Faculty of Engineering

Float and Anchorage System for In-Stream Vertical Micro Hydro Turbine

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FLOAT AND ANCHORAGE SYSTEM FOR IN-STREAM VERTICAL MICRO HYDRO TURBINE

Bong Chien Chai

This thesis is submitted in fulfillment of the requirements for the Degree of Master of Engineering (Civil Engineering)

Faculty of Engineering

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For my beloved family and friends

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Pengapung dan Anchorage Sistem untuk Micro Hidro Turbin yang Menegak

ABSTRAK

Pengapung boleh direka dalam pelbagai saiz dan bentuk. Ia boleh dibuat oleh bahan-bahan seperti aluminium, kaca, kayu, konkrit, keluli atau lain-lain. Bahan yang paling sesuai untuk pengapung adalah gentian kaca. Pengapung gentian kaca adalah ringan, kuat, dan mudah untuk dibaiki. Terdapat beberapa kelemahan pada pegapung besar untuk Micro Hidro Turbin, seperti, pegapung besar lebih berat, sukar untuk mengangkut. Penyelesaian masalah ini adalah dibahagikan pengapung besar kepada beberapa pelampung kecil. Terdapat dua konsep Anchorage untuk Micro Hidro Turbin. Iaitu Conceptual Anchorage Sistem 1 (CAS1) dan Conceptual Anchorage Sistem 2 (CAS2). CAS1 boleh berfungsi dalam keadaan air surut dan air pasang, ia adalah sistem yang stabil. CAS2 menunjukkan prestasi yang baik dalam ujian, ia juga berfungsi dengan bagus pada masa air surut, air pasang dan juga mampu bertahan arus yang kuat.

ABSTRACT

Floats can be in many different sizes and styles, all of them are designed to remain suspended within or on the surface of water without sinking. It can be made by a lot of materials, such as aluminum, fiberglass, wood, concrete, steel or etc. The most suitable material of float for the Sustainable In-stream Vertical Micro Hydro Turbine is fiberglass. Fiberglass float is lightweight, strong, and easily to be repaired. There are a few disadvantages of the large float for the Sustainable In-stream Vertical Micro Hydro Turbine, such as weight of the float is consider as heavy, difficult to transport and extra care required during handling. The solution to handle the huge dimension problem is divided the large float into a number of small floats. There are two conceptual anchorage and mooring system for the Sustainable In-stream Vertical Micro Hydro Turbine. There are Conceptual Anchorage System 1 (CAS1) and Conceptual Anchorage System 2 (CAS2). The CAS1 could provide a strong anchoring for the Sustainable In-stream Vertical Micro Hydro Turbine, it can accommodate the rise and fall of tide and it is a stable system. The CAS2 shows good performance during the test, it can hold the floating turbine in a stable manner, it is also able to accommodate the rise and fall of tide and also able to withstand strong current.

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LIST OF ABBREVIATIONS

CAS1	Conceptual Anchorage System 1
CAS2	Conceptual Anchorage System 2
CQR	Clyde Quick Release
DPS	Dynamic Positioning System
FB	Buoyant Force
IVMHT	In-stream Vertical Micro Hydro Turbine
MBM	Multi-buoy moorings
SPH2O	Specific gravity of water
SPM	Single point mooring

CHAPTER 1

INTRODUCTION

1.0 Introduction

Sarawak is the state of Malaysia that full of hydroelectric resources. In Sarawak, there are a lot of mountains, rivers, and rainfall to give large opportunities for hydroelectricity development. Hydro represents non-consumptive, non-radioactive, and non-polluting use of water resources towards energy development with most mature technology characterized by highest prime moving efficiency and excellent operational flexibility [1]. It contributes to a significant percentage of world electric supply today. The scale of hydro power can be classified according to table 1.1. Different types of hydro will accommodate for different types of applications or end users. The micro hydro power may provide electricity to a village or small number populations.

Table 1.1: Classification of Hydro Power

Output (Kw)	Classification
Up to 300	Micro Hydro Power
101 to 2000	Mini Hydro Power
2001 to 25000	Small Hydro Power

The definition of micro hydropower varies in different countries and can even include system with a capacity of a few kilowatts [2-6]. One of the many definitions for micro hydropower is hydro systems up till a rated capacity of approximately 300kW capacity [7]. The limit is set to 300kW because this is about the maximum size for most stand-alone hydro systems not connected to grid.

Commonly there are two type of turbine for micro hydro, vertical axis turbine and horizontal axis turbine [8]. For this research will more focus on the float and the anchorage system of the vertical turbine micro hydro. In this chapter will cover the statement of problems for this project. Besides, the clear objectives of this project will be stated in order to overcome the problems. The benefits and expected outcomes at the end of anchorage and float system of micro turbine will be briefly explained. In addition, the expected outcomes are discussed based on the objectives. The brief explanation of the content for each chapter for the anchorage for micro hydro will be covered in the project report outline.

1.1 In-stream Vertical Micro Hydro Turbine (IVMHT)

The micro hydro project is part of Unimas' community based project in collaboration with the Ministry of Rural and Regional Development where Unimas will become the first university to develop a sustainable in-stream vertical micro hydro turbine generator prototype that would provide electricity in rural areas in the Sarawak. The turbine will rotate to generate electricity by a motor system as shown in Figure 1.1.

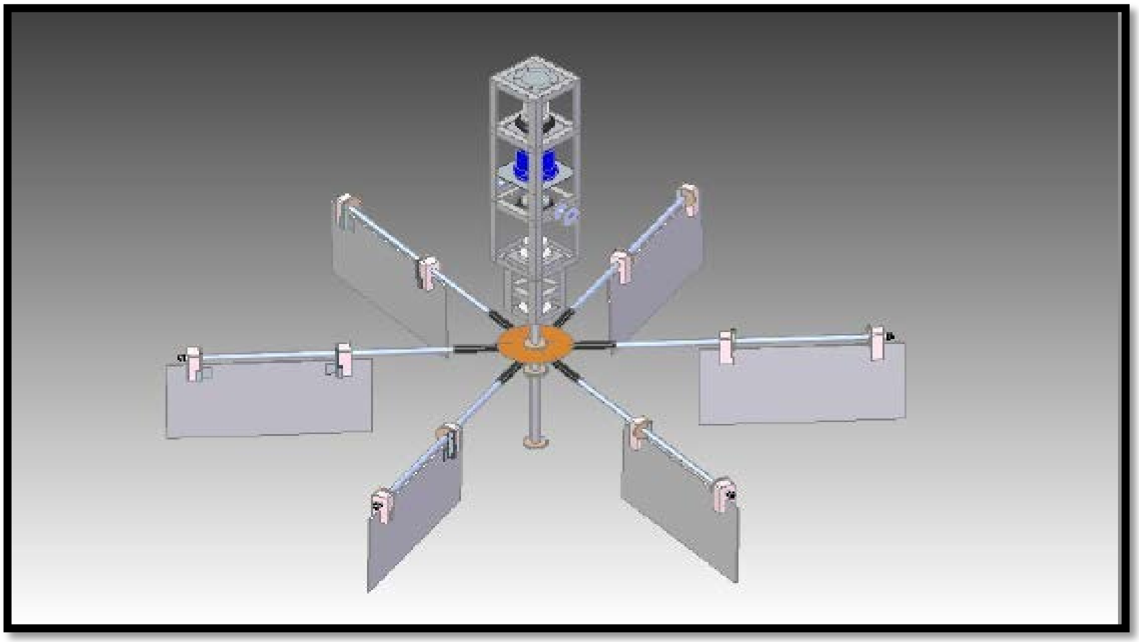

Figure 1.1: In-stream Vertical Micro Hydro Turbine (IVMHT)

The turbine has to cater at the speed of river between 1.3m/s to 2.72m/s, which had been measured by the technician of Civil Engineering, Faculty Engineering, Universiti Malaysia Sarawak (APPENDIX A). The floating and anchorage design has to suit for the current speed and fluctuation of water level of the river.

1.2 Statement of Problems

There are two types of Micro Hydro, which is supported by fixed structure or anchorage and float system to support the instream micro hydro system. For instream micro hydro system, the adequacy of the anchorage and float system design is important because it will affect the stability and functional of the micro hydro turbine to produce electricity. Besides, the huge dimension of float is considered heavy, difficult to transport and extra care required during handling.

1.3 Objectives

The purpose of this project is to design a suitable turbine floating system and anchorage for In-stream Vertical Micro Hydro Turbine. There are three objectives must be achieved:

- To investigate the suitable material for float.
- To design the floating system for the Sustainable In-stream Vertical Micro Hydro Turbine.
- To design the anchorage to sustain for different water levels.

1.4 Expected Outcome

The floating system and anchorage are very important part for the overall project because it will affect the functional of the micro hydro turbine to produce electricity and achieved the goal of the project.

There are several outcomes expected from this research:

- Identification of suitable design options of float and anchorage system for In-stream Vertical Micro Hydro Turbine.
- Proposal of a float system that can support the In-stream Vertical Micro Hydro Turbine.

1.5 Outline

Chapter 1 provides a brief introduction and overview of float and anchorage system for in-stream vertical micro hydro turbine, this chapter also covers the statement of problems which describes the real time problems faced, objectives, and expected outcomes from this study.

Chapter 2 reviews some literature, which discusses the shape, material, and characteristic of floats and anchorage system. This chapter also present the summary and results of the recent studies relating to the float and anchorage system for micro hydro turbine.

Chapter 3 explains the design methodology used to construct a float and anchorage system. Some of the material chosen for float and anchorage will be discussed in this section.

Chapter 4 presents results and discussions of the basic configuration and operation of the conceptual float and anchorage system for IVMHT.

Chapter 5 the concluding remarks and suggestions of further research are presented in this section.

1.6 Research Methodology

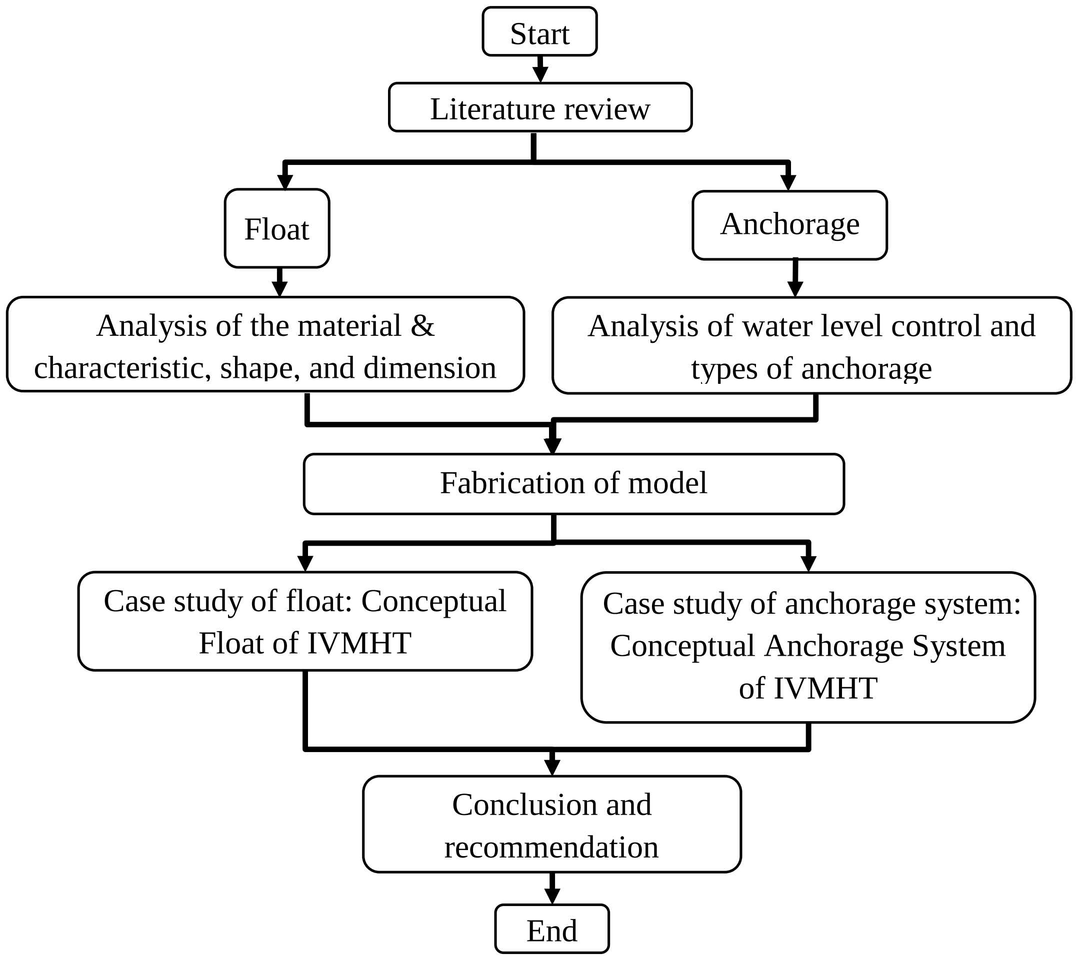

Figure 1.2: Flow Chart of Research Methodology

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

To achieve the objectives as described in chapter 1, this section will discuss on the research that previously done on float material, characteristic, shapes, types of anchorage. The float is used to support a vertical turbine on water. It may be simply constructed from sealed cylinders such as pipes or barrels and even fabricated boxes from metal. These may be used to support a simple platform, creating a raft. The basic design is usually implemented as a simple catamaran (Figure 2.1) or, with three rows of floats. A fixed platform can be used as a dock. An anchor is a device that made by metal, which is used to connect a raft to the bed of a body of water to prevent the raft from drifting due to wind or current [9]. Anchors can either be temporary or permanent [10]. A permanent anchor is used in the creation of a mooring, and is seldom moved; a specialist service is normally needed to move or maintain it. Raft carries one or more temporary anchors which may be of different designs and weights [11-12].

Figure 2.1: Catamaran Float [13]

2.1 Float Materials & Characteristics

Floats can be in many different sizes and styles, all of them are designed to remain suspended within or on the surface of water without sinking. A floating structure that serves as a dock or to support a bridge is normally termed as pontoon. Pontoon can be from 1 to 9 meter long with flat bottom base [14]. With the rough current river nature along with its debris, the right material for pontoon must be durable, light and flexible, which is one of the major reasons for popularity of aluminum and fiberglass.

2.1.1 Aluminum Float

Aluminum pontoons are robust. Aluminum is light [15], strong, corrosion-resistant, non-sparking and easy to be cleaned [16]. Aluminum's standard hardness is 420 MPa [17]. However aluminum is not abrasion-resistant [18]; it can be cut with carbide tools. Aluminum is subjected to electrolysis, pitting and crevice corrosion, but these liabilities can be managed as long as the installation of different metals and electrical items are correctly done [19].

For example, very beamy pontoon will exhibit a gentler roll if built in steel. Fairly narrow or light-displacement pontoon, which tends to have a narrower water plane and less inherent form stability, will benefit most from aluminum construction. An aluminum bare pontoon, built to the same strength standard, will weight roughly 45% less than the same pontoon in steel [20]. As a result, if high strength is of the highest priority, the aluminum float can be built to the same structural weight as the steel float, and then be considerably stronger [21].

The Physical properties of Aluminum are the features that can be observed without changing the substance into another substance. Physical properties are such as color, luster, freezing point, boiling point, melting point, density, hardness and odor. The Chemical properties are the characteristics that determine how it will counter with other substances or change from one substance to another. Chemical properties are only observable during a chemical reaction. Reactions to substances may be brought about by burning, rusting, heating, explosion, ruining [22].

Aluminum generates a protective oxide coating and is particularly corrosion resistant [23]. Different kinds of surface treatment such as anodising, painting, or lacquering can further improve this property. It is useful for applications where protection and conservation are required. It owes its stability to the continuous film of aluminium oxide that rapidly grows on a nascent aluminium surface that is exposed to oxygen, water, or other oxidants. The molecular volume of the oxide is about 1.3 times greater than that of the aluminum consumed in the oxidation reaction [24].

Aluminium foil, even when it is rolled to only 0.007 mm thickness [25], is still absolutely impermeable and let's neither light aroma nor taste substances out. Moreover, the metal itself is non-toxic and reliefs no aroma or taste substances which make it ideal for packaging sensitive products such as food or treatments [26].

Aluminium is ductile and malleable [27]; it has a low melting point and density. Malleability is the property of a metal to be bent by compression without cracking or bursting, and ductility is the ability to deform plastically without fracture under tensile force [28-29]. In a molten condition it can be processed in a number of ways. Its ductility allows products of aluminium to be basically formed close to the end of the product's design.

2.1.2 Fibreglass Float

There are many advantages of using fibreglass [30] for pontoon building. The first advantage of fiberglass pontoon is low maintenances as compared to a wooden float. Secondly, the fiberglass float is sturdier than metal float; fiberglass is sturdier than aluminium and metal floats that are prone to dents which may destabilize the float by creating an imbalance in the centre of buoyancy. Thirdly, fiberglass float will have no shrinkage of planks, as fibreglass is a plastic material, which is highly resistant to moisture [31]. The fourthly, the fibreglass float will not corrode in water [32]; fiberglass is an inert material and is therefore not disposed to corrosion or electrolysis in water as in aluminium float. Lastly, by using material of fibreglass is simpler to construct the float [33], fiberglass float is easier to construct as compared to a wooden or even aluminium float.

The advantages of owning a fiberglass float far outweigh the disadvantages. Fiberglass is a material that is easy to repair and maintain in the long run as compared to other materials [34]. Even after repair, the fiberglass will be as good as new due to the unique nature of the polyester resin [35]. With great confidence, it is possible to make both structural as well as superficial repairs in a fiberglass boat.

Density fiberglass is measured and stated either as formed or as bulk annealed samples. ASTM C 693 is one of the test methods used for density determinations [36]. The fiberglass density is less than the bulk forged value by approximately 0.04g/cc at room temperature.

Tensile strength of fiberglass is usually defined as the pristine single-filament [37] or the multifilament element [38] measured in air at room temperatures. The respective strand strengths are normally 20 to 30% lower than the values reported in due to surface defects introduced during the strand-forming process [39]. Moisture has a detrimental effect on the pristine strength of fiberglass. This is best demonstrated by measuring the pristine single-filament strength at liquid nitrogen temperatures where the influence of moisture is minimized. The result is an increase of 50 to 100% in strength over a measurement at room temperature in 50% relative humidity air. The loss in strength of fiberglass exposed to moisture while under an external load is known as static fatigue [40]. The strength of fiberglass decreases as the fibers are exposed to increasing temperature [41].

The Young’s modulus of elasticity of annealed silicate fiberglass ranges from about 52 GPa to 87GPa. As the fiber is heated, the modulus gradually increases [42].

High strength fiberglass annealed properties measured at 20°C is Young’s Modulus 93.8 GPa, Shear Modulus 38.1 GPa, Poisson’s Ratio 0.23, Bulk Density 2.488 g/cc [43].

Fiberglass has the chemical resistance of corrosive and leaching actions of acids, bases, and water. The lower this value, the more resistant the glass is to the corrosive solution.

2.1.3 Wooden Float

The wooden floats are more solid. The wooden float is more stable and in the end safer. Wood can rot although in boat construction only those timbers with the highest levels of rot resistance are used. Timber expands and contracts as it absorbs moisture and dries out and therefore its movement is greater than that experienced with other construction materials [44]. Another great advantage of wooden floats, due to the fact that they attract water and release it is that they don't contain as much condensation and dampness as compared to other material.

Wood is a natural, heterogeneous, anisotropic, hygroscopic composite material with high strength and stiffness relative to its weight. Dissimilar with other common structural materials, it often exhibits a markedly viscous response to external influences under normal use conditions. Its thermal, mechanical, properties are appropriate to be used as a floating material [45]. Wood does not essentially expand against heat. By the effect of heat, it dehydrates and gains strength. When the humidity increases the moisture content will increases, the wood will expands [46]. The humidity level of wood does not drop under 5% even in the driest climate.

The coefficient of thermal conductivity of the wood is very low compared to Aluminum, steel, marble and glass [44]. For this reason, wood can be suitable for making matches, handles of hardware equipment and also floating system.

Specific heat of wood is high [47]. Wood requires about twice amount of heat energy than stones and concrete; correspondingly, three times of energy is needed for heating or cooling steel [46].

Despite of all advantages of wood to become floating material, it has a hygroscopic property. This means that it will adsorb surrounding condensable vapors and loses moisture to air below the fiber saturation point. To a first approximation the volumetric shrinkage is proportional to the number of water molecules that are adsorbed within the cell wall, and that in turn is related to the number of accessible hydroxyls on the cellulose, hemicelluloses and lignin, and to the amount of cell wall material, the basic density of wood [48].

All biotic agents include bacteria, fungi, insects, marine borers and vertebrates [49]. Insects drill holes and drive lines into wood. It's may cause the wood to decay partially and even completely. Generally wood will not be attacked by the common fungi at moisture contents below the fiber saturation point [50]. The fiber saturation point for different wood lies between 20 to 35% but 30% is accepted generally. It is recommended that wood in service must have moisture content at least 3% less than fiber saturation point to provide desirable safety against fungi.

Subterranean termites damage wood that is untreated, moist, in direct contact with standing water, soil, and other sources of moisture. Dry wood termites attack and inhabit wood that has been dried to moisture contents as low as 5 to 10%. The damage by dry wood termites is less than subterranean termites [46].

2.1.4 Concrete Float

Concrete is the most commonly used composite material in the construction industry [51]. It is durable, weather-resistant, environmentally neutral and economically affordable. Concrete pontoon is a floating concrete structure made from concrete materials. A floating concrete structure is a solid body made of reinforced concrete and an inner chain of chambers filled with a lightweight impermeable material, normally polystyrene [52].

The disadvantages of concrete pontoon are several; they are heavier, more costly to construct and as the walls are thicker their carrying capacity is much less. The advantages are that much less steel is required. They are heavy, robust and difficult to dispose [53].

The most possible deterioration mechanism in concrete marine or floating structures is chloride ingress, as was concluded from test results from several Dutch marine or floating structures [54]. Supposable deterioration mechanisms are carbonation, leaching, alkali-silica reactions, freeze thaw action, and erosion. These appeared virtually absent from the structures that have been researched. The most severe deterioration of concrete is expected around the water level and above it, in the splash zone, because the structure will be changing between wet and dries at periods. Carbonation is strongly reduced when concrete is wet for long periods of time; from the water line downwards. Differences in exposure will cause a large amount of scatter in the chloride profiles of different areas on one structure.

2.1.5 Steel Float

There are many advantages in using steel as a building material. Steel is a very structurally stable material. It is also eco-friendly and energy efficient. According to Hewlett, a freelance writer in Houston, construction steel is recyclable with the rates of over 90 percent. Unlike wood, there's no need to worry about the material rotting or damages caused by insects. It is very durable and can withstand most weather conditions. There's also no need for deforestation that are harmful to the environment. Steel structure compared to wood is stronger and sturdier. With the advancement of technology, steel can be form and bend to the user's need. Constructing steel is faster than most materials, thus making it more cost-effective [55].

Steel is one of the most sustainable construction materials. Its strength and durability coupled with its ability to be recycled, again and again, without ever losing quality make it truly compatible with long term sustainable development [56].

Since steel contain metal material, if not treated carefully it can be toxic to the environment as well. It may also have a tendency for corrosion and rust if not maintain correctly [57], thus it might not be as cost effective due to constant maintenance

2.2 Float Shapes

The shapes design of the floats has to suit the purpose of their usage. For practical purposes there are assumed to be three basic hull forms, graded according to the shape of their midsection, or largest transverse section: flat bottom (Figure 2.2), V-bottom (Figure 2.3), and round bottom (Figure 2.4) [58].

2.2.1 Flat-Bottom Model

The flat-bottom model is suited for protected waters, but is occasionally used along the coast when built to sufficient size. Large-powered flat bottom models are seen in harbours and river; formerly such boats were commonly fitted with sail [58].

A boat with flat-bottom surface is very stable in calm weather. However, the flat, broad bow area creates a rough ride [59]. These boats are usually limited to low horsepower motors because they are not able to handle well at high speed.

A float with a flat-bottomed float normally is used to support a structure such as a floating bridge on water and it acts as an elastic foundation. It may be simply constructed from closed cylinders such as barrels or fabricated as boxes from composite material or concrete [54].

Flat-bottom floats are easiest to build, take less time, require fewer tools, and cost less than other floats of similar size [60].

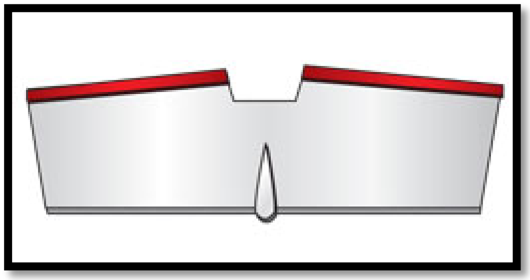

Figure 2.2: Flat Bottom Model [59]

2.2.2 V-Bottom Model

V-bottom model are designed to operate at high speeds [61] and to "cut" through rough water, which provides a smoother ride than flat-bottomed or round hull boats. V-hulls are not as efficient as flat or round bottomed boats, and need larger engines to move at similar speeds [62].

The V-shape also allows the hull to bank in a turn, not roll outward like a round or flat-bottomed hull [63]. And, at displacement speeds, the deep-V hull has more draft than the typical planing hull, so it behaves like a displacement hull.

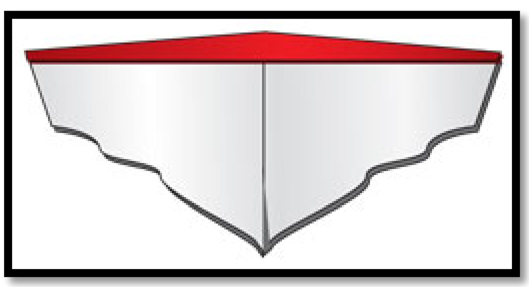

Figure 2.3: V-bottom Model [60]

2.2.3 Round Bottom Model

This shape of hull almost always refers to displacement hulls. The round at the bilge or near the waterline helps reduce wetted surface area and usually allows for good reserve stability. These move easily through the water, especially at slow speeds. However, tend to roll unless they are outfitted with a deep keel or stabilizers. [64].

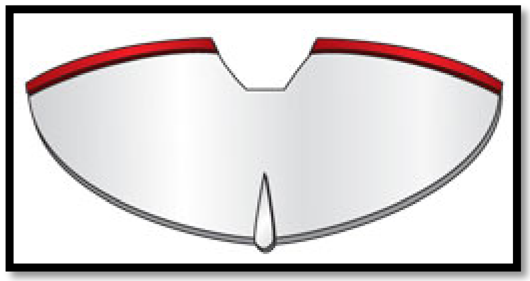

Figure 2.4: Round Bottom Model [60]

2.3 Mooring System

The mooring system must be designed to ensure the floating structure is kept in position so that the facilities installed on the floating structure can be reliably operated and to prevent the structure from drifting away and sway under critical river conditions and storms [65]. A freely drifting floating structure may lead to not only damage to the surrounding facilities but also to the loss of human life if it collides with ships or woods [66]. There are two major systems used for mooring: slack and pre-stressed [67]. Slack mooring (Figure 2.7) is used to moor ships, which drift around one anchorage point. Such mooring systems are well adapted for stiff constructions such as ships. Pre-stressed mooring systems (Figure 2.5-2.6) are well adapted for use in flexible constructions, and in correctly designed systems the forces will be equally spread over the entire legs. Pre-stressing of the mooring system is performed at high tide and forces can be up to several tens of kilo Newton. There are a few mooring systems such as the dolphin-guide frame system, mooring by cable / chain and anchor, tension leg method, pier/quay wall method and mooring by sliding piles.

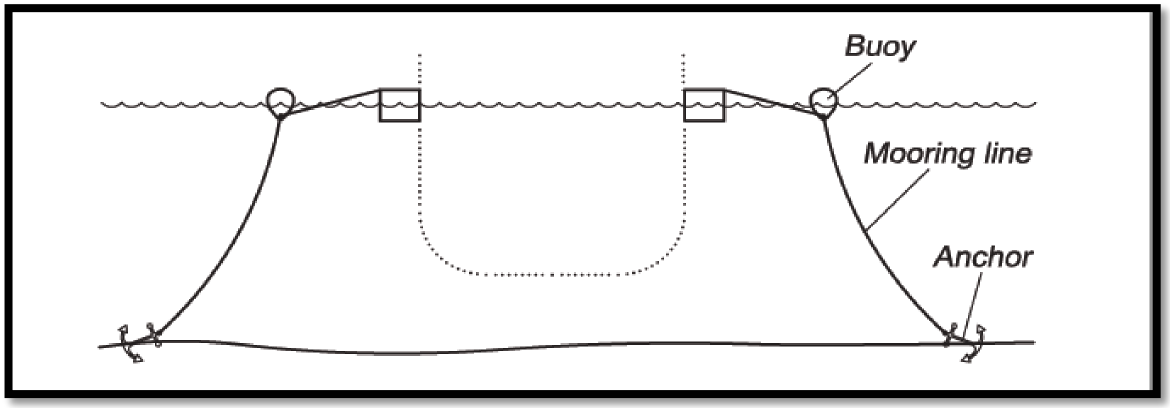

Figure 2.5: Pre-stressed Mooring Systems with Normal Condition and No Load [67]

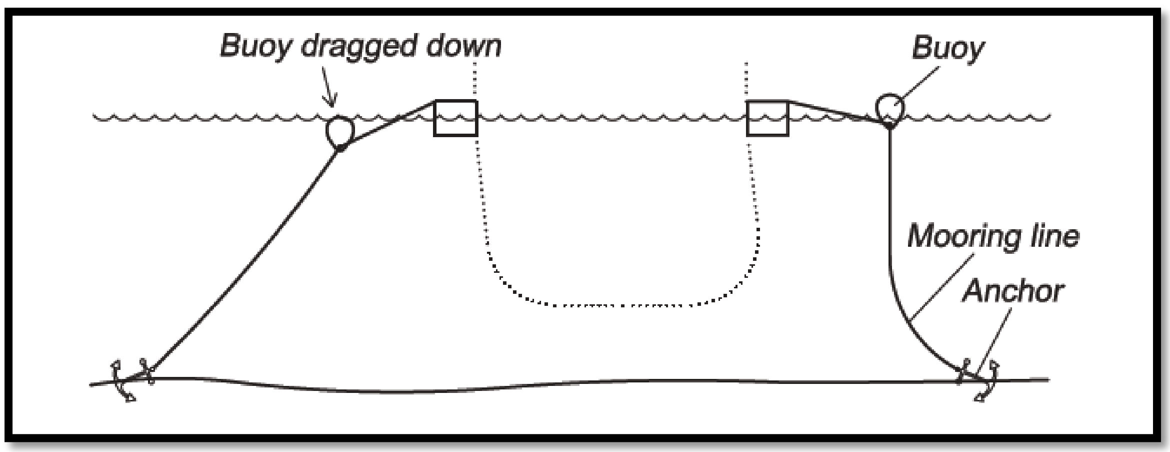

Figure 2.6: Pre-stressed Mooring System with Loaded Condition [67]

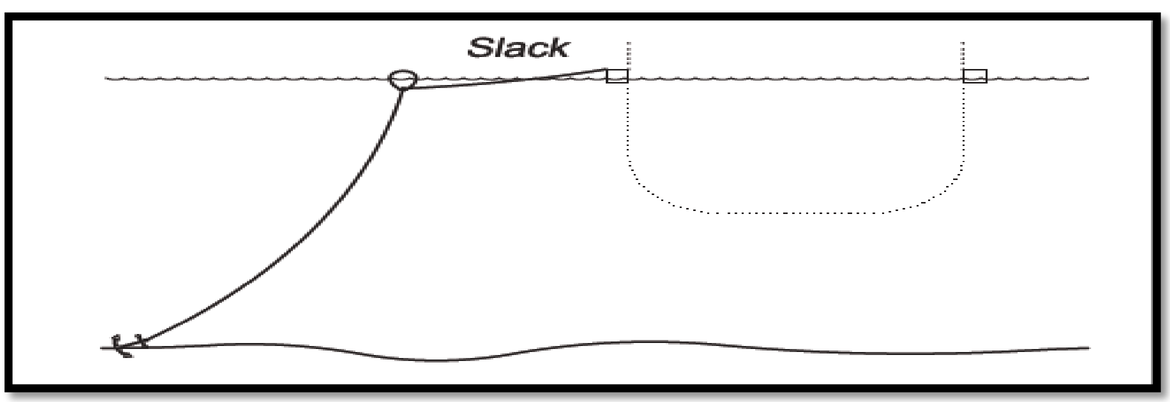

Figure 2.7: Slack Mooring System [67]

a) The Dolphin- Frame guide system

The Dolphin- Frame guide system (Figure 2.8) consists of a frame guide, which surrounds the very large floating structure and enough dolphins to absorb the design forces. The frame guide distributes the mooring forces to the installed dolphins which in turn passes the forces to the seabed. The layout of the mooring dolphins is such that the horizontal displacement of the floating structure is adequately controlled and the mooring forces are appropriately distributed [68].

The behavior of the floating structure under various loading conditions is examined. The layout and quantity of the devices are adjusted so that the displacement of floating structure and the mooring forces do not exceed the allowable values. Finally, devices such as dolphins and guide frames are designed by applying the design load based on the calculated mooring forces.

The Dolphin-frame guide method represents a truss construction fixed on a foundation in the seabed or riverbed. The rectangular shape of the cross section provides a sufficient stiffness against the lateral loads. This method is used when the floating structure requires minimum transverse movements at both sides.

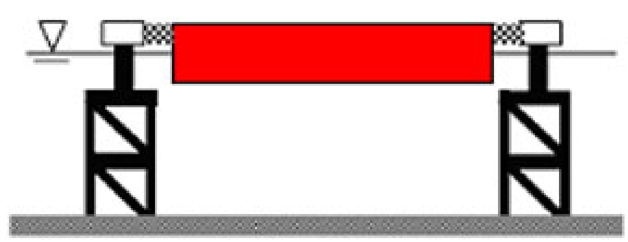

Figure 2.8: The Dolphin- Frame guide system [68]

b) Mooring by Cable / Chain and Anchor

The Chain/Cable method mooring system consists of two parts: the mooring lines and the anchors. The mooring line is a catenary [69]. The lines themselves could be made up of chains, wires, high technology fiber ropes or a combination. The mooring lines are terminated at the seabed or riverbed using anchors or piles; such a mooring system is often referred to as a single point mooring.

The Chain/Cable method mooring systems can generally be divided into the following systems:

- Single point mooring (SPM): Vessels are secured by a single line or structure [70]. The floating object is allowed to weather vane; that is, swing around in order to align itself with prevailing wind, wave, and current conditions. This alignment tends to reduce the load on the mooring system. However, the mooring forces enter the structure at one point, which will have to withstand a very large force. An SPM requires a lot of space and as such, is mostly preferred at an offshore location.
- Multi-buoy moorings (MBM) or Spread moorings: An MBM holds a vessel in a relatively fixed position and the vessel cannot turn head into the prevailing waves. As a result, an MBM can experience relatively high loads if wind, currents, or waves act at an angle to the mooring. The floating body cannot move and rotate freely, but the mooring forces are distributed better over the structure. Smaller forces are easier to introduce into a structure [70].

- Dynamic Positioning System (DPS): Dynamic Positioning System [71] could be employed, mainly to relieve the structure of some of the loads by turning it head into the waves. This system would only be effective when the structure can rotate freely, such as when located offshore. A fixed location near the shore would not permit such movements; therefore, a DPS will be useless. Mooring system components include anchors, sinkers, anchor chains, buoys, and mooring lines. The type of mooring to be used depends on the location, the water depth, the type of structure, current, wave loads, and other influencing factors.

2.4 Types of Anchorage

There are many types of anchor in the market, such as admiralty pattern anchor, navy pattern anchor, Clyde Quick Release Plough anchor, Bruce/claw anchor, Mushroom Anchor, and Fluke anchor. All of the types have their own characteristic and usage.

2.4.1 Admiralty Pattern

Admiralty Pattern (Figure 2.9) consists of a central shank with a ring or shackle for attaching the rode [72]. At one end of the shank there are two arms, carrying the flukes, while the stock is mounted to the other end, at ninety degrees to the arms. When the anchor lands on the bottom, it will generally fall over with the arms parallel to the riverbed. As a strain comes onto the rode, the stock will dig into the bottom, canting the anchor until one of the flukes catches and digs into the bottom.

Since one fluke always protrudes up from the set anchor, there is a great tendency of the rode to foul the anchor as the vessel swings due to wind or current shifts. When this happens, the anchor may be pulled out of the bottom, and in some cases may need to be hauled up to be re-set. In the mid-1800s, numerous modifications were attempted to alleviate these problems, as well as improve holding power, including one-armed mooring anchors [73].

Handling and stowage of these anchors requires special equipment and procedures. Once the anchor is hauled up to the hawse pipe, the ring end is hoisted up to the end of a timber projecting from the bow known as the cathead [73]. The crown of the anchor is then hauled up with a heavy tackle until one fluke can be hooked over the rail.

Figure 2.9: Admiralty Pattern Anchor [73]

2.4.2 Stockless Anchor

Stockless anchor (Figure 2.10) holding power to weight ratio is significantly lower than admiralty pattern anchors, their ease of handling and stowage aboard large ships led to almost universal adoption. In contrast to the elaborate stowage procedures for earlier anchors, stockless anchors are simply hauled up until they rest with the shank inside the hawse pipes, and the flukes against the hull [74].

While there are numerous variations, stockless anchors consist of a set of heavy flukes connected by a pivot or ball and socket joint to a shank. Cast into the crown of the anchor is a set of tripping palms, projections that drag on the bottom, forcing the main flukes to dig in.

Figure 2.10: Stockless Anchor [74]

2.4.3 CQR (Clyde Quick Release) Plough Anchor

CQR (Clyde Quick Release) Plough anchor was designed by mathematician Geoffrey Ingram Taylor at 1933 [75]. They are generally good in all bottoms, but not exceptional in any. The CQR design has a hinged shank, allowing the anchor to turn with direction changes rather than breaking out, while other plough types have a rigid shank. Plough anchors (Figure 2.11) are usually stowed in a roller at the bow.

Owing to the use of lead or other dedicated tip-weight, the plough is heavier than average for the amount of resistance developed, and may take a slightly longer pull to set thoroughly. It cannot be stored in a hawse pipe.

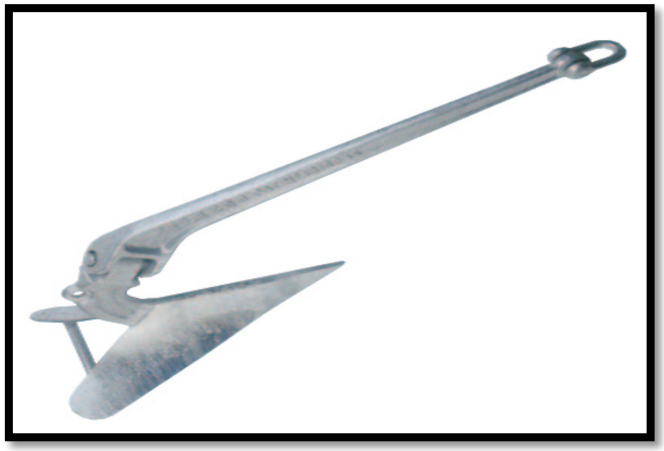

Figure 2.11: CQR (Clyde Quick Release) Plough Anchor [75]

2.4.4 Bruce/ Claw

The claw shaped anchor (Figure 2.12) was designed by Peter Bruce from the Isle of Man in the 1970s [76]. Bruce gained its early reputation from the production of large scale commercial anchors for ships and fixed installations such as oil rigs. It was intended to address some of the problems of the only general-purpose option then available, the plough. Claw-types set quickly in most seabed or riverbed and although not an articulated design, they have the reputation of not breaking out with tide or wind changes, instead slowly turning in the bottom to align with the force.

Claw types have difficulty penetrating weedy bottoms and grass. They offer a fairly low holding power to weight ratio and generally have to be over-sized to compete with other types. On the other hand they perform relatively well with low rode scopes and set fairly reliably. They cannot be used with hawse pipes.

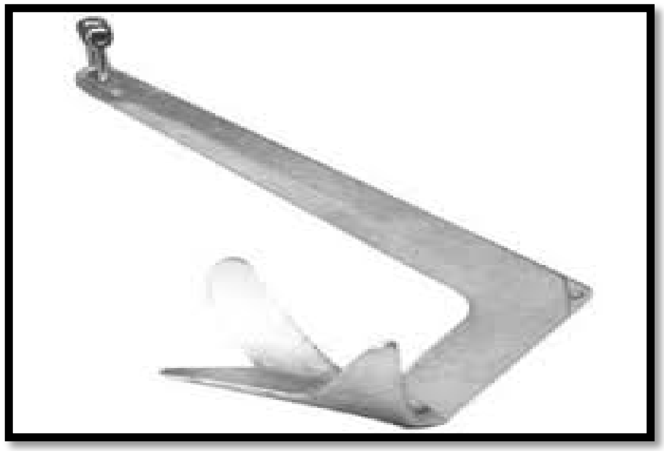

Figure 2.12: Claw Shaped Anchor [76]

2.4.5 Mushroom

The mushroom anchor (Figure 2.13) is suitable where the seabed or riverbed is composed of silt or fine sand. It was designed by Robert Louis Stevenson, for use by an 82 ton converted fishing boat, Pharos, which was used as a light vessel between 1807 and 1810 near to Bell Rock whilst the lighthouse was being constructed. It was equipped with a 1.5 ton example [74].

It is shaped like an inverted mushroom, the head becoming buried in the silt. A counterweight is often provided at the other end of the shank to lay it down before it becomes buried.

A mushroom anchor will normally sink in the silt to the point where it has displaced its own weight in bottom material, thus greatly increasing its holding power. These anchors are only suitable for a silt or mud bottom, since they rely upon suction and cohesion of the bottom material, which rocky or coarse sand bottoms lack. The holding power of this anchor is at best about twice its weight until it becomes buried, when it can be as much as ten times its weight.

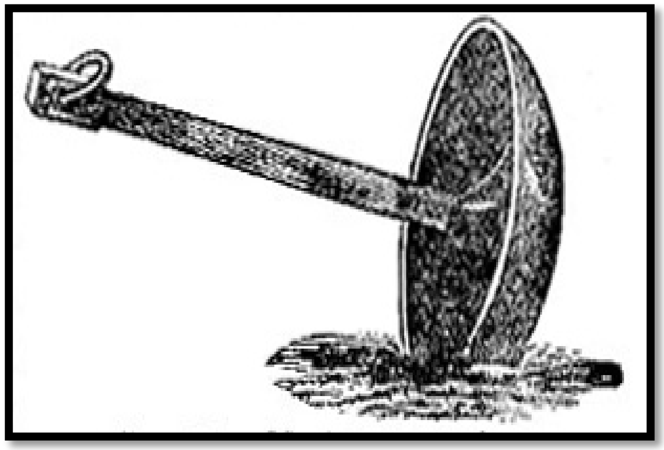

Figure 2.13: Mushroom Anchor [74]

2.4.6 Danforth / Fluke Anchor

American Richard Danforth (Figure 2.14) designed the Danforth pattern in the 1940s for use aboard landing craft. It uses a stock at the crown to which two large flat triangular flukes are attached [75]. The stock is hinged so the flukes can orient toward the bottom (and on some designs may be adjusted for an optimal angle depending on the bottom type). Tripping palms at the crown act to tip the flukes into the seabed or riverbed. The design is a burying variety, and once well set can develop high resistance. Its light weight and compact flat design make it easy to retrieve and relatively easy to store; some anchor rollers and hawsepipes can accommodate a fluke-style anchor.

The fluke anchor has difficulty penetrating kelp and weed-covered bottoms, as well as rocky and particularly hard sand or clay bottoms. If there is much current or the vessel is moving while dropping the anchor it may "kite" or "skate" over the bottom due to the large fluke area acting as a sail or wing. Once set, the anchor tends to break out and reset when the direction of force changes dramatically, such as with the changing tide, and on some occasions it might not reset but instead drag [75].

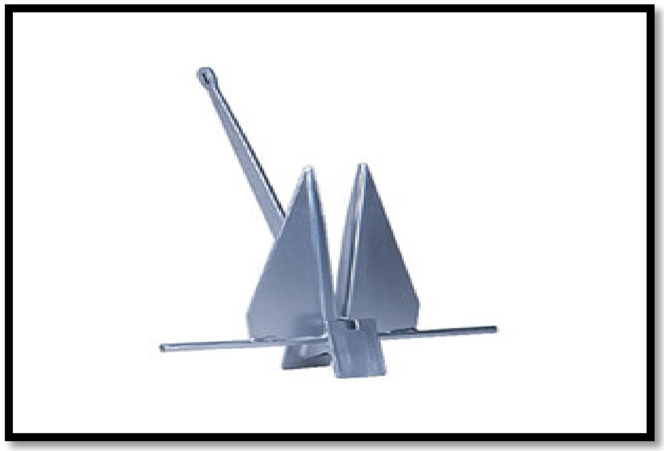

Figure 2.14: Danforth Anchor [75]

2.4.7 Concrete Block / Deadweight

This is an anchor which relies solely on being a heavy weight (Lawson, 1995). It is usually just a large block of concrete (Figure 2.15) or stone at the end of the chain. Its holding power is defined by its weight underwater regardless of the type of seabed or riverbed, although suction can increase this if it becomes buried. Consequently deadweight anchors are used where mushroom anchors are unsuitable, for example in rock, gravel or coarse sand. An advantage of a deadweight anchor over a mushroom is that if it does become dragged, then it continues to provide its original holding force. The disadvantage of using deadweight anchors in conditions where a mushroom anchor could be used is that it needs to be around ten times the weight of the equivalent mushroom anchor [76].

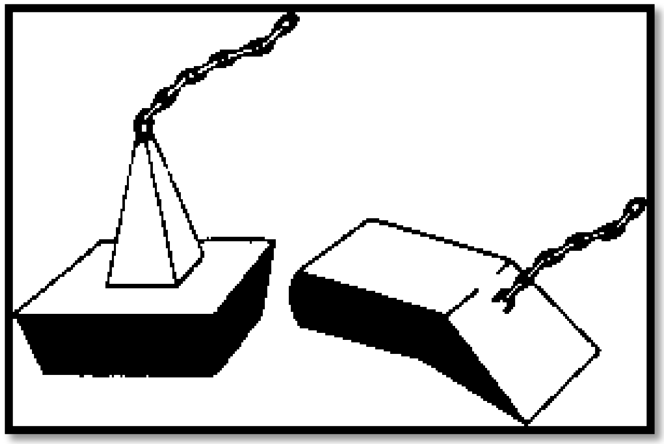

Figure 2.15: Deadweight Anchor [76]

2.4.8 Screw Anchor

Screw anchors (Figure 2.16) can be used to anchor permanent moorings, floating docks, fish farms, etc. These anchors must be screwed into the seabed or riverbed [77] with the use of a tool, so require access to the bottom, either at low tide or by use of a diver. Hence they can be difficult to install in deep water without special equipment. Screw anchors may not be ideal in extremely soft mud.

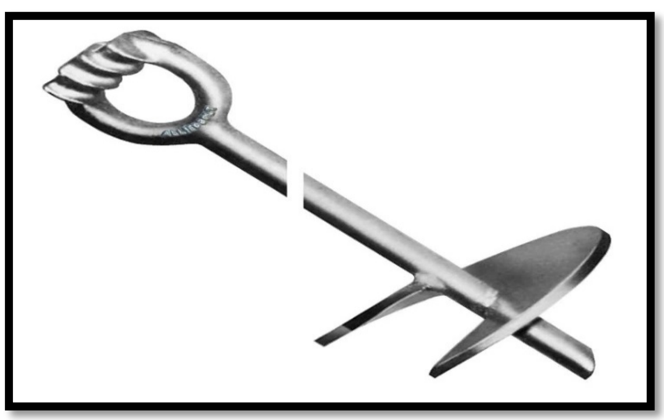

Figure 2.16: Screw Anchor [77]

2.4.9 Grapnel Anchor

The grapnel (Figure 2.17) has superb holding power, but only when it can hook on something, such as buried logs, branches, or rocks. The folding grapnel makes a very compact package and conveniently will set as a lunch hook for very small craft. Grapnel anchors are also useful for dragging the bottom to pick up lost anchor rode and such [78].

Figure 2.17: Grapnel Anchor [78]

2.5 Anchoring Gear

The elements of anchoring gear included the anchor and the cable (also called a rode). The cable is very important for the anchoring. It will affect the efficiency of the anchorage system. There are many types of cable, such as NYLON in three-strand twist, Studless Chain, and Stud-Link Chain. All of the types have their own characteristic and usage.

2.5.1 Twisted Nylon

Nylon (Figure 2.18), in three-Strand twist or double-braid form, is the leading choice for use as an anchoring line [79]. Lines generally come in a "soft" or "medium" lie. Soft lines are generally softer to the touch, and loosely woven. These aren't as good as medium or hard lines for anchoring, as they are more prone to unraveling and chafing. Tightly wrapped lines are the best choice for anchoring.

Lines that have been treated with a wax-like coating are available. These lines help the line resist water/salt absorption. To help keep your lines in good shape, clean them from time to time by soaking them in soapy water. Never use bleach, as it can break down the line.

Figure 2.18: Twisted Nylon [79]

2.5.2 Chain

There are many advantages of using chain anchor rode [80]. The chain doesn't chafe or abrade on rock, coral, or other underwater hazards, the weight of chain creates sag (a catenary curve) that absorbs shock when surges lift and straighten it. With a proper windlass and anchor locker, the entire rode and chain self-stow and self-deploy reliably. The weight of the chain increases anchor holding power by lowering the angle of pull to be more nearly horizontal.

Drawbacks of chain are it is heavier and more expensive than rope. Except in short lengths and small sizes, chain can't be managed by hand and requires a windlass, which adds more weight and ore expense. Though chain has the catenary sag to help absorb shocks, once the catenary has been straightened out under load there is no elasticity left to be absorb shock. Rope has elasticity or stretch to absorb shock.

There are two types of chain that commonly using for anchorage system, Stud-Link Chain (Figure 2.19) and Short-link Open Chain (Figure 2.20). The studs (crossbars between each link) make the chain stronger and heavier [81]. The studs also somewhat reduce the tendency of chain links to kink and lock in bunch. Stud-link chain isn't welded; the links are forged as a unit. The crossbar with hollowed ends to mate with the inside of the chain link is inserted into the red-hot link, which is then hammered tight. When the link cools, the studs are fixed in place with incredible strength. Minimum available size for stud-link is usually 5/8 inch (15.8mm). Breaking strength of standard grad 2, 5/8-inch stud-link is 33200 pounds (15060 kg). It is important that chain under load be straight and smoothly extended. Any kink or hockle dramatically reduces the strength of the chain and result in a complete failure.

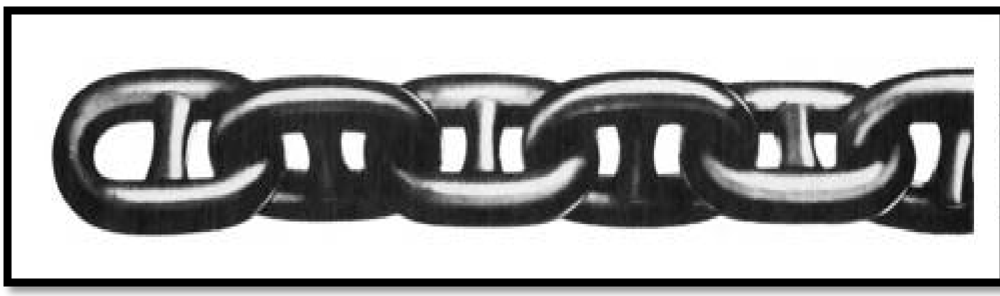

Figure 2.19: Stud-link chain (source by Boat Mechanical Systems Handbook, Dave Gerr, 2008)

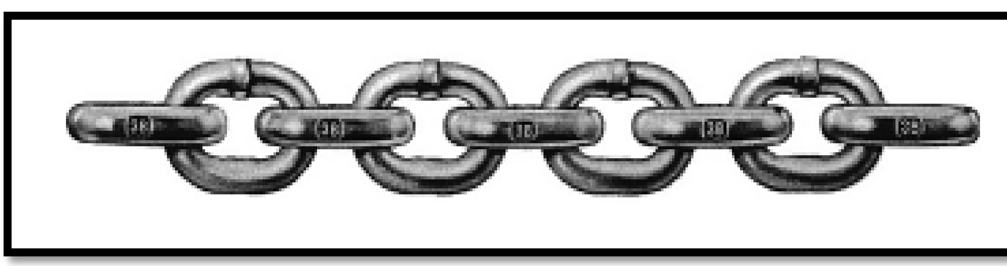

Figure 2.20: Short-link open chain (source by Boat Mechanical Systems Handbook, Dave Gerr, 2008)

2.6 Summary

Aluminum is lightweight, strong, and fairly easily repaired. It has very little problem in regards to corrosion, or rusting, and has excellent durability. One of the problems of aluminum is electrolytic corrosion (galvanic corrosion) apart from proper maintenances.

As discussed previously boats were constructed mostly of wood. The yearly maintenance involved would definitely require some major experience, and a substantial amount of tools for the upkeep.

Concrete on the other hand is heavier and more costly to construct. They are heavy, robust and difficult to dispose.

Fiberglass is the most suitable material to be the float system for micro hydro out of all of other materials. Fiberglass Construction is also lightweight, strong, and easily to be repaired. Furthermore, it has very little problem in regards to maintenance, which requires simple waxing, cleaning, compounds of its gel coat to keep its proper. Age, water, and storage conditions might affect the longevity of fiberglass; without proper care and maintenance.

The shape of the float is very important, it’s may affect the stability of the floating system. Flat-bottomed float is an ideal shape for the float of IVMHT. A float with a flat-bottomed float normally is very stable and used to support a structure such as a floating bridge on water and it acts as an elastic foundation. Besides, Flat-bottom floats are easiest to build, take less time, require fewer tools, and cost less than other floats of similar size.

Type of anchorage that will be used is the deadweight. The advantages of the deadweight anchor are its resists uplift, allowing short mooring line scope and no setting distance is required. Deadweight anchor is reliable because most holding force is due to anchor mass. It is simple, on-site construction is feasible. The size is limited only by load-handling equipment. Besides, it is economical if material is readily available and reliable on thin sediment cover over rock. The most important is the mooring line connection is easy to inspect and service.

CHAPTER 3

METHODOLOGY

3.0 Introduction

In continuation of previous chapter, this section will discuss the methodology of the float and anchorage system. When designing a float, the designer must take into consideration the maximum amount of load that it is intended to support. Each float can support a load equal to the mass of the water that it displaced, but this load also includes the mass of the all permanent or temporary structure and the float itself. If the maximum load of a whole structure is exceeded, one or more floats become submerged and will proceed to sink. Besides, this section will present the conceptual anchorage system that will be used to hold a floating in-stream horizontal turbine. Anchorage system is one of the integral elements to ensure the system is sustainable. Hence, the objective of this section is to review and discuss different types of anchoring system.

3.1 General Descriptions of Float

There are a few procedures to design and produce the float. Firstly, the ultimate load must be determined. After that, the buoyancy force should be calculated to make sure the float can sustain the ultimate load of the micro hydro structure. Secondly, the float with high buoyancy force might in the huge float size. There are a few disadvantages of the large float, such as weight of the float is consider as heavy, difficult to transport and extra care required during handling. The solution to handle the huge dimension problem is divided the large float into a number of small floats. The dimension of the platform for the micro hydro is 2.4m length and 0.6m width. It is the sufficient size for the turbine and all the fixed materials for the micro hydro system. The dimension of large float (Figure 3.1) is 2.4m length, 0.6m height and 0.6m width, then it can be divided to small floats as 2 numbers of the 1.2m length, 0.3m height and 0.3m width. The figures will show the functional of the small floats. The advantages of the large float that had divided in a few numbers of small floats are the weight of the float is reasonably lighter, easy to handle, easy to transport, relatively easy to be made, flexible and versatile. Lastly, the material to make the floats must be determined. It's should also lightweight, strong, and easily to be repaired.

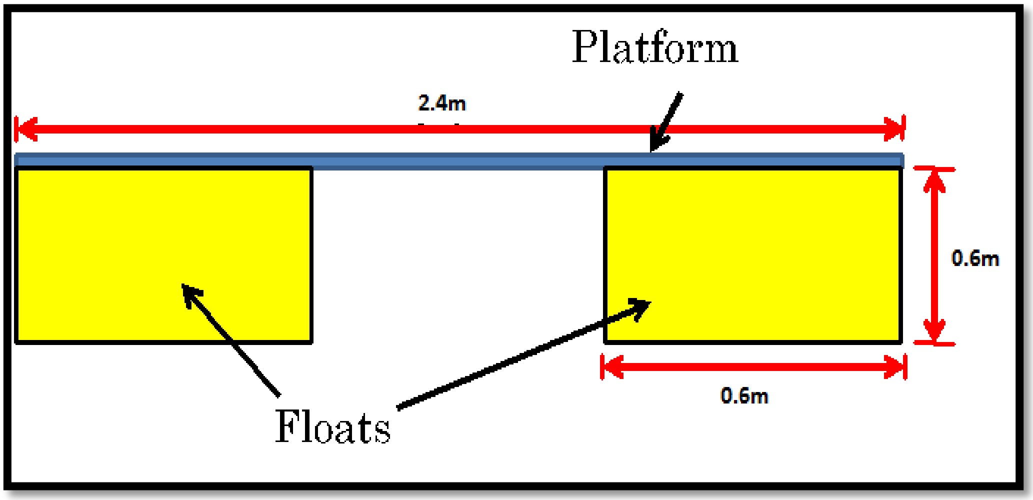

Figure 3.1: Large Float

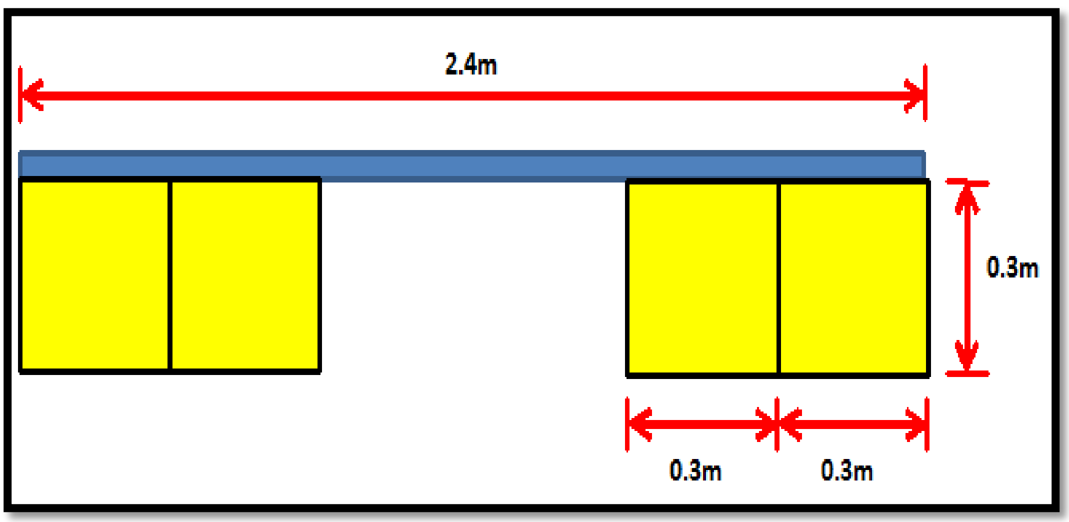

Figure 3.2: Composed Small Floats 1

In Figure 3.2 and Figure 3.3 shown that a big float from 0.6m wide is divided to two small floats with 0.3m wide each float.

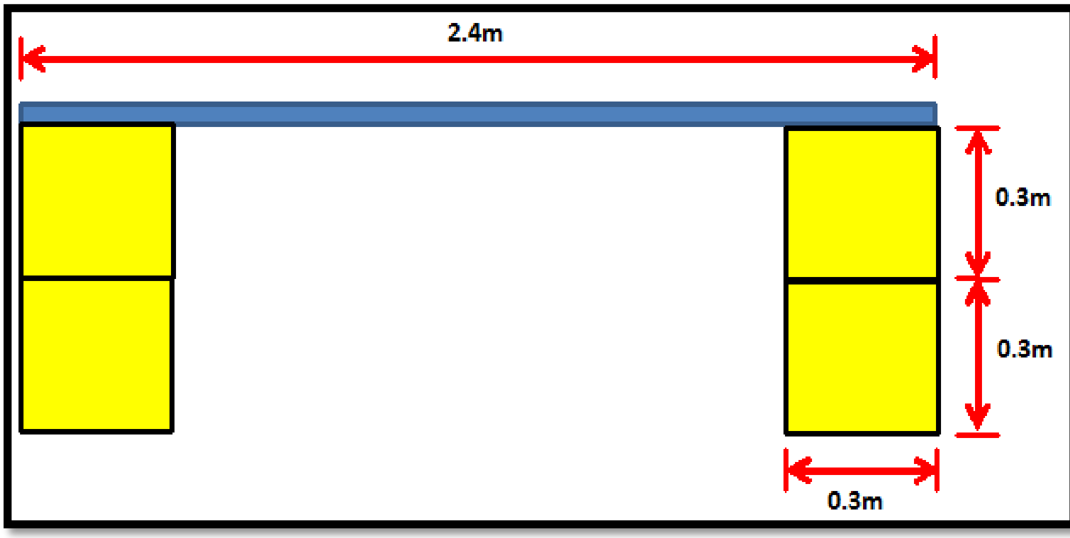

Figure 3.3: Composed Small Floats 2

Divided floats have a few advantages such as easy and cheap maintenance, as example, it's can be replaced a unit of float when one unit of the float is flawing (Figure 3.4). When increase in weight, we can add more float to accommodate weight increment.

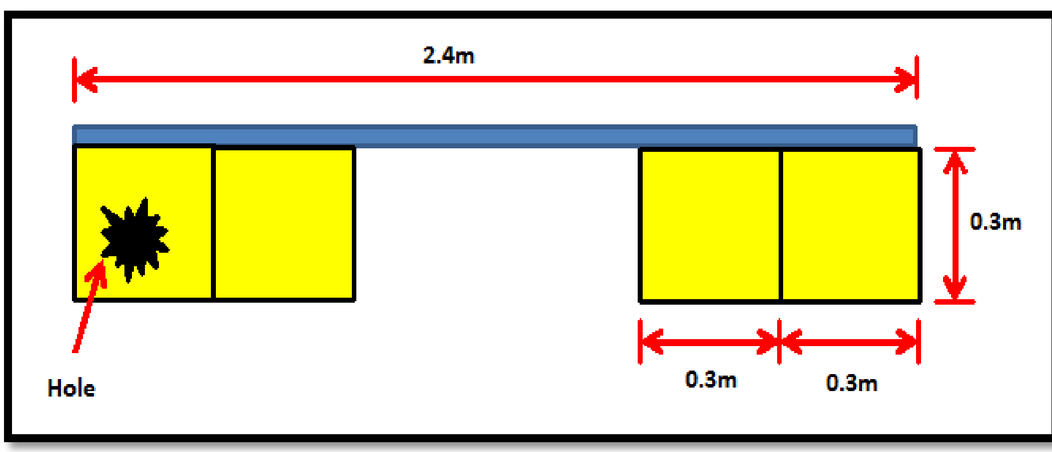

Figure 3.4: Replaceable Float

3.1.1 Platform and Float Connection

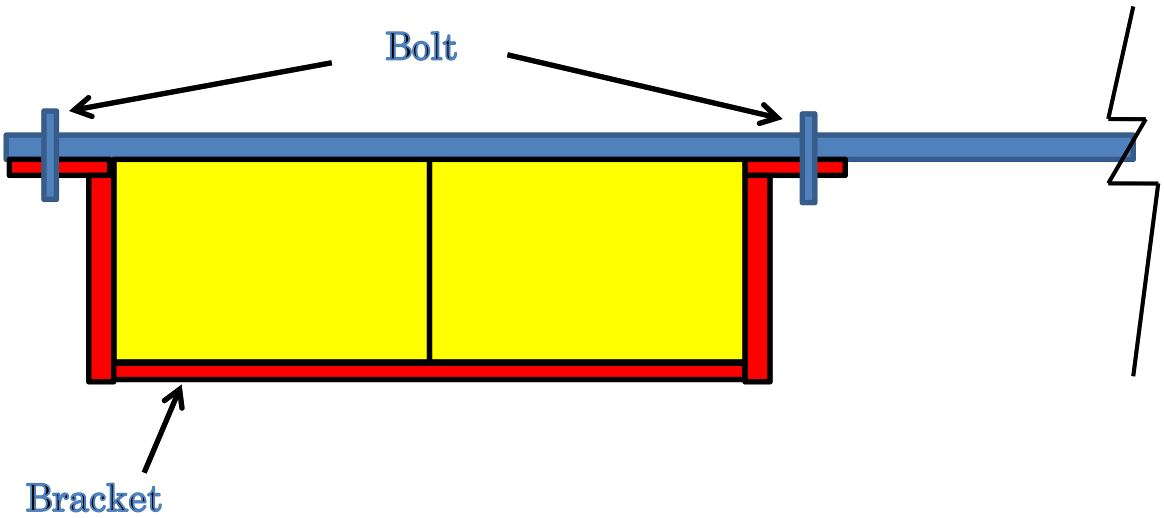

Figure 3.5: Front View Connection

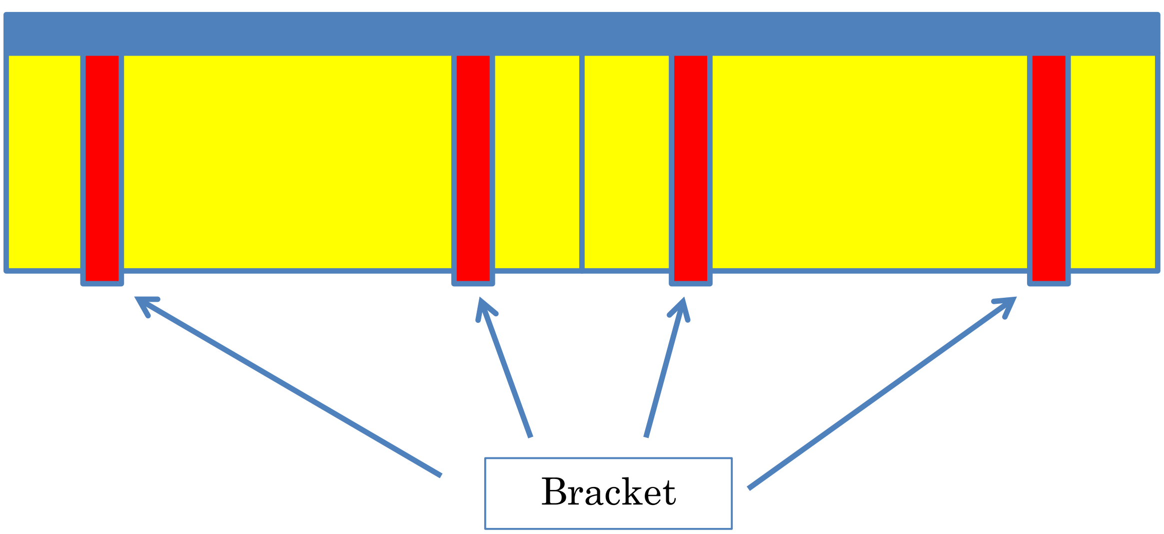

Figure 3.6: Side View Connection

The floats are connected by bracket to the platform and lock with the blots as shown in the Figure 3.5 and Figure 3.6.

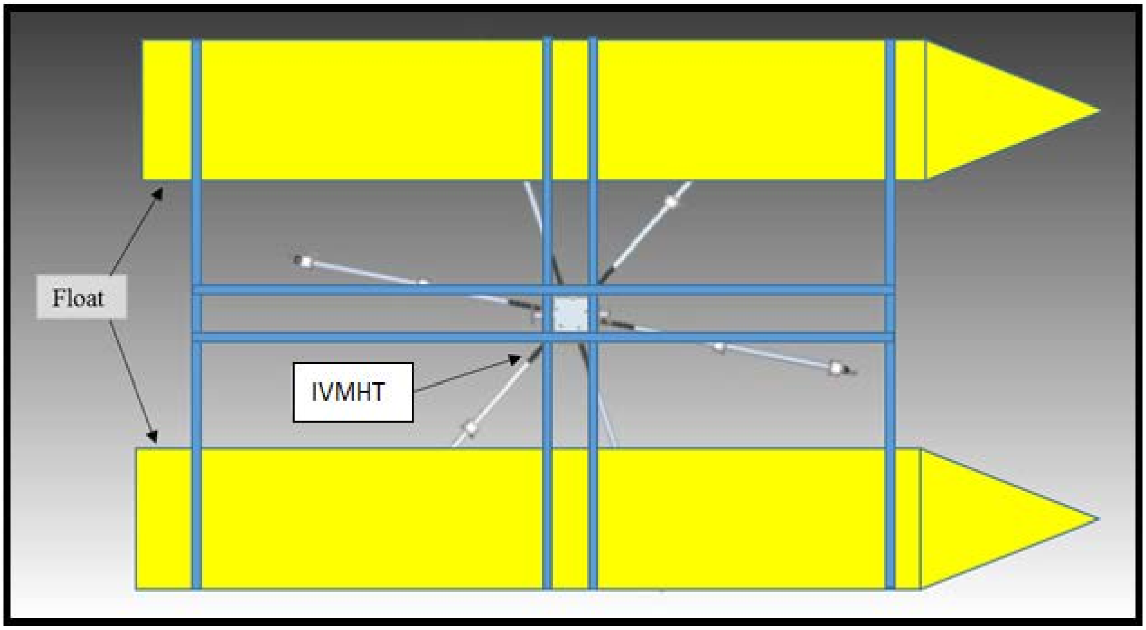

Figure 3.7: Plan View of Conceptual Float of IVMHT

The IVMHT is attached at the platform which is shown in the catamaran type floating system as shown in Figure 3.7.

3.1.2 Buoyancy Force

The buoyancy of the each float is around 28.3Kg, 25% submersed in the water. When 50% submersed the buoyancy is approximately 56.6Kg.

Buoyancy, or buoyant force, is based on Archimedes' Principle (John McLester, 2007). This principle states, "Any object, wholly or partly immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object." Archimides' Principle (O'Brien, 2010) is important in hydro-engineering applications, such as shipbuilding, floating deck.

Summarize of the buoyancy of the conceptual design is shown in Table 3.1 (APPENDIX B), the dimension of float is 1.2m length, 0.3m height and 0.3m width, which had mentioned in page 39.

Table 3.1: Buoyancy for Conceptual Pontoon

No. pontoon / Submerged (%)	**25%**	**50%**	**75%**
1	28.3 kg	56.6 kg	84.9 kg
2	56.6 kg	113.2 kg	169.8 kg
3	84.9 kg	169.8 kg	254.7 kg
4	113.2 kg	226.4 kg	339.7 kg

3.1.3 Float System Construction

The conceptual floats are built by using fiberglass in laboratory of University Malaysia Sarawak. Fiberglass material is easy to be molded into shapes. Three layers applied for each float.

The first step is to make a 0.3m wide x 0.3m height x 1.2m long wooden formwork. Secondly, applied enough grease to the surface of the formwork (Figure 3.8) and Lay the fiberglass mat onto the formwork and cut into desire size (Figure 3.9). Thirdly, mixed half a liter of resin with 2 cap of hardener (Figure 3.10). Fourthly, applied the resin and hardener mixed to the fiber glass using roller paint brush (Figure 3.11). After that let the fiberglass to dry for 2 – 3 hours.

Figure 3.8: Formwork with Grease

Figure 3.9: Fiberglass Mat

Figure 3.10: Mixing of Resin with Hardener

Figure 3.11: Applying Resin to the First Layer of Fiberglass Cloth

Figure 3.12: Painting the Fiberglass Float

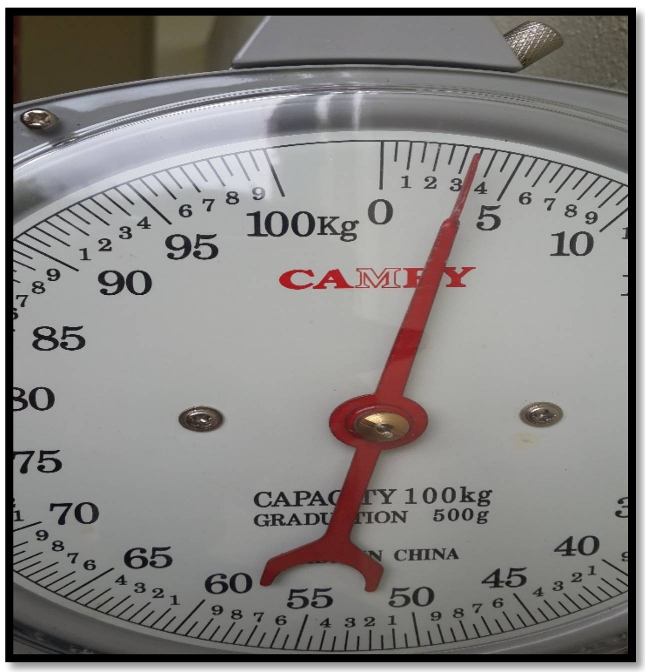

Figure 3.13: Measuring the Weight of Fiberglass Float

Figure 3.14: Getting ready for Float Experiment

Make sure that the fiberglass is dried before applying second layer. Repeat twice from step 2 to 5. Took the fiberglass out of the mold when it is dry. Grind the fiberglass float if the surface is not level and smooth. After that, painted fiberglass float with blue color (Figure 3.12). Measure the weight of the fiberglass float (Figure 3.13). Lastly, repeat all with cylinder shape (For CAS1). The fiberglass floats had been tested the buoyancy force at the river nearby SK. Lepong Gaat, Kapit (Figure 3.14).

3.2 General Descriptions of Anchorage

The design constraints are the anchorage system must not consist of fixed structure, any sort of piling must be avoided, it must not obstruct the river traffic/user and it must also be able to accommodate the water tide. All of these constraints need to be considered in order to select the most suitable anchorage mooring system for the project. In the end, the most suitable anchorage mooring system is finally discussed and proposed

According to the complete anchoring handbook by Alain Poiraud [83], the anchors achieve holding power by "hooking" into the sea/riverbed, via sheer mass. The anchors depend on their ability to bury themselves in the river bed to attain their holding power. So, they need a certain amount of weight to sufficiently start the burying process, and a near horizontal pull. This is where chain weight and the catenary curve are vital [84]. The chain must lead from the anchor horizontally or parallel with the bottom, even under strain. Any lead upwards decreases the anchors holding power, the loss depending upon the angle and type of anchor. Most anchors will break out of the ground once the angle of pull reaches about 10 degrees from the horizontal. The essential features of an efficient anchor should have sufficient weight for initial penetration, must bury itself deeply when subjected to a horizontal pull. Once buried it must have the greatest possible resistance to movement in the direction of pull. It must remain rotationally stable even when pulled through the riverbed.

For anchor design and installation, the availability of good soil data is outmost importance as the soil is of great influence on anchor behaviour. The following are influenced by the soil conditions encountered. Some anchors are more suited for soft soil conditions (soft clay), while others are more suited for hard soils (sand and hard clays), although there are a number of anchor types on the market that are suited for most soil conditions encountered. In hard soil like sand and hard clay, the maximum attainable ultimate holding capacity with a certain anchor type and size is higher than the attainable ultimate holding capacity in very soft clay. In very soft clay the anchor will penetrate deeper than in harder soil like sand. As a consequence, the drag length of the anchor will also be longer in very soft clay than in hard soil. When an anchor is installed in very soft clay, the required retrieval forces will be higher than in hard soil like sand. For example, in very soft clay the required retrieval force of an anchor can be equal to 80%-90% of the installation load while in hard soil (sand) the retrieval force might only be 20%-30% of the installation load [85].

3.2.1 Holding Conditions

The holding power of any anchor differs with its size, weight, and with the bottom condition, and is not a fixed value. The sea/river bed is far from regular even within a relatively small area and anchor performance is affected not only by the nature of the bottom- sand, mud, silt etc. But also by local inclusions of rocks, scrap metal and the like. Compared with sand, soft mud lessens holding power by about a third [86], whereas firm clay can increase it by as much as two thirds. Once an anchor own dead weight has caused it to initially penetrate, as it moves horizontally so it continues to bury itself deeper. If it is too light to effect this initial penetration it will glide over the surface. Having embedded itself, resistance to movement through the river bed is related to the amount of material that would be removed by the anchor if it pulled out.

In principle an anchor with the largest effective fluke (blade) area has the highest holding power, subject of course to it being of sufficient strength. Effective fluke area varies with the angle that the fluke takes up in operation. Too shallow an angle reduces the effective area and the holding power, whereas too steep an angle prevents the anchor from fully penetrating the river bed. Such an anchor develops deficient downward pressure and will plough up the surface without digging in any deeper. Obviously, material that is more compacted is more difficult to displace, so an anchor also needs to be streamlined to achieve penetration without unnecessary ground disturbance. An anchor which digs deeper will again be in contact with more compacted material and have proportionately greater resistance to movement. Once it has fully penetrated, the actual weight of an anchor has very little effect on its holding power.

Another method to increase holding power is to drop the anchor on an up slope. This might be a sand bar or an area where the depth gets shallower from a deeper area. Sentinel and kellet (Figure 3.15) can also be used to increase the holding power of the anchor. The sentinel moves down the anchor line, forcing the rope down with it, thus providing a more horizontal pull on the anchor [87].

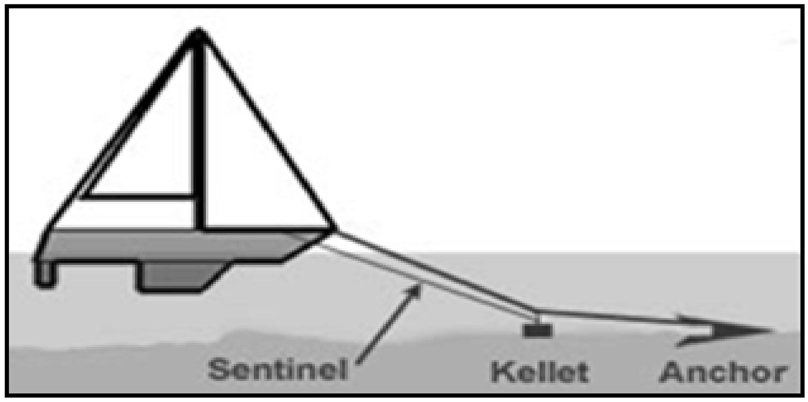

Figure 3.15: Sentinel and Kellet (Launer, 2007)

3.2.2 Force Exerted

The anchorage system are generally dependent on three main factors- wind drag, current drag and wave loading [88], each of which is in itself immensely variable.

I. Wind drag

This is the load resulting from the combination of wind pressure and suction on the float above water. Aerodynamic loads increase with the square of the wind velocity. Effectively, this means that if the wind speed doubles the wind force acting on the float goes up four times. Having arrived at a figure which itself is not so easy when it is realized that a float rigging can add up to a third of the total air load it then becomes difficult. The figure so far is based on frontal area (cross section facing the wind), waves causing swinging at anchor.

II. Current drag

In most instances current drag is a relatively minor load although it can be significant if the boat has a very large area below water or is anchored in, or even across, a strong current [88].

III. Wave action load

Wave action is likely to impose by far the highest loads on a boat and her ground tackle. She will heave, pitch, rear and yaw, but if she is allowed ample freedom the actual loads applied to the anchor will be modest [88]. The freedom is achieved through weight providing resilience in the mooring system and take into account these factors and conditions are maximum depth of water, rise and fall of tide, maximum flow speed, prevailing wind and strength, abnormal conditions of wind and river flow, site conditions- sheltered or exposed, type of bottom- sand, mud, shale and size and number of float to be moored.

3.3 Anchoring and Mooring

A mooring is a buoy connected to an extremely heavy anchor or weight. A mooring consists of an anchor, a chain, a mooring pendant, and a buoy [89].

3.3.1 Catenary Anchor-Leg Mooring Systems

This system (Figure 3.16) includes a buoy which is designed to dive at an angle downwardly through large river flow or swells during bad weather. The buoy has a circular or wedge shape to reduce its drag coefficient so that undue stresses will not be placed on the buoy's anchor chains as it dives through the water.

The advantage of using these buoys is that they do not require construction of a costly jetty or dock for mooring the In-stream Vertical Micro Hydro Turbine. However, since loading facilities are often located in unprotected waters, the buoys must be designed to accommodate and withstand great environmental forces produced by large swells or waves, high winds and/or strong currents. These environmental forces can become particularly fierce when the buoy is placed in a very shallow location because the waves tend to build up and become very steep before they break in the shallow water.

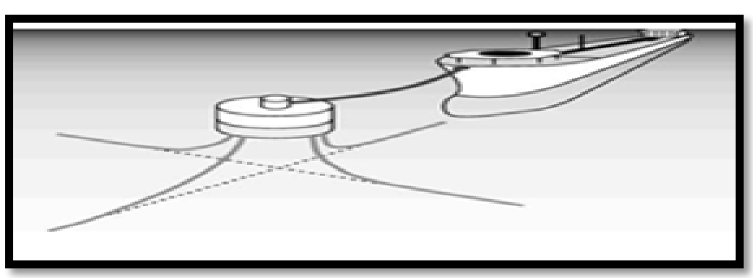

Figure 3.16: Multiple anchor-leg mooring [90]

3.3.2 Single anchor leg mooring system

The floating buoy (Figure 3.17) is anchored to the riverbed by one single anchor leg, connected to a base type anchor point (ballasted and/ or piled) [91]. The buoy can be attached to the base by either one single chain or by a chain or tubular column; this can be seen in the figure below.

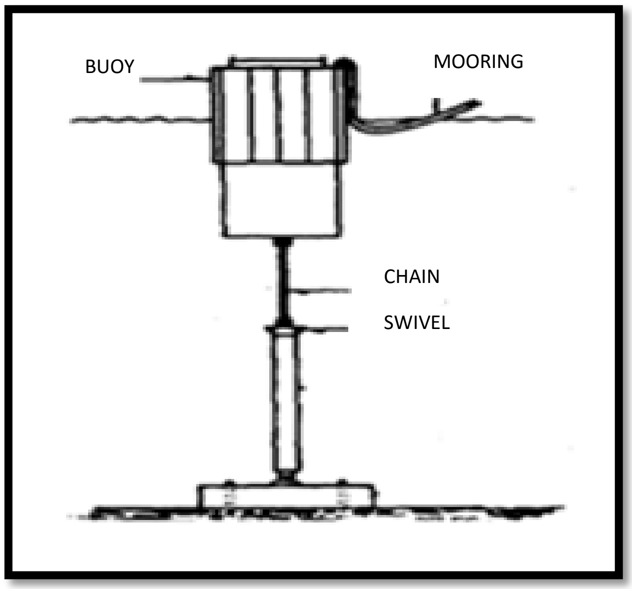

Figure 3.17: Single anchor leg mooring [91]

3.3.3 Column Mooring (Support Frame)

This system is a fixed structure (Figure 3.18). It is strong and durable; it can withstand large swells or waves, high winds and strong currents. It is suitable for high stream river and for bad environment conditions.

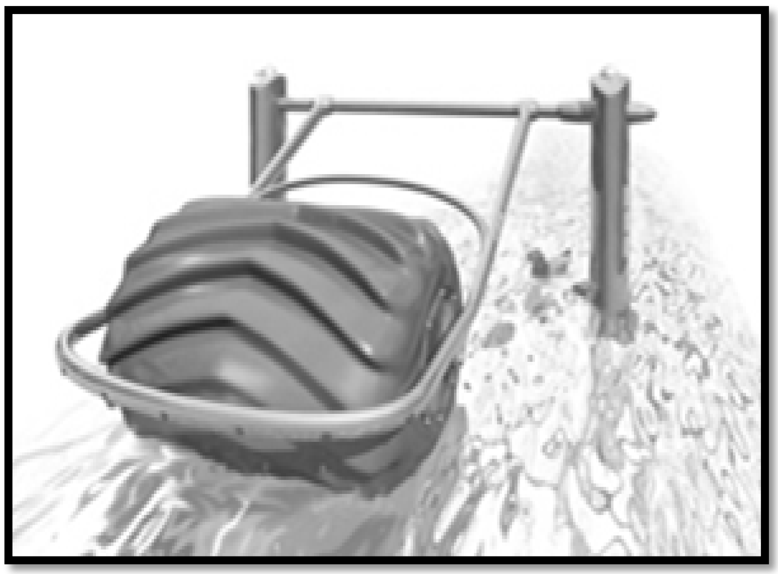

Figure 3.18: Column Mooring [93]

3.3.4 Trot Anchor mooring system

A trot mooring (Figure 3.19) consists of a long and heavy ground chain anchored at each end, with risers at intervals so that a single assembly serves to moor a number of boats. Additional anchors may be required to hold the ground chain in position, particularly if the main current flow is across the line of the chain. Anchors are often laid on triangular bridles themselves attached to the main ground chain, so that any imposed stress is redistributed to two or more anchorage points. The usual design principle applies equally to trot moorings in that sufficient resilience must be built in to accommodate shock loads.

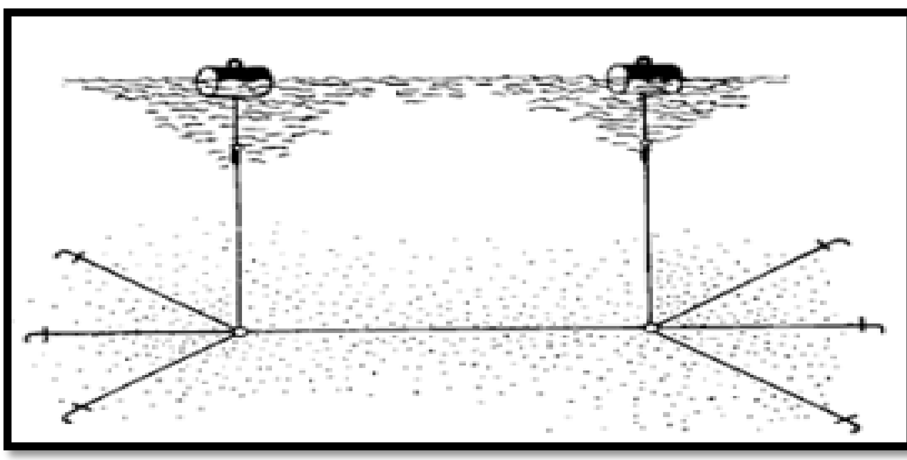

Figure 3.19: Trot Mooring [93]

3.4 Conceptual Anchoring and Mooring of IVMHT

There are two conceptual anchorage and mooring system for the Sustainable In-stream Vertical Micro Hydro Turbine. There are Conceptual Anchorage System 1 (CAS1) and Conceptual Anchorage System 2 (CAS2).

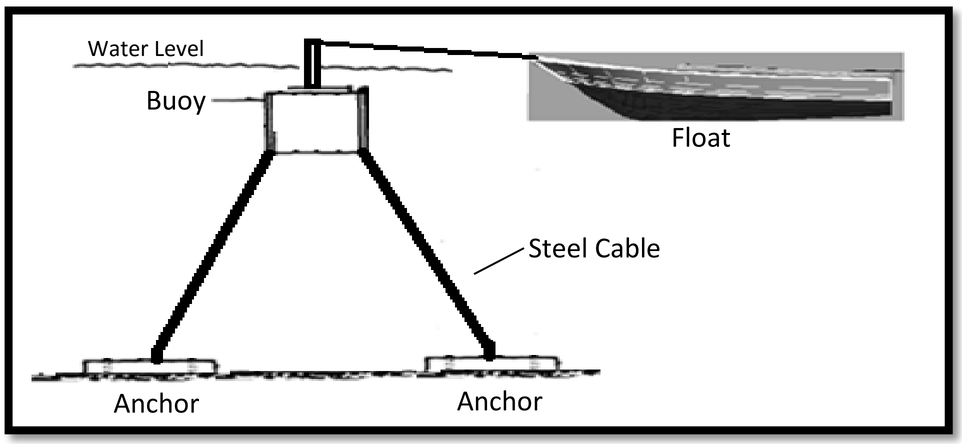

Figure 3.20 : Conceptual Anchorage System 1 (CAS1)

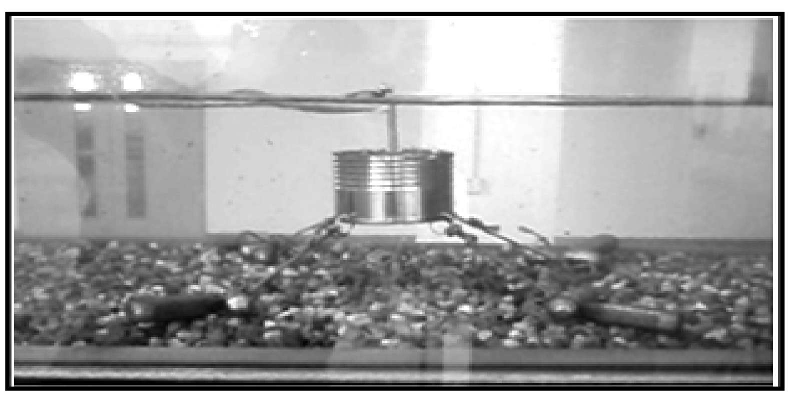

Figure 3.21 : Submerged Buoy Used in CAS1

The CAS1 (Figure 3.20-3.21) consists of cylindrical buoy attached to four anchors by using steel cable. Float connects to the mooring by using steel cable. The buoy will float when the water level is low and submerged when the water level is high. The cylindrical shape of the buoy is selected to reduce the magnitude of the drag force when it is submerged into the river. A laboratory test had been done by using an open flow channel in the Civil Engineering Laboratory, Faculty of Engineering, UNIMAS to observe the behavior and practicality of this system. By observation, this system could provide a strong anchoring for the Sustainable In-stream Vertical Micro Hydro Turbine, it can accommodate the rise and fall of tide and it is a stable system. However, when the buoy submerged, the river flow at the downstream will become turbulence. This phenomenon becomes apparent with the size and shape of the buoy. If the size of the buoy is relatively small than the river cross-section, these phenomena could be reduced. Furthermore, the shape of the buoy also plays important role in reducing the turbulence, aerodynamic shape is preferred. This system has huge potential to be used as the anchoring for the Sustainable In-stream Vertical Micro Hydro Turbine since the turbine are located in unprotected area and it must be able to withstand fierce environmental force produced by large waves, high winds and strong currents.

The second anchoring system that can be considered is the CAS2 (Figure 3.22-3.23). In this system, a continuous steel cable runs through two pulley system on the turbine platform in which two of its end is tied to an anchorage. In between the two pulley system, a weight is attached to the cable. This weight is not fixed to the cable in which it can move to a new position to accommodate the rise or fall of the water level. This project requires two of this system where each unit applied to each side of the turbine platform in order to enhance the stability of the floating turbine.

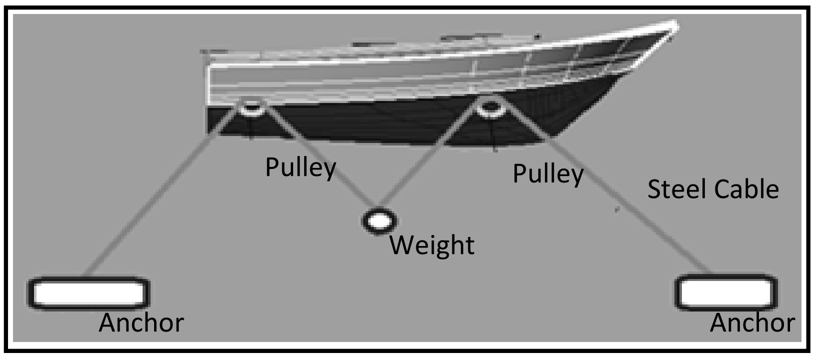

Figure 3.22 : Conceptual Anchorage System 2 (CAS2)

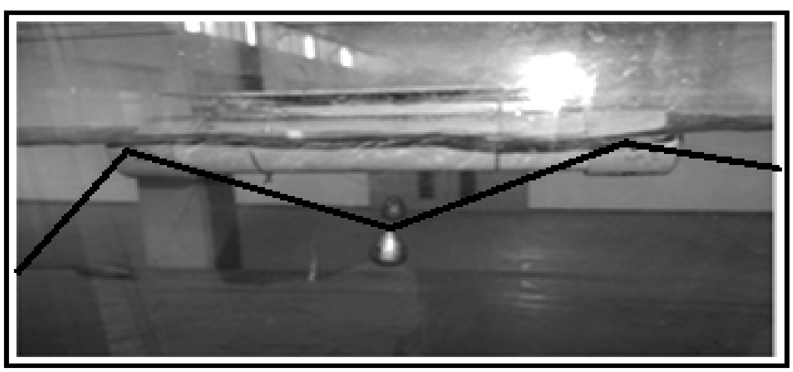

Figure 3.23 : Laboratory emulation of CAS2

A laboratory test also had been done to observe the behavior and practicality of this system. This system shows good performance during the test, it can hold the floating turbine in a stable manner, it is also able to accommodate the rise and fall of tide and also able to withstand strong current. However, this system has its limitation if it is used for this project since the difference in the height of highest and lowest water level at the selected site is extreme. When the water level is at its lowest, it is fear that the weight might be submerged in the river bed, thus preventing the system from working properly.

The 2^{nd} generation of the CAS2 (Figure 3.24). Since, the CAS2 when the water level is at its lowest, the weight might be submerged in the river bed, thus preventing the system from working properly. The 2^{nd} generation of CAS2 can prevent this scenery. In this system, a continuous steel cable runs through two pulley system on the turbine platform in which two of its end is tied to an anchorage. In between the two pulley system, a weight is attached to the cable. This weight is not fixed to the cable in which it can move to a new position to accommodate the rise or fall of the water level. This project requires two of this system where each unit applied to each side of the turbine platform in order to enhance the stability of the floating turbine. A laboratory test also had been done to observe the behavior and practicality of this system. The difference between CAS2 and 2^{nd} generation CAS2 are the 2^{nd} generation attached with 4 columns and rail.

Figure 3.24 : Laboratory emulation of 2^{nd} generation of CAS2

3.4.1 General Formation for Conceptual Anchorage System 2

In this system, a continuous steel cable runs through two pulley system on the turbine platform in which two of its end are tied to an anchorage. In between the two pulley system, a weight is attached to the cable. This weight is not fixed to the cable in which it can move to a new position to accommodate the rise or fall of the water level. When in low tide and low water discharges, the system will be fixed in a position as shown in the Figure 3.25 with the θ1 in 45̊. When in low tide and high water discharges, the θ1 will changed from 45̊ to higher degree, therefore the θ3 with changed frequently with the changing of θ1.

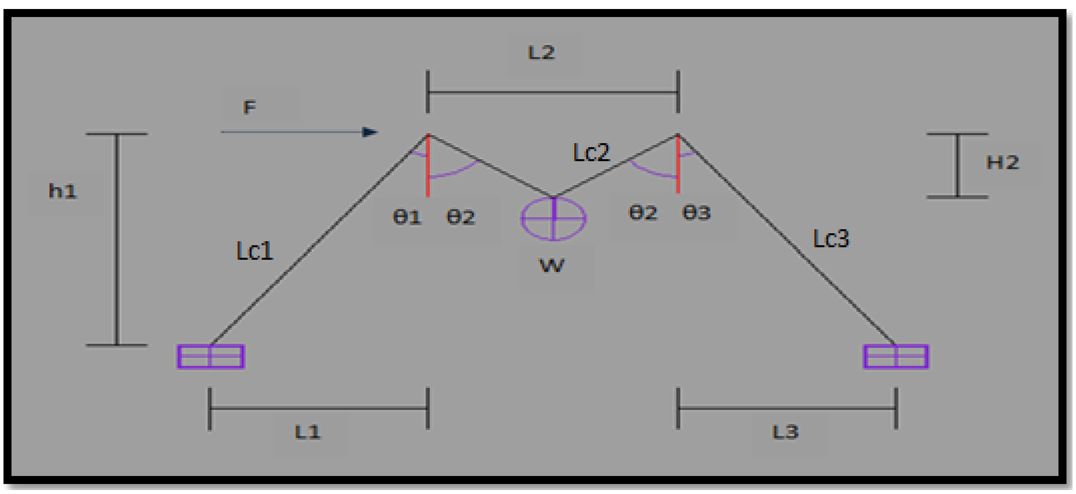

Figure 3.25: Analysis of Laboratory emulation of 2nd generation of CAS2

A. Low Tide and Low Discharges

The measured height of water at the river Sk. Lepong Gaat when low tide is 2.5m, and the velocity as mentioned in Chapter 1 is 1.3m/s. The Force Resistance is very important to make sure the anchorage and floating system is in stable situation. The most importance is the anchorage system can sustains the force resistance.

<u>General Formation</u>

Force Resistance

$$F = 2\,(T \sin \theta 1 - T \sin \theta 2 + T \sin \theta 2 - T \sin \theta 3)$$

$F = 2T\,(\sin \theta 1 - \sin \theta 3)$……………………………………………….. (3.1)

Cable Tension

$\uparrow + \Sigma F_y = 0;$ $\quad W = 2T \cos \theta 2$

$T = W/2 \cos \theta 2$………………………………………………………… (3.2)

Weight

$W = (F \cos \theta 2) / (\sin \theta 1 - \sin \theta 3)$………………………………………….(3.3)

Where: F is the force resistance toward the floating structure, N

T is the tension of the cable, N

W is dead weight that attached in the cable, kg

$\theta 1$ is the angle that intersection between L1 and L2,

$\theta 2$ is the angle at internal L2,

$\theta 3$ is the angle that intersection between L2 and L3.

B. Low Tide and High Discharges

The measured height of water at the river Sk. Lepong Gaat when low tide is 2.5m, and the highest velocity as mentioned in Chapter 1 is 2.72 m/s.

Table 3.2: Formation Formula in Low Tide and High Discharges

Θ1	L1	Lc1	L3	Lc3	Θ3	Lc2	Θ2	T	F
45° ↓	L1= h1 tan θ1	$Lc1 = (L_1^2 + h_1^2)^{1/2}$	L3 = L – L1 – L2	$Lc3 = (L_3^2 + h_1^2)^{1/2}$	$\Theta 3 = \tan^{-1}(L3/h1)$	Lc2 = (Lc – Lc1 – Lc3)/2	$\Theta 2 = \sin^{-1}(L2/2Lc2)$	T = W/2cos Θ2	F = 2T (sin Θ1 – sin Θ3)

Where: F is the force resistance toward the floating structure, N

T is the tension of the cable, N

W is dead weight that attached in the cable, kg

θ1 is the angle that intersection between L1 and L2,

θ2 is the angle at internal L2,

θ3 is the angle that intersection between L2 and L3,

L1 is the bottom length of 1st section according to θ1, m

L2 is the middle bottom length of the system, m

L3 is the bottom length of 3rd section according to θ3, m.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.0 Introduction

In continuation of previous chapter, this section will discuss the results and analysis of the conceptual fiberglass flat bottom float and the two conceptual anchorage systems that stated in the previous section.

4.1 Discussions of Float

Floats can be made with a number of materials. The fiberglass is more preferable since it is cheap and durable. Fiberglass floats can break, and aluminum floats may bend. Fiberglass can be molded, whereas aluminum cannot be molded, but only welded into any shape. Fiberglass boats are corrosion resistant (Table 4.1: Relative Performance – Corrosion and Water Resistance), whereas aluminum and steel floats may not be able to resist corrosion in water if not properly maintained and sealed. Fiberglass boats are flexible, whereas aluminum floats bend, and the rivets may leak. Refer to the Table 4.2: Thermal Performance, fiberglass is the best in natural thermal performance compare to other material. So, the ideal material to be used as float is fiberglass.

Table 4.1: Relative Performance – Corrosion and Water Resistance [95]

Relative Performance - Corrosion and Water Resistance		
Material	Performance Best ● Medium ϴ Worst o	Comments
Stainless Steel	●	A marine grade 316 is required for high salt or high chemical environments.
Steel	ϴ	Galvannealing and finishes prevent corrosion in most circumstances.
Wood	o	Material does not corrode; but water will degrade wood and cause mold.
Aluminum	o	Finish may be applied to reduce corrosion.
Fiberglass	●	Material does not corrode.

Refer to Table 4.1, stainless steel are commonly specified for environments requiring corrosion or water resistance. A marine grade 316 is required for high salt or high chemical environments, such as coastal applications (salt) and indoor swimming pools. Steel earned a medium performance rating for corrosion and water resistance. While naturally susceptible to rust, steel is a versatile material and cost effective galvanized coatings and applied finishes are readily available. Wood does not corrode, but water will degrade wood. Because corrosive materials frequently are encountered in a moist environment, wood doors are not well suited to many corrosive environments. Aluminum is susceptible to corrosion. Although a corrosion-reducing finish may be applied to aluminum, aluminum is rarely chosen for corrosive environments. Fiberglass is naturally resistant to corrosion. The conclusion, stainless steel and fiberglass doors have the best performance for corrosion resistance.

Table 4.2: Thermal Performance [95]

Thermal Performance					
Material (core)	Relevant Standards	Typical U-Factor Range	Typical Measured Overall R-Value	Performance Best ● Medium ϴ Worst o	Comments
Steel (Polyurethane)	ASTM C1199-09 ASTM C1363-05 ASTM E1423-06	0.38	2.65	ϴ	Steel doors with a polyurethane core transmit little heat compared to other materials. It's U-Factor is just above fiberglass.
Steel (Polystyrene)		0.41	2.44	ϴ	
Steel (Honeycomb)		0.56	1.79	ϴ	
Hollow Metal (Steel Stiffened)		0.61	1.63	o	Hollow metal doors with a steel stiffened core transfer the most heat of the steel core materials.
Wood		0.40	2.50	ϴ	Wood doors transfer more heat than fiberglass and some steel doors, however their thermal transmittance is relatively low.
Aluminum		0.83	1.20	o	Aluminum doors allow the most heat flow of all the materials.
Fiberglass		0.35	2.85	●	Fiberglass doors have the best natural thermal performance of the materials.

According to Table 4.2, fiberglass are the best natural thermal performance compare to steel, wood, and aluminum.

Table 4.3: Relative Performance – Maintenance and Repair [95]

Relative Performance - Maintenance and Repair		
Material	Performance Best ● Medium ϴ Worst o	Comments
Steel	●	Does not crack or dent easily. Often repaired in field with body filler or re-welding for a relatively low cost.
Wood	o	Susceptible to cracking. Expensive to repair, but may be repaired in some circumstances.
Aluminum	ϴ	Dents. Must be replaced when dented as it cannot be reannodized.
Fiberglass	●	Requires minimal maintenance. However the purchase price can be 3-6 times that of steel.

As mentioned in Table 4.3, steel floats provide superior performance because steel does not crack or dent easily. They can often be repaired in the field, which provides an economic advantage over wood and aluminum floats. Wood has the lowest relative performance in terms of maintenance and repair. Wood is susceptible to cracking and can be expensive to repair. Damaged wood doors are frequently replaced rather than repaired. Aluminum floats often get dented. A dented aluminum door cannot be repaired; it must be replaced as it cannot be reannodized. Fiberglass floats offered superior performance for maintenance and repair.

4.1.1 Analysis of Floats

Once a float (Figure 4.1) cannot support the overall load of the structure, another same float is added on (Figure 4.2) to increase the buoyancy.

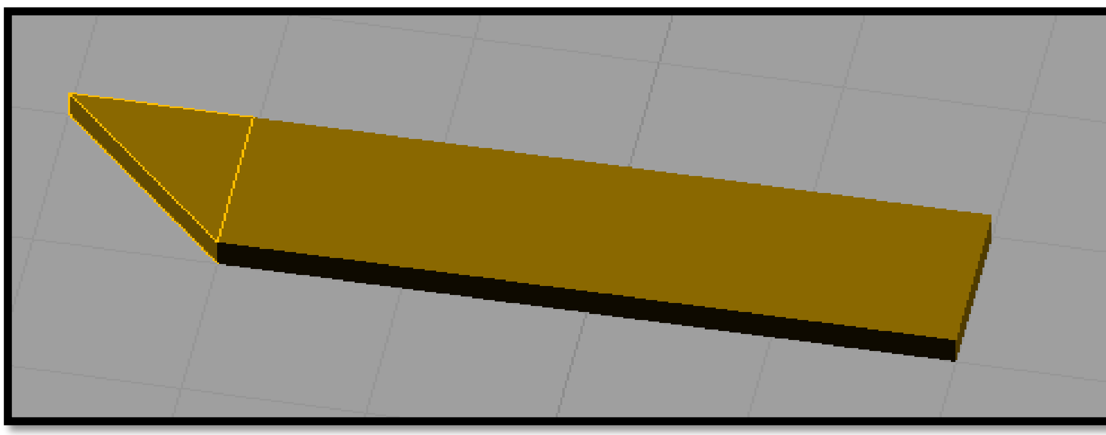

Figure 4.1: Conceptual Pontoon

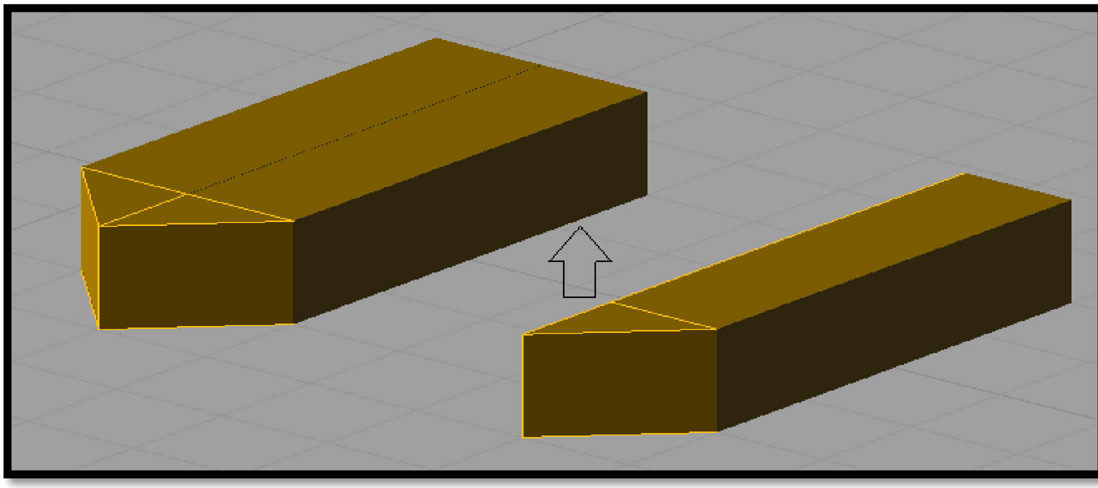

Figure 4.2: Combination of Two Pontoon

On the other hand, when 2 pontoons combined together still can't to support the load of whole structure (if the weight of the micro hydro system is increasing), and then another pontoon will add on again (Figure 4.3).

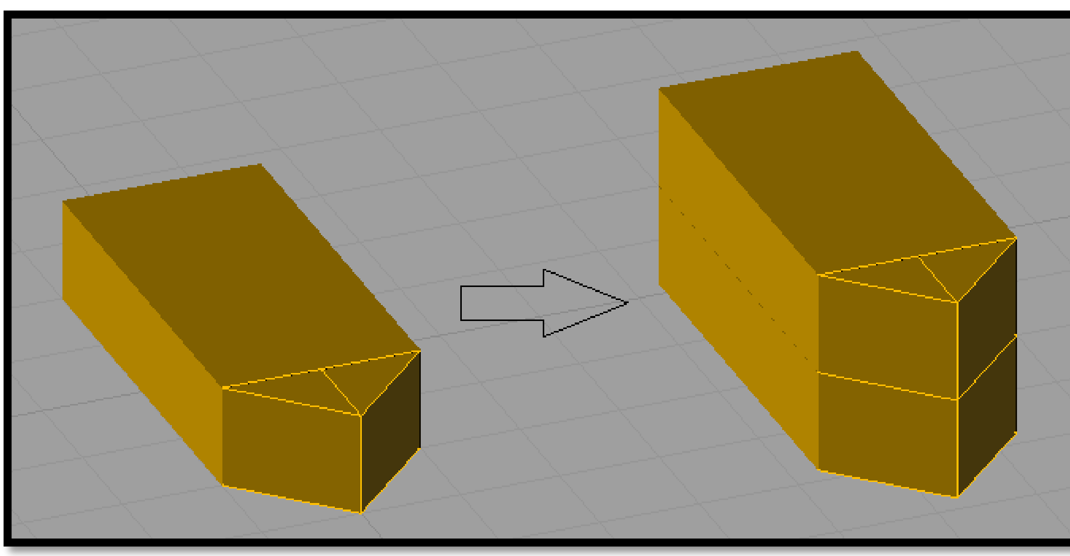

Figure 4.3: Combinations of Four Pontoon

4.2 Discussions of Anchorage System

There are two possible anchorage systems, which had stated in the Chapter 3. Some calculation will show to prove the functional of the anchorage system.

4.2.1 Conceptual Anchorage System 1 (CAS1)

The CAS1 ((Figure 3.20-3.21) consists of cylindrical buoy attached to four anchors by using steel cable. Micro Hydro Turbine connects to the mooring by using steel cable. The buoy will float when the water level is low and submerged when the water level is high. The cylindrical shape of the buoy is selected to reduce the magnitude of the drag force when it is submerged into the river. A laboratory observation had been done by using an open flow channel in the Civil Engineering Laboratory, Faculty of Engineering, UNIMAS to observe the behavior and practicality of this system. By observation, this system could provide a strong anchoring for the Micro Hydro turbine, it can accommodate the rise and fall of tide and it is a stable system. However, when the buoy submerged, the river flow at the downstream will become turbulence. This phenomenon becomes apparent with the size and shape of the buoy. If the size of the buoy is relatively small than the river cross-section, these phenomena could be reduced. Furthermore, the shape of the buoy also plays important role in reducing the turbulence, aerodynamic shape is preferred. This system has huge potential to be used as the anchoring for the In-stream Vertical Micro Hydro turbine since the turbine are located in unprotected area and it must be able to withstand fierce environmental force produced by large waves, high winds and strong currents.

4.2.2 Conceptual Anchorage System 2 (CAS2)

The second anchoring system that can be considered is the CAS2 (Figure 4.4). In this system, a continuous steel cable runs through two pulley system on the turbine platform in which two of its end is tied to an anchorage. In between the two pulley system, a weight is attached to the cable. This weight is not fixed to the cable in which it can move to a new position to accommodate the rise or fall of the water level. This project requires two of this system where each unit applied to each side of the turbine platform in order to enhance the stability of the floating turbine. A laboratory test also had been done to observe the behavior and practicality of this system. This system shows good performance during the test, it can hold the floating turbine in a stable manner, it is also able to accommodate the rise and fall of tide and also able to withstand strong current. However, this system has its limitation if it is used for this project since the difference in the height of highest and lowest water level at the selected site is extreme. When the water level is at its lowest, it is fear that the weight might be submerged in the river bed, thus preventing the system from working properly.

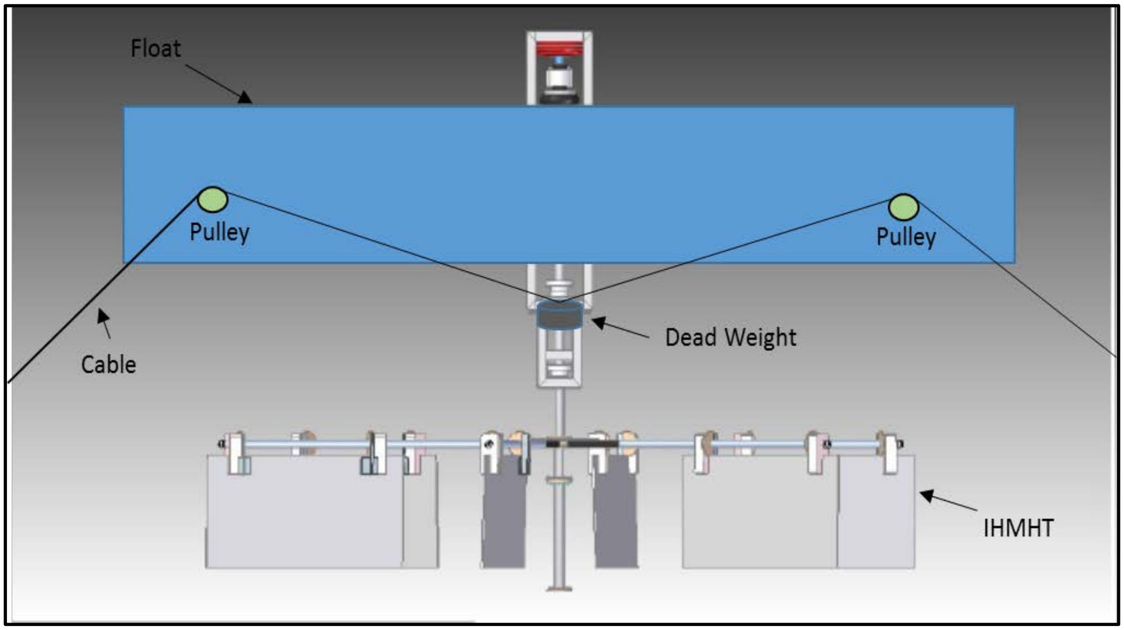

Figure 4.4: Elevation view of CAS2

4.2.2.1 Calculations of Conceptual Anchorage System 2

From the formula 3.1 to 3.3, there are a few parameter are concerned for the CAS2. The first parameter is force resistance or drag force that produces by the river flow. In the low tide condition, the height of the water level is 2.5 m. So, we can set the h2 = 2 m. If the platform of the Sustainable In-stream Vertical Micro Hydro turbine is 5 m, then we can set the L2 = 4m.

When,

h1 =	2.50	m
h2 =	2.00	m
L1 =	2.50	m
L2 =	4.00	m

For the low tide and low discharges, set θ1 and θ2 equal to 45°, but with different θ3, which θ3 equal to 40°, 35°, 30° and, 25°. The force resistance will increase with interval 25N from 50N to define the value of the weight.

Table 4.4: Force Resistance and weight in differ theta 3

Force Resistance, N / Theta 3	**40°**	**35°**	**30°**	**25°**
50	56.0332 kg	26.9902 kg	17.4017 kg	12.6638 kg
75	84.0498 kg	40.4853 kg	26.1026 kg	19.0025 kg
100	112.0664 kg	53.9804 kg	34.8034 kg	25.3367 kg
125	140.0830 kg	67.4755 kg	43.5043 kg	31.6709 kg
150	168.0997 kg	80.9706 kg	52.2051 kg	38.0051 kg
175	196.1163 kg	94.4657 kg	60.9060 kg	44.3393 kg
200	224.1329 kg	107.9608 kg	69.6068 kg	50.6735 kg

From the table 4.4, the weight is increasing through the force resistance. It is because, when force resistance is increasing, the weight has to increase to manage the stability of the floats.

Comparison between the 4 types of theta 3, the theta 3 = 25° is the most suitable to be chosen for the anchorage system. From the Table 4.4 shown that the theta 3 should smaller than 30°, it is because the weight is lighter compare to the theta 3 that excess 30°. In the real scale of the anchorage system the weight should be reasonable and not very heavy for the manpower to carry and build. So, theta 3 must smaller than 30°, and then the weight will be more reasonable and also can functional as to manage the stability of the floats and turbine system.

For the low tide and high water discharges, set θ1 and θ2 equal to 45̊, and θ3 equal to 20°, after calculation with the equation 3.1-3.3 with the force resistance equal to 500N, the result of mass, M=98.71 kg (Appendix C).

Table 4.5: Force Resistance and Cable Tension when mass is 98.71 kg

theta1	L1	Lc1	L3	Lc3	theta3	Lc2	h2	theta2	Cable tension, T	F
45	2.50	3.54	0.91	2.66	20.00	2.83	2.00	45.00	684.77	500.00
46	2.59	3.60	0.82	2.63	18.18	2.81	1.98	45.35	689.00	561.26
47	2.68	3.67	0.73	2.60	16.26	2.79	1.95	45.76	694.07	626.62
48	2.78	3.74	0.63	2.58	14.22	2.77	1.91	46.25	700.17	696.74
49	2.88	3.81	0.53	2.56	12.06	2.74	1.88	46.82	707.54	772.38
50	2.98	3.89	0.43	2.54	9.77	2.71	1.83	47.48	716.50	854.54
51	3.09	3.97	0.32	2.52	7.35	2.68	1.78	48.27	727.50	944.49
52	3.20	4.06	0.21	2.51	4.80	2.64	1.73	49.21	741.16	1043.97
53	3.32	4.15	0.09	2.50	2.11	2.60	1.66	50.32	758.42	1155.43
54	3.44	4.25	-0.03	2.50	-0.71	2.55	1.58	51.67	780.67	1282.52

When the mass is 98.71 kg, the maximum tension of the cable is 758.42N; the existing force toward the anchorage system is 1155.43N. If choose the mass in 98.71 kg, the strength of the cable must be more than 758.42N. The θ1 maximum can reach 53°, θ2 maximum until 50.32°, θ2 become 2.11°.

For the low tide and high water discharges, set θ1 and θ2 equal to 45̊, and θ3 equal to 25°, after calculation with the equation 3.1-3.3 with the force resistance equal to 500N, the result of mass, M=126.68 kg (Appendix D).

Table 4.6: Force Resistance and Cable Tension when mass is 126.6839 kg

theta1	L1	Lc1	L3	Lc3	theta3	Lc2	h2	theta2	Cable tension, T	F
45	2.50	3.54	1.17	2.76	25.00	2.83	2.00	45.00	878.77	500.00
46	2.59	3.60	1.08	2.72	23.31	2.81	1.98	45.28	883.03	571.69
47	2.68	3.67	0.98	2.69	21.50	2.80	1.96	45.60	888.18	648.07
48	2.78	3.74	0.89	2.65	19.58	2.78	1.93	45.99	894.42	729.88
49	2.88	3.81	0.79	2.62	17.53	2.76	1.90	46.46	901.98	818.01
50	2.98	3.89	0.69	2.59	15.35	2.73	1.86	47.00	911.18	913.53
51	3.09	3.97	0.58	2.57	13.03	2.71	1.82	47.65	922.44	1017.81
52	3.20	4.06	0.47	2.54	10.56	2.67	1.77	48.42	936.35	1132.61
53	3.32	4.15	0.35	2.52	7.93	2.64	1.72	49.34	953.76	1260.30
54	3.44	4.25	0.22	2.51	5.14	2.59	1.65	50.45	975.90	1404.22
55	3.57	4.36	0.10	2.50	2.19	2.55	1.57	51.79	1004.68	1569.35
56	3.71	4.47	-0.04	2.50	-0.93	2.49	1.48	53.44	1043.22	1763.64

When the mass is 126.68 kg, the maximum tension of the cable is 1004.68N; the existing force toward the anchorage system is 1569.35N. If choosing the mass in 126.68 kg, the strength of the cable must be more than 1004.68N. The θ1 maximum can reach 55°, θ2 maximum until 51.79°, θ2 become 2.19°.

For the low tide and high water discharges, set θ1 and θ2 equal to 45̊, and θ3 equal to 30°, after calculation with the equation 3.1-3.3 with the force resistance equal to 500N, the result of mass, M=174.02 kg (Appendix E).

Table 4.7: Force Resistance and Cable Tension when mass is 174.02 kg

theta 1	L1	Lc1	L3	Lc3	theta 3	Lc2	h2	theta2	Cable tension, T	F
45	2.50	3.54	1.44	2.89	30.00	2.83	2.00	45.00	1207.11	500.00
46	2.59	3.60	1.35	2.84	28.45	2.82	1.99	45.20	1211.42	588.63
47	2.68	3.67	1.26	2.80	26.79	2.81	1.97	45.45	1216.74	682.80
48	2.78	3.74	1.17	2.76	25.02	2.79	1.95	45.75	1223.27	783.40
49	2.88	3.81	1.07	2.72	23.12	2.78	1.92	46.11	1231.24	891.48
50	2.98	3.89	0.96	2.68	21.09	2.76	1.90	46.54	1240.99	1008.35
51	3.09	3.97	0.86	2.64	18.90	2.73	1.86	47.06	1252.93	1135.57
52	3.20	4.06	0.74	2.61	16.56	2.71	1.82	47.68	1267.65	1275.11
53	3.32	4.15	0.63	2.58	14.05	2.67	1.77	48.41	1285.96	1429.52
54	3.44	4.25	0.50	2.55	11.36	2.64	1.72	49.30	1309.00	1602.19
55	3.57	4.36	0.37	2.53	8.49	2.60	1.66	50.38	1338.50	1797.83
56	3.71	4.47	0.24	2.51	5.41	2.55	1.58	51.70	1377.10	2023.43
57	3.85	4.59	0.09	2.50	2.15	2.49	1.49	53.33	1429.14	2290.09
58	4.00	4.72	-0.06	2.50	-1.32	2.43	1.38	55.38	1502.29	2617.07

When the mass is 174.07 kg, the maximum tension of the cable is 1429.14N; the existing force toward the anchorage system is 2290.09N. If choosing the mass in 174.07 kg, the strength of the cable must be access 1429.14N. The θ1 maximum can reach 57°, θ2 maximum until 53.33°, θ2 become 2.15°.

For the low tide and high water discharges, set θ1 and θ2 equal to 45̊, and θ3 equal to 35°, after calculation with the equation 3.1-3.3 with the force resistance equal to 500N, the result of mass, M=269.90 kg (Appendix F).

Table 4.8: Force Resistance and Cable Tension when mass is 269.90 kg

theta1	L1	Lc1	L3	Lc3	theta3	Lc2	h2	theta2	cable tension, T	F
45	2.50	3.54	1.75	3.05	35.00	2.83	2.00	45.00	1872.23	500.00
46	2.59	3.60	1.66	3.00	33.61	2.82	1.99	45.14	1876.66	622.25
47	2.68	3.67	1.57	2.95	32.12	2.81	1.98	45.31	1882.36	751.54
48	2.78	3.74	1.47	2.90	30.52	2.80	1.96	45.52	1889.55	889.05
49	2.88	3.81	1.37	2.85	28.80	2.79	1.95	45.79	1898.50	1036.20
50	2.98	3.89	1.27	2.80	26.95	2.78	1.92	46.11	1909.57	1194.67
51	3.09	3.97	1.16	2.76	24.95	2.76	1.90	46.50	1923.24	1366.54
52	3.20	4.06	1.05	2.71	22.80	2.74	1.87	46.97	1940.13	1554.31
53	3.32	4.15	0.93	2.67	20.46	2.71	1.83	47.54	1961.10	1761.15
54	3.44	4.25	0.81	2.63	17.94	2.68	1.79	48.23	1987.34	1991.08
55	3.57	4.36	0.68	2.59	15.22	2.65	1.73	49.06	2020.55	2249.41
56	3.71	4.47	0.54	2.56	12.28	2.61	1.67	50.09	2063.27	2543.47
57	3.85	4.59	0.40	2.53	9.11	2.56	1.60	51.34	2119.42	2883.90
58	4.00	4.72	0.25	2.51	5.70	2.51	1.51	52.91	2195.45	3287.33
59	4.16	4.85	0.09	2.50	2.06	2.44	1.41	54.91	2302.72	3782.28
60	4.33	5.00	-0.08	2.50	-1.82	2.37	1.27	57.49	2463.55	4423.80

When the mass is 269.90 kg, the maximum tension of the cable is 2302.72N; the existing force toward the anchorage system is 3782.28N. If choosing the mass in 269.90 kg, the strength of the cable must be access 2302.72N. The θ1 maximum can reach 59°, θ2 maximum until 54.91°, θ2 become 2.50°.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

As the closing of the study, the last chapter presented the conclusions, recommendations and the limitation of the study. The first section is about the conclusion of the overall of the study. For the recommendations, the researcher will state out the implement for the improvement of the floats system and anchorage. Moreover, there is some suggestion to other researchers as guideline for their future relevant study. Lastly, the researcher would point out some limitation faced along the process to conduct the study from the beginning to the end.

5.1 Conclusions

In conclusion, the studies shows fiberglass is the most suitable material for the float system comparing to other construction materials. The material is easily repaired and has chemical resistance of corrosive and leaking actions of acid in the water environment.

The conceptual floats are designed based on the literature and experiment in the laboratory. The results showed that catamaran float is preferable. The large float of catamaran type has to be divided into a few numbers of small floats for maintenance handling.

Finally, the two types of anchorage system as mentioned previously shows a very promising results which suit to the river current of 1.3m/s to 2.7m/s and the fluctuation of water level of the river. They are very suitable for the In-stream Vertical Micro Hydro Turbine.

5.2 Recommendations and Limitations

Although the researches presented here have demonstrated the effectiveness of the float and anchorage system for IVMHT. It could be further developed in a number of ways:

I. Extending the experiment in the real situation. The proposed experiment should adopt to the murky condition and muddy riverbed which could decrease the holding resistance of the anchor.

II. Extending the experiment in the present of woody debris. In principle, the proposed project is to be implemented in a river situated in remote area. There is clearly much work to be done in the area of handling IVMHT systems in the extreme conditions. Woody debris is a natural component of the river systems. This debris can vary in size from small twigs to whole trees. IVMHT float and anchorage systems has to perceive this risk.

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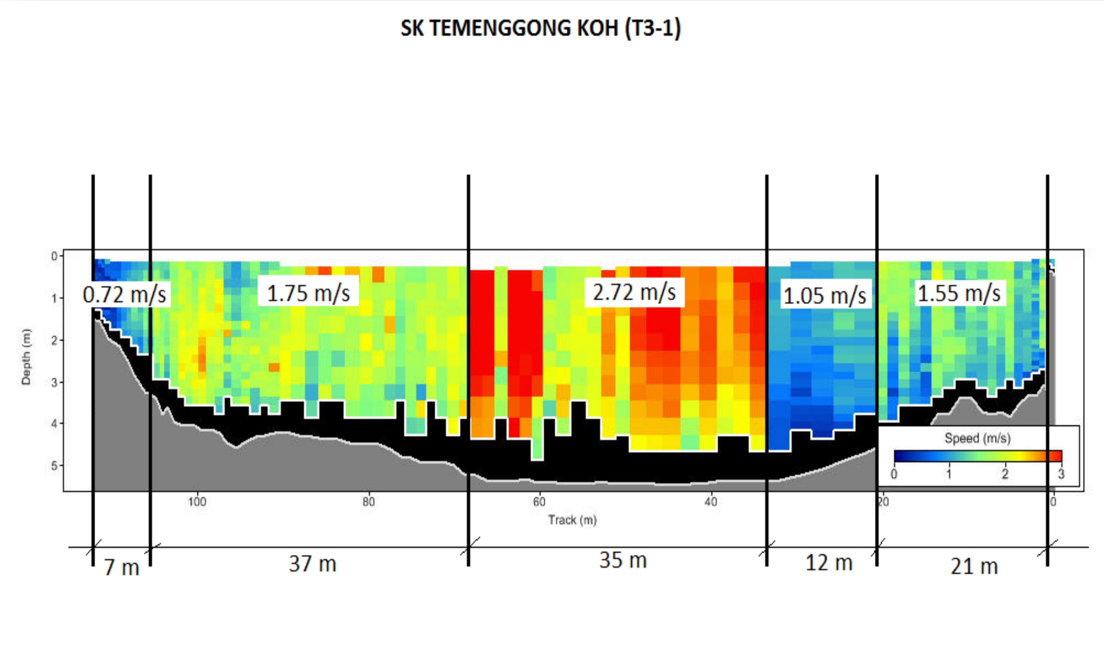
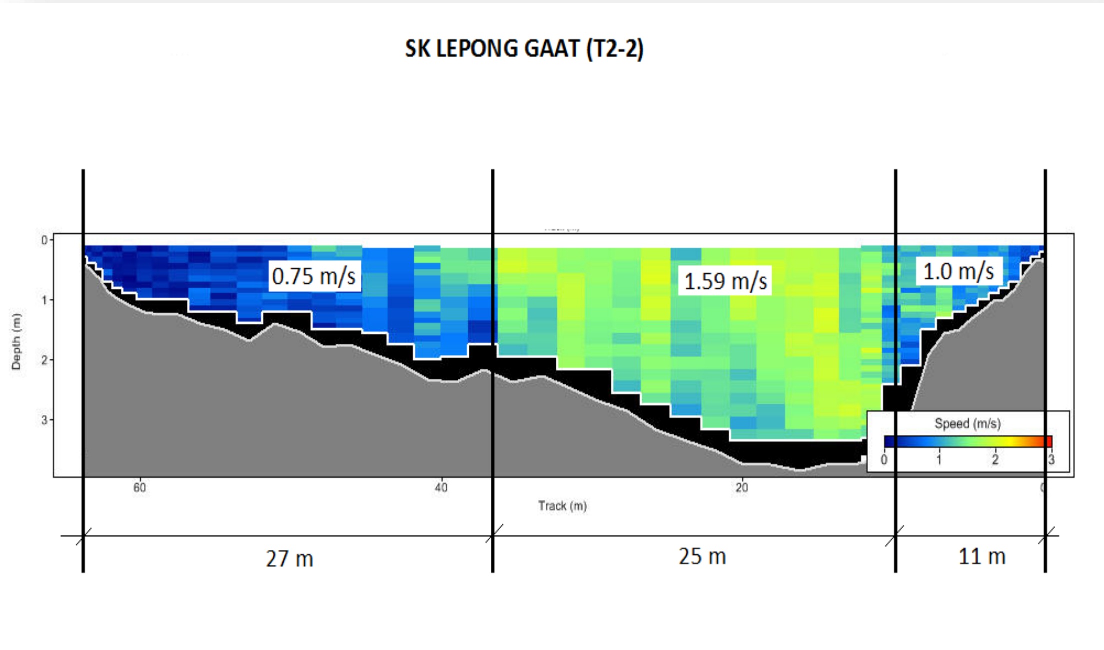
APPENDIX A

Water velocity at SK Temenggong Koh and SK Lepong Gaat





- Average velocity form 1.3 m/s to 2.72 m/s.

APPENDIX B

Buoyant Forces:

The Steps

- Obtain the volume of the object on which you wish to calculate the bouyant force. We will call this value for the volume "V."

- Determine what percentage (based on volume) of the object will be submerged in the water.

- Convert this percentage to a decimal number. We will call this value "v." For example; if 100 percent of the object is to be submerged, v= 1.0 . If 50 percent of the object is to be submersed, v= 0.50 .

- Substitute this value into the equation for buoyant force:

  FB = (V)(v) x (SPH2O)

  Where FB = buoyant force and SPH2O = Specific gravity of water (considered constant at 62.4 lb per cubic foot).

- Multiply V by v, and then multiply by 62.4 in order to get the value for the buoyant force, expressed in pounds. Consider the following example of a 2-foot by 2-foot by 2 foot cube to be submersed 25 percent of the way in water.

  V = 2*2*2 = 8 cubic feet

  v = 25% = 0.25

  SPH2O = 62.4 pounds per cubic foot

  FB = 8 *0.25 * 62.4 = 124.8 pounds = 56.6 kg

The calculations of buoyancy for Conceptual Pontoon, which Length 4 feet, height 1 foot and width 1 feet:

When submersed 25%,

- v=0.25
- FB = (V)(v) x (SPH2O)
- FB =(4ft^3)(0.25)x(62.4)
- FB = 62.4 pounds= 28.3 kg

When submersed 50%

- v=0.50
- FB = (V)(v) x (SPH2O)
- FB =(4ft^3)(0.50)x(62.4)
- FB = 124.8 pounds= 56.6 kg

When submersed 75%

- v=0.75
- FB = (V)(v) x (SPH2O)
- FB =(4ft^3)(0.75)x(62.4)
- FB = 187.2 pounds= 84.91 kg

APPENDIX C

Set

h1	2.50	m
h2	2.00	m
L1	2.50	m
L2	4.00	m

Find theta1

theta1 45 deg

Set

theta3 20 deg

Find L3

L3 0.91 m

Calculate theta2 and alpha

alpha 0.365087

theta2 45 deg

Calculate drag force

F 500 N

Find require W

W 968.4096 N

Mass

m 98.71657 kg

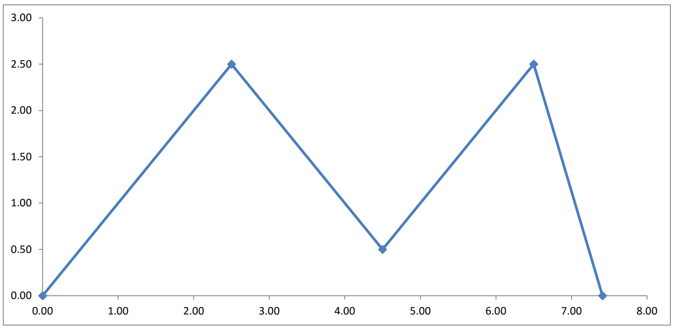
Cable profile

x	y
0.00	0.00
2.50	2.50
4.50	0.50
6.50	2.50
7.41	0.00

Lc1	3.54
Lc2	2.83
Lc3	2.66

Total Cable Length

Lc 11.85 m



Determine the cable profile when the water velocity increases

ITERATIVE PROCESS

when water velocity increases, drag force increase as well

F 300 N

From previous calculation

h1 2.50 m
L2 4.00 m
W 968.4096 N

Find suitable values

theta1	L1	Lc1	L3	Lc3	theta3	Lc2	h2	theta2	cable tension, T	F
45	2.50	3.54	0.91	2.66	20.00	2.83	2.00	45.00	684.77	500.00
46	2.59	3.60	0.82	2.63	18.18	2.81	1.98	45.35	689.00	561.26
47	2.68	3.67	0.73	2.60	16.26	2.79	1.95	45.76	694.07	626.62
48	2.78	3.74	0.63	2.58	14.22	2.77	1.91	46.25	700.17	696.74
49	2.88	3.81	0.53	2.56	12.06	2.74	1.88	46.82	707.54	772.38
50	2.98	3.89	0.43	2.54	9.77	2.71	1.83	47.48	716.50	854.54
51	3.09	3.97	0.32	2.52	7.35	2.68	1.78	48.27	727.50	944.49
52	3.20	4.06	0.21	2.51	4.80	2.64	1.73	49.21	741.16	1043.97
53	3.32	4.15	0.09	2.50	2.11	2.60	1.66	50.32	758.42	1155.43
54	3.44	4.25	-0.03	2.50	-0.71	2.55	1.58	51.67	780.67	1282.52
55	3.57	4.36	-0.16	2.51	-3.67	2.49	1.49	53.30	810.17	1431.09
56	3.71	4.47	-0.30	2.52	-6.76	2.43	1.38	55.31	850.83	1611.13
57	3.85	4.59	-0.44	2.54	-9.98	2.36	1.26	57.85	910.02	1841.71
58	4.00	4.72	-0.59	2.57	-13.30	2.28	1.10	61.16	1003.90	2164.56
59	4.16	4.85	-0.75	2.61	-16.72	2.19	0.90	65.71	1177.05	2694.95
60	4.33	5.00	-0.92	2.66	-20.21	2.09	0.62	72.73	1630.98	3951.69
61	4.51	5.16	-1.10	2.73	-23.75	1.98	#NUM!	#NUM!	#NUM!	#NUM!
62	4.70	5.33	-1.29	2.81	-27.33	1.86	#NUM!	#NUM!	#NUM!	#NUM!
63	4.91	5.51	-1.50	2.91	-30.91	1.72	#NUM!	#NUM!	#NUM!	#NUM!
64	5.13	5.70	-1.72	3.03	-34.46	1.56	#NUM!	#NUM!	#NUM!	#NUM!
65	5.36	5.92	-1.95	3.17	-37.97	1.38	#NUM!	#NUM!	#NUM!	#NUM!
66	5.62	6.15	-2.21	3.33	-41.41	1.19	#NUM!	#NUM!	#NUM!	#NUM!
67	5.89	6.40	-2.48	3.52	-44.77	0.97	#NUM!	#NUM!	#NUM!	#NUM!
68	6.19	6.67	-2.78	3.74	-48.01	0.72	#NUM!	#NUM!	#NUM!	#NUM!
69	6.51	6.98	-3.10	3.98	-51.14	0.45	#NUM!	#NUM!	#NUM!	#NUM!
70	6.87	7.31	-3.46	4.27	-54.14	0.14	#NUM!	#NUM!	#NUM!	#NUM!
71	7.26	7.68	-3.85	4.59	-57.01	-0.21	#NUM!	#NUM!	#NUM!	#NUM!
72	7.69	8.09	-4.28	4.96	-59.74	-0.60	#NUM!	#NUM!	#NUM!	#NUM!
73	8.18	8.55	-4.77	5.38	-62.33	-1.04	#NUM!	#NUM!	#NUM!	#NUM!
74	8.72	9.07	-5.31	5.87	-64.78	-1.54	#NUM!	#NUM!	#NUM!	#NUM!
75	9.33	9.66	-5.92	6.43	-67.11	-2.12	0.69	-70.91	1480.33	5587.22

APPENDIX D

Set

h1	2.50	m
h2	2.00	m
L1	2.50	m
L2	4.00	m

Find theta1

theta1 45 deg

Set

theta3 25 deg

Find L3

L3 1.17 m

Calculate theta2 and alpha

alpha 0.284489

theta2 45 deg

Calculate drag force

F 500 N

Find require W

W 1242.769 N

Mass

m 126.6839 kg

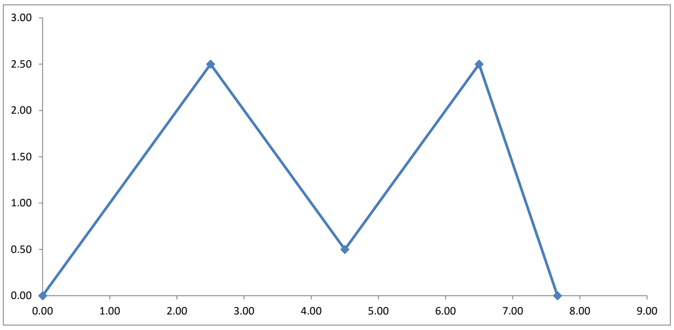
Cable profile

x	y
0.00	0.00
2.50	2.50
4.50	0.50
6.50	2.50
7.67	0.00

Lc1	3.54
Lc2	2.83
Lc3	2.76

Total Cable Length

Lc 11.95 m



Determine the cable profile when the water velocity increases

ITERATIVE PROCESS

when water velocity increases, drag force increase as well

F 300 N

From previous calculation

h1	2.50	m
L2	4.00	m
W	1242.769	N

Find suitable values

theta1	L1	Lc1	L3	Lc3	theta3	Lc2	h2	theta2	cable tension, T	F
45	2.50	3.54	1.17	2.76	25.00	2.83	2.00	45.00	878.77	500.00
46	2.59	3.60	1.08	2.72	23.31	2.81	1.98	45.28	883.03	571.69
47	2.68	3.67	0.98	2.69	21.50	2.80	1.96	45.60	888.18	648.07
48	2.78	3.74	0.89	2.65	19.58	2.78	1.93	45.99	894.42	729.88
49	2.88	3.81	0.79	2.62	17.53	2.76	1.90	46.46	901.98	818.01
50	2.98	3.89	0.69	2.59	15.35	2.73	1.86	47.00	911.18	913.53
51	3.09	3.97	0.58	2.57	13.03	2.71	1.82	47.65	922.44	1017.81
52	3.20	4.06	0.47	2.54	10.56	2.67	1.77	48.42	936.35	1132.61
53	3.32	4.15	0.35	2.52	7.93	2.64	1.72	49.34	953.76	1260.30
54	3.44	4.25	0.22	2.51	5.14	2.59	1.65	50.45	975.90	1404.22
55	3.57	4.36	0.10	2.50	2.19	2.55	1.57	51.79	1004.68	1569.35
56	3.71	4.47	-0.04	2.50	-0.93	2.49	1.48	53.44	1043.22	1763.64
57	3.85	4.59	-0.18	2.51	-4.21	2.43	1.37	55.50	1096.94	2000.89
58	4.00	4.72	-0.34	2.52	-7.63	2.36	1.24	58.12	1176.41	2307.84
59	4.16	4.85	-0.49	2.55	-11.20	2.27	1.08	61.58	1305.45	2745.02
60	4.33	5.00	-0.66	2.59	-14.88	2.18	0.87	66.43	1554.01	3489.85
61	4.51	5.16	-0.84	2.64	-18.66	2.08	0.56	74.28	2293.40	5479.41
62	4.70	5.33	-1.04	2.71	-22.51	1.96	#NUM!	#NUM!	#NUM!	#NUM!
63	4.91	5.51	-1.24	2.79	-26.40	1.83	#NUM!	#NUM!	#NUM!	#NUM!
64	5.13	5.70	-1.46	2.90	-30.28	1.68	#NUM!	#NUM!	#NUM!	#NUM!
65	5.36	5.92	-1.70	3.02	-34.15	1.51	#NUM!	#NUM!	#NUM!	#NUM!
66	5.62	6.15	-1.95	3.17	-37.94	1.32	#NUM!	#NUM!	#NUM!	#NUM!
67	5.89	6.40	-2.22	3.35	-41.65	1.10	#NUM!	#NUM!	#NUM!	#NUM!
68	6.19	6.67	-2.52	3.55	-45.25	0.86	#NUM!	#NUM!	#NUM!	#NUM!
69	6.51	6.98	-2.85	3.79	-48.71	0.59	#NUM!	#NUM!	#NUM!	#NUM!
70	6.87	7.31	-3.20	4.06	-52.03	0.29	#NUM!	#NUM!	#NUM!	#NUM!
71	7.26	7.68	-3.59	4.38	-55.18	-0.05	#NUM!	#NUM!	#NUM!	#NUM!
72	7.69	8.09	-4.03	4.74	-58.18	-0.44	#NUM!	#NUM!	#NUM!	#NUM!
73	8.18	8.55	-4.51	5.16	-61.01	-0.88	#NUM!	#NUM!	#NUM!	#NUM!
74	8.72	9.07	-5.05	5.64	-63.67	-1.38	#NUM!	#NUM!	#NUM!	#NUM!
75	9.33	9.66	-5.66	6.19	-66.19	-1.95	#NUM!	#NUM!	#NUM!	#NUM!

APPENDIX E

Set

h1	2.50	m
h2	2.00	m
L1	2.50	m
L2	4.00	m

Find theta1

theta1 45 deg

Set

theta3 30 deg

Find L3

L3 1.44 m

Calculate theta2 and alpha

alpha 0.207107

theta2 45 deg

Calculate drag force

F 500 N

Find require W

W 1707.107 N

Mass

m 174.017 kg

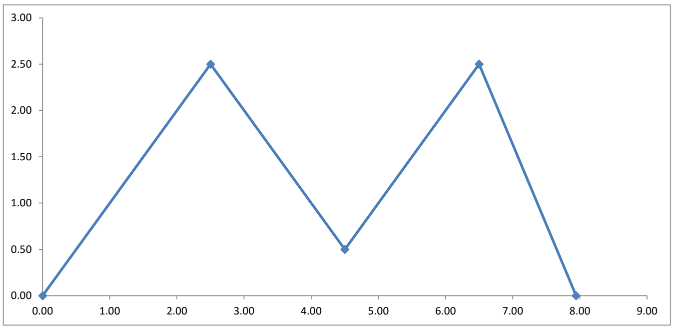
Cable profile

x	y
0.00	0.00
2.50	2.50
4.50	0.50
6.50	2.50
7.94	0.00

Lc1	3.54
Lc2	2.83
Lc3	2.89

Total Cable Length

Lc 12.08 m



Determine the cable profile when the water velocity increases

ITERATIVE PROCESS

when water velocity increases, drag force increase as well

F 300 N

From previous calculation

h1	2.50	m
L2	4.00	m
W	1707.107	N

Find suitable values

theta1	L1	Lc1	L3	Lc3	theta3	Lc2	h2	theta2	cable tension, T	F
45	2.50	3.54	1.44	2.89	30.00	2.83	2.00	45.00	1207.11	500.00
46	2.59	3.60	1.35	2.84	28.45	2.82	1.99	45.20	1211.42	588.63
47	2.68	3.67	1.26	2.80	26.79	2.81	1.97	45.45	1216.74	682.80
48	2.78	3.74	1.17	2.76	25.02	2.79	1.95	45.75	1223.27	783.40
49	2.88	3.81	1.07	2.72	23.12	2.78	1.92	46.11	1231.24	891.48
50	2.98	3.89	0.96	2.68	21.09	2.76	1.90	46.54	1240.99	1008.35
51	3.09	3.97	0.86	2.64	18.90	2.73	1.86	47.06	1252.93	1135.57
52	3.20	4.06	0.74	2.61	16.56	2.71	1.82	47.68	1267.65	1275.11
53	3.32	4.15	0.63	2.58	14.05	2.67	1.77	48.41	1285.96	1429.52
54	3.44	4.25	0.50	2.55	11.36	2.64	1.72	49.30	1309.00	1602.19
55	3.57	4.36	0.37	2.53	8.49	2.60	1.66	50.38	1338.50	1797.83
56	3.71	4.47	0.24	2.51	5.41	2.55	1.58	51.70	1377.10	2023.43
57	3.85	4.59	0.09	2.50	2.15	2.49	1.49	53.33	1429.14	2290.09
58	4.00	4.72	-0.06	2.50	-1.32	2.43	1.38	55.38	1502.29	2617.07
59	4.16	4.85	-0.22	2.51	-4.97	2.36	1.25	58.02	1611.61	3041.98
60	4.33	5.00	-0.39	2.53	-8.79	2.27	1.08	61.55	1791.73	3651.21
61	4.51	5.16	-0.57	2.56	-12.77	2.18	0.87	66.58	2147.69	4706.48
62	4.70	5.33	-0.76	2.61	-16.88	2.07	0.54	74.98	3293.63	7728.55
63	4.91	5.51	-0.96	2.68	-21.07	1.95	#NUM!	#NUM!	#NUM!	#NUM!
64	5.13	5.70	-1.18	2.77	-25.31	1.81	#NUM!	#NUM!	#NUM!	#NUM!
65	5.36	5.92	-1.42	2.87	-29.56	1.64	#NUM!	#NUM!	#NUM!	#NUM!
66	5.62	6.15	-1.67	3.01	-33.77	1.46	#NUM!	#NUM!	#NUM!	#NUM!
67	5.89	6.40	-1.95	3.17	-37.90	1.26	#NUM!	#NUM!	#NUM!	#NUM!
68	6.19	6.67	-2.24	3.36	-41.92	1.02	#NUM!	#NUM!	#NUM!	#NUM!
69	6.51	6.98	-2.57	3.58	-45.78	0.76	#NUM!	#NUM!	#NUM!	#NUM!
70	6.87	7.31	-2.93	3.85	-49.48	0.46	#NUM!	#NUM!	#NUM!	#NUM!
71	7.26	7.68	-3.32	4.15	-53.00	0.12	#NUM!	#NUM!	#NUM!	#NUM!
72	7.69	8.09	-3.75	4.51	-56.32	-0.26	#NUM!	#NUM!	#NUM!	#NUM!
73	8.18	8.55	-4.23	4.92	-59.44	-0.69	#NUM!	#NUM!	#NUM!	#NUM!
74	8.72	9.07	-4.78	5.39	-62.37	-1.19	#NUM!	#NUM!	#NUM!	#NUM!
75	9.33	9.66	-5.39	5.94	-65.10	-1.76	#NUM!	#NUM!	#NUM!	#NUM!

APPENDIX F

Set

h1	2.50	m
h2	2.00	m
L1	2.50	m
L2	4.00	m

Find theta1

theta1 45 deg

Set

theta3 35 deg

Find L3

L3 1.75 m

Calculate theta2 and alpha

alpha 0.13353

theta2 45 deg

Calculate drag force

F 500 N

Find require W

W 2647.738 N

Mass

m 269.902 kg

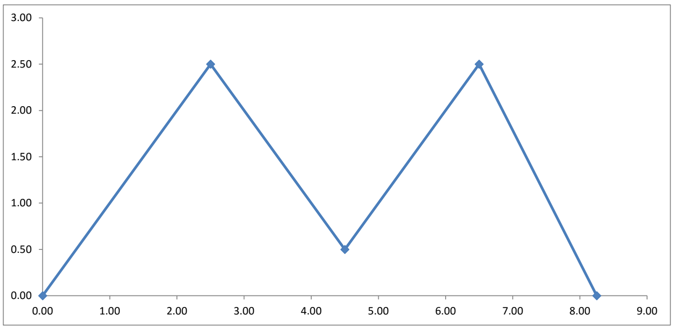
Cable profile

x	y
0.00	0.00
2.50	2.50
4.50	0.50
6.50	2.50
8.25	0.00

Lc1	3.54
Lc2	2.83
Lc3	3.05

Total Cable Length

Lc 12.24 m



Determine the cable profile when the water velocity increases

ITERATIVE PROCESS

when water velocity increases, drag force increase as well

F 300 N

From previous calculation

h1	2.50	m
L2	4.00	m
W	2647.738	N

Find suitable values

theta1	L1	Lc1	L3	Lc3	theta3	Lc2	h2	theta2	cable tension, T	F
45	2.50	3.54	1.75	3.05	35.00	2.83	2.00	45.00	1872.23	500.00
46	2.59	3.60	1.66	3.00	33.61	2.82	1.99	45.14	1876.66	622.25
47	2.68	3.67	1.57	2.95	32.12	2.81	1.98	45.31	1882.36	751.54
48	2.78	3.74	1.47	2.90	30.52	2.80	1.96	45.52	1889.55	889.05
49	2.88	3.81	1.37	2.85	28.80	2.79	1.95	45.79	1898.50	1036.20
50	2.98	3.89	1.27	2.80	26.95	2.78	1.92	46.11	1909.57	1194.67
51	3.09	3.97	1.16	2.76	24.95	2.76	1.90	46.50	1923.24	1366.54
52	3.20	4.06	1.05	2.71	22.80	2.74	1.87	46.97	1940.13	1554.31
53	3.32	4.15	0.93	2.67	20.46	2.71	1.83	47.54	1961.10	1761.15
54	3.44	4.25	0.81	2.63	17.94	2.68	1.79	48.23	1987.34	1991.08
55	3.57	4.36	0.68	2.59	15.22	2.65	1.73	49.06	2020.55	2249.41
56	3.71	4.47	0.54	2.56	12.28	2.61	1.67	50.09	2063.27	2543.47
57	3.85	4.59	0.40	2.53	9.11	2.56	1.60	51.34	2119.42	2883.90
58	4.00	4.72	0.25	2.51	5.70	2.51	1.51	52.91	2195.45	3287.33
59	4.16	4.85	0.09	2.50	2.06	2.44	1.41	54.91	2302.72	3782.28
60	4.33	5.00	-0.08	2.50	-1.82	2.37	1.27	57.49	2463.55	4423.80
61	4.51	5.16	-0.26	2.51	-5.93	2.29	1.11	60.98	2729.14	5337.68
62	4.70	5.33	-0.45	2.54	-10.23	2.19	0.89	65.99	3253.97	6902.29
63	4.91	5.51	-0.66	2.58	-14.70	2.08	0.56	74.40	4923.22	11272.38
64	5.13	5.70	-0.88	2.65	-19.29	1.95	#NUM!	#NUM!	#NUM!	#NUM!
65	5.36	5.92	-1.11	2.74	-23.96	1.80	#NUM!	#NUM!	#NUM!	#NUM!
66	5.62	6.15	-1.36	2.85	-28.63	1.62	#NUM!	#NUM!	#NUM!	#NUM!
67	5.89	6.40	-1.64	2.99	-33.25	1.43	#NUM!	#NUM!	#NUM!	#NUM!
68	6.19	6.67	-1.94	3.16	-37.77	1.20	#NUM!	#NUM!	#NUM!	#NUM!
69	6.51	6.98	-2.26	3.37	-42.14	0.95	#NUM!	#NUM!	#NUM!	#NUM!
70	6.87	7.31	-2.62	3.62	-46.32	0.66	#NUM!	#NUM!	#NUM!	#NUM!
71	7.26	7.68	-3.01	3.91	-50.29	0.33	#NUM!	#NUM!	#NUM!	#NUM!
72	7.69	8.09	-3.44	4.26	-54.02	-0.05	#NUM!	#NUM!	#NUM!	#NUM!
73	8.18	8.55	-3.93	4.65	-57.52	-0.48	#NUM!	#NUM!	#NUM!	#NUM!
74	8.72	9.07	-4.47	5.12	-60.77	-0.97	#NUM!	#NUM!	#NUM!	#NUM!
75	9.33	9.66	-5.08	5.66	-63.80	-1.54	#NUM!	#NUM!	#NUM!	#NUM!

APPENDIX G

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Kuching, Sarawak, Malaysia

JARIMAS TURBINE: CONCEPTUAL ANCHORAGE SYSTEM

A.Baharun, A.A.Abdullah, C.C.Bong,and R.Bustami

Abstract— **This paper presents the conceptual anchorage system that will be use to hold a floating in-stream horizontal turbine. The turbine will be floating on one of the rivers in Sarawak rural areas with intention to supply electricity to nearby school. Anchorage system is one of the integral elements in this project to ensure the system is sustainable. A survey has been done to find a potential site with river that has strong water flow and near to school. Hence, the objective of this paper is to review and discuss different types of anchoring system. The design constraints are the anchorage system must not consist of fixed structure, any sort of piling must be avoided, it must not obstruct the river traffic/user and it must also be able to accommodate the water tide. All of these constraints need to be considered in order to select the most suitable anchorage mooring system for the JARIMAS project. In the end, the most suitable anchorage mooring system is finally discussed and proposed.**

Keywords: **floating in-stream Horizontal Turbine, electric, anchorage/mooring system**

I. Introduction

THE anchors achieve holding power by "hooking" into the sea/riverbed, via sheer mass. The anchors depend on their ability to bury themselves in the river bed to attain their holding power. So, they need a certain amount of weight to sufficiently start the burying process, and a near horizontal pull. This is where chain weight and the catenary curve are vital. The chain must lead from the anchor horizontally or parallel with the bottom, even under strain. Any lead upwards decreases the anchors holding power, the loss depending upon the angle and type of anchor. Most anchors will break out of the ground once the angle of pull reaches about 10 degrees from the horizontal [1],[2]. The essential features of an efficient anchor are as follows:

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1. It must have sufficient weight for initial penetration.
2. It must bury itself deeply when subjected to a horizontal pull.
3. Once buried it must have the greatest possible resistance to movement in the direction of pull.
4. It must remain rotationally stable even when pulled through the sea bed.
5. It must break out of the ground easily when pulled upwards.

The basic anchoring consists of determining the location, dropping the anchor, laying out the scope, setting the hook, and assessing where the float ends up. The float will seek a location which is sufficiently protected; has suitable holding ground, enough depth at low time and enough room for the float to swing. The location to drop the anchor should be approached from down wind or down current, whichever is stronger. As the chosen spot is approached, the vessel should be stopped or even beginning to drift back. The anchor should be lowered quickly but under control until it is on the bottom [3]. The vessel/float should continue to drift back, and the cable should be veered out under control so it will be relatively straight. Once the desired scope is laid out, the vessel/float should be gently forced astern. A hand on the anchor line may telegraph a series of jerks and jolts, indicating the anchor are dragging, or a smooth tension indicative of digging in. As the anchor begins to dig in and resist backward force, the engine may be throttled up to get a thorough set. If the anchor continues to drag, or sets after having dragged too far, it should be retrieved and moved back to the desired position (or another location chosen.). With the anchor set in the correct location, everything should be reconsidered [4].

A. Holding Conditions

The holding power of any anchor differs with its size, weight, and with the bottom condition, and is not a fixed value. The sea/river bed is far from regular even within a relatively small area and anchor performance is affected not only by the nature of the bottom- sand, mud, silt etc. But also by local inclusions of rocks, scrap metal and the like. Compared with sand, soft mud lessens holding power by about a third, whereas firm clay can increase it by as much as two thirds. Once an anchor own dead weight has caused it to initially penetrate, as it moves horizontally so it continues to bury itself deeper. If it is too light to effect this initial penetration it will glide over the surface. Having embedded itself, resistance to movement through the river bed is related to the amount of material that would be removed by the anchor if it pulled out.

In principle an anchor with the largest effective fluke (blade) area has the highest holding power, subject of course to it being of sufficient strength. Effective fluke area varies with the angle that the fluke takes up in operation. Too shallow an angle reduces the effective area and the holding power, whereas too steep an angle prevents the anchor from fully penetrating the river bed. Such an anchor develops insufficient downward pressure and will plough up the surface without digging in any deeper. Obviously, material that is more compacted is more difficult to displace, so an anchor also needs to be streamlined to achieve penetration without unnecessary ground disturbance. An anchor which digs deeper will again be in contact with more compacted material and have proportionately greater resistance to movement. Once it has fully penetrated, the actual weight of an anchor has very little effect on its holding power [2]-[4].

Another method to increase holding power is to drop the anchor on an up slope. This might be a sand bar or an area where the depth gets shallower from a deeper area[5]. Sentinel and kellet (Fig. 1) can also be used to increase the holding power of the anchor. The sentinel moves down the anchor line, forcing the rope down with it, thus providing a more horizontal pull on the anchor [6].

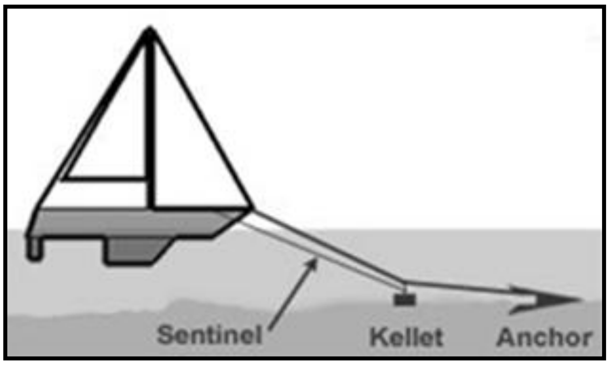

Fig.1.Sentinel and Kellet [5].

B. Force Exerted

The anchorage system are largely dependent on three main factors- wind drag, current drag and wave loading [4],[7]-[9], each of which is in itself immensely variable.

1. Wind drag

This is the load resulting from the combination of wind pressure and suction on the hull above water, the superstructure and the rigging. Calculating a meaningful figure is complex. Aerodynamic loads increase with the square of the wind velocity. Effectively, this means that if the wind speed doubles the wind force acting on the boat goes up four times. If it trebles, it goes up nine times. Having arrived at a figure which itself is not so easy when it is realized that a float rigging can contribute up to a third of the total air load it then becomes difficult. The figure so far is based on frontal area (cross section facing the wind), but takes no account of tidal current or waves causing swinging at anchor [4].

2. Current drag

In most instances current drag is a relatively minor load although it can be significant if the boat has a very large area below water or is anchored in, or even across, a strong current.

3. Wave action load

Wave action is likely to impose by far the highest loads on a boat and her ground tackle. She will heave, pitch, rear and yaw, but if she is allowed ample freedom the actual loads applied to the anchor will be modest. The freedom is achieved through weight providing resilience in the mooring system and take into account these factors and conditions:

1. Maximum depth of water.
2. Rise and fall of tide.
3. Maximum flow speed.
4. Prevailing wind and strength.
5. Abnormal conditions of wind and river flow.
6. Site conditions- sheltered or exposed.
7. Type of bottom- sand, mud, shale etc.
8. Type, size and number of float to be moored.

The remainder of the paper is organized as follow, Section II, The Anchoring and Mooring. Section III discussed on the JARIMAS conceptual anchorage system. Section IV provides concluding remarks.

II. THE ANCHORING AND MOORING

A mooring is a buoy connected to an extremely heavy anchor or weight. A mooring consists of an anchor, a chain, a mooring pendant, and a buoy [10]. Usually, each mooring has a distinctive mark so it will appear as a signal for people.

A. Catenary anchor-leg mooring systems

This system as shown in Fig. 2, includes a buoy which is designed to dive at an angle downwardly through large river flow or swells during bad weather. The buoy has a circular or wedge shape to reduce its drag coefficient so that undue stresses will not be placed on the buoy's anchor chains as it dives through the water [11], [12].

The advantage of using these buoys is that they do not require construction of a costly jetty or dock for mooring the floats or ship. However, since loading facilities are often located in unprotected waters, the buoys must be designed to accommodate and withstand great environmental forces produced by large swells or waves, high winds and/or strong currents. These environmental forces can become particularly fierce when the buoy is placed in a very shallow location because the waves tend to build up and become very steep before they break in the shallow water [13].

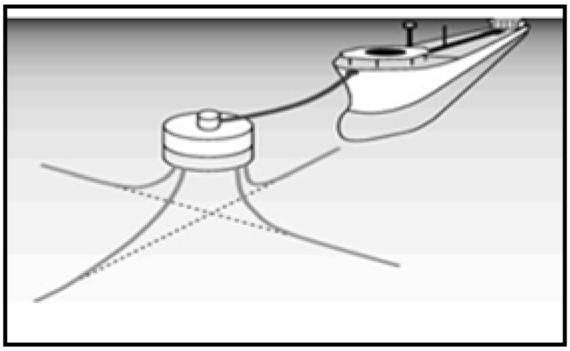

Fig. 2. Multiple anchor-leg mooring [14]

B. Single anchor leg mooring system

The floating buoy (Fig. 3) is anchored to the riverbed by one single anchor leg, connected to a base type anchor point (ballasted and/ or piled). The buoy can be attached to the base by either one single chain or by a chain or tubular column [15],[16]; this can be seen in the figure below.

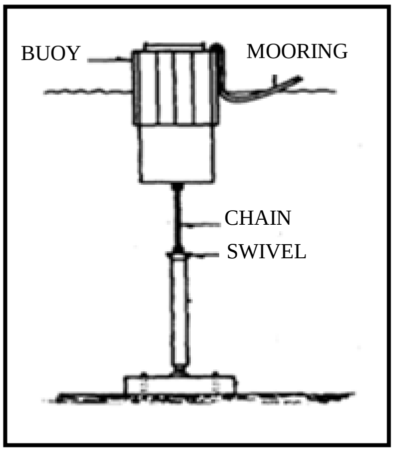

Fig. 3. Single anchor leg mooring [16]

C. Column Mooring (Support Frame)

This system is a fixed structure (Fig. 4). It is strong and durable; it can withstand large swells or waves, high winds and strong currents. It is suitable for high stream river and for bad environment conditions.

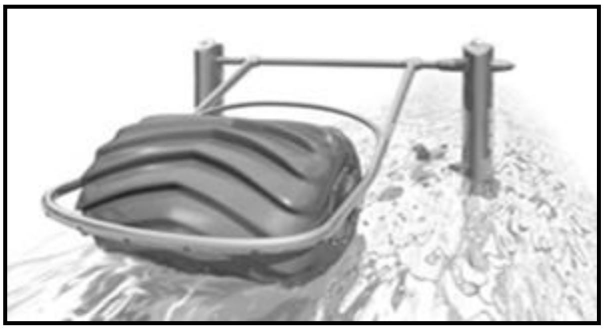

Fig. 4. Column Mooring [17]

D. Trot Anchor mooring system

A trot mooring in Fig. 5 consists of a long and heavy ground chain anchored at each end, with risers at intervals so that a single assembly serves to moor a number of boats. Additional anchors may be required to hold the ground chain in position, particularly if the main current flow is across the line of the chain. Anchors are often laid on triangular bridles themselves attached to the main ground chain, so that any imposed stress is redistributed to two or more anchorage points. The usual design principle applies equally to trot moorings in that sufficient resilience must be built in to accommodate shock loads [3], [18].

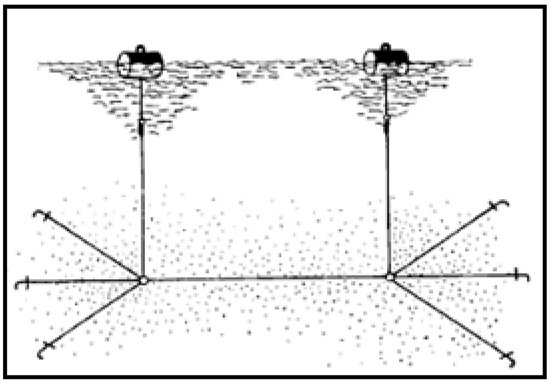

Fig. 5. Trot Mooring [18]

III. JARIMAS CONCEPTUAL ANCHORING AND MOORING

There are two conceptual anchorage and mooring system for JARIMAS. There are JARIMAS Anchorage System 1 (JAS1) and JARIMAS Anchorage System 2 (JAS2).

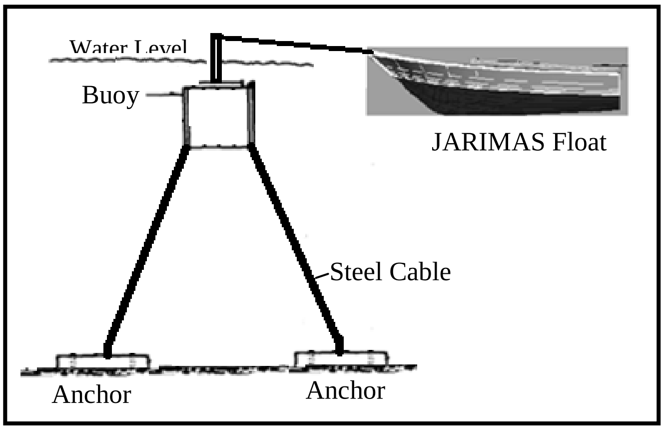

Fig. 6. JARIMAS Anchorage System 1 (JAS1)

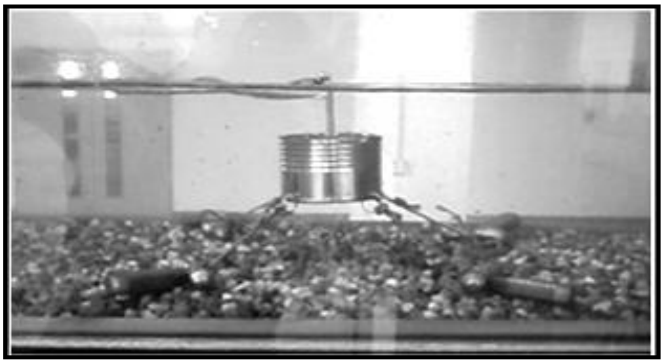

Fig. 7. Submerged Buoy Used in JAS1

The JAS1 (Fig.6-7) is consists of cylindrical buoy attached to four anchors by using steel cable. JARIMAS turbine connects to the mooring by using steel cable. The buoy will float when the water level is low and submerged when the water level is high. The cylindrical shape of the buoy is selected to reduce the magnitude of the drag force when it is submerged into the river. A laboratory test had been done by using an open flow channel in the Civil Engineering Laboratory, Faculty of Engineering, UNIMAS to observe the behavior and practicality of this system. By observation, this system could provide a strong anchoring for the JARIMAS turbine, it can accommodate the rise and fall of tide and it is a stable system. However, when the buoy submerged, the river flow at the downstream will become turbulence. This phenomenon becomes apparent with the size and shape of the buoy. If the size of the buoy is relatively small than the river cross-section, these phenomena could be reduced. Furthermore, the shape of the buoy also plays important role in reducing the turbulence, aerodynamic shape is preferred. This system has huge potential to be used as the anchoring for the JARIMAS turbine since the turbine are located in unprotected area and it must be able to withstand fierce environmental force produced by large waves, high winds and strong currents.

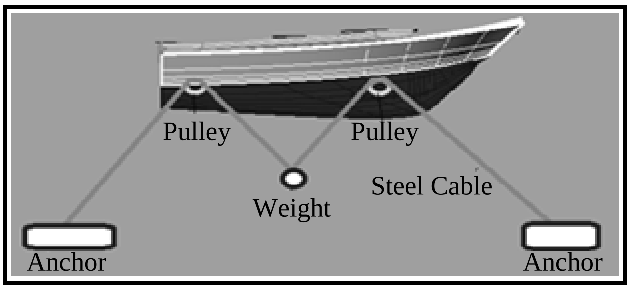

Fig. 8. JARIMAS Anchorage System 2 (JAS2)

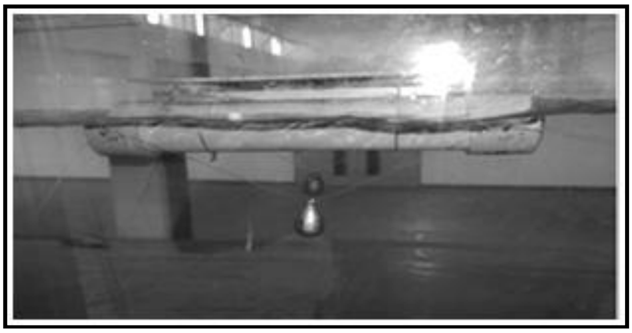
Fig. 9. Laboratory emulation of JAS2

The second anchoring system that can be considered is the JAS2 (Fig. 8-9). In this system, a continuous steel cable runs through two pulley system on the turbine platform in which two of its end is tied to an anchorage. In between the two pulley system, a weight is attached to the cable. This weight is not fixed to the cable in which it can move to a new position to accommodate the rise or fall of the water level. This project requires two of this system where each unit applied to each side of the turbine platform in order to enhance the stability of the floating turbine. A laboratory test also had been done to observe the behavior and practicality of this system. This system shows good performance during the test, it can hold the floating turbine in a stable manner, it is also able to accommodate the rise and fall of tide and also able to withstand strong current. However, this system has its limitation if it is used for this project since the difference in the height of highest and lowest water level at the selected site is extreme. When the water level is at its lowest, it is fear that the weight might be submerged in the river bed, thus preventing the system from working properly.

IV. CONCLUSIONS

This paper has reviewed the most suitable anchorage mooring system for the JARIMAS project. The emphasis has been put on anchorage-mooring concepts. Indeed, it has been described the strength and the weakness of each anchorage-mooring. These anchorage systems are only being observed in the laboratory testing i.e. control environment, in actual condition the use of these systems are still uncertain. A small scale test is further required in this project to determine the performance and practicality of these anchorage systems in the actual river and environment.

V. ACKNOWLEDGEMENT

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