Computational Fluid Dynamic Analysis on Green Building Materials

Pranay Addepalli & S. Vincent

Department of Mechanical Engineering, BITS Pilani Dubai Campus, International Academic City, P.O Box 345055, Dubai, U.A.E.

Abstract. Energy saving is a necessary aspect in today’s global progression. In the present investigation, the green materials for houses are taken and assessed on the usability in the desert conditions of the United Arab Emirates (U.A.E.) Major parameters such as resistance to solar radiation, weathering according to the local conditions plays a vital role in selecting materials. All the selected materials strictly fall within the local and international green ratings. This is then infused into a home design and the comparison is done in this house on Computational Fluid Dynamics (CFD) analysis showing the difference in temperatures and wind profiles. Results have been done for 100 cycles of fluid flow and the energy consumption has been done. This study gives insights on the importance of using green materials in design and construction.

1. Introduction
Materials are the essential components of buildings construction. Chemical, physical and mechanical properties of materials as well as an appropriate design are accountable of the building mechanical strength. The design of green buildings should thus begin with the selection and use of ecofriendly materials with related or better features than traditional building materials [1]. Materials which are eco-friendly and/or reusable are referred to as Green materials. Different green materials exist but all are not suitable to different climatic conditions. Organisations such as Leadership in Energy and Environmental Design (LEED) and ESTIDAMA/Al Safat (U.A.E Green Rating bodies) have certain standard ratings for materials used in harsh desert conditions.

The standard rated materials have been incorporated into a villa design enabling us to see how these materials reduce the energy consumption. In addition, a computer model based on Ansys Fluent has been using to predict the temperature profiles inside the villa [2]. Major parameters and properties need to be considered while selecting are the resistance to solar radiation, weathering, thermal as well as mechanical properties and good abrasion resistance [3]. Green building is a concept incorporating a wide spectrum of solution and best practices. It is an out-come of design philosophy which emphasizes on optimum utilization of resources and increases the efficiency of resource utilization [4].

Green building also referred as sustainable building, is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from sitting to design, construction, operation, maintenance, renovation, and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability and comfort. Since buildings are responsible for 80 per cent of the city’s carbon emissions
and Dubai Water and Electricity Authority’s headquarters (DEWA) is the largest LEED certified building in the world [5], selection of optimum green material plays a vital role in reducing carbon footprint. The government of UAE suggests that a Green building in the region should follow the below mentioned values: Energy saving – 30%; Carbon saving – 35%; Water saving – 40%; Waste cost saving – 75%. In the present investigation, green material selection has been optimized based on the conditions pertaining to UAE region and CFD analysis has been carried out to estimate energy consumption.

2. Material Selection for a Green Building

Based on the environmental conditions of UAE region, the various characteristics of green buildings and the materials selected is as follows.

2.1. Characteristics of a Green Building

The goal of a green design of a building is to be as sustainable as possible. Various features that are implemented into a green building are:

1) Ventilation systems designed for efficient heating and cooling.
2) Energy-efficient lighting.
3) Water-saving fixtures (all plumbings).
4) Landscaping with native vegetation.
5) Renewable energy sources such as solar power / wind power.
6) Non-synthetic, non-toxic materials used for exterior and interior.
7) Responsibly-harvested wood – which have the certification.
8) Adaptive reuse of older buildings.
9) Use of recycled architectural materials.
10) Efficient use of space.
11) Optimal location on the land, maximizing sunlight, winds.
12) Rainwater harvesting.

2.2. Materials

The various materials chosen for the local conditions are briefly explained below [6-9]:

1) LVR Paints – Higher the Light Refractive Index number lighter the colour. We use a paint that has a rating above 60.
2) Foamed Concrete - This is used for making lightweight bricks/blocks. It has many benefits such as low water absorption, fire and sound resistance.
3) FoamGlas - They are insulation elements produced from recycled glass, i.e. from sand, dolomite, and lime. The insulation elements consist of cellular glass with closed cell structure. Green roofs, parking decks, Roof decks, façade and wall insulation systems and Indoor insulation are the places where foamGlas is used.
4) Gypsum board - This material is used to make false ceilings which are light and sound proof.
5) Acoustic Liner – Non-Fibrous and antibacterial, used in HVAC ducts and plenums.
6) Doors – Plastic doors are chosen because they have high acoustic value, strength and energy efficiency.
7) Pilkington Solar-E Glass - Solar control performance coated glasses offering low solar heat coefficient gain, reduced glare and low- emissivity.
8) Floor Tiling – Aerotiles will be used since they have a high solar reflective index (95%)
3. **Design Model**

For the present investigation, a villa of the size 2100 sq. feet in the U.A.E. region has been selected. The 3D design of the villa has been made using CATIA software and further computational fluid dynamic analysis has been done using ANSYS software. The detailed 3D view of the villa is as follows:

![Figure 1 – Blue Print of the Villa (3D Model with a scale of 10:1)](image)

4. **Results & Discussions**

The 3D - CATIA model of the villa is imported to ANSYS. The CFD analysis and inferences results are as follows.

4.1. **Meshing**

Meshing of the structure has been done in Ansys Fluent. Meshing for the outer surfaces has been done with a refinement 3 so that the outer surfaces have more meshed cells and hence we get a more detailed/accurate report.
4.2. Setup

After meshing of the model, the initial parameters such as pressure and velocity based on average values in Dubai has been entered.

1. Pressure – 1 bar
2. X velocity – 8 m/s
3. Y velocity – 5 m/s
4. Z velocity – 3 m/s

The velocity parameters were taken for 100 Iterations.

Figure 4 shows the graph of velocity vs iterations done using ANSYS Setup. It can be inferred that around 20 iterations, the values for velocity and energy are the lowest and it almost converges. The analysis was continued to check for further convergence. Since the convergence was prominent at 20 iterations, these readings were used for further analysis.

4.3. Temperature Model

The temperature profile obtained from the CFD Analysis is shown in figure 5a and 5b. Contour 1 was taken on the top surface where the temperature and velocity profile are maximum according to local conditions. The corresponding temperature analysis has been done at a local time of 1pm for the month of February and the figures below show the variation in temperature on the surface of the building. It can be observed from figure 5a and 5b that although there is a wide range of temperature variation on the building, there is no abnormality in the temperature profile. This indicates that the
construction materials selected can withstand the surrounding conditions. It can also be observed that the temperature on the roof is low, which can lead to decrease in energy consumption on the villa.

![Figure 5a. Temperature Profile Front](image)

![Figure 5b. Temperature Profile Bottom](image)

4.4. Velocity Model

Figure 6a and 6b indicates the wind profile for strong and weak winds, respectively. From the analysis of figure 6a, it can be observed that a very small area on the roof of the villa is experiencing a strong incoming wind. The weak wind profile in figure 6b indicates that there are no significant changes on the villa structure.

![Figure 6a. Velocity Profile Top View (Strong Wind)](image)
4.5. Energy Consumption

For a villa of this size (2100 sq. feet), the required energy consumption has been calculated and tabulated in Table 1. This power consumption is an average value, and it fluctuates during the various months especially during summer where it might go up. The Energy consumption has been taken on average for 24 hours or one cycle – Morning 6am to the next morning 6am.

| Unit Name                | Power consumed (kW) | Time on use (hours) |
|--------------------------|---------------------|---------------------|
| Refrigerator             | 4.35                | 24                  |
| Television               | 0.19                | 6                   |
| Dishwasher               | 108                 | 1                   |
| Washing Machine          | 0.2                 | 0.5                 |
| Phone Charger (4)        | 0.04                | 3                   |
| Router                   | 0.14                | 24                  |
| Laptop                   | 0.1                 | 6                   |
| Vacuum Cleaner           | 0.35                | 0.25                |
| LED Light Bulbs (32)     | 2.24                | 6                   |
| Water Heater (2)         | 4                   | 0.5                 |
| Air Conditioning         | 36.92               | 6                   |
| Miscellaneous            | 1.37                | 24                  |
| **Total**                | **47.7**            |                     |

Table 1 shows the breakdown of the average energy consumption per day

The total energy consumption of the villa using green building materials is found to be 47.70 kW. The average energy consumption of a villa this size with conventional building materials will be much higher than the villa built using green materials. Green buildings economize an average 30% of energy consumption over conventional buildings [10]. One of the main reasons for this is that green buildings provide higher lighting quality, thereby reducing the need for excess artificial lighting. Another reason is that it reduces the energy consumption of the HVAC system.

5. Conclusion

From the present investigation it can be concluded that the green materials selected for the analysis are suitable for the harsh desert climatic conditions. The Villa design is drawn on CATIA, and then imported to ANSYS. The temperature profile and wind profile from the CFD analysis shows that the
villa can withstand the atmospheric conditions. Total Energy consumption was found to be 47.7kW, for a day in the month of February. CFD analysis shows the temperature on the roof is less, which results in the lower energy consumption of the villa. Hence it can be concluded that the optimum selection of green materials plays a major role in the green building design.

6. References
[1] Usman A, Mohd Faris K and Hassan T 2012 Management in Construction Research Association Postgraduate Conference
[2] Subin M, Jason L, Ram K and Periasamy C 2018 IOP Conf. Series.: Mater. Sci. Eng.346 012068
[3] Manoj Kumar Singh,Sadhan Mahapatra & Atreya Kumar Sudhir 2012 Tezpur University Volume 1.
[4] Kushagra V, Mayank C, Prasenjit S and Tari A 2014 International Journal of Scientific and Research Publications, Volume 4, Issue 2.
[5] https://www.usgbc.org/resources/leed-v4-building-design-and-construction-current-version.
[6] https://www.dpm.gov.abudhabi/en/Urban-Planning/Windows-and-Glazing.
[7] Vijayabharati P, Aravindh Kumar J, Joshua a and Jayaprakash H 2013 International Journal of Engineering Research and Applications Vol. 3, Issue 2, pg 1270-1272.
[8] https://www.thefuturebuild.com.
[9] https://www.ecomena.org/green-building-uae/.
[10] Nelson A, Rakau O, Dörrenberg P 2010 Deutsche Bank Research, 1-23.