



## **Marine Engineering Design Final Report**

# **Design of a Multi-Purpose Floating Structure**

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## **Abstract**

Singapore and Hong Kong are prime examples of countries that are limited in development by land constraints. Often they would not be able to host large scale events due to the need for extra inland space to build facilities. A solution to the problem might be land reclamation, which is subjected to escalating labour and material costs over the years, not to mention availability of reclaimable area.

Other countries including European countries also suffer the same fate when it comes to hosting large scale events as it would require them to inject huge sum of expenses to build similar facilities and supporting structures for the same purposes, therefore wasting resources and affecting local communities with the required construction and even demolishment of existing buildings. Under-utilisation of existing facilities is also a common occurrence, compounded by the exceeding of maintenance cost over generated revenue.

Hence the aim of this project is to design a multi-purpose floating structure that can be built easily, mobilised to the required location and yet possess the flexibility to be reconfigured to cater to the required purpose. As such, a solution with minimal adverse social impact is administered to the problem of recurring expenses to build potential structural white elephants.

# 1 Introduction

This chapter provides the overall description of the identification of basic needs, problem arising, aims and objectives to be achieved from the project.

## 1.1 Identification of Basic Needs and Problem arising

Countries that are limited by land are constantly sourcing for alternate options to extend the development of their infrastructure and also to improve the living standards of their citizens. Singapore and Hong Kong are the examples of typical countries that are affected by land constrain for centuries whereby the land demand is greater than what is available. Often, they are unable to host large scale events such as FIFA World Cup, Olympic, etc, as they are not able to provide the minimum required capacity for facilities to hold the events or accommodations.

Land reclamation is one of the beneficial methods for small countries to adopt to increase the availability of land. With this availability of land, it allows for more housing estates, recreational facilities, expansion of transportation system including sea- and airports for the growing population. Singapore have been increasing its land area through land reclamation from 581.5km square prior to 1960s to 633km square by 1990 making up close to 8.9% of the total land area (Elvin, 2000).

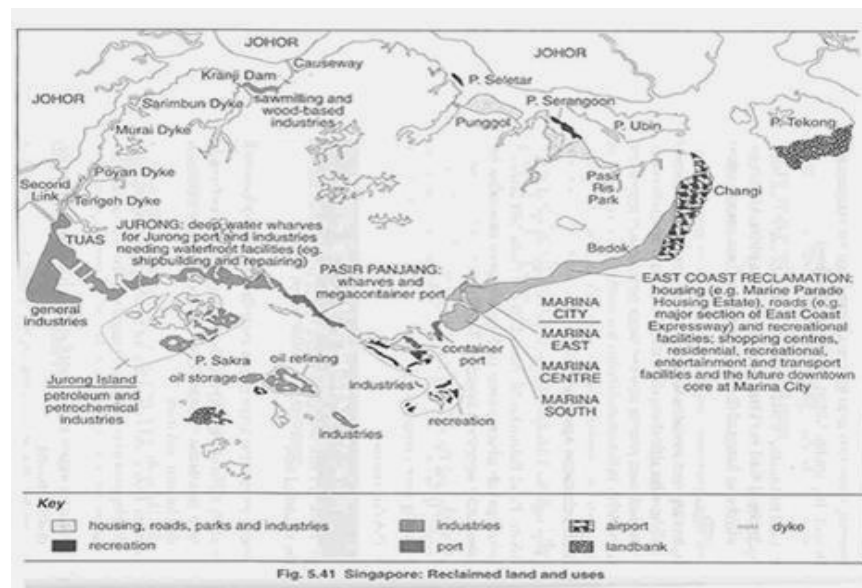


Figure 1: Singapore reclaimed land and uses (Elvin, 2000)

However, there are limitations to reclaimable land area as venturing into deeper water of more than 15m in depth would be too costly. Taking an example of 7.7 square miles of reclaimed land, it will require 9.6 billion cubic feet of sand. Even without consideration of other expenses, the 9.6 billion cubic feet of sand will incur an approximately cost of at least S\$1.9 billion. In order to ensure the reclaimed land is firm and stable, the land is required to stay idle for at least 10 years to let the foundation consolidate before construction on it is allowed.

Furthermore, countries such as Malaysia and Indonesia, the sources of sand for Singapore's land reclamation, are faced with adverse environmental impacts from the sand export business. Sand export to Singapore has thus been banned to prevent further environmental degradation.

Other countries that are not affected by physical land constrain also suffered the same fate of the need to inject huge sums of money to build similar facilities and supporting structures for the same purpose. These constructions waste unnecessary resources and affect local communities as some countries would demolish existing buildings to make way for new facilities. This action caused great social impact on the existing tenants for relocation and also lost of cultural heritages.

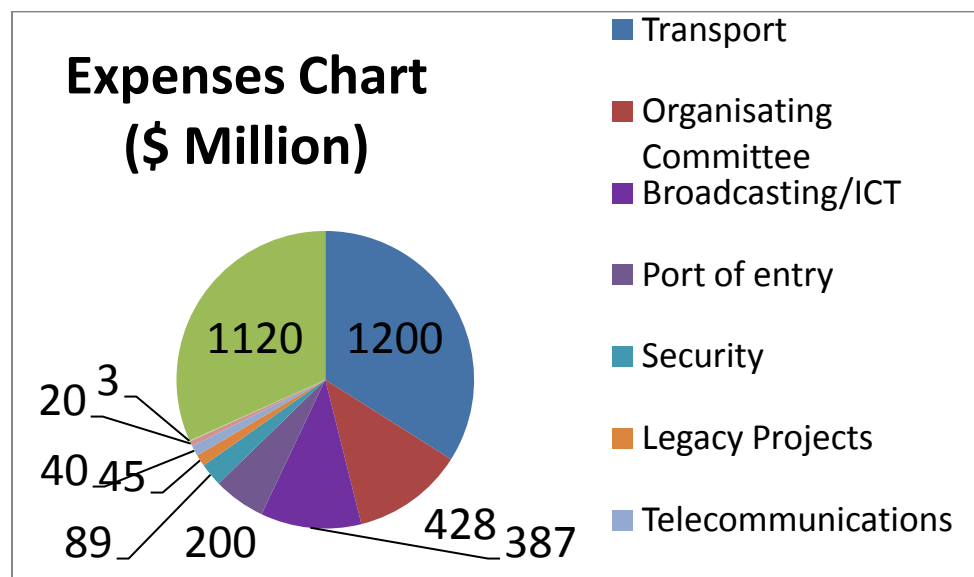


Figure 2: Expenses breakdown for a stadium construction

It is known that a stadium's construction would takes up as high as \$1.12 billion out of a total of \$3.5billion which is about a third of total project expense each construction.

According to a case study of demolishing existing buildings in South Africa (hosting country for World Cup 2010), the country had to bulldoze 2 schools in Nelspruit to construct a stadium, thus forcing the students in the school to transfer to hot and airless classrooms. Another case study showed that for the World Cup 2014 and 2016 Olympic Games that will be held in Brazil, homes for the poor residents of Rio de Janeiro will be bulldozed to make way for the event's facilities. The most recently demolished shantytown is called Favela do Metro on the north side of the city, where a neighbourhood once home 1,000 people has been reduced to rubble.

There has been an increasing interest in countries around the world concerning on the environmental issues in recent years. The process of construction and demolishment will require high usage of machinery and transport vehicle etc that will emit pollutants and waste of raw materials and natural resources.

It is also not an easy task to manage infrastructure for long-term sustainability after the events, and the most significant reason is the high operating and maintenance cost. An example is China's Bird's Nest stadium that had been built for the 2008 Olympics. The initial building cost is \$450 million and the annual maintenance is estimated to be about \$15 million. After the Olympic event, the function of this stadium had been converted into a snow park with its main revenues received from the entrance ticket of \$26. The snow park had been receiving an approximately 300 visitors per day and this revenue is barely 20% of the total maintenance costs. The problem of under-utilisation of the facilities still persists, resulting in the phenomenon of 'structural white elephants'



Figure 3: Beijing's Bird's Nest winter wonderland

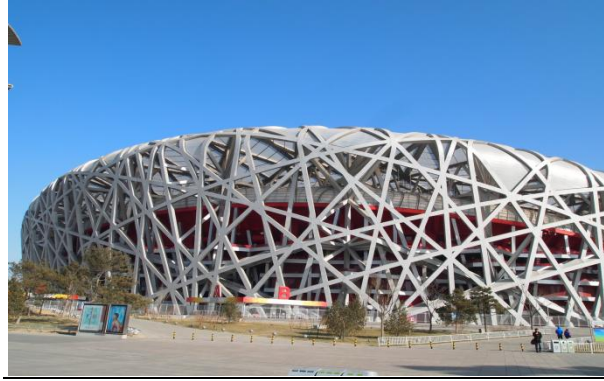


Figure 4: Exterior of the Beijing's Bird's Nest

## **1.2 Aim of the Project**

The aim of the project is to design a multi-purpose floating structure that can be easily built, relocated to the required location. It also possesses the ability to be reconfigured for the required purpose to eliminate the problem of recurring expenses to build potential structural white elephants with minimal social impact.

## **2 Literature Review on Floating Structures**

The history and functions of floating structures with reference to some of those in existence will be reviewed in the following sections.

### **2.1 History of Floating Structures**

The history of floating concrete sea structures goes back to the 19th century. In 1848, Lambot, for the first time used reinforced concrete to build a boat. During World War I, 14 concrete ships were built due to the shortage of steel - including the 130 m long U.S.S. Selma. At that time reinforced concrete had already been used in shipbuilding (small ships) in the Scandinavian countries. World War II concrete ships saw widespread wartime service in battle zones. Twenty-four of these ships were large sea-going vessels and 80 were sea-going barges of large size. The cargo capacities ranged from 3,200 to 140,250 tons.

Floating structures in South East Asia existed for more than thousand years and served mainly as living accommodation for people, especially fishermen. To date, tribes built their houses near rivers, lakes and seas for convenience of travelling around in their small boats or raft to capture

marine life for self-consumption or retail profit. Such “floating structures” still exist today but mostly in developing countries like Cambodia, Vietnam, Thailand, Indonesia and also in China village areas.



Figure 5: Kompong Phluk village, Cambodia

In Europe, such as Amsterdam and Zwolle, such floating accommodations exist in the form of houseboats. The economic crisis in 1930 resulted in citizens unable to afford houses on land, thus forcing them to start a living in a cheaper option- houseboat. It became very popular, therefore when old narrow harbours were no longer able to meet the new ships specifications and demands, more spaces were made available for houseboats



Figure 6: Houseboat in Amsterdam, Netherlands



Figure 7: Houseboat for Students in Zwolle, Netherlands

## 2.2 Other Functionalities of Floating Structures

Floating structures can also exist in different functionality such as utility buildings, airfields and semi-submersibles.

Floating utility buildings are commonly seen in the Netherlands and function as both an info-centre in IJburg and also a detention centre in Zaandam as there is no building ground available for them except to provide a mooring site. In another part of Europe, Paris had a 25 meters pool built on floating structure named *La Piscine Josephine Baker*.



Figure 8: Info-centre in IJburg



Figure 9: Detention centre in Zaandam [left] and officer leaving to land [right]

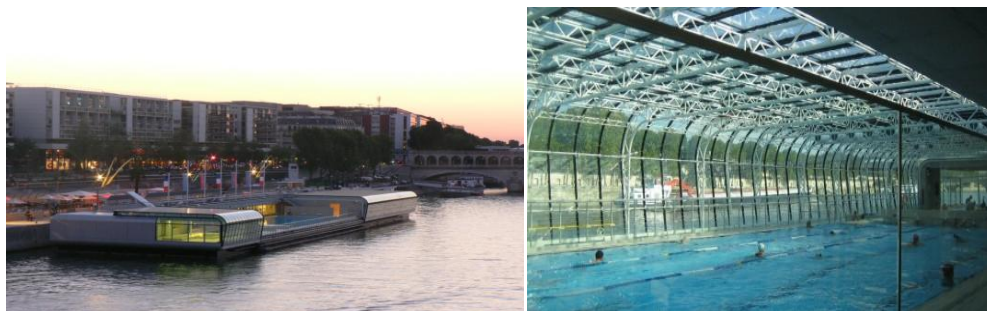


Figure 10: La Piscine Josephine Baker in Paris, France [left] and the interior of the swimming pool [right]

Japan built its first “Mega-Float” airfield with 1000 metre floating runway in Tokyo Bay in 2000. This project involved building connectable steel boxes that served as the body of the platform, to be situated in calm, shallow waters of up to 30 meters in depth. This Mega-Float is able to eliminate most of the noise a runway might experience and qualities such as being earthquake-resistant.



Figure 11: "Mega-float" airfield in Japan

Since the 1970s, offshore engineering has become one of the booming business and demand for strong effective deep water offshore structures increased. Semi-submersibles served important roles in offshore drilling rigs, oil production platforms and also heavy lift cranes.



Figure 12: Saipem Scarabeo 7 semi-submersible drilling rig docked in Cape Town



Figure 13: Brazilian Petrobras P-51 semi-submersible oil platform

## 2.3 Existing Floating Structures

Singapore built her first floating stadium, which is also the world's largest floating platform available that is currently in service since 2007 to hold Singapore's National Day Parade annually and also others event such as Passing-Out-Parade for the Singapore Army Force, Countdown Party concerts, exhibitions, and the arts and cultural performances on the waters of Marina Bay.



Figure 14: 2007 Singapore's National Day Parade



Figure 15: A soccer field when Platform is not in use

### 3 Parameters of Design Considerations

This Chapter will identify key parameters taken into consideration during preliminary generated designs.



The multi-functional floating structure design should take the following parameters into consideration:

1. Catered for offshore environment
2. Modular concept
3. Independent structure
4. Able to host large scale events
5. Able to be reused
6. Comparable or better than current infrastructure
7. Environmentally friendly
8. Able to satisfy event standard requirements
9. Ease of relocation

10. Attractive.
11. Easily accessible
12. Consider human safety and comfort

### **Technical Challenge (location)**

Location of the multi-purpose platform is important due to implications of the technical challenges faced in different locations around the world. As different coasts have different characteristics such as water depths, wave heights and wind speeds, these serve as boundary conditions which the design will be based on.

### **Structure design and materials**

Structure design is to be modular to achieve different need and provide a good structure stability. The harsh offshore environment has to be taken in consideration of material requirement and its manufacturing availability.

### **Transportation**

Knowing that large scale events demand large structure, if it is able to be reusability means that the multi-purpose platform structure had to be transport by a means to another spot.

### **Human accessibilities**

The accessibilities for audience to reach the multi-purpose platform structure is a major concern because on-shore people had been typically use road transport by bus or car to access to the location. Having the location offshore will create a huge problem

### **Assembly issues**

Assembly issues to provide strong joint methods between difference modular. Upon assembling or dismantling the joint had to be efficient and reliable.

### **Power supply**

The power needed to power up the floating structure with green resources.

### **Labour**

Skills requirement and technology level for handling this platform

### **Safety concern**

This multi-purpose platform involved with large amount of people to go onboard e.g. for a soccer match required 65000 people. Safety concern must not be compromised.

### **Time-scale**

Time required on the process of dismantling and assembling of the modular structure.

### **Money**

The cost of solution implementation since our goal is set on targeting for its reusability to prevent any re-construction of similar infrastructure or white elephant to occur again. Our overall cost to construct had to be beneficial.

### **Maintainability**

The maintainability period required and type of machinery or process needed to maintain the structure.

### **Drainage system**

Drainage system of floating platform structure is important since the collection of excessive water would cause the instability of the structure such as reduce stabilities and increasing its displacement.

### **Mooring**

The Mooring system is key concern since securing of the multi-purpose platform had to be flexible and efficient.

## 4 Idea Creation

The value-add of the design creation would be the ease of construction, relocation and reconfiguration for its required purpose of usage thus eliminating the problem of recurring expenses or the problem of underutilisation structures. Designing an offshore floating structure would be able to provide robust beneficial relocation in which existing structure that had been built traditionally onshore will not be able to achieve and this concept allows user to rent it when there is a need or pass on to others when the infrastructure is no longer required.

However there are several challenges and factors that need to be taken into consideration to ensure that the design of the idea will fit and suit the countries natural geographical location such as water depths near shore, the wind speed and wave height and it will be covered in this chapter.

### 4.1 Technical Challenge – Water depth, Wave height and Wind Speed

Water depth, wave height and wind speed are some important technical challenges faced in the design creation. Good study on the bathymetry of countries that in need of a solution for additional land space for facilities would allow a better design specification of the draught to meet the water depth around the shore. The draught of the design should be able to counter the harsh wave height limit to expect to be encountered from the wind speed at different seasonal to ensure that the design will remain stable while taking human safety and comfort as top priority.

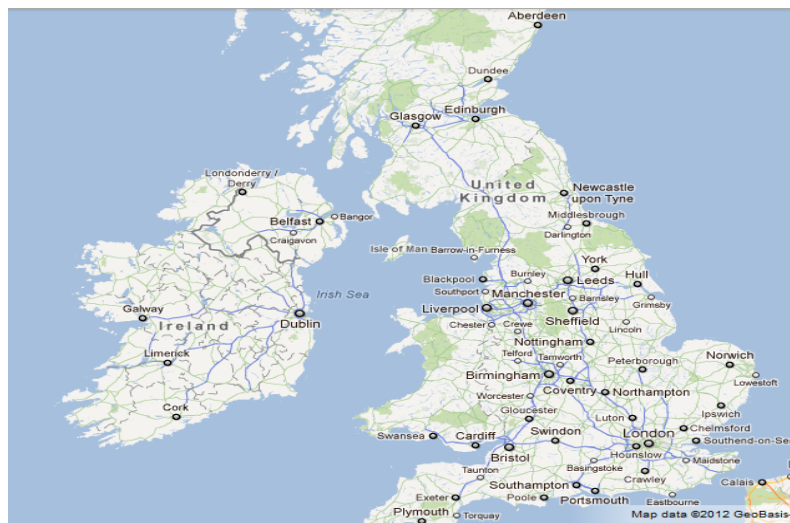


Figure 16: Map of United Kingdom (googlemap)

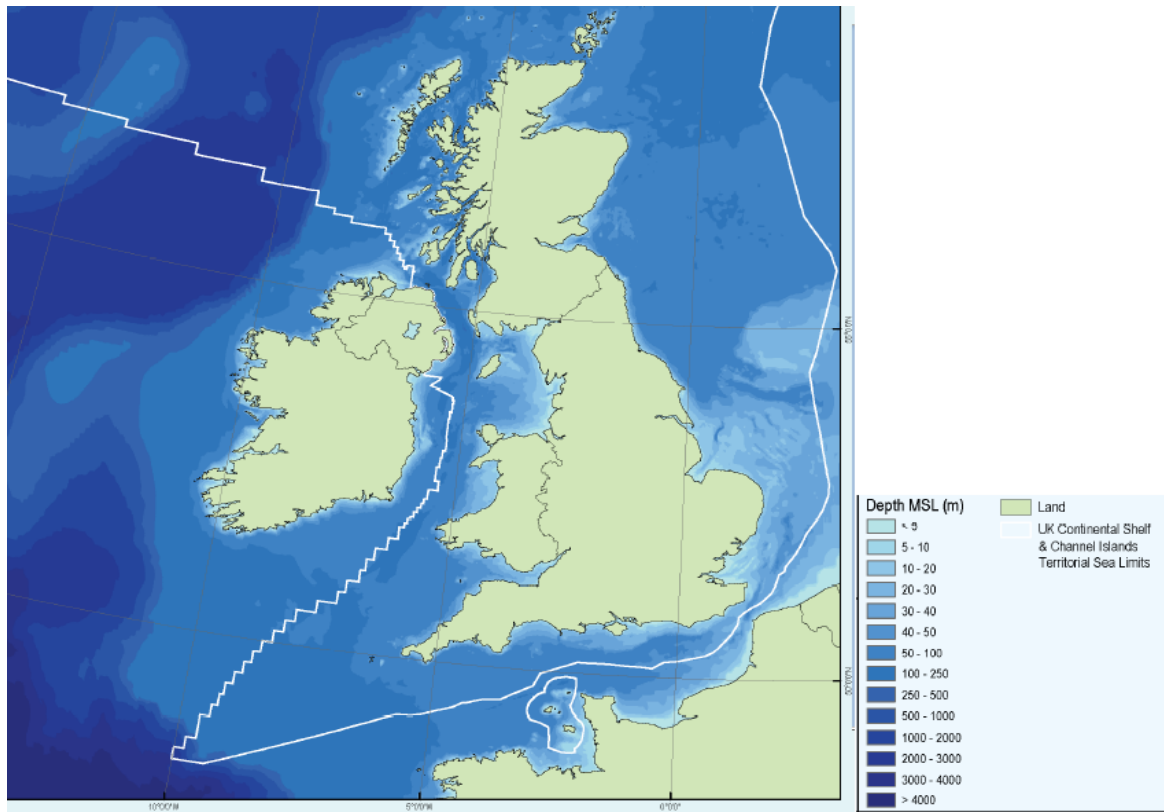


Figure 17: Bathymetric of United Kingdom

To calculate the wave experienced, some used linear wave theory to assume regular sinusoidal waves to do calculation and modelling. However in other situation where floating structures were being used either inlands or close to shore, the use of linear wave theory will not be valid, but it could give simple understanding on the description of waves.

The proposed design idea is to allow relocation and reusability hence the design draught would need to be suitable for most countries water depth, wave height and wind speed.

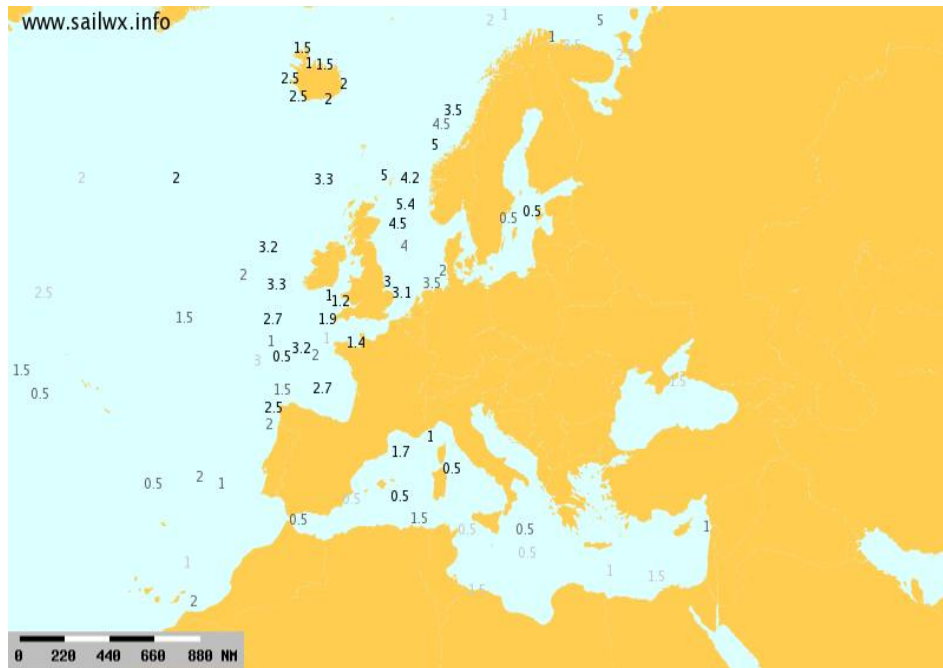


Figure 18: Average wave height along coastline in Europe (sailwx)

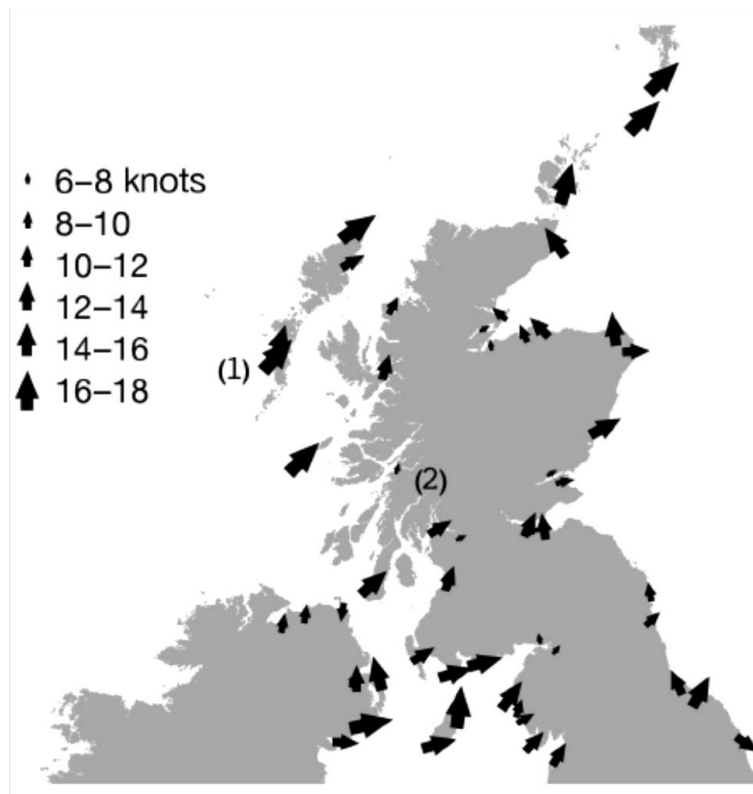


Figure 19: Average wind speed and average angle weighted by speed for each coastal site

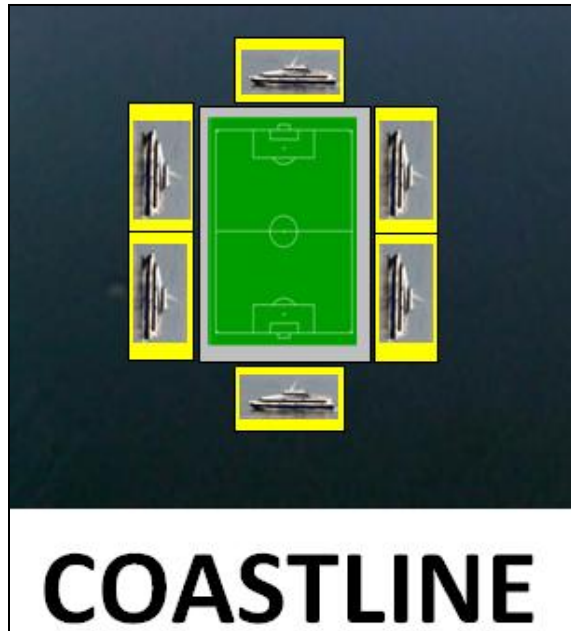
#### **4.1.1 Generation of Designs Structure Idea**

The design consideration for multi-purpose floating platform is to cater a platform to host the events. This means that a broad series of infrastructures has to be taken into considerations. In order to proceed to an efficient design stage, the main focus of the design will be targeting at the basic requirements to accomplish the floating soccer stadium while enabling the flexibilities of diffusing into other infrastructures.

This multi-purpose platform will be classified under very large floating structures (VLFSs). Basically, there are two types of VLFSs (semisubmersible type and the pontoon-type). Semi-submersible type floating structures are raised above the sea level using column tubes or ballast structural elements to minimize the effects of waves while maintaining a constant buoyancy force. In this way, they can reduce the wave induced motions and are therefore suitably deployed in high seas with large waves.

Pontoon-type floating structures look like a big giant plate floating on the sea. Pontoon-type floating structures are suitable for use in only calm waters, often inside a cove or a lagoon and near the shoreline.

## Design 1



### Legends



Special cruise vessel



Soccer pitch



Figure 20: Proposed multi-purpose floating platform Design 1

By reconstructing or converting a cruise vessel, spectators can sit on the side of the vessel to watch the match. The power supply system will depend on electric generators onboard the ship. The advantages include the provision of readily accommodation, leisure facilities and transportation by the cruise vessel.

## Design 2

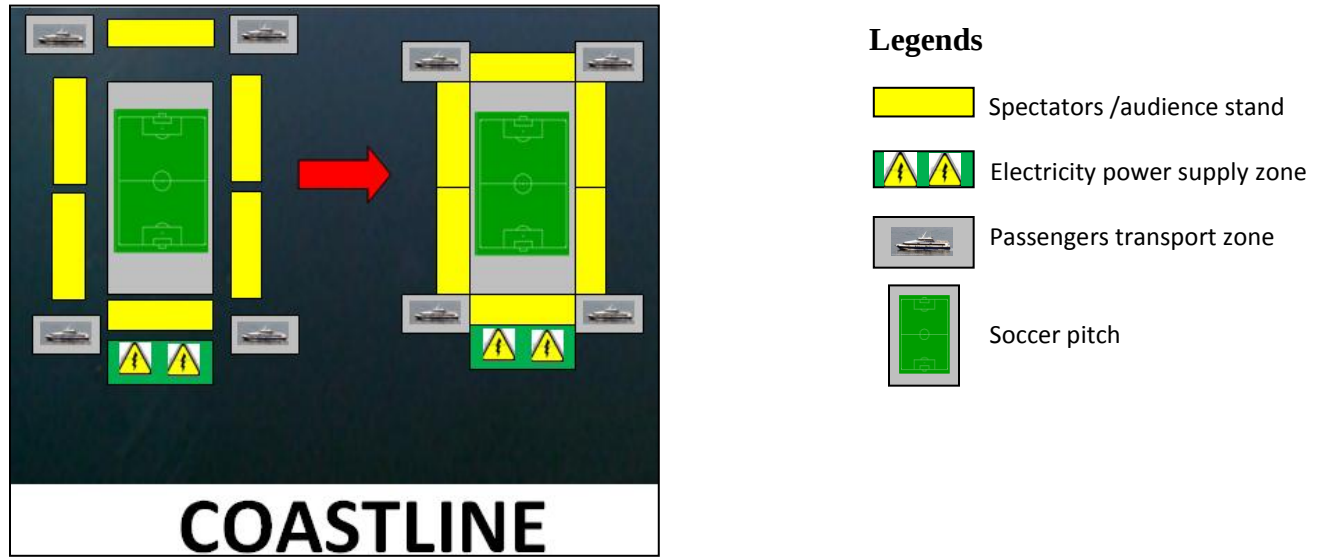


Figure 21: Proposed multi-purpose floating platform Design 2

This design consists of 12 floating modules which can be assembled and dismantled. The accommodation and spectator stand modules include luxury hotel rooms alongside with a spectator stand. The spectator stand, built on the side of the modules facing the soccer pitch, can hold up to 50,000 spectators. Spectators can be transported to the platform via passenger vessels.

### Design 3



Figure 22: Proposed multi-purpose floating platform Design 3

Design 3 concept is similar to that of design 2. The only difference is that one of the modules is making use of the decommissioned Semi-submersible platform to reinstall into accommodation and spectator stand modules.

## Design 4

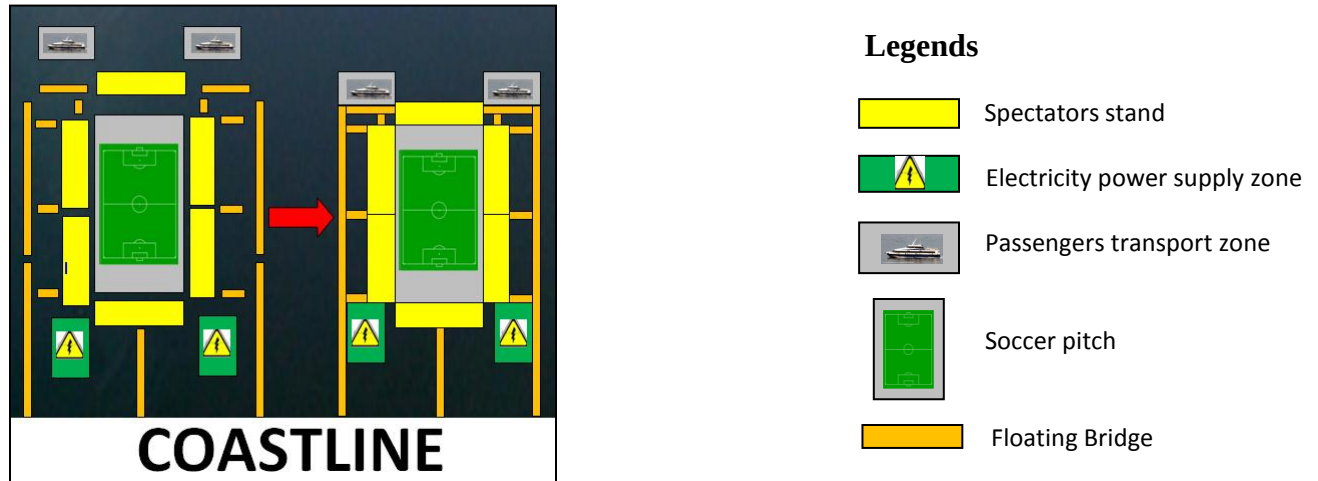


Figure 23: Proposed multi-purpose floating platform Design 4

This design consists of 11 floating modules which can be assembled and dismantled. The spectator stand, built on the side of the modules facing the soccer pitch, can hold up to 50,000 spectators. Spectators can be transported to the platform via passenger vessels and bridge modules

## Design 5

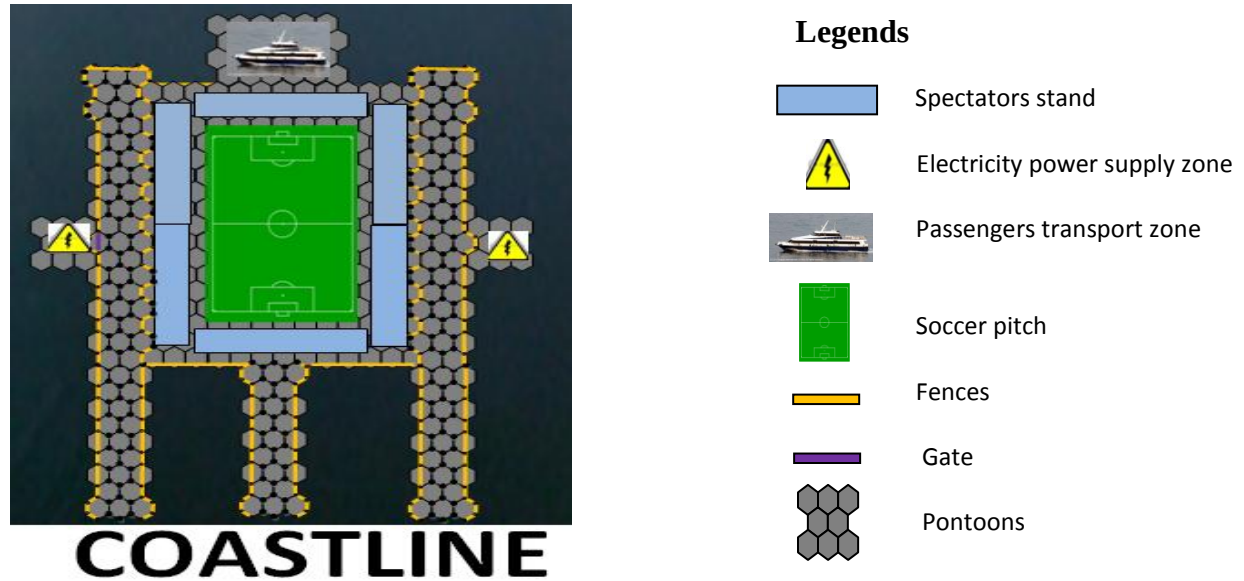


Figure 24: Proposed multi-purpose floating platform Design 5

This design is using pontoons type designs. Pontoons are assembled into one large piece of floating plate to support the entire infrastructure on top of it. The spectator stand, built on the side of the modules facing the soccer pitch, can hold up to 50,000 spectators. Spectators can be transported to the platform via passenger vessels and bridge modules.

### 4.1.2 Analysis and Discussion of Design Generated (Pros and Cons)

Ranking systems [1 as the worst design and 5 as the best design]

Table 1: Analysis of Design Generation

| Parameter                      | Idea 1    | Idea 2    | Idea 3    | Idea 4    | Idea 5    |
|--------------------------------|-----------|-----------|-----------|-----------|-----------|
| Technical Challenge (location) | 1         | 2         | 3         | 4         | 5         |
| Structure design               | 1         | 4         | 3         | 2         | 5         |
| Materials                      | 1         | 2         | 3         | 4         | 5         |
| Transportation                 | 5         | 4         | 3         | 1         | 2         |
| Human accessibilities          | 3         | 2         | 1         | 4         | 5         |
| Assembly issues                | 5         | 4         | 3         | 2         | 1         |
| Power supply                   | 5         | 1         | 3         | 2         | 4         |
| Labour                         | 1         | 2         | 3         | 4         | 5         |
| Safety concern                 | 3         | 2         | 1         | 4         | 5         |
| Time-scale                     | 5         | 4         | 3         | 2         | 1         |
| Flexibility                    | 1         | 2         | 3         | 4         | 5         |
| <b>Total</b>                   | <b>31</b> | <b>29</b> | <b>28</b> | <b>33</b> | <b>43</b> |

The following is the summary of the ranking of the design from the best to worst: 5, 4, 1, 2, 3.

Flexibility in transformation to support another infrastructure is important since our approach is to design a multi-purpose floating structure. Safety concern is very important factors too, since it regards on the lives of 50000 people inside the stadium.

Clearly seen, Idea 5 has the most efficiency in reconfiguring to a relevant required platform base while having the best in rank whiles the safest approach to human escape's routes. Therefore, the team has decided to use pontoon-type approach which is idea 5 to in-depth design into detailed problem evaluation.

## 4.2 Selected Structure Design

In this chapter, parameters of the Pontoon design in terms of shapes considerations, materials selection, technical detail such as reserve buoyancy, drag coefficient and also the cost of each pontoon and connection parts.

### 4.2.1 Parameters of Pontoon Design

To satisfy the requirement of having a multipurpose floating structure, the pontoon that forms the foundation of the floating structure should be based on the following parameters:

- **Made of suitable material of sufficient strength and density**

Both tensile and compressive strengths of a material indicates the load bearing ability of a structure; and in the case of any construction project, it is a significant consideration.

As the foundation of a floating structure, it is implicit that the pontoons possess sufficient buoyancy so that it floats and have the ability carry additional payload, as components are going to be constructed or mounted on it so as to cater to its designated purpose.

Choice of material also has an impact on overall cost of construction, influencing the capital costs, etc.

- **Pontoon Shape**

Shape of the pontoon is of particular importance to achieve the design aim of a highly modular and reconfigurable floating platform. Chosen shape should be of simple geometry so as to reduce production complexity and facilitate reproduction similar-shaped pontoons.

- **Pontoon Connection**

In view of the modularity and anticipated of a large number of pontoons, a simple and efficient method of pontoon-pontoon connection has to be devised so as to ensure the result of a structurally sound foundation that will not disintegrate unless on intention.

- **Overall Improvement from Existing Designs**

The design outcome of the pontoon and connection system should showcase a markedly different approach from existing designs. As the project concept is sighted into the future, generated ideas and solutions will be extrapolated from existing technologies.

#### **4.2.1.1 Shapes Considerations**

Various pieces of pontoons formed up into difference shapes and sizes of a single large pontoon. This will mainly function as the base of the floating platform. The flexibility of the small pieces of pontoon is important since difference types of shapes and size are required to sustain the necessary infrastructure on top. The geometric shapes consideration for the individual piece of small pontoon has to achieve excellent properties in terms of ease of assembling or dismantling, arranging flexibility, and physical strength.

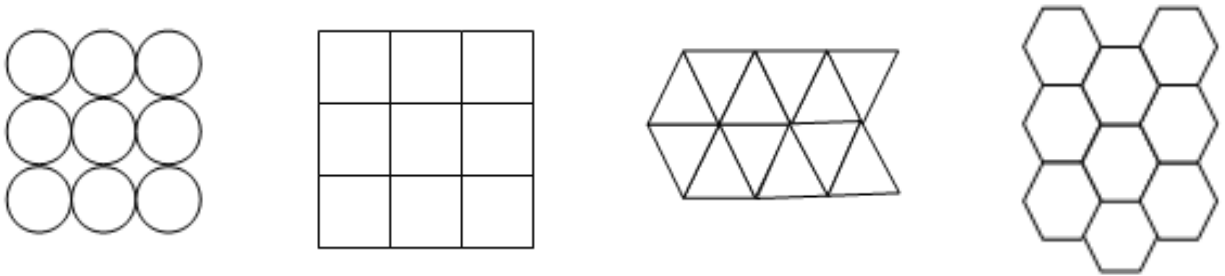


Figure 25: Basic geometric shapes

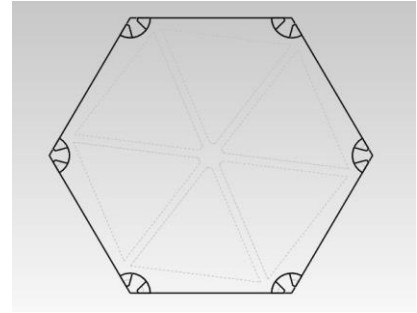
The basic geometric shapes are square, circle, triangular shapes shown above. All of the shapes have their own advantages and disadvantages.

Hexagonal shape consists of major beneficial properties from the combination of the three basic shapes. Hexagonal shape is commonly found in nature structure such as bee's comb. Nevertheless, this shape has also been applied in the design of airplane wings and satellites walls too.

Professor Thomas Hales of the University of Michigan had carry out a research in 1999. He had created a proof that demonstrated that the perfect hexagon was the most efficient method of creating a tiled pattern that offers full coverage.

The main hexagonal benefits are:

- Strongest shape per material weight beside circle
- No empty space in-between
- Allow similar production of pontoon throughout
- Reduce the complexity of assembly and manufacturing
- Create more space with the given material.
- Excellent compressive and tensile strength
- converging at 60 degree angles
  - prevent any shearing or collapsing
  - Able to balance each other out and distribute the load



The pieces of hexagonal shapes can be configure into difference size and shapes of pontoon for catering difference infrastructure. Some example of the integrated hexagonal pontoon are illustrate below:

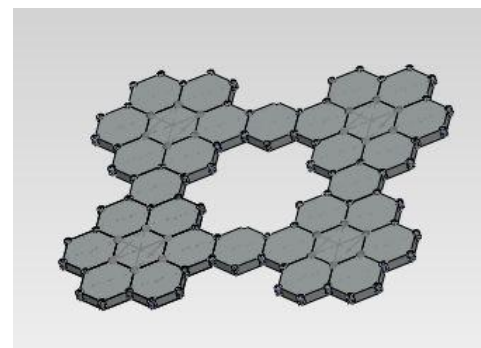
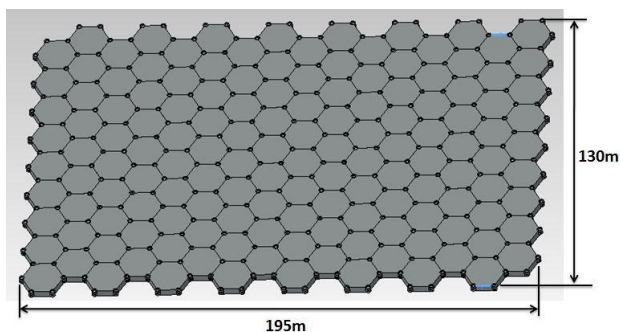
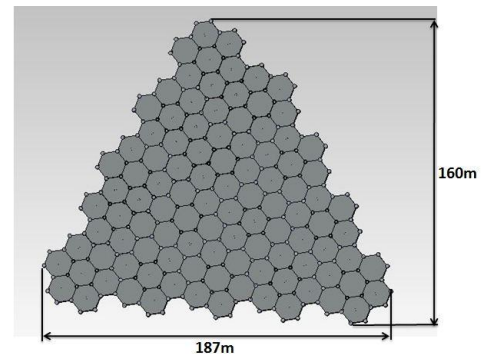
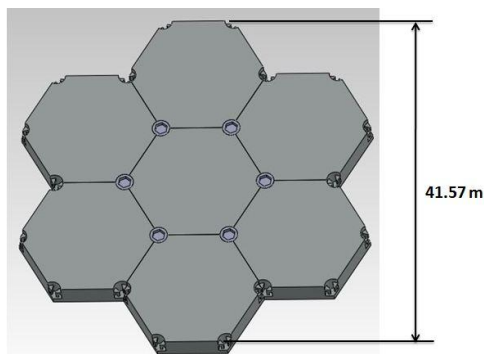


Figure 26: Examples of the integrated hexagonal pontoons

### 4.2.1.2 Materials Selection

Most major structures are built today with the use of concrete or steel. Both materials have their own merits and the following section will review their characteristics with respect to each of the subsequent design criteria:

- **Resistance to Corrosive Effects of Water**

Steel, an alloy of iron, oxidizes in the presence of water and oxygen to form oxides of iron, thereby reducing its structural strength and integrity. Corrosion prevention measures such as coating application and cathodic protection by use of sacrificial anodes or impressed current cathodic protection systems (ICCP) are practised in both marine and onshore applications to control rate of corrosion, but these measures increase capital and maintenance costs.

For example, although zinc sacrificial anodes are easy to install and requires no additional maintenance over the course of its lifetime, use of a large number of anodes and replacement of these anodes over the long run may prove to be expensive, especially so when the cost of zinc and other anode materials (typically magnesium and aluminium) are generally more costly than steel itself

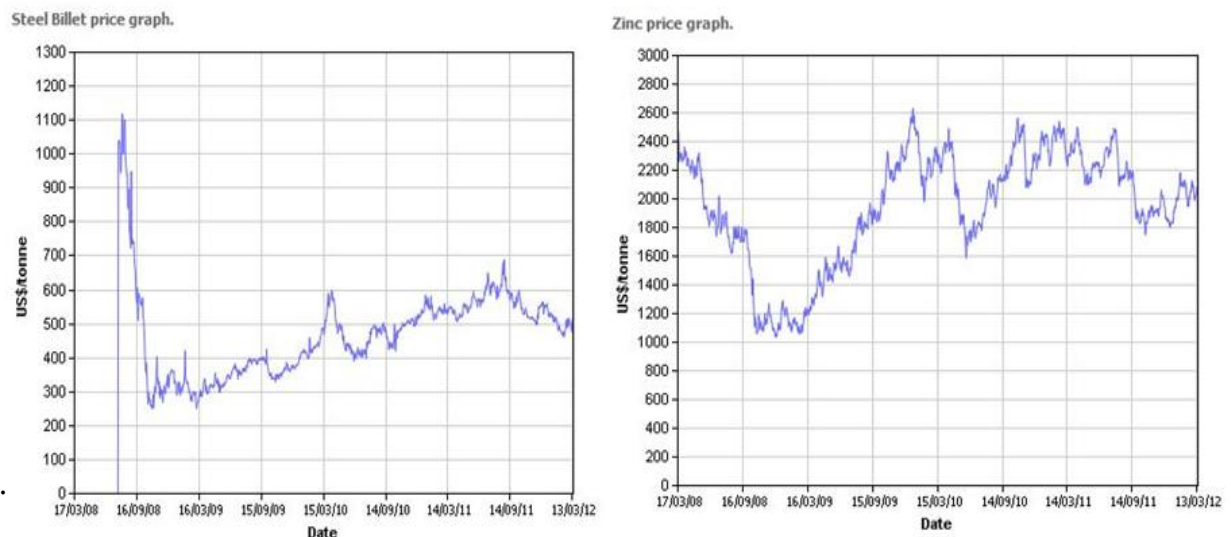


Figure 27: Comparison of steel and zinc prices from March 2008 to 2012 (Exchange, 2012), with current zinc prices 4 times that of steel.

Similarly, ICCP systems provide an alternate means of corrosion protection and their range of application are just as widespread, ranging from hull protection of marine vessels to mitigating of corrosion effects of buried pipelines. However, such system requires a continuous supply of DC power and comes with a higher cost of installation (Center, 2011).

Unlike steel, the ability to withstand the action of water without serious deterioration makes concrete an ideal material for building structures immersed in water.

Some of the earliest known applications of concrete as a building material consisted of aqueducts and waterfront retaining walls constructed by the Romans. Today, structural elements exposed to moisture, such as piles, exterior walls and pipes are frequently built with reinforced and pre-stressed concrete (Mehta & Monteiro, 2006). Applications of concrete as a building material at a larger magnitude under such conditions are hydroelectric dam construction, offshore platforms and floating structures.



Figure 28: Roman aqueducts transporting water, withstanding the test of time (Century, 2011)

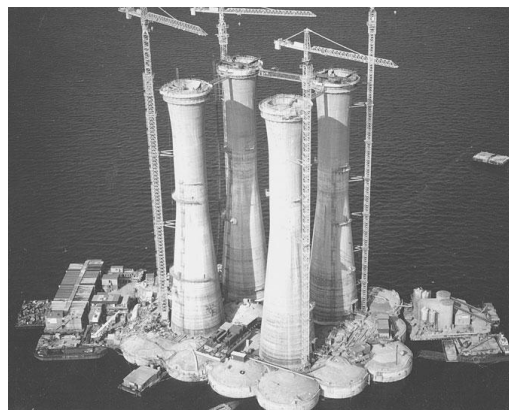


Figure 29: Gravity base structure of the Stratfjord B offshore concrete platform (Mehta & Monteiro, 2006)

- **Construction Properties**

Steel has a higher compressive and tensile strength compared to concrete. It is ductile and malleable, and it deflects and yields before failure compared to concrete which can fail catastrophically without warning. However, according to Gjerde (1982), compared to steel girders of the same slenderness, the deflection of pre-stressed concrete girders is only about 35 percent, exhibiting better control of structural deflection.

Concrete demonstrates good compressive load bearing abilities, although its strength is a function of its hydration process, which is relatively slow. Generally, tensile and flexural strengths of concrete are in the order of 10 and 15 percent of compressive strength respectively (Mehta & Monteiro, 2006).

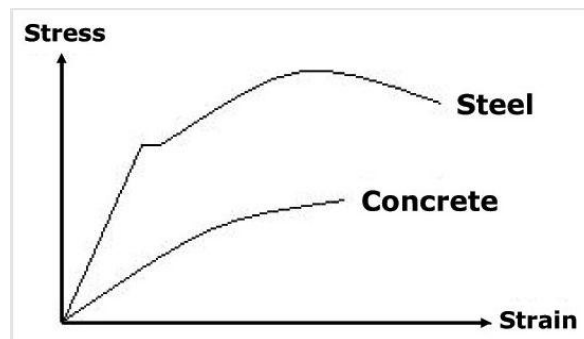


Figure 30: Typical stress-strain curve of concrete and steel (Goode J.S., 2006)

As a commonly used construction material, steel comes in various standardised and uniform shapes as supporting members, such as I-beams, C-channels and T-beams, etc. These are usually welded together to form a supporting frame or base of a structure. The ability of steel to be welded together to form different skeletal structures also provide it with a low level of flexibility, making it an attractive building material.

Concrete on the other hand has no limits on the type of shape, size and form that the designer has in mind. This is because freshly mixed concrete is of a plastic consistency, which enables the material to flow into prefabricated formwork and cure to its permanent shape. The formwork can then be removed and reused for repetitive components or recycled for other uses. As such,

constructions of complex shapes that cannot be achieved with the use of steel members are made possible by switching to concrete.



Figure 31: Typical steel structures consisting of geometric shapes (Buildings, 2011)

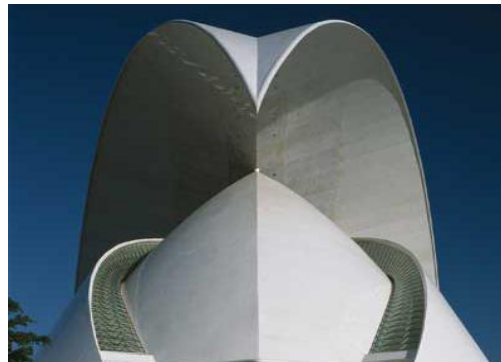


Figure 32: An example of complex shaped structure built in concrete (Feeder, 2005)

Although steel and concrete exists as compound materials in various grades with different constituents of raw materials, it is safe to assume that steel is generally three times as dense as concrete. Density has significant influence on marine structures due to importance of displacement and buoyancy considerations.

Concrete is considered to be a safer building material, especially after the September 11<sup>th</sup> WTC attacks, although both concrete and steel demonstrates superior fire resistant properties to other construction materials such as wood, glass, etc. Nonetheless, concrete does not require additional fireproofing treatments to meet stringent fire codes and performs well during both natural and manmade disasters (Madsen, 2005).

- **Cost**

As shown earlier, price of a steel billet is about US\$500 per tonne, whereas the price of concrete is relative lower at a range of US\$ 60 to US\$100 per cubic metre. This is partly contributed by the fact that cost of making concrete, namely aggregate, water and Portland cement are relatively inexpensive and commonly available in most parts of the world, compared to that of steel where it involves production mines, complex refining process and dedicated transport infrastructures.

The above-discussed showed that **concrete** is a much more appropriate material for use in our pontoon design in view of the following characteristics:

- Non-corrosive property in water and lower density compared to steel
- Lower costs in terms of price of material and maintenance in the long run
- Ease of production in view of the highly repetitive and reusing of moulding formworks

## **Type of Concrete**

There are three broad categories of concrete, namely:

➤ **Normal-weight concrete**

Contains natural sand and gravel or crushed rock aggregates, generally having a density of  $2400 \text{ kg/m}^3$  and is the most commonly used concrete for structural purposes.

➤ **Lightweight concrete**

Refers to concrete that has density lower than  $1800 \text{ kg/m}^3$ .

➤ **Heavyweight concrete**

It is produced from high density aggregates and generally of density about  $3200 \text{ kg/m}^3$ , usually used for radiation shielding.

Although not practised in the United States, it is prevalent in Europe to subdivide each weight categories and assign grading to cements and concrete based on their compressive strengths. The subcategories are as follows:

- a. Low-strength concrete: less than 20 MPa
- b. Moderate-strength concrete: 20 to 40 MPa
- c. High Strength concrete: more than 40MPa

An example of typical proportions of is shown in Table 2. It is noted that the influence of the cement paste content and water-cement ratio on the strength of concrete is of inverse relation to each other.

Table 2: Typical Proportions of Materials in Concrete Mixtures of Different Strengths (Mehta & Monteiro, 2006)

|                         | Low-strength<br>(kg/m <sup>3</sup> ) | Moderate-strength<br>(kg/m <sup>3</sup> ) | High-strength<br>(kg/m <sup>3</sup> ) |
|-------------------------|--------------------------------------|-------------------------------------------|---------------------------------------|
| Cement                  | 255                                  | 356                                       | 510                                   |
| Water                   | 178                                  | 178                                       | 178                                   |
| Fine aggregate          | 801                                  | 848                                       | 890                                   |
| Coarse aggregate        | 1169                                 | 1032                                      | 872                                   |
| Cement paste proportion |                                      |                                           |                                       |
| percent by mass         | 18                                   | 22.1                                      | 28.1                                  |
| percent by volume       | 26                                   | 29.3                                      | 34.3                                  |
| Water/cement by mass    | 0.70                                 | 0.50                                      | 0.35                                  |
| Strength, MPa           | 18                                   | 30                                        | 60                                    |

In addition to the above-mentioned conventional types of concrete, recent advances in concrete technology has brought forth new types of concrete mixtures that offers solution to inherent limitations of using concrete as a building material.

### ➤ Structural Lightweight Concrete

Structural lightweight concrete is developed to overcome the low strength-weight ratio of concrete compared to steel which place it at an economic disadvantage especially in the construction of tall buildings, long-span bridges and floating structures. It is made with a cellular lightweight aggregate so that its weight is two-third of the weight of concrete made with the typical aggregate of conventional concrete. However, it comes at a price of slight reduction in the strength of the concrete, therefore requiring special procedures such as a minimum 28-day strength in excess of 17MPa and air-dried unit weight of not exceeding 1850kg/m<sup>3</sup> to ensure structural integrity (Institute, 1987).

Table 3: Requirements for lightweight structural concrete (P.K. Mehta & Langley, 2000)

| Air-dried, 28-day<br>unit weight, max.<br>[lb/ft <sup>3</sup> (kg/m <sup>3</sup> )] | 28-day splitting<br>tensile strength,<br>min. [psi (MPa)] | 28-day compressive<br>strength, min.<br>[psi (MPa)] |
|-------------------------------------------------------------------------------------|-----------------------------------------------------------|-----------------------------------------------------|
| All lightweight aggregates                                                          |                                                           |                                                     |
| 110 (1760)                                                                          | 320 (2.2)                                                 | 4000 (28)                                           |
| 105 (1680)                                                                          | 300 (2.1)                                                 | 3000 (21)                                           |
| 100 (1600)                                                                          | 290 (2.0)                                                 | 2500 (17)                                           |
| Combination of normal sand and lightweight aggregate                                |                                                           |                                                     |
| 115 (1840)                                                                          | 330 (2.3)                                                 | 4000 (28)                                           |
| 110 (1760)                                                                          | 310 (2.1)                                                 | 3000 (21)                                           |
| 105 (1680)                                                                          | 300 (2.1)                                                 | 2500 (17)                                           |

### ➤ High Strength Concrete

With the advent of high-range water reducing admixtures (super-plasticizers) composed of salts of naphthalene sulfonate and melanine sulfonate, it is possible to achieve high strength and workability concrete mixtures, found suitable for use in production of cast-in-place structural components for tall buildings. Definition of “high-strength” was increased from 40 MPa to 55 MPa when concrete mixtures of strengths up to 120 MPa were made commercially available.

➤ **Self-Consolidating Concrete (SCC)**

This class of concrete can be defined as flowing concrete that can be cast into place without the use of vibrators to form a product free of unfilled cavities or entrapped air voids, made possible by the use of super-plasticizers based on sulphonated naphthalene. Although expensive, the ability to place and consolidate concrete rapidly with little or no cost present savings that may equal or exceed the cost of the super-plasticizer to produce a better quality end product. In Europe and Japan, SCC has been used for underwater concreting and for the construction of heavily reinforced structures (Mehta & Monteiro, 2006).

➤ **High Performance Concrete (HPC)**

High performance refers to products that last longer compared to conventional ones. HPC was suggested by Mehta and Aitcin (1990) to define concrete mixtures that possess the following three properties: high-workability, high-strength and high durability. The development of such concrete mixtures was to increase the durability of built structures by decreasing permeability of level to less than 0.4. Permeability is one of the main causes of concrete failure as it leads to cracking. Since the 1970s, some 20 concrete platforms have been installed in the British and Norwegian sector of the North Sea, not to mention long span bridges in different parts of the world, all of which constructed of HPC.

➤ **High Performance, High Volume Fly Ash Concrete (HVFA)**

HVFA is developed as an alternative to Portland-cement based concrete to offer a more crack-resistant concrete mixture. Compared to conventional concrete mixture, the HVFA contains one-third less mixing water, therefore resulting in less drying shrinkage and reduced risk of thermal shrinkage and cracking.

Table 4: HVFA concrete compared to conventional Portland-cement concrete  
(Mehta & Monteiro, 2006)

|                                                            |                              |
|------------------------------------------------------------|------------------------------|
| Flowability/pumpability                                    | Easier                       |
| Workability/compactibility                                 | Easier                       |
| Bleeding                                                   | None or negligible           |
| Finishing                                                  | Quicker                      |
| Setting time                                               | Slower up to 2 h             |
| Early strength (up to 7 days)                              | Lower but can be accelerated |
| Ultimate strength- 90 days +                               | Higher                       |
| Crack resistance                                           | Higher                       |
| • Plastic shrinkage                                        | Higher if unprotected        |
| • Thermal shrinkage                                        | Lower                        |
| • Drying shrinkage                                         | Lower                        |
| Resistance to penetration of chloride ions                 | Very high after 3 months     |
| Electrical resistivity                                     | Very high after 3 months     |
| Durability                                                 |                              |
| • Resistance to sulfate attack                             | Very high                    |
| • Resistance to alkali-silica expansion                    | Very high                    |
| • Resistance to reinforcement corrosion                    | High                         |
| Cost                                                       |                              |
| • Materials                                                | Lower                        |
| • Labor                                                    | Similar                      |
| • Life cycle                                               | Very low                     |
| Environmental benefits ( reduced CO <sub>2</sub> emission) | Very high                    |

### ➤ Shrinkage-Compensating Concrete

According to the Report of ACI Committee (1991), shrinkage-compensating concrete is an expansive cement concrete which when properly restrained by reinforcement of other means will expand an amount equal or slightly greater than the anticipated drying shrinkage. Due to the restraint, compressive stresses will be induced in the concrete during expansion but subsequent drying shrinkage will reduce these stresses. Ideally, a residual compression force will remain the concrete, thereby eliminating the risk of shrinkage cracking.

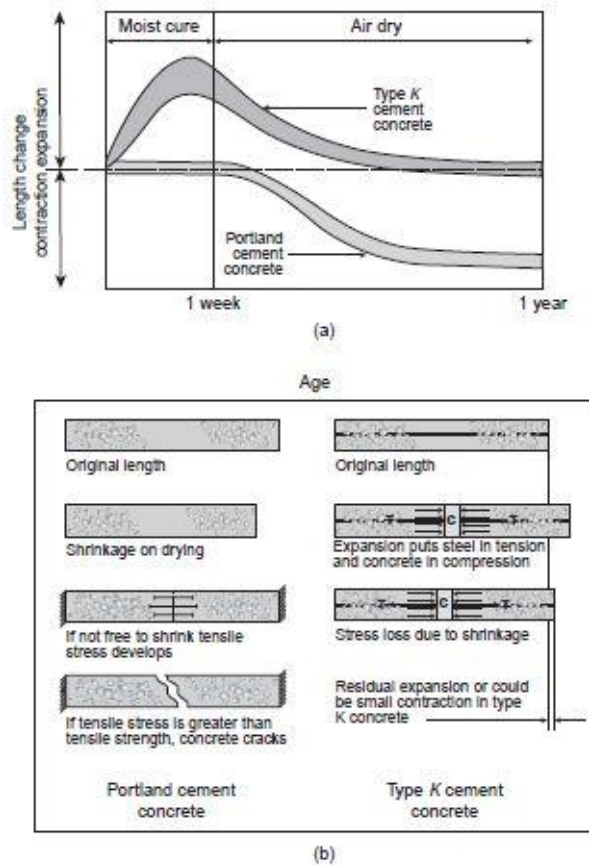


Figure 33: (a) Comparison of length change characteristics between Portland cements and Type K shrinkage-compensating concrete and (b) Illustration showing why Type K concrete is resistant to cracking from drying shrinkage (Williams, 1981)

### ➤ Fibre-Reinforced Concrete

Concrete containing hydraulic cement, water, aggregate and discontinuous discrete fibres is called a fibre-reinforced concrete. Fibres of various shapes and sizes produced from steel, plastic, glass and natural materials are being used, with steel fibre most commonly used for both structural and non-structural purposes. Due to the natural occurring micro-cracks which are responsible for the low tensile strength of concrete, the addition of fibres brings about possible strength and toughness improvement.

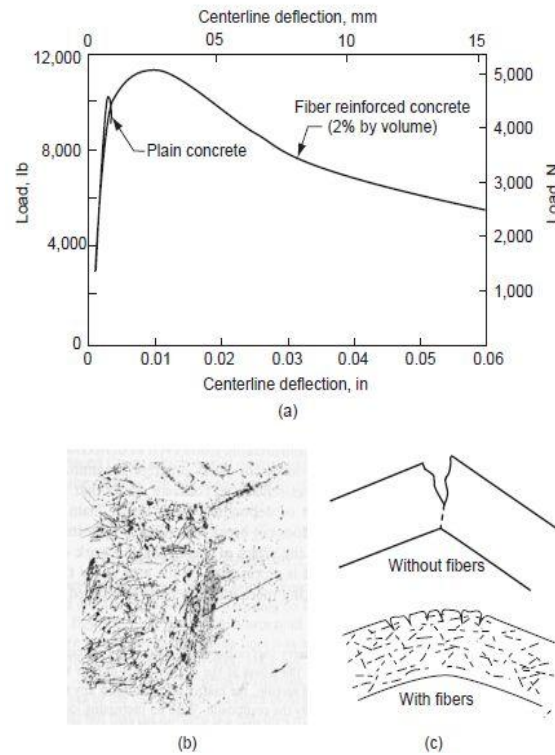


Figure 34: (a) Load deflection behaviour of plain and fibre-reinforced concrete (Hanna, 1977); (b) cross section of a steel-fibre-reinforced beam after fracture showing that the failure mode is fibre pullout (Krenchel, 1974) and (c) mechanism of increase in flexure toughness of concrete with fibres (Johnson, 1980)

### ➤ Concrete Containing Polymers

Concrete containing polymers can be classified into three categories:

- Polymer Concrete (PC) is formed by polymerizing a mixture of monomer and aggregate with no other bonding material present, usually used as an overlay or in repair jobs
- Latex-modified Concrete (LMC) which is usually made by replacing part of the mixing water with latex (polymer emulsion). LMC exhibits excellent bonding capabilities and high durability in aggressive conditions.
- Polymer-impregnated Concrete (PIC) which is produced by impregnating or infiltrating a hardened Portland cement concrete with a monomer and subsequent polymerizing the monomer in situ. PIC is usually used for the production of high strength pre-cast products and for improving the durability of bridge deck surfaces.

Due to the high material cost and cumbersome production technology of these polymer-containing concrete, the use of PC, LMC and PIC are limited.

Table 5: Typical Mechanical Properties of Concretes Containing Polymers (Johnson, 1980)

|                                | PC                                                  | PIC                          |                        |           |                                                        |                               |                                                                 |
|--------------------------------|-----------------------------------------------------|------------------------------|------------------------|-----------|--------------------------------------------------------|-------------------------------|-----------------------------------------------------------------|
|                                | Polyester<br>1:10<br>polymer/<br>aggregate<br>ratio | LMC                          |                        | Air-cured | LMC<br>containing<br>styrene<br>butadiene<br>air-cured |                               | MMA<br>impregnated<br>thermal-<br>catalytical<br>polymerization |
|                                |                                                     | Poly-<br>merized<br>MMA 1:15 | Control<br>Moist-cured |           |                                                        | Control<br>unimp-<br>regnated |                                                                 |
| Compressive strength           | 18,000                                              | 20,000                       | 5800                   | 4500      | 4800                                                   | 5300                          | 18,000                                                          |
| Tensile strength               | 2000                                                | 1500                         | 535                    | 310       | 620                                                    | 420                           | 1500                                                            |
| Flexural strength              | 5000                                                | 3000                         | 1070                   | 610       | 1430                                                   | 740                           | 2300                                                            |
| Elastic modulus, $\times 10^6$ | 5                                                   | 5.5                          | 3.4                    | —         | 1.56                                                   | 3.5                           | 6.2                                                             |

Listed above are discussions on some of the recent notable advances in concrete technology. Other novel types of concrete mixtures such as roller-compacted concrete, mass concrete and heavyweight concrete are all commercially viable but implementation requires additional mixing and casting procedures, potentially complicating the production of pontoon design and deviating from our design goals.

## Choice of Concrete

On review of various commercially available types of concrete commonly used in the market, high performance concrete (HPC) is deemed suitable for our application. Further to description in previous section, HPC can be subdivided into different classes; two of the predominant types are shown in the table below:

Table 6: HPC mix proportions and properties (Langley, Gilmour, & Trompsch, 1995)

| Mix proportions, kg/m <sup>3</sup>                             | Class A<br>concrete<br>for main<br>piers and<br>T-beams | Class C<br>concrete<br>for massive<br>foundations | Abrasion-<br>resistant<br>ice shield<br>concrete |
|----------------------------------------------------------------|---------------------------------------------------------|---------------------------------------------------|--------------------------------------------------|
| Portland cement                                                | 416                                                     | 285                                               | 478                                              |
| Silica fume                                                    | 34                                                      | 22                                                | 42                                               |
| Fly ash, Class F                                               | —                                                       | 133                                               | 60                                               |
| Fine aggregate                                                 | 737                                                     | 744                                               | 650                                              |
| Coarse aggregate                                               | 1030                                                    | 1054                                              | 980                                              |
| Water                                                          | 153                                                     | 159                                               | 142                                              |
| Superplasticizer                                               | 3                                                       | 2                                                 | 6                                                |
| W/cm                                                           | 0.34                                                    | 0.37                                              | 0.25                                             |
| <b>Properties</b>                                              |                                                         |                                                   |                                                  |
| Entrained air, %                                               | 6.1                                                     | 7.0                                               | —                                                |
| Slump, mm                                                      | 200                                                     | 185                                               | —                                                |
| Compressive Strength, MPa                                      |                                                         |                                                   |                                                  |
| 1-day                                                          | 35                                                      | 9.7                                               | —                                                |
| 3 days                                                         | 52                                                      | 27.4                                              | —                                                |
| 28 days                                                        | 82                                                      | 50.0                                              | 100                                              |
| 91 days                                                        | —                                                       | 76.0                                              | —                                                |
| <b>Rapid chloride permeability, Coulombs<br/>(AASHTO T277)</b> |                                                         |                                                   |                                                  |
| 28 days                                                        | 300                                                     | 420                                               | —                                                |
| 90 days                                                        | —                                                       | —                                                 | —                                                |

The choice of using HPC is obvious, as it has a proven track record as the designated concrete mix for sophisticated structures with longer service life of up to 120 years. When exposed to aggressive fluids and demanding environmental exposure conditions, it is essential that the concrete should remain crack-free and impermeable over time. HPC mixtures are being used for the construction of structural components of offshore oil-drilling platforms, long-span bridges and highway bridge decks (Mehta & Monteiro, 2006).

For example, some of the completed projects during the 1970s involve construction process that includes fabrication of massive oil-storage cells and pre-stressed concrete shafts on a dry dock

under rigorous quality control conditions, and then towing the structural components to the job site in the middle of the North Sea. The HPC is required to withstand the corrosive action of seawater and impacts and erosion from high tidal waves. According to Moksnes and Sandvik (1996), precautions taken to prevent thermal cracking of HPC included cooling of the concrete constituents, partly replacing the mixing water with crushed ice, increasing the silica fume content from 3 to 9 percent, etc.

The HPC used to model the pontoons will possess the following properties:

Table 7: Properties of our pontoons design

| Property                           | Value    | Units             |
|------------------------------------|----------|-------------------|
| Elastic Modulus in X               | 4.1e+010 | N/m <sup>2</sup>  |
| Poisson's Ration in XY             | 0.21     | N/A               |
| Shear Modulus in XY                | 1.7e+010 | N/m <sup>2</sup>  |
| Mass Density                       | 1281.5   | kg/m <sup>3</sup> |
| Tensile Strength in X              | 5000000  | N/m <sup>2</sup>  |
| Compressive Strength in X          | 30000000 | N/m <sup>2</sup>  |
| Yield Strength                     | 4000000  | N/m <sup>2</sup>  |
| Thermal Expansion Coefficient in X |          | /K                |
| Thermal Conductivity in X          | 0.2256   | W/(m·K)           |

#### 4.2.1.3 Coating

The usage of HPC as the choice of material enables the structure to equip with properties of high-workability, high-strength and high durability. As the floating structure is designed to be offshore to be exposure between the seawater and air, it is susceptible for the concrete to face corrosive effect. Since concrete is a porous material, if it is not protected, it can absorb water, sodium chloride (salt), carbon dioxide and allow acid precipitation causing lost of integrity in time. This is more visible for concrete that is permanently submerged in the water where magnesium and hydrogen carbonate ions form layers in which cause slower attachment of calcium carbonate which will reduce the concrete pH resulting pressure to cause cracks and ruptures in the concrete.

Another problem faced would be the risk of biological growth attached to the concrete floating platform such as barnacles, mussels, algae (macro-fouling) and bacteria (micro-fouling). Macro-fouling could happen within 2 weeks while micro-fouling could happen within a day or two. The effect of such biological growth is that it has the potential to cause surface staining, produce chemical changes and thus decrease the durability hence resulting in the increased of maintenance costs for removal. Marine growth could possible increase the total weight of the structure but this value is insignificant as compared to the total weight with deck loading due to the low specific gravity of marine growth.



Figure 35: Marine growths on concrete structure

Coatings for concretes differ very much from the aim from decorative paint. Having a coating helps to maintain the integrity of the concrete structure and protect any reinforcing steel if applicable against corrosion. Protection coating do not only repel water but also allow the concrete to “breathe” to allow water vapour to escape from concrete to air.

### **Surface Preparation**

Correct proper surface preparation is critical for the performance of the chosen coating system. All of the concrete need to be cured, clean and free from any possible form of contaminations such as marine growth and the possible way to remove would be by mechanical equipment such as light grit blasting or high pressure water jetting (approximately 150 bars) while damage surface defects should be repaired using approved repair medium.

One applicable application of the concrete protection for the floating structure would be solvent epoxy coatings as they would be put in seawater for usage. Before any application of generic type of product, there should also be application of appropriate primer as part of a complete system.



Figure 36: High Pressure Water Jetting



Figure 37: Application of Primer coating on concrete

### 4.2.2 Design of the Pontoon

Formation of pontoon platform requires two basic components – the individual hexagonal pontoons and the connecting pins. As such, the macro structure of the floating platform can be created with repetitive use of just two components.

#### Hexagon Pontoon

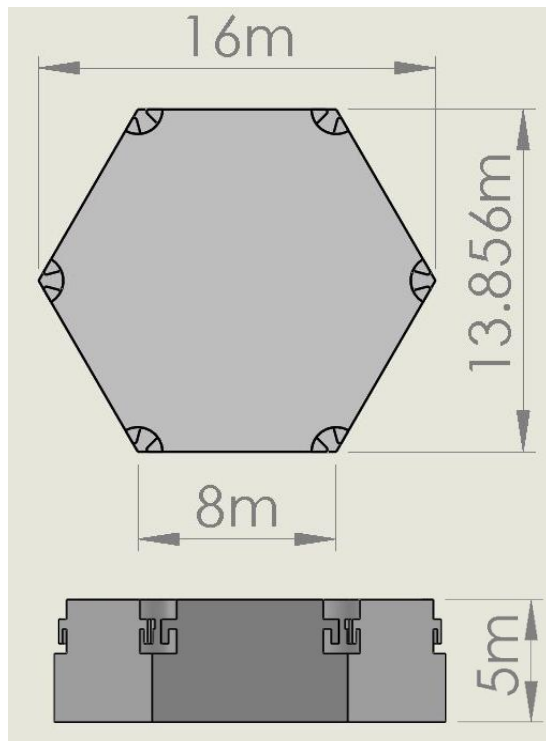


Figure 38: Top side view of the individual hexagon pontoon

The dimensions of the hexagon pontoon are designed such that the pontoon is able to displace more water than its own mass, so as to achieve a buoyant steady state in water.

The exterior of the pontoon has the following dimensions:

Side Length = 8m

Max. Length = 16m

Height = 5m

A solid pontoon of such dimensions will not be able to float on water with the chosen type of concrete; therefore reduction of its mass will have to be carried out. Without altering its external design, empty chambers are hollowed out of the pontoon to create watertight chambers.

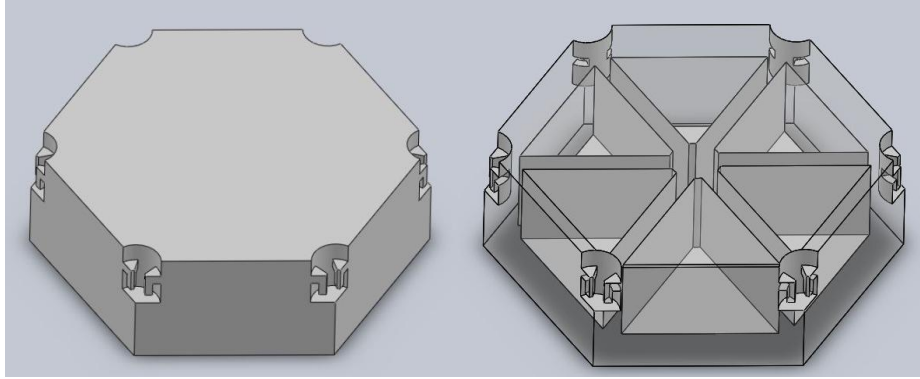


Figure 39: Internal watertight air chambers of the hexagon pontoon

By having six internal watertight air chambers of triangular shape, the mass of the pontoon can be reduced significantly by 61%, achieving a state of buoyancy with 3.77m draft in unloaded condition. It has an approximate payload capacity of 200 tons before pontoon top surface is level with the waterline.

#### **4.2.3 Design of the Connecting Pin**

Each hexagon pontoon has one-third of a circular slot incorporated into every one of its six corners to cater to the housing of the connecting pin. A single connecting pin is designed to hold three hexagon pontoons together, resisting opposing pontoon motion relative to each other in the three degrees of freedom – surge, sway and heave.

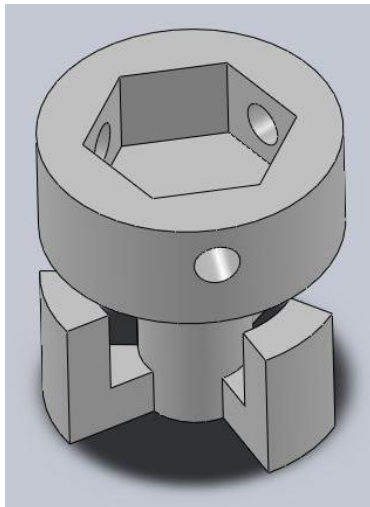


Figure 40: Connecting pin with hexagonal cut

The connecting pin is to be made of the same high performance lightweight concrete used for producing the hexagon pontoon. The connecting pin is designed to be of a single solid piece, so as to facilitate ease of production, where it can be cast out of the same formworks in a standard process workflow.

Main specifications of the connecting pin are as follows:

Diameter= 2.00m

Height= 2.20m

Mass= 3.59 tons



Figure 41: Hexagonal socket screw and bolt

The top of the connecting pin has a hexagonal socket cut within the circumference for purposes of effecting rotation, similar to the action of the common Allen® key tool and its corresponding bolt. Three holes are cut on the hexagonal socket face to serve as lifting holes, to be illustrated in later sections of this report.

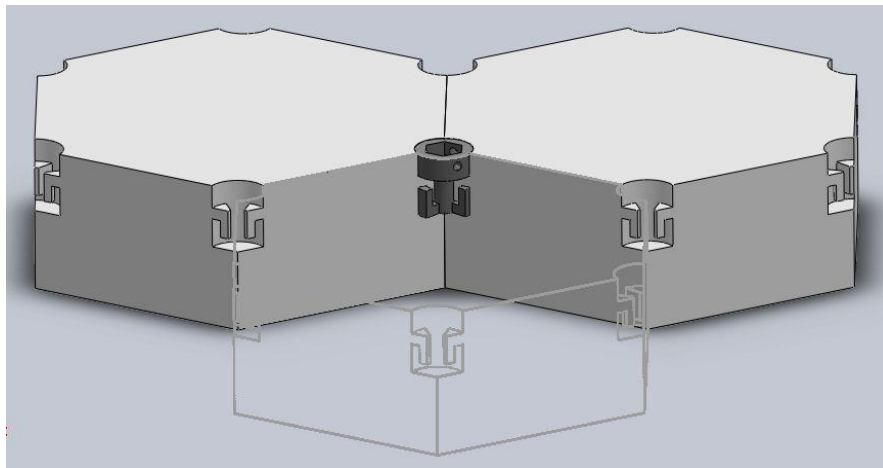


Figure 42: Illustration of a single connecting pin holding 3 pontoons together

#### **4.2.4 Assembly of the Pontoons and Connecting Pins**

The pontoons are manoeuvred into mating position by tugboats in water before the connecting pin is inserted and rotated to its final position to hold the sub-assembly together. A hydraulic pin connecting tool is designed to perform both the lifting and rotation of the connecting pin. The hydraulic tool can be fitted to the end of an articulated crane similar to that of the offshore construction vessels and anchor handling tugs, or it can also be mounted to a custom construction vehicle analogous to that of a forklift or excavator.

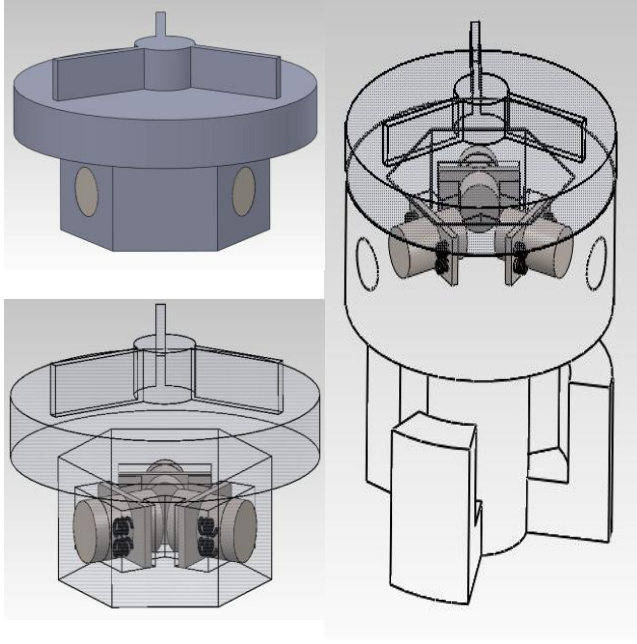


Figure 43: Illustration of the hydraulic pin connecting tool, showing the rotary vane [top left], internal pistons and springs [bottom left] and locking arrangement with connecting pin [right]

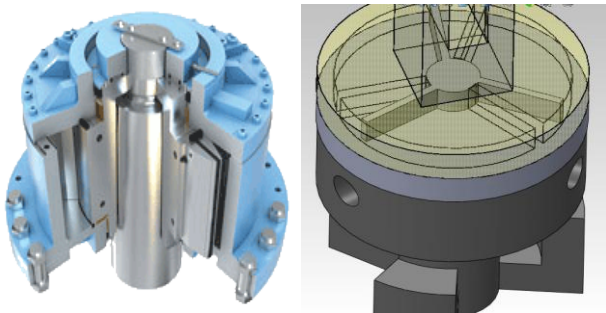


Figure 44: Rotary vane steering gear [left] and modified design on pin connecting tool [right]

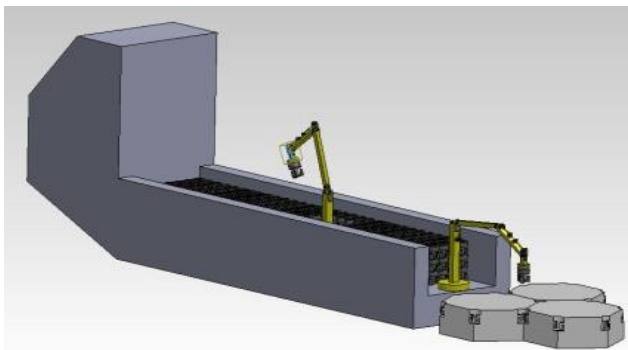


Figure 45: Example of the hydraulic pin connecting tool fitted to the end of the articulated crane of an offshore supply vessel loaded with connecting pins

The lower half of the hydraulic pin connecting tool houses three pistons that rely on hydraulic pressure and spring action to work. The hydraulic pressure causes linear displacement of the pistons which in turn compresses a set of springs, before extending into the cut holes of the connecting pin to result in a locking arrangement.

The locking arrangement between the tool and connecting pin allows the pin to be lifted into that air, facilitating transfer from point to point.

On release of the hydraulic pressure, each piston is then retracted back into the tool by the set of springs which is no longer held under compression.

To rotate the connecting pin into its locking position, the concept of the rotary-vane steering gear is utilised to produce the required torque. As the power required to rotate the pin is anticipated to be a fraction of what these steering gears are designed to handle, a scaled down version is designed for the specific purpose of rotating the connecting pin.

Working principle of the pin connecting tool to produce rotation remains the same as the rotary steering gear. Alternate chambers are filled and drained of hydraulic oil to result in a net rotation movement of the vane component. Advantage of this design is that it is of a more much compact design, hence lighter footprint and mass, thereby making it suitable to be implemented as part of a tool that is expected to be highly mobile.

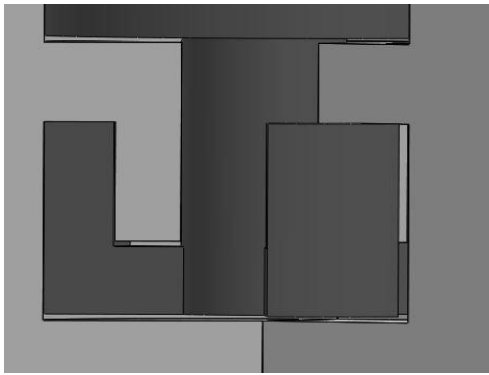


Figure 46: Rotation of the connecting pin within clearances to avoid contact with neighbouring walls to reduce frictional effects

To reduce power required to rotate the connecting pin, it is possible to position the connecting pin within the clearances of the walls of its neighbouring slots so as to avoid incurring of frictional losses. In this manner, an even smaller rating of hydraulic system can be achieved, with adverse effects such as abrasion and impact loading mitigated to avoid unnecessary component damage.

#### **4.2.5 Transportation of Pontoons Structure and Connecting Pins**

Transportation of the required components are categorised into two types – over long distance or over short distance. In view of the massive tonnage of components that is to be moved, transportation via air and land is deemed unfeasible and the sea route remains the best of choice.

##### **Use of Tugboats**

The pontoons, pre-assembled in various modular configurations, can be moved by tugboats across short sea distances. It is not uncommon for large structures to be towed on water. It is proposed that the hexagonal pontoons be pushed by the tugs instead of being towed, so as to avoid the need to create strong points on pontoons for line fixtures.



Figure 47: Examples of structures being towed across water

Drag coefficients of various modular configurations can be determined numerically by means of computational fluid dynamics to achieve an optimised configuration that incurs the least drag. This would be helpful in estimating required fuel costs, type of tugs to charter, etc.

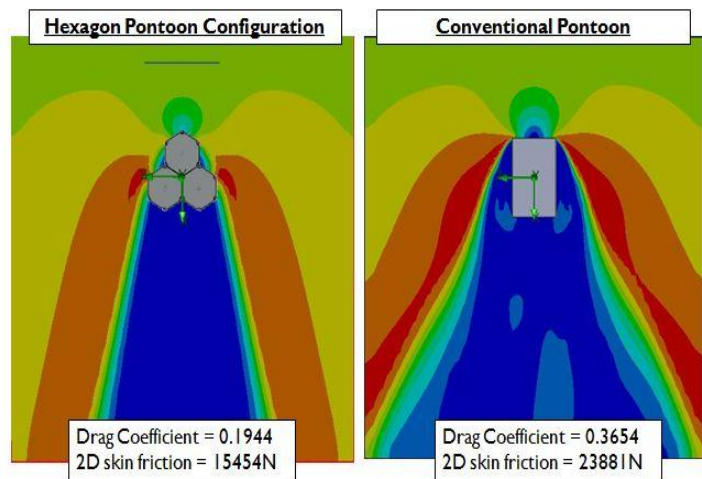


Figure 48: Comparison of moving similar (500m<sup>2</sup>) across water at 3 knots

### Use of Heavy-lift vessels

It is also not uncommon for large structures to be transported on specialised heavy-lift vessels. These vessels can take on ballast to sink their decks underwater, manoeuvre into position under the floating structure and then de-ballast to lift the entire structure out of water, bearing its load on their decks. As such, the structure can be brought across large span of water at a much higher speed and possibly much more cost effectively.



Figure 49: Heavy-left vessel MV Blue Marlin ballasting to sink deck below water level before taking on cargo [top]. Heavy-lift vessel transporting a semi-submersible [bottom left] and X band radar dome [bottom right].

The advantage of using heavy-lift vessel is that as the pontoons are all carried on the deck of the vessel, consideration for pontoon resistance and ability to withstand sea effects are eliminated. Unlike towing across long sea distances, with accurate weather forecasts and optimised sea routes and loading/unloading plans, pontoons can be brought to desired location swiftly and reliably.

The current biggest heavy lift vessel is the Dockwise Vanguard “Type O Super Vessel”. Its main specifications are as such:

- Loading Deck Dimensions

|          |                     |
|----------|---------------------|
| Length:  | 275m                |
| Width:   | 25m                 |
| Payload: | up to 110, 000 tons |

The designed hexagonal pontoon has a mass of 642 tons, therefore assuming under maximum loading condition, the number of pontoons transported on each voyage is calculated to be about 170.

As part of the inherent design criteria, the concept of modular configuration allows purpose-built structures to be pre-assembled away from final location, further increasing the flexibility and streamlining of the entire operation.



Figure 50: The Dockwise Vanguard: Type O Super Vessel" carrying another vessel [top] and a semi-sub structure [bottom]

#### 4.2.6 Construction on Hexagon Pontoons

Assembly of the pontoons result in a floating platform that is capable of multipurpose use. Different types of structures can be placed on the floating platform to achieve its desired purpose. These structures can be pre-built and transported to the floating platform location, or built in-situ on the pontoons themselves.



Figure 51: The Saipem 7200 with her dual crane traversing off the coastline [left] and the crane vessel in the midst of a lifting operation [right]

To place pre-built structures on the pontoons, crane vessels can be utilise to facilitate lifting. One of the largest crane vessels in the market is the Saipem 7200. Typical of crane vessels, she is capable of self-propulsion with anti-heeling ballasting system to ensure optimum and safe lifting operations. With combined use of the dual cranes onboard, the Saipem 7200 has a lifting capacity of 14000 tons at a distance of 42 metres.

Possible drawbacks of using crane vessels could be due to that of available water depth near the coastline, which is considered an ideal location for anchoring of the floating structure. For example, although the Saipem 7200 has a transit draft of 10.5 metres, its draft can change up to 27.5 metres during lifting operations due to required ballasting. A solution to this problem can be to carry out lifting operations further away from the coast in deeper water, where the crane vessel can lift and place the structure on a small assembly of pontoons. This sub-assembly can then be towed a short distance to the main site in shallower waters for final assembly with rest of the pontoons.

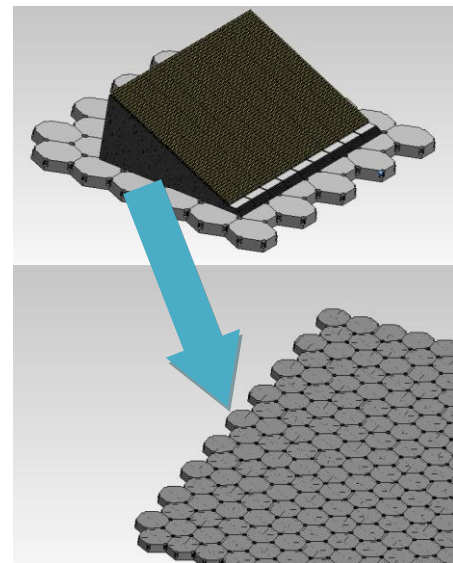


Figure 52: Towing of sub-assembly from deeper waters across short distance to main site at shallower waters

Another possible drawback of using crane vessels is the high charter rates of such vessels. By rule of thumb, as the lifting capacity of the vessel increases, its day rate increases as well. A typical 5000 tonnes lifting capacity crane vessel has charter rates of about US\$280k to US\$500k per day. A possible solution would be to sign long term contracts for a better position to negotiate a lower charter rate. Another possibility would be to once again exploit the modular design characteristic of the structures such that a single large component can be further broken down into smaller sections, thereby reducing the required lifting capacity of the crane vessel, hence cutting down charter costs.

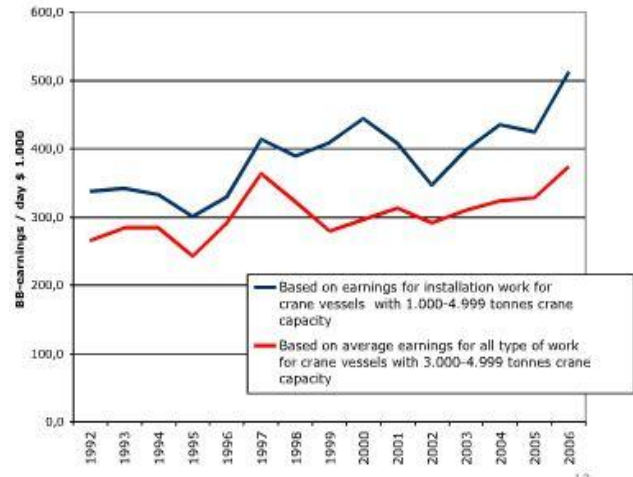


Figure 53: Historical day's rates of lifting vessels, which is influenced by oil demand and offshore construction projects

#### 4.2.7 Securing of Components on the Floating Platform

In order to prevent lateral displacement of the components placed on the floating structure, it is necessary to implement a securing mechanism between the structure and hexagonal pontoons. On land, such a problem is tackled with by piling foundation supports into the ground. However when it comes to the floating hexagonal pontoons, any method that involves piling into or breaching of the exterior pontoon walls is deemed unsuitable as it will compromise the pontoon's structural integrity and buoyancy.

The proposed method would be to make use of existing pontoon connection characteristics such as the connecting slots at each corner of the hexagon pontoons and the corresponding connecting pin. Therefore instead of using to secure adjacent pontoons together, the hole is used to secure the structure to the pontoons, preventing lateral displacement.

The securing mechanism should be hydraulically powered to result in a compact and lightweight system, which generally holds true when in comparison to an equivalent mechanical system. The securing mechanism should not interfere with the shape and outline of the hexagonal pontoon, so as not to negate benefits and design criteria defined earlier in the report. Lastly, the securing mechanism should be capable of lower the pin into the connection hole and rotating it to its proper securing position.

Similar to the hydraulic tool presented earlier in this report, a securing mechanism has to be designed to perform its required task as no such equipment is available in the market that satisfies the listed criteria. As such, a design extrapolated from the marriage of two hydraulic tools currently available in the market – the rotary vane steering gear and hydraulic bottle jack – is derived to carry out the securing of the structures placed onto the floating platform.

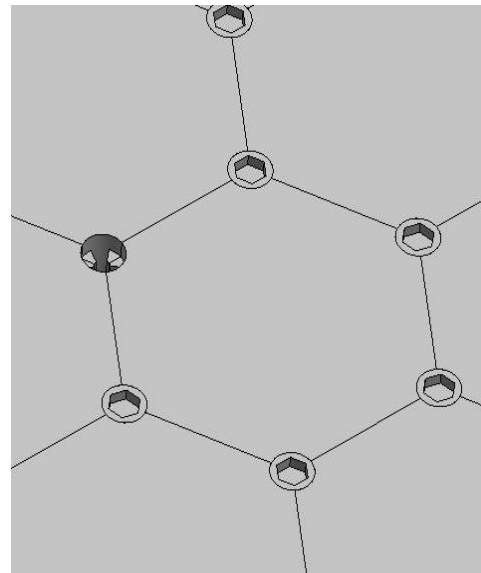


Figure 54: One of the connecting pin holes to be used for securing of structure instead of holding pontoons together

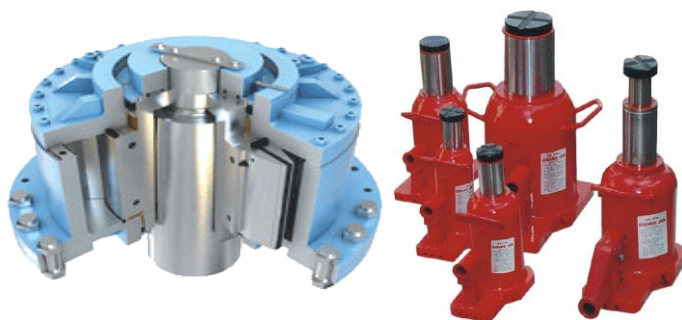


Figure 55: Extrapolation from the marriage of the two devices to design the securing mechanism – rotary vane steering gear [left] and hydraulic bottle jack [right]

The securing mechanism uses the same design of the hydraulic pin connecting tool (less the rotary component on top) depicted in earlier sections of this report to create a locking arrangement with the connecting pin. Re-iterating, the hydraulic pin connecting tool sits in the hexagonal socket of the connecting pin and houses three pistons that rely on hydraulic pressure and spring action to work. The hydraulic pressure causes linear displacement of the pistons which

in turn compresses a set of springs, before extending into the cut holes of the connecting pin to result in a locking arrangement. Extending above the hydraulic pin connecting tool is a piston that is displaced linearly by hydraulic pressure to lift and lower the connecting pin. The piston also carries the rotary vane component which uses hydraulic pressure to create a torque that will turn the connecting to its final securing position.

To facilitate implementation of securing mechanism, the securing mechanism together with its hydraulic system and a securing pin can be incorporated into the design of the structure that is to be placed on the floating platform. When activated, the piston will lower the connecting pin into the pontoon and rotated to its securing position. Consequently when the structure is to be removed, the piston will rotate and retract the connecting pin back into the securing mechanism. The number of securing mechanisms required will depend on the size of the structure.

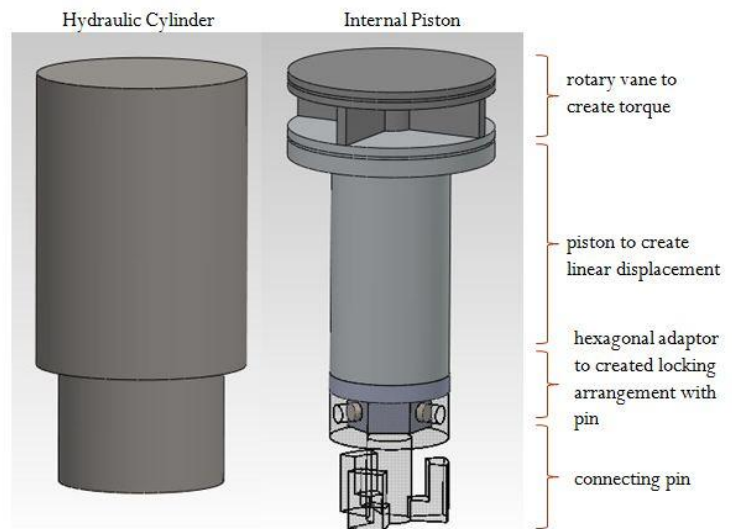


Figure 56: Illustration of the Securing mechanism

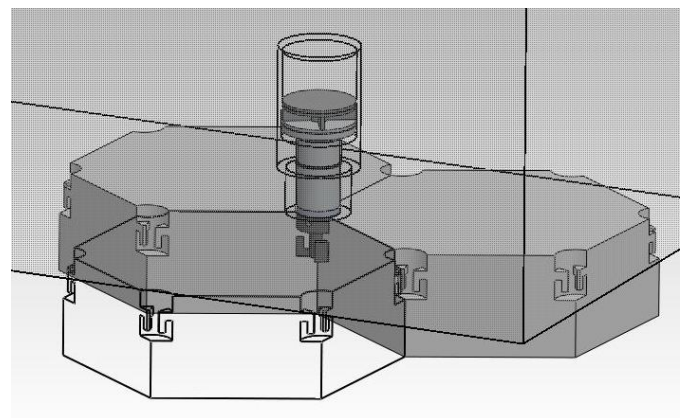


Figure 57: Incorporation of securing mechanism in the structure that is to be placed on the pontoons

#### 4.2.8 Human Accessibilities

As the main function is to host large scale events, the expected crowd onboard the multi-purpose platform will be huge. For instance, approximately 65,000 spectators will turn up for a typical soccer match. The human transportation to and fro the multi-purpose platform and coastline will need to be accessible and efficient in evacuation during fire outbreak. The most common forms of human transportation that are allowed near coastline depth are mainly the ferry and floating bridges.

##### Ferry



Figure 58: Ferry transportation in Venice



Figure 59: Penguin Ferry Transportation

A transportation ferry is usually a small vessel or boat that can be used to carry passengers across low level water near coast. Ferries are used as one of the main public transport systems of many waterside islands and cities as it allows direct transit between places near coast location at a relatively lower capital cost than that of bridges or tunnels.

Typical transportation ferries like the “Penguin Ferry” are used to transport Singapore Army Recruits to Tekong Island and from Singapore to Tioman Island. This ferry can only carry a capacity of 200 passengers per trip which is equivalent to 300 ferry trips to send a total of 60,000 spectators over to the floating multi-purpose platform.

### **Floating Bridges**

The concept of floating bridges has been known for a long time and small floating bridges are commonly found all over the world. Floating bridges are usually temporary structures or pontoons that can be used for long period of time. Permanent floating bridges are useful in providing accessibility across waterways where the spot is not economically feasible to suspend a bridge from anchored piers.



Figure 60: Yumemai Bridge, Japan



Figure 61: Floating Pontoons Bridge

Yumemai Bridge in Japan is a 410 m long floating bridge built in 1999. This bridge is supported by floating on two square shaped steel pontoons which are constructed across a water channel. The length, breadth and height of the pontoon were 58 m, 58 m and 8 m, respectively.



Figure 62: Floating Bridge use in wartime

During wartime, floating bridges were also greatly used by armies as crossings. These floating modules can be easily assembled by Army engineers to form floating bridges for soldiers and vehicles to cross rivers and lakes. Such bridges are usually temporary and are normally destroyed after crossing the water passenger.

Table 8: Analysis between Transport Ferry and Floating Bridge methods

| <i><b>Method</b></i>   | <i><b>Advantages</b></i>                                                                                                                                 | <i><b>Disadvantages</b></i>                                                                                                    |
|------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| <b>Transport ferry</b> | <ul style="list-style-type: none"> <li>• Easy available in current market</li> </ul>                                                                     | <ul style="list-style-type: none"> <li>• High risk of sea-sick</li> <li>• Safety issue upon emergency of evacuation</li> </ul> |
| <b>Floating bridge</b> | <ul style="list-style-type: none"> <li>• Ease of setting escape route (safety)</li> <li>• Freedom of people access to and back from the shore</li> </ul> | <ul style="list-style-type: none"> <li>• Set up lead time for usage.</li> <li>• Structural issue</li> </ul>                    |

These main highlights of advantages and disadvantages between the transport ferry and bridge are discussed in the above table. The considerations have been discussed, leading to a combination of these two types of transportation method while making use of our available pontoons to re-shape into a ferry terminal to cater for the ferry and floating bridge.

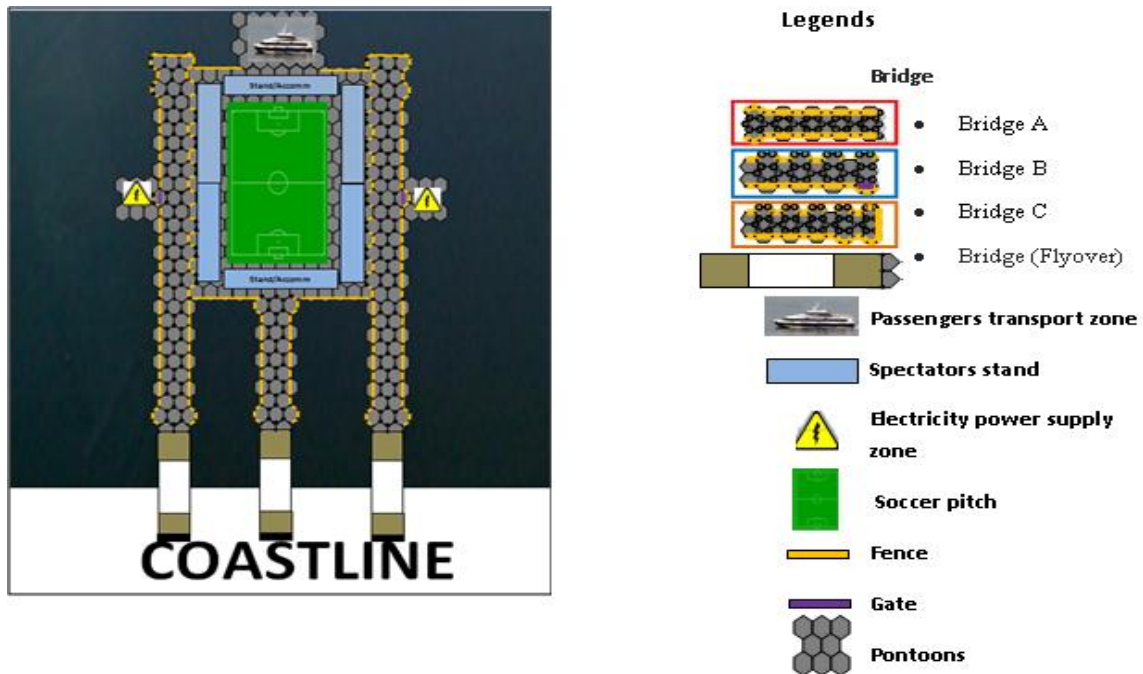
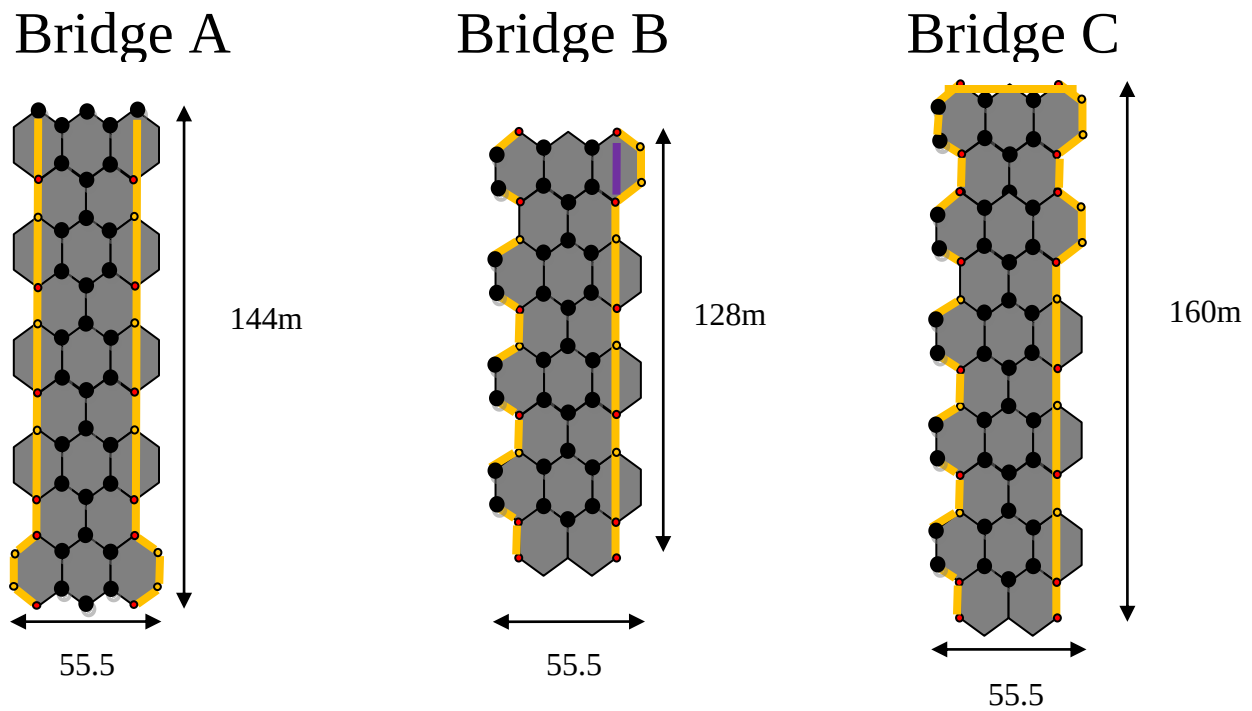


Figure 63: Modified Design with access zone

### **Bridge of Multi-purpose platform**

The bridge is designed to allow walking only since the walking distance between the coastline and the multi-purpose platform is about 200 m apart. During emergency evacuation to hospital, transportation will be relying on high speed rescue vessel that will be standby on the dock platform. The bridge consists of four different parts (Bridge A, B, C and Flyover Bridge).

## Hexagonal Pontoons Bridge



Three Bridge A, two Bridge B and two Bridge C form the bridge of the platform. The regular hexagonal pontoons are used to form Bridge A, B and C. The hexagonal pontoons platform can be further improved. Its appearance is as shown below:

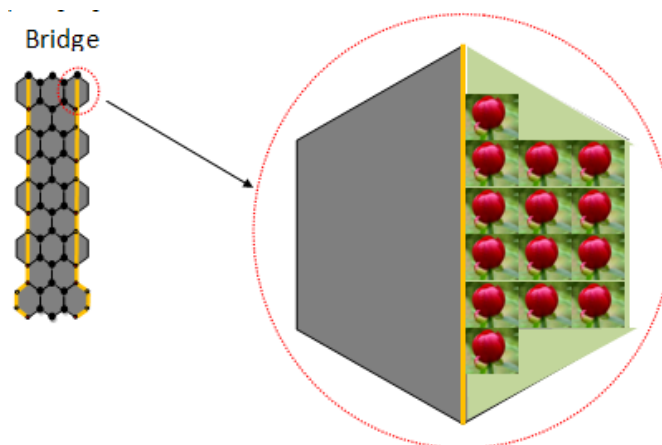


Figure 64: Hexagonal pontoons platform

## Flyover Bridge

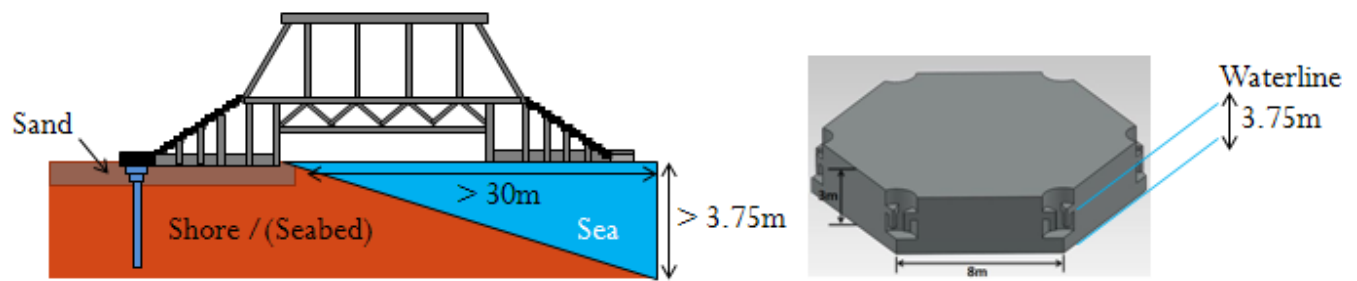
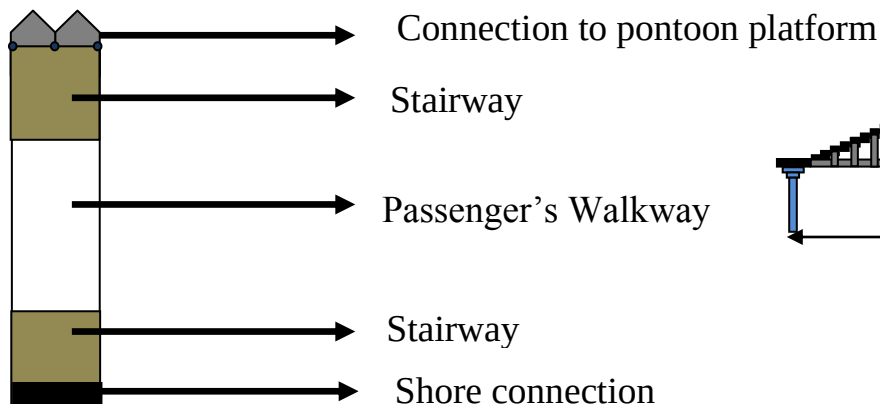


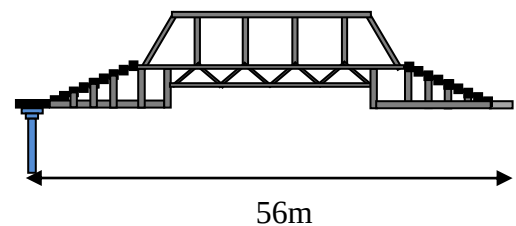
Figure 65: Illustration of pontoon's water draught and proposed flyover bridge

Since the water draught of our pontoon without any loads above is 3.75m, our pontoon will only able to function properly at least 30 m apart with an assumption reference from low tide water level. This flyover bridge is a temporary floating structure bridge that is used to set margin for high and low tides. There will be three flyover bridges in all.

### Top view



### Side view



The flyover bridge provides the link way between the shoreline and pontoons bridge. Each flyover bridge structure will be piled into the sand bed by three piles and attached to the pontoons bridge. The spectators will walk up the shoreline's stairway, leading to the passenger's walkway, and then finally the staircase to reach the main pontoons bridge.

## 4.2.9 Artificial Soccer Pitch

There are many different companies available that study on artificial soccer pitch for the different usage and functionalities. Generally some companies like Desso DLW Sports Systems are equipped with two types of applications for football; the sand-filled system and the sand-rubber filled system. The sand-filled applications had been used for DD Crown Soccer and DD Soccrilan while sand-rubber filled application had been used for DD Soccer Grass, DD Challenge and DD Rugby Pro.

### 4.2.9.1 Sub-base Construction

An artificial surface for football requires a stable, even and water-permeable sub-base for outdoor use. Although water can permeate easily through the artificial grass layers, the slope of the top-layer should still be used as extra surface drainage in case of heavy rains.

In general, the 3 types of slopes:

#### **Gable Roof**

The gable roof pitch is recommended for large(r) playing fields. There should be no construction problems with the top-layer, soil levelling or drainage. The goal area for football should be made in such a way, that the clear goal height is 2.44 m.

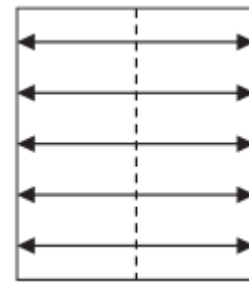


Figure 66: Gable-roof fall

#### **Turtleback Fall**

The turtleback fall pitch is mostly used for large playing fields with a surrounding athletic track or for playing fields where the peripheral kerbstones have to have the same overall height.

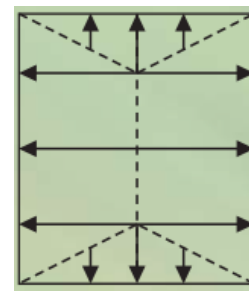


Figure 67: Turtleback Fall

### **Pent Roof Fall**

Small playing fields should be installed with at least one pent roof fall pitch, which drains to one side in the direction of one longitudinal side.

The slope of the pitch surface should be 0 – 1.0%, preferably 0.4%.

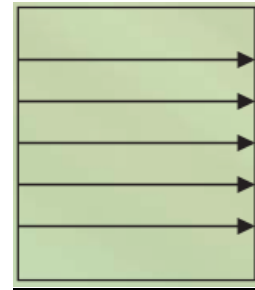


Figure 68: Pent Roof Fall

### **4.2.9.2 Unbound sub-base**

The unbound sub-base (a sub-base without bonding agent) needs to have a firm granulate shell and has to consist of a highly permeable material, e.g. crushed stone, gravel or a mixture of mineral substances. The sub-base must be able to endure the load capacity and be able to drain the rainwater seeping through the coating therefore the surface of the unbound sub-base needs to have the same slope as the surface layer installed on top.

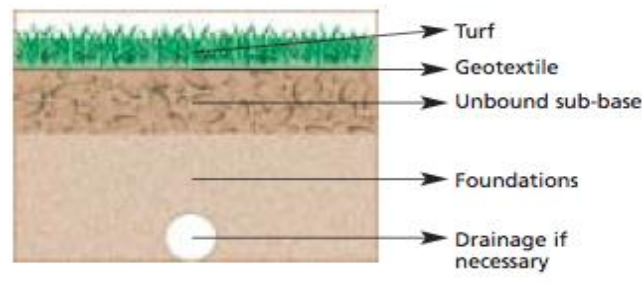


Figure 69: Breakdown of Unbound sub-base

### **Foundations:**

Thickness layer: at least 150 mm when compacted.

Height layer: deviations max. +/- 15 mm from the nominal height.

Evenness: max. 10 mm gap-width underneath the 3 m levels board.

### **Unbound Sub-base:**

Thickness layer: at least 60 mm when compacted

Height of layer: deviations max. +/- 15 mm from the nominal height.

Evenness: max. 5 mm gap-width underneath the 3 m straight edge.

### **Final grade:**

The final grade aggregate layer should not be more than a few mm thick. The granulate size is 0.3 mm or 0.5 mm.

### **Geotextile:**

On top of the unbound base it is essential to put a geotextile of min 125 grs/m<sup>2</sup>. Rolls of geotextile should be installed side-by-side, not overlapping, to prevent additional unevenness.

### **4.2.9.3 Bound (Engineered) sub-base**

The combined sub-base (a sub-base with bonding agent) is a layer consisting of mixtures of mineral granulate substances, the granulate shells of which are stabilized by means of a bonding agent. It is usually made of an asphalt mixture and has to have good water-permeability.

### **Foundations:**

The foundation for a bound base uses the same specification as for an unbound base.

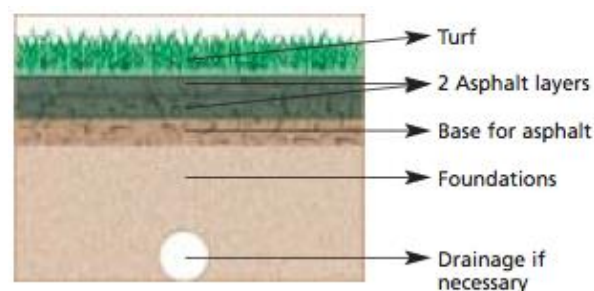


Figure 70: Breakdown of Bound sub-base

### **Bottom layer (Base for asphalt)**

Porosity:  $\geq 0.01$  cm/sec.

Rate of compression:  $\geq 90\%$

Thickness layer: minimum 40 mm when compacted.

Height of layer: deviations max. +/- 10 mm of the nominal height.

Evenness: max. 10 mm gap underneath the 3 m straight edge.

### **Top layer (2 layers of asphalt)**

Porosity:  $\geq 0.01$  cm/sec.

Rate of compression:  $\geq 90\%$

Thickness layer: 30 mm when compacted.

Height of layer: deviations max. +/- 10 mm of the nominal height.

Evenness: max. 5 mm gap underneath the 3 m straight edge.

The mixture has to be applied hot, by means of a road-finishing machine fitted with a heated board. Manual application is only possible in exceptional cases (small areas). Compacting must also be performed when the material is hot using medium/heavy tandem rollers are usually used.

#### **4.2.9.4 Elastic layer by means of loose shock pads**

The (water-permeable) elastic layer is installed directly underneath the turf and on top of a typical unbound base (as described before). The layers usually consist of pre-fabricated rolls that are rolled out on top of the stone sub-base. The material has to be handled and installed in accordance with the manufacturer's instructions. This elastic layer together with the surface construction should achieve between 50 and 65% force degradation.

#### **Foundations:**

The foundation for a bound base uses the same specifications as for an unbound base.

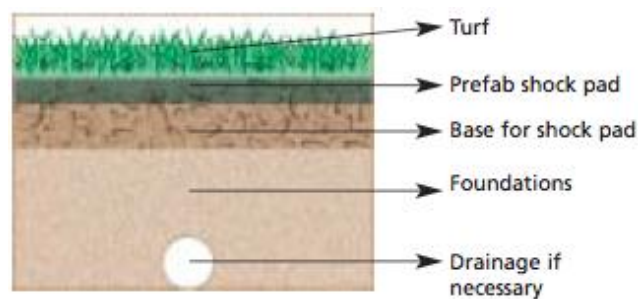


Figure 71: Breakdown of Elastic layer by means of loose shock pads

#### **Installation instructions for the loose laid shock pads:**

Ideal temperature for installation: 10 - 25°C (50 - 80° F), extra care has to be taken at temperatures below 10°C.

Count the number of rolls and check that their combined length and width fits the field dimensions. Under normal circumstances the length of each roll should cover the field width plus a bit extra for cut-loss.

Place rolls along the longest edge of the field. Make sure the sub-base is perfectly flat and free of foreign objects. Unbound sub-bases must be perfectly levelled and compacted before rolls are unrolled.

Put the first roll in its position to be unrolled along the outside edge of the field. Make sure that the beginning of the roll overlaps the field edge by about 1 percent of the total roll length. About

the shock pads along the long side to the other field edge. To position the roll correctly insert a pipe or stick into the carton core of the roll. Do not walk over the unbound base to avoid deforming it.

Repeat this procedure roll by roll down the length of the field. If temperatures are below 10°C (50°F) and higher temperatures are expected, leave a gap of about 5 mm between rolls

### **Application of joint tape:**

It is not necessary to use joint tape, however to allow rolls to adjust and expand / shrink depending on changing temperatures. Before joint tape is applied, roll seams have to abut to avoid adhesive penetrating into the sub-base.

Traditionally, the rolls tend to slightly “tail-out” at the beginning and the end. If this is the case and this effect builds up to a degree where the seams curve too much, use a chalk line and cut back the material to a straight line from time to time.

Place the end of the joint tape at the beginning of the seam. Put a weight on the tape to hold it in place as the tape unrolls. Stretch the tape and hold it in place exactly over the centre of the joint by weighing down both ends.

Pour or spray an adequate amount of adhesive over the tape and spread adhesive over the entire width of tape but not much further, using a flat steel trowel.

If there are head-seams in the playfield area (for instance at the centre of the field) they should be double cut to achieve a cut-to-fit joint. Apply joint tape and adhesive immediately after cutting as described above.

The overlapping roll ends at the long sides of the field should only be cut after the turf has been laid.

### **Edging**

Edging the base material has to be done immediately after the preparation in order to get the carpet correctly fitted at the kerbstone.

### **Workforce**

For the installation and gluing of the elastic layer, 4 people should be sufficient to install a full-size pitch.

#### **4.2.9.5 Elastic layer (E-layer) in situ**

An elastic in-situ layer built on a bound sub-base, consists of a rubber granulate and polyurethane as a bonding agent, for an unbound sub-base minerals are added. The mixture must be prepared on site and applied immediately.

Only experienced companies with suitable machinery and workforce are recommended for the production and application of an elastic sub-base. If these are not available it is better to employ a sub- contractor.

No precise guidelines for composition are given because experienced companies should be familiar with the suitable materials and their composition.

### **Foundations:**

The foundations for an E-layer use the same specification for an unbound or bound base. Where the requirements regarding stability and evenness are very high an asphalt base is most appropriate. In case of an unbound base the thickness of the E-layer should be a minimum of 25 mm, or in the case of a bound base, a minimum of 15 mm.

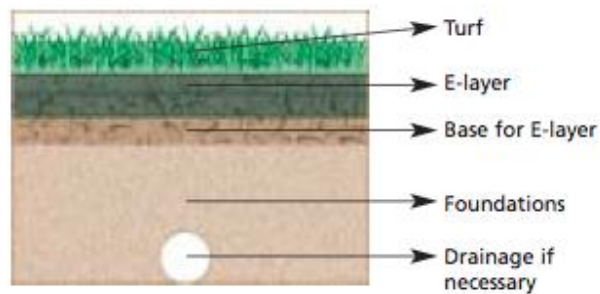


Figure 72: Breakdown of Elastic layer in situ

### **Elastic layer requirements:**

Force degradation: between 50 and 60% together with the top coating, measured with the Artificial Athlete

Thickness layer: 15 mm on a bound base, 25 mm when unbound.

Height of layer: deviations max. +/- 1.5 mm from the nominal height

Evenness: max. 5 mm underneath the 3 m straight edge.

Tensile strength:  $\geq 0.2$  MPA

Stability:  $\geq 0.25$  N/mm

### **4.2.9.6 Drainage**

Drainage is required when the subsoil below the pitch construction is not sufficiently permeable. In cases where drainage is required, the drainage pipes are usually installed parallel to the longitudinal axis of the playing field.

The fall of the duct should not be more than 1:200 (0.2%), and is not permitted to be any less than 1:1000 (0.01%).

The collection duct must be accessible to allow it to be checked and cleaned. For this reason adequate shafts must be included, usually at each corner and where there is any change in the fall of the base.

### **Kerbstones/Surrounding drainage channel:**

After the filter bed and frost resistant layer has been installed, the kerbstones (or drainage channel) have to be positioned in accordance with the drawings. The recommended size of the kerbstone is 100 x 20 x 8 cm. The height of the kerbstones has to be carefully observed; The top of the kerbstone must be 5 mm below the top of the artificial grass.

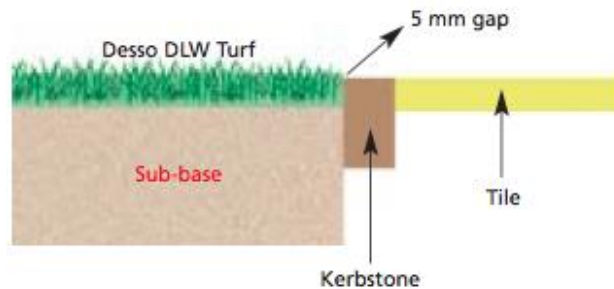


Figure 73: Application of Kerbstone

### **4.2.9.7 Overall installation guide**

#### **Roll Positions/ Laying Plan (Annex B)**

Companies that provide the artificial field like Desso DLW Sports Systems will provide a laying plan that gives all the necessary information for laying the football pitch. This plan will be sent prior to delivery of the carpet. Each roll has a reference number: the last two digits of which indicate the specific roll e.g. UK 5126\_8 is roll 8, UK5126\_26 is roll 26. Some rolls have lines tufted in.

E.g. according to the plan, rolls 1, 2, 3 and 4 have tufted-in sidelines. Other rolls have lines to be used for the goal lines and the middle line. The remaining rolls are uniform green.

#### **Rolling out the rolls:**

Measurements are marked out for the inside of the perimeter lines using a “splash-line”, indicated on the asphalt or marked on the kerbstones. Start rolling out 2 rolls with tufted-in lines and if using an unbound sub-base roll out the geotextile. Check the dimensions of the field. Straighten out the roll with sidelines by means of a wire and apply a small quantity of sand. From the side rolls, it is easy to reach any spot on the field. Do not apply any sand within 50 cm

of the sidelines. Apply the remainder of the sand (and finally the rubber in sand/rubber systems) after gluing the sideline.

The roll with the goal line can then be rolled out (refer to roll position list, Annex B). Check the dimensions again and straighten this line with a wire. When moving the rolls by a few centimetres, allow air under the carpet to aid repositioning by wafting the carpet up and down.

### **Preparation of the seam:**

Roll out the next roll and make sure that there is 5 cm of carpet overlapping the roll with the goal line. Turn back 50 cm of the roll with the goal line and cut out two pole rows.



Figure 74: Preparation of the seam

After completing this, turn the roll back again and use this cut as a guide for the straight edge for the other carpet roll. Use a special cutting device for this (refer to Annex A). Check if the side of the rolls makes a good seam.

### **Gluing the seam:**

Make sure that the rolls are lying completely flat. The next step is the gluing of the seam. Turn back 40 cm of the roll along the whole length of the seam. Unroll the 23 cm wide seaming tape. For a DD Soccer Grass 3/4 surface a 30 cm wide seaming tape should be used. The glue can be applied during this rolling out or afterwards.

The glue is 2-part PU, in tins of 13.2 kg. For gluing the seams, one tin should be sufficient for a length of 15 m. For spreading the glue use a kit spreader. Stick the carpet edges in position along the glued-in seaming tape. For a good seam a small gap of 0.5 cm is acceptable.

After closing the carpet at the seams, either put weights e.g. a sandbag of approx. 6 kg all along the seam or walk on it for 15 minutes, heel to toe until the glue bonds.

Make sure that when closing the seam no tension or wrinkles occur. After finishing the rolls in the middle section the side runs can then be started.



Figure 75: Gluing of the seam

### **Markings:**

Cut out the lines, by means of a double cutting knife (refer to Annex A). Cut the separate line material in such a way that it will fit snugly within the space cut out of the green carpet. Fix in place using a 30 cm wide seaming tape.



Figure 76: Cutting in markings

For circles cut the PVC tape in short sections so that a circle can be made out of it. The gluing process itself is as mentioned above. The remaining markings are cut in with a straight edge. It is recommended that the carpet be cut in the direction of the poles. Glue as before.

### **Filling the sand/rubber mix in\*:**

Before using sand the fibres should be brushed up. The sand should be applied in very thin layers. Do not use too much sand in the first application: the fibres should be able to emerge through the sand. After applying all the sand top it off with rubber if appropriate. Always spread the sand or rubber in front on the machine, never run it backwards. This way the machine will always drive over the already filled-in parts of the pitch. For the correct amount of sand (and rubber if applicable) to be used, please consult the system guidelines and technical specification sheet for the relevant surface. The final height of the sand must be 20 – 33 mm below the top of the fibre.

\*In case of sand-filled systems the rubber part is not applicable



Figure 77: Filling in sand/rubber mix

#### 4.2.9.8 Overview of materials required

| Materials          |                  | Amount of glue<br>Helmitin 149 | Remarks<br>Temp > 15°C                  |
|--------------------|------------------|--------------------------------|-----------------------------------------|
| Tape 20 cm<br>wide | All seams in 3/8 | 0,44 Kg/m<br>seam              | Tape and back of<br>carpet must be dry! |
| Tape 23 cm<br>wide | All seams in 3/4 | 0,66 Kg/m<br>seam              | Tape and back of<br>carpet must be dry! |
| Tape 30 cm<br>wide | All cut-in lines | 0,88 Kg/m<br>Cut-in lines      | Tape and back of<br>carpet must be dry! |

Figure 78: Overview of the materials required

Refer to the system guidelines of the product for the specific details regarding amount of sand (and rubber, if applicable).

#### **Rubber infill granulates for use on outdoor pitches:**

For optimum performance, it had been suggested to use a rubber infill product that meets the following requirements/characteristics:

- Granulate size
  - Granules < 0.5 mm < 1%
  - Granules > 2.5 mm < 2%

Remark: The narrower the distribution curve, the better the performance of the system.

- Density of granulate (non-floating when it rains)
- Compliant with DIN 18035 part 7
- ISA testing procedure
  - Weakness for shattering - no disintegration
  - Durability against duration loading - no deformation after releasing of load

#### **Rubber infill granulates for use on indoor pitches:**

Recycle Styrene butadiene rubber is not suitable for indoor use.

- Granulate size
  - Granules < 0.5 mm < 1%
  - Granules > 2.5 mm < 2%

Remark: The narrower the distribution curve, the better the performance of the system

- Compliant with DIN 18035 part 7
- ISA testing procedure
  - Weakness for shattering - no disintegration
  - Durability against duration loading - no deformation after releasing of load

#### **4.2.9.9 Duration**

A total project including base would takes about 6 to 8 weeks on average to install.

#### 4.2.10 Audience Stands

As the floating structure is targeted to equip and serve as a multi-purpose stadium, the design of the audience stands should be suitable for all-round events to ensure that enough spacing and comfort is available for the user.

Table 9: Event in relation to time spend

| Event          | Seating Time        |
|----------------|---------------------|
| Soccer         | 1.5 to 2 hours      |
| Concert        | 1 to 8 hours        |
| Rugby          | 1.5 hour to 2 hours |
| Rugby 7 a side | 8 hours             |

#### Spectators view

The stadium should fulfil 2 main criteria; the stadium should be large enough to accommodate the no of audience in the stand. All audience should be able to watch the action as close as possible with a calculation done to fulfil the limits set.

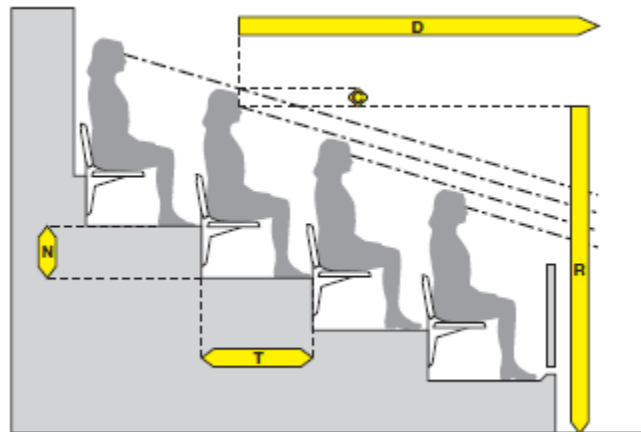


Figure 79: Audience's viewing angle.

D is the distance to focus on the pitch. C is the eyesight value .N is the riser height. T is seat to seat width. R is riser height to focus.

‘C’ value is the assumed distance, In general 0.15m will be a excellent design value, 0.12m will be very good,0.09m reasonable and 60mmis minimum for most situation. The seating's aim to

be in the region of 0.12m for sighting and this will determined the riser height assuming C is 0.12m.

A formula derived in the book by Stadia, 4th edition- A design and development guide helps to indicate the riser height to see whether the seating have met the requirement.

$$N = \frac{(R+C) \times (D+T)}{D} - R$$

Where, N is the riser height,

R is the height between eyes on 'point of focus' on the playing field,

D is the distance from eye to 'point of focus' on the playing field,

C is the 'sightline',

T is the depth of seating row.

Given

R= 8.1m (assumed fourth row from the front)

D=22.5m (assumed fourth row from the front)

T=0.85m (calculated)

$N = [(8.1+0.12) \times (22.5+0.85)/22.5] - 8.1$

$= 0.4305\text{m}$

We will set our N as 0.45m to satisfy the audience viewing.

## Seat



Figure 80: Stadium Seats

Currently the new trend of stadium seat is tip-up seats, although it can cost more than other types but the main advantage is it is less robust and becoming the norm. A single seat in the stadium seat weights 2.3kg.

The floating stadium have to be build using lightweight concrete as it is 25 to 35 percent lighter than a conventional concrete. It is essential for the stadium to be built as light as possible for the stadium to float in the sea. It should have a density of 1.2815 ton/m<sup>3</sup>.

#### 4.2.10.1 Calculations for the structure

##### Front view without the roof

Total got 9 sections and 1 more additional stairs for end sections to exit= Total Length = 91m

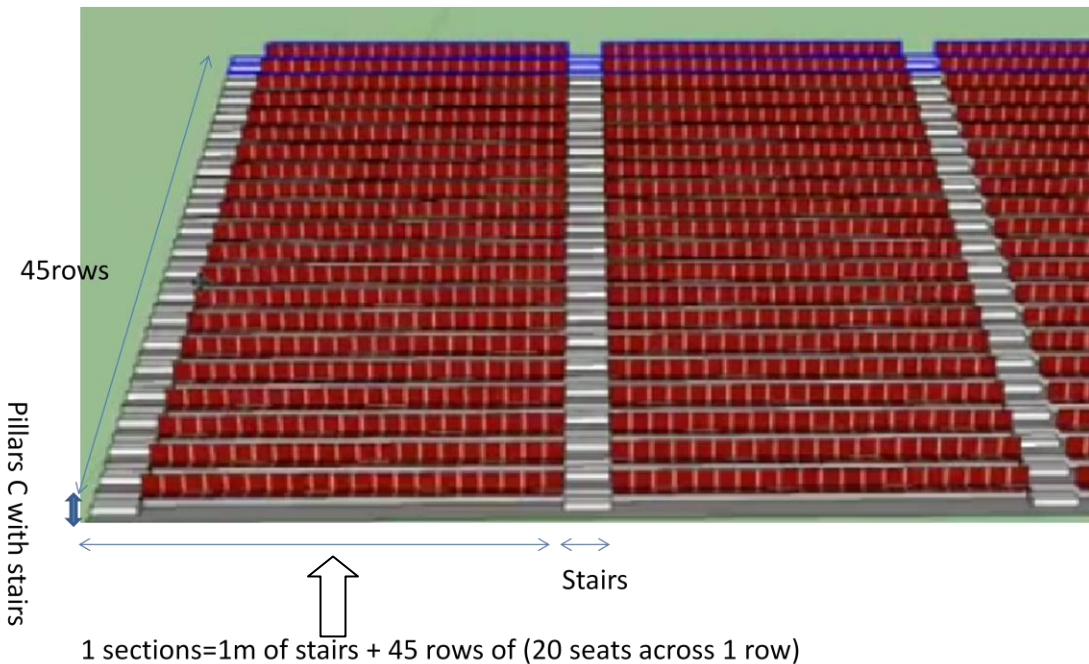


Figure 81: Section of a stand

Total capacity= 45rows of seat X 20 Seats X 9 sections

= 8100 people

Total weight inclusive of seats without human

=2.3kg (per seat) x 8100 + 5,926,284.9kg (Calculated value of the entire structure weight)

=5,944,914.9kg

=5.944 tonnes

Total weight inclusive of seats with human

= [2.3kg (per seat) + (60kg-assumed human weight)] x 8100] + 5,926,284.9kg (calculated value of the entire structure weight)

=6,430,914.9kg

=6.431 tonnes

**Side View without the roof**

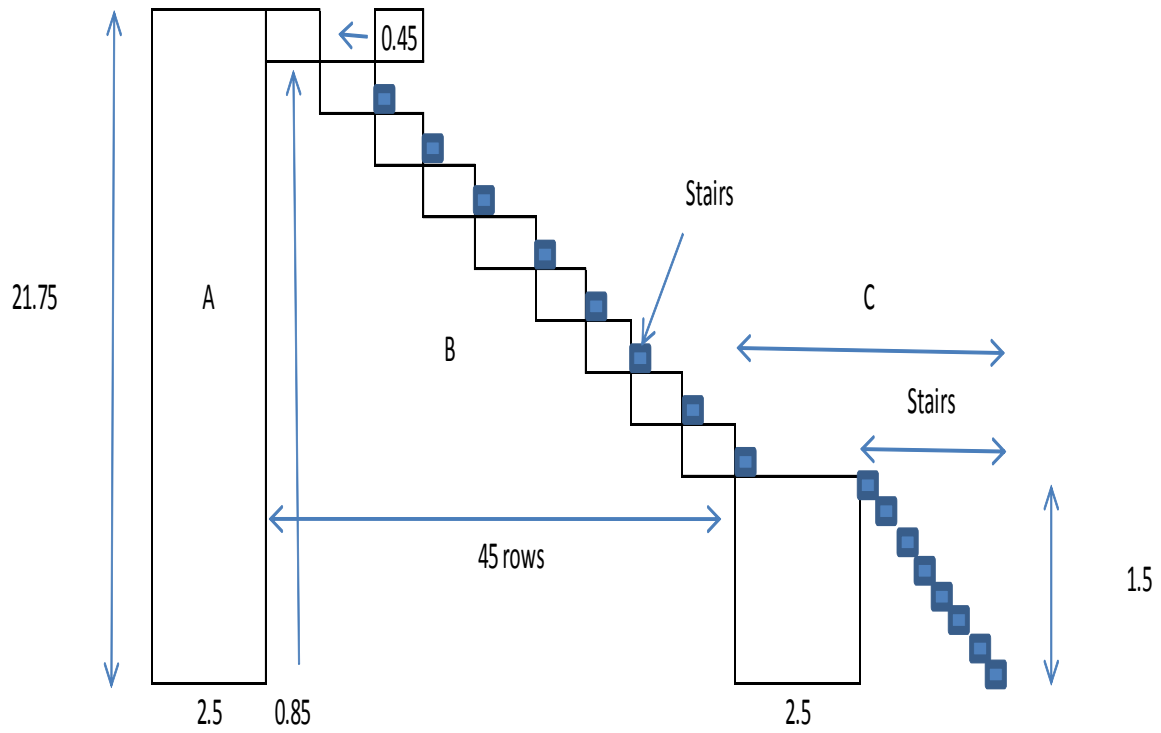


Figure 82: Side view of the designed stadium

CAL. A

$$\begin{aligned}\text{Height of the pillar} &= 1.5 + [N(\text{riser height}) \times 45 \text{ rows}] \\ &= 21.75 \text{ m}\end{aligned}$$

$$\begin{aligned}\text{Pillars A (Total 10)} &= 2.5 \times 2.5 \times 21.75 \times 10 \\ &= 1359.375 \text{ m}^3\end{aligned}$$

Cal. B

(Width of the stand + Height of the stand) x Length of the stadium

$$\begin{aligned}&= [0.85 \times 0.2 (\text{Assume thickness of the concrete}) \times 45 + [0.45 \times 0.2 \times 45] \times 91 \\ &= 1064.7 \text{ m}^3\end{aligned}$$

Stairs (Height x Length x Breath)

$$\begin{aligned}&= 0.17 \times 0.85 \times 0.5 \times 45 (\text{rows}) \times 10 (\text{sections}) \\ &= 32.5125 \text{ m}^3\end{aligned}$$

Total Weight of B

$$\begin{aligned}&= 32.5125 + 1064.7 \\ &= 1097.2125 \text{ m}^3\end{aligned}$$

Cal. C

Pillars C at the front structure (also have 10 at each sections)

$$\begin{aligned}&= 1.5 \times 2.5 \times 2.5 \times 10 \\ &= 93.75 \text{ m}^3\end{aligned}$$

Stairs

$$\begin{aligned}&= 0.17 \times 0.85 \times 0.5 \times 8 (\text{due to the pillar is 1.5m so got 8 stairs}) \times 10 (\text{sections}) \\ &= 5.78 \text{ m}^3\end{aligned}$$

Total weight of C

$$\begin{aligned}&= 93.75 \times 5.78 \\ &= 99.53 \text{ m}^3\end{aligned}$$

CAL. Total weight with Concrete weight

$$\begin{aligned}&= 2556.1175 \times 1281.5 (\text{kg/m}^3) \\ &= 3,275,665.22 \text{ kg/m}^3 \\ &= 3275.665217 \text{ tonnes/m}^3\end{aligned}$$

#### 4.2.11 Solar Panel Roof

There are many types of roof like the post and beam structure, goal post structure, and etc. Any structure has its own pros and cons for consideration. Cantilever structure is the one being considered as the roof structure offers absolutely no obstruction to viewing of the pitch. The multipurpose stadium is to provide a wonderful experience for the spectators and this is a key to choosing cantilever structure.

##### Cantilever structure

A cantilevered roof is fixed or being supported by securing in to the back of the stand while the other end facing towards the field hangs free and unsupported by any weights. Below is an example of Cantilever structure.

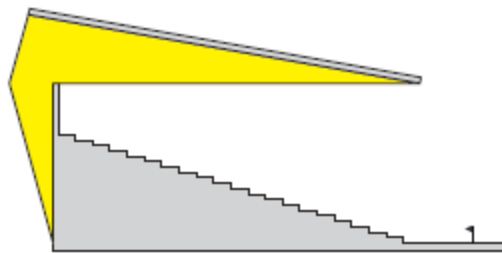
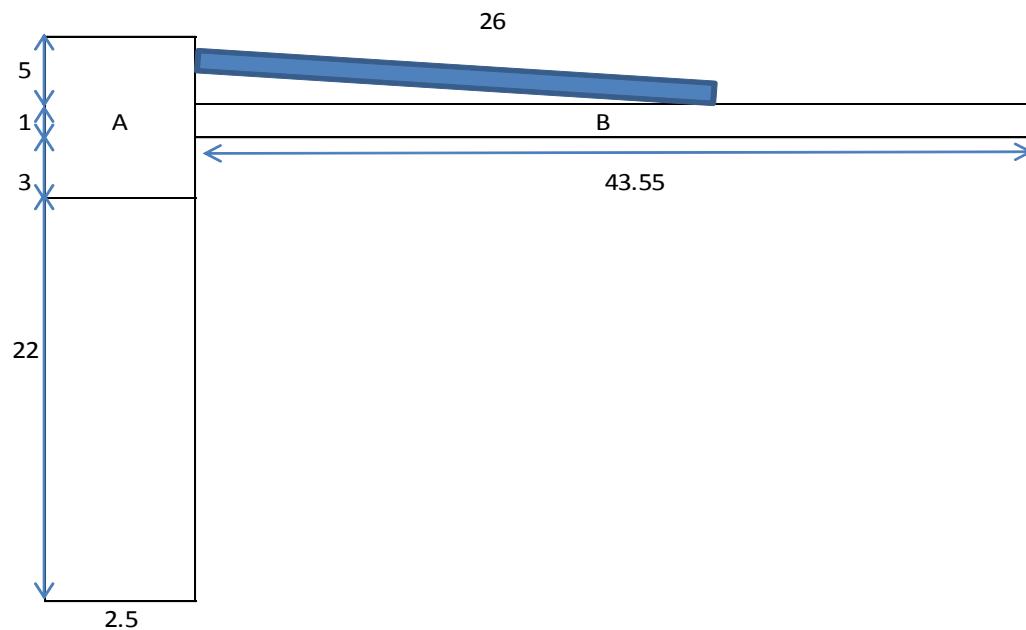


Figure 83: Example of a Cantilever Structure

Roof



Cal A(10 pillars) x Assume concrete weight

$$= 4.5 \times 0.5 \times 3 \times 10 \times 1281.5$$

$$= 86501.25 \text{ kg/m}^3$$

$$= 86.50125 \text{ tonnes/m}^3$$

Cal B +720 solar panels

$$= 43.55 \times 91 \times 0.5 \times 1281.5 + (720 \times 27.5)$$

$$= 2,559,124.29 \text{ kg/m}^3$$

$$= 2559.124288 \text{ tonnes/m}^3$$

10 Cable tension(aluminium)

$$= \pi \times R^2 \times L \times \text{Weight of steel}$$

$$= 10 \times \pi \times 0.0475 \times 26 \times 2710$$

$$= 4994.3587 \text{ kg}$$

$$= 4.994 \text{ tonnes}$$

Total

$$= \text{Cables} + A + B$$

$$= 2,650,619.90 \text{ kg}$$

$$= 2650.619897 \text{ tonnes}$$

Total weight of the Roof plus the structure

$$= (2650.62 + 3275.67) \text{ tonnes}$$

$$= 5926.85 \text{ tonnes}$$

## Overhead view of the roof structure

Top View

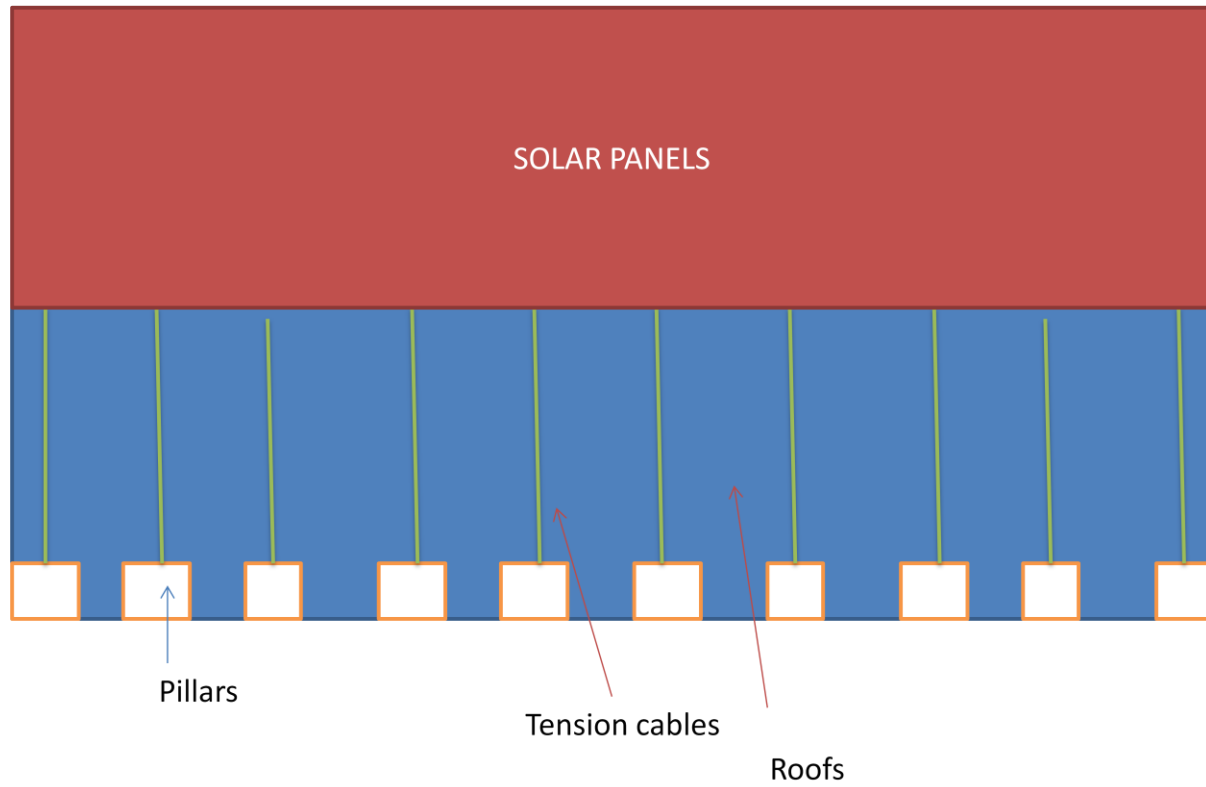


Figure 84: Top view of the designed stand

## **Solar Panel**



Figure 85: KYOCERA solar panel

The multi-purpose floating stadium hopes to incorporate solar panel on the roof for the purpose of fully utilizing the area on the roof and eventually hope to aim to play a part in generating its own power and reduce the usage of using fossil fuels to generate the power required for the stadium. The solar panel installed on board could be of KD 315-80 F series from Kyocera, it has a good field performance and able to harness the highest amount of solar panel compared to other models.

Solar power has gone from a relatively expensive energy source to more practical cost over the last several years. The technology advancement and improvement of solar panels, the continually increased of fuel price makes solar power an attractive alternative. It offers attractive advantages that can be taken off by the stadium. Sunlight is free and inexhaustible and is a relatively clean energy being produced. Solar power does not caused any pollution and no emissions will be produced when solar energy is used to generate electricity.

Solar energy is excellent and capable for power generation in remote areas and the floating stadium can generate enough energy to produce enough energy to be self sufficient other than match days and it requires little maintenance and this is an attractive bonus as compared to other power generation source that is dependable of their own system.

However, the possible drawbacks are the amount of power generated is subjected to the amount of sunlight it will get. Another limitation is the low efficiency of solar panels converting the solar energy to electricity.

#### 4.2.12 Sanitary Recycling Plant System

The purpose of installing a Sanitary Recycling Plant System on board has the ability to recycle the amount of human waste that could be produced from the capacity of 65000 that could be on board the floating structure.

From a survey done by Wolgast at 1993, each individual was able to produced 1-1.5 L of urine per day up to 4 to 5 times. An adult can average close of 450 L to 550 L urine per year. Children will roughly produce about half of the amount by adults.

Table 10: The fertiliser Equivalent of Human Excreta (Drangert 1998)

| Nutrient in kg      |                          |                          |       |                                   |
|---------------------|--------------------------|--------------------------|-------|-----------------------------------|
| Nutrient            | In urine<br>(500 l/year) | In faeces<br>(50 l/year) | Total | Required for<br>250 kg of cereals |
| <b>N Nitrogen</b>   | 4.0                      | 0.5                      | 4.5   | 5.6                               |
| <b>P Phosphorus</b> | 0.4                      | 0.2                      | 0.6   | 0.7                               |
| <b>K Potassium</b>  | 0.9                      | 0.3                      | 1.2   | 1.2                               |

The total amount of human waste produced is close to what is required to fertilise 250kg of cereal. By recycling the human waste to extract the nutrients out, it could provide potential market for farmers as well as doing a part in saving the Earth.

#### **4.2.12.1 Current available technology**

There are currently more than two methods of recycling available in the market but struvite and compost would be the most relevant methods to be understudied and installed on board.

Struvite is a phosphate mineral and majority of phosphorus in urine can be obtained by crystallised into a white odourless powder through a simple precipitation reaction known as Struvite. Struvite is bio available whereby nutrients can be easily absorbed by the plant and its nature properties allow slow and steady release of nutrients. It is compact, easily stored, transported and do not produce odour smell. Through struvite recovery, over 90% of phosphate can easily be removed from urine.

Compost is rich in nutrients and is the key ingredient in organic farming and could be recycled as fertilizers through sewage. The decomposition process is aided by shredding the plant matter, adding water and ensuring proper aeration by regularly turning the mixture to break it down into simpler components and converted into plant-nourishing nitrites and nitrates throughout the process of nitrification.

The conventional phosphorus origins will run dry sooner or later, many different sources stated the exhaustion of phosphorus suggesting from about 50 years to 400 years. Since human waste contains rich nutrients in it, it would be beneficial to be converted into fertiliser. According to the international journal Nature 2010, phosphate rock deposit will last only about 300 to 400 years. Phosphate rock is a non-renewable source similar to oil. However, unlike oil prices, it does not directly impact everybody's daily life as much as oil pump does. Nobody really pays much attention to it, but through this sanitary system, it helps to educate the people in the depletion of conventional phosphorus and the benefits and advantages of recycling human wastes.

### How to collect human wastes:

The floating structure would install urine diversion toilet or composting toilet, in short named UD toilets would help to separate urine and faeces for easier conversion that will be done later in the system describe below. This is critical as urine is valuable in providing the ingredients for converting them into organic fertiliser. The advantages are reduction of toilet flush water consumption. Undiluted urine separation as a way to recycle human waste into agricultural fertiliser. The relatively easy handling, comfort and the toilet is a modern design.



Figure 86: Waterless Urinal

Figure 87: Urine Diversion Toilet

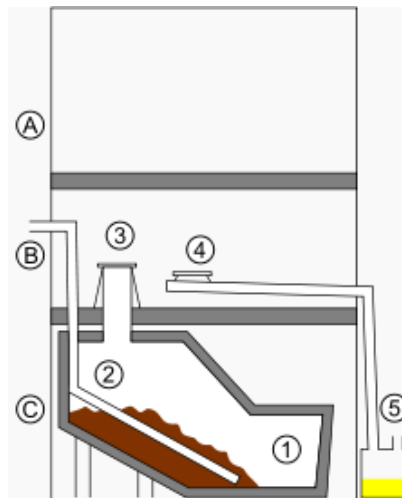


Figure 88: Urine-diverting-dehydration toilet system

A) Second floor B) First floor C) Ground floor

1: Humus compartment, 2: Ventilation pipe, 3: UD Toilet seat, 4: Urinal, 5: Urine collection and dehydration

#### 4.2.12.2 Sanitary system

This is the current technology that is used by SANIRESCH at their main building and it is able to suit for the use on board the floating stadium.

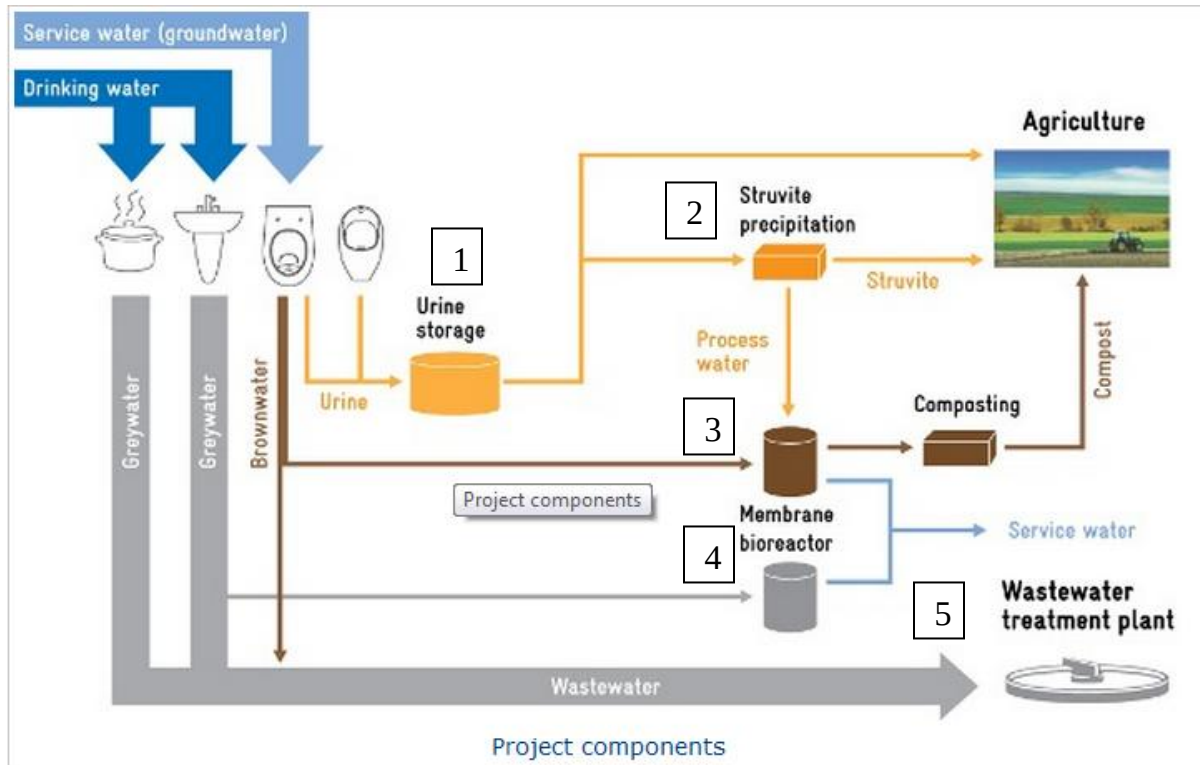


Figure 89: Sanitary System from Saniresch

#### Urine Storage tank:

20 Water tanks (IBC tanks) are stacked on top of one another, approximately 1m<sup>3</sup> are used as storage purpose before entering into the system and after the urine is processed before transporting it to onshore.



Figure 90: IBC Tanks

## Magnesium –Ammonium –Phosphate Reactor (Struvite Precipitation Reactor)

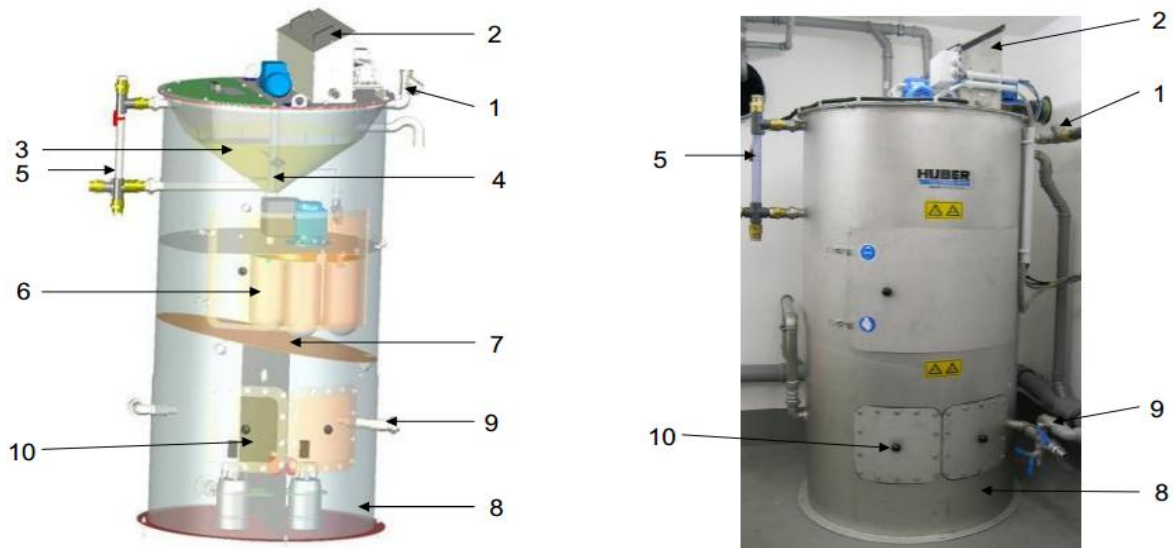


Figure 91: M-A-P reactor

1. Filler
2. Dosing Unit
3. Precipitation tank(trough-shaped)
4. Stirrer
5. Level Probe
6. Filter bag
7. Collecting tray for process water
8. Chamber for process water
9. Outlet
10. Inspection opening

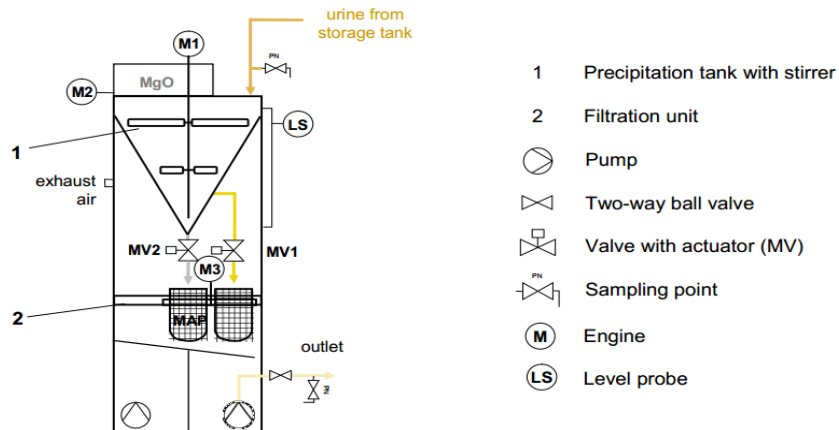


Figure 92: Set-up of the reactor

### **“Yellowwater” treatment in a Precipitation reactor:**

Yellowwater (urine) is treated with the help of a chemical-physical process in a precipitation reactor. In this process, the crystalline magnesium-ammonium-phosphate (MAP; also known as struvite) is produced by adding magnesium oxide as they will stir, which is considered to be a valuable fertiliser in agriculture.

Urine flows into the precipitation tank whereby Magnesium Oxide will be added by a dosing unit and it will be well mixed by means of a stirrer. The phosphates and part of the ammonium are precipitated due to a chemical reaction. It will take roughly 3hr for sedimentation to take place and crystals will be formed. The supernatant will be filtered to the first filter bag by filtering revolver through MV1. The crystallized product (Struvite) which settles in the precipitation tank will then passed into the filtration unit via MV2. The tray directly below the filter bag collects the filtered urine and it will proceed to a water chamber and out of the system. The filter bag with the Struvite will be put away separately in the automated system after 20 cycles and old filter bags will be replaced by new filter bags.

### **Specification of the reactor:**

Flow capacity approx 1400l/ week

MAP yield 0.7 to 1.3g/l urine

Stirring time: 3 min, 30 s stirring/30s break

Sedimentation duration: 90 min

### How Struvite is formed:

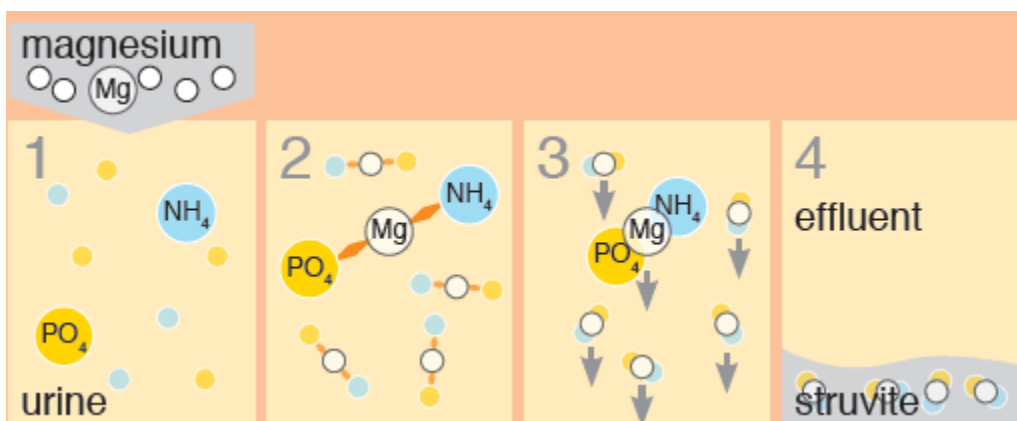


Figure 93: Formation of Struvite

1. Urine contains phosphate (PO<sub>4</sub>) and ammonium (NH<sub>4</sub>); both important nutrients.
2. Magnesium(Mg) is added to the urine
3. Magnesium mix with the urine and formed Struvite (MgNH<sub>4</sub>PO<sub>4</sub>·6H<sub>2</sub>O) powder,
4. Struvite is formed and can be separated into a separate bag while effluent will flow out.

### Advantages of using Struvite reactor:

It reduced weight and volume of nutrients as compared to urine in its original form. It can be easily transported, stored and handled without producing odour smell. It work in a simple technology meaning it can be built and operated almost anywhere with simple construction and operation and the end product would be a user-friendly fertiliser product.

### Drawbacks

However, there are drawbacks from using the methods as it requires a high volume of urine and it is low yields (approximate 1kf of Struvite is produced from 500L of urine). The reactor could not ensure 100% recovery of nitrogen and potassium and requires soluble magnesium source to react with the urine. If the Struvite production site is located away, the transportation cost of urine reduces its economic viability. There might also be possible corrosion of metal appliances that required maintenance.

### **“Brown-water” treatment in a Membrane Technology:**

The membrane technology is used for treatment of wastewater and the production of process water. The procedural combination of membrane ultrafiltration and activated sludge process optimise the biological treatment process. The membrane reactor is needed when particularly, the floating structure is limited by space, and there is a relatively high number of people. With the use of a MBR it is possible to treat wastewater within a limited area available.

Using a primary screen in pre-treatment, most of the solids are being removed; the brownwater (faeces and flush water) is treated in a membrane bioreactor (MBR). In the MBR, detrimental substances, as well as solid, bacteria and almost all viruses will be degraded or rather restrained. The bathing water quality that is produced by MBR has to fulfil EU regulations before used. Due to microbiological properties, permeate can be used as process water in buildings and for irrigation in agriculture without any problems.

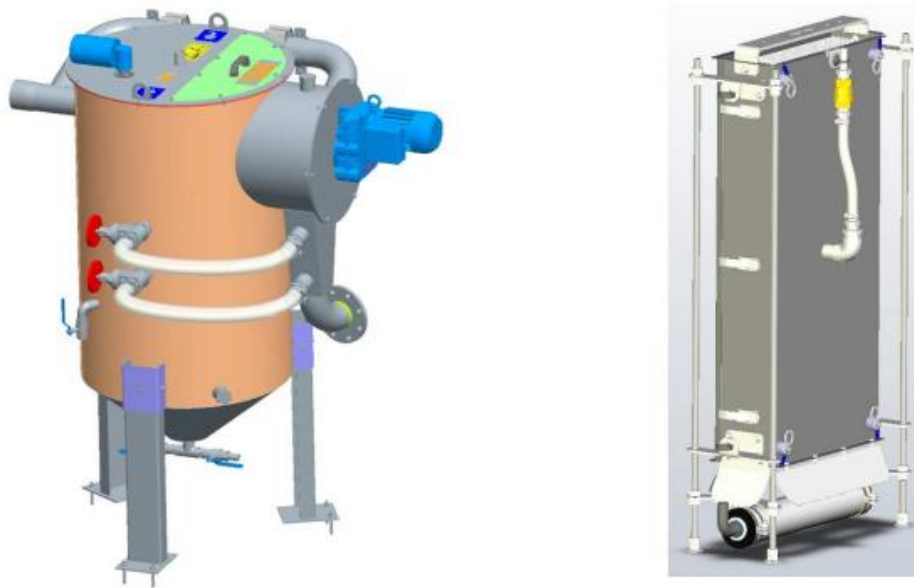


Figure 94: Brown-water Membrane Technology

### **Specification of the membrane:**

Flow Capacity: 14l/h, 350l/d

Pre-treatment (mesh size):3mm

Filtration: 120s

Trans-membrane pressure: 50 mbar

### **“Grey-water” treatment in the membrane bioreactor**

Membrane bioreactors just like the one treating brown-water are also very effective in treating grey-water (the kitchen and wash water). The treated water has to fulfil the EU regulations before using it as bathing water and is well-suited for in-door usage as process water. The processed water can be used for toilet flushing, heating and air conditioning. The process water can be also used for irrigation in agriculture or for garden.



Figure 95: Grey-water Membrane technology

**Specification of the membrane:**

Flow capacity: 20 till 25 l/h, 500 till 600 l/d

Pre-treatment-sieve for solids: 3mm

Filtration: 270s

Trans-membrane pressure: 60mbar

**Sewage Plant:**

Sewage plant will be attached to the sanitary system to break down sewage into simpler components that can be disposed to the sea like a conventional sewage plant onboard vessel.

The sewage plant consists of three sections. The first is the Aeration tank whereby the raw sewage had to pass through a maserator before entering into the aeration tank. The maserator is a gearing device that grounds the raw sewage into tiny pieces. In the aeration tank there are bacteria that feed on the raw sewage and convert them to inert sludge. These bacteria require air to survive therefore there a constant compressed air supply is blown into the tank. In the aeration tank, there is a separating screen that allows the inert sludge to pass through to the next stage called the settling tank. In the settling tank, the inert sludge settles to the bottom of the tank when it is pumped out at specific intervals.

The clean water then overflows to the next tank called the holding tank via a chlorinator unit. The chlorinator unit consists of a wire mesh container containing chlorine tablets for sterilization of the water. When the sterilised water reaches a certain level in the holding tank, a pump will be activated and pump the sterilized water overboard.

### Alternative methods in nutrient recovery of human urine:

Using nitrification or distillation recovery process is still in the pilot phase and only about 6 months of experimentation. It is developed by Swiss Federal Institute of Aquatic Science and technology. Nutrients are recovered through nitrification/distillation which is much higher than nutrients recovery by Struvite precipitation. Below illustrate the process.

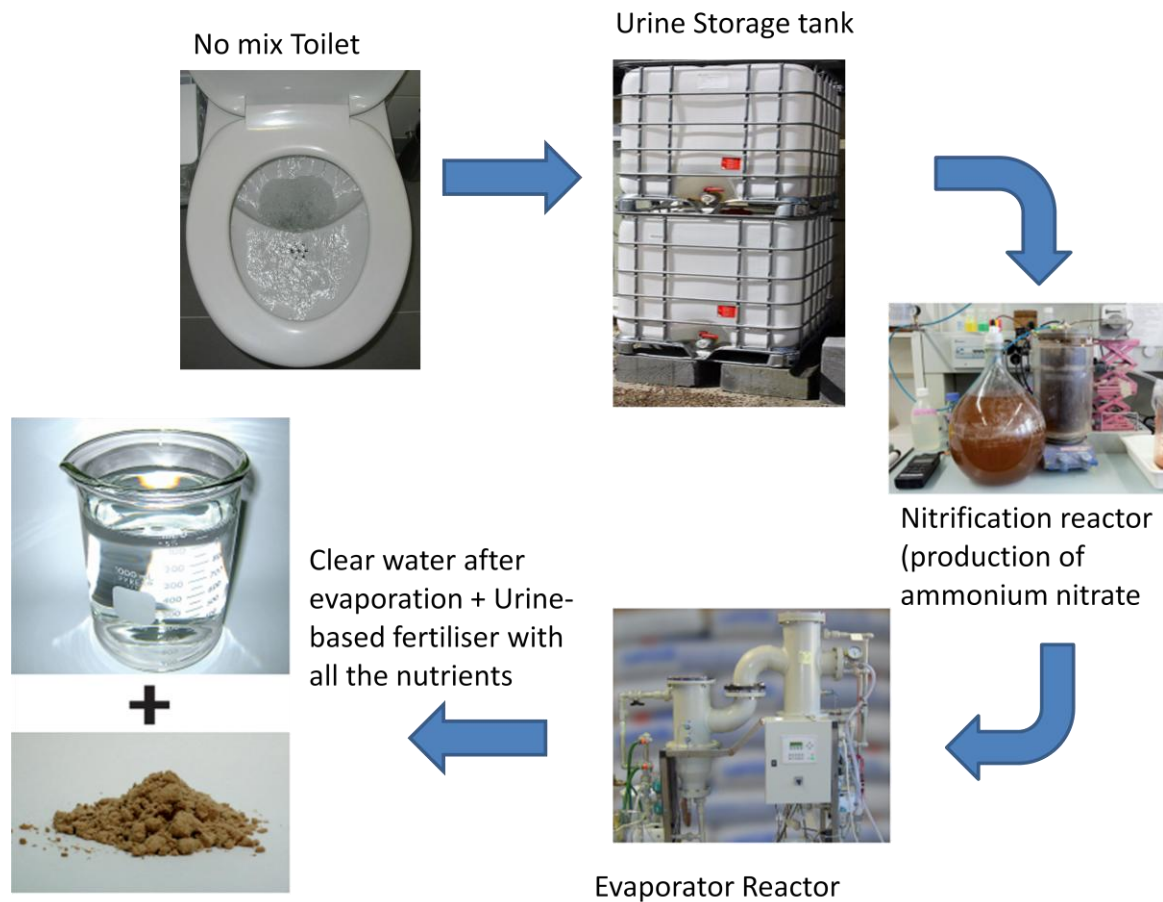


Figure 96: Process of Nitrification

## 4.2.13 Stadium toilets

Table 11: The UK Football Stadia Design Advisory Council's minimum recommendation for newly construct or refurbished sports stadia and stands. These figures apply to each individual accessible area.

|                                                                                                                                                                                                                                                                     | Urinals            | WCs                                                                        | Wash basins                                                                |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Male                                                                                                                                                                                                                                                                | 1 per 70 males     | 1 for every 600 males, but not less than 2 per toilet area, however small  | 1 for every 300 males, but not less than 2 per toilet area, however small  |
| Female                                                                                                                                                                                                                                                              | No recommendations | 1 for every 35 females, but not less than 2 per toilet area, however small | 1 for every 70 females, but not less than 2 per toilet area, however small |
| <i>Note: Slab or trough-type urinals should be calculated on the basis of not less than 600mm per person. All suitable wall areas not needed for other purposes should be exploited for additional urinal provision over and above the minimum recommendations.</i> |                    |                                                                            |                                                                            |

This table is useful for calculations of the floating stadium as it give us a guideline on a number of specifications we need to follow in designing the stadium toilets.

### **Recommended Toilets requirement and location:**

Table 12: Illustration of the number of toilet required

| Capacity | Types of provision | Male to female ratio(85:15)<br>(6885 to 1215) |
|----------|--------------------|-----------------------------------------------|
| 8100     | Males WCs          | 12                                            |
|          | Males Urinal       | 100                                           |
|          | Males Wash Basin   | 24                                            |
|          | Female WCs         | 36                                            |
|          | Females Wash Basin | 16                                            |

Based on the regulations, calculation of the number of toilets is made for the single stand while the grand stand will be double the size.

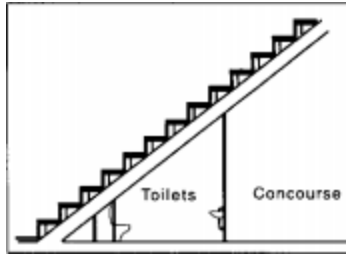


Figure 97: Location of the Toilet

Stadium toilets will be design as such that they are immediately underneath the seating deck which is easy to locate and accessible to the audience. There will be four toilets located around the stand.

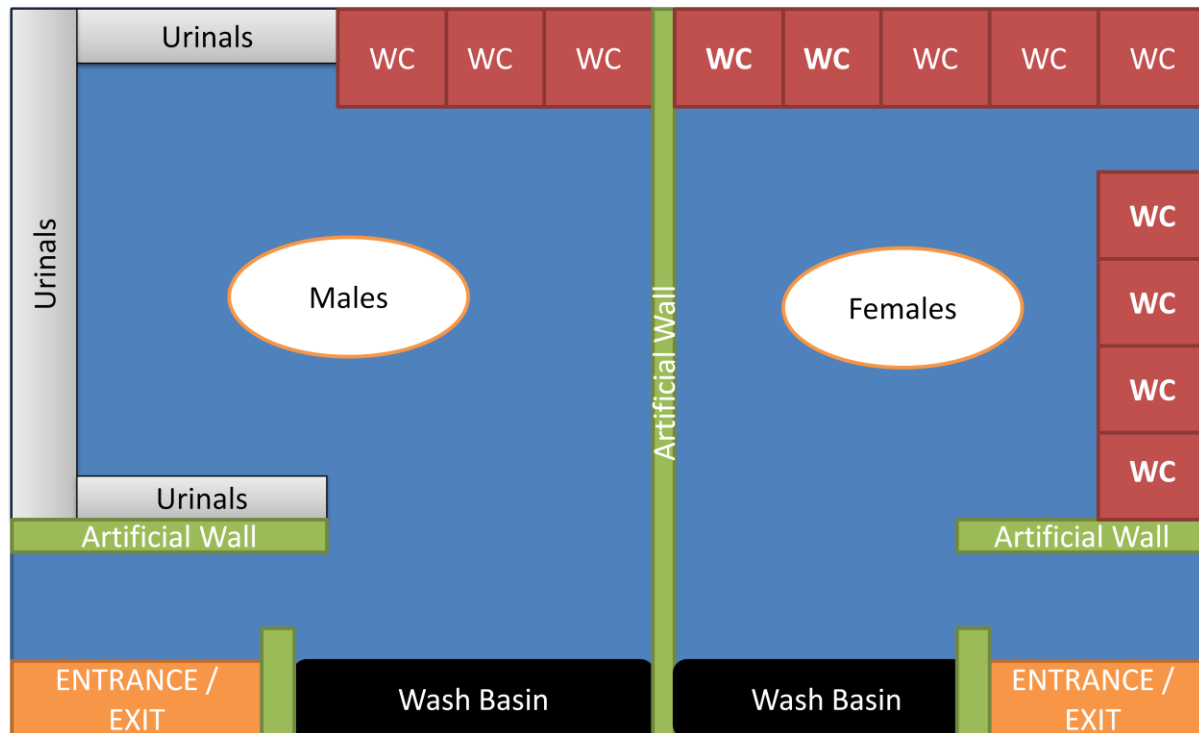


Figure 98: Layout of Female and Male toilet layout

The above design was selected for easy installation and a simple layout. It will be have 4 toilets of this size in each of the stand.

For the male toilets, there will have 3 WCs and 25 Urinals. There are 6 wash basins.

For the female toilets, there will have 9 WCs and 4 wash basins.

### **Cost analysis of Sanitary System:**

The projected time for break-even point is about 7-9 years. The maintenance includes once or twice a year check-up on the system. Other cost includes a suction truck which we will be renting on a week to week basis to transport the urines to the land for sales, the wages paid to the operators manning the system.

Table 13: Cost Analysis and weight of Sanitary System

| Items                                 | Cost(Sing dollar) | Weight |
|---------------------------------------|-------------------|--------|
| M-A-P Reactor                         | 82,110            | 500kg  |
| 40 IBC storage Tank(1m <sup>3</sup> ) | 4,080             | 2400kg |
| Grey water installation               | 14,676            | 200kg  |
| Brown water installation              | 56,775.50         | 200kg  |
| Sewage Plant                          | 24,700            | 270kg  |
| Piping                                | 6,000,000         | -      |
| Maintenance                           | 9,000             | -      |
| Other costs                           | 244,000           | -      |
| Total                                 | 6,435,341.5       | 3570kg |

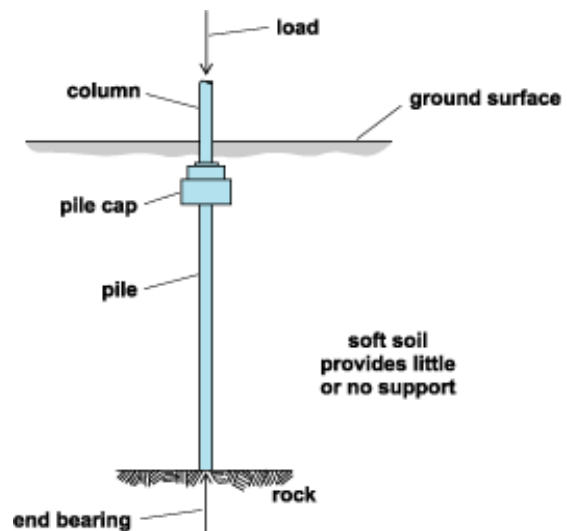
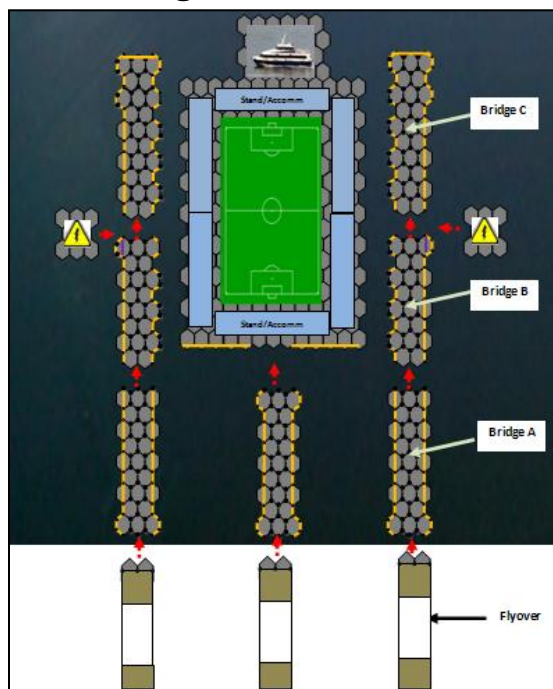
### **Business opportunities:**

In Europe alone, Sweden and Germany are utilizing their technology to grow crops in their own land. A survey conducted by Liener et al.(20030) among 467 Swiss farmers thought that it was a good or very good idea, and 42% willing to purchase it. The education is important to people who have the cognitive inertial that using human urine is not hygienic and unsafe. We seek to educate the positive benefits that come with recycling our waste through our plants. The benefits of using human urine or Struvite contain huge potential. Once the perception of human urine as organic fertilizer has changed, many farmers will treat human urine as a source of fertilizers which are precious as compared to normal chemical fertilizer.

Table 14: Illustration of the number of countries using Human urine for crops

| European Countries | Crops                             |
|--------------------|-----------------------------------|
| Finland            | Cabbage, tomato                   |
| Germany            | Ryegrass                          |
| Sweden             | Barley, cabbage, wheat            |
| Switzerland        | Different vegetables              |
| Other countries    |                                   |
| China              | Wheat, corn, rice, bamboo         |
| Japan              | Vegetables, fruits                |
| Mexico             | Cabbage, celery, lettuce          |
| South Africa       | Tomato, spinach, lettuce, cabbage |

#### 4.2.14 Bridge to Hexform



The bridge connection part is connected by regular pontoons pins that are used throughout the whole pontoon platform. Pieces of Pontoons will be assembled together to form Bridge A, B, C at the assembling sites before transporting over to join up with the main hex form.

The side of the flyover bridge that is faced to the shoreline will be piled by the three piles while the other side will be connected to the pontoons bridges by regular pontoons pins.

#### 4.2.15 Electricity Consumption

Research on electricity consumption has been done to allow a clear picture of the cost of the electricity. Electricity consumption usage has been breakdown into 2 parts; in the combination arrangement of a stadium and the accommodation on board.

##### 4.2.15.1 Electricity Consumption for Accommodation

Electricity consumption for accommodation had been done on America's Hotels, where electricity cost per unit accounts to USD\$2,196 per available room each year on energy, which is about 19607kWh usage annually. The usage of energy is largely use for cooling in air-conditioning in the cooling tower.

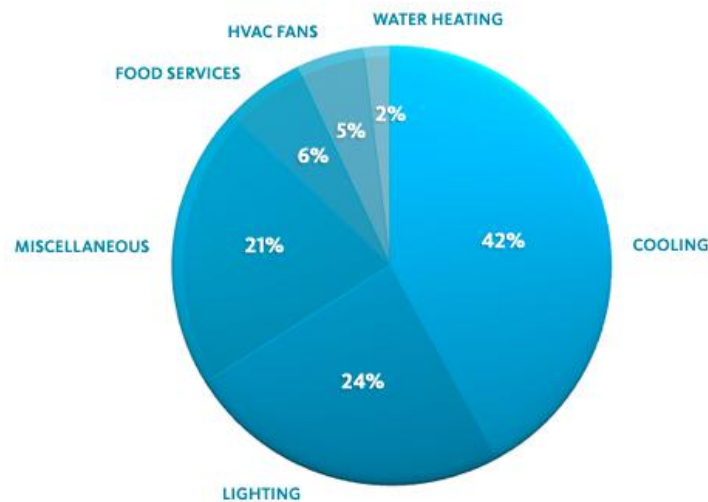


Figure 99: Breakdown of Electricity Usage for Accommodation (Based on Hawaiian Electric Company Data)

#### 4.2.15.2 Electricity Consumption for Stadium

Electricity consumption for stadium is fully on the lightings to power up the area zone in the stadium. Field lighting itself used the most energy to ensure the audience could view the match with adequate lightings during the night follow by the parking lamp post which could be automatic programmed to switch on from 7pm to the following day 7am. The different usage of the field for different sports would also affect the usage of energy based on the size of the stadium.

| Stadium Lighting Zone | Electricity Cost |
|-----------------------|------------------|
| Parking               | \$ 58,277        |
| Concourse             | \$ 8,611         |
| Restrooms             | \$ 377           |
| Office                | \$ 8,121         |
| Suites                | \$ 385           |
| Press Box             | \$ 318           |
| Concessions           | \$ 5,306         |
| Locker rooms          | \$ 94            |
| Field Lighting        | \$ 104,276       |
| TOTAL                 | \$ 185,766       |

Figure 100: Breakdown of Electricity Usage for Stadium

| Stadium Name                     | Location       | Size (Sq Ft)                     | Seats   | Type       | Annual Electricity Use (kWh) |
|----------------------------------|----------------|----------------------------------|---------|------------|------------------------------|
| Safeco Field (Mariners)          | Seattle, WA    | 1,172,127                        | 47,500  | Baseball   | 10,550,715                   |
| Sports Authority Field (Broncos) | Denver, CO     | 1,700,000                        | 76,125  | Football   | 19,286,082                   |
| Toyota Center (Houston Rockets)  | Houston, Texas | 775,000 (indoor)                 | 18,300  | Multi-use  | 14,200,000                   |
| Baker Sports Center (Davidson)   | Charlotte, NC  | 20,000 (arena only)              | 4,800   | Basketball | Unknown                      |
| Charlotte Motor Speedway         | Charlotte, NC  | 189,000 (Towers and Garage only) | 140,000 | NASCAR     | 8,666,847                    |

Figure 101: Annual Electricity usage for some Stadiums

#### 4.2.16 Mooring System

Generally, recommended type of mooring system depends on the capacity of mooring forces, water depth, the length of mooring lines, whether or not there is a midpoint or sinker, and the topography and the nature of the seabed.

There are two types of mooring system that can be considered for the floating platform; the detachable dolphin mooring system and the chains and cables mooring system.

Firstly is a detachable dolphin mooring system with the view to ease the process of installation, to keep the floating platform in position and to prevent the structure from drifting away is implemented. The detachable dolphin mooring system has the advantages that most of its components are detachable and reusable. The detachable mooring system comprises four components, namely the mooring dolphin, anchor clamping block, and the rollers.

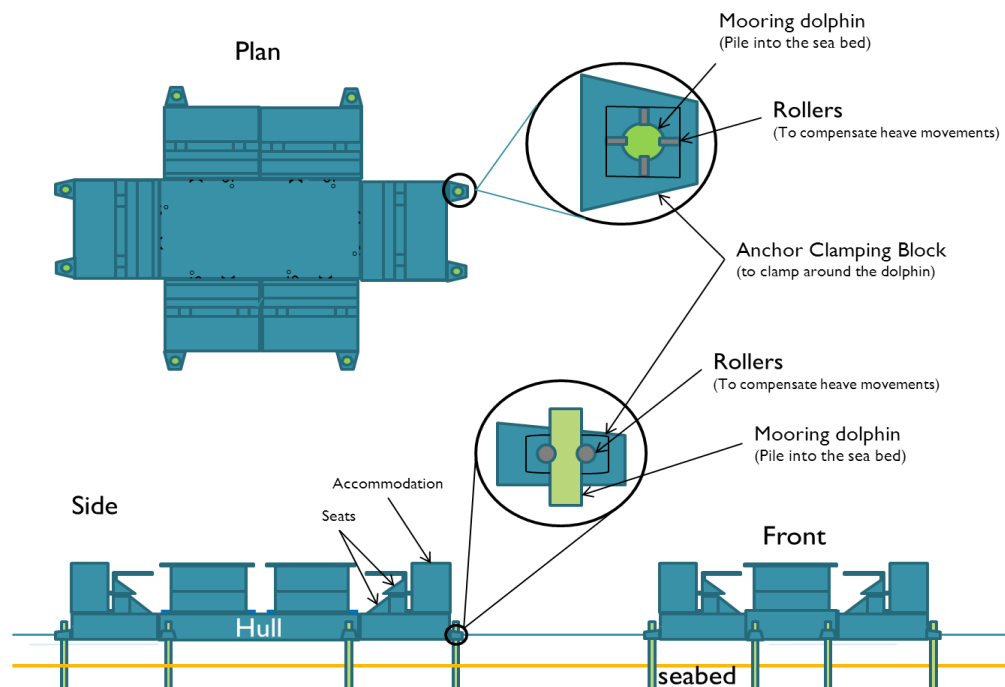


Figure 102: Detachable mooring system

Secondly is the mooring systems involving cables and chains. As the floating platform will be moving from time to time from one country to another for the purpose of hosting game or providing disaster relief shelter, it is not feasible to use the detachable mooring system. This is

because it will take some time for the country to construct the mooring dolphins and it also has a substantial amount of construction cost attached to it.

Therefore the most simplest and economical is the mooring systems involving cables and wires.

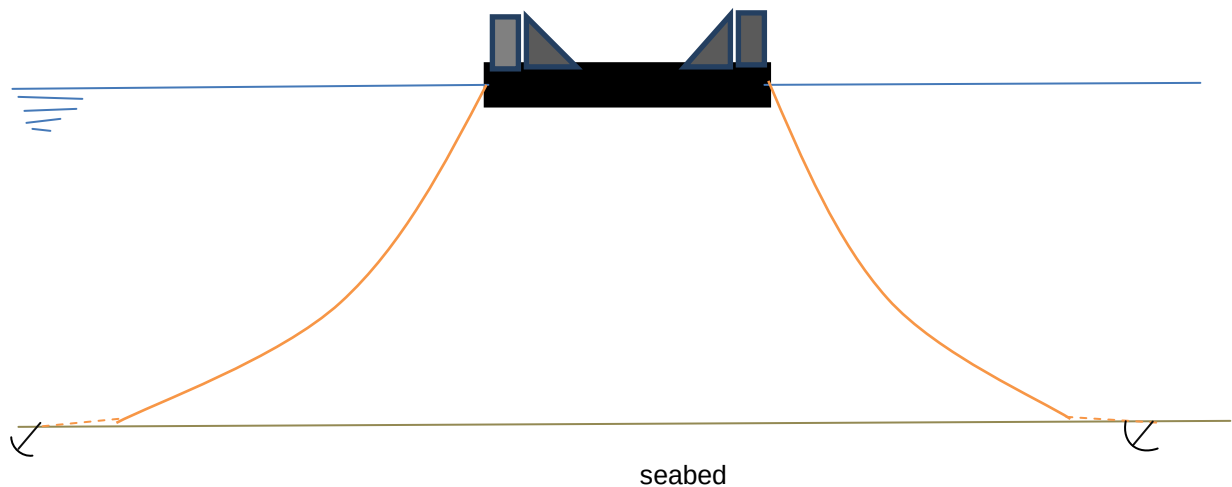


Figure 103: Mooring systems involving cables and chains

In order to check whether the cables and chains mooring system can withstand the environmental forces acting on it such as wave height, wind speed, heaving moment and heeling moment, a simulation program called MOSES is used to check whether the mooring system can withstand the environmental forces that act on it.

The following parameters are assumed for the simulation:

- Wave height of 2m at interval of 4.326 sec
- Wind speed at 30 knots
- Wave type is ISSC wave spectrum
- Compute hydrodynamic forces base on 3D Diffraction Theory
- B\_CAT is Catenary to ground mooring
- Mooring chain is 1tonne/metre
- Water depth at 50 m
- Length of mooring chain at 150 m

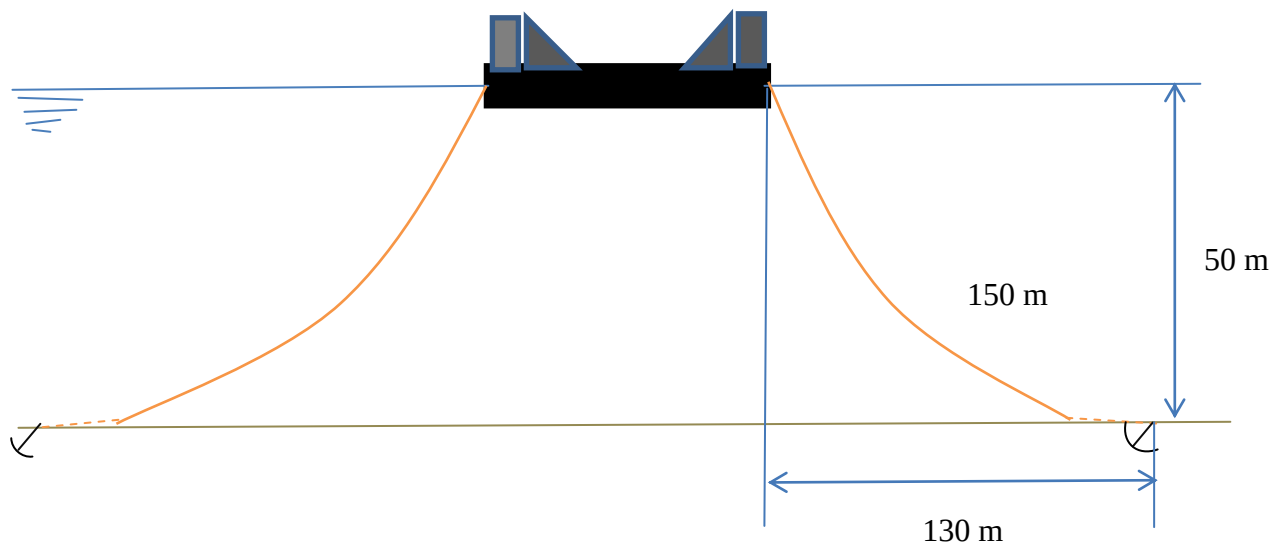


Figure 104; Designed mooring system

After running the simulation, it is observed that the mooring system is able to withstand the environmental forces that are acting on it. A snapshot of the simulation is shown below.

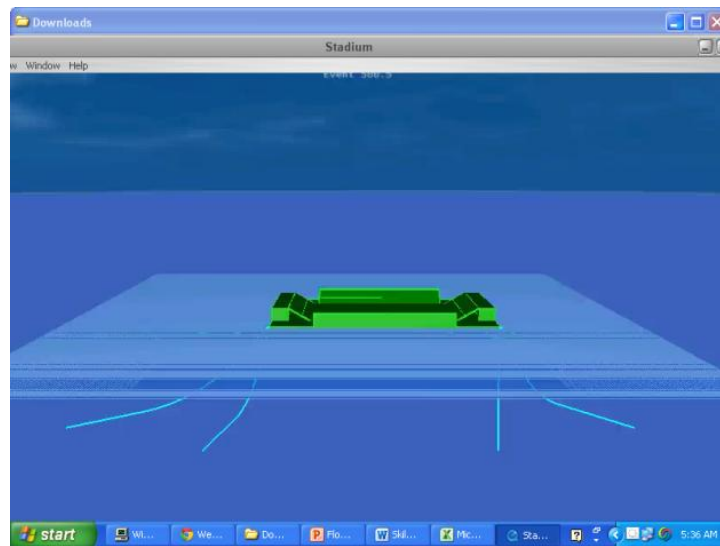


Figure 105: Snapshot of the MOSES simulation

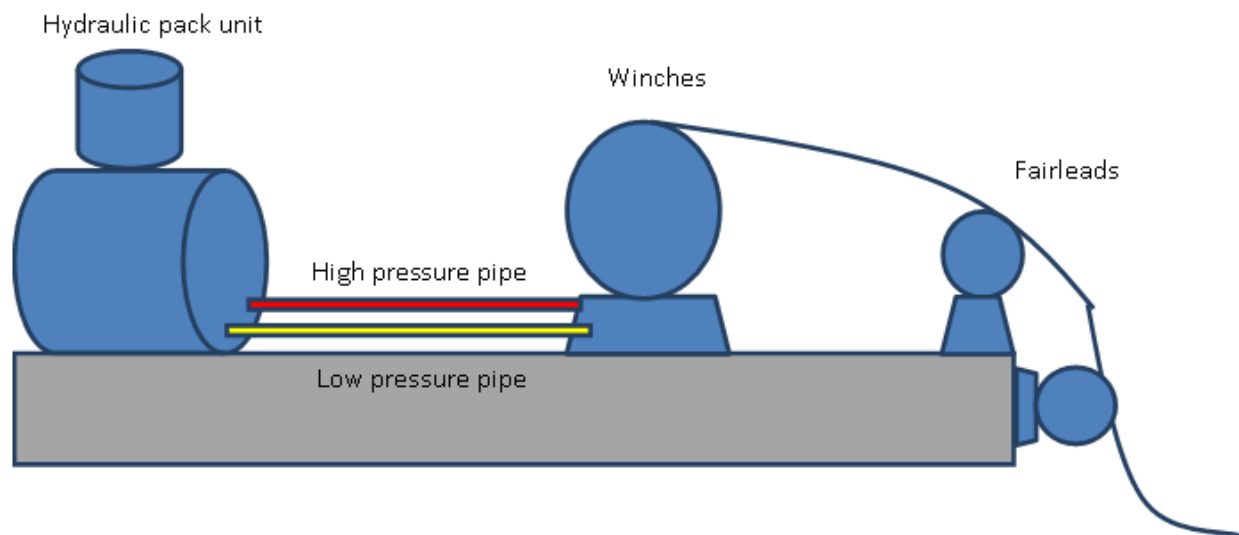


Figure 106: Mooring system arrangement and piping arrangement on the floating platform

### **4.3 Labour**

The labour required for constructing the platform is as follows:

For the following man-hours calculation it is assumed that the normal working hours for the worker is 9 hours for dayshift and 9 hours for nightshift.

It is also assumed that flat rate is \$3.00 per hour for the worker including Saturday, Sunday and Public holidays.

The fabrication of 1 hexagon pontoons would need:

#### **Dayshift**

Required manpower = 2

Hours = 9

Days = 4

Total man-hours = 72 man-hours

Total man-days = 8 man-days

#### **Nightshift**

Required manpower = 2

Hours = 9

Days = 4

Total man-hours = 72 man-hours

Total man-days = 8 man-days

Therefore for the fabrication of 345 piece of hexagon pontoon, the manpower breakdown is as follows:

The workshop space will be fully maximized and will be divided into 18 bays.

Each bay will produce 1 hexagon pontoon.

At the end of 4 days, 18 hexagon pontoons will be fabricated.

To fabricate 345 pontoons, it will take 76 days

Total dayshift man-hours to fabricate 345 hexagon pontoons = 24,624 man-hours

Total dayshift man-days to fabricate 345 hexagon pontoons = 2,736 man-days

Nightshift man-hours will be similar to dayshift man-hours.

Nightshift man-days will be similar to dayshift man-days.

Total man-hours to fabricate 345 hexagon pontoon = 49,248 man-hours

Total man-days to fabricate 345 hexagon pontoon = 5,472 man-days

Labour cost for dayshift = \$147,744.00

Labour cost for nightshift = \$147,744.00

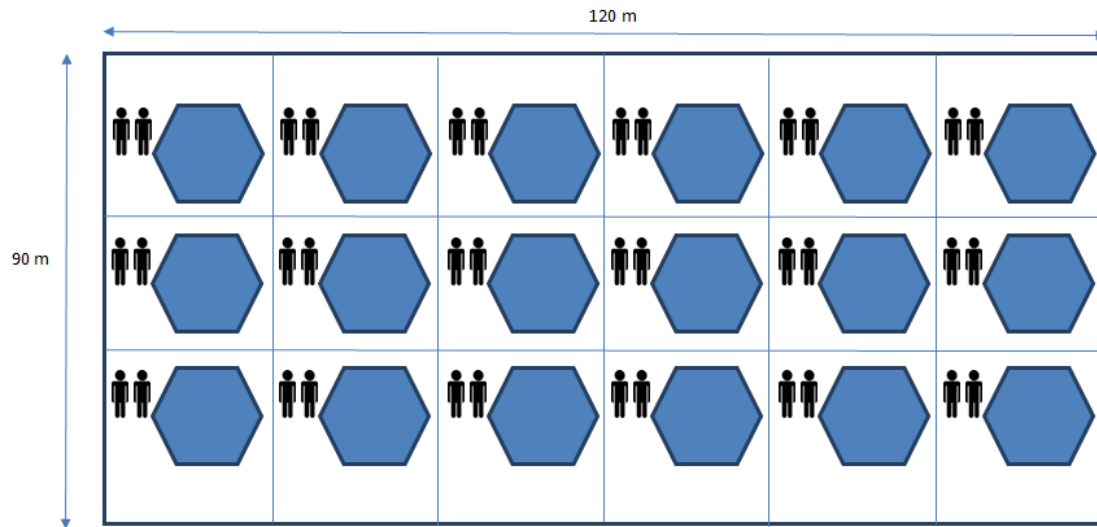


Figure 107: Proposed workshop layout for pontoon cutting

The manpower and breakdown for fabrication of 1 connecting pin is as follows:

**Dayshift**

Required manpower = 2

Hours = 9

Days = 2

Total man-hours = 36 man-hours

Total man-days = 4 man-days

### **Nightshift**

Required manpower= 2

Hours = 9

Days = 2

Total man-hours = 36 man-hours

Total man-days = 4 man-days

The manpower and breakdown to fabricate 2070 connecting pin is as follows:

The workshop space will be fully maximized and will be divided into 72 bays.

Each bay will produce 2 connecting pins in 2 days

With 72 bays, the workshop can produce 144 connecting pins.

To produce 2070 pins, the workshop will take 30 days

Total dayshift man-hours to produce 2070 pins = 38,880 man-hours

Total nightshift man-hours will be similar to dayshift man-hours.

Labour cost for dayshift = \$116, 640.00

Labour cost for nightshift = \$116, 640.0

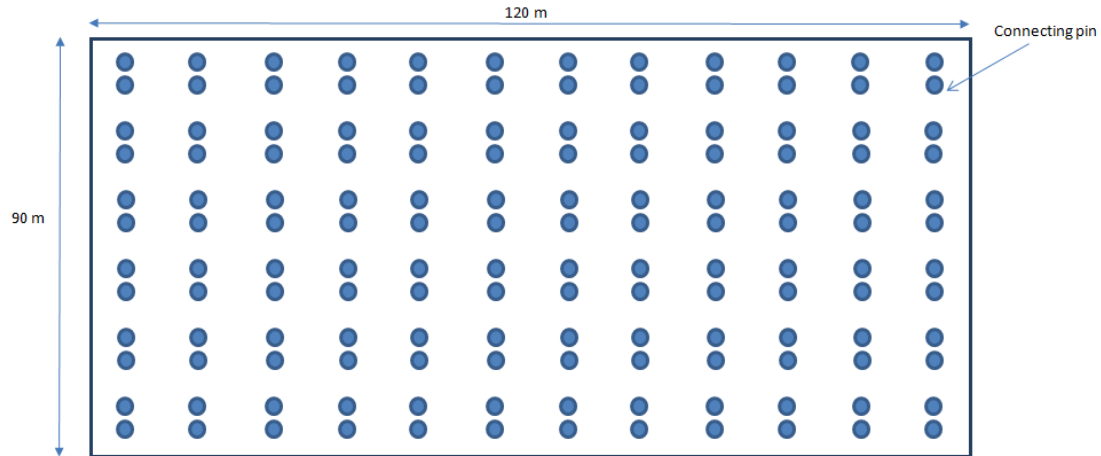


Figure 108: Proposed workshop layout for Connecting pin cutting

### 4.3.1 Skill Requirement

#### Fabrication of hexagon pontoon:

- Skill in moulding of concrete to desired shape by using mould cast.
- Skill in cutting concrete block to desired shape by using concrete cutting machine or plasma cutting machine
- Skill in grinding concrete block by using hand held grinder or grinding machine

#### Fabrication of connecting pins:

- Skill in moulding of concrete to desired shape by using mould cast.
- Skill in cutting concrete block to desired shape by using concrete cutting machine or plasma cutting machine
- Skill in grinding concrete block by using hand held grinder or grinding machine

**Fabrication of Accommodation Block:**

- Skill in cutting steel into shape by plasma cutting machine.
- Skill in cutting steel into shape by gas torch cutting machine.
- Skill in grinding of sharp edges by hand held grinder or grinding machine
- Welding skill - The welder must be 6G qualified and must be able to perform GTAW(Gas Tungsten Arc Welding)/SMAW(Shielded Metal Arc Welding),FCAW(Flux Cored Arc Welding) and GMAW(Gas Metal Arc Welding) on various types of pipe material and size

**Erection of Accommodation Block:**

- Welding skill - The welder must be 6G qualified and must be able to perform GTAW(Gas Tungsten Arc Welding)/SMAW(Shielded Metal Arc Welding),FCAW(Flux Cored Arc Welding) and GMAW(Gas Metal Arc Welding) on various types of pipe material and size
- Skill in grinding of sharp edges by hand held grinding machine
- Skill in insulation of bulkheads

**Fabrication of Spectator Stand:**

- Skill in cutting steel into shape by plasma cutting machine.
- Skill in cutting steel into shape by gas torch cutting machine.
- Skill in grinding of sharp edges by hand held grinder or grinding machine
- Welding skill - The welder must be 6G qualified and must be able to perform GTAW(Gas Tungsten Arc Welding)/SMAW(Shielded Metal Arc Welding),FCAW(Flux Cored Arc Welding) and GMAW(Gas Metal Arc Welding) on various types of pipe material and size

### **Installation of Spectator Stand:**

- Welding skill - The welder must be 6G qualified and must be able to perform GTAW/SMAW and GMAW
- Skill of using hand grinder to cut and grind steel
- Skill of using gas cutting torch to cut steel
- Skill of using of hand tools like hammer, spanner
- Skills of using hand tools like hand drill, impact wrench

### **Fabrication of pipe in workshop:**

- Skill of using cutting torch to cut pipe
- Skill of using hand grinder to cut and grind pipe
- Welding skill - The welder must be 6G qualified and must be able to perform GTAW(Gas Tungsten Arc Welding)/SMAW(Shielded Metal Arc Welding),FCAW(Flux Cored Arc Welding) and GMAW(Gas Metal Arc Welding) on various types of pipe material and size
- Skill of hydro-testing of pipe
- Skill of blasting and painting of pipe

### **Installation of pipe on-site:**

- Skill of using cutting torch to cut pipe
- Skill of using hand grinder to cut and grind pipe
- Welding skill - The welder must be 6G qualified and must be able to perform GTAW(Gas Tungsten Arc Welding)/SMAW(Shielded Metal Arc Welding),FCAW(Flux Cored Arc Welding) and GMAW(Gas Metal Arc Welding) on various types of pipe material and size
- Skill of hydro-testing of pipe
- Skill of using power tools like impact wrench to tighten bolt & nuts.

### **Installation and termination of wiring and air-conditioning ducting:**

- Skills in running cable/wire and terminating them
- Skills in running air-conditioning ducting
- Skills in installing lighting, air-conditioning and other electrical equipments

### **Fabrication of bridge and flyover:**

- Skill in cutting steel into shape by plasma cutting machine.
- Skill in cutting steel into shape by gas torch cutting machine.
- Skill in grinding of sharp edges by hand held grinder or grinding machine
- Welding skill - The welder must be 6G qualified and must be able to perform GTAW(Gas Tungsten Arc Welding)/SMAW(Shielded Metal Arc Welding),FCAW(Flux Cored Arc Welding) and GMAW(Gas Metal Arc Welding) on various types of pipe material and size

### **Assembly of hexagon pontoon to form floating platform:**

- Skills in assembling one hexagon pontoon to another hexagon pontoon
- Skills in using specialized hydraulic tools to join and tightened one hexagon pontoon to another hexagon pontoon.
- Skills in lifting/hoisting and fixing of connecting pins to hexagon pontoon

**Mating and lifting of accommodation block/spectator stand, bridge, flyover and field to floating platform:**

- Skills in coordinating of lifting activities of the accommodation block/spectator stand, bridge, flyover and field to floating platform
- Skills in coordinating of mating activities of the accommodation block/spectator stand, bridge, flyover and field to floating platform

**Mooring of Floating Platform:**

- Skills in installing of hydraulic winch
- Skills in laying out mooring lines to seabed

## 4.3.2 Technology Levels

### Fabrication of hexagon pontoon & connecting pins:

Technology in moulding of concrete blocks

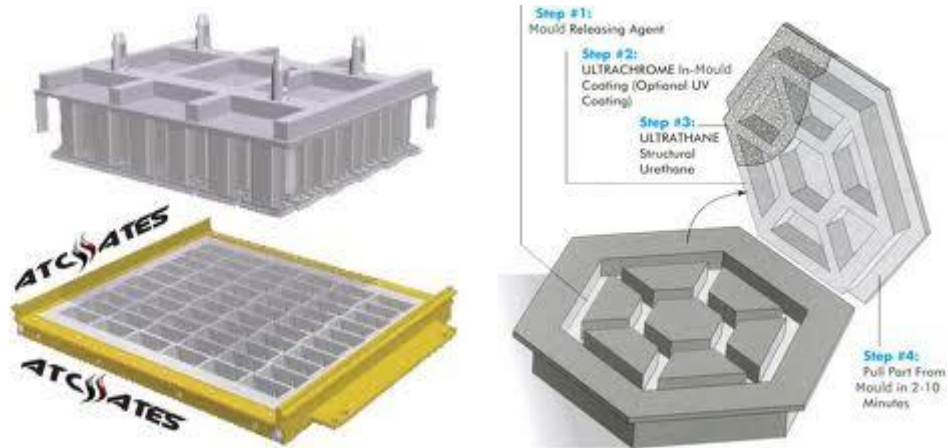


Figure 109: Multiple Concrete mould casting    Figure 110: Single Concrete mould casting

Plasma cutting technology or using concrete cutter to cut concrete blocks into desire shape



Figure 111: Plasma cutting machine in a workshop    Figure 112: Concrete cutting machine

### **Fabrication of accommodation block/spectator stand/bridge/flyover:**

Plasma cutting technology to cut steel plate into shape



Figure 113: Plasma cutting machine cutting a steel plate

Automatic cutting machine to cut steel plate into desired shape

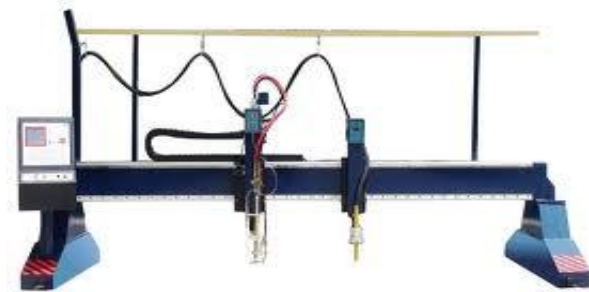


Figure 114: Automatic gas cutting machine will expedite the process of cutting steel plate into desired shape

Automatic welding machine to weld steel plates



Figure 115: The process of welding using automatic welding machine

### **Fabrication of pipes:**

Automatic gas cutting machine to cut pipe of various length and size faster compared to manual gas cutting. The cutting nozzle of the gas torch that automatically rotates and cut around the pipe faster and more precise



Figure 116: The cutting nozzle of the gas torch

Automatic welding machine to weld pipe of various length and size faster compared to manual welding. The machine will rotate the pipe and the welding nozzle will weld the pipe joint evenly and in most cases the welding defects is minimal and close to zero.



Figure 117: The automatic welding machine for pipes

### **Installation of pipe in accommodation block:**

Tightening of bolt and nut can be done by impact wrench and other power tools rather than using the conventional hammer and spanner method. Using of impact wrench and cassette wrench will expedite the process of joining pipes especially in tightening bolt & nuts.



Figure 118: Example of impact wrench and power tools

### **Mating and lifting of accommodation block/spectator stand, bridge, flyover and field to floating platform:**

Technology in using heavy duty floating cranes and other heavy duty lifting gears to lift and mate the accommodation block/spectator stand, bridge, flyover and field to floating platform.



Figure 119: Floating cranes in operation for heavy lift process

## 4.4 Multi Purpose Floating Platform Construction Schedule

Please kindly refer to Annex C.

## 4.5 Cost Analysis

In this Chapter, it will display the cost based on number of labour, the man-hours and the cost of labour.

### **Fabrication and erection of 1 accommodation block:**

#### **Fabrication of block in workshop (day shift)**

|                        |             |
|------------------------|-------------|
| Manpower               | 30          |
| Days                   | 90          |
| Hours                  | 9           |
| Total hours in 90 days | 810         |
| Man-hours              | 24,300      |
| Man-days               | 2,700       |
| Labour cost            | \$72,900.00 |

#### **Erection of accommodation block at site (day shift)**

|                         |              |
|-------------------------|--------------|
| Manpower                | 50           |
| Days                    | 150          |
| Hours                   | 9            |
| Total hours in 150 days | 1,350        |
| Man-hours               | 67,500       |
| Man-days                | 7,500        |
| Labour cost             | \$202,500.00 |

#### **Fabrication of block in workshop (night shift)**

|                                    |             |
|------------------------------------|-------------|
| Same manpower in day/s Labour cost | \$72,900.00 |
|------------------------------------|-------------|

#### **Erection of accommodation block at site (night shift)**

|                                    |              |
|------------------------------------|--------------|
| Same manpower in day/s Labour cost | \$202,500.00 |
|------------------------------------|--------------|

|                                                    |                     |
|----------------------------------------------------|---------------------|
| <b>Total labour cost for 1 accommodation block</b> | <b>\$550,800.00</b> |
|----------------------------------------------------|---------------------|

|                                              |                       |
|----------------------------------------------|-----------------------|
| <b>Labour cost for 4 accommodation block</b> | <b>\$2,203,200.00</b> |
|----------------------------------------------|-----------------------|

**Fabrication and installation of Spectator stand:**

**Fabrication of spectator stand in workshop (day shift)**

|                        |             |
|------------------------|-------------|
| Manpower               | 20          |
| Days                   | 60          |
| Hours                  | 9           |
| Total hours in 60 days | 540         |
| Man-hours              | 10,800      |
| Man-days               | 1,200       |
| Labour cost            | \$32,400.00 |

**Installation of spectator stand (day shift)**

|                        |             |
|------------------------|-------------|
| Manpower               | 30          |
| Days                   | 90          |
| Hours                  | 9           |
| Total hours in 90 days | 810         |
| Man-hours              | 24,300      |
| Man-days               | 2,700       |
| Labour cost            | \$72,900.00 |

**Fabrication of spectator stand in workshop (night shift)**

|                                    |             |
|------------------------------------|-------------|
| Same manpower in day/s Labour cost | \$32,400.00 |
|------------------------------------|-------------|

**Installation of spectator stand (night shift)**

|                                    |             |
|------------------------------------|-------------|
| Same manpower in day/s Labour cost | \$32,400.00 |
|------------------------------------|-------------|

|                                         |                      |
|-----------------------------------------|----------------------|
| <b>Total cost for 1 spectator stand</b> | <b>\$ 170,100.00</b> |
|-----------------------------------------|----------------------|

|                                         |                     |
|-----------------------------------------|---------------------|
| <b>Total cost for 4 spectator stand</b> | <b>\$680,400.00</b> |
|-----------------------------------------|---------------------|

**Fabrication and installation of Pipes:****Fabrication of pipes in workshop during day shift  
(sewage/sanitary, domestic freshwater, hot water) :**

|                         |             |
|-------------------------|-------------|
| Manpower                | 30          |
| Days                    | 120         |
| Hours                   | 9           |
| Total hours in 120 days | 1080        |
| Man-hours               | 32,400      |
| Man-days                | 3,600       |
| Labour cost             | \$97,200.00 |

**Installation of pipes on site during day shift  
(sewage/sanitary, domestic freshwater, hot water) :**

|                         |              |
|-------------------------|--------------|
| Manpower                | 50           |
| Days                    | 150          |
| Hours                   | 9            |
| Total hours in 150 days | 1350         |
| Man-hours               | 67,500       |
| Man-days                | 7,500        |
| Labour cost             | \$202,500.00 |

**Fabrication of pipes in workshop during night shift  
(sewage/sanitary, domestic freshwater, hot water) :**

|                                    |             |
|------------------------------------|-------------|
| Same manpower in day/s Labour cost | \$97,200.00 |
|------------------------------------|-------------|

**Installation of pipes on site during night shift  
(sewage/sanitary, domestic freshwater, hot water) :**

|                                    |              |
|------------------------------------|--------------|
| Same manpower in day/s Labour cost | \$202,500.00 |
|------------------------------------|--------------|

### **Fabrication and installation of Wiring and Air-conditioning**

#### **Fabrication of cable ladder/trunking in workshop during day shift:**

|                        |             |
|------------------------|-------------|
| Manpower               | 20          |
| Days                   | 60          |
| Hours                  | 9           |
| Total hours in 60 days | 540         |
| Man-hours              | 10,800      |
| Man-days               | 1,200       |
| Labour cost            | \$32,400.00 |

#### **Installation/termination of wiring on site during day shift (lighting, power-points, air-conditioning):**

|                         |              |
|-------------------------|--------------|
| Manpower                | 40           |
| Days                    | 120          |
| Hours                   | 9            |
| Total hours in 120 days | 1080         |
| Man-hours               | 43,200       |
| Man-days                | 4,800        |
| Labour cost             | \$129,600.00 |

#### **Fabrication of cable ladder/trunking in workshop during night shift:**

|                                    |             |
|------------------------------------|-------------|
| Same manpower in day/s Labour cost | \$32,400.00 |
|------------------------------------|-------------|

#### **Installation/termination of wiring on site during night shift (lighting, power-points, air-conditioning):**

|                                    |              |
|------------------------------------|--------------|
| Same manpower in day/s Labour cost | \$129,600.00 |
|------------------------------------|--------------|

### **Fabrication of Bridge**

#### **Fabrication of bridge A, B and C during day shift:**

|                        |              |
|------------------------|--------------|
| Manpower               | 30           |
| Hours                  | 9            |
| Days                   | 90           |
| Total hours in 90 days | 810          |
| Man-hours              | 24300        |
| Man-days               | 2700         |
| Labour cost            | \$729,000.00 |

#### **Fabrication of bridge A, B and C during night shift:**

|                                    |              |
|------------------------------------|--------------|
| Same manpower in day/s Labour cost | \$729,000.00 |
|------------------------------------|--------------|

#### **Fabrication of bridge D, E and F during day shift:**

|                        |              |
|------------------------|--------------|
| Manpower               | 30           |
| Hours                  | 9            |
| Days                   | 90           |
| Total hours in 90 days | 810          |
| Man-hours              | 24300        |
| Man-days               | 2700         |
| Labour cost            | \$729,000.00 |

#### **Fabrication of bridge D, E and F during night shift:**

|                                    |              |
|------------------------------------|--------------|
| Same manpower in day/s Labour cost | \$729,000.00 |
|------------------------------------|--------------|

#### **Fabrication of Flyover A, B and C during day shift:**

|                        |             |
|------------------------|-------------|
| Manpower               | 30          |
| Hours                  | 9           |
| Days                   | 80          |
| Total hours in 80 days | 72810       |
| Man-hours              | 21600       |
| Man-days               | 2400        |
| Labour cost            | \$64,800.00 |

#### **Fabrication of Flyover A, B and C during night shift:**

|                                    |             |
|------------------------------------|-------------|
| Same manpower in day/s Labour cost | \$64,800.00 |
|------------------------------------|-------------|

### **Assembly**

#### **Assembly of hexform to form floating platform during day shift:**

|                      |          |
|----------------------|----------|
| Manpower             | 10       |
| Hours                | 9        |
| Days                 | 2        |
| Total hours in 2days | 18       |
| Man-hours            | 180      |
| Labour cost          | \$540.00 |

#### **Assembly of hexform to form floating platform during night shift:**

|                                    |          |
|------------------------------------|----------|
| Same manpower in day/s Labour cost | \$540.00 |
|------------------------------------|----------|

#### **Towing of floating platform to site:**

|                        |          |
|------------------------|----------|
| Pilots                 | 3        |
| Hours                  | 7        |
| Man-hours              | 21       |
| Labour cost for pilots | \$840.00 |

**Mating and lifting of accommodation block/spectator stand, bridge, flyover and field to floating platform during day shift:**

|                                 |            |
|---------------------------------|------------|
| crane operators                 | 1          |
| manpower                        | 10         |
| Hours                           | 10         |
| labour cost for crane operators | \$200.00   |
| Man-hours                       | 100        |
| labour cost                     | \$1,000.00 |

**Mating and lifting of accommodation block/spectator stand, bridge, flyover and field to floating platform during night shift:**

|                             |            |
|-----------------------------|------------|
| Same manpower in day/s      |            |
| Labour cost crane operators | \$200.00   |
| Labour cost                 | \$1,000.00 |

**Installation of winches and mooring lines during day shift:**

|                         |             |
|-------------------------|-------------|
| Manpower                | 10          |
| Hours                   | 9           |
| Days                    | 14          |
| Total hours for 14 days | 126         |
| Man-hours               | 1260        |
| Labour cost             | \$12,600.00 |

**Installation of winches and mooring lines during night shift:**

|                                    |             |
|------------------------------------|-------------|
| Same manpower in day/s Labour cost | \$12,600.00 |
|------------------------------------|-------------|

**Final piping installation, wiring termination and commissioning during day shift:**

|                        |              |
|------------------------|--------------|
| Manpower               | 100          |
| Hours                  | 9            |
| Days                   | 3            |
| Total hours for 3 days | 27           |
| Man-hours              | 2700         |
| Man-days               | 300          |
| Labour cost            | \$270,000.00 |

## **5 Future Market Opportunities**

Having a floating structure equipped with required configuration of facilities are attractive as user can have their preferred arrangement and design while having minimal restriction of the area of land that can be used to build the structure. The view to the surrounding at sea would be able to provide a more relax feeling to the people who use it and most people do not have strong objections onboard any floating structures so long it do not bring any discomfort and safety issues to the user.

As climate had been changing over the years, there are assessments done that prove that in each seasons, the temperature changed will be more extreme; winter will have more rain or snow while summer will be of higher temperature and dryer. Global warming resulted in worldwide sea level rising especially when high temperature caused the melting of ice and there will be a larger water area.

The shortage of land is also a big issues especially when world populations are increasing, the need of area for living, working and recreation would also increased, hence having a space for multiple usage especially near coastal and river would be a good solution since there is a larger water area available instead of reclamation of land for building the facilities.

## **6 Conclusion**

This report had greatly emphasized how a multi-purpose floating structure would benefit the future design of expansion of usage beyond the traditional land reclamations. The opportunity of reconfigurations to suit individual design and demand needs enable to optimise the structure usage and also if the same demand of design is needed, there will be no need to rebuild the facilities but to actually relocate the whole configurations.

In conclusion, the marine engineering and technical aspect of the project has been addressed. This project has enriched the team through critical thinking and analysis. It is through individual effort and good team coordination, thus allows the completion of this detailed report.

## 7 References

- Mehta, P. K., & Langley, W. S. (2000). *Concr. Int.*, 22(7), 27-32.
- Williams, J. V., Jr. (1981). *Concr. Int.*, 3(4), 58.
- Moksnes, J., & Sandvik, M. (1996). *3rd CANMET/ACI Conference on Marine Structures*. Paper presented at the Symposium Honoring O.E. Gjorv.
- Langley, W. S., Gilmour, R., & Trompsch, E. (1995). ACI SP-154.
- Weickgenant, J. (2011). Buoyant Market, from <http://www.metropolismag.com/story/20110512/bouyant-market>
- Wikipedia. (2012). Composting toilet, from [http://en.wikipedia.org/wiki/Composting\\_toilet](http://en.wikipedia.org/wiki/Composting_toilet)
- Authority, U. R. (2001). Concept Plan 2001, from <http://www.ura.gov.sg/conceptplan2001/index.html>
- Mehta, P. K., & Aitcin, P. C. (1990). Concr. Aggregates. *American Society for Testing Materials*, 12(2), 70-78.
- Feeder, F. (2005). Concrete Architecture Retrieved 17th March, 2012, from <http://www.futurefeeder.com>
- Jotun. Concrete Protection Brochure.
- Madsen, J. J. (2005). Concrete vs. Steel Retrieved 17th March, 2012, from <http://www.buildings.com>
- Mehta, P. K., & Monteiro, P. J. M. (2006). *Concrete: microstructure, properties, and materials*: McGraw-Hill.
- Hitoshi Fuji, K. I., Masanori Shuku. (1982). Design of mooring system of oil storage barges in shallow water.
- Buildings, F. S. (2011). Different Types of Steel Buildings Retrieved 17th March, 2012, from <http://www.futuresteelbuildings.me/>
- Iberahin Jusoh, J. W. (1996). Effects of Marine Growth and Hydrodynamic Loading on Offshore Structures.
- D. Andrew, M. C. Energy Demand Characteristic and the Potential for Energy Efficiency in Sports Stadium and Arenas.
- Energy, H. Energy Solutions - Hotels, from <http://www.hawaiienergy.com/56/hotels>
- Star, E. (December 2007). Facility Type: Hotels and Motels, from [www.energystar.gov/ia/business/EPA\\_BUM\\_CH12\\_HotelsMotels.pdf](http://www.energystar.gov/ia/business/EPA_BUM_CH12_HotelsMotels.pdf)
- Krenchel, H. (1974). Fibre Reinforced Concrete. *ACI SP(44)*, 45-77.

AFP. (2007). Floating Dutch prison for illegal aliens, from <http://afp.google.com/article/ALeqM5jl92ZkOsszNjpyV3MAxRJRHbLwiw>

Wikipedia. (2012). Galvanic Anode Retrieved 17th March, 2012, from [http://en.wikipedia.org/wiki/Galvanic\\_anode](http://en.wikipedia.org/wiki/Galvanic_anode)

Institute, A. C. (1987). Guide for Structural Lightweight Concrete

Gcaptain. (2011). Heavylift "Super Vessel", from <http://gcaptain.com/heavylift-super-vessel-dockwise/?32564>

Jotun. HPI - Hydrocarbon Processing Industry Concept.

Technology, H. (February 2011). HUBER Brown Water Treatment.

Strauss, M. (2000). Human Waste (Excreta and Wastewater) Reuse.

System, D. D. S. Installation Manual.

Koh Hock Seng, L. Y. B. (2007). Integrated Floating Platform.

Japan, S. R. C. o. Introduction of Mega-Float, from [http://www.srcj.or.jp/html/megafloat\\_en/index.html](http://www.srcj.or.jp/html/megafloat_en/index.html)

233, R. o. A. C. (1991). Manual of Concrete Practice, Part 1.

Center, N. (2011). Marine Cathodic Protection Retrieved 17th March, 2012, from <http://www.nstcenter.com/writeup.aspx?title=Marine%20Cathodic%20Protection&page=NavyCommunityAppExtShipCathodicProtection.html>

Choy. (2003). Marine Engineering Knowledge 2. *SP-SMA*.

David K. Woolf, P. D. C., Peter G.Challenor. (19 November 2002). Measurements of the offshore wave climate around the British Isles by satellite altimeter.

Saniresch. (February 2012). Meeting of all Saniresch projects, from <http://saniresch.de/images/stories/downloads/summary-15.02.12-en.pdf>

Gjerde, T. (1982). Nordisk Betong (Stockholm). No. 2–4, 95-96.

research, E. a. (2011). Nutrient Recovery from Urine - Production of urine-based fertilizer, from [http://www.eawag.ch/forschung/eng/gruppen/vuna/research/evaporation/VUNA\\_Brochure\\_Urine\\_Separation.pdf](http://www.eawag.ch/forschung/eng/gruppen/vuna/research/evaporation/VUNA_Brochure_Urine_Separation.pdf)

Jotun. Paints and Coatings for Working Vessels.

Penguin Vessel. from <http://www.penguin.com.sg/vessel-specs/penguin-seletar/>

Exchange, L. M. (2012). Price Comparison Charts Retrieved 17th March, 2012, from <https://secure.lme.com/Data/Community/Login.aspx?ReturnUrl=%2fData%2fcommunity%2findex.aspx>

Johnson, C. D. (1980). *Progress in Concrete Technology*. Malhotra, V.M.

Saniresch. (2012). Project components, from <http://www.saniresch.de/en/project-components>

Hanna, A. C. (1977). Report RD049.01P *Portland Cement Association* Skokie, IL.

Saniresch. Roediger-no mix toilet.

Century, H. o. D. T. t. t. (2011). Rome Retrieved 17th March, 2012, from <http://iammodernman.wordpress.com/2011/04/18/rome/>

A, S. (2012). [Sales Manager UK North, Desso DLW Sports System].

Spaces, M. (2010). Sewage treatment on board - biological and chemical sewage treatment plant working principles, from <http://www.machineryspaces.com/sewage-treatment.html>

Department of the Army, C. o. E. (1984). *Shore Protection Manual Volume 1*.

Goode J.S., J. F., Natalie Mach, Denali Lander, Christopher Valenti, Denise Carlson, Malinda Zarske. (2006). *Strength of Materials* Retrieved 17th March, 2012, from <http://www.teachengineering.org>

M, F. (2005). Structural Analysis for the Design of VLFS. *Marine Structures* 18, 201-226.

David Adler, G. C., Bill Gilson, Nick Parkinson, Rod Sheard, Richard Taylor, Nigel Ward, Terry Ward, Simon Inglis. (December 1993). Toilet facilities at stadium - Planning, design and types of installation. (9).

Elvin, Y., Xiao. (2000). Urban Housing Development of Singapore, from <http://library.thinkquest.org/C006891/>

Watanabe E, U. T., Wang C.M, Moan T. (2004). Very Large Floating Structures: Application, Analysis and Design. *Core Report NO 2004-2*.

AWI. Digital Atlas of the North Sea - An overview about geo-information considering the sea floor and the bottom water column.

ABPmer, T. M. O., Proudman Oceanographic Laboratory. (March 2008). Atlas of UK Marine Renewable Energy Resources. *A Strategic Environmental Assessment Report*.

Koekoek, M. (September 2010). Connecting Modular Floating Structures.

Dr Koh Hock Seng, L. Y. B. Integrated Floating Platform.

**Annex A:**  
**Equipment for installations of artificial  
soccer field**



Figure 120: Cutting device for seams

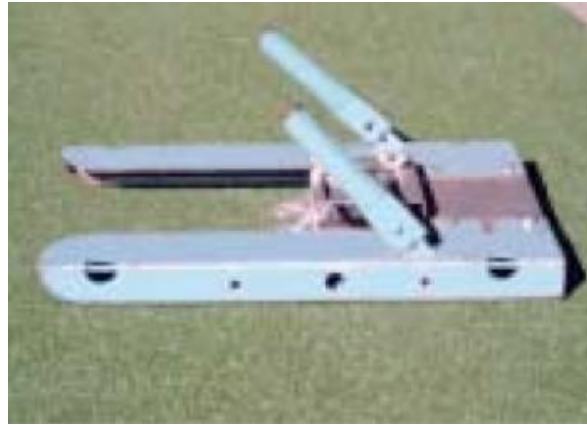


Figure 121: Double cutting knife



Figure 122: Gluing Kit

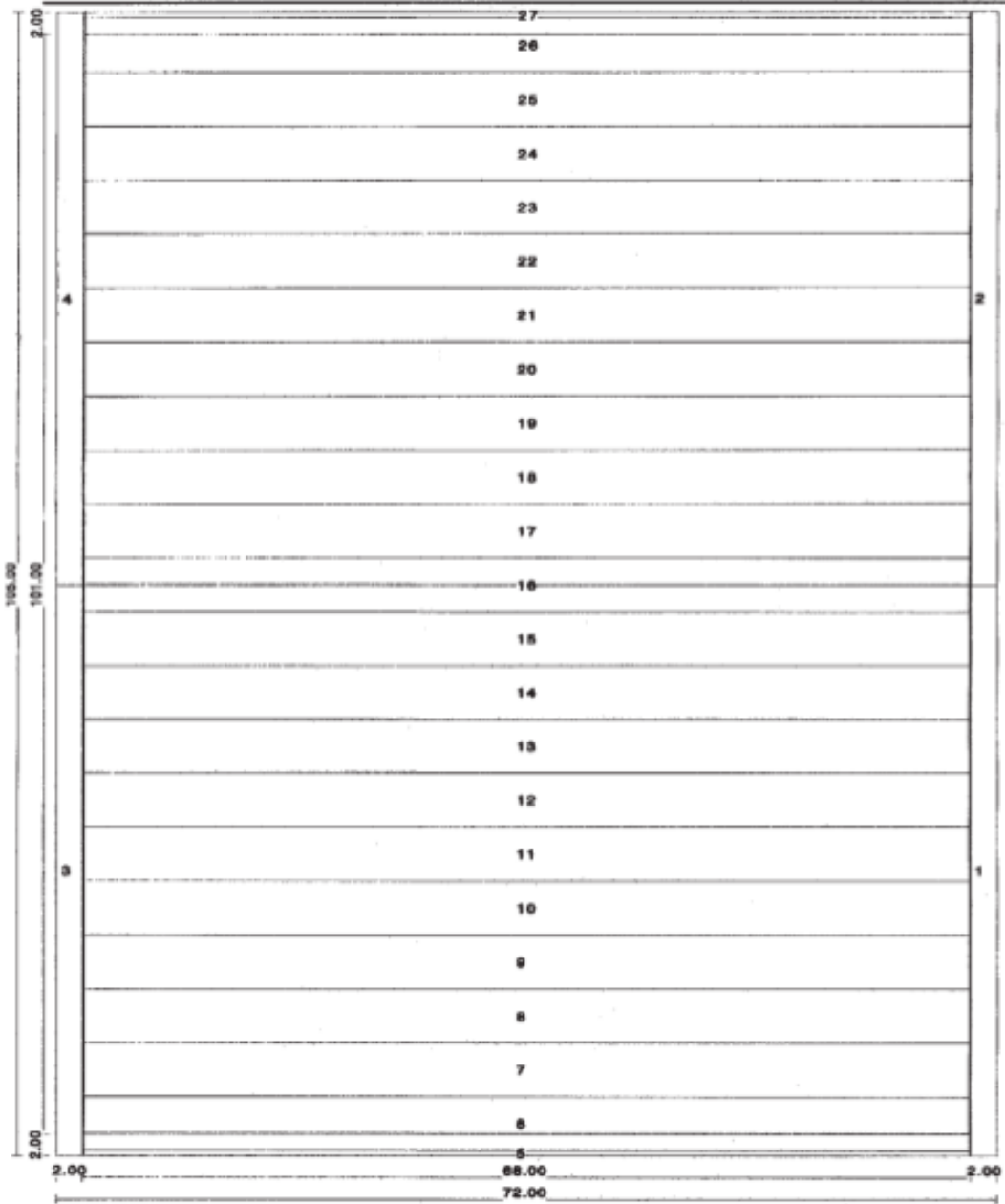
**Annex B:**  
**Example of the Shop Drawings**

# LAYING PLAN

Date : 27-2-01  
Version : 1

Project :  
Quality : Soccergras Crown

Fieldnumber : UK5128  
Partnumber : 91EC027000100



Page : 11  
Date : 27-2-01  
Version : 1

DESSO **LAYING PLAN**

Doc no. : 30.09.GR002  
Date : 16-05-1994  
Version : 1

Quality : Soccergras Crown Article number : 91E  
Project : Fieldnumber : UK5126

Extra requisites

1. Tape

15.38 rollen PVC tape van 20 cm breedte voor naden  
6.49 rollen PVC tape van 25 cm breedte voor belijning

2. Lijm

69.82 potten Helmipur 149 (12kg + 1,2kg) voor naden  
29.45 potten Helmipur 149 (12kg + 1,2kg) voor belijning  
99.28

Cutt losses

|                 | Number | Length   | Width | Useful<br>Width | Total      |
|-----------------|--------|----------|-------|-----------------|------------|
| Middle lines    | 1      | 70.50    | 5.000 | 4.950           | 352.50     |
| Back lines      | 2      | 68.00    | 5.000 | 4.950           | 680.00     |
| Endrolls        | 2      | 68.00    | 0.575 | 0.525           | 78.20      |
| Side lines      | 4      | 52.70    | 2.500 | 2.120           | 527.00     |
| Unirolls        | 18     | 68.00    | 5.000 | 4.950           | 6120.00    |
| Separate lining | 1      | 68.00    | 0.760 | 0.600           | 51.68      |
| Extra lines     | 1      | 68.00    | 0.390 | 0.300           | 26.52      |
|                 |        |          |       |                 | 7835.90 m2 |
| Nett surface    |        | 105.00 x | 72.00 | =               | 7560.00 m2 |
| Cutt losses     | 3.65 % |          |       |                 |            |
| Number of rolls | 29     |          |       |                 |            |

Page : 2  
Date : 27-2-01  
Version : 1

DESSO

## ROLL POSITION

Doc no. : 30.09.GR002  
Date : 16-05-1994  
Version : 1

Fieldnumber : UK5126  
Project :  
Quality : Soccergras Crown  
Partnumber : 91EC027000100  
Client : SC

| Nr        | Length [m] | Width [cm] | Colour | Characteristic            | Remark |
|-----------|------------|------------|--------|---------------------------|--------|
| UK5126_16 | 68.00      | 500.0      | M34    | Roll includes middle line |        |
| UK5126_00 | 2.50       | 500.0      | 027    | Roll 11 m. points         |        |
| UK5126_06 | 68.00      | 500.0      | A34    | Roll includes backline    |        |
| UK5126_26 | 68.00      | 500.0      | A34    | Roll includes backline    |        |
| UK5126_05 | 68.00      | 57.5       | 027    | Endroll                   |        |
| UK5126_27 | 68.00      | 57.5       | 027    | Endroll                   |        |
| UK5126_29 | 68.00      | 76.0       | 034    | Separate lines            |        |
| UK5126_28 | 68.00      | 39.0       | 025    | Extra lines               |        |
| UK5126_03 | 52.70      | 250.0      | Z34    | Roll has a sideline       |        |
| UK5126_01 | 52.70      | 250.0      | Z34    | Roll has a sideline       |        |
| UK5126_04 | 52.70      | 250.0      | Z34    | Roll has a sideline       |        |
| UK5126_02 | 52.70      | 250.0      | Z34    | Roll has a sideline       |        |
| UK5126_07 | 68.00      | 500.0      | 027    |                           |        |
| UK5126_08 | 68.00      | 500.0      | 027    |                           |        |
| UK5126_09 | 68.00      | 500.0      | 027    |                           |        |
| UK5126_10 | 68.00      | 500.0      | 027    |                           |        |
| UK5126_11 | 68.00      | 500.0      | 027    |                           |        |
| UK5126_12 | 68.00      | 500.0      | 027    |                           |        |
| UK5126_13 | 68.00      | 500.0      | 027    |                           |        |
| UK5126_14 | 68.00      | 500.0      | 027    |                           |        |
| UK5126_15 | 68.00      | 500.0      | 027    |                           |        |
| UK5126_17 | 68.00      | 500.0      | 027    |                           |        |
| UK5126_18 | 68.00      | 500.0      | 027    |                           |        |
| UK5126_19 | 68.00      | 500.0      | 027    |                           |        |

Side rolls

Uniroils

Extra requisites + cult losses



## **Annex C:**

# **Construction Schedule**





# **Annex D:**

## **MOSES Simulation Results**





















**Appendix E:**

**Email with SembCorp Marine to  
understudy Singapore's Floating  
Platform and agenda**

Re: Assistance in Floating Platform Structure

Harishen [harishen.hrd@jspl.com.sg]

Sent: 13 February 2012 02:52

To: [Pei Heng](#)

[Dennis SIT \[denniswan1988@hotmail.com\]](#); [auntiekiller@gmail.com](#); [Jireh SIT Jireh](#)

Cc: [\[f3n9\\_yun77@yahoo.com.sg\]](#); [Zul SIT \[zach\\_hunt02@yahoo.com.sg\]](#); [Raymond SIT \[raymondjtjs@gmail.com\]](#)

Thank you.

See you all on Wednesday

Regards,

Harishen

----- Original Message -----

From: "Pei Heng" <p.t.heng@newcastle.ac.uk>

To: "Harishen" <harishen.hrd@jspl.com.sg>

Cc: "Dennis SIT" <denniswan1988@hotmail.com>; <auntiekiller@gmail.com>;

"Jireh SIT Jireh" <f3n9\_yun77@yahoo.com.sg>; "Zul SIT"

<zach\_hunt02@yahoo.com.sg>; "Raymond SIT" <raymondjtjs@gmail.com>

Sent: Monday, February 13, 2012 2:28 PM

Subject: RE: Assistance in Floating Platform Structure

Hi Harishen,

The following is our details for security clearance:

- 1) Heng Pei Ting
- 2) Wan Zhen Wei Dennis
- 3) Lew Jireh
- 4) Edward Lim Theng Loon
- 5) Zulfadli Bin Rahmat

Thank you!

Warmest Regards,  
Heng Pei Ting Fion

---

From: Harishen [harishen.hrd@jspl.com.sg]

Sent: 13 February 2012 02:44

To: Pei Heng

Cc: Dennis SIT; auntiekiller@gmail.com; Jireh SIT Jireh; Zul SIT; Raymond SIT

Subject: Re: Assistance in Floating Platform Structure

Hi Pei Ting,

Thank you for the agenda.

Also - please send the namelist of your group with NRIC for security clearance.

Regards,  
Harishen

----- Original Message -----

From: "Pei Heng" <p.t.heng@newcastle.ac.uk>  
To: "Harishen" <harishen.hrd@jspl.com.sg>  
Cc: "Dennis SIT" <denniswan1988@hotmail.com>; <auntiekiller@gmail.com>;  
"Jireh SIT Jireh" <f3n9\_yun77@yahoo.com.sg>; "Zul SIT"  
<zach\_hunt02@yahoo.com.sg>; "Raymond SIT" <raymondts@gmail.com>  
Sent: Monday, February 13, 2012 2:18 PM  
Subject: RE: Assistance in Floating Platform Structure

Hi Harishen,

Please find attached the agenda for Wednesday's meeting and also the competition we had registered for.

The current confirmed members attending the meeting will be 5.

Thank you.

Warmest Regards,  
Heng Pei Ting Fion

---

From: Harishen [harishen.hrd@jspl.com.sg]  
Sent: 09 February 2012 22:38  
To: Pei Heng  
Cc: Dennis SIT; auntiekiller@gmail.com; Jireh SIT Jireh; Zul SIT; Raymond SIT  
Subject: Re: Assistance in Floating Platform Structure

Hi Pei Ting,

How many of you are coming?  
and please forward us your agenda for the day.

Thank you,  
Regards,  
Harishen

----- Original Message -----

From: "Pei Heng" <p.t.heng@newcastle.ac.uk>  
To: "Harishen" <harishen.hrd@jspl.com.sg>  
Cc: "Dennis SIT" <denniswan1988@hotmail.com>; <auntiekiller@gmail.com>;  
"Jireh SIT Jireh" <f3n9\_yun77@yahoo.com.sg>; "Zul SIT"  
<zach\_hunt02@yahoo.com.sg>; "Raymond SIT" <raymondts@gmail.com>  
Sent: Thursday, February 09, 2012 11:05 PM  
Subject: Re: Assistance in Floating Platform Structure

Hi Harishen,

My team and I would like to meet the relevant department head on the 15th Feb 2012(wed). Please kindly assist to schedule an appointment with him for us.

Thank you very much!

Warmest regards,  
Pei Ting

On Feb 9, 2012, at 3:01 PM, "Harishen" <harishen.hrd@jspl.com.sg> wrote:

> Hi Pei Ting,  
>  
> We have communicated with relevant department head (GM of Sembcorp Marine  
> Technology), and he is willing to assist you in the project.  
> Possible date: 14th or 15th Feb 2012  
> Time: 9AM  
>  
> Please let know your availability for the meet up.  
>  
> Regards,  
> Harishen  
>  
> ----- Original Message -----  
> From: "Pei Heng" <p.t.heng@newcastle.ac.uk>  
> To: <harishen.hrd@jspl.com.sg>  
> Sent: Wednesday, February 08, 2012 2:57 PM  
> Subject: Assistance in Floating Platform Structure  
>  
>  
> Hi Harishen,  
>  
> How are you? Sorry that I might need to disturb you for awhile to get your  
> assistance in one of my module "Marine Engineering Design".  
>  
> My team and I are actually doing on a project on floating structures  
> platform and we are understudying the Singapore's marina floating  
> Platform.  
> The information on the web are limited and we get get to know that this  
> project is actually a joined collaboration with Sembcorp Marine and DSTA.  
>  
> I would like to check with you if there is any personnel we can get in  
> contact with to understand the planning of such structures?  
>  
> Warmest Regards,  
> Heng Pei Ting Fion  
>  
>

# **AGENDA for meeting with GM SembCorp Marine Technology**

**Date: 15<sup>th</sup> February 2012**

**Time: 9am**

**Location: Jurong Shipyard**

1. Welcome/open meeting
2. A list of specific points to be discussed:
  - Purpose of our Project
  - Our Idea Generation
  - Understudy of Singapore's Marine Floating Platform
    - Why build a floating platform instead building the structure of land?
    - What are the design considerations for building this platform?
      - Pontoon Connection type
      - Mooring system
      - Ballast
      - Stability calculation
      - Wave Breaking
      - Material
        - Composition steel
        - Concrete
      - Audience Stand
        - Reason why build on land
        - Dimension
        - Specification
        - Lifespan
      - Interlink Bridge availability
      - Fouling protection system
      - Maintenance Programme and Cost
      - Software recommendation
3. Close meeting

## **Appendix F:**

### **Minutes of Meeting**











