PLANNING AND DESIGN OF NET ZERO ENERGY RESIDENTIAL BUILDING

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Abstract: As the country is developing day by day the consumption of power is also very high. If we are going for NZERB building, we can save energy locally which mean to save energy in global level. The use of this technology used in residential buildings has shown huge amount savings in the electricity bill. The proper design and alignment of the building can make the building cheaper than that of the conventional type of buildings. Usage of hollow bricks and avoidance of columns and beams will result in lowering of temperature inside the building.

Index-Terms – NZERB, Conventional Building.

I. INTRODUCTION

Fast rate of urbanization and increase in the consumption of electricity has become a major problem in Jammu. Due to increase in consumption of electricity the Jammu electricity board is unable to fulfill the requirements of the public and industrial sectors in Jammu, this is the major problem faced. Officials were banking on a number of projects, which would generate 14,000 MW of power, from thermal, nuclear and other power projects. Most of these should have been completed by 2012. But the projects have got delayed. Hence requirement has brought in new building technologies by utilizing the renewable energy resources. In housing aspects, it is necessary to design the material adopted structurally in a proportion with reference standard codes. Designing of building is the most essential work to be proposed in any projects. Before starting the project, it is necessary to prepare layout and plan in a plot as per the Government Rules and Regulation for getting an approval without any delay and to execute the project. Overall cost of the project should be economical so estimation of building is very important. As a whole we have incorporated all the needs for a building to be built with efficient, eco-friendly and economic, also abiding by the Government Rules. This project envisages the preparation of a Residential layout by incorporating the Jammu Government rules and the preparation of a plan for a residential building in a plot by using software. Finally, this project will end up with the preparation of an estimation of the prepared plan.

II. LITERATURE REVIEW

Anna Joanna,
Aalborg University, Department of Civil Engineering,
According to ANNA,”With energy conservation arrangements, such as high-insulated constructions, solar heating system. Extra Energy supply for the electric installations in the house is taken from the municipal mains” (Ref 2).

Saitoh, (1988) (JAPAN)
According to SAITOH, “… a multi-purpose natural energy autonomous house will meet almost all the energy demands for solar panel and cooling as well as supply of hot water. For this purpose, solar energy, the natural underground coldness and sky radiation cooling are utilized.”

• Solar panels are designed to harness.
• Solar energy in buildings include systems that capture heat (such as Solar water heating systems and passive heating).
• It converts solar energy into electrical energy, its done with the help of photovoltaic (PV) systems (Ref 3).

III. OBJECT & SCOPE OF INVESTIGATION:

2.1 OBJECTIVE

• Design a building with Net zero energy concept.
• To eliminate the necessity of active energy loads on the building.
• Comparing the net zero energy building with conventional building.

2.2 Scope

• Functional planning of G+1 Residential building
• Design of load bearing structure using hollow bricks
• Design of solar panels
IV. RESEARCH METHODOLOGY

This entire project is a planning and design in nature and the methodology followed in this project is listed as below:

- Selection of site where renewable energy is available
- Study the climate conditions of area
- Aligning the building to utilize maximum amount of renewable resources
- Planning and design of proposed NZERB building
- Comparison of the NZERB building with other conventional building

Design experience in the following areas has been gained during the course of the project:

- Design of slabs
- Design of footings
- Design of wall using Hollow bricks
- Design of solar panels

4.1 REALISTIC DESIGN CONSTRAINTS

Economic: Building shall be designed such that the entire energy requirements are met by solar energy only due to shortage of conventional energy.

Sustainability Constraints: The design shall be such that the requirement of cooling does not fluctuate throughout the year.

Economic Constraint: The materials adopted for construction are economical compared to conventional materials.

4.2 REFERENCE TO CODES AND STANDARDS

The codes for design of buildings and structures, Design co-efficient, Limit state design method and Fixing of dimensions are shown in Table 1.1.

<table>
<thead>
<tr>
<th>Codes /Standards</th>
<th>Context</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS 875 :1987 -1,2</td>
<td>Design loads for buildings and structures (Dead load , Imposed load )</td>
</tr>
<tr>
<td>IS 456 :2000</td>
<td>Design co-efficient, Limit state design method used for slab and footing</td>
</tr>
<tr>
<td>IS 2572-1963(R 1997)</td>
<td>Design of Hollow bricks</td>
</tr>
<tr>
<td>IS 1905 :1987</td>
<td>Structural use of Unreinforced Masonry</td>
</tr>
<tr>
<td>SP 20 :1991</td>
<td>Handbook of Masonry design and Construction</td>
</tr>
</tbody>
</table>

4.3 APPLICATION OF EARLIER COURSE WORK

The codes for building drawing, layout and planning and Byelaws, Setbacks, Open space, Floor area ratio are shown in Table 1.2

<table>
<thead>
<tr>
<th>Course Code and Name</th>
<th>Context</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-303 Building drawing</td>
<td>Building drawing</td>
</tr>
<tr>
<td>C-606 Architecture &amp;</td>
<td>layout and planning, Byelaws, Setbacks, Open space, Floor area ratio</td>
</tr>
<tr>
<td>Town Planning</td>
<td>R.C.C Design</td>
</tr>
<tr>
<td>C-604 Design of structure I</td>
<td>R.C.C Design</td>
</tr>
<tr>
<td>C-701 Design of structure II</td>
<td>Estimation &amp; costing</td>
</tr>
</tbody>
</table>

4.4 MULTIDISCIPLINARY COMPONENT AND TEAM WORK

- This project involves in multidisciplinary team work and helps interacting with the builders who deal with the non conventional building methods and use of waste and cost effective building materials.
- It also involves interaction with software people to learn about the function and operation of the software’s used in this project for the design, analyse and estimation of the parts of the structure.
V. RESULTS AND DISCUSSION

Planning: The key plan of the residential building is drawn by considering the alignment of the building with respect to the JDA. The key plan of the site is shown in the figure given below.

Key Plan: The ground floor of the building consists of one hall, two bedrooms, one dining, one kitchen. The allocations of the rooms in the plan have been done with due consideration of sun diagram as per the requirement of zero energy building. The plan has been prepared using software. The Ground Floor plan is shown in Figure 2.

Fig.1

Fig.2 Ground Floor Plan (All dimensions in meter)
The first floor of the building consists of one hall, two bedrooms, one dining, and one kitchen. The allocations of the rooms in the plan have been done with due consideration of sun diagram as per the requirement of zero energy building. The plan has been prepared using software. The First Floor plan is shown in Figure 3.

Fig. 3 First Floor plan

5.1 ANALYSIS AND DESIGNS

Slab Design (Ref 6): The analysis and designs of the slab for Hall, Bedroom, Bathroom, Dining, Kitchen, Staircase, Portico are done with proper considerations as per IS 456:2000.

Design of Hall: Using M20 Concrete Fe415 steel

Live Load = 2 kN/m² (Ref 7)

1. Effective Span

Lₓ = 3.26 m
Lᵧ = 5.1 m
Aspect ratio = \( \frac{Lᵧ}{Lₓ} = \frac{5.1}{3.26} = 1.56 < 2 \)

Hence Two Way Slab

2. Load Calculation

Assuming Slab Thickness

\[ d = \frac{Lₓ}{32} = \frac{3260}{32} = 101.875 \text{ mm} = 100 \text{ mm} \]

Assume 10Ø bar, Clear Cover 20mm

\[ D = 100 + \frac{10}{2} + 20 = 125 \text{ mm} = 130 \text{ mm} \]

∴ Actual Depth \( (d) = 130 - 5 - 20 = 105 \text{ mm} \)

Self Weight of a Slab \( \frac{D}{1000} \times 25 = \frac{130}{1000} \times 25 \)
Assume Floor Finish = 40 mm

· Weight of Floor Finish = 0.04 × 24 = 0.96 kN m²

Imposed Load = 2 kN m² (Ref 8)

· Total Load = 6.21 kN m²

Factored Load \( W_u \) = 1.5 × 6.21 = 9.315 kN m²

Consider 1m width of slab

· Load per meter Length = 9.127 kN m

3. Finding Design Bending Moment

Refer Table 26, Page No. 91 of IS456

Two adjacent edges are discontinuous

\[ \frac{L_y}{L_x} = 1.56 \] (Already found out)

Refer Table 26

Short Span \( \alpha_x = 0.068 \)

Long Span \( \alpha_y = 0.037 \)

[Note that Lx only to be taken, where it is long span or short span only coefficient varies].

\[ M_U = W_u \times \text{Co-efficient} \times L_x^2 \] ……..(1)

Where,

\( M_U \) = Moment in short span direction

\( W_u \) = Ultimate load

\( L_x \) = Length in x direction

\[ M_U^{(+)} \text{ Short} = 0.068 \times 9.315 \times 3.26^2 = 6.731 \text{ kN.m} \] (Ref 9)

\[ M_U^{(+)} \text{ Long} = 0.037 \times 9.315 \times 3.26^2 = 3.662 \text{ kN.m} \]

Take the Highest Moment and check for adequacy of the section.

\[ M_{U,\text{lim}} = 0.36 \times \frac{X_u \text{max}}{d} \left[ 1 - 0.42 \times \frac{X_u \text{max}}{d} \right] fck b d^2 \]

(or)

\[ = 0.138 fck b d^2 \] ……..(2)

Where,

\( M_{U,\text{lim}} \) = Ultimate limiting moment of resistance

\( fck \) = Characteristic compressive strength of concrete

\( b \) = Width

\( d \) = Effective depth

\[ = 0.138 \times 20 \times 1000 \times 105^2 \]

\[ = 30.42 \text{kN.m} \]

(Mu Limit) > (Mu Short)

∴ Hence ok

4. Calculation of Steel

\[ A_{st}^{(+)} \text{ Short} = b d \frac{fck}{fy} \left[ 1 - \sqrt{1 - 4.598} \right] \]

Where,

\( A_{st}^{(+)} \text{ Short} \) = Area of steel required

\( b \) = Width

\( d \) = Effective depth

\( fck \) = Characteristic compressive strength of concrete

\( fy \) = Yield stress of steel

\[ R = \frac{Mu}{bdf^2} = 6.731 \times 106 \times \frac{1}{1052 \times 1000} = 0.6105 \]

\[ A_{st}^{(+)} \text{ Short} = 1000 \times 105 \times \left( \frac{20}{2} \right) \times 415 \left[ 1 - \sqrt{1 - 4.598} \times \frac{0.61}{20} \right] \]

\[ = 184.27 \text{ mm}² \]

Minimum Steel = 0.12% \times D \times B

\[ A_{st,\text{min}} = \left( \frac{0.12}{100} \right) \times 130 \times 1000 = 156 \text{ mm}² \]

\[ A_{st}^{(+)} \text{ Short} < A_{st,\text{min}} \]
5. Check for maximum Spacing

   i. \[3d = 3 \times 105 = 315 \text{ mm}\]
   ii. 300

Max Spacing = 300 mm
∴ d for long span bars
\[d = D - \text{Clear Cover} - \frac{d}{2} - \phi\]
= 130 - 20 - \frac{10}{2} - 10 = 95 \text{ mm}.

6. Calculation of \(A_{st}\) for Long Span

\[A_{st}^{(+)}_{\text{Long}} = b d \frac{f_{ck}}{2 f_y} [1 - \sqrt{1 - 4.598 \frac{R}{r_{ck}}}]\]

Same as equation (3)
\[R = \frac{M_{ub}}{b d^2}\]
\[= \frac{3.662 \times 10^6}{1000} \times 95^2\]
\[= 0.4057\]
\[A_{st}^{(+)}_{\text{Long}} = 1000 \times 95 \times \left(\frac{20}{2}\right)\times 415 \times [1 - \sqrt{4.598 \times \frac{0.4057}{20}}]\]
\[= 109.37 \text{ mm}^2\]
\[A_{st}^{(+)}_{\text{Long}} < A_{st,\text{min}}\]

7. Spacing for all Steel

   i. \[3d = 3 \times 95 = 285 \text{ mm}\]
   ii. 300

Spacing = 285 mm

8. Check for Deflection

Short Span \(L_x = 3260 \text{ mm}\)
\[A_{st}^{(+)}_{\text{Short}} = 116.37 \text{ mm}^2\]
Basic Value = 20
\[F_s = 0.58 \times 415 \times \frac{184.27}{184.27} = 240.2 \text{ N/mm}^2\]
\[P_{r} = \frac{A_{st}^{(+)}_{\text{Short}}}{bd} \times \left(\frac{184.27 \times 100}{1000 \times 105}\right)\]
\[= 0.175\%\]
Modification Factor = 1.62
Modified Basic Value = 20 \times 1.62 = 32.8
\[\frac{Span}{d} = \frac{3260}{105} = 31.047\]
\[31.047 < 32.8\]
∴ Hence its ok

Design of Bed Room: Using M20 Concrete
Fe415 steel
Live Load = 2 kN/m²

1. Effective Span
\(L_A = 3.23\text{m}\)
\(L_y = 3.73\text{m}\)
Aspect ratio \(= \frac{L_y}{L_x} = 3.73/3.23 = 1.154 < 2\) Hence Two Way Slab

2. Load Calculation
Assuming Slab Thickness \( d = \frac{Lx}{32} = \frac{3230}{32} = 100 \text{ mm} \)

Assume 100 bar, Clear Cover = 20mm

\[ D = 100 + \frac{10}{2} + 20 = 125 \text{ mm} \]

\[ \therefore \text{Actual Depth (d)} = 125 - 5 - 20 = 100 \text{ mm} \]

Self-Weight of a Slab \[ = \frac{D}{1000} \times 25 = \frac{125}{1000} \times 25 = 3.125 \text{ kN/m} \]

Assume 40 mm Floor Finish

\[ \therefore \text{Weight of Floor Finish} = 0.04 \times 24 = 0.96 \text{ kN/m}^2 \]

Imposed Load = 2 \( \text{ kN/m}^2 \)

Total Load = 6.08 \( \text{ kN/m}^2 \)

Factored Load \( W_u \) = 1.5 \times 6.96 = 9.127 \( \text{ kN/m}^2 \)

Consider 1m width of slab

\[ \therefore \text{Load per meter Length} = 9.127 \text{ kN/m} \]

3. Finding Design Bending Moment

Refer Table 26, Page No.91 of IS456

Two adjacent edges are discontinuous

\[ \frac{L_y}{L_x} = 1.154 \text{(Already found out)} \]

Refer Table 26

Short Span \( \alpha_x = 0.043 \)

Long Span \( \alpha_y = 0.035 \)

[ Note that Lx only to be taken, where it is long span or short span only coefficient varies ].

\( M_u = W_u \times \text{Co-efficient} \times L_x^2 \)

Same as equation (1)

\( M_u(+ \text{ Short}) = 0.043 \times 9.13 \times 3.23^2 = 4.09 \text{ kN.m} \)

\( M_u(+ \text{ Long}) = 0.035 \times 9.13 \times 3.23^2 = 3.33 \text{ kN.m} \)

Take the Highest Moment and check for adequacy of the section.

\[ M_{u,\text{lim}} = 0.36 \times \frac{X_u \text{ max}}{d} \left[ 1 - 0.42 \times \frac{X_u \text{ max}}{d} \right] \frac{fck}{2} b d^2 \]

\[ M_{u,\text{lim}} = 0.138 f_{ck} b d^2 \]

\[ M_{u,\text{lim}} = 0.138 \times 20 \times 1000 \times 100 \]

\[ M_{u,\text{lim}} = 27.6 \text{ kN/m}^2 \]

\( (M_u \text{ Limit}) > (M_u \text{ Short}) \)

\[ \therefore \text{Hence its ok} \]

4. Calculation of Steel

\[ A_{st(+ \text{ Short})} = b d \frac{fck}{2} \left[ 1 - \sqrt{1 - 4.598 \frac{R}{fck}} \right] \]

Same as equation (3)

\[ R = \frac{M_u}{bd^2} = 4.1 \times 106 \times \frac{1}{1000} \times 1000 = 0.41 \]

\[ A_{st(+ \text{ Short})} = 1000 \times 100 \times \frac{20}{2} \times 415 \left[ 1 - \sqrt{1 - 4.598 \times 0.41} \right] = 116.37 \text{ mm}^2 \]

Minimum Steel = 0.12% \times D \times B

\[ A_{st,\text{min}} = \frac{0.12}{100} \times 125 \times 1000 = 150 \text{ mm}^2 \]

\[ A_{st(+ \text{ Short})} < A_{st,\text{min}} \]

5. Check for maximum Spacing

i. \( 3d = 3 \times 100 = 300 \text{ mm} \)

ii. 300

Max Spacing = 300 mm
&d for long span bars
\[ d = D - \text{Clear Cover} - \frac{d}{2} - \phi \]
\[ d = 125 - 20 - 10/2 - 10 \]
\[ d = 90 \text{ mm} \]

6. Calculation of \( A_{st} \) for Long Span

\[
A_{st}^{(+)}_{\text{Long}} = b d \frac{f_{ck} f_y}{2 f_{ck} \left[ 1 - \sqrt{1 - 4.598 \frac{R}{f_{ck}}} \right]} \]

Same as equation (3)
\[
R = \frac{M_{u}}{bd^2} = 3.33 \times \frac{106}{1000 \times 100^2} = 0.33
\]
\[
A_{st}^{(+)}_{\text{Long}} = 1000 \times 100 \times 20 \times 415 \left[ 1 - 4.598 \times \frac{0.33}{20} \right] = 93.2 \text{ mm}^2
\]
\[ A_{st}^{(+)}_{\text{Long}} < A_{st, \text{min}} \]

7. Spacing for Steel

\[
A_u = \frac{\pi}{4} \times 10^2 = 78.5 \text{ mm}^2
\]

\[
\text{spacing}^{(+)}_{\text{Short}} = \frac{78.5}{116.37} \times 1000 = 674.5 \text{ mm}
\]

\[
\text{spacing}^{(+)}_{\text{Long}} = \frac{78.5}{93.2} \times 1000 = 842.27 \text{ mm}
\]

8. Check for Deflection

Short Span \( L_x = 3230 \text{ mm} \)

\[
A_{st}^{(+)}_{\text{Short}} = 116.37 \text{ mm}^2
\]

Basic Value = 20

\[
F_s = 0.58 \times 415 \times \frac{121.32}{121.32} = 240.7 \frac{N}{\text{mm}^2}
\]

\[
P_{cm} = \frac{A_{st}^{(+)}_{\text{Short}}}{bd} = (1.22 \times 10^{-3}) \times 100 = 0.122\%
\]

Modification Factor = 1.7

Modified Basic Value = 20 \times 1.7 = 34

\[
\frac{\text{Span}}{d} = \frac{3230}{100} = 32.3
\]

\[ 32.3 < 34 \]

∴ Hence its ok

**Design of Bed Room:** Using M20 Concrete

Fe415 steel

Live Load = 2 kN/m²

1. Effective Span

\[ L_x = 3.85 \text{ m} \]

\[ L_y = 3.95 \text{ m} \]

\[
\text{Aspect ratio} = \frac{L_y}{L_x} = \frac{3.95}{3.85} = 1.027 < 2
\]

Hence Two Way Slab

2. Load Calculation

Assuming Slab Thickness

\[
d = \frac{L_x}{32} = \frac{3850}{32} = 120.31 \text{ mm} = 120 \text{ mm}
\]
Assume 10∅ bar, Clear Cover 20 mm

\[ D = \frac{120 + 10}{2} + 20 = 145\text{mm} = 150\text{ mm} \]

∴ Actual Depth \( (d) \) = 150-5-20 = 125 mm

Self-Weight of a Slab = \[ \frac{D}{1000} \times 25 = \frac{150}{1000} \times 25 \]

= 3.75 \( \text{kN/m}^2 \)

Assume 40 mm Floor Finish

∴ Weight of Floor Finish = 0.04 × 24 = 0.96 \( \text{kN/m}^2 \)

Imposed Load = 2 \( \text{kN/m}^2 \)

∴ Total Load = 6.75 \( \text{kN/m}^2 \)

Factored Load \( (W_u) \) = 1.5 × 6.75 = 10.125 \( \text{kN/m}^2 \)

Consider 1m width of slab

Load per meter Length = 10.125 \( \text{kN/m} \)

3. Finding Design Bending Moment

Refer Table 26, Page No. 91 of IS 456

Two adjacent edges are discontinuous

\[ \frac{L_y}{L_x} = 1.027 \text{ (already found out)} \]

Refer Table 26

Short Span \( \alpha_x = 0.048 \)

Long Span \( \alpha_y = 0.047 \)

[ Note that Lx only to be taken, where it is long span or short span only coefficient varies]

\[ M_u = W_u \times \text{Coefficient} \times L_x^2 \]

Same as equation (1)

\[ M_u(+) \text{ Short} = 0.048 \times 10.125 \times 3.85^2 = 7.203 \text{kN.m} \]

\[ M_u(+) \text{ Long} = 0.047 \times 10.125 \times 3.85^2 = 7.063 \text{kN.m} \]

Take the Highest Moment and check for adequacy of the section.

\[ M_{u,\text{lim}} = \frac{0.36 \times X_u \max}{d} \left[ 1 - \frac{0.42 \times X_u \max}{d} \right] fck b d^2 \]

\[ = 0.138 f_{ck} b d \]

Same as equation (2)

\[ = 0.138 \times 20 \times 1000 \times 125^2 \]

\[ = 43.125 \text{kN.m} \]

\( (M_u \text{ Limit}) > (M_u \text{ Short}) \)

∴ Hence ok

4. Calculation of Steel

\[ A_{st(+) \text{ Short}} = b d \frac{f_{ck}}{R} \left[ 1 - \sqrt{1 - 4.598 \frac{R}{f_{ck}}} \right] \]

Same as equation (3)

\[ R = \frac{M_u}{b d} = 7.203 \times 10^6 \times \frac{1}{1252 \times 1000} = 0.460 \]

\[ A_{st(+) \text{ Short}} = 1000 \times 125 \times \left( \frac{20}{2} \right) \times 415 \left[ 1 - \sqrt{1 - 4.598 \times \frac{0.46}{20}} \right] \]

= 164.08 mm²

Minimum Steel = 0.12% × D × B

\[ A_{st,\text{min}} = \frac{0.12}{100} \times 150 \times 1000 \]
A_{st}(+) Short < A_{st,min}

5. Check for maximum Spacing
   i. \(3d = 3 \times 125 = 375 \text{ mm}\)
   ii. 300

Max Spacing = 300 mm
\[d = D - \text{Clear Cover} - \frac{d}{2} - \phi\]
\[d = 150 - 20 - \frac{10}{2} - 10\]
d= 115 mm

6. Calculation of \(A_{st}\) for Long Span
\[A_{st}(+)_{\text{Long}} = b \frac{f_{tk}}{f_{ty}} \left[1 - \sqrt{1 - 4.598 \frac{R}{f_{ck}}}\right]\]

Same as equation (3)
\[R = \frac{M_{u}}{b d f_{ck}} = \frac{7.663 \times 10^6}{1000 \times 1152} = 0.553\]
\[A_{st}(+)_{\text{Long}} = 1000 \times 115 \times \left(\frac{20}{2}\right) \times 415 \left[1 - \sqrt{4.598 \times \frac{0.553}{20}}\right]\]
\[= 181.11 \text{ mm}^2\]
\[A_{st}(+)_{\text{Long}} < A_{st,min}\]

7. Spacing for all Steel
   i. \(3d = 3 \times 115 = 345 \text{ mm}\)
   ii. 300

Spacing = 300 mm

8. Check for Deflection

Short Span \(L_x = 3850 \text{ mm}\)
\[A_{st}(+)_{\text{Short}} = 180 \text{ mm}^2\]

Basic Value = 20
\[F_s = 0.58 \times 415 \times \frac{180}{180} = 240.2 \text{ N/mm}^2\]

\[P_t = \frac{A_{st}(+)_{\text{Short}}}{bd} = \frac{180 \times 100}{(1000 \times 125)}\]
\[= 0.144\%\]

Modification Factor = 1.8

Modified Basic Value = 20 \times 1.8 = 36
\[\frac{\text{Span}}{d} = \frac{3850}{125} = 30.8\]
30.8 < 35.6
∴ Hence its ok

Design of Bathroom: Using M20 Concrete
Fe415 steel
Live Load = 2 \(\text{kN/m}^2\)

1. Effective Span

\(L_x = 2.38 \text{ m}\)
\(L_y = 4.28 \text{ m}\)
Aspect ratio = \(\frac{L_y}{L_x} = \frac{4.28}{2.38} = 1.798 < 2\)
Hence Two Way Slab
2. Load Calculation

Assuming Slab Thickness

\[ d = \frac{L_x}{32} = \frac{2380}{32} = 74.375 \text{ mm} = 80 \text{ mm} \]

Assume 10Ø bar, Clear Cover 20 mm

\[ D = 80 + \frac{10}{2} + 20 = 105 \text{ mm} = 110 \text{ mm} \]

\[ \therefore \text{Actual Depth }\quad d = 110-5-20 = 85 \text{ mm} \]

Self-Weight of a Slab

\[ = \frac{D}{1000} \times 25 = \frac{110}{1000} \times 25 = 2.75 \text{ kN/m}^2 \]

Assume 40 mm Floor Finish

\[ \therefore \text{Weight of Floor Finish } = 0.04 \times 24 = 0.96 \text{ kN/m}^2 \]

Imposed Load = 2 \text{ kN/m}^2

\[ \therefore \text{Total Load } = 5.75 \text{ kN/m}^2 \]

Factored Load \( W_u \) = 1.5 \times 5.75 = 8.625 \text{ kN/m}^2

Consider 1m width of slab

\[ \therefore \text{Load per meter Length } = 8.625 \text{ kN/m}^2 \]

3. Finding Design Bending Moment

Refer Table 26, Page No.91 of IS456

Two adjacent edges are discontinuous

\[ \frac{L_y}{L_x} = 1.798 \text{ (already found out)} \]

Refer Table 26

Short Span \( a_x = 0.085 \)

Long Span \( a_y = 0.047 \)

[ Note that \( L_x \) only to be taken, where it is long span or short span only coefficient varies ].

\[ M_u = W_u \times \text{Co-efficient} \times L_x^2 \]

Same as equation (1)

\[ M_u(+ \text{Short}) = 0.085 \times 8.625 \times 2.38^2 = 4.127 \text{ kN.m} \]

\[ M_u(+ \text{Long}) = 0.047 \times 8.625 \times 2.38^2 = 2.29 \text{ kN.m} \]

Take the Highest Moment and check for adequacy of the section.

\[ M_{u,\text{lim}} = \frac{0.36 \times X_u \text{ max}}{d} \left[ 1 - \frac{0.42 \times X_u \text{ max}}{d} \right] f_{ck} b d^2 \]

(or)

\[ = 0.138 f_{ck} b d^2 \]

Same as equation (2)

\[ = 0.138 \times 20 \times 1000 \times 85^2 \]

=19.94 kN.m

\( M_u \text{ Limit}) > (M_u \text{ Short}) \]

\[ \therefore \text{Hence its ok} \]

4. Calculation of Steel

\[ A_{u(+ \text{ Short})} = b d \frac{f_{ck}}{2f_y} \left[ 1 - \sqrt{1-4.598 \frac{R}{f_{ck}}} \right] \]

Same as equation (3)

\[ R = \frac{M_u}{bd^2} = 4.1527 \times \frac{106}{(852 \times 1000)} = 0.574 \]
\[ A_{st}^{(s)} \text{ Short} = 1000 \times 85 \times \left( \frac{20}{2} \right) \times 415 \left[ 1 - \sqrt{1 - 4.598 \times \frac{0.57}{20}} \right] = 139.92 \text{ mm}^2 \]

Minimum Steel = 0.12\% \times D \times B

\[ A_{st, min} = \left( \frac{0.12}{100} \right) \times 110 \times 1000 = 132 \text{ mm}^2 \]

\[ A_{st}^{(s)} \text{ Short} < A_{st, min} \]

5. Check for maximum Spacing

i. \[ 3d = 3 \times 855 = 255 \text{ mm} \]

ii. \[ 300 \]

Max Spacing = 255 mm

\[ d = D - \text{Clear Cover} - \frac{d}{2} \phi \]

\[ d = 110 - 20 - \frac{10}{2} - 10 \]

\[ d = 75 \text{ mm} \]

6. Calculation of \( A_{st} \) for Long Span

\[ A_{st}^{(s)} \text{ Long} = b \frac{d f_{ck}}{2 f_y} \left[ 1 - \sqrt{1 - 4.598 \frac{R}{f_{ck}}} \right] \]

Same as equation (3)

\[ R = \frac{M_u b d^2}{b d^2} = \frac{2.29 \times 10^6}{1000 \times 752} = 0.4082 \]

\[ A_{st}^{(s)} \text{ Long} = 1000 \times 75 \times \left( \frac{20}{2} \right) \times 415 \left[ 1 - \sqrt{4.598 \times \frac{0.4082}{20}} \right] = 86.88 \text{ mm}^2 \]

\[ A_{st}^{(s)} \text{ Long} < A_{st, min} \]

7. Spacing for all Steel

i. \[ 3d = 3 \times 75 = 225 \text{ mm} \]

ii. \[ 300 \]

Max Spacing = 225 mm

8. Check for Deflection

Short Span \( L_s = 2380 \text{ mm} \)

\[ A_{st}^{(s)} \text{ Short} = 139.92 \text{ mm}^2 \]

Basic Value = 20

\[ F_s = 0.58 \times 415 \times \frac{139.92}{139.92} = 240.2 \text{ N/mm}^2 \]

\[ P_t = \frac{A_{st}^{(s)} \text{ Short}}{bd} = \frac{(139.92 \times 100)}{(1000 \times 85)} = 0.1646\% \]

Modification Factor = 1.9

Modified Basic Value = 20 \times 1.9 = 38

\[ \frac{\text{Span}}{d} = \frac{2380}{85} = 28 \]

\[ 28 < 38 \]

\[ \therefore \text{Hence its ok} \]

Design of Portico Using M20 Concrete

Fe415 steel

Live Load = 2 kN/m²

1. Effective Span

\[ L_e = 3.78 \text{ m} \]
L_y = 6.93 m

Aspect ratio = \( \frac{L_y}{L_x} = \frac{6.93}{3.78} = 1.83 < 2 \)

Hence Two Way Slab

2. Load Calculation

Assuming Slab Thickness

\[ d = \frac{L_x}{32} = \frac{3780}{32} = 118.124 \text{ mm} = 120 \text{ mm} \]

Assume 10\( \phi \) bar, Clear Cover 20 mm

\[ D = 120 + 10 \times \frac{10}{2} + 20 = 150 \text{ mm} \]

\[ \therefore \text{ Actual Depth (d)} = 150 - 5 - 20 = 125 \text{ mm} \]

Self-Weight of a Slab = \( \frac{D}{1000} \times 25 = \frac{150}{1000} \times 25 = 3.75 \text{ kN/m}^2 \)

Assume 40 mm Floor Finish

\[ \therefore \text{ Weight of Floor Finish} = 0.04 \times 24 = 0.96 \text{ kN/m}^2 \]

Imposed Load = 2 \text{ kN/m}^2

\[ \therefore \text{ Total Load} = 6.75 \text{ kN/m}^2 \]

Factored Load \( (W_u) \) = 1.5 \times 6.75 = 10.125 \text{ kN/m}^2

Consider 1m width of slab

\[ \therefore \text{ Load per meter Length} = 10.125 \text{ kN/m} \]

3. Finding Design Bending Moment

Refer Table 26, Page No.91 of IS456

Two adjacent edges are discontinuous

\[ \frac{L_y}{L_x} = 1.83 \text{(already found out)} \]

Refer Table 26

Short Span \( \alpha_x = 0.087 \)

Long Span \( \alpha_y = 0.047 \)

[ Note that Lx only to be taken, where it is long span or short span only coefficient varies]

\[ M_u = W_u \times \text{ Co-efficient} \times L_x^2 \]

\[ M_u(+ \text{ Short}) = 0.087 \times 10.125 \times 3.78^2 = 12.58 \text{ kN.m} \]

\[ M_u(+ \text{ Long}) = 0.047 \times 10.125 \times 3.78^2 = 6.79 \text{ kN.m} \]

Take the Highest Moment and check for adequacy of the section.

\[ M_u,\text{lim} = \frac{0.36 \times X_{u\text{max}}}{d} \left[ 1 - 0.42 \times \frac{X_{u\text{max}}}{d} \right] f_{ck} b d^2 \]

\[ = 0.138 f_{ck} b d^2 \]

Same as equation (2)

\[ = 0.138 \times 20 \times 1000 \times 125^2 \]

\[ = 43.125 \text{ kN.m} \]

\[ (M_u,\text{lim}) > (M_u,\text{Short}) \]

\[ \therefore \text{ Hence ok} \]

4. Calculation of Steel

\[ A_{st(+ \text{ Short})} = b d \times \frac{f_{ck}}{2\delta_y} \left[ 1 - \sqrt{1 - 4.598 \frac{R}{f_{ck}}} \right] \]

Same as equation (3)
\[ R = \frac{M_u}{b d^2} = \frac{12.58 \times 10^6}{1252 \times 1000} = 0.805 \]

\[ A_{st}^{(\text{e})} \text{ Short} = 1000 \times 125 \times \frac{20}{2} \times 415 \left[ 1 - \sqrt{1 - 4.598 \times 0.8 \frac{R}{f_{ck}}} \right] \]
\[ = 184.27 \text{ mm}^2 \]

Minimum Steel = 0.12% × D × B
\[ A_{st, \text{min}} = \left( \frac{0.12}{100} \right) \times 130 \times 1000 \]
\[ = 156 \text{ mm}^2 \]

\[ A_{st}^{(\text{e})} \text{ Short} < A_{st, \text{min}} \]

5. Check for maximum Spacing
i. \(3d = 3 \times 105 = 315 \text{ mm}\)
ii. \(300 \)

Max Spacing = 300mm
\(\therefore d\) for long span bars
\(d = D - \text{Clear Cover} - \frac{d}{2} - 0\)
\(d = 130 - 20 - 10/2 - 10\)
\(d = 95 \text{ mm}\)

6. Calculation of \(A_{st}\) for Long Span
\[ A_{st}^{(\text{e})}_{\text{Long}} = b d f_{ck} \left[ 1 - \sqrt{1 - 4.598 \frac{R}{f_{ck}}} \right] \]

Same as equation (3)
\[ R = \frac{M_u}{b d^2} = \frac{3.662 \times 10^6}{952 \times 1000} = 0.4057 \]
\[ A_{st}^{(\text{e})}_{\text{Long}} = 1000 \times 95 \times \frac{20}{2} \times 415 \left[ 1 - \sqrt{4.598 \times 0.4057} \frac{R}{f_{ck}} \right] \]
\[ = 109.37 \text{ mm}^2 \]

\[ A_{st}^{(\text{e})}_{\text{Long}} < A_{st, \text{min}} \]

7. Spacing for all Steel
i. \(3d = 3 \times 95 = 285 \text{ mm}\)
ii. \(300 \)

Spacing = 285 mm

8. Check for Deflection
Short Span \(L_s = 3260 \text{ mm}\)
\[ A_{st}^{(\text{e})} \text{ Short} = 116.37 \text{ mm}^2 \]
Basic Value = 20
\[ F_s = 0.58 \times 415 \times \frac{184.27}{184.27} = 240.2 \frac{N}{\text{mm}^2} \]
\[ P_c = \frac{A_{st}^{(\text{e})} \text{ Short}}{b d} = \frac{184.27 \times 100}{1000 \times 105} \]
\[ = 0.175\% \]
Modification Factor = 1.62
Modified Basic Value = 20 × 1.62
\[ = 32 \]
\[ \frac{\text{Span}}{d} = \frac{3260}{105} = 31.047 \]
\[ 31.047 < 32.8 \]
\(\therefore\) Hence ok.

Design of Kitchen: Using M20 Concrete
Fe415 steel
Live Load = 2 \text{kN/m}^2

1. Effective Span
   
   \( L_x = 2.23 \text{ m} \)
   \( L_y = 3.73 \text{ m} \)
   
   Aspect ratio = \( \frac{L_y}{L_x} = 3.73 + \frac{0.23}{2.23} + 0.23 = 1.67 < 2 \)
   
   Hence Two Way Slab

2. Load Calculation
   
   Assuming Slab Thickness \( d = \frac{L_x}{32} = \frac{2230}{32} = 65 \text{ mm} \)
   
   Assume 10\( \phi \) bar, Clear Cover 20mm
   
   \( D = 65 + \frac{10}{2} + 20 = 90 \text{ mm} \)
   
   \( \therefore \) Actual Depth \( d = 90 - 5 - 20 = 65 \text{ mm} \)
   
   Self Weight of a Slab = \( \frac{D}{1000} \times 25 = \frac{90}{1000} \times 25 \)
   = 2.25 \text{kN/m}^2
   
   Assume Floor Finish = 40 mm
   
   Weight of Floor Finish = \( 0.04 \times 24 = 0.96 \text{kN/m}^2 \)
   
   \( \therefore \) Imposed Load = 2 \text{kN/m}^2
   
   \( \therefore \) Total Load = 5.25 \text{kN/m}^2
   
   Factored Load \( W_u \) = 1.5 \times 5.25 = 7.875 \text{kN/m}^2
   
   Consider 1m width of slab
   
   \( \therefore \) Load per meter Length = 7.875 \text{kN/m}

   Finding Design Bending Moment
   
   Refer Table 26, Page No.91 of IS456
   
   Two adjacent edges are discontinuous
   
   \( \frac{L_y}{L_x} = 1.67 \) (already found out)

   Refer Table 26
   
   Short Span \( \alpha_x = 0.06 \)
   
   Long Span \( \alpha_y = 0.035 \)

   [ Note that \( L_x \) only to be taken, where it is long span or short span only coefficient varies ]

   \( M_u = W_u \times \text{Co-efficient} \times L_x^2 \)
   
   Same as equation (1)

   \( M_u (+) \) Short = 0.06 \times 7.88 \times 2.23^2 = 2.35 \text{kN.m} \)

   \( M_u (+) \) Long = 0.035 \times 7.88 \times 2.23^2 = 1.373 \text{kN.m} \)

   Take the Highest Moment and check for adequacy of the section.

   \( M_{u,lim} = \frac{0.36 \times X_u \max}{d} \left[ 1 - \sqrt{1 - 4.598 \times \frac{R}{f_{ck}}^2} \right] f_{ck}b d^2 \)
   
   \( (or) \)

   \( M_{u,lim} = 0.138 f_{ab} b d^2 \)
   
   = 0.138 \times 20 \times 1000 \times 65^2
   
   = 11.66 \text{kN.m} \)

   \( (M_u \text{ Limit}) > (M_u \text{ Short}) \)
   
   \( \therefore \) Hence ok

3. Calculation of Steel
   
   \( A_{st} (+) \) Short = \( b \frac{f_{ck} \left[ 1 - \sqrt{1 - 4.598 \frac{R}{f_{ck}}} \right]}{2fy} \)
   
   Same as equation 4.3

   \( R = \frac{40}{b d^2} = 2.735 \times \frac{106}{1000 \times 65^2} = 0.55 \)

   \( A_{st} (+) \) Short = \( 1000 \times 65 \times 20^2 \times 415 \left[ 1 - \sqrt{1 - 4.598 \times 0.55} \right] \)
   
   = 103.56 \text{mm}^2

   Minimum Steel = 0.12% \times D \times B

   \( A_{st,min} = \frac{0.12}{100} \times 90 \times 1000 \)
   
   = 108 \text{ mm}^2

   \( A_{st} (+) \) Short < \( A_{st,min} \)

4. Check for maximum Spacing

i. 3d = 3 \times 65 = 195 \text{ mm }

ii. 300

Max Spacing = 195 mm

\( \therefore d \) for long span bars

\( d = D - \text{Clear Cover} - \frac{d}{2} \cdot \phi \)

\( d = 90 - 20 - \frac{10}{2} \cdot 10 \)

\( d = 55 \text{ mm} \)
5. Calculation of $A_{st}$ for Long Span

$$A_{st}^{(+)\text{Long}} = \frac{bd}{f_{yk}} \left[1 - \sqrt{1 - \frac{4.596\beta f_{ck}^2}{f_{yk}^2}}\right]$$

$$= \frac{1.373 \times 106}{1000 \times 55^2} = 0.115$$

$$A_{st}^{(+)\text{Long}} = 1000 \times 55 \times \frac{20}{2} \times 415 \left[1 - \frac{0.115}{20}\right] = 71.05 \text{ mm}^2$$

$$A_{st}^{(+)\text{Long}} < A_{st,\text{min}}$$

6. Spacing for all Steel

$$A_u = 78.5 \times 10^2 = 78.5 \text{ mm}^2$$

$$A_{st}^{(+)\text{Short}} = \frac{78.5}{103.56} \times 1000 = 758.01 \text{ mm}$$

$$A_{st}^{(+)\text{Long}} = \frac{78.5}{71.05} \times 1000 = 1104.8 \text{ mm}$$

7. Check for Deflection

Short Span $L_x = 2230$ mm

$$A_{st}^{(+)\text{Short}} = 103.56 \text{ mm}^2$$

Basic Value $= 20$

$$F_s = 0.58 \times 415 \times 103.56 \times 1000 = 240.7 \text{ N/mm}^2$$

$$P_t = \frac{A_{st}(+)\text{Short}}{1000} = 103.56 \times 65 \times 0.16\%$$

Modification Factor $= 1.8$

Modified Basic Value $= 20 \times 1.8 = 36$

$$\frac{\text{Span} - \text{d}}{65} = 34.3 < 36$$

∴ Hence OK

Design of Dining Room: Using M20 Concrete

Fe415 steel

Live Load $= 2 \text{ kN/m}^2$

1. Effective Span

$L_x = 2.6$ m

$L_y = 3.73$ m

Aspect ratio $= \frac{L_y}{L_x} = \frac{3.73 + 0.23}{26} = 0.23 < 2$

Hence Two Way Slab

2. Load Calculation

Assuming Slab Thickness

$$d = \frac{L_x}{32} = \frac{2600}{32} = 80 \text{ mm}$$

Assume 10Ø bar, Clear Cover 20 mm

$$D = 80 + 10 + 20 = 105 \text{ mm}$$

Actual Depth (d) $= 105 - 20 = 80 \text{ mm}$

Self-Weight of a Slab $= \frac{D}{1000} \times 25 = \frac{105}{1000} \times 25$

$= 2.625 \text{ kN/m}^2$

Assume Floor Finish $= 40 \text{ mm}$

Weight of Floor Finish $= 0.04 \times 24 = 0.96 \text{ kN/m}^2$

Imposed Load $= 2 \times \frac{\text{kN}}{\text{m}^2}$

Total Load $= 5.62 \text{ kN/m}^2$

Factored Load ($W_u$) $= 1.5 \times 5.62 = 8.43 \text{ kN/m}^2$

Consider 1m width of slab $\text{kn}$

Load per meter Length $= 8.43 \text{ kN/m}$

3. Finding Design Bending Moment

Refer Table 26, Page No.91 of IS456

One edge discontinuous

$L_y = 1.43$ (already found out)

Refer Table 26

Short Span $a_s = 0.049$

Long Span $a_s = 0.028$

[Note that $L_x$ only to be taken, where it is long span or short span only coefficient varies].

$$M_o = W_u \times \text{Co-efficient} \times L_x^2$$

Same as equation (1)

$$M_o(+)\text{Short} = 0.049 \times 8.43 \times 2.6^2 = 2.79 \text{ kN.m}$$

$$M_o(+)\text{Long} = 0.028 \times 8.43 \times 2.6^2 = 1.595 \text{ kN.m}$$
Take the Highest Moment and check for adequacy of the section.

\[ M_{u, \text{lim}} = \frac{0.36 \times X_u \max}{d} \left[ 1 - 0.42 \times \frac{X_u \max}{d} \right] f_{ck} b d^2 \]

(or)

\[ M_{u, \text{lim}} = 0.138 f_{ck} b d^2 \]

Same as equation (2)

\[ M_{u, \text{lim}} = 0.138 \times 20 \times 1000 \times 80^2 \]

\[ M_{u, \text{lim}} = 17.66 \text{ kN.m} \]

(Mu Limit) > (M_u Short)

\[ \therefore \]

Hence its ok

4. Calculation of Steel

\[ A_{st}^{(+)} \text{ Short} = b \frac{f_{ck}}{2 f_y} \left[ 1 - \sqrt{1 - 4.598 \frac{R}{f_{ck}}} \right] \]

Same as equation (3)

\[ R = \frac{M_u b d^2}{b d^2} = 2.79 \times \frac{106}{1000 \times 80^2} = 0.435 \]

\[ A_{st}^{(+)} \text{ Short} = 1000 \times 80 \times 20 \times 415 \left[ 1 - \sqrt{1 - 4.598 \times \frac{0.435}{20}} \right] \]

= 99.15 mm²

Minimum Steel = 0.12% × D × B

\[ A_{st,\text{min}} = \frac{0.12}{100} \times 105 \times 1000 = 126 \text{ mm}^2 \]

\[ A_{st}^{(+)} \text{ Short} < A_{st,\text{min}} \]

5. Check for maximum Spacing

i. \[ 3d = 3 \times 80 = 240 \text{ mm} \]

ii. \[ 300 \]

Max Spacing = 240 mm

\[ :d \text{ for long span bars} \]

\[ d = D - \text{Clear Cover} - \frac{d}{2} - \emptyset \]

\[ d = 105 - 20 - \frac{10}{2} - 10 \]

\[ d = 70 \text{ mm} \]

6. Calculation of \( A_{st}^{(+)} \) for Long Span

\[ A_{st}^{(+)} \text{ Long} = b \frac{f_{ck}}{2 f_y} \left[ 1 - \sqrt{1 - 4.598 \frac{R}{f_{ck}}} \right] \]

Same as equation (3)

\[ R = \frac{M_u b d^2}{b d^2} = 1.595 \times \frac{106}{1000 \times 70^2} \]

= 0.325

\[ A_{st}^{(+)} \text{ Long} = 1000 \times 70 \times 20 \times 415 \left[ 1 - 4.598 \times \frac{0.325}{20} \right] \]

= 64.34 mm²

\[ A_{st}^{(+)} \text{ Long} < A_{st,\text{min}} \]

7. Spacing for Steel

\[ A_{st} = \frac{1}{4} \times 10^2 = 78.5 \text{ mm}^2 \]

\[ A_{st}^{(+)} \text{ Short} = 78.5 \times 99.15 \times 1000 = 791.7 \text{ mm} \]

\[ A_{st}^{(+)} \text{ Long} = \frac{78.5}{64.34} \times 1000 = 1200.08 \text{ mm} \]

8. Check for Deflection

Short Span \( L_s = 2600 \) mm

\[ A_{st}^{(+)} \text{ Short} = 99.15 \text{ mm}^2 \]

Basic Value = 20

\[ F_x = 0.58 \times 415 \times \frac{99.15}{99.15} = 240.7 \text{ N/mm}^2 \]

\[ P_t = \frac{A_{st}^{(+)} \text{ Short}}{b d} \]

\[ = \frac{99.15}{1000 \times 70} \]

= 0.14%

Modification Factor = 1.8

Modified Basic Value = 20 × 1.8 = 36

\[ \frac{d}{80} = \frac{2600}{80} = 32.5 \]

\[ 32.5 < 36 \]

\[ \therefore \]

Hence ok

Design of Wall:

1. Calculation of Loads

Maximum short span = 3.60 m

Width of corridor = 1.50 m

Height of the storey = 3 m

Live load = 2 \( \text{ kN/m} \)
2. Assumptions
- Height of the Plinth from ground = 0.5 m
- Height of the Plinth above Footing = 1 m
- Height of the Parapet Wall = 1 m
- Thickness of Roof Slab = 110 mm
- Brick Size = 230 × 115 × 75

3. Slenderness Ratio and Stress Factor
- Ground Floor + First Floor
  \[ H = 3 + 0.115 + 0.5 + 3 + 0.115 + 1 = 7.73 \text{ m} \]
- Effective Height \( (h) \) = 0.75H = 0.75 × 7.73 = 5.797 m
- Slenderness Ratio \( \frac{h}{t} = \frac{5.797}{0.23} = 25.21 \)

4. Shape modification factor
- Crushing Strength of Modular Brick = 5 kN m²
- \[ \frac{H}{w} = \frac{75}{115} = 0.652 \]
- Shape Modification Factor = \( K_p = 1 \) (From table 10 of IS: 1905-1987)

5. Area reduction factor:
- Area Reduction Factor
  \[ K_a = 0.7 + 1.5 A = 0.7 + 1.5 \times 0.3 = 1.15 \]
  \[ \therefore K_a = 1 \] (From clause 5.4.1.2)

6. Stress Reduction Factor:
- \( k_s = 0.46 \) (from table 9)

7. Permissible Stress
- \( F_c = K_s \times K_a \times K_p \times \text{Basic compressible stress} \)
  - Where,
    - \( K_s \): Stress reduction factor
    - \( K_a \): Area reduction factor
    - \( K_p \): Shape modification factor
  - \( F_c = 0.46 \times 0.48 \times 1 \times 1 \)
    - \( = 0.21 \text{ kN/} m^2 \)

8. Safe Load
- \[ Q = \left( \frac{f_c}{t} + \frac{6x}{t} \right) A \]
  - \[ = 63 \text{ kN/} m \]

9. Wall Area
- Outer wall = Total Perimeter x 3 (floor height)
  \[ = ((11.31 \times 2) + (8.93 \times 2)) \times 3 \]
  - \[ = 40.83 \text{ m}^3 \]
- Inner wall = \((4.87 \times 3) + (4.87 \times 3) + (3.5 \times 2 \times 3)\)
  \[ = 29.22 + 21 = 50.22 \text{ m}^3 \]
- Total wall volume = 91.05 m³

10. Deductions:
- Outer Deductions = \(1.098 + 1.089 + 2.226 + 1.089 + 1.4884 + 1.4884 + 1.4884 + 1.4884 + 1.4884 + 1.4884 + 1.4884\)
  \[ = 14.042 \text{ m}^3 \]
- Inner Deductions = \(1.89 + 1.89 + 2.496 + 1.746 + 1.746\)
  \[ = 9.768 \text{ m}^3 \]
- Total Deduction = 23.81 m³
- Total wall volume – Total Deductions = 91.05 - 23.81 = 67.24 m³
- % Opening = \(\frac{23.81}{67.25} \times 100\)
  \[ = 35.4 \% \]
- \(\therefore\) Thickness = 1 Brick thick wall (using nomograms)

11. For Hall
- \[ W_u = \frac{W_{ix}}{6} \times \{3 - \left(\frac{1}{L_y}\right)^{2}\} \] (4.5)
- \( W_u \) is calculated by equation 4.5
- Where,
  - \( W_u \): Factored load
  - \( W \): Load from the slab
  - \( L_x \): Short span
  - \( L_y \): Long span
- \( W_{ix} = (9.315 \times \frac{(3.03+0.23)}{6}) \times \{3 - \left(\frac{3+0.23}{4.87+0.23}\right)^2\} \)
- \( W_u = 13.11 \times 10^{3} \text{ kN/m} \)
  - For bed room:
\[ W_u = \frac{Wl}{6} \times (3 - \left( \frac{k}{by} \right)^2) \]
\[ = (9.127 \times (3 + 0.23)) \times \left( 3 - \left[ \frac{3 + 0.23}{3.5 + 0.23} \right]^2 \right) \]
\[ = 11.055 \times 10^3 \text{ kN/m} \]

For dining room:
\[ W_u = \frac{Wl}{6} \times (3 - \left( \frac{k}{by} \right)^2) \]
\[ = (0.43 \times (2.37 + 0.23)) \times \left( 3 - \left[ \frac{2.37 + 0.23}{3.5 + 0.23} \right]^2 \right) \]
\[ = 9.81 \times 10^3 \text{ kN/m} \]

Total:
\[ 13.11 + 11.055 + 9.81 = 33.98 \times 10^3 \text{ kN/m} \]

Hence the design is ok.

### Design of Footing:

Load from Walls = 126.7 kN/m

10% for the weight of the Building = 63 + 6.3 = 70 kN/m

1. Area of Footing = \( \frac{\text{Load}}{\text{SBC}} \)
   
   Assume SBC = 150 kN/m²

   \[ A = \frac{70}{150} = 0.47 \text{ m}^2 \]

   Consider 1m Length room

   Breadth of the Footing Required = \( \frac{\text{Area}}{L} \) = 0.47

2. Minimum Width = (2w + 300) mm
   
   = (2 × 230 + 300) = 760 mm

   Provide Width of P.C.C = 760 mm

   It is customary to provide 150 to 300 mm P.C.C thickness

   :: Provide = 300 mm

   :: The Projection of P.C.C beyond the brick work should not be more than \( \frac{1}{2} \) of the thickness of P.C.C

   Projection = \( \frac{300}{2} = 150 \text{ mm} \)

   Actual work of Brick work = 760 – 300 = 460 mm

   :: Brick work projection beyond the wall

   Depth of the Brick work = 115 × 2 = 230 mm

   This depth has to be Provided by means of series steps

   The thickness of each step is given by modular brick = 200 mm

   :: The offset in the brick is also given as modular = 100 mm

### Design of Hollow Brick Wall:

#### Step 1: Calculation of loads

Maximum short span = 3.6 m

Height of the storey = 3 m

Live load = \( \frac{2}{m^2} \)

#### Step 2: Assumptions

Height of the Plinth from ground = 0.5 m

Height of the Plinth above Footing = 1 m

Height of the Parapet Wall = 1 m

Thickness of Roof Slab = 0.120 m

Hollow Brick Size = 0.40 × 0.20 × 0.20 m

### EFFECTIVE LENGTH OF WALL

(From Table 5 of IS 1905-1987)

Wall A = 3.82 × 0.9 = 3.438 m (continuous on one end & discontinuous on other end)

Wall B = 3.23 × 0.8 = 2.584 m (continuous on both ends & supported by cross wall)

Wall C = 3.7 × 0.9 = 3.33 m (continuous on one end & discontinuous on other end)

Wall D = 3.2 × 0.9 = 2.88 m (continuous on one end & discontinuous on other end)

Wall E = 2.57 × 0.8 = 2.056 m (continuous on both ends & supported by cross wall)

Wall F = 2.8 × 0.9 = 2.52 m (continuous on one end & discontinuous on other end)

Wall G = 3.7 m (discontinuous on both ends and braced by cross wall)

Wall H = 3.23 × 0.9 = 2.907 m (continuous on one end & discontinuous on other end)

Wall I = 3.82 × 0.9 = 3.438 m (continuous on one end & discontinuous on other end)

Wall J = 3.438 m (continuous on one end & discontinuous on other end)

Wall K = 3.72 × 0.8 = 2.976 m (continuous on both ends & supported by cross wall)

Wall L = 2.15 × 0.9 = 1.935 m (continuous on one end & discontinuous on other end)

Wall M = 5.07 m (continuous on one end & discontinuous on other end)
Step 3: Slenderness ratio and stress factor
Ground floor:
\[ H = 2.6 + 0.6 + 1 = 4.2 \text{ m} \]
Effective height = \( 0.75 \times H = 3.15 \text{ m} \)
Slenderness ratio = \( \frac{H}{t} = \frac{3.15}{0.2} = 15.75 \)

Step 4: Shape modification factor
Crushing Strength of Hollow Brick = 4.1 \( \frac{N}{\text{mm}^2} \)
\[ \frac{H}{W} = \frac{20}{20} = 1 \]
Shape Modification Factor = \( K_p = 1.2 \) (From table 10 of IS: 1905-1987)

Step 5: Stress Reduction Factor
\( k_s = 0.74 \) (From table 9)

Step 6: Area reduction factor
Gross area = \( 200 \times 1000 = 200000 \text{ mm}^2 \)
\( A = 0.2 \text{ m}^2 \)
\( K_a = 1 \) (From clause 5.4.1.2)

Step 7: Permissible stress
\[ F_c = 0.74 \times 1.2 \times 1 \times 0.44 = 0.39 \frac{N}{\text{mm}^2} \]
Safe allowable load per meter length is \( q = 0.39 \times 2 \times 10^3 = 78 \text{ kN/m} \)

Step 8: Slenderness ratio and stress factor
First floor:
\[ H = 2.6 + 0.8 = 3.4 \text{ m} \]
Effective height = \( 0.75 \times H = 2.55 \text{ m} \)
Slenderness ratio = \( \frac{H}{t} = \frac{2.55}{0.2} = 12.75 \)

Step 9: Stress Reduction Factor
\( k_s = 0.81 \)

Step 10: Area reduction factor
Gross area = \( 200 \times 1000 = 200000 \text{ mm}^2 \)
\( A = 0.2 \text{ m}^2 \)
\( K_a = 1 \)

Step 11: Permissible stress
\[ F_c = 0.81 \times 1.2 \times 1 \times 0.44 = 0.427 \frac{N}{\text{mm}^2} \]
Safe allowable load per meter length is \( q = 0.427 \times 2 \times 10^3 = 85 \text{ kN/m} \)

The values of slenderness ratio for effective length and height of the building is given in Table 1.3

<table>
<thead>
<tr>
<th>Brickwork</th>
<th>Ground floor</th>
<th>First Floor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>A</td>
<td>3.15</td>
<td>3.44</td>
</tr>
<tr>
<td>B</td>
<td>3.15</td>
<td>2.58</td>
</tr>
<tr>
<td>C</td>
<td>3.15</td>
<td>3.33</td>
</tr>
<tr>
<td>D</td>
<td>3.15</td>
<td>2.88</td>
</tr>
<tr>
<td>E</td>
<td>3.15</td>
<td>2.056</td>
</tr>
<tr>
<td>F</td>
<td>3.15</td>
<td>2.52</td>
</tr>
<tr>
<td>G</td>
<td>3.15</td>
<td>3.7</td>
</tr>
<tr>
<td>H</td>
<td>3.15</td>
<td>2.90</td>
</tr>
<tr>
<td>I</td>
<td>3.15</td>
<td>3.44</td>
</tr>
<tr>
<td>J</td>
<td>3.15</td>
<td>3.44</td>
</tr>
<tr>
<td>K</td>
<td>3.15</td>
<td>2.976</td>
</tr>
<tr>
<td>L</td>
<td>3.15</td>
<td>1.935</td>
</tr>
</tbody>
</table>
The values of stress reduction factor for slenderness ratio of the building is given in Table 1.4

<table>
<thead>
<tr>
<th>Wall type</th>
<th>Ground floor</th>
<th>First floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.74</td>
<td>0.81</td>
</tr>
<tr>
<td>B</td>
<td>0.81</td>
<td>0.81</td>
</tr>
<tr>
<td>C</td>
<td>0.74</td>
<td>0.81</td>
</tr>
<tr>
<td>D</td>
<td>0.75</td>
<td>0.81</td>
</tr>
<tr>
<td>E</td>
<td>0.89</td>
<td>0.89</td>
</tr>
<tr>
<td>F</td>
<td>0.83</td>
<td>0.83</td>
</tr>
<tr>
<td>G</td>
<td>0.74</td>
<td>0.81</td>
</tr>
<tr>
<td>H</td>
<td>0.75</td>
<td>0.81</td>
</tr>
<tr>
<td>I</td>
<td>0.75</td>
<td>0.81</td>
</tr>
<tr>
<td>J</td>
<td>0.74</td>
<td>0.81</td>
</tr>
<tr>
<td>K</td>
<td>0.75</td>
<td>0.81</td>
</tr>
<tr>
<td>L</td>
<td>0.88</td>
<td>0.88</td>
</tr>
</tbody>
</table>

The calculation of permissible stress of the building is given in the Table 1.5

\[ F_c = k_s \times k_p \times k_a \times \text{basic compressive stress} \]

<table>
<thead>
<tr>
<th>Wall type</th>
<th>Permissible stress- ground floor (N/mm(^2))</th>
<th>Permissible stress- first floor (N/mm(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.528x0.74=0.390</td>
<td>0.528x0.81=0.427</td>
</tr>
<tr>
<td>B</td>
<td>0.528x0.81=0.427</td>
<td>0.528x0.81=0.427</td>
</tr>
<tr>
<td>C</td>
<td>0.528x0.74=0.390</td>
<td>0.528x0.81=0.427</td>
</tr>
<tr>
<td>D</td>
<td>0.528x0.75=0.396</td>
<td>0.528x0.81=0.427</td>
</tr>
<tr>
<td>E</td>
<td>0.528x0.89=0.469</td>
<td>0.528x0.89=0.469</td>
</tr>
<tr>
<td>F</td>
<td>0.528x0.83=0.4382</td>
<td>0.528x0.83=0.4382</td>
</tr>
<tr>
<td>G</td>
<td>0.528x0.74=0.390</td>
<td>0.528x0.81=0.427</td>
</tr>
<tr>
<td>H</td>
<td>0.528x0.75=0.396</td>
<td>0.528x0.81=0.427</td>
</tr>
<tr>
<td>I</td>
<td>0.528x0.75=0.396</td>
<td>0.528x0.81=0.427</td>
</tr>
<tr>
<td>J</td>
<td>0.528x0.74=0.390</td>
<td>0.528x0.81=0.427</td>
</tr>
<tr>
<td>K</td>
<td>0.528x0.75=0.396</td>
<td>0.528x0.81=0.427</td>
</tr>
<tr>
<td>L</td>
<td>0.528x0.88=0.4646</td>
<td>0.528x0.88=0.4646</td>
</tr>
<tr>
<td>M</td>
<td>0.528x0.75=0.390</td>
<td>0.528x0.81=0.427</td>
</tr>
</tbody>
</table>
The values of safe allowable load for the building is given in Table 1.6

### Table 1.6 Safe Allowable Loads

<table>
<thead>
<tr>
<th>Wall type</th>
<th>q = f_s × 2 × 10^3 kN/m (ground floor)</th>
<th>q = f_s × 2 × 10^5 kN/m (first floor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>78</td>
<td>85.4</td>
</tr>
<tr>
<td>B</td>
<td>85</td>
<td>85.4</td>
</tr>
<tr>
<td>C</td>
<td>78</td>
<td>85.4</td>
</tr>
<tr>
<td>D</td>
<td>79.2</td>
<td>85.4</td>
</tr>
<tr>
<td>E</td>
<td>93</td>
<td>93.8</td>
</tr>
<tr>
<td>F</td>
<td>87.6</td>
<td>87.6</td>
</tr>
<tr>
<td>G</td>
<td>78</td>
<td>85.4</td>
</tr>
<tr>
<td>H</td>
<td>79.2</td>
<td>85.4</td>
</tr>
<tr>
<td>I</td>
<td>79.2</td>
<td>85.4</td>
</tr>
<tr>
<td>J</td>
<td>78</td>
<td>85.4</td>
</tr>
<tr>
<td>K</td>
<td>79.2</td>
<td>85.4</td>
</tr>
<tr>
<td>L</td>
<td>92</td>
<td>92</td>
</tr>
<tr>
<td>M</td>
<td>78</td>
<td>85.4</td>
</tr>
</tbody>
</table>

**Design of Footing for Hollow Brick wall:**

Load from Wall = 78 kN/m

Load from wall (critical wall M) + 10% for the weight of the Building + weight of slab (hall, bed room & dining) + floor finish

= 78 + 7.8 + 4.6575 + 4.125 + 4.5635 + 1

= 100.236 kN/m

Factored load = 1.25 × 100 = 125 kN/m

1. Area of Footing = \( \frac{\text{Load}}{\text{SBC}} = \frac{125}{50} = 0.833 \text{ m}^2 \)

Assume SBC = 150 kN/m²

Consider 1m Length room

2. Minimum Width = \((2w+300)\) mm

= \((2 \times 200+300)\) = 700 mm

Provide Width of P.C.C = 700 mm

It is customary to provide 150 to 300 mm P.C.C thickness

Provide = 300 mm

The projection of P.C.C beyond the brick work should not be more than \(\frac{1}{2}\) of the thickness of P.C.C

= \(\frac{300}{2}\) = 150 mm

Actual work of Brick work = 700 – 300 = 400 mm

Brick work projection beyond the wall

Depth of the Brick work = 200 × 2 = 400 mm

These depth has to be Provided by means of series steps

The thickness of each step is given by hollow brick = 200 mm

**12 Design of Stair Case:**

**Length** = 4 m

**Live load** = 2 kN/m²

**Rise** = 150 mm

**Thread** = 250 mm

Using M20 Concrete and Fe415.

**Step 1: Calculation of self-weight**

Assume waist slab thickness = \(\frac{4000}{20}\) = 200 mm

D = 200 mm

Self-weight = \(\frac{D}{1000} \times \frac{\sqrt{R^2+T^2}}{T} \times 2\) = 5.83 kN/m² (4.6)

Self-weight is calculated by equation 4.6

Where,

\(D = \text{Diameter}\)

\(R = \text{Rise}\)

\(T = \text{Thread}\)

**Step 2: Calculation of load on waist slab**

1. Assume 40 mm Floor finish

Floor Finish = \(\frac{40}{1000} \times 24 = \frac{1}{\text{kN/m}^2}\)

2. Weight of steps = \(\frac{1}{2} \times R \times T \times \frac{1}{25} = 1.875 \text{ kN/m}^2\)
3. Live load \( = 3 \text{kN/m}^2 \)

4. Self weight \( = 5.83 \text{kN/m}^2 \)

\( W_a = 11.075 \text{kN/m}^2 \)

\( W_o = 1.5 \times 11.075 = 17.55 \text{kN/m}^2 \)

**Step 3: Calculation of** \( M_u \)

\[
M_u = \frac{17.55 \times 16}{0.36 \times X_{u \text{max}} \left( 1 - 0.42 \times X_{u \text{max}} \right)} \text{kN.m}
\]

\[
M_{u, \text{lim}} = 0.36 \times 0.48 \times 1000 \times d^2 = 113 \text{ mm}
\]

Assume clear cover 20 mm

Diameter of bar = 20 mm

D = 113 + 20 + 10 = 143 mm

D = 150 mm (approximately)

\( d = 150 - 20 - 10 = 120 \text{ mm} \)

**Step 4: Calculation of** \( A_{st} \)

\[
R = \frac{35 \times 10^6}{1000 \times 120 \times 120} = 2.43
\]

\[
A_{st} = \frac{2 \times 415}{970.6} = 970.6 \text{ mm}^2
\]

Number of Bars = \[
\frac{970.6}{4 \times 20^2} = 4 \text{ bars}
\]

\[
A_{st \text{ actual}} = 4 \times \pi \left( \frac{20}{4} \right)^2 \times 1000 = 1256 \text{ mm}^2
\]

\[
P_t = \frac{A_{st}}{bd} \times 1000 = \frac{1256}{1000 \times 120} \times 1000 = 1.04\%
\]

**Step 5: Check for deflection**

Basic value = 20

\[
F_s = 0.58f_y \times \frac{A_{st \text{ required}}}{A_{st \text{ provided}}} = 0.58 \times 415 \times \frac{970}{1256} = 185.89 \text{ N/mm}^2
\]

For \( P_t = 1.04\% \), Modification factor = 1.2 (Fig 4 of IS 456-2000)

\[
d_{\text{required}} = \frac{4000}{1.2 \times 32} = 104.166 \text{ mm}
\]

\[
d_{\text{actual}} = 120 \text{ mm}
\]

**Step 6: Providing distribution steel**

\[
A_{st min} = \frac{0.122bd}{100} \times \frac{0.12 \times 1000 \times 150}{100} = 480 \text{ mm}^2
\]

Spacing of 8 mm diameter = \[
\frac{1000 \times \pi}{4 \times 8} = 270 \text{ mm}
\]

Main steel = 4 No.s 20 bars

Distribution = 8 mm diabars @ 270 mm c/c
Table 1.7

<table>
<thead>
<tr>
<th>PARTICULARS</th>
<th>ITEMS</th>
<th>UNITS</th>
<th>USAGE IN(HRS)</th>
<th>VOLTAGE(W)</th>
<th>CONSUMPTION</th>
<th>INVERTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>HALL</td>
<td>CFL (Ref 13)</td>
<td>4</td>
<td>5</td>
<td>20</td>
<td>400</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>FAN</td>
<td>2</td>
<td>5</td>
<td>50</td>
<td>500</td>
<td>100</td>
</tr>
<tr>
<td>BED ROOM 1</td>
<td>T.V</td>
<td>1</td>
<td>5</td>
<td>80</td>
<td>400</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>CFL</td>
<td>2</td>
<td>3</td>
<td>15</td>
<td>90</td>
<td>30</td>
</tr>
<tr>
<td>BED ROOM 2</td>
<td>FAN</td>
<td>1</td>
<td>10</td>
<td>50</td>
<td>500</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>CFL</td>
<td>2</td>
<td>3</td>
<td>15</td>
<td>90</td>
<td>30</td>
</tr>
<tr>
<td>KITCHEN</td>
<td>OVEN</td>
<td>1</td>
<td>1</td>
<td>900</td>
<td>900</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>CFL</td>
<td>3</td>
<td>4</td>
<td>15</td>
<td>180</td>
<td>45</td>
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<tr>
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<td>50</td>
<td>200</td>
<td>50</td>
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<td>Mixer</td>
<td>1</td>
<td>1</td>
<td>450</td>
<td>450</td>
<td>450</td>
</tr>
<tr>
<td>DINING ROOM</td>
<td>AUTO - FRIDGE</td>
<td>1</td>
<td>18</td>
<td>150</td>
<td>2700</td>
<td>195</td>
</tr>
<tr>
<td></td>
<td>CFL</td>
<td>3</td>
<td>4</td>
<td>15</td>
<td>180</td>
<td>45</td>
</tr>
<tr>
<td>TOILET 1</td>
<td>FAN</td>
<td>1</td>
<td>3</td>
<td>50</td>
<td>150</td>
<td>50</td>
</tr>
<tr>
<td>TOILET 2</td>
<td>HEATER</td>
<td>1</td>
<td>1</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>WATER PUMP</td>
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<td>1</td>
<td>750</td>
<td>750</td>
<td>750</td>
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<tr>
<td>WASHING</td>
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<td>1</td>
<td>2</td>
<td>90</td>
<td>180</td>
<td>90</td>
</tr>
<tr>
<td>MACHINE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>8365</td>
<td>3175</td>
<td></td>
</tr>
</tbody>
</table>

DESIGN OF SOLAR PANEL AND ITS COMPONENTS:

Designing of Solar Panel

Power rating of each appliance that will be drawing power from the system. The calculation of loads for the Solar Panels are given below in Table 1.7

Power Inverter Sizing

Appliance total power draw = 3175 W

To provide a small buffer or margin your minimum size inverter choice should be around 3500W.

A modified sine wave inverter with a 3500W continuous power rating will therefore be your obvious choice in this specific solar system design.

Determining the Size and Number Of Solar Panels

Divide the total daily power requirement by the number of charge hours for that geographic region eg. (8365×1.2)/6=1673 WATTS

250 Watt Solar Panel

\[
\text{Total watt/ 250 watt solar panel} = \frac{1673}{250} = 7 \text{ PANELS}
\]

= 7 x 250W panels.

Number of Batteries

250W panels produce 4.8Amps, thus 14x 4.8 A = 67.2A x 6 Hrs

= 403.2.Ah

105Ah batteries, should be discharged to no more than 50%, thus we divide total amps by 105A x 50% = 50Ah

\[
\frac{403.2}{50} = 8.08 \times 105\text{Ah batteries.}
\]

For ease of possible 24V or 48V configuration, this would mean 3 in series of 3 batteries.
Size of Regulators

Let’s say we had 20A regulators at our disposal.

One 250W panel produces around 4.8Amps.

The regulators are put in series

\[ 14 \times 4.8A = 67.2 \]

So 14 solar panels would need 4 x 20A solar regulators.

Complete the solar power system

Well we have the following:

i. 7x2x 250W solar panels

ii. 4 x 20A solar regulators

iii. x 105A.H deep cycle batteries (3 in series)

1 x 3500W modified sine wave power inverter.

RATE ANALYSIS:

Solar panels = Rs.32/W
Regulator = Rs 1800
Batteries = Rs 8000/series
Inverter = Rs 4800

Total Cost

Solar panels = 14x250x32 = Rs 112000
Regulator = Rs 1800
Batteries = 8000x3 = 24000 = Rs 24000
Inverter = Rs 4800

Total = 112000 + 1800 + 24000 + 4800 = Rs. 142600/-

CHARACTERISTICS OF HOLLOW BRICKS:

Parameters of Hollow Brick Used In Net Zero Energy Residential Building

I. LENGTH : 400 mm
II. WIDTH : 200 mm
III. HEIGHT: 200 mm
IV. WEIGHT: 11.1 kg
V. DENSITY: 694 kg/m³
VI. COMpressive STRENGTH : 4.1 \( \frac{N}{mm^2} \)
VII. WATER ABSORPTION : 15%
VIII. U-VALUE : 1.1 W/m²
IX. SOUND INSULATION : 46 DB
X. FIRE RESISTANCE 240 min

Available Sizes

I. 400 X 200 X 200 mm
II. 400 X 150 X 200 mm
III. 400 X 100 X 200 mm
IV. 200 X 200 X 200 mm
V. 200X 150 X 200 mm
VI. 200 X 100 X 200 mm
Hollow Brick

Bigger Size
I. Hollow brick is same in size as that of concrete blocks
II. 1 Hollow brick = 9 Clay Bricks
III. Less mortar joints, hence less plumb & alignment
IV. Faster construction

Light Weight
I. Ease of handling, Transportation
II. Saves labour
III. Less dead load, Savings in Structural Cost
IV. (Steel & Concrete) by 10 to 15%

Thermal Insulation
I. Savings on mortar
II. Low ‘U’ Values – 1.0 W/m²
III. Better Thermal Insulation = less energy loss through walls
IV. Savings on Energy consumption, Comfortable inside temperature

U-value determines thermal Insulation. Lesser the Value higher the Insulation and vice versa. U-values are mentioned in Figure 3
ESTIMATION:
Abstract estimate of conventional building

<table>
<thead>
<tr>
<th>S.No</th>
<th>Description</th>
<th>Nos</th>
<th>Length (m)</th>
<th>Breadth (m)</th>
<th>Depth (m)</th>
<th>Quantity (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Excavation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exterior wall</td>
<td>1</td>
<td>39.48</td>
<td>0.76</td>
<td>0.53</td>
<td>15.9</td>
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<tr>
<td></td>
<td>Interior wall</td>
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<td>0.76</td>
<td>0.53</td>
<td>9.06</td>
</tr>
<tr>
<td>2</td>
<td>P.C.C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exterior wall</td>
<td>1</td>
<td>39.48</td>
<td>0.76</td>
<td>0.3</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Interior wall</td>
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4 Earth Filling

|                          |     |      |     |     |        |
| Hall                     | 1   | 3.03 | 4.87| 0.5 | 7.378  |
| Water closet             | 1   | 3.62 | 2.15| 0.5 | 3.89   |
| Bed Room1                | 1   | 3.62 | 3.72| 0.5 | 6.73   |
| Bed Room2                | 1   | 3.5  | 3   | 0.5  | 5.25   |
| Dinning                  | 1   | 3.5  | 2.37| 0.5  | 4.147  |
| Kitchen                  | 1   | 3.5  | 2.6 | 0.5  | 4.55   |

5 Flooring Concrete

|                          |     |      |     |     |        |
| Hall                     | 1   | 3.03 | 4.87| 0.1 | 1.48   |
| Water closet             | 1   | 3.62 | 2.15| 0.1 | 0.778  |
| Bed Room1                | 1   | 3.62 | 3.72| 0.1 | 1.346  |
| Bed Room2                | 1   | 3.5  | 3   | 0.1  | 1.05   |
| Dinning                  | 1   | 3.5  | 2.37| 0.1  | 0.829  |
| Kitchen                  | 1   | 3.5  | 2.6 | 0.1  | 0.91   |

6 R.C.C

|                          |     |      |     |     |        |
| Door D                   | 1×2 | 1.4  | 0.23| 0.15| 0.0684 |
| Door D1                  | 1×3 | 1.05 | 0.23| 0.15| 0.0945 |
| Door D2                  | 1   | 1.2  | 0.23| 0.15| 0.036  |
| Sun Shade                | 1   | 1.2  | 0.45| 0.075| 0.0405 |
| Window W                 | 1×2 | 1.52 | 0.23| 0.15| 0.07512|
| Sun Shade                | 1×2 | 1.52 | 0.45| 0.075| 0.1026 |
| Window W1                | 1×5 | 1.52 | 0.23| 0.15| 0.228  |
| Sun Shade                | 1×5 | 1.52 | 0.45| 0.075| 0.0256 |
| Window W2                | 1×2 | 1.2  | 0.23| 0.15| 0.072  |
| Sun Shade                | 1×2 | 1.2  | 0.45| 0.075| 0.081  |

| Roof Slab                |     |      |     |     |        |
| Hall, Water Closet, Bed Room1 | 1 | 6.65 | 4.87| 0.1 | 3.24   |
| Bed Room2,Dinning,Kitchen | 1   | 3.5  | 7.97| 0.1  | 2.79   |

7 Plastering

|                          |     |      |     |     |        |
| Exterior wall            | 1   | 39.24| -    | 7.5  | 294.3  |
| Interior wall            | 1   | 22.51| -    | 7.5  | 168.82 |

| Deductions              |     |      |     |     |        |
| Window W1               | 1×2 | 1.22 | -   | 0.9  | 2.196  |
| Window W2               | 1×5 | 1.22 | -   | 1.22 | 7.442  |
| Window W3               | 1×2 | 0.9  | -   | 1.21 | 2.178  |
| Door D                  | 1×2 | 0.84 | -   | 2.1  | 3.528  |
| Door D1                 | 1×3 | 0.75 | -   | 2    | 4.5    |
| Door D2                 | 1   | 0.9  | -   | 2.1  | 1.89   |
| Spacing S               | 1   | 1.2  | -   | 2.08 | 2.496  |
| Spacing S1              | 1   | 0.9  | -   | 2.1  | 1.89   |

8 White Washing

|                          |     |      |     |     |        |
|                        | -   | -    | -   | -    | 437    |

9 Colour Washing

|                          |     |      |     |     |        |
|                        | -   | -    | -   | -    | 437    |
Rate Analysis: Rates Proposed Conventional Building

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Proposed NZERB Building

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<td>35.00</td>
<td>Cft</td>
<td>39158.00</td>
</tr>
<tr>
<td>3</td>
<td>PCC 1:5:10,</td>
<td>12.96</td>
<td>458.10</td>
<td>90.00</td>
<td>Cft</td>
<td>41229.00</td>
</tr>
<tr>
<td>4</td>
<td>Brick Work in C.M. 1:5, using country brick For Basement level</td>
<td>95.50</td>
<td>3376.00</td>
<td>125.00</td>
<td>Cft</td>
<td>422000.00</td>
</tr>
<tr>
<td>5</td>
<td>Flooring Work</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PCC 1:4:8</td>
<td>5.50</td>
<td>194.23</td>
<td>90.00</td>
<td>Cft</td>
<td>17480.50</td>
</tr>
<tr>
<td>6</td>
<td>R.C.C (LINTEL,SUNSHADES &amp; ROOF SLAB)</td>
<td>6.84</td>
<td>241.55</td>
<td>350.00</td>
<td>Cft</td>
<td>84542.50</td>
</tr>
<tr>
<td>7</td>
<td>Plastering in C.M 1:4, Inside and outside wall surface</td>
<td>463.12</td>
<td>16371.29</td>
<td>30.00</td>
<td>Sft</td>
<td>491139.00</td>
</tr>
</tbody>
</table>
VI. CONCLUSION:
In this research we have completed the design of the Conventional building by using modular bricks and Net Zero Energy Residential Building by using Hollow Brick. The plan of the building was prepared by Auto-Cad software. IS 456:2000code book was used to design Slab and Footing. Design of wall was done by using IS 1905:1987. The Comparison of the Conventional Building and NZERB was completed by using the parameters such as the temperature by using instrument infrared thermometer which was found to be 4°C less in NZERB compared to conventional building under same condition. Hence by using the renewable resources the impact on the active energy loads can be reduced, thus we can conserve electricity locally and globally.

REFERENCES
4. National Building Code of India (NBC) and Jammu Development Authority (JDA).