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Study on the Impact of Planning and Materials in Energy Consumptions of a Building at Al-hail in Sultanate of Oman

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Abstract: ***Green building or sustainable building is an ecofriendly concept established by civil engineers to increase the efficiency of buildings in terms of energy, water, and materials, over the entire life cycle of the building. This study is aimed to develop a sustainable building at Al-Hail(Oman)with high energy efficiency and lower cost. Considering the wind and solar directions plan was selected. Based on the selection of materials and method, two proposals were considered for the simulation in Revit 2016 software [Proposal 1 (Green Roof + Double Glazed Windows + AAC Blocks + Terrazzo tiles) and Proposal 2 (Normal Roof + Single Glazed Windows + Hollow Blocks + Oman Marble)] were compared.The parameters identified were cost, thermal properties and U-values of the materials for the building.It was observed that estimated energy used in Proposal 1 due to air conditioning reduced 62% than Proposal 2 because of selected materials with high thermal resistance performance. The study enlighten the facts of conservation of energy by utilizing the available resources with minimum cost.***

Keywords: Green building;solar orientation; Thermal Conductivity, U-Value, Grey Water Systems

1. Introduction

Due to continued growth of population and urbanization, the level of pollutionincreased in the environment which has a negative effect on the whole biodiversity and ecosystems. (Mehta, & Sharma, (2014).commented that building and construction activities in worldwide consume 3 billion tons of raw materials each year and represent 40 percent of total global use.The manufacturing processes of construction materials required huge amount of natural resourcesand create high level of pollution which adversely affect the environment and human. Green building construction will be a solution to this problem to reduce the amount of pollution.Several studies have been conducted for the sustainability and the construction of green buildings.The materials chosen for the construction increase theenergy efficiency of the structure and it should be based onthe evaluation process and building requirements ((Mehta, Mehta, & Sharma, 2014). Green concrete is a sustainable concrete prepared by replacing industrial waste to reduce the consumption of natural resources and energy.Green concreteincreased the dependence on recycled materials,effective use of supplementary cementations material,improvedthe mechanical properties of concrete and reuse of wash water.(Wangchuk et al., 2013).Green and energy efficient concepts in fundamental planning of the building lighting and waste recycling will improve the cost and energy savings in green buildings(Vinutha & Ravindra, 2014).Lightweight concrete blocks are environmentally friendly and it helps to reduce at least 30% of environmental waste by using them as a part of block mixture (Trieu Cuong Group, 2016).Lightweight concrete blocks perform well for all the structural properties than a normal weight load bearing blocks.Comparing the properties of compressive strength, water absorption and thermal conductivity of cellular light-weight concrete(CLC) blocks with normal burnt clay bricks, CLC blocks performed better than the latter one. Due to the multicellular structure CLC blocks exhibits excellent insulating property by their large number of closed cavities.Lightweight concrete blocks have all the structural properties of normal weight load bearing blocks and it could have better performance than normal blocks.(Siram, 2012).

Conventional concrete buildings consume high amount of electric energy and this energy generated from non-renewable energy sources like oil, gas and others. Sultanate of Oman is a country which can utilize solar energy in the whole year round. Several studies has been conducted to promote the solar power to save the fossil fuel resources.According to(Ma & Xue, 2013) the application of solar energy and building integration technology in residential buildings, mainly has three aspect which are: Solar Thermal Technology, Solar Photovoltaic Technology, and Solar Optical Technology. Mainly solar panels set on roofs, balconies, exterior walls or somewhere with plentiful sunshine.Providing green roof in the building is more effective in reducing heat gain than heat loss. The experiments conducted to study the thermal performance of green roofs comparing with modified bituminous roof proved thatthe green roof could reduce the temperature and the daily temperature fluctuation in the summer season. Also green roof significantly moderated the heat flow through the roofing system and reduced the average daily energy demand for space conditioning due to the heat flow through the roof in the summer by more than 75%. (Liu & Baskaran, 2003).. There is a big gap in constructing green buildings especially in Oman and this could be due to several factors. Encourage the constructing of green building in Oman will be a quantum leap and huge development toward conserving the environment and utilizing the renewable energy sources such as solar power and new waste water conservation methods such as grey water systems in construction field and that will prevail benefits on Oman society and the environment at the same time. The main objective of this work to plan, a green building by consume the available resources to assess the energy efficiency and low cost by using the simulation by

RIVET software.

2. Methodology

2.2 2.1 Selection of the plan of a building

The building plan has been decided based on the factors affecting the building as ground water and storm water flow (Wadis), the amount of sunlight, and the direction of the wind. (Vinutha & Ravindra, 2014)The perfect location for a green building can cut energy costs as well as reduce the environmental impact on the land.Detailed study of wind direction and sun exposure has been done to decide the best building orientation. (Figure. 2) The available land located in Al Hail Al Janubiyah at coordinates 23°38'06.9"N 58°13'10.8"E.(Figure 1).By analyzing the impact of the sun and winds on the site location a spatial orientation and arrangement done to minimize the direct sun exposure on the building to provide passive solar design and to increase the energy efficiency with morecomfort of the building. A simulation models of solar analysis have been conducted to study the behavior of three proposed building shapes under sun exposure effect.

Figure 1: Selected Location Adapted From (Google Mapping, 2016)

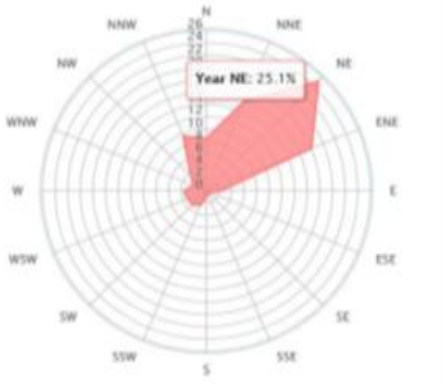


Figure 2: Annual Wind Direction Distribution in Muscat Adapted from (Wind & Weather Statistic Muscat - Seeb Airport, 2016)

2.3 Selection of the materials for the building

2.3.1 Walls

Based on three parameters such as Thermal conductivity (also known as Lambda),Thermal resistance (also known as R-value) andThermal transmittance (commonly known as the U-value) materials has been decided for the super structure. For the superstructure three alternative materials has been selected and tested such asIsolated Blocks, (AAC) / Lightweight Blocks and Nudura Wall System. The material with more advantages, higher thermal resistance properties and lower cost is selected for the building.

2.3.2 Windows

A comparison have done between double glazed windows and triple glazed windows. Double glazed window it consists of two pane of glass and a gap between them which makes it lighter than triple glazed window and able to reduce up to 50% of heat loss.While Triple glazed window consists of three pane of glass and two gaps between them that makes it heavier than double glazed window but it has lower U-values than double glazed windows which means higher thermal property resistance.Based on the comparison between double glazed windows and triple glazed windows the suggested type of window is double glazed windows which have two pane of glass and a gap between them filled with argon gas. The U-value for double glazing is 1.45 $W/m^2.K$ Triple glazed windows can perform better than double glazed windows in terms of thermal resistance. But the cost of triple glazing is 75% proximately more than double glazing windows

2.3.3 Roofs

Top Roof Garden is the type roof which will be provided in this green building project and that because of top roof garden has shown high thermal performance comparing with normal concrete roof. As the researchers (Liu &Baskaran, 2003) proved that green roof significantly moderated the heat flow through the roofing system and reduced the average daily energy demand for space conditioning due to the heat flow through the roof in the summer by more than 75%.

2.3.4 Floors

Locally available and the best eco-friendly material is applied as a floor finishing for this green building project with Oman Marble and Terrazzo tiles.Both of Oman Marble and Terrazzo tiles are locally made from natural resources.Terrazzo tiles usually made up of waste materials like remaining pieces of marble, quartz, granite, glass and other suitable waste materials placed into cement mixture. Hence can say terrazzo tiles are recycled material which makes them environmentally friendly perfectly adaptable to green building (Wangchuk et al., 2013). Considering the cost durability and finishing decided to provide terrazzo tiles for the flooring.

2.4 Conservation of Energy

2.4.1 Gray water Systems

Grey water is a term given to waste water coming from baths, sinks, washing machines and kitchen. In other words is any wash water that has been used in the home except water from toilets. A research have done to select suitable grey water treatment system for the green building. Also a meeting have done with handmade grey water treatment team in Caledonian College to discuss the possibility of implementing this handmade system in this green building project.Bio-Rock is a grey water treatment system that works without electricity and zero energy and it costs 600 O.R (Omani Rial) only compared to the other system in

market which cost around 3000.O.R.The treatment process which includes three stages. In stage 1 the grey water enters a primary tank to provide separation and the breakdown of organic solids (Primary Treatment). The grey water then passes through an effluent filter before discharging into the Bio-Rock unit which combines the aerobic process (Secondary Treatment) and filtration process (Tertiary Treatment). The effluent from the system has a cleanliness up to 99% and can be used for irrigation purpose(AlMukhini, 2016)

2.4.2 LED Lighting

LED lights consumes 75% less energy and in terms of durability it is 25 times longer than incandescent bulbs or as known also by yellow lights. Moreover LED lights emit very little heat compare with incandescent bulbs as it releases 90% of their energy as heat.(AlAmri, 2016)

2.4.3 Solar Panels

Oman has a high ratio of sky clearness and receives extensive daily solar radiation ranging from 5500 - 6000 W/m2 / day in July to 2500 - 3000 W/m2 / day in January. This is one of the highest solar energy densities in the world. This huge amount of solar radiation must be used in proper way to provide clean electricity without the need to utilizing the fossil fuel resources.As (Heretic, 2014) mentioned that sun Latitude in Muscat is 23.6^{o}. Solar panels were installed on top roof with inclination of 23.6^{o} where the rays hit perpendicularly on the panels to ensure full utilization of solar energy.

2.5 Modelling

2.5.1 Revit 2016.Software

Revit software is a building information modeling software for architects and structural engineers. Which allows the users to design a building in 3D models and access building information from the building model's database. Revit software suggested to run the energy simulation and make a comparison between the selected materials to implement them into the green building project and a standard materials. Two proposals based materials and the technology is considered for the green building. The simulation comparison have been done between Proposal 1 (Green Roof + Double Glazed Windows + AAC Blocks + Terrazzo tiles) and Proposal 2 (Normal Roof + Single Glazed Windows + Hollow Blocks + Oman Marble).

3. Result and Discussion

3.1 Selection of Plan

Three plan has been considered for the building. Selected plans were checked for the solar exposure effect. (Figure 4.).Best plan has been selected in such a way to ensure that the southern edge of building not facing direct sun exposure Figure. 4.c. The idea of design is to provide zigzag shape on southern edge of building and that will prevent any direct sun exposure hit on that side. Also the zigzag edge provided on northern side to make use of wind direction which provides air circulation inside the building. The walls on northern edge of building are placed parallel to North-East direction which match with the wind direction in Muscat where it almost acting from North East direction. Finally Proposal 3 was the best proposal which can meets the good plan of green building design requirement.

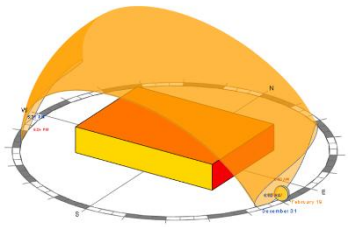


Figure 4 (a): Sun Exposure Effect on Proposal1 by Revit Software 2016

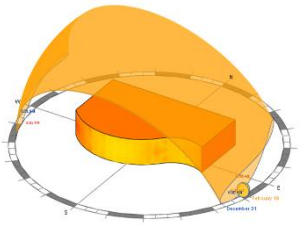


Figure 4 (b): Sun Exposure Effect on Proposal2 by Revit Software 2016

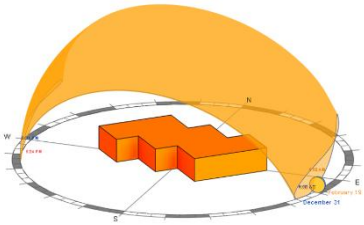


Figure 4 (c): Sun Exposure Effect on Proposal 3 by Revit Software 2016

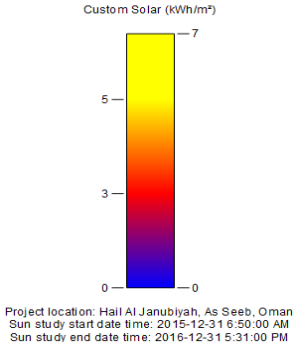


Figure 5: Cumulative Insolation Scale by Revit Software 2016

Figure 6: Selected plan proposal 3

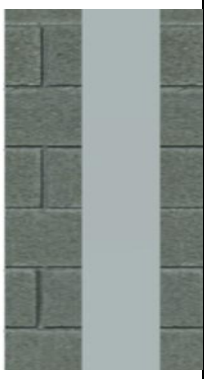
3.2 Selection of Material

Table 1: Comparison between the Properties of Materials Used For the Walls

Type	Thermal Conductivity ($W/m^2.K$)	U-Value ($W/m^2.K$)	Density (Kg/m^3)	Compressive Strength (N/mm^2)	Cost (OMR per piece)
Hollow Blocks	0.83	4.17	900	5	0.18
Solid Blocks	1.33	6.65	2000	7	0.3
Isolated Blocks	0.1	0.5	800	7.5	0.5
(AAC) / Lightweight Blocks	0.054	0.27	600	6.7	0.55
Nadura Wall System	0.036	0.18	2400	30	Not available

Based on the comparison between the three alternatives which are Isolated Blocks, (AAC) / Lightweight Blocks and Nudura Wall System. AAC blocks is the best alternative.As a solution of the shortage in AAC blocks thermal resistance properties comparing to Nadura walls system, a cavity wall is suggested to be provided. The suggested cavity wall consists of double layer of AAC blocks (200 mm and 150 mm) with 150 mm air gap between them as shown in Figure

Table 2: Thermal Conductivity and R-Value for Suggested AAC Block Cavity Wall

Materials	Thickness ln (m)	Thermal Conductivity k (W/m.K)	Thermal Resistance R = l / k (m^2k/W)	
AAC Block	0.2	0.054	3.7	
Air Gap	0.15	0.18	0.18	
AAC Block	0.15	0.054	2.8	
Total R			6.68	AAC Cross Section Cavity Walls by Revi Software 2016

Based on the comparison between double glazed windows and triple glazed windows the suggested type of window is double glazed windows which have two pane of glass and a gap between them filled with argon gas. The U-value for double glazing is 1.45 W/m2.K Triple glazed windows can perform better than double glazed windows in terms of thermal resistance. But the cost of triple glazing is 75% proximately more than double glazing windows.

3.3 Simulation by Rivet software

Considering the selection of the materials and technology two proposals were suggested and tested for annual Carbon Emissions,annual energy Use/Cost,electricity energy Use,monthly heating load and monthly cooling load.Proposal 1 (Green Roof + Double Glazed Windows + AAC Blocks + Terrazzo tiles) and Proposal 2 (Normal Roof + Single Glazed Windows + Hollow Blocks + Oman Marble) considered for testing .Results were summarized below.

3.3.1 Annual carbon emission

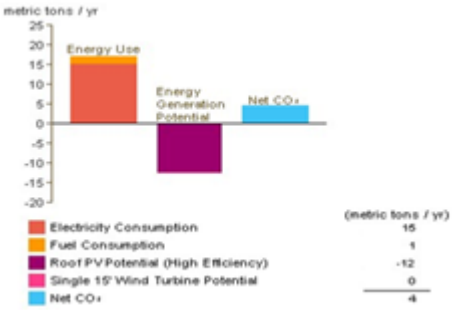


Figure 7 (a): Proposal1

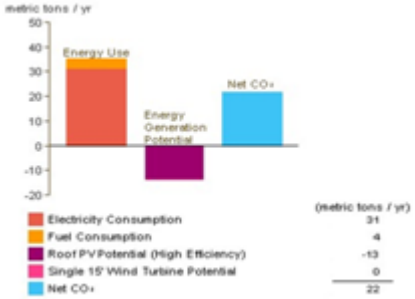


Figure 7 (b): Proposal2

The annual carbon emission generated from Proposal 1 is approximately 16 metric tons while in Proposal 2 the amount of annual carbon emission is 35 which is 2.2 times more than Proposal 1. By implementing high efficiency solar panels into the green building on the top roof area the annual carbon emission can be reduced to 4 metric tons per year.

3.3.2 Annual Energy Use/Cost:

Table 3: Annual aenergy use/cost

	Annual Energy Use (KWh)	Monthly Energy Use/ Cost (KWh)	Annual Energy Cost (OR)	Monthly Energy Cost (OR)
Proposal 1	57659	4805	404	33.6
Proposal 2	120145	10012	841	70.1

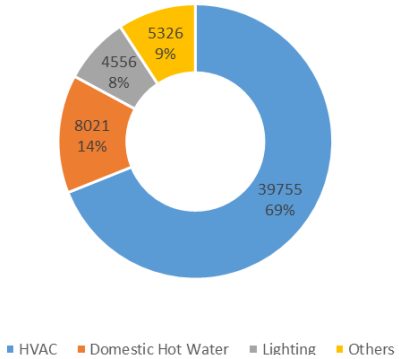


Figure 8 (a): Proposal1

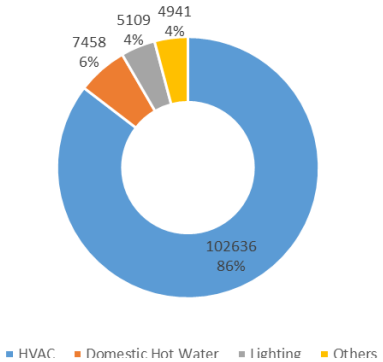


Figure 8 (b): Proposal 2

The estimate annual energy use from Proposal 1 is 57659 KWh and the average monthly energy use cost is **approximately** 4805 KWh. However in Proposal 2, the estimated annual energy usage increased to 120145 KWh.The estimated energy use in Proposal 1 due to air conditioning is 39755 KWh and it is increased to 102636 KWh in Proposal 2(Figure 8.a and8.b). Hence g energy consumption for the air conditioning in Proposal 1 less than 38% of air conditioning energy consumption in Proposal 2.This is because of the selected materials with high thermal resistance performance. Proposal 2 consumed 553 KWh more than Proposal 1 for lighting purpose. The energy use due to water heaters can be avoided by using solar water heater which costs around 400 OMR only. Moreover the energy use cost due to air conditioning can be reduced if high efficiency air conditioning type selected. Implementing LED lights into Proposal 1 can reduce 75% of energy consumption therefore light energy use will be 1139 KWh.

3.3.3 Monthly heating and cooling load

Monthly heating and cooling load for the selected proposals awere compared in the following figures Figure 9a, b, c and d.

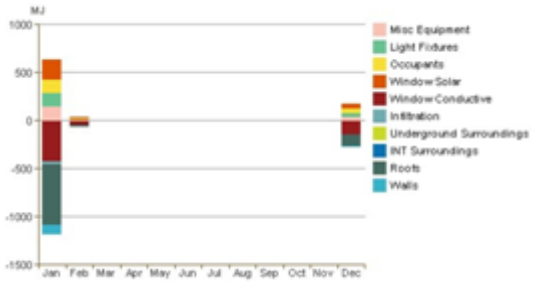


Figure 9 (a): Monthly heating load of Proposal 1

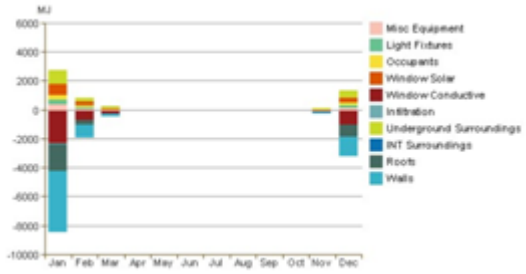


Figure 9 (b): Monthly heating load of Proposal 1

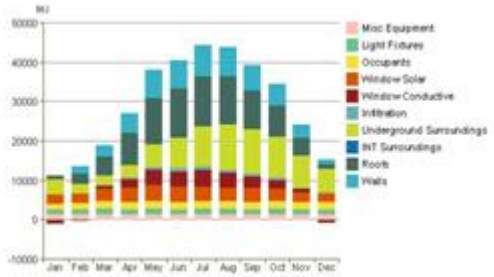


Figure 9 (c): Monthly Cooling load of Proposal 13

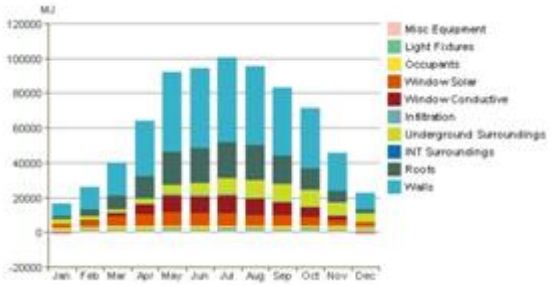


Figure 9 (d): Monthly Cooling load of Proposal 2

In the winter including December, January and February season in Oman the temperature inside the building get lower than 22^0 C. Hence the building required to be heated up to an acceptable range. The charts shown in Figure 9a and b illustrated that Proposal 1 perform better than Proposal 2 and it is required lesser heating load.During the summer season in Oman from the month of June, July and August, the average temperature reaches above or more than 46^0C.The indoor building temperature will be more than 22^0Cand it is essential to be cool down to an acceptable range. The charts shown in Figure 9b and 9 c illustrated that, Proposal 1 perform better than Proposal 2 and it is required lesser cooling load.

4. Conclusion

From the study it is concluded that the planning of a building should be finalized based on the solar orientation and wind directions, it will save the energy also reduce the environmental impact on the building. Perfect selection of the materials and technology will reduce the cost and energy consumption ofthe building. Following observations were achieved after considering all these factors in the study for the building.

Based on the selection of materials and method two proposals were considered for the simulation in Revit 2016 software [Proposal 1 (Green Roof + Double Glazed Windows + AAC Blocks + Terrazzo tiles) and Proposal 2 (Normal Roof + Single Glazed Windows + Hollow Blocks + Oman Marble)] were compared. The performance of the building per year was estimated.

1) Annual carbon emission for the Proposal 2 was 6 times more than the proposal 1.
2) Annual Energy use/cost for proposal1 was 47% less than Proposal 2.
3) The estimated energy used in Proposal 1 due to air conditioning reduced 62% than Proposal 2 because of selected materials with high thermal resistance performance.
4) Proposal 1 performed better than Proposal 2 considering the monthly cooling and heating.
5) Bio-Rock - grey water treatment system which works without electricity and has a low cost had provided. It is recommended to do simulation for the different materials to get optimum energy consumption and maintain a database for all the materials including the thermal properties, durability, and energy efficiency with cost which will minimize the selection of the material process for planning a green building.

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