Investigation of Dynamic Thermal Parameters of Various Insulation Filled Bricks Exposed to Periodic Thermal Variations for Energy Efficient Stuffed Bricks Design

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CONTENTS

1. Introduction

2. Objectives

3. Unsteady thermal response characteristics & cyclic admittance method

4. Thermal performance of Stuffed bricks exposed to sinusoidal solar thermal excitation

5. Conclusion

6. References
1. INTRODUCTION

Fig. 1.1 YEARLY GLOBAL WARMING
Fig.1.2 ICE MELTING IN ARCTIC CIRCLE
Solar-Passive Building Design

- Thermal comfort
  - Reduce energy demand of Space-Conditioning
- Visual comfort
  - Reduce energy demand of Artificial lighting

Reduction in energy consumption and GHG emission

Fig. 1.3 Solar Passive Building Design Elements
2. OBJECTIVES

1. ENERGY EFFICIENT STUFFED BRICK AND INSULATION MATERIALS.

2. UNSTEADY STATE THERMAL CHARACTERISTICS OF FIVE BRICK MATERIALS.

3. THE EFFECT OF INSULATION FILLS IN STUFFED BRICKS ON UNSTEADY STATE THERMAL CHARACTERISTICS.

4. OPTIMUM INSULATION LAYERS IN STUFFED BRICKS
3. UNSTEADY THERMAL RESPONSE CHARACTERISTICS & CYCLIC ADMITTANCE PROCEDURE

Fig. 3.1 THERMAL MASS
THERMAL INSULATION AND THERMAL MASS
Fig. 3.2 THERMAL TRANSMITTANCE AND ADMITTANCE
**Fig. 3.3 DECREMENT FACTOR AND TIME LAG**

- Decrement Factor
- Decremental Time lag (6-12 h)
Fig. 3.4 THE SCHEMATIC REPRESENTATION OF TIME LAG AND DECREMENT FACTOR

One Dimensional Diffusion Equation:
\[
\frac{\partial^2 T(X, t)}{\partial X^2} = \frac{\rho C_p}{k} \frac{\partial T(X, t)}{\partial t}
\]  
\[
3.1
\]

With Boundary Conditions:
\[
k \left( \frac{\partial T}{\partial x} \right)_{x=0} = h_i [T_{x=0}(t) - T_i]
\]  
\[
3.2
\]
\[
k \left( \frac{\partial T}{\partial x} \right)_{x=L} = h_0 [T_{sa}(t) - T_{x=L}(t)]
\]  
\[
3.3
\]
**Space/Time Independent Solutions (Davies M.G., 2004):**

\[ T(x, t) = A \exp \left( \frac{x}{\xi} \right) \exp \left( \frac{t}{\zeta} \right) \]

\( \xi \) and \( \zeta \) are properties of the system, they have units of distance and time respectively.

The above equation satisfies the Fourier equation if,

\[ \xi^2 = \kappa \zeta \]

Value of \( \zeta \) leads to different solutions.

If \( \zeta \) is taken equal to \(-z\) (where \( z \) is real and positive)
then imposition of boundary conditions on a finite thickness slab gives
“**TRANSIENT SOLUTION**”.

If \( \zeta \) is an imaginary number and equal to \( P/(j2\pi) \) (where \( j = \sqrt{-1} \))
then imposition of periodic convective boundary conditions on a finite thickness slab gives
“**PERIODIC SOLUTION**” with sinusoidal excitation with Period \( P \).
The Periodic Solution (Davies M.G., 2004)

\[ T(x, t) = A \exp\left(\frac{x}{\xi}\right) \exp\left(\frac{t}{\zeta}\right) \]

Condition to be satisfied is \( \xi^2 = \alpha \zeta \) \( \text{Where Diffusivity } \alpha = k/\rho C_p \)

For Periodic Solution, \( \zeta = P/(j2\pi) \)

i.e., \( \xi^2 = \kappa \left(\frac{P}{(j2\pi)}\right) \)

\[ \frac{x}{\xi} = \frac{x}{\pm (\kappa P/j2\pi)^{1/2}} = \pm (i + j) \left(\frac{\pi \rho c_p x^2}{\lambda P}\right)^{1/2} \]

\[ = \pm (1 + j) \beta x \]

Where, \( \beta = \sqrt{\frac{\pi \rho c_p}{\lambda P}} \)

Solution to the Fourier Equation is,

\[ T(x, t) = [A' \exp(\beta x + j\beta x) + B' \exp(-\beta x - j\beta x)] \exp(j2\pi t/P) \]

\[ = [A \sinh(\beta x + j\beta x) + B \cosh(\beta x + j\beta x)] \exp(j2\pi t/P) \]
\[ T_0 = T_1 \cosh(z + jz) + q_1 \left( \frac{\sinh(z + jz)}{a} \right) \]

\[ q_0 = T_1 \left( \sinh(z + jz) \right) \times a \]

\[ + q_1 \cosh(z + jz) \]

Arranging the above terms in the Matrix form i.e.,

\[
\begin{bmatrix}
T_0 \\
q_0
\end{bmatrix} = \begin{bmatrix}
\cosh(z + jz) & \left( \frac{\sinh(z + jz)}{a} \right) \\
\left( \sinh(z + jz) \right) \times a & \cosh(z + jz)
\end{bmatrix}
\begin{bmatrix}
T_1 \\
q_1
\end{bmatrix}
\]

Where

\[ z^2 = \frac{\pi \rho c_p X^2}{\lambda P} = \frac{\pi c r}{P} \]

\[ a^2 = j2\pi \lambda \rho c_p / P = j2\pi c / rP \]

\[ z = \text{Cyclic thickness of the slab, dimensionless but effectively in radians} \]

\[ a = \text{Characteristic Admittance of slab in W/m}^2 \text{ K} \]
### Values of Hyperbolic Functions in Cartesian form:

<table>
<thead>
<tr>
<th></th>
<th>( \cosh(z + jz) )</th>
<th>( \sinh(z + jz)/a )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Real</strong></td>
<td>( \cosh(z) \cos(z) )</td>
<td>( \cosh(z) \sin(z) )</td>
</tr>
<tr>
<td><strong>Imaginary</strong></td>
<td>( j \sinh(z) \sin(z) )</td>
<td>( j \left[ \cosh(z) \sin(z) - \sinh(z) \cos(z) \right]/(a\sqrt{2}) )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>( \sinh(z + jz).a )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Real</strong></td>
<td>( \left[ -\cosh(z) \sin(z) + \sinh(z) \cos(z) \right].a/\sqrt{2} )</td>
</tr>
<tr>
<td><strong>Imaginary</strong></td>
<td>( j \left[ \cosh(z) \sin(z) + \sinh(z) \cos(z) \right].a/\sqrt{2} )</td>
</tr>
</tbody>
</table>
Let,

\[ A = \cosh(z) \cos(z) \]

\[ B = \sinh(z) \sin(z) \]

\[ C = \left[ \cosh(z) \sin(z) + \sinh(z) \cos(z) \right]/(\sqrt{2}) \]

\[ D = \left[ \cosh(z) \sin(z) - \sinh(z) \cos(z) \right]/(\sqrt{2}) \]

Then The Matrix of a single layer has the form

\[
\begin{bmatrix}
A + jB & (C + jD)/a \\
(-D + jC).a & A + jB
\end{bmatrix}
\]
Fig. 3.5 SINGLE CAPACITY CIRCUIT

\[
\begin{bmatrix}
T_e \\
q_e
\end{bmatrix} = 
\begin{bmatrix}
1 & r_1 \\
0 & 1
\end{bmatrix} 
\begin{bmatrix}
m_1 & m_2 & m_3 & m_4 \\
n_1 & n_2 & n_3 & n_4 \\
1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1
\end{bmatrix}
\begin{bmatrix}
t_i \\
q_i
\end{bmatrix}
\]

\[
\begin{bmatrix}
T_e \\
q_e
\end{bmatrix} = 
\begin{bmatrix}
M_1 & M_2 \\
M_3 & M_4
\end{bmatrix}
\begin{bmatrix}
t_i \\
q_i
\end{bmatrix}
\]

m, n are no. of layers of the wall and M1, M2, M3 and M4 are components of the matrix.
Unsteady state Thermal Characteristics of the wall (CIBSE., 2006):

Thermal Admittance, \( Y \).

\[
y_c = \left( \frac{q_i}{\theta_i} \right)_{t_e=0} = -M_1/M_2
\]

\[ Y = |y_c| \] \( \rightarrow 3.19 \)

Decrement Factor, \( f \).

\[
f_c = -\frac{1}{UM_2}
\]

\[ f = |f_c| \] \( \rightarrow 3.21 \)

Decremental time lag, \( \phi \).

\[
\phi = \frac{12}{\pi} \arctan \left( \frac{\text{Im}(f_c)}{\text{Re}(f_c)} \right)
\]

\( \rightarrow 3.23 \)

Areal Thermal heat capacity, \( \chi \).

\[
\chi = \frac{t}{2\pi} \left| \frac{M_4 - 1}{M_2} \right|
\]

\( \rightarrow 3.24 \)
GRAPHICAL USER INTERFACE
COMPUTER PROGRAM
For
Unsteady State Thermal Characteristics of
Homogeneous & Composite Walls
A SOFTWARE FOR UNSTEADY STATE THERMAL CHARACTERISTICS OF THE WALL

By

S. SABOOR
(Research Scholar)

Under The Guidance of Prof. T. P. ASHOK BABU

Department of Mechanical Engineering National Institute of Technology Karnataka Surathkal -575025
4. THERMAL PERFORMANCE OF STUFFED BRICKS EXPOSED TO SINUSOIDAL SOLAR THERMAL EXCITATION

Table 4.1 Thermo physical properties of the brick materials

<table>
<thead>
<tr>
<th>Brick material</th>
<th>Code</th>
<th>k</th>
<th>ρ</th>
<th>Cp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mud brick</td>
<td>B-1 (MB)</td>
<td>0.75</td>
<td>1731</td>
<td>880</td>
</tr>
<tr>
<td>Burnt brick</td>
<td>B-2 (BB)</td>
<td>0.811</td>
<td>1820</td>
<td>880</td>
</tr>
<tr>
<td>Concrete block</td>
<td>B-3 (CB)</td>
<td>1.74</td>
<td>2410</td>
<td>880</td>
</tr>
<tr>
<td>Fly ash brick</td>
<td>B-4 (FAB)</td>
<td>0.360</td>
<td>1700</td>
<td>857</td>
</tr>
<tr>
<td>Foam glass</td>
<td>I-1 (FG)</td>
<td>0.055</td>
<td>160</td>
<td>750</td>
</tr>
<tr>
<td>Asbestos fiber</td>
<td>1-2 (AF)</td>
<td>0.06</td>
<td>640</td>
<td>840</td>
</tr>
</tbody>
</table>

Figure 4.1 Configurations of the bricks (All dimensions are in “m”)
### Table 4.2 Mud brick with foam glass insulation material

<table>
<thead>
<tr>
<th>MB with FG Configuration</th>
<th>U (W/m²K)</th>
<th>f</th>
<th>ϕ (h)</th>
<th>Y (W/m²K)</th>
<th>ω (h)</th>
<th>χ (J/m²K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC-1</td>
<td>2.8048</td>
<td>0.75336</td>
<td>3.9118</td>
<td>4.2737</td>
<td>1.4119</td>
<td>60797</td>
</tr>
<tr>
<td>BC-2</td>
<td>0.4525</td>
<td>0.9386</td>
<td>2.5657</td>
<td>1.8469</td>
<td>4.0568</td>
<td>29867</td>
</tr>
<tr>
<td>BC-3</td>
<td>0.4899</td>
<td>0.7764</td>
<td>4.0292</td>
<td>1.9555</td>
<td>3.7253</td>
<td>33034</td>
</tr>
<tr>
<td>BC-4</td>
<td>0.5339</td>
<td>0.7019</td>
<td>5.0626</td>
<td>2.1046</td>
<td>3.4474</td>
<td>36459</td>
</tr>
<tr>
<td>BC-5</td>
<td>0.5867</td>
<td>0.6519</td>
<td>5.7125</td>
<td>2.2575</td>
<td>3.2165</td>
<td>39883</td>
</tr>
<tr>
<td>BC-6</td>
<td>0.6511</td>
<td>0.6184</td>
<td>6.1351</td>
<td>2.4142</td>
<td>3.0153</td>
<td>43478</td>
</tr>
</tbody>
</table>

### Table 4.3 Burnt brick with foam glass insulation material

<table>
<thead>
<tr>
<th>BB with FG Configuration</th>
<th>U (W/m²K)</th>
<th>f</th>
<th>ϕ (h)</th>
<th>Y (W/m²K)</th>
<th>ω (h)</th>
<th>χ (J/m²K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC-1</td>
<td>2.9197</td>
<td>0.74693</td>
<td>3.9355</td>
<td>4.4045</td>
<td>1.3641</td>
<td>62491</td>
</tr>
<tr>
<td>BC-2</td>
<td>0.4531</td>
<td>0.9362</td>
<td>2.6091</td>
<td>1.9177</td>
<td>4.0603</td>
<td>31051</td>
</tr>
<tr>
<td>BC-3</td>
<td>0.4908</td>
<td>0.7644</td>
<td>4.2029</td>
<td>2.0250</td>
<td>3.7233</td>
<td>34235</td>
</tr>
<tr>
<td>BC-4</td>
<td>0.5354</td>
<td>0.6865</td>
<td>5.2147</td>
<td>2.1742</td>
<td>3.4395</td>
<td>37688</td>
</tr>
<tr>
<td>BC-5</td>
<td>0.5888</td>
<td>0.6349</td>
<td>5.8896</td>
<td>2.3278</td>
<td>3.2043</td>
<td>41151</td>
</tr>
<tr>
<td>BC-6</td>
<td>0.6541</td>
<td>0.6006</td>
<td>6.3261</td>
<td>2.4858</td>
<td>2.9999</td>
<td>44809</td>
</tr>
</tbody>
</table>

### Table 4.4 Concrete brick with foam glass insulation material

<table>
<thead>
<tr>
<th>CB with FG Configuration</th>
<th>U (W/m²K)</th>
<th>f</th>
<th>ϕ (h)</th>
<th>Y (W/m²K)</th>
<th>ω (h)</th>
<th>χ (J/m²K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC-1</td>
<td>3.9947</td>
<td>0.73609</td>
<td>3.6727</td>
<td>5.3355</td>
<td>0.98347</td>
<td>70521</td>
</tr>
<tr>
<td>BC-2</td>
<td>0.4572</td>
<td>0.9196</td>
<td>2.8710</td>
<td>2.3803</td>
<td>4.0335</td>
<td>38878</td>
</tr>
<tr>
<td>BC-3</td>
<td>0.4973</td>
<td>0.6877</td>
<td>4.8589</td>
<td>2.4692</td>
<td>3.6794</td>
<td>41928</td>
</tr>
<tr>
<td>BC-4</td>
<td>0.5450</td>
<td>0.5921</td>
<td>6.1191</td>
<td>2.6108</td>
<td>3.3733</td>
<td>45397</td>
</tr>
<tr>
<td>BC-5</td>
<td>0.6028</td>
<td>0.5342</td>
<td>6.9372</td>
<td>2.7634</td>
<td>3.1219</td>
<td>49033</td>
</tr>
<tr>
<td>BC-6</td>
<td>0.6744</td>
<td>0.4987</td>
<td>7.4480</td>
<td>2.9257</td>
<td>2.9038</td>
<td>53053</td>
</tr>
</tbody>
</table>
### Table 4.5 Fly ash brick with foam glass insulation material

<table>
<thead>
<tr>
<th>Configuration</th>
<th>U (W/m²K)</th>
<th>f</th>
<th>ϕ (h)</th>
<th>Y (W/m²K)</th>
<th>ω (h)</th>
<th>χ (J/m²K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC-1</td>
<td>1.7897</td>
<td>0.6400</td>
<td>5.34</td>
<td>3.6448</td>
<td>1.764</td>
<td>56658</td>
</tr>
<tr>
<td>BC-2</td>
<td>0.4438</td>
<td>0.9344</td>
<td>2.6821</td>
<td>1.7703</td>
<td>4.0152</td>
<td>28722</td>
</tr>
<tr>
<td>BC-3</td>
<td>0.4764</td>
<td>0.7760</td>
<td>4.1785</td>
<td>1.8725</td>
<td>3.6895</td>
<td>31644</td>
</tr>
<tr>
<td>BC-4</td>
<td>0.5141</td>
<td>0.6990</td>
<td>5.1548</td>
<td>2.0099</td>
<td>3.4177</td>
<td>34747</td>
</tr>
<tr>
<td>BC-5</td>
<td>0.5583</td>
<td>0.6448</td>
<td>5.8348</td>
<td>2.1480</td>
<td>3.1928</td>
<td>37764</td>
</tr>
<tr>
<td>BC-6</td>
<td>0.6109</td>
<td>0.6060</td>
<td>6.3065</td>
<td>2.2865</td>
<td>2.9984</td>
<td>40839</td>
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</table>

### Table 4.6 Mud brick with asbestos fiber insulation material

<table>
<thead>
<tr>
<th>Configuration</th>
<th>U (W/m²K)</th>
<th>f</th>
<th>ϕ (h)</th>
<th>Y (W/m²K)</th>
<th>ω (h)</th>
<th>χ (J/m²K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC-1</td>
<td>2.8048</td>
<td>0.7533</td>
<td>3.9118</td>
<td>4.2737</td>
<td>1.4119</td>
<td>60797</td>
</tr>
<tr>
<td>BC-2</td>
<td>0.4894</td>
<td>0.6513</td>
<td>6.3317</td>
<td>2.4181</td>
<td>3.3967</td>
<td>41956</td>
</tr>
<tr>
<td>BC-3</td>
<td>0.5291</td>
<td>0.5658</td>
<td>6.7176</td>
<td>2.3838</td>
<td>3.2561</td>
<td>41452</td>
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<tr>
<td>BC-4</td>
<td>0.5759</td>
<td>0.5377</td>
<td>7.0252</td>
<td>2.4437</td>
<td>3.0710</td>
<td>43079</td>
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<tr>
<td>BC-5</td>
<td>0.6316</td>
<td>0.5270</td>
<td>7.1740</td>
<td>2.5391</td>
<td>2.9136</td>
<td>45498</td>
</tr>
<tr>
<td>BC-6</td>
<td>0.6994</td>
<td>0.5255</td>
<td>7.1997</td>
<td>2.6534</td>
<td>2.7718</td>
<td>48446</td>
</tr>
</tbody>
</table>

### Table 4.7 Burnt brick with asbestos fiber insulation material

<table>
<thead>
<tr>
<th>Configuration</th>
<th>U (W/m²K)</th>
<th>f</th>
<th>ϕ (h)</th>
<th>Y (W/m²K)</th>
<th>ω (h)</th>
<th>χ (J/m²K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC-1</td>
<td>2.9197</td>
<td>0.7469</td>
<td>3.9355</td>
<td>4.4045</td>
<td>1.3641</td>
<td>62491.44</td>
</tr>
<tr>
<td>BC-2</td>
<td>0.4901</td>
<td>0.6504</td>
<td>6.3650</td>
<td>2.4806</td>
<td>3.4052</td>
<td>43053</td>
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<tr>
<td>BC-3</td>
<td>0.5303</td>
<td>0.5584</td>
<td>6.7915</td>
<td>2.4429</td>
<td>3.2632</td>
<td>42468</td>
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<tr>
<td>BC-4</td>
<td>0.5775</td>
<td>0.5275</td>
<td>7.1358</td>
<td>2.5027</td>
<td>3.0729</td>
<td>44115</td>
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<tr>
<td>BC-5</td>
<td>0.6340</td>
<td>0.5150</td>
<td>7.3104</td>
<td>2.5999</td>
<td>2.9103</td>
<td>46599</td>
</tr>
<tr>
<td>BC-6</td>
<td>0.7028</td>
<td>0.5123</td>
<td>7.3535</td>
<td>2.7168</td>
<td>2.7639</td>
<td>49643</td>
</tr>
</tbody>
</table>
### Table 4.8 Concrete brick with asbestos fibre insulation material

<table>
<thead>
<tr>
<th>Configuration</th>
<th>U (W/m²K)</th>
<th>f</th>
<th>(\phi) (h)</th>
<th>Y (W/m²K)</th>
<th>(\omega) (h)</th>
<th>(\chi) (J/m²K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC-1</td>
<td>3.9947</td>
<td>0.73609</td>
<td>3.6727</td>
<td>5.3355</td>
<td>0.9834</td>
<td>70521</td>
</tr>
<tr>
<td>BC-2</td>
<td>0.4949</td>
<td>0.6435</td>
<td>6.5613</td>
<td>2.8919</td>
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<td>50411</td>
</tr>
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<td>BC-3</td>
<td>0.5378</td>
<td>0.5123</td>
<td>7.2328</td>
<td>2.8303</td>
<td>3.2819</td>
<td>49238</td>
</tr>
<tr>
<td>BC-4</td>
<td>0.5887</td>
<td>0.4653</td>
<td>7.8014</td>
<td>2.8848</td>
<td>3.0674</td>
<td>50929</td>
</tr>
<tr>
<td>BC-5</td>
<td>0.6503</td>
<td>0.4441</td>
<td>8.1286</td>
<td>2.9887</td>
<td>2.8795</td>
<td>53766</td>
</tr>
<tr>
<td>BC-6</td>
<td>0.7263</td>
<td>0.4359</td>
<td>8.2666</td>
<td>3.1181</td>
<td>2.7090</td>
<td>57366</td>
</tr>
</tbody>
</table>

### Table 4.9 Fly ash brick with asbestos fibre insulation material

<table>
<thead>
<tr>
<th>Configuration</th>
<th>U (W/m²K)</th>
<th>f</th>
<th>(\phi) (h)</th>
<th>Y (W/m²K)</th>
<th>(\omega) (h)</th>
<th>(\chi) (J/m²K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC-1</td>
<td>1.7897</td>
<td>0.6400</td>
<td>5.34</td>
<td>3.6448</td>
<td>1.764</td>
<td>56658</td>
</tr>
<tr>
<td>BC-2</td>
<td>0.4793</td>
<td>0.6341</td>
<td>6.5313</td>
<td>2.3147</td>
<td>3.3238</td>
<td>40125</td>
</tr>
<tr>
<td>BC-3</td>
<td>0.5134</td>
<td>0.5548</td>
<td>6.9026</td>
<td>2.2827</td>
<td>3.1949</td>
<td>39608</td>
</tr>
<tr>
<td>BC-4</td>
<td>0.5529</td>
<td>0.5257</td>
<td>7.2138</td>
<td>2.3331</td>
<td>3.0231</td>
<td>40934</td>
</tr>
<tr>
<td>BC-5</td>
<td>0.5988</td>
<td>0.5119</td>
<td>7.3887</td>
<td>2.4137</td>
<td>2.8770</td>
<td>42917</td>
</tr>
<tr>
<td>BC-6</td>
<td>0.6532</td>
<td>0.5060</td>
<td>7.4591</td>
<td>2.5093</td>
<td>2.7461</td>
<td>45296</td>
</tr>
</tbody>
</table>
Figure 4.2 Admittance and Transmittance of insulated bricks with foam glass insulation

CB with FG (Y)=2.9257 W/m²K for BC-6
FAB with FG (Y)=2.28 W/m²K for BC-6

Figure 4.3 Admittance and Transmittance of insulated bricks with asbestos fiber insulation

CB with AF (Y)=3.1181 W/m²K for BC-6
FAB with AF (Y)=2.50 W/m²K for BC-6
Figure 4.4 Decrement factor of insulated bricks with foam glass insulation

CB with FG (f)= 0.4987 for BC-6
MB with FG (f)=0.6184 for BC-6

Figure 4.5 Decrement factor of insulated bricks with asbestos fibre insulation

CB with AF (f)= 0.4359 for BC-6
MB with AF (f)=0.525 for BC-6
Figure 4.6 Time lag of insulated bricks with foam glass insulation
CB with FG ($\phi$) = 7.44 h for BC-6
MB with FG ($\phi$) = 6.13 h for BC-6

Figure 4.7 Time lag of insulated bricks with asbestos fiber insulation
CB with AF ($\phi$) = 8.26 h for BC-6
MB with AF ($\phi$) = 7.19 h for BC-6
Figure 4.8 Areal thermal capacity of insulated bricks with foam glass insulation

CB with FG ($\chi$) = 53053 J/m²K for BC-6
FAB with FG ($\chi$)=40839 J/m²K for BC-6

Figure 4.9 Areal thermal capacity of insulated bricks with asbestos fiber insulation

CB with AF ($\chi$) = 57366 J/m²K for BC-6
FAB with AF ($\chi$)=45296 J/m²K for BC-6
5. CONCLUSION

The thermal admittance, decrement time lag and areal thermal heat capacity of the insulation filled bricks increase with the increase in the number of insulation layers in the bricks due to improved thermal mass. These enhanced dynamic parameters make the stuffed bricks more energy efficient than the ordinary solid bricks.

The decrement factor of the insulation filled bricks decreases with the increase in the number of insulation layers in the bricks. The lower decrement factor values are essential to reduce the effect of outdoor climatic changes on indoor conditions.
The concrete blocks with the shell of the bricks filled with five layers of asbestos fiber insulation offer the highest admittance (3.11W/m²K), the lowest decrement factor (0.435), the highest time lag values (8.26 h) and the highest areal thermal heat capacity (57366 J/m²K) among all insulation filled bricks studied.

Stuffed bricks with five foam glass insulation layers (BC-6) decrease the decrement factor of mud bricks, burnt bricks, dense concrete bricks and fly ash bricks by 17.91%, 35.84%, 45.76% and 35.14%, respectively as compared to the stuffed bricks with single foam glass insulation layer (BC-2).
Stuffed bricks with five foam glass insulation layers (BC-6) increase the time lag of mud bricks, burnt bricks, dense concrete bricks and fly ash bricks by 36.23%, 58.75%, 61.45% and 57.47%, respectively as compared to the stuffed bricks with single foam glass insulation layer (BC-2).

In hot regions, the wall thermal transmittance should be as low as possible and the wall admittance should be as high as possible whereas, In cold regions, the wall thermal transmittance should be as high as possible and the wall admittance should be as low as possible. For reducing cooling loads, the stuffed bricks are recommended and for reducing heating loads, the hollow bricks are recommended.
HOLLOW BRICKS Vs STUFFED BRICKS

### Hollow Bricks

- **CB Configuration**
  - C-a: U = 3.994 W/m²K, f = 0.736, ϕ = 3.672, Y = 5.335 W/m²K, χ = 70521 J/m²K
  - C-b: U = 2.630 W/m²K, f = 0.976, ϕ = 1.100, Y = 2.986 W/m²K
  - C-c: U = 1.802 W/m²K, f = 0.938, ϕ = 2.005, Y = 2.692 W/m²K
  - C-d: U = 1.376 W/m²K, f = 0.868, ϕ = 3.143, Y = 2.813 W/m²K
  - C-e: U = 1.110 W/m²K, f = 0.764, ϕ = 4.452, Y = 2.973 W/m²K
  - C-f: U = 0.930 W/m²K, f = 0.641, ϕ = 5.842, Y = 3.605 W/m²K

- **Hollow Bricks (For reducing heating loads)**

### Stuffed Bricks

- **CB with FG Configuration**
  - BC-1: U = 3.9947 W/m²K, f = 0.73609, ϕ = 3.6727, Y = 5.3355 W/m²K
  - BC-2: U = 0.4572 W/m²K, f = 0.9196, ϕ = 2.8710, Y = 2.3803 W/m²K
  - BC-3: U = 0.4973 W/m²K, f = 0.6977, ϕ = 4.8589, Y = 2.4692 W/m²K
  - BC-4: U = 0.5450 W/m²K, f = 0.5921, ϕ = 6.1191, Y = 2.6108 W/m²K
  - BC-5: U = 0.6028 W/m²K, f = 0.5342, ϕ = 6.9372, Y = 2.7634 W/m²K
  - BC-6: U = 0.6744 W/m²K, f = 0.4987, ϕ = 7.4480, Y = 2.9257 W/m²K

- **Stuffed Bricks (For reducing cooling loads)**

- **CB with AF Configuration**
  - BC-1: U = 3.9947 W/m²K, f = 0.73609, ϕ = 3.6727, Y = 5.3355 W/m²K
  - BC-2: U = 0.4949 W/m²K, f = 0.6435, ϕ = 6.5613, Y = 2.8919 W/m²K
  - BC-3: U = 0.5378 W/m²K, f = 0.5123, ϕ = 7.2328, Y = 2.8303 W/m²K
  - BC-4: U = 0.5887 W/m²K, f = 0.4653, ϕ = 7.8014, Y = 2.8848 W/m²K
  - BC-5: U = 0.6503 W/m²K, f = 0.4441, ϕ = 8.1286, Y = 2.9887 W/m²K
  - BC-6: U = 0.7263 W/m²K, f = 0.4359, ϕ = 8.2666, Y = 3.1181 W/m²K

### Graphs and Diagrams

- Graph showing sinusoidal solar temperature variation.
- Diagram illustrating direction of heat flow.
6. REFERENCES


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THANK YOU