing with water level 60mm, some debris started to pass through the boom.

Figure 4.15: Floating debris captured by PVC boom when testing with water level 100mm, some debris stucked at the boom.

4.1.2.3 Styrofoam Boom

Figure 4.16: Floating debris captured by Styrofoam boom when testing with water level 20mm, all the debris was blocked by the boom.

Figure 4.17: Floating debris captured by Styrofoam boom when testing with water level 20mm, all the debris was blocked by the boom.

Figure 4.18: Floating debris captured by Styrofoam boom when testing with water level 20mm, all the debris was blocked by the boom.

4.2 DISCUSSION

Floating debris boom was used to block and capture floating debris that causes river pollution. There are two types of connection, which are hinged connection and drilled-hole connection. Three types of materials are used such as Styrofoam, bamboo, and PVC. Further discussion is conducted in this section to study on the relationship between the type of connection and type of material used in various flow rates.

4.2.1 Performance of Six Floating Debris Boom in a Graph

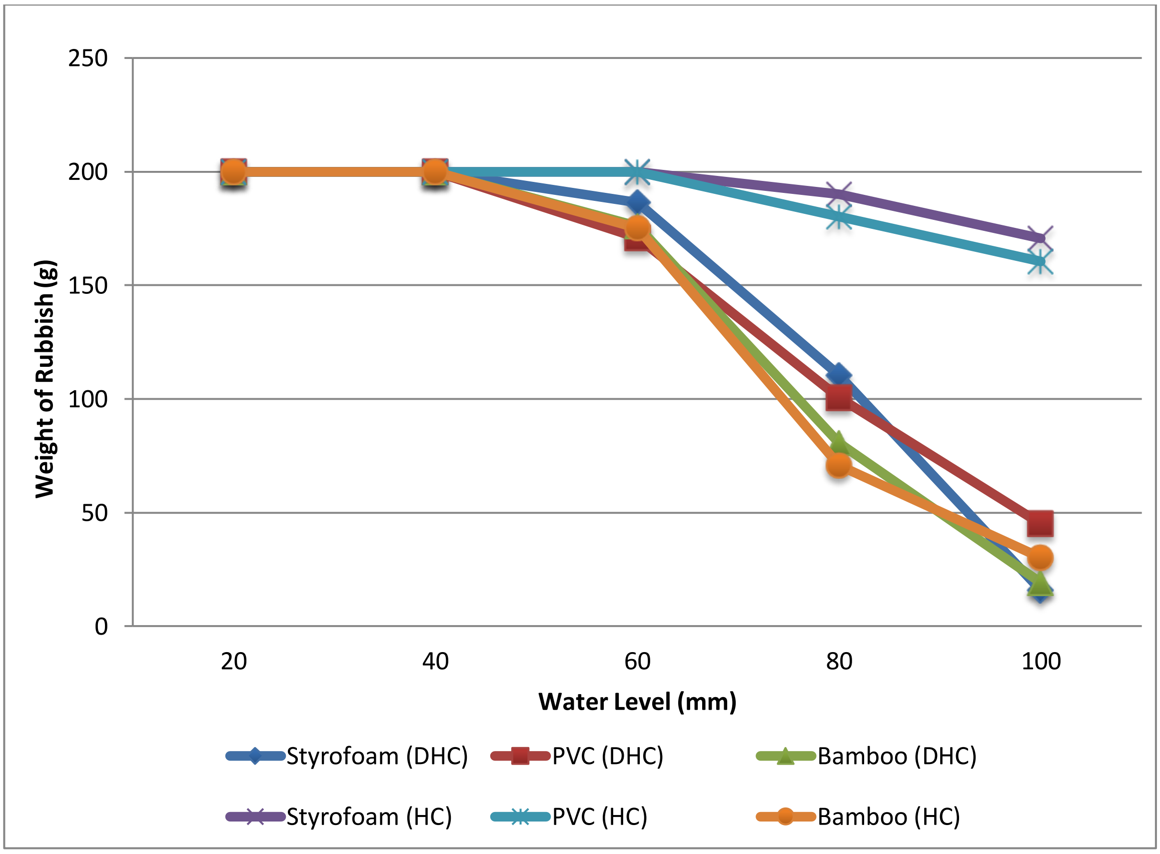
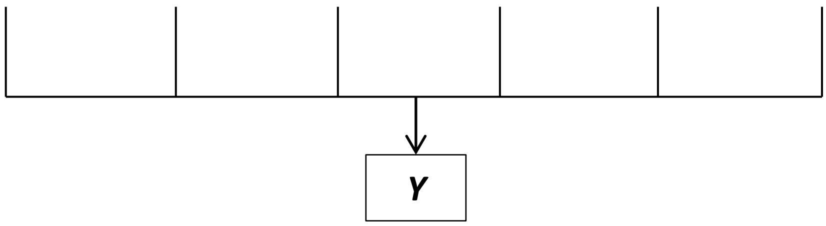


Figure 4.19: Graph of performance for each boom

4.2.2 Rubbish Reduction for Floating Debris Boom

Table 4.3: Data collected for all floating debris boom

Water Level (mm)	Flow Rate (l/s)	Weight of Rubbish (g) Drilled-hole Connection			Weight of Rubbish (g) Hinged Connection		
		Styrofoam	PVC	Bamboo	Styrofoam	PVC	Bamboo
20	0.64	200	200	200	200	200	200
40	1.57	200	200	200	200	200	200
60	4.06	186.45	171.05	176.1	200	200	175.14
80	6.54	110.36	100.68	80.64	190.08	180.22	70.81
100	10.21	15.76	45.2	19.18	170.75	160.58	30.33



$$Rubbish\ Reduction$$

$$= \frac{initial\ \ weight\ of\ rubbish\ (g) - remaining\ weight\ of\ rubbish(g)}{initial\ weight\ of\ rubbish\ (g)} X\ 100\%$$

$$= \frac{200 - Y}{200}\ x\ 100\%$$

= Z%

Drilled-hole Connection

Table 4.4: Data calculated for rubbish reduction

Water Level (mm)	Flow Rates (l/s)	Rubbish Reduction (%)		
		Styrofoam	PVC	Bamboo
20	0.64	0.00	0.00	0.00
40	1.57	0.00	0.00	0.00
60	4.06	6.78	14.48	11.95
80	6.54	44.82	49.66	59.68
100	10.21	92.12	77.40	90.41

For Styrofoam,

Rubbish reduction = $\frac{200-186.45}{200}\ x\ 100\% = 6.78\%$

Rubbish reduction = $\frac{200-110.36}{200}\ x\ 100\% = 44.82\%$

For PVC,

Rubbish reduction = $\frac{200-171.05}{200}\ x\ 100\% = 14.48\%$

For bamboo,

Rubbish reduction = $\frac{200-176.10}{200}\ x\ 100\% = 11.95\%$

Hinged Connection

Table 4.5: Data calculated for rubbish reduction

Water Level (mm)	Flow Rates (l/s)	Rubbish Reduction (%)		
		Styrofoam	PVC	Bamboo
20	0.64	0.00	0.00	0.00
40	1.57	0.00	0.00	0.00
60	4.06	0.00	0.00	12.43
80	6.54	4.96	9.89	64.60
100	10.21	14.63	19.71	84.84

For Styrofoam,

Rubbish reduction = $\frac{200-190.08}{200}\ x\ 100\% = 4.96\%$

Rubbish reduction = $\frac{200-170.75}{200}\ x\ 100\% = 14.63\%$

For PVC,

Rubbish reduction = $\frac{200-180.22}{200}\ x\ 100\% = 9.89\%$

For bamboo,

Rubbish reduction = $\frac{200-175.14}{200}\ x\ 100\% = 12.43\%$

According to Figure 4.19, hinged connection was showing the better performance than drilled-hole connection due to the stronger bonding in hinged connection that able to hold the booms together without breakage. Initially the performance of each boom was good, but when they were tested with higher flow rates, the booms seem to be difficult to resist to it. The data shown indicated that floating debris boom which is made from Styrofoam with hinged connection has the good level of effectiveness to capture most of the floating debris. Based on Table 4.5, rubbish reduction for Styrofoam boom is the lowest compare to PVC boom and bamboo which means that it captured the heaviest weight of floating debris among the three materials. This is because the weight of Styrofoam is the lightest among the three materials. As a result, floating debris is easily trapped by the booms because the majority of the booms are above water surface. Furthermore, hinge on booms allow for free movement and often prevent easy movement. However, the result for Styrofoam boom with drilled-hole connection is different with hinged connection. There is a breakage between the booms when it was tested with higher flow rates. Hence, hinged connection has more capable of withstanding the higher flow rate.

For PVC boom under hinged connection and drilled-hole connection, both results showed that PVC boom has a good performance than bamboo boom. The result of PVC is slightly different with Styrofoam boom because its weight is heavier than Styrofoam. Besides that, the PVC has hole that will let the water getting inside when tested with high flow rate. Therefore, half of the PVC boom was sank into the water and then affecting the performance of the boom. For bamboo boom, it was the heaviest among the three materials. Bamboo boom was still able to resist for lower water level since there is not much movement of the water and the flow rate was low also. In spite of that, when it tested with higher water level and flow rate, ¾ of it body was sank in the water. At last, the debris can be easily passed through the boom.

4.3 SUMMARY

According to the data collected, for hinged connection, it showed that three materials have good performance when testing with a lower water level which is 20mm and 40 mm. When the water level increased to 60mm, floating debris was starting to pass through the bamboo while the PVC boom and Styrofoam boom were still able to capture the floating debris. When the water level increased up to 80mm and above, floating debris starting to pass through the PVC boom and Styrofoam boom. In this connection, Styrofoam has the best performance compare to PVC and bamboo. In the result, the weight of debris captured by Styrofoam is the heaviest among three materials. Hence, the Styrofoam has the potential to be chosen as a material for floating debris boom.

Nevertheless, there is a different result for drilled-hole connection. As referring to Table 4.2, PVC has the best performance compare to Styrofoam and bamboo. The reason for that result was due to the floating debris boom which is made of Styrofoam has broken into two parts when testing with water level which is 100mm. The Styrofoam boom under drilled-hole connection might not be strong enough to resist the higher flow rate and water level. For the bamboo boom, it has less effectiveness compare to PVC boom and Styrofoam boom because most of it body part was submerged into the water which the floating debris able to pass through it easily.

By comparing both connection, we can observed that floating debris booms under hinged connection were able to block and capture the debris when the water level increased until 60mm. However, floating debris booms which is under drilled-hole connection were able to resist the water level until 40mm, when water level is increased more than 40mm and above, floating debris was started to pass through the boom.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.0 INTRODUCTION

This chapter elaborates the results of hypothesis testing that mentioned in the previous chapter and also the theoretical and practical significance of this research. Limitations and recommendations for the research are discovered in this chapter as well. In the end, a conclusion is described.

5.1 CONCLUSION

The aim of this research is to determine the modeling of the floating debris boom which has a good connection with good level of effectiveness of material in various flow rates in a rectangular open channel. The problem statement, research objectives and research questions have been explained in Chapter 1, Chapter 2 focused on the overview of floating debris boom. The second chapter also explained how the floating debris boom helps in reducing debris in real life. Subsequently, the relationships between the independent variables and dependent variables were formed. This research answered for the following objectives:

(i) To figure out which type of connection is best for connecting between the booms and the piers

Two types of connection which are hinged and drilled-hole were testing for the strongest connection of connecting the booms and the piers. Both connections showed a good performance at lower flow rates. However, when tested with higher flow rate, the result indicated that hinged connection was stronger than drilled-hole connection as it is more capable of withstanding the higher flow rate. The bonding between hinged connections was stronger than drilled-hole connections.

(ii) To determine the type of material to be used for the boom.

Based on the literature review, an experiment was done by a PHD candidate who was using wood, Styrofoam, and PVC as the material for making the floating debris boom (Ho, 2005). Hence, in my research, I have used another material which is bamboo to replace the wood. Bamboo and PVC showed good performance at lower flow rates but unable to resist at higher flow rate. According to the experiment, Styrofoam was showing its best level of effectiveness for capturing the floating debris such as crushed plastic bottles, plastic bags, and pieces of Styrofoam.

(iii) To obtain the data of floating boom performance in rectangular open channel over various flow rates.

This objective aimed to obtain the data of boom performance in rectangular open channel. In order to test the hypothesis, five different flow rates were testing for each floating debris boom. The results of analysis have fulfilled the research objectives by showing that connection and types of material used has a significant influence on the performance of floating debris boom.

As a conclusion, the objectives of this research have been achieved. After the analysis of result, it can be concluded that floating debris boom that made from Styrofoam with hinged connection can be created with the good level of effectiveness which can resist itself for different flow rates. Performance for PVC boom and bamboo boom was good at initially but at last they were not able to resist the higher flow rate. This floating debris boom can be used for capturing the debris, making the cleaning process easier as the floatable debris has been trapped in the floating boom. The floating debris boom can be installed at any river that facing serious river pollution which bring negative effect to human health and environment.

5.2 RECOMMENDATIONS FOR FUTURE RESEARCH

Consequently, some recommendations need to be considered for this research. The surface of the materials has to be same for all booms. In this research, bamboo and PVC have the rough surface whereas for the Styrofoam, it has the flat surface. The flat surface of Styrofoam boom enables it to capture the floating debris more easily and it was not slippery compare to bamboo and PVC. The level of effectiveness of Styrofoam is the best among the three materials. Hence, same surface has to be chosen for further research on this.

In addition, there is a consideration has to be taken in this research if chosen a specific area to install the floating debris boom. This will be the wind velocity because different locations have the different wind velocity. Wind velocity will affect the performance of floating debris boom as the boom might not resist to high velocity. High wind velocity might sweep past the floating debris to pass through the boom. In the end, the function of floating debris boom might not perform well in the river to reduce the water pollution.

Last but not least, the durability of the materials has to be considered also if used for long term employment. This is because the surface of bamboo used in this experiment started to mold after contact with water for a long time. It showed that bamboo was not suitable for long term use. Some prevention might be taken for this problem which is putting an Aluminium coating on the surface of the bamboo boom. Aluminium was chosen as coating because it has low density and excellent corrosion resistance which enable it more durable.

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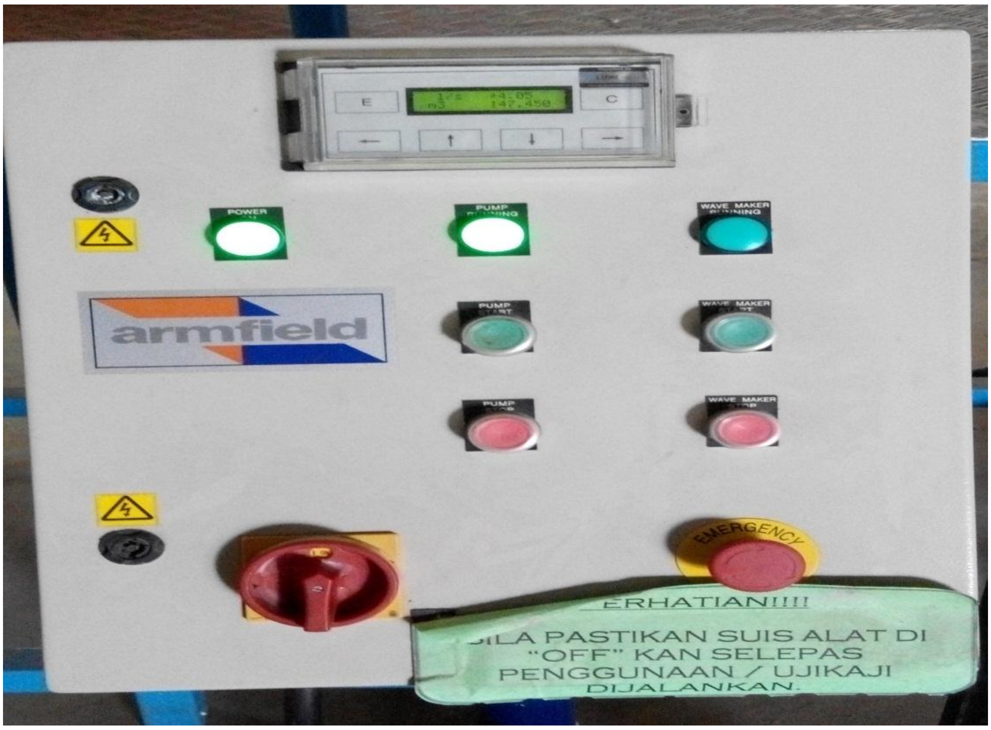
APPENDICES

Photos of Laboratory Preparation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