"ANALYSIS AND DESIGN OF A SUSTAINABLE BUNGALOW BY USING CIRCULAR ECONOMY"

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Abstract - *The design for the G+1 bungalow at the Pali Jambhulpada. to develop a sustainable bungalow by using various construction materials, systems, and techniques. Particularly, the 4R principle method used for waste management. The terracotta pot technique used for thermal insulation to reduce the need for artificial cooling. Solar panels install to generate renewable energy and lower electricity consumption. The terrace had terrazzo flooring, which helps to maintain a cooler indoor environment. A rainwater harvesting system design and implemented to optimize water usage. For landscaping, design a drought-resistant tree system that requires a minimum quantity of water and provides shade. Finally, to calculate environmental impact and construction cost, which lower than that of a conventional bungalow.*

Key Words: *Sustainable bungalow, Terracotta pot technique, Solar panels Landscaping,*

1.INTRODUCTION

The proposed sustainable bungalow is located at the Pali Jambhulpada in the Raigad district of Maharashtra. This place is connected to the road & spread over more than 2 acres. The aim of this is a create a modern and durable living space, including an effective plan, sustainable structural design, and organic features. The residential bungalow is planned with an area of 82.04 sq. m. as the G+1 structure and a total height of 6 m. Design secures enough natural light, proper ventilation, residential dimension, and stock space for the inhabitants to be comfortable and functional. For architectural modelling, Revit architecture software is used for modelling, accurately activated for 3D visualization and effective integration of design components. Structural analysis and design are done using the Staad Pro, which ensures the stability, strength, and safety of the bungalow. The work is designed Increase the natural beauty of the site by incorporating native plants, shaking areas to improve biodiversity, and trees and air quality. This includes a harvest of rainwater. The system, which helps with water conservation, charging groundwater, and reducing dependence on external water sources. This initiative to stop the earth ensures a stable and permanent water supply. In order to further promote energy efficiency, the project integrates solar panel energy solutions by installing solar energy with high-efficiency panels. It helps to reduce costs of power, reduce carbon emissions, and provide a reliable source of renewable energy. With solar energy, the purpose of the project is to achieve energy self-supply while contributing to environmental stability. The choice of Another important feature of sustainable building material is Project. It uses terracotta, recycled wood, aluminium, cork, and terrazzo, all of which are environmentally friendly and contribute to energy efficiency, resource security, and environmental impacts. This material not only improves durability and aesthetics in the bungalow but also reduces waste and promotes a small carbon footprint in the construction. Overall, the project is designed as a modern, durable, and environmentally responsible housing development. By integrating advanced design technologies, renewable energy solutions, and environmentally friendly materials, projects provide a comfortable, durable, and energy living space. It acts as a model for future housing projects that prefer stability, functionality, and long-term flexibility.

2. METHODOLOGY

2.1 TOPOGRAPHY: -

2.1.1. Site Selection: -

The site is located at Pali jambhulpada in the Raigad district. The site is well connected to roadway.

500 m away jambhulpada bus stop

25 km away khopoli railway station

51 km away from Mumbai airport

Fig. 01: Map view

2.2. PLANNING: -

The G+1 bungalow is created by using BIM software.

2.2.1. Details of the structure

1. Size of beam= 0.23 x 0.3 m.

2. Size of footing = 2.4 x 2.4 x 1.2 m.

3. Size of column = 0.23 x 0.3 m.

2.2.2. Plan Of the Bungalow

Autodesk Revit is a 3D Building Information Modelling (BIM) software by Autodesk, designed for architects, engineers, designers, and contractors. It allows users to create and design 3D models with default furniture and components, annotate with 2D elements, and access building data. With 4D BIM capabilities, it helps plan and track a building's lifecycle from conception to demolition.

Fig. 02: - 3D view

2.2.3. Energy Analysis: -

The energy analysis is done by using Revit software.

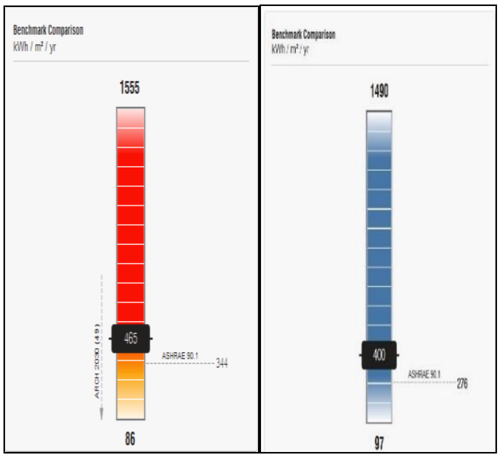


Fig. 03: - Benchmark of conventional bungalow and sustainable bungalow

The Insight 360 program offers the intensity of pure annual energy consumption and annual costs for the unit per unit EUI. It credits the use of energy to the main parameters that can significantly affect it. Insight 360 provides the energy consumption price for the BIM model and other options provided by the program. In addition, for reference in all additional comparative data, the BIM model EUI should be taken as zero, as it is considered a baseline. The factors used by Insight 360 are construction orientation, window wall condition, Window shadow, window glass materials used, Wall construction, Roof, Daylight and coating control, Air infiltration, Light and plug load efficiency, HVAC system, Operating plan, PV analysis.

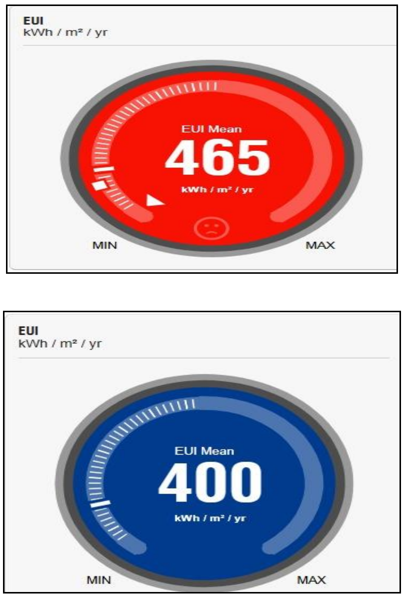


Fig. 04: - Range of energy use intensity and energy cost of conventional and sustainable bungalow

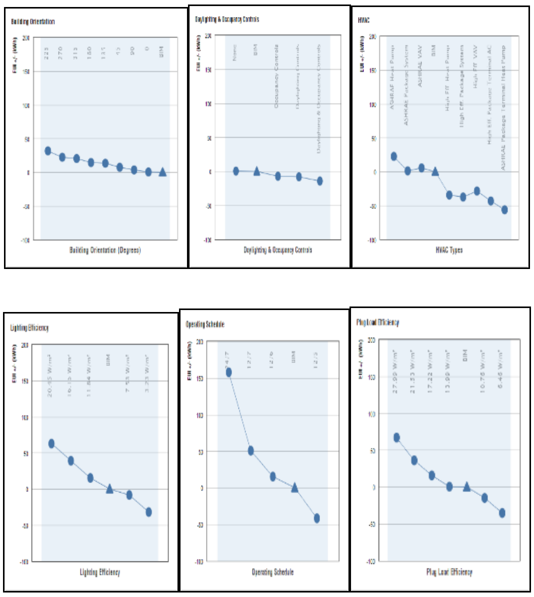
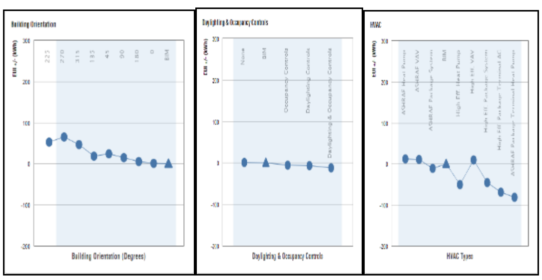


Fig. 05: - Conventional bungalow energy cost of factor in autodesk insight



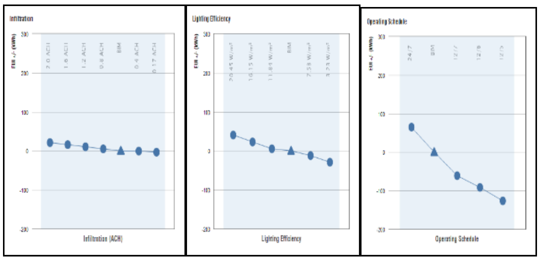


Fig. 06: - Sustainable bungalow energy cost of factor in autodesk insight

2.3. ANALYSIS

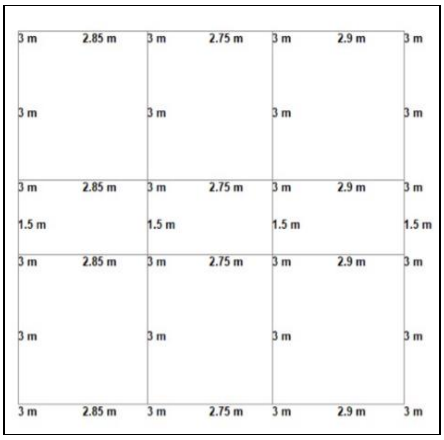


Fig. 07: - Plan

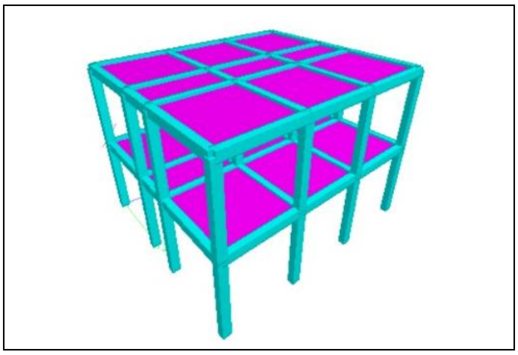


Fig. 08: - Rendering view

2.3.1. Load Calculations

1. Slab thickness = 0.12 m.
2. Dead load

   Self-Weight = Y -1kN/m.

   Member Load = Uniform Forces = -5 kN/m.

3. Live load

   Member Load = Uniform Forces = -5 kN/m.

4. Load combination=1.5(DL+LL)

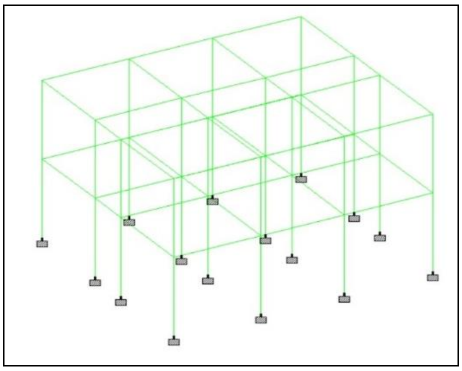


Fig. 09: - Displacement diagram

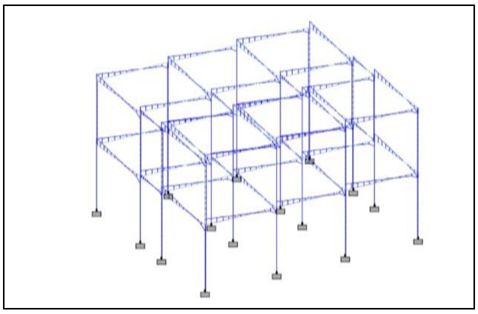


Fig 10: - Shear force diagram

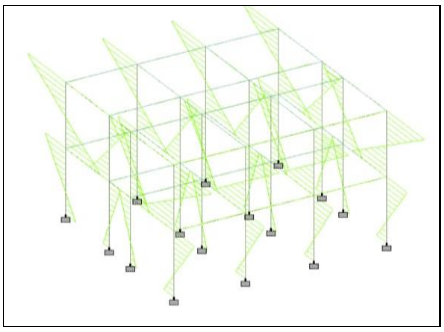
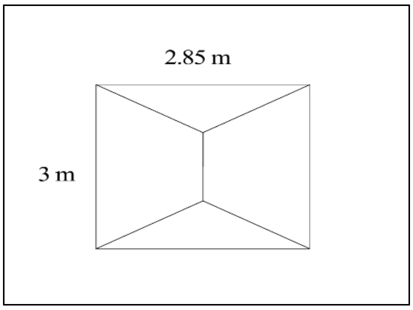


Fig 11: - Bending moment diagram

2.3.2. Manual calculation of design of continuous beam:



- Size of beam is 230 X 300 mm
- Thickness of slab = 120 mm
- Dead Load = 5 KN /m^2
- Live Load = 5 KN / m^2
- M25, fck = 25 Mpa
- Fe415, fy = 415 Mpa
- Thickness of floor finish = 40mm
- Density of Concrete = 25 KN /m^3.

Step 1 - Load calculations:

A) Dead Load =

self-weight = b x D x ρ

= 1 x 0.12 x y25

= 3 KN/m

Floor Finish Load = 1 KN/ m^2 = 1 x 1 =1 KN/m

Dead Load = 3 + 1 = 4 KN/m

B) Live Load = 5 KN/m^2 = 5 x 1 = 5 KN/m

Total slab load = 4 + 5 = 9 KN/m

Factored load slab = 1.5 γg 13.5 KN/m

a) load on B1, due to slab ρ (2.9 x 3)

Triangle △ = WLx/3

=13.5 x 2.9/3

= 13.05 KN/m

b) self-weight of beam = b x d x ρ

= 0.23 x 0.3 x 25

= 1.73 KN/m

c) required wall load on B1 = b x D x ρ

= 0.23 x (3 – 0.12) x 12

= 7.95 KN/m

Factored load on B1

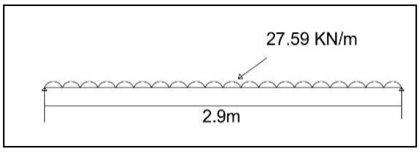
= (a) + (1.5 x b) + (1.5 x c)

= 13.05 + (1.5 x b) + (1.5 x c)

= 27.57 KN/m x length

= 27.57 x 2.9

= 79.53 KN



Mu $= wl^2/8 = 27.57 \times 2.9^2 / 8 = 28.98$ KN-m

Mulim = 0.138 $f_{ck}bd^2$

$= 0.138 \times 25 \times 230 \times 300^2$

$= 71.42 \times 10^6$ N.mm

= 71.42 KN-m

Mu < Mulim

= 28.98 KN-m < 71.42 KN-m …………….. (Hence section is Under Reinforced)

Design is safe

Step 2: - Area Of Steel

Mulim = 0.87fy x Ast x d x (1 – Ast x fy / b x d fck)

$71.42 \times 10^6 = 0.87 \times 415 \times Ast \times 300 \times (1 - Ast \times 415 / 1000 \times 300 \times 25)$

Ast = 685.36 mm^2

No. of bars = Ast/ast = $685.36 / \pi/4 \times 20^2 = 2.18 = 4$ Numbers

Provide 4 Numbers of 20 mm diameter

Ast = 685.36 mm^2

Step 3:- Reinforcement diagram

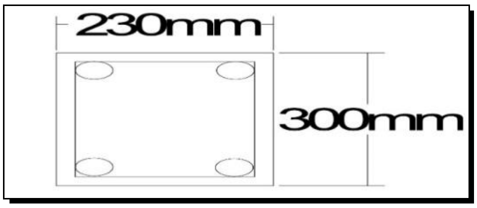


Fig. 12: - Reinforcement of beam

Step 4: - To calculate support reactions

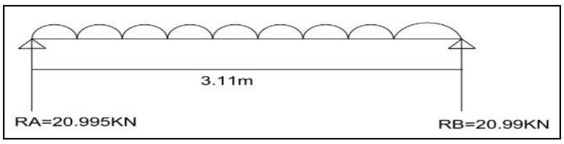


Fig. 13: - Calculate support reactions

Take a moment about A point

13.5 x 3.11 x 3.11/ 2 – RB x 3.11 = 0

RB = 20.99 KN

We know that,

RA + RB = Total Load

RA + 20.99 = 13.5 x 3.11

RA = 20.995 KN

Step 5: - To calculate shear force diagram

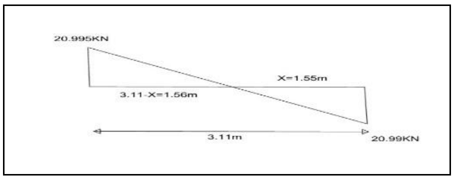


Fig. 14: - Shear force diagram

AL = 0 KN

AR = 20.995 KN

BL = 20.995 – (13.5 X 3.11)

= - 20.99 KN

BR = - 20.99 + 20.99 = 0 KN

20.995 / 3.11 – X = 20.99 / X

20.995X = 65.28 - 20.99 X

41.985 X = 65.28

X = 1.5548 m from B

The manual calculation and STAAD Pro calculation are the same, so the design is safe and correct

2.3.3. Manual calculation of design of column: -

- column size = 230 mm x 300 mm.
- Grade of concrete = f_{ck} = 25 Mpa.
- Grade of steel = fe = 415 Mpa.
- Height of column = 3m per floor.
- Total height = 6m.
- Effective length factor (k) = 1 for column with fixed end.
- Axial load: - assume P = 500KN (Based on general residential load considerations)

Step 1: - Slenderness ratio check:

$$\lambda = \frac{l_e}{k_{min}}$$

Leff = k x l = 1 x 6 = 6000 mm

γmin = minimum radius of gyration

γmin = Least Lateral Dimension / √12

γmin = 230 / √12 = 66.4 min

λ = 6000 / 66.4 = 90.36

since, λ > 12 The column is classified as a long column

Step 2: - Axial load carrying capacity (Euler's Buckling Load)

Euler's formula for a long column is:

$$P_{cr} = \frac{\pi^2 EI}{(KL)^2}$$

Ec = 5000 √ fck = 5000 x √25 = 25000 Mpa

I = bd^3 / 12 = 230 x 300^3 / 12 = 517500000 mm^4

Now,

Pcr = π^2 x 25000 x 517500000 / $(6000)^2$

Pcr = 685 KN

Since P = 500 KN < Pcr = 685 KN

The column is safe against buckling

Step 3: - Design of axial load (Pu = 500 KN)

Pn = 0.4 x fck x Ag + 0.67 x fy x As

Assuming 1% of steel and reinforcement of 230 x 300 mm

As = 0.01 x (230 x 300) = 690 mm^2

Gross Area (Ag) = 230 x 300 = 69000 mm^2

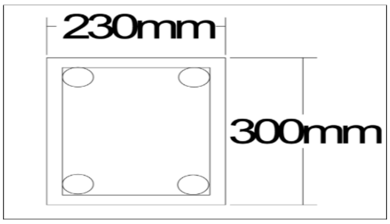
Pn = 0.4 x 25 x 69000 + 0.67 x 415 x 690

Pn = 881.85 KN

Since, Pn = 881.85 KN > P = 500 KN

The column is safe

Step 4 :- Reinforcement details



No. of bars = Asc / AΦ

= 690/π/4 x 20^2

= 2.196 = 4 Numbers

Lateral Tie:

Diameter = 8mm

Spacing minimum of (16 x 20 mm, 48mm or 300mm)

= 300mm c/c

2.4. TECHNIQUES

2.4.1. Landscape: -

It improves the aesthetics and stability of a region. Through elements such as gardens, seating, flowers, and routes. G+1 bungalow has the facility for environmentally friendly landscape work. Household facilities, shaded sitting, and strategically Planted trees for shade and air quality. This design is supplemented Architecture that promotes biodiversity and stability.

Basic principles of landscape design:

1. Unit in design
2. Focus points
3. Balance and symmetry
4. Rhythm and repetition

Fig. 15: - Landscape Revit design

2.4.2. Rainwater Harvesting: -

We have used the PVC pipe for G+1 structure of rainwater harvesting because the smooth inner surface of PVC pipes allows water to flow efficiently with minimal friction. They are lightweight, installation and maintenance are easier compared to metal pipes. moreover, they are more affordable than other materials, such as metal or concrete pipes. The PVC pipe has a length of 6 meters, a diameter of 80 mm, and cost is 250 per piece.

Fig. 16: - Rain water harvesting Revit design

2.4.2.1. Design of Rainwater Harvesting: -

Roof Area= 73.4921m^2

Annual Rainfall= 3422.2mm (As per Indian metrological Department 2022)

Runoff = 0.85(Assuming Minimum Losses)

1) Maximum RWH Capacity = Roof Area X Annual Rainfall

= 73.4921 X 3.4222

= 251,360 litres

2) Monthly Rain Capture = R/2 = 3.422/2 = 0.2852 m

3) Monthly Rainwater Capacity = Roof Area X Monthly Rain Capture X Runoff

=73.4921 X 0.2852 X 0.85

= 17,810 litres

4) Annual Rainfall = Roof Area X Rainfall X Runoff

= 73.4921 X 3.4222 X 0.85

= 213,650 litres

5) Area Of Tank Required = Annual Rainfall/D

(Assuming 1.2 m Depth of Tank)

= 213.65/1.2

= 178.02 m^2

6) Percentage of Water Stored

= Storage Capacity/total rainwater available X 100

= 213,650/251360X100

= 85%

2.4.3. Solar Panel: -

For our G+1 bungalow, we have installed 4 solar panels that generate 3 kW of energy. Solar panels help reduce greenhouse gas emissions, making bungalows more environmentally friendly. the cost of the solar panels is 78000, resulting in a 13.98% savings in energy.

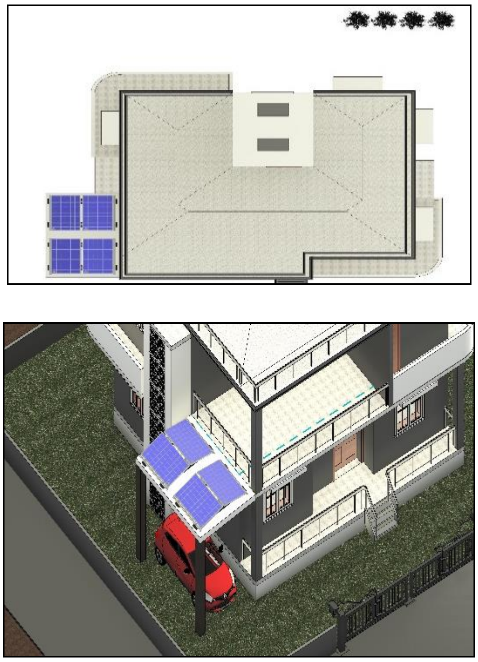


Fig. 17: - Solar power system Revit design

2.4.4. Materials: -

Material plays an important role in sustainability by affecting energy efficiency, resource protection, and environmental impact. Durable materials such as cork, terracotta, recycled wood, aluminum and terrazzo contribute to environmentally friendly construction and design. Materials are fundamental to development when they directly affect environmental protection, energy efficiency, and long-term feasibility in architecture and Production. choosing the right material can be important to reduce waste, reduce footprints with low carbon, and promote energy capacity.

Following Materials we used in our project: -

- Terracotta
- Recycled Wood

- Aluminum
- Cork
- Terrazzo

2.4.4.1. Terracotta

Terracotta is a natural soil - based material, is widely used in architecture due to thermal insulation, low maintenance and long -term properties, making it an environmentally friendly alternative for facades, ceilings and floors.

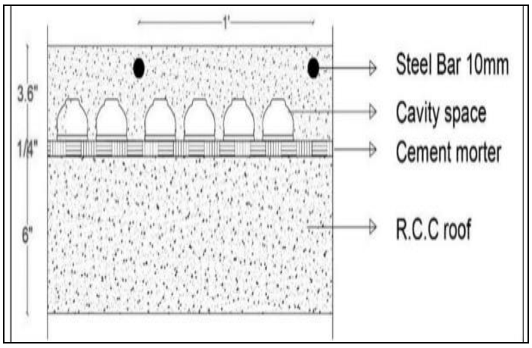


Fig. 18: - Roof section after clay pots installed

2.4.4.2. Recycled Wood: -

We are using recycled wood for doors in G+1 bungalow because is more affordable than the new wood. It provides a unique, rustic, and natural look to the doors. Using recycled wood repurposes old materials, preventing waste. By choosing recycled wood, we contribute to sustainability while maintaining quality and aesthetics in our bungalow. The cost of the recycled wood door is ₹ 8,000.

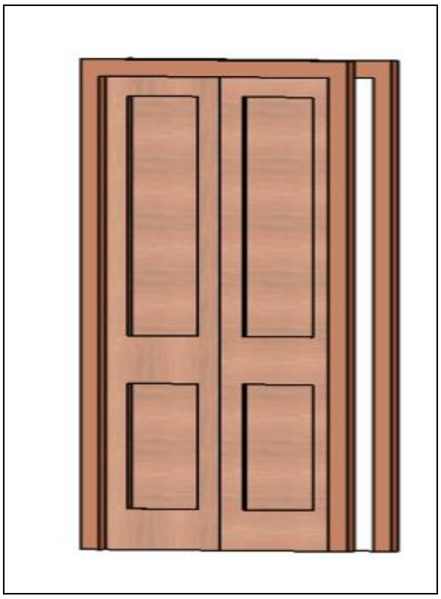


Fig. 19: - Recycled wood for doors

2.4.4.3. Aluminum

Aluminum is used for windows in our G+1 bungalow. It is widely used in sustainable bungalow because it is lightweight, durable, and highly recyclable. With excellent corrosion resistance, aluminum is ideal for long-term use with minimal maintenance. Aluminum also enhances energy efficiency in bungalow by providing effective insulation and reflecting heat, which helps regulate indoor temperatures. Its versatility in construction, along with its sustainability benefits, makes aluminum a preferred material for sustainable bungalow. The cost of the window is ₹2,500.

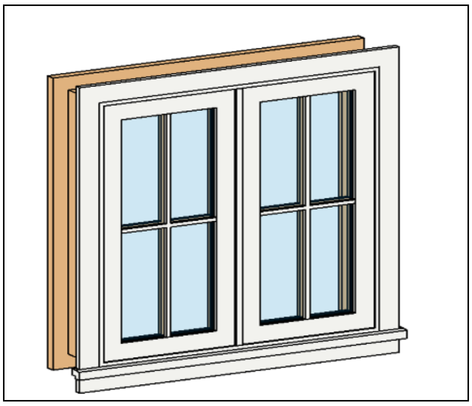


Fig. 20: - Aluminum for windows

2.4.4.4. Cork

Cork is used for flooring in our G+1 bungalow because it is an eco-friendly and sustainable material. It is cut from the bark of cork oak allows trees, without damaging them continue to revive and absorb carbon dioxide. Cork is naturally durable, resistant to moisture, and provides excellent thermal and sound insulation, making it an energy-efficient choice for flooring. It is also soft and comfortable underfoot, reducing strain while walking. Its unique texture and warm appearance add aesthetic value to the bungalow while promoting sustainability. The cost of cork flooring is ₹850 per square meter.

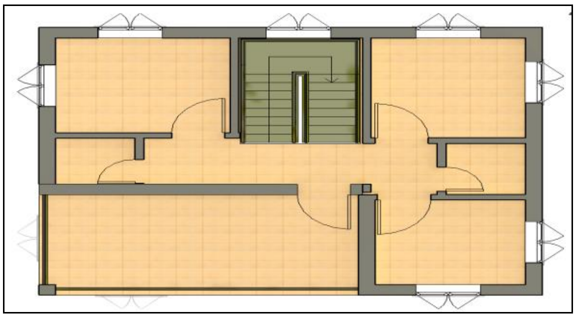


Fig. 21: - Cork for flooring

2.4.4.5. Terrazzo

We have used terrazzo flooring for the terrace in our G+1 bungalow. Terrazzo is used for terrace flooring because it is durable, weather-resistant, and low maintenance. It is made from a mix of marble, quartz, granite, and other recycled materials, making it an eco-friendly and sustainable choice. Its long lifespan and minimal maintenance requirements make it a cost-effective flooring option for sustainable bungalow. Our terrace area is 67.35 square meters, and the cost of terrazzo flooring is ₹475 per square meter.

Fig. 22: - Terrazzo for terrace flooring

3. RESULT

- The Building Information Modelling softwares like Autodesk Revit architecture and Autodesk Insight is found to be very effective for in developing and creating energy efficient bungalow.
- From the Bungalow Performance Analyses there is about 13.98 % Energy Cost savings for the conventional bungalow compared to the sustainable Bungalow.
- We reduced cost of sustainable bungalow approximately 1 Lakhs.

4. CONCLUSION

The estimation and comparison between conventional and sustainable bungalows highlight the advantages of sustainability in construction. sustainable bungalows not only reduce costs but also minimize environmental impact through efficient resource utilization. The incorporation of construction debris for plinth filling helps in waste reduction, while well-designed windows enhance natural lighting and ventilation, reducing energy consumption. Additionally, water-efficient plumbing fixtures contribute to water conservation. overall, sustainable bungalows demonstrate superior energy efficiency and eco-friendliness compared to conventional designs, making them a practical and responsible choice for modern construction.

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