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# THE FLOATING HOUSE, SKINS & SPACES DUBAI (UNITED ARAB EMIRATES) – PALM JUMEIRAH

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**ABSTRACT**

The concept of building floating houses on coastal areas has been expanding widely, especially with the large urban growth, and the lack of properties to cover the increased market demands. However, the aspiration of building new floating houses that offer highly comfortable and integrity structure on water top become a reality. The innovative developed floating houses are designed and refined to reflect eco-friendly design. To improve energy consumption in such houses, integrating active systems and considering lightweight materials with proper insulation for building skins and roof insulation will help in achieving optimum energy efficiency levels. The main purpose of choosing the project in UAE generally is the hot climate, and the new trend of building houses in coastal areas. IES software will be used in the current study methodology to compare between three different building skins that will form the core of the research, with integrating three active systems to enhance energy efficiency and billing rates.



**KEYWORDS**: Building Skins, Active Systems, Energy Efficiency, Floating Systems, Thermal Aspects

## INTRODUCTION

The alarming expansion of population and urban growth in coastal countries form a major concern to urban planners and engineers, while overcrowded lands are escalated and the high pressure on it require recovering and radical solutions. Furthermore, land reclamation may cause a big damage to the ecological system and increase the wastes of toxic materials. All these factors are resulting with negative impacts on the environment and its life cycle. The new concept of expanding the scope of modern and sustainable architecture became highly focused by many countries recently. However, the aspiration of building new floating houses that offer highly comfortable and integrity structure on water top become a reality. The new developed floating houses are the best proof of the ecofriendly modern houses in architecture. To enhance the efficiency in such houses, the energy consumption can be considered by assigning low energy equipment, systematic walls and roof insulation, reducing the water and energy consumption to the maximum and using high durable materials that result in adequate lifecycle cost. The study is located in Dubai Palm Jumeirah – United Arab Emirates. The main purpose of choosing the project in UAE generally is the hot climate, and the new trend of building houses in coastal areas. Therefore, the study firstly will focus on the climate index of UAE, secondly, the usage of lightweight materials on the floating structure and to what extend these materials can tolerate and resist the weather conditions to form a solution that will improve the indoor environment of the proposed house/structure in terms of reducing solar heat gain in addition of the focus on thermal comfort through materials resistant and conductivity. (RESEARCH QUESTION) Thus, energy consumption will be reduced and the level of energy efficiency will be improved. Three Building skins with three Active systems have been proposed for the current study and results have been analyzed and discussed.

## SIGNIFICANCE OF STUDY

The study highlights the floating system used to carry the load of the structure, in three different sustainable materials applied and simulated. However, few studies focus the importance of green material in United Arab Emirates (UAE) especially with floating houses. The architecture development is expanding rapidly and the need to address insulation walls and roof materials is essential in hot climate such UAE.

## LIMITATION OF STUDY

This study lacks the experimental methodology due to budget and time constraints, while a very well equipped lab with facilities is required to accomplish the experiments in different conditions. Apart from that, the long periods of time required testing the three proposed samples and the errors that might appear on human health and comfort, especially that the project is located on coastal area and the humidity level is significantly high. Answering this research question will need deeper study and evidence.

**Dubai Climate Analysis**

The overall climate of the United Arab Emirates (UAE) region appear to be dry in summer with noticeable high degrees of temperature up to 48°c and mostly 90% relative humidity. The chance of precipitation in summer is very low especially with the high humidity and temperature. Figure (1-a) demonstrates the mean temperature in Dubai – UAE, while in winter season (end of November till end of April) the percentage varies between 17°c - 26°c. Despite the fact that is summer season the mean average temperature ranges between 32°c - 36°c and that between May to the end of October. The mostly chances of precipitations appear from November to April with low degrees in temperatures. The UAE is almost known by dominant clear sky with sunny days and less rains, and dusty air in the dry summer between Junes and August.

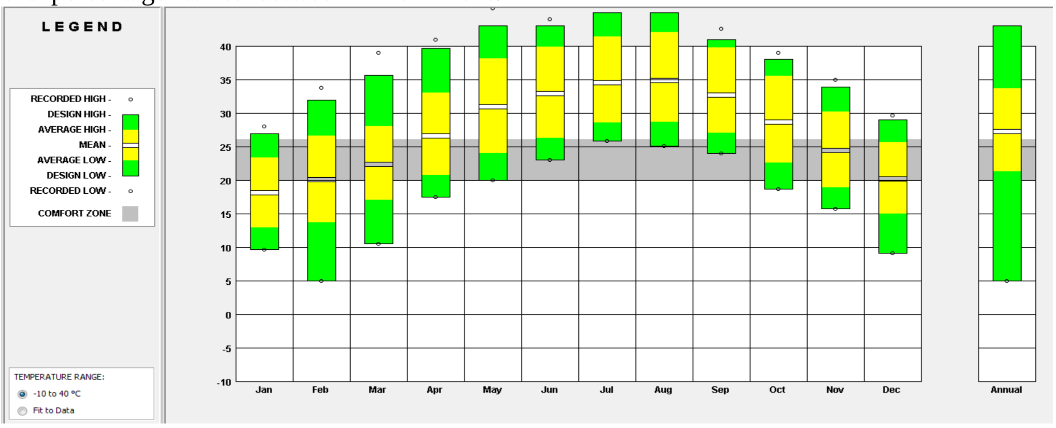
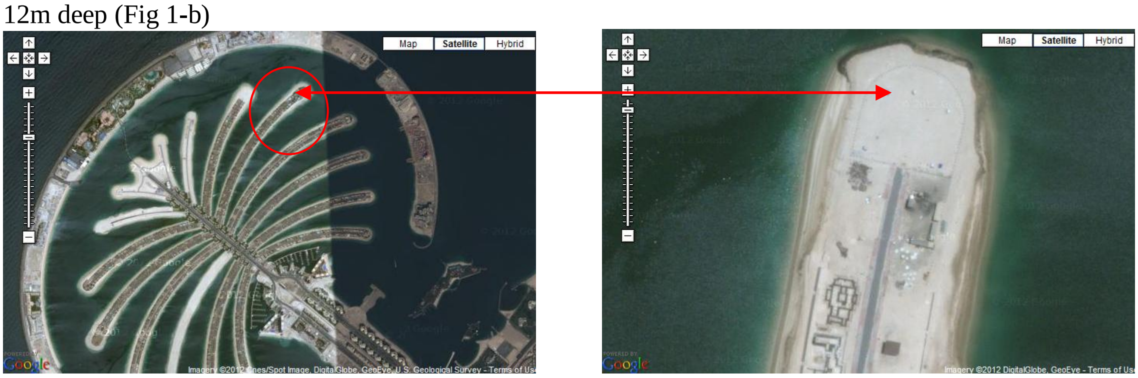



Figure 1-a Climate Consultant 2011 (Temperature Range)

**Project Location** Palm Jumeriah – Dubai the 7th leaf on right, the depth in that particular spot is 10m – 12m deep (Fig 1-b)




(Figure 1-b) Palm Jumeirah – Google earth - 2012

**FLOATING TECHNIQUE**

**Mooring System**

This system is divided into three different categories that have different criteria and structuring.

The Three different mooring structures can be categorized; the line types system (Fig 3b & 4b) while it has two different systems; Chain/cable and the tension leg system, the third system is the pile-type dolphins system with rubber fender (Fig 5c). In past chemical fiber ropes and hollow columns links where used as connecting system, but studies have shown that these types require long construction period and have negative impact on the marine eco-system.

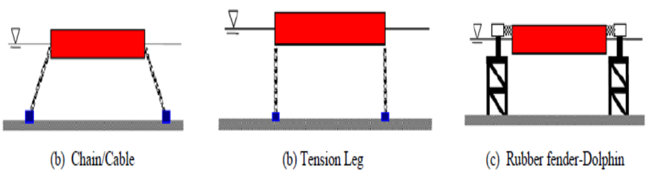



Fig 3b & 4b: Various mooring system Line types (Fig 5c) Pile type dolphins system – (Wang & Tay 2011)

The rubber fender dolphin system is very effective to be used in large floating structures while the chain cable or tension leg can be used for small floating units such as; houses, exhibition, and bridges. The cable or chain mooring system the one will be applied as a supportive system to this floating house project (Fig 6).


Fig 6: Cable/Chain mooring system – Supflex 2010

The cable mooring systems are eco-friendly were there are no any damages can be caused to the marine life, or interrupt the sea currents, they can be easily constructed, expanded or shifted to another place with less efforts and time; and they can afford any seismic movements due to the isolated bottom stand they have. In the case of high sea waves, a solution can be added to the cable/chain mooring system by integrating breakwater system (Fig 7) that prevents any severe sea. The breakwater wall, has little impact on the seabed, and does not disturb the sea currents or the marine life (Wang & Tay 2011).

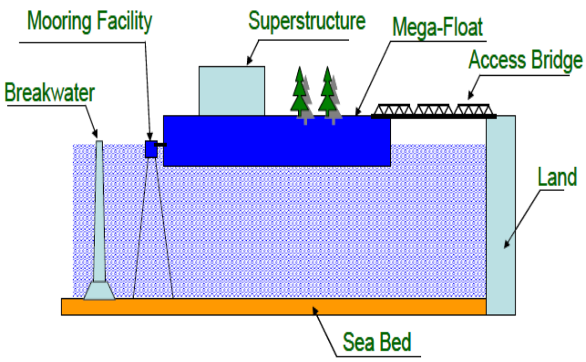



Fig 7: Mega-float structure showing the breakwater system – (Wang & Tay 2011)

## THE THREE PROPOSED SKINS

### Skin No. 1 – Curtain Wall System and Q Panel Building System

This system can be fixed to high, mid and low residential and commercial buildings in many regions considering different temperature and weather variables. The unitized curtain wall system (Fig 8 & 9) is presented as assembled units in factory and transferred to the site to be erected on the building. This system will form the first skin to be tested on the floating house project – Dubai integrated with the Q Panel material.

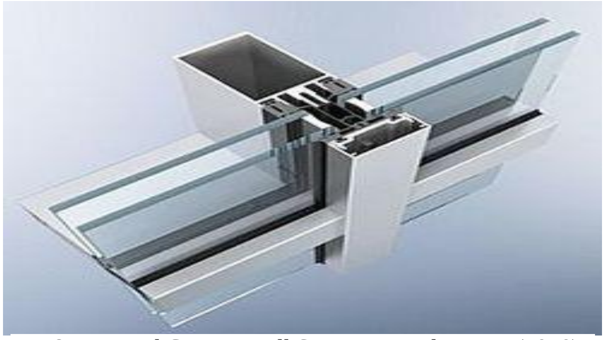


Fig 8: Unitized Curtain Wall System–Facade nexus (2010)

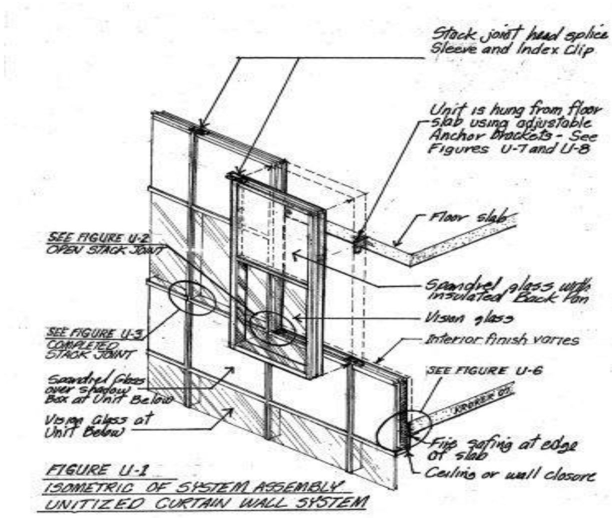
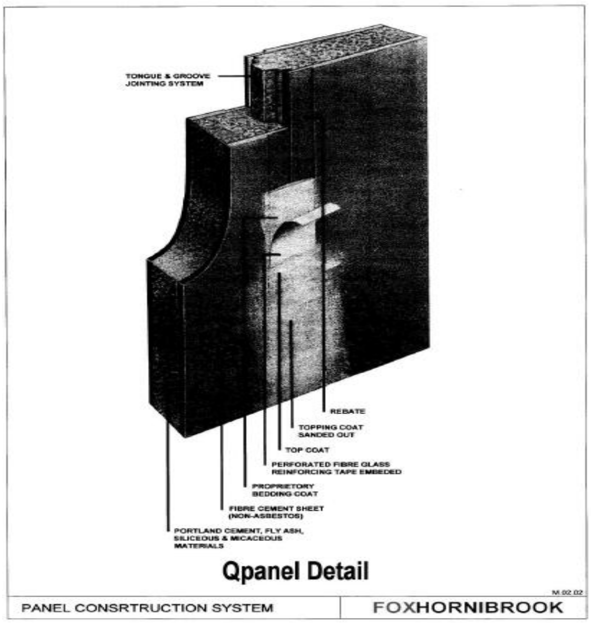



Fig 9: Unitized Curtain Wall System – India mart (2010)

### Q Panel Building System (Skin I cont...)

An innovative light weight material customized and developed globally for advanced quality of immediate construction purpose, supremely applied for remote areas. The Q panel system is identified as a very light weight sandwich panels adjusted with simple joinery techniques to assure strength and stability. It comprises two sheets of fiber cement 4mm thick filled with a low compact concrete core which is a mixture of silicaceous, Portland cement and amassed Micaceous that form the material essence. It terms of strength the Q panel is light in weight, ease and fast in installation while it's prefabricated in factory and delivered ready for erection on site. The thermal properties include less overheating transfer while it has two different thicknesses; the 50 mm Q panel wall has 2.17 W/M²K thermal transmittance coefficients (U – Value). The 70 mm Q panel wall has 1.79 W/M²K thermal transmittance coefficients. Moreover, the U – Value can be enhanced by adding more thermal resistant materials to the core composition. The material also has good acoustic properties and specified as echo-friendly material where no resources has to be diminished (Arnold, J 2012, pers. Comm., 12 August). This system will be integrated as a new material with the curtain wall windows in skin

I to demonstrate the thermal aspects and performance in UAE.



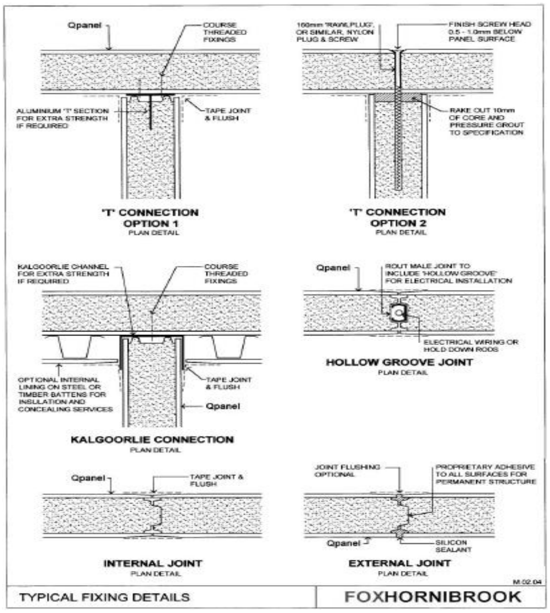




Fig 10: Q panel construction system and fixing details – Arnlod (2012)

**Skin No. 2 – Structurally Insulated Wall Panels with Polycarbonate wall cladding**

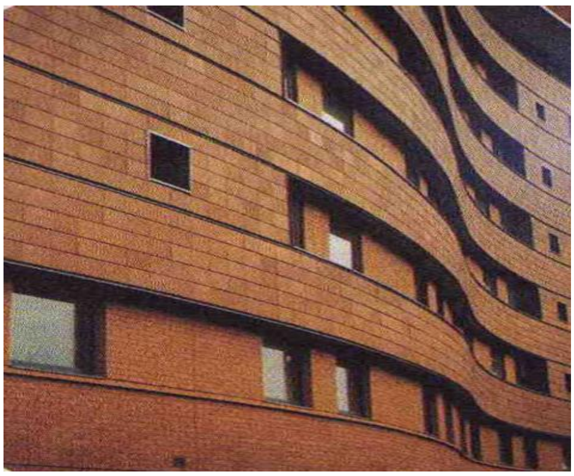
The need of using lightweight materials to construct floating house is essential in terms of feasibility, energy efficiency and aesthetically. Implementing structural insulated panels (SIPs) as one of the strategies can provide optimum solution, while these insulated panels can be manufactured and assembled in the factory and delivered to be erected directly to the structure. The SIPs serves in several parts of the building/house, roofs, ceilings, walls and floors. Moreover, the insulation performance that can be provided by these panels compared to the former construction strategies (timbers or studs), contribute in higher energy savings estimated between 12% - 14%. The appropriate fittings and regular maintenance serve in less infiltration and present better comfortable indoor environment. The panel details include oriented strand boards (OSB) filled with (9.36cm. – 18.72cm) foam board to improve insulation. The final layer can be manufactured as required by customer, either by pressing the panel or fixed in a vacuum to strengthen the boarding and core simultaneously.


**Safety Issues**

The use of fire rated materials in the SIPs interior is highly recommended, where the gap of escape time to the house users can be increased significantly. The gypsum board sheets can provide high fire rated parameters when used to cover the SIPs interior.

**Skin No. 3 – Clay Wall**

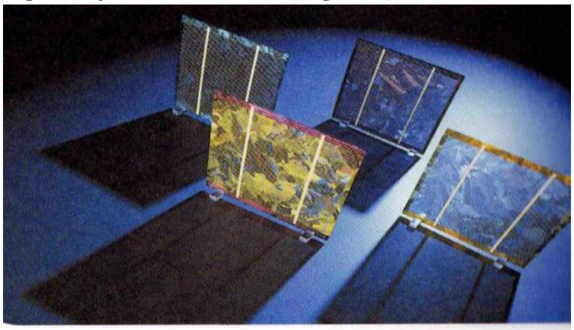
In order to preserve the historical identity that the United Arab Emirates traditional buildings comprise, the idea of using clay cladding as building skin to this project is essential and has many historical semantics and durable properties.



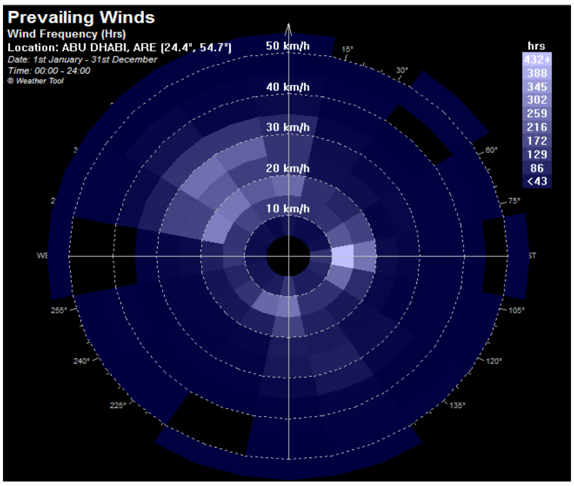
The type of clay that will be applied to the floating house skin is Lock Clad Terracotta Rain screen (Fig 16). This material combines both aesthetic and strength. The installation of these fired clay pieces is relatively simple, were the rain water screen panels are assembled on aluminum bars that form a significant conserve between the outdoor and indoor environments. The extruded aluminum bars are framing the lightweight clay tiles. Furthermore, the clay tiles enhance the thermal insulation, and energy efficiency. The water penetration into such a material with its porous property is reduced with the use of rain screens, while the problem of aggregation - disaggregation and shrinkage appearance is solved and the clay tiles can be more reliable in different weather conditions (Luke 2009).

**The Active Systems**

**Active system No 1** integrated with the Q panel and curtain wall (skin I) and with the structurally insulated walls and roof (skin II) – photovoltaic cells inserted in the roof tiles or as PV modules to generate electricity and collect sunlight during day time and especially summer season (Fig 17-a).



**Active system No 2** includes micro wind turbine installed at the house roof in building skin III – clay tiles material. In an effort to increase community awareness and reduce level of risk that result from the remarkable increases of greenhouse gas emissions, the implementation of renewable power technologies expands widely in the last few years. Integrating micro wind turbines into buildings to produce green power has acceptable cost potential and enhances energy efficiency in different environment. These devices in commercial market are able to produce power starting from 0.4 KW to 1.5 KW at specified wind speed 12.5 m/s (Ledo *et al* 2011).




**Design Proposal**

*The Developed Layout Plan (Fig 19)*

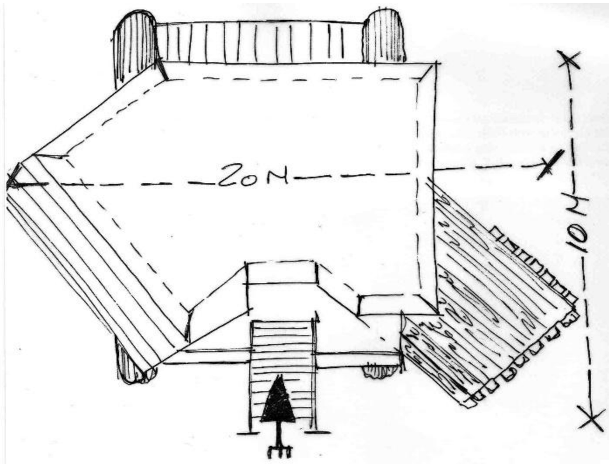
**Program:**
Ground floor plan

- Main Entrance
- Lobby
- Living Area
- Dining Area
- Kitchen
- Toilet
- Stairs
- Small Sitting Area
- Terrace (Painting Area)

**Program:**
1rst floor plan

- Master Bedroom
- Bedroom 1
- Bedroom 2
- Pantry
- Small Sitting Area
- Stairs

(Fig 19) Develo




The 1rst floor plan is typical to the ground floor plan.
**Note:** The layout plan is not to scale and represent just the overall house outlines.

**Bubble and Zoning**

Ground floor bubble diagram (Fig 20)

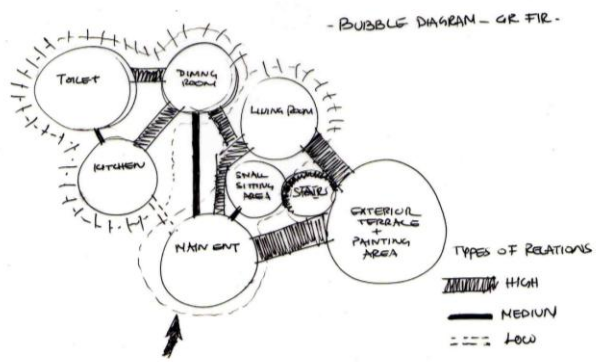



Fig 20: Bubble Diagram G.F – Author (2012)

Ground floor zoning plan (Fig 21)

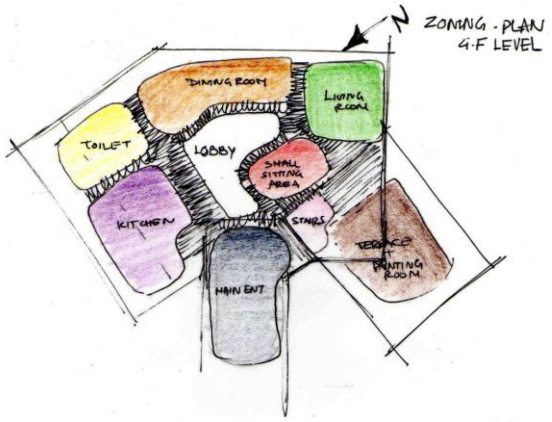



Fig 21: Zoning plan G.F – Author (2012)

First floor bubble diagram (Fig 22)

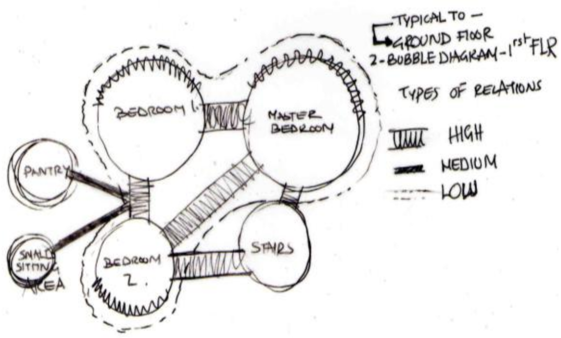



Fig 22: Bubble Diagram F.F – Author (2012)

First floor zoning plan (Fig 23)

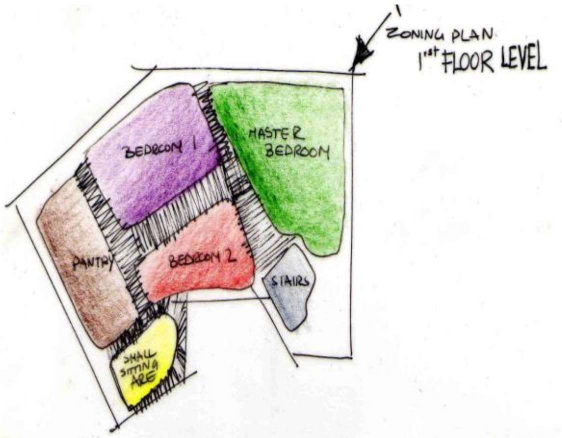



Fig 23: Zoning plan 1rst floor – Author (2012)

**Primary Idea Sketches**

The use of curtain wall system with angled profile glazing system as mentioned in the proposed skin No 1 (Fig 24 & 25)

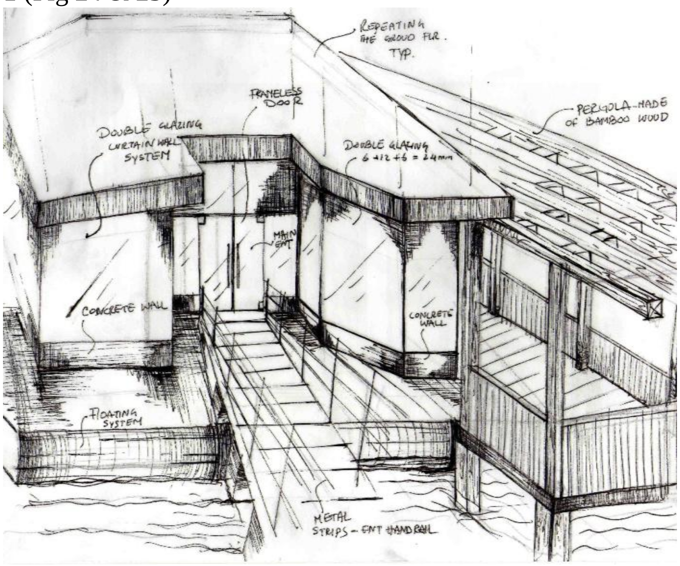



Fig 24: Primary concept of floating house – Author (2012)

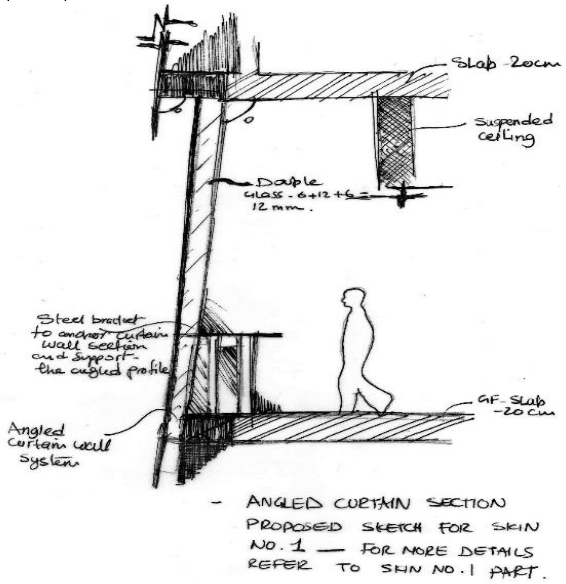



Fig 25: Primary concept angled curtain wall system– Author (2012)

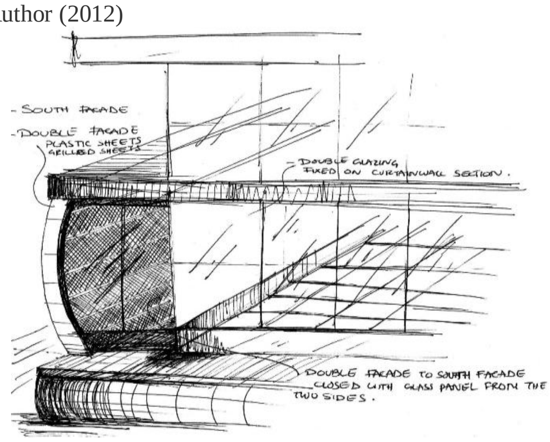



Fig 26: Double skin facade on the south side covered with plastic or glass from three sides– Author (2012

On the south facade the use of double skin facade to reduce heat gain and control proper daylight diffuse is applied as initial concept to the house (Fig 25 & 26). The type of double facade to be tested; polycarbonate wall (Plastic sheet) with opaque effect or glazing panels connected to the curtain wall system.

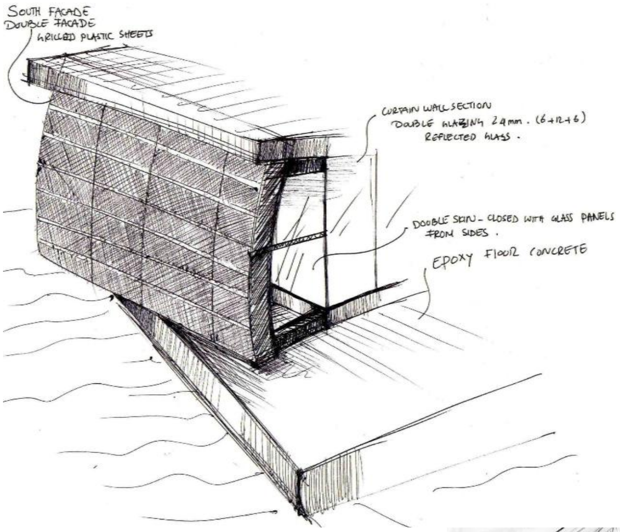



Fig 26: Double skin facade on the south side covered with plastic or glass from three sides – Author (2012)

The outdoor pergola which forms the outdoor terrace and the painting area of the house owner, the material used to cover the top shield is bamboo wood to enhance the sustainability concept and material of the floating house (Fig 27 & 28).

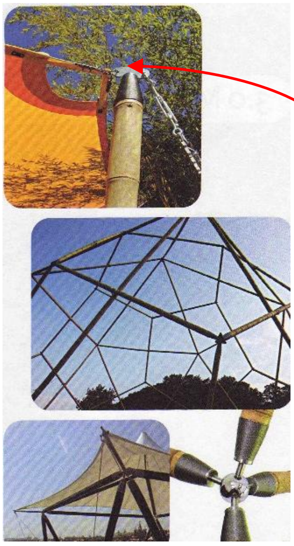


Fig 27: Outdoor Pergola – Luke (2009)

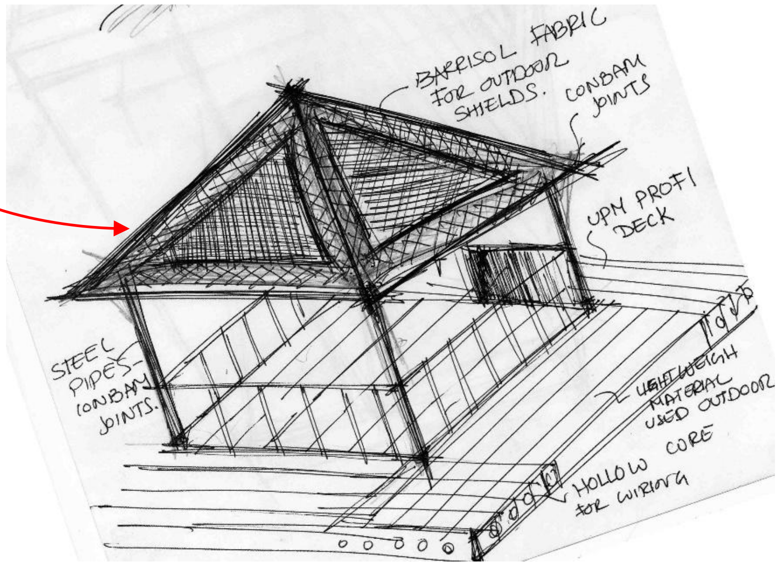



Fig 28: Outdoor Pergola – Author (2012)

The outdoor flooring material is called UPM PROFI, is a combination between paper and plastic merged with polypropylene. This material is light in weight and consists of hollow core that can be used to connect cables and electrical wiring. Very easy to install and shift to another place, the material also is water proof and has high durability (Fig 29).

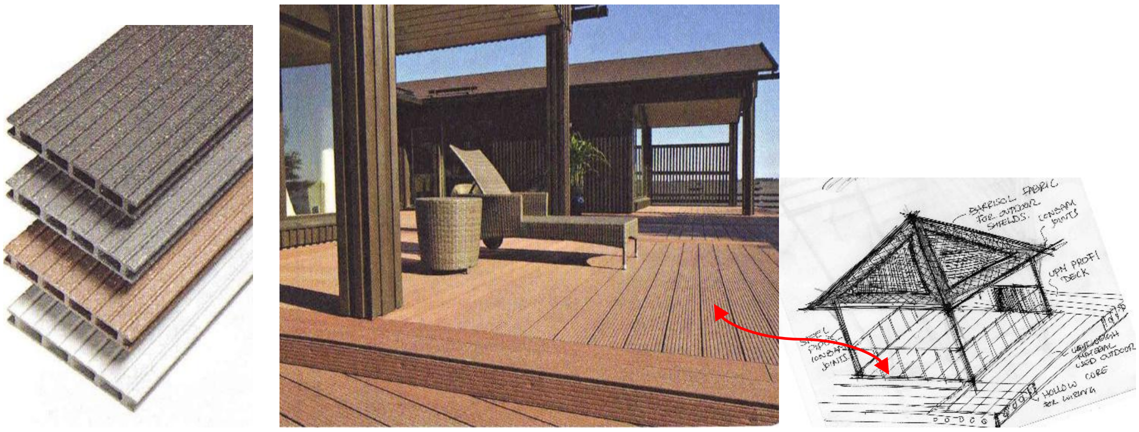


Fig 29: UPM PROFI – Luke (2009)

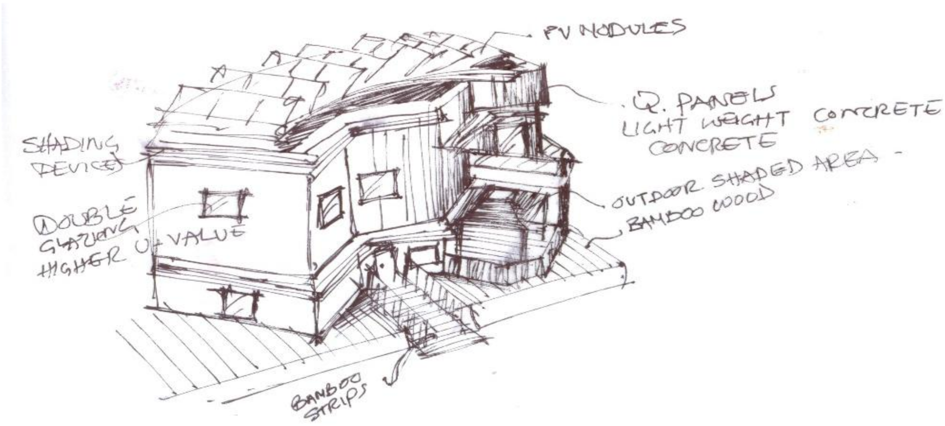



Fig 28-b: Final Proposal – Author (2012)

**The Final Concept Elevations & 3D – Perspectives**

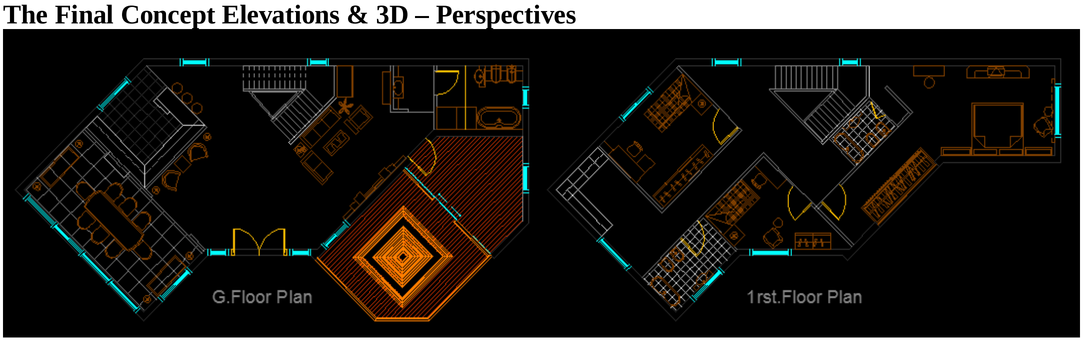
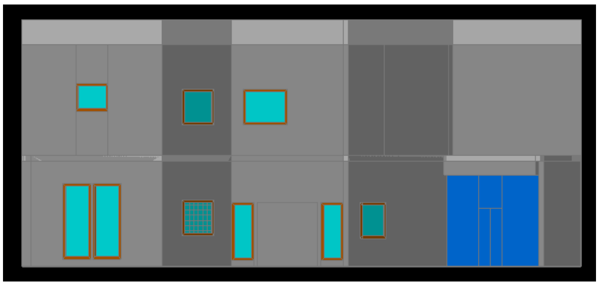
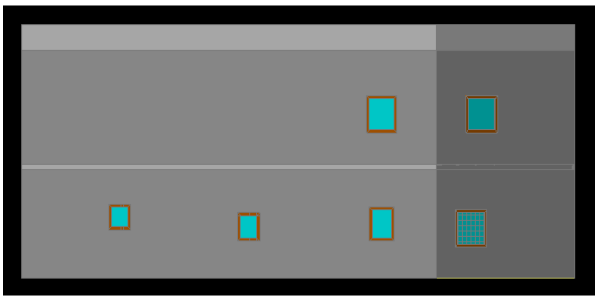



Fig 29 - a (AutoCAD 2012)

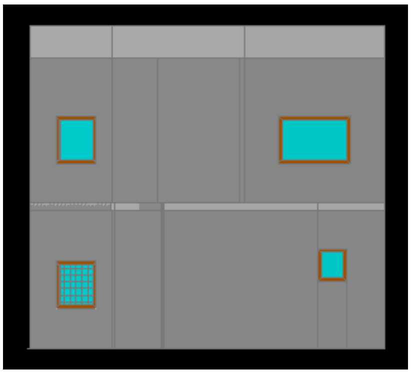
**TOP VIEW PLA**



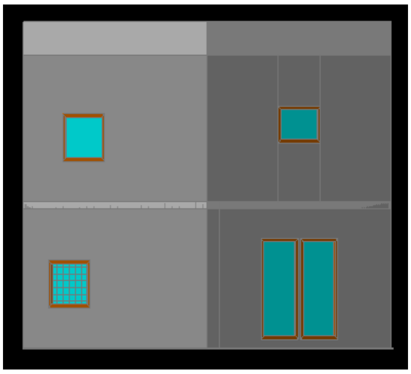
**FRONT ELEVATION**
Fig 29 - b (AutoCAD 2012)



**BACK ELEVATION** Fig 29 - c (AutoCAD 2012)



RIGHT ELEVATION



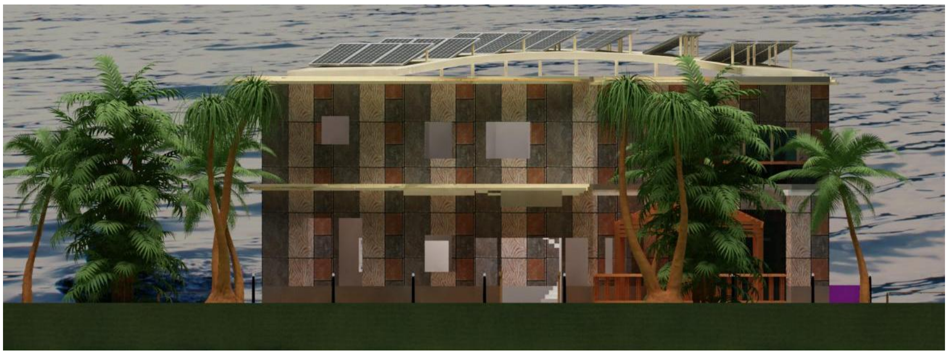
LEFT ELEVATION

Fig 29 - d (AutoCAD 2012)

**Colored Front Elevation (Skin I)**

Fig 29 - e (3D-Max 2010

**Colored Front Elevation (Skin II)**



**Colored Left Elevation (Skin II)**

Fig 29 - f (3D-Max 2010)

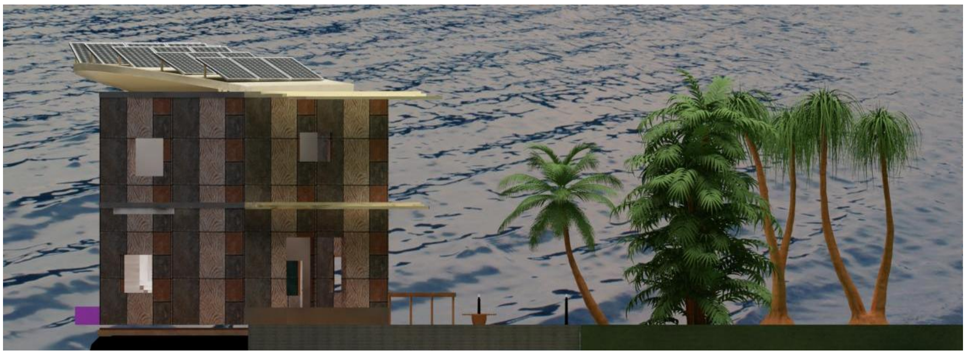
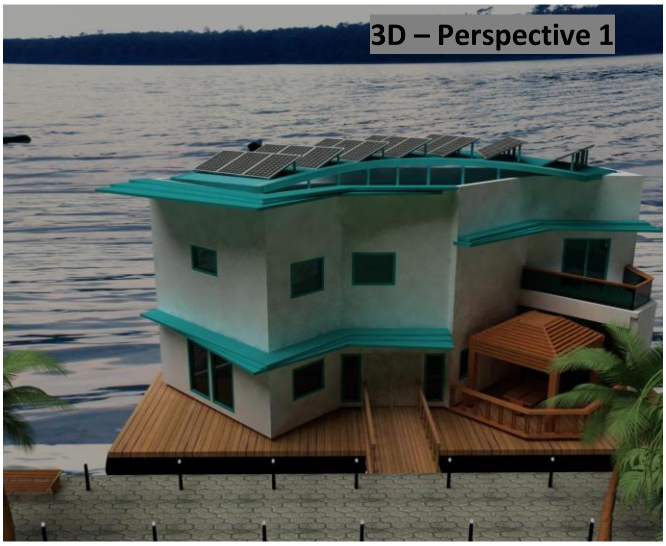
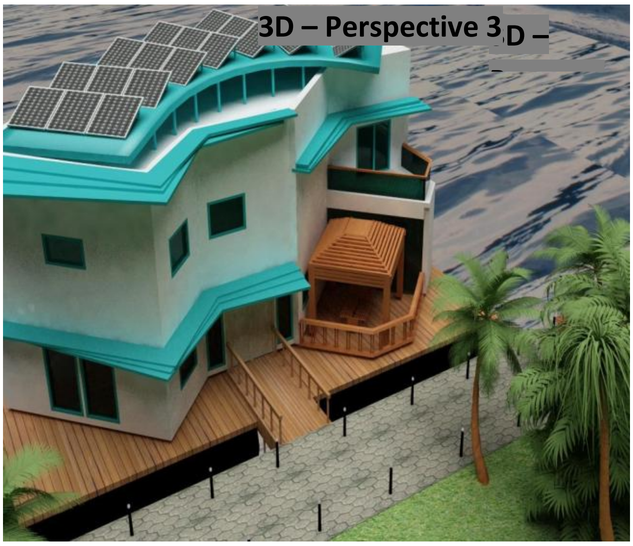


Fig 29 - g (3D-Max 2010)

**Skin I Curtain wall system & Q Panel 3D – Perspectives**




3D – Perspective I Skin I Fig 29 – h (3D-Max 2010)

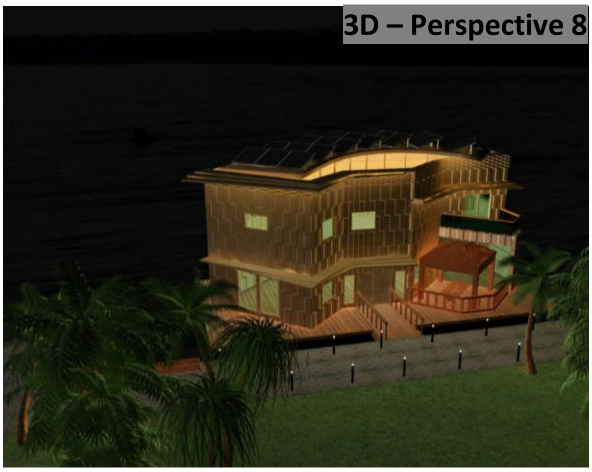
3D – Perspective 3 Skin I Fig 29 – j (3D-Max 2010)


3D – Perspective 4 Skin I Fig 29 – k (3D-Max 2010)

**Skin II structurally insulated wall panels 3D – Perspectives**



**Skin III Clay Tiles 3D – Perspectives**


3D – Perspective 7 Skin III Fig 29 – n (3D-Max 2010)

**Final Results and Comparison**

Table 7 shows the three different skins comparison in terms of construction materials and active system annual loads. However, Skin I is less than skin II and III in terms of U – Value and thermally have better performance. The used glazing system in skin I is large double glazing with reflective coating, while in skin II and II is large double glazing with absorbing coating with the same U – value (2.919 M/m²K). In skin I the sustainability material is integrating curtain wall with Q panel. In skin II the SIP and the result shows that this material is better to be adopted in cold climate region where the thermal aspect results showed better performance with low temperature. The final sustainable material used was clay tiles which show good thermal properties in hot climate region. Finally, the active system integrating to each skin, as table 4 clarifies, the PV modules applied to the structure I, results in 35% electricity output from the total electricity consumption. Additionally, the same system has been applied to the structure II and 20% electricity output was achieved. The second system is micro wind turbine installed to the structure III, and the final productivity was 14% of the total electricity consumption yearly. As a result, skin I have the highest electricity output percentage in terms of energy efficiency in consuming electricity yearly. All three skins are based on concrete structure as primary load.

Table 7: Sustainability materials and Active system variables (Author 2012)

| Floating House | Glazing System (U – Value W/m²K) | Sustainable Material | U – Value | Total R – Value | Active System |
|---|---|---|---|---|---|
| Skin I | Large double glazing with reflective coating (2.919 W/m²K) | Curtain wall with Q - panel | (1.77 W/m²K) | ( 0.39 m²K/W) | PV Modules (35 %) |
| Skin II | Large double glazing with absorbing coating (2.919 W/m²K) | Structurally insulated wall panels (SIP) | (0.43 W/m²K) | ( 2.11 m²K/W) | PV Modules (20 %) |
| Skin III | Large double glazing with absorbing coating (2.919 W/m²K) | Clay tiles | (2.26 W/m²K) | ( 0.27 m²K/W) | Wind turbine (14 %) |

The major thermal aspects comparison and daylight factor (DF) is clarified below in table 8. While, in skin I the DF as a mean value in room 001 is less than II and III. In skin I (2.3%) is low percent as daylight uniformity. Thermally this value shows better results while it can create good balance with the thermal mass, but in terms of daylight uniformity the need of artificial light is must to improve the lighting level overall the room. In skin II and III the value is (5.7%) and the room appears with strong daylight, but the overheating problem can cause less comfort in the place and reduce energy cooling loads. Conversely, skin I has better values in CO2 concentration in room 001, while less CO2 emissions is achieved by 360 PPM, and this number shows the optimum between the other two skins II and III, as in skin II the mean value is 1655 PPM and skin III is 455 PPM. The total carbon emission (CE) to the whole structure in skin I is the lowest (25,990 KgCO2) in compare to skin II where the highest value by (45,571 KgCO2) and the middle value achieved in skin III (4.1 KgCo2/h). On the other hand, the cooling load has different parameters, whereas skin III has the lowest mean value between I and II but the maximum value is less in skin I and has been reduced significantly in compare to skin II and III as shown in the above charts section. Finally, the total energy consumption yearly to the house is 50.5 MWH in skin I which form the lowest value. However, skin II records the highest total energy consumption value by (88.1 MWH) and skin III the middle value by (69.3 MWH). As a result, the

optimum skin is number one, where integrating double glazing (reflective coating) with the Q panel light weight concrete has shown better results in terms of thermal aspects and daylight factors and this will result on less energy loads and more comfort space. Furthermore, integrating active system to the whole skin can enhance the energy efficiency and reduces consumption.

Table 8: Daylight diffuse and Thermal aspects (Author 2012)

| Floating House | Daylight Factor Diffuse Room 001 (Dining Room) | Co2 Concentration PPM Room 001 (Dining Room) | Total Carbon Emission (CE) (KgCo2) | Cooling load KW Room 001 (Dining Room) | Total Energy Consumption Yearly |
|---|---|---|---|---|---|
| Skin I | 2.3 % (Mean Value) | 360 PPM (Mean Value) | 25,990 KgCO2 | 0.75 KW (Mean Value) | 50.5 MWH |
| Skin II | 5.7 % (Mean Value) | 1655 PPM (Mean Value) | 45,571 KgCO2 | 0.9 KW (Mean Value) | 88.1 MWH |
| Skin III | 5.7 % (Mean Value) | 455 PPM (Mean Value) | 35,792.1KgCO2 | 0.48 KW (Mean Value) | 69.3 MWH. |

## CONCLUSION

The floating mechanical technique applied to this project was mooring system and mainly the chain cables or tension legs. This system has the ability to react with the different water conditions, and in case of high waves, a system can be integrated called break water system to balance the structure and reduce the risk of waving. As building/house materials, three different skins have been applied to the structure to test their performance in terms of daylight factor and thermal properties to achieve the optimum efficiency in energy and sustainability materials. Jumeirah palm island Dubai – UAE was the location of the floating house. The sun location, temperature, humidity and wind directions and speed have been studied to choose the best location of the floating house structure. Furthermore, the climatic data were helpful to integrate active systems. The first skin combined curtain wall system with Q panel as new light weight material in UAE. Skin II comprise structurally insulated wall panel another sustainable material used widely in the UK and Europe. The third skin was clay tiles which have good thermal properties. Two active systems have been integrated into the three skins, the first was PV modules and the second is micro wind turbine. The PV modules in skin I records 35% output electricity from the totals annual bills yearly, while in skin II the percentage was 20%. Additionally, the micro wind turbine device achieved 14 % electricity output in skin III from the total yearly bills. The IES software was used to simulate the structure with the three different materials. The result shows that skin I has the best building system energy with less total energy consumption yearly and low carbon emission rates in compare to skin II and III. Room 001 (dining room) has been tested as one zone to examine the daylight uniformity over the three building materials. This room is south facing facade, and the other variables simulated were; CO2 concentration and cooling loads. As a result, building material I have the best values with the minimum CO2 concentration and cooling loads followed by building material II. SIP skin has shown high energy consumption and carbon emission due to the weak thermal properties the material has in hot climate region, while this skin can achieve better outcomes in the cold climate areas.

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