

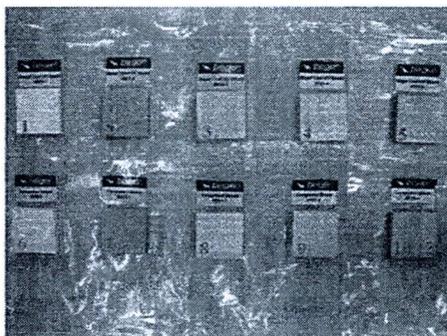
## **APPENDIX**

MTEC No. 2391/54



## Report of Sample Analysis

**Issued Date** : 24 May 2011  
**Customer** : Beger Company Limited.  
 90, 92 Bantudthong Rd., Rachatavee Bangkok 10400  
 Tel: 0-2611-3434 Fax: 0-2215-7320  
**Serviced by** : Thermal Analysis Laboratory,  
 Materials Characterization Research Unit,  
 National Metal and Materials Technology Center  
**Date received** : 20 May 2011  
**Date analyzed** : 20-24 May 2011  
**Samples** : Ten samples, as specified by customer and shown in the picture below.



- |                               |                             |
|-------------------------------|-----------------------------|
| 1. Beyer Cool UV Shield#000-1 | 6. Competitor Shield#000-1  |
| 2. Beyer Cool UV Shield#018-3 | 7. Competitor Shield#018-3  |
| 3. Beyer Cool UV Shield#054-2 | 8. Competitor Shield#054-2  |
| 4. Beyer Cool UV Shield#101-4 | 9. Competitor Shield#101-4  |
| 5. Beyer Cool UV Shield#115-4 | 10. Competitor Shield#115-4 |

**Objective** : To determine the thermal conductivity of the samples.  
**Instrument used** : Hot Disk Thermal Constant Analyser (Hot Disk AB)  
**Condition** : Room temperature  
 Disk type: Kapton Insulation  
 (Sensor No. C7577, Radius = 2.001 mm.)

MTEC No.2391/54

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**Results and Interpretation:**

Thermal conductivities of the sample are reported in the table below.

| Samples                         | Condition Used       |                    | Thermal Properties                         | Measurement Results        | Average | S.D.   |        |        |
|---------------------------------|----------------------|--------------------|--|----------------------------|---------|--------|--------|--------|
|                                 | Out Put of Power (W) | Measuring Time (s) |  |                            |         |        |        |        |
| 1. "Beger Cool UV Shield#000-1" | 0.03                 | 20                 | Thermal Conductivity (W / m K)             | 0.2369<br>0.2387<br>0.2387 | 0.2381  | 0.0010 |        |        |
|                                 |                      |                    | Thermal Diffusivity (mm <sup>2</sup> / s ) | 0.1417<br>0.1349<br>0.1283 |         |        | 0.1350 | 0.0067 |
|                                 |                      |                    | Specific Heat (MJ/m <sup>3</sup> K)        | 1.6720<br>1.7700<br>1.8610 |         |        |        |        |
| 2. "Beger Cool UV Shield#018-3" | 0.03                 | 20                 | Thermal Conductivity (W / m K)             | 0.2213<br>0.2205<br>0.2201 | 0.2206  | 0.0006 |        |        |
|                                 |                      |                    | Thermal Diffusivity (mm <sup>2</sup> / s ) | 0.1430<br>0.1374<br>0.1350 |         |        | 0.1385 | 0.0041 |
|                                 |                      |                    | Specific Heat (MJ/m <sup>3</sup> K)        | 1.5480<br>1.6050<br>1.6310 |         |        |        |        |
| 3. "Beger Cool UV Shield#054-2" | 0.03                 | 20                 | Thermal Conductivity (W / m K)             | 0.2251<br>0.2259<br>0.2259 | 0.2256  | 0.0005 |        |        |
|                                 |                      |                    | Thermal Diffusivity (mm <sup>2</sup> / s ) | 0.1397<br>0.1316<br>0.1365 |         |        | 0.1359 | 0.0041 |
|                                 |                      |                    | Specific Heat (MJ/m <sup>3</sup> K)        | 1.6120<br>1.7170<br>1.6550 |         |        |        |        |
| 4. "Beger Cool UV Shield#101-4" | 0.03                 | 20                 | Thermal Conductivity (W / m K)             | 0.2281<br>0.2296<br>0.2269 | 0.2282  | 0.0014 |        |        |
|                                 |                      |                    | Thermal Diffusivity (mm <sup>2</sup> / s ) | 0.1414<br>0.1331<br>0.1333 |         |        | 0.1359 | 0.0047 |
|                                 |                      |                    | Specific Heat (MJ/m <sup>3</sup> K)        | 1.6130<br>1.7250<br>1.7020 |         |        |        |        |

| Samples                         | Condition Used       |                    | Thermal Properties                       | Measurement Results        | Average | S.D.   |
|---------------------------------|----------------------|--------------------|--|----------------------------|---------|--------|
|                                 | Out Put of Power (W) | Measuring Time (s) |  |                            |         |        |
| 5. "Beger Cool UV Shield#115-4" | 0.03                 | 20                 | Thermal Conductivity (W / m K)           | 0.2238<br>0.2238<br>0.2241 | 0.2239  | 0.0002 |
|                                 |                      |                    | Thermal Diffusivity (mm <sup>2</sup> /s) | 0.1380<br>0.1326<br>0.1292 | 0.1333  | 0.0044 |
|                                 |                      |                    | Specific Heat (MJ/m <sup>3</sup> K)      | 1.6220<br>1.6880<br>1.7350 | 1.6817  | 0.0568 |
| 6. "Competitor Shield#000-1"    | 0.03                 | 25                 | Thermal Conductivity (W / m K)           | 0.2552<br>0.2550<br>0.2550 | 0.2551  | 0.0001 |
|                                 |                      |                    | Thermal Diffusivity (mm <sup>2</sup> /s) | 0.1379<br>0.1357<br>0.1401 | 0.1379  | 0.0022 |
|                                 |                      |                    | Specific Heat (MJ/m <sup>3</sup> K)      | 1.8510<br>1.8790<br>1.8200 | 1.8500  | 0.0295 |
| 7. "Competitor Shield#018-3"    | 0.03                 | 20                 | Thermal Conductivity (W / m K)           | 0.2553<br>0.2508<br>0.2530 | 0.2530  | 0.0023 |
|                                 |                      |                    | Thermal Diffusivity (mm <sup>2</sup> /s) | 0.1391<br>0.1419<br>0.1353 | 0.1388  | 0.0033 |
|                                 |                      |                    | Specific Heat (MJ/m <sup>3</sup> K)      | 1.8360<br>1.7680<br>1.8700 | 1.8247  | 0.0519 |
| 8. "Competitor Shield#054-2"    | 0.03                 | 20                 | Thermal Conductivity (W / m K)           | 0.2556<br>0.2558<br>0.2557 | 0.2557  | 0.0001 |
|                                 |                      |                    | Thermal Diffusivity (mm <sup>2</sup> /s) | 0.1352<br>0.1374<br>0.1342 | 0.1356  | 0.0016 |
|                                 |                      |                    | Specific Heat (MJ/m <sup>3</sup> K)      | 1.8900<br>1.8620<br>1.9050 | 1.8857  | 0.0218 |

| Samples                       | Condition Used       |                    | Thermal Properties                        | Measurement Results        | Average | S.D.   |        |        |
|-------------------------------|----------------------|--------------------|---|----------------------------|---------|--------|--------|--------|
|                               | Out Put of Power (W) | Measuring Time (s) |   |                            |         |        |        |        |
| 9. "Competitor Shield#101-4"  | 0.03                 | 20                 | Thermal Conductivity (W / m K)            | 0.2683<br>0.2669<br>0.2675 | 0.2676  | 0.0007 |        |        |
|                               |                      |                    | Thermal Diffusivity (mm <sup>2</sup> /s ) | 0.1408<br>0.1352<br>0.1340 |         |        | 0.1367 | 0.0036 |
|                               |                      |                    | Specific Heat (MJ/m <sup>3</sup> K)       | 1.9060<br>1.9740<br>1.9960 |         |        |        |        |
| 10. "Competitor Shield#115-4" | 0.03                 | 20                 | Thermal Conductivity (W / m K)            | 0.2545<br>0.2494<br>0.2531 | 0.2523  | 0.0026 |        |        |
|                               |                      |                    | Thermal Diffusivity (mm <sup>2</sup> /s ) | 0.1347<br>0.1352<br>0.1489 |         |        | 0.1396 | 0.0081 |
|                               |                      |                    | Specific Heat (MJ/m <sup>3</sup> K)       | 1.8900<br>1.8450<br>1.7000 |         |        |        |        |

**Remarks:**

1. Thermal conductivity is a measure of the ability to transmit heat through the material.
2. Thermal diffusivity is a measure of transient heat flow and is defined as the thermal conductivity divided by the product of specific heat times density.
3. Specific heat is the quantity of heat needed to raise the temperature of a unit mass of the substance 1 degree of temperature.
4. Hot Disk Thermal Constant Analyser (Hot Disk AB)
  - Reproducibility - Thermal Conductivity  $\pm 2\%$
  - Thermal Diffusivity  $\pm 5\%$
  - Specific Heat  $\pm 7\%$

**One example of the equation validation in the 1<sup>st</sup> second of the experiment:**

Temperature at Node 1: Coating film at outside wall

$$T_1^1 = \frac{[300(1-0.87)-10(30-36)-\frac{0.2381}{1/1000}(30-30)]}{500 \times 3520 \times \frac{1/1000}{2 \times 1}} + 30 = 30.1125 \text{ } ^\circ\text{C}$$

Temperature at Node 2: In the middle of fiber-cement wall

$$T_2^1 = \left[ 2.92 \times 10^{-6} \times \frac{1}{(2 \times 10^{-3})^2} (30 - 2 \times 30 + 30) \right] + 30 = 30 \text{ } ^\circ\text{C}$$

Temperature at Node 3: Coating film at inside wall

$$T_3^1 = \frac{2 \times 1}{1/1000} \left[ \frac{2.92 \times 10^{-6}}{1/1000} (30 - 30) - \frac{5}{500 \times 3250} (30 - 25) \right] + 30 = 29.97 \text{ } ^\circ\text{C}$$

**The calculation of Overall Thermal Transfer Value**

**Not painted color.**

$$\text{OTTV}_i = (U_w)(1-\text{WWR})(\text{TD}_{\text{eq}}) + (U_f)(\text{WWR})(\Delta T) + (\text{WWR})(\text{SHGC})(\text{SC})(\text{ESR})$$

Determine Heat transfer coefficient of opaque wall

$$U_w = \frac{1}{R_{\text{total}}}$$

$$\text{In this case} \quad R_{\text{total}} = R_0 + \frac{\Delta x_1}{k_1} + R_i$$

Define, Heat resistant of air film external building  $R_0 = 0.044 \text{ m}^2\text{-K / W}$

Heat Resistant of air film internal building  $R_i = 0.120 \text{ m}^2\text{-K / W}$

$$\begin{aligned} \text{Thus } R_{\text{total}} &= 0.044 + \frac{0.01}{0.398} + 0.120 \\ &= 0.189 \text{ m}^2\text{-K / W} \end{aligned}$$

$$\text{so } U_w = \frac{1}{0.189} = 5.29 \text{ W / m}^2\text{-K} \quad \#$$

Determine, density and specific heat value (DSH)

$$DSH_{\text{total}} = DSH_1 + DSH_2 + DSH_3$$

$$\text{From } DSH_i = (\rho_i)(C_{pt})(\Delta x_i)$$

$$DSH_{\text{total}} = (1860)(1)(0.01)$$

$$DSH_{\text{total}} = 18.6 \text{ kJ / m}^2\text{-K} \quad \#$$

Define coefficient absorptivity equal 0.7

Use DSH and coefficient absorptivity for open value into table  $TD_{\text{eq}}$

So, get value  $TD_{\text{eq}}$  of each direction wall is

$$\text{North } TD_{\text{eq}} = 11.9 \text{ K}$$

$$\text{South } TD_{\text{eq}} = 18.87 \text{ K}$$

$$\text{East } TD_{\text{eq}} = 19.04 \text{ K}$$

$$\text{West } TD_{\text{eq}} = 17.51 \text{ K}$$

### North wall

Opaque wall, without glass and shading (WWR = 0)

$$\begin{aligned} OTTV_N &= (U_w)(1-WWR)(TD_{\text{eq}}) \\ &= (5.29)(1-0)(11.9) \\ &= 62.95 \text{ W / m}^2 \quad \# \end{aligned}$$


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### East wall

Opaque wall, without glass and shading (WWR = 0)

$$\begin{aligned} OTTV_E &= (U_w)(1-WWR)(TD_{\text{eq}}) \\ &= (5.29)(1-0)(19.04) \\ &= 100.72 \text{ W / m}^2 \quad \# \end{aligned}$$


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**West wall**

Opaque wall, without glass and shading (WWR = 0)

$$\begin{aligned}
 OTTV_w &= (U_w)(1-WWR)(TD_{eq}) \\
 &= (5.29)(1-0)(17.51) \\
 &= 92.62 \quad W / m^2 \quad \#
 \end{aligned}$$


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**South wall**

Opaque wall, door but calculate same opaque wall (WWR = 0)

$$\begin{aligned}
 OTTV_s &= (U_w)(1-WWR)(TD_{eq}) \\
 &= (5.29)(1-0)(18.87) \\
 &= 99.82 \quad W / m^2 \quad \#
 \end{aligned}$$


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Overall Thermal Transfer value of external wall (OTTV)

$$\begin{aligned}
 OTTV &= \frac{(A_N)(OTTV_N) + (A_E)(OTTV_E) + (A_W)(OTTV_W) + (A_S)(OTTV_S)}{A_N + A_E + A_W + A_S} \\
 &= \frac{(8)(62.95) + (8)(100.72) + (8)(92.62) + (8)(99.82)}{8 + 8 + 8 + 8} \\
 &= 89.02 \quad W / m^2 \quad \#
 \end{aligned}$$


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Calculation to determine Roof Thermal Transfer Value (RTTV) in case the building was not painted

$$RTTV = (U_r)(1-SRR)(TD_{eq}) + (U_s)(SRR)(\Delta T) + (SRR)(SHGC)(SC)(ESR)$$

Determine overall heat transfer coefficient of roof ( $U_r$ )

$$U_r = \frac{1}{R_{\text{total}}}$$

Where  $R_{\text{total}} = R_0 + \frac{\Delta x_1}{k_1} + R_i$

Define, Heat resistant of air film external building  $R_0 = 0.044 \text{ m}^2\text{-K} / \text{W}$

Heat Resistant of air film internal building  $R_i = 0.120 \text{ m}^2\text{-K} / \text{W}$

Thus  $R_{\text{total}} = 0.044 + \frac{0.01}{0.398} + 0.120$   
 $= 0.189 \text{ m}^2\text{-K} / \text{W}$

so  $U_w = \frac{1}{0.189} = 5.29 \text{ W} / \text{m}^2\text{-K} \quad \#$

Determine, density and specific heat value (DSH)

$$\begin{aligned} \text{DSH}_{\text{total}} &= \text{DSH}_1 + \text{DSH}_2 + \text{DSH}_3 \\ \text{From } \text{DSH}_i &= (\rho_i)(C_{pt})(\Delta x_i) \\ \text{So } \text{DSH}_{\text{total}} &= (1860)(1)(0.01) \\ &= 18.6 \text{ kJ} / \text{m}^2\text{-K} \quad \# \end{aligned}$$

Define coefficient absorptivity equal 0.7

Use DSH and coefficient absorptivity for open value into table  $\text{TD}_{\text{eq}}$

So get value  $\text{TD}_{\text{eq}}$  of roof equal

North direction  $\text{TD}_{\text{eq}} = 32 \text{ K}$

### Roof

Opaque roof (SRR)

$$\begin{aligned} \text{RTTV} &= (U_r)(1-\text{SRR})(\text{TD}_{\text{eq}}) \\ &= (5.29)(1-0)(32) \\ &= 169.28 \text{ W/m}^2 \end{aligned}$$

Overall Heat transfer into the building (Heat Gain)

$$\begin{aligned}
 Q &= \text{OTTV} + \text{RTTV} + Q_{\text{floor}} + Q_{\text{other}} \\
 &= (89.02 \times 32) + (169.28 \times 8) + 0 + 0 \\
 &= 4,212.48 \quad \text{W}_{\text{th}} \quad \#
 \end{aligned}$$

### Conventional paint color

$$\text{OTTV}_i = (U_w)(1-\text{WWR})(\text{TD}_{\text{eq}}) + (U_f)(\text{WWR})(\Delta T) + (\text{WWR})(\text{SHGC})(\text{SC})(\text{ESR})$$

Determine Heat transfer coefficient of opaque wall

$$U_w = \frac{1}{R_{\text{total}}}$$

$$\text{In this case} \quad R_{\text{total}} = R_0 + \frac{\Delta x_3}{k_3} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + R_i$$

Define, Heat resistant of air film external building  $R_0 = 0.044 \text{ m}^2\text{-K} / \text{W}$

Heat Resistant of air film internal building  $R_i = 0.120 \text{ m}^2\text{-K} / \text{W}$

$$\begin{aligned}
 \text{Thus} \quad R_{\text{total}} &= 0.044 + \frac{0.0001}{0.255} + \frac{0.01}{0.398} + \frac{0.0001}{0.255} + 0.120 \\
 &= 0.189 \text{ m}^2\text{-K} / \text{W}
 \end{aligned}$$

$$\text{so} \quad U_w = \frac{1}{0.189} = 5.22 \text{ W} / \text{m}^2\text{-K} \quad \#$$

Determine, density and specific heat value (DSH)

$$\text{DSH}_{\text{total}} = \text{DSH}_1 + \text{DSH}_2 + \text{DSH}_3$$

$$\text{From} \quad \text{DSH}_i = (\rho_i)(C_{\text{pt}})(\Delta x_i)$$

$$\text{DSH}_{\text{total}} = (1860)(1)(0.01)$$

$$\text{DSH}_{\text{total}} = 18.6 \text{ kJ} / \text{m}^2\text{-K} \quad \#$$

Define coefficient absorptivity equal 0.7

Use DSH and coefficient absorptivity for open value into table  $\text{TD}_{\text{eq}}$

So, get value  $\text{TD}_{\text{eq}}$  of each direction wall is

|       |           |   |       |   |
|-------|-----------|---|-------|---|
| North | $TD_{eq}$ | = | 11.5  | K |
| South | $TD_{eq}$ | = | 18    | K |
| East  | $TD_{eq}$ | = | 17.24 | K |
| West  | $TD_{eq}$ | = | 15.9  | K |

**North wall**

Opaque wall, without glass and shading (WWR = 0)

$$\begin{aligned}
 OTTV_N &= (U_w)(1-WWR)(TD_{eq}) \\
 &= (5.22)(1-0)(11.5) \\
 &= 60 \text{ W / m}^2 \quad \#
 \end{aligned}$$


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**East wall**

Opaque wall, without glass and shading (WWR = 0)

$$\begin{aligned}
 OTTV_E &= (U_w)(1-WWR)(TD_{eq}) \\
 &= (5.22)(1-0)(18) \\
 &= 95 \text{ W / m}^2 \quad \#
 \end{aligned}$$


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**West wall**

Opaque wall, without glass and shading (WWR = 0)

$$\begin{aligned}
 OTTV_W &= (U_w)(1-WWR)(TD_{eq}) \\
 &= (5.22)(1-0)(17.24) \\
 &= 90 \text{ W / m}^2 \quad \#
 \end{aligned}$$


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**South wall**

Opaque wall, door but calculate same opaque wall (WWR = 0)

$$\begin{aligned}
 OTTV_s &= (U_w)(1-WWR)(TD_{eq}) \\
 &= (5.22)(1-0)(15.9) \\
 &= 83 \text{ W / m}^2 \quad \#
 \end{aligned}$$


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Overall Thermal Transfer value of external wall (OTTV)

$$\begin{aligned} \text{OTTV} &= \frac{(A_N)(\text{OTTV}_N) + (A_E)(\text{OTTV}_E) + (A_W)(\text{OTTV}_W) + (A_S)(\text{OTTV}_S)}{A_N + A_E + A_W + A_S} \\ &= \frac{(8)(60) + (8)(95) + (8)(90) + (8)(83)}{8 + 8 + 8 + 8} \\ &= 82 \quad \text{W / m}^2 \quad \# \end{aligned}$$


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Calculation to determine Roof Thermal Transfer Value (RTTV) in case the building was not painted

$$\text{RTTV} = (U_r)(1-\text{SRR})(\text{TD}_{\text{eq}}) + (U_s)(\text{SRR})(\Delta T) + (\text{SRR})(\text{SHGC})(\text{SC})(\text{ESR})$$

Determine overall heat transfer coefficient of roof ( $U_r$ )

$$\begin{aligned} U_r &= \frac{1}{R_{\text{total}}} \\ R_{\text{total}} &= R_0 + \frac{\Delta x_3}{k_3} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + R_i \end{aligned}$$

Define, Heat resistant of air film external building  $R_0 = 0.044 \text{ m}^2\text{-K / W}$

Heat Resistant of air film internal building  $R_i = 0.120 \text{ m}^2\text{-K / W}$

$$\begin{aligned} \text{Thus } R_{\text{total}} &= 0.044 + \frac{0.0001}{0.277} + \frac{0.01}{0.398} + \frac{0.0001}{0.277} + 0.120 \\ &= 0.1915 \text{ m}^2\text{-K / W} \end{aligned}$$

$$\text{so } U_w = \frac{1}{0.189} = 5.22 \text{ W / m}^2\text{-K} \quad \#$$

Determine, density and specific heat value (DSH)

$$\begin{aligned} \text{DSH}_{\text{total}} &= \text{DSH}_1 + \text{DSH}_2 + \text{DSH}_3 \\ \text{From } \text{DSH}_i &= (\rho_i)(C_{pt})(\Delta x_i) \\ \text{So } \text{DSH}_{\text{total}} &= (1860)(1)(0.01) \\ &= 18.6 \text{ kJ / m}^2\text{-K} \quad \# \end{aligned}$$

Define coefficient absorptivity equal 0.7

Use DSH and coefficient absorptivity for open value into table  $\text{TD}_{\text{eq}}$

So get value  $\text{TD}_{\text{eq}}$  of roof equal

$$\text{North direction } \text{TD}_{\text{eq}} = 31.84 \text{ K}$$

### Roof

Opaque roof (SRR)

$$\begin{aligned} \text{RTTV} &= (U_r)(1-\text{SRR})(\text{TD}_{\text{eq}}) \\ &= (5.22)(1-0)(30.84) \\ &= 161 \text{ W/m}^2 \end{aligned}$$

Overall Heat transfer into the building (Heat Gain)

$$\begin{aligned} Q &= \text{OTTV} + \text{RTTV} + Q_{\text{floor}} + Q_{\text{other}} \\ &= (82 \times 32) + (161 \times 8) + 0 + 0 \\ &= 3912 \text{ W}_{\text{th}} \quad \# \end{aligned}$$


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### Beger Cool UV shield paint color

$$\text{OTTV}_i = (U_w)(1-\text{WWR})(\text{TD}_{\text{eq}}) + (U_f)(\text{WWR})(\Delta T) + (\text{WWR})(\text{SHGC})(\text{SC})(\text{ESR})$$

Determine Heat transfer coefficient of opaque wall

$$U_w = \frac{1}{R_{\text{total}}}$$

$$\text{In this case } R_{\text{total}} = R_0 + \frac{\Delta x_3}{k_3} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + R_i$$

Define, Heat resistant of air film external building  $R_0 = 0.044 \text{ m}^2\text{-K} / \text{W}$

Heat Resistant of air film internal building  $R_i = 0.120 \text{ m}^2\text{-K} / \text{W}$

$$\begin{aligned} \text{Thus } R_{\text{total}} &= 0.044 + \frac{0.0001}{0.2381} + \frac{0.01}{0.398} + \frac{0.0001}{0.2381} + 0.120 \\ &= 0.201 \text{ m}^2\text{-K} / \text{W} \end{aligned}$$

$$\text{so } U_w = \frac{1}{0.201} = 4.975 \text{ W} / \text{m}^2\text{-K} \quad \#$$

Determine, density and specific heat value (DSH)

$$\begin{aligned} \text{DSH}_{\text{total}} &= \text{DSH}_1 + \text{DSH}_2 + \text{DSH}_3 \\ \text{From } \text{DSH}_i &= (\rho_i)(C_{pt})(\Delta x_i) \\ \text{DSH}_{\text{total}} &= (1860)(1)(0.01) \\ \text{DSH}_{\text{total}} &= 18.6 \text{ kJ} / \text{m}^2\text{-K} \quad \# \end{aligned}$$

Define coefficient absorptivity equal 0.7

Use DSH and coefficient absorptivity for open value into table  $\text{TD}_{\text{eq}}$

So, get value  $\text{TD}_{\text{eq}}$  of each direction wall is

$$\begin{aligned} \text{North } \text{TD}_{\text{eq}} &= 10.25 \quad \text{K} \\ \text{South } \text{TD}_{\text{eq}} &= 14.27 \quad \text{K} \\ \text{East } \text{TD}_{\text{eq}} &= 14.47 \quad \text{K} \\ \text{West } \text{TD}_{\text{eq}} &= 13.26 \quad \text{K} \end{aligned}$$

### North wall

Opaque wall, without glass and shading ( $\text{WWR} = 0$ )

$$\begin{aligned} \text{OTTV}_N &= (U_w)(1-\text{WWR})(\text{TD}_{\text{eq}}) \\ &= (4.975)(1-0)(10.25) \\ &= 51 \text{ W} / \text{m}^2 \quad \# \end{aligned}$$


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**East wall**

Opaque wall, without glass and shading (WWR = 0)

$$\begin{aligned} \text{OTTV}_E &= (U_w)(1-\text{WWR})(\text{TD}_{\text{eq}}) \\ &= (4.975)(1-0)(14.27) \\ &= 71 \text{ W / m}^2 \quad \# \end{aligned}$$


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**West wall**

Opaque wall, without glass and shading (WWR = 0)

$$\begin{aligned} \text{OTTV}_W &= (U_w)(1-\text{WWR})(\text{TD}_{\text{eq}}) \\ &= (4.975)(1-0)(14.47) \\ &= 72 \text{ W / m}^2 \quad \# \end{aligned}$$


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**South wall**

Opaque wall, door but calculate same opaque wall (WWR = 0)

$$\begin{aligned} \text{OTTV}_S &= (U_w)(1-\text{WWR})(\text{TD}_{\text{eq}}) \\ &= (4.975)(1-0)(13.26) \\ &= 66 \text{ W / m}^2 \quad \# \end{aligned}$$


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Overall Thermal Transfer value of external wall (OTTV)

$$\begin{aligned} \text{OTTV} &= \frac{(A_N)(\text{OTTV}_N) + (A_E)(\text{OTTV}_E) + (A_W)(\text{OTTV}_W) + (A_S)(\text{OTTV}_S)}{A_N + A_E + A_W + A_S} \\ &= \frac{(8)(60) + (8)(95) + (8)(90) + (8)(83)}{8 + 8 + 8 + 8} \\ &= 82 \text{ W / m}^2 \quad \# \end{aligned}$$


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Calculation to determine Roof Thermal Transfer Value (RTTV) in case the building was not painted

$$RTTV = (U_r)(1-SRR)(TD_{eq}) + (U_s)(SRR)(\Delta T) + (SRR)(SHGC)(SC)(ESR)$$

Determine overall heat transfer coefficient of roof ( $U_r$ )

$$U_r = \frac{1}{R_{total}}$$

$$\text{In this case } R_{total} = R_0 + \frac{\Delta x_3}{k_3} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + R_i$$

Define, Heat resistant of air film external building  $R_0 = 0.044 \text{ m}^2\text{-K} / \text{W}$

Heat Resistant of air film internal building  $R_i = 0.120 \text{ m}^2\text{-K} / \text{W}$

$$\begin{aligned} \text{Thus } R_{total} &= 0.044 + \frac{0.0001}{0.2381} + \frac{0.01}{0.398} + \frac{0.0001}{0.2381} + 0.120 \\ &= 0.201 \text{ m}^2\text{-K} / \text{W} \end{aligned}$$

$$\text{so } U_w = \frac{1}{0.201} = 4.975 \text{ W} / \text{m}^2\text{-K} \quad \#$$

Determine, density and specific heat value (DSH)

$$DSH_{total} = DSH_1 + DSH_2 + DSH_3$$

$$\text{From } DSH_i = (\rho_i)(C_{pt})(\Delta x_i)$$

$$\begin{aligned} \text{So } DSH_{total} &= (1860)(1)(0.01) \\ &= 18.6 \text{ kJ} / \text{m}^2\text{-K} \quad \# \end{aligned}$$

Define coefficient absorptivity equal 0.7

Use DSH and coefficient absorptivity for open value into table  $TD_{eq}$

So get value  $TD_{eq}$  of roof equal

$$\text{North direction } TD_{eq} = 30.15 \text{ K}$$

**Roof**

Opaque roof (SRR)

$$\begin{aligned}
 \text{RTTV} &= (U_r)(1-\text{SRR})(\text{TD}_{\text{eq}}) \\
 &= (4.975)(1-0)(30.15) \\
 &= 150 \quad \text{W/m}^2
 \end{aligned}$$

Overall Heat transfer into the building (Heat Gain)

$$\begin{aligned}
 Q &= \text{OTTV} + \text{RTTV} + Q_{\text{floor}} + Q_{\text{other}} \\
 &= (65 \times 32) + (150 \times 8) + 0 + 0 \\
 &= 3280 \quad \text{W}_{\text{th}} \quad \#
 \end{aligned}$$


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**Total Heat Transfer Calculation**

Heat Gain for Beger Cool UV Shield case is 3280 W and the periods of test condition are 8 hr. Total heat transfer to Beger Cool UV Shield building is 3280 J/s x 8 hour x 3600 s = 94.46 MJ

Heat Gain for Conventional color case is 3912 W and the periods of test condition are 8 hr. Total heat transfer to Conventional color building is 3912 J/s x 8 hour x 3600 s = 112.66 MJ

Heat Gain for No Color case is 4212 W and the periods of test condition are 8 hour Total heat transfer to no color building is 4212 J/s x 8 hr. x 3600 s = 121.31 MJ.

## SIMULATION PROGRAM CODE

```

clc
clear all
TIME=[8 9 10 11 12 13 14 15 16 17];
pg=400;%density of gypsum
ho=10;%heat transfer coefficient outer
hi=5;%heat transfer coefficient inner
C=0.34*1000;%C
delta_X=2.5/1000;% distant between (mm.)
delta_t=1;%Time between(sec)
Tamb_o=[36 39 40 41 46 45 40 37 36 35];%Tamp ambient outer
%Tamb_o=[303 303 303 303 303 303 303 303 303 303];%Tamp ambient outer
Tamb_i=20;%Tamp ambient inner
q=[300 350 400 450 500 500 200 150 100 100];%Heat flux
pc1=81.7/100;%density of BG white
pc2=77.5/100;%density of BG gray
pc3=80/100;%density of TOA white
pc4=68.2/100;%density of TOA gray
k1=0.2381;%conductivity of BG white
k2=0.2256;%conductivity of BG gray
k3=0.255;%conductivity of TOA white
k4=0.2557;%conductivity of TOA gray
L1=k1/(pg*C);%of BG white
L2=k2/(pg*C);%of BG gray
L3=k3/(pg*C);%of TOA white
L4=k4/(pg*C);%of TOA gray
T10_BGwhite=30;%Tamp first Node 1

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T20_BGwhite=30;%Tamp first Node 2
T30_BGwhite=30;%Tamp first Node 3
T10_BGgrey=30;%Tamp first Node 1
T20_BGgrey=30;%Tamp first Node 2
T30_BGgrey=30;%Tamp first Node 3
T10_TOAwhite=30;%Tamp first Node 1
T20_TOAwhite=30;%Tamp first Node 2
T30_TOAwhite=30;%Tamp first Node 3
T10_TOAgrey=30;%Tamp first Node 1
T20_TOAgrey=30;%Tamp first Node 2
T30_TOAgrey=30;%Tamp first Node 3
n1=0;%Number Loop of BG white
n2=0;%Number Loop of BG gray
n3=0;%Number Loop of TOA white
n4=0;%Number Loop of TOA gray
%T10=First position is node and second position is Number of loop
%T1,n=%wall Temp node 1
%T2,n=%wall Temp node 2
%T3,n=%wall Temp node 3

%%%%%%%%%%Wall Temp BG white %%%%%%%%%%%

fprintf(1,'+++++ BG white Wall
Temp +++++\n');
while(n1<10)
n1=n1+1;

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    T1_BG_white=(((q(n1)*(1-pc1))-ho*(T10_BGwhite-Tamb_o(n1)))-
(k1/delta_X)*(T10_BGwhite-
T20_BGwhite)))/(pg*C*(delta_X/(2*delta_t)))+T10_BGwhite;
    T2_BG_white=((L1*(delta_t/(delta_X^2)))*(T10_BGwhite-
(2*T20_BGwhite)+T30_BGwhite))+T20_BGwhite;
    T3_BG_white=(((2*delta_t)/delta_X)*((L1/delta_X)*(T20_BGwhite-
T30_BGwhite))-((hi/(pg*C))*(T30_BGwhite-Tamb_i))))+T30_BGwhite;
    fprintf(1,'T1,%d = %.3f T10 = %.3f || T2,%d = %.3f T20 = %.3f || T3,%d = %.3f T30
=%.3f\n',n1,T1_BG_white,T10_BGwhite,n1,T2_BG_white,T20_BGwhite,n1,T3_BG_white
,T30_BGwhite);
    T10_BGwhite=T1_BG_white;
    T20_BGwhite=T2_BG_white;
    T30_BGwhite=T3_BG_white;
    T1BGwhite(n1)=T10_BGwhite;
    T2BGwhite(n1)=T20_BGwhite;
    T3BGwhite(n1)=T30_BGwhite;
    End
    %%%%%%%%%%%Wall Temp BG gray %%%%%%%%%%%

    fprintf(1,'+++++++ BG gray Wall
Temp ++++++ \n');
    while(n2<10)
        n2=n2+1;
        T1_BG_gray=(((q(n2)*(1-pc2))-ho*(T10_BGgray-Tamb_o(n2)))-
(k2/delta_X)*(T10_BGgray-
T20_BGgray)))/(pg*C*(delta_X/(2*delta_t)))+T10_BGgray;
        T2_BG_gray=((L2*(delta_t/(delta_X^2)))*(T10_BGgray-
(2*T20_BGgray)+T30_BGgray))+T20_BGgray;

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T3_BG_gray=(((2*delta_t)/delta_X)*(((L2/delta_X)*(T20_BGgray-
T30_BGgray))-((hi/(pg*C))*(T30_BGgray-Tamb_i))))+T30_BGgray;

fprintf(1,'T1,%d = %.3f T10 = %.3f || T2,%d = %.3f T20 = %.3f || T3,%d = %.3f T30 =
%.3f\n',n2,T1_BG_gray,T10_BGgray,n2,T2_BG_gray,T20_BGgray,n2,T3_BG_gray,T30_B
Ggrey);

T10_BGgrey=T1_BG_grey;
T20_BGgrey=T2_BG_grey;
T30_BGgrey=T3_BG_grey;
T1BGgrey(n2)=T10_BGgrey;
T2BGgrey(n2)=T20_BGgrey;
T3BGgrey(n2)=T30_BGgrey;

End

%%%%%%%%%%Wall Temp TOA white %%%%%%%%%%%

fprintf(1,'+++++++ TOA white Wall
Temp ++++++ \n');
while(n3<10)
n3=n3+1;

T1_TOA_white=(((q(n3)*(1-pc3))-(ho*(T10_TOAwhite-Tamb_o(n3)))-
(k3/delta_X)*(T10_TOAwhite-
T20_TOAwhite)))/(pg*C*(delta_X/(2*delta_t)))+T10_TOAwhite;

T2_TOA_white=((L3*(delta_t/(delta_X^2)))*(T10_TOAwhite-
(2*T20_TOAwhite)+T30_TOAwhite))+T20_TOAwhite;

T3_TOA_white=(((2*delta_t)/delta_X)*(((L3/delta_X)*(T20_TOAwhite-
T30_TOAwhite))-((hi/(pg*C))*(T30_TOAwhite-Tamb_i))))+T30_TOAwhite;

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fprintf(1,'T1,%d = %.3f T10 = %.3f || T2,%d = %.3f T20 = %.3f || T3,%d = %.3f T30 =
%.3f\n',n3,T1_TOA_white,T10_TOAwhite,n3,T2_TOA_white,T20_TOAwhite,n3,T3_TO
A_white,T30_TOAwhite);

T10_TOAwhite=T1_TOA_white;
T20_TOAwhite=T2_TOA_white;
T30_TOAwhite=T3_TOA_white;
T1TOAwhite(n3)=T10_TOAwhite;
T2TOAwhite(n3)=T20_TOAwhite;
T3TOAwhite(n3)=T30_TOAwhite;

end

%%%%%%%%%Wall Temp TOA gray %%%%%%%%%%

fprintf(1,'+++++ TOA gray Wall
Temp +++++ \n');
while(n4<10)
n4=n4+1;
T1_TOA_gray((((q(n4)*(1-pc4))-(ho*(T10_TOAgray-Tamb_o(n4)))-
(k4/delta_X)*(T10_TOAgray-
T20_TOAgray)))/(pg*C*(delta_X/(2*delta_t))))+T10_TOAgray;
T2_TOA_gray=((L4*(delta_t/(delta_X^2))*(T10_TOAgray-
(2*T20_TOAgray)+T30_TOAgray))+T20_TOAgray;
T3_TOA_gray((((2*delta_t)/delta_X)*(((L4/delta_X)*(T20_TOAgray-
T30_TOAgray))-((hi/(pg*C))*(T30_TOAgray-Tamb_i))))+T30_TOAgray;
fprintf(1,'T1,%d = %.3f T10 = %.3f || T2,%d = %.3f T20 = %.3f || T3,%d = %.3f T30
=%.3f\n',n4,T1_TOA_gray,T10_TOAgray,n4,T2_TOA_gray,T20_TOAgray,n4,T3_TOA_gr
ay,T30_TOAgray);

T10_TOAgray=T1_TOA_gray;
T20_TOAgray=T2_TOA_gray;

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```

T30_TOAgray=T3_TOA_gray;
T1TOAgray(n4)=T10_TOAgray;
T2TOAgray(n4)=T20_TOAgray;
T3TOAgray(n4)=T30_TOAgray;
end
fprintf(1,'+++++
+++++ \n');
%%%%%%%%%%%%Comparison BG white Wall Temp
%plot(TIME,T1BGwhite,'r');hold on
%plot(TIME,T2BGwhite,'b');
%plot(TIME,T3BGwhite,'g');
%%%%%%%%%%%%Comparison BG gray Wall Temp figure1
%figure
%plot(TIME,T1BGgray,'r');hold on
%plot(TIME,T2BGgray,'b');
%plot(TIME,T3BGgray,'g');
%%%%%%%%%%%%Comparison TOA white Wall Temp figure2
%figure
%plot(TIME,T1TOAwhite,'r');hold on
%plot(TIME,T2TOAwhite,'b');
%plot(TIME,T3TOAwhite,'g');
%%%%%%%%%%%%Comparison TOA gray Wall Temp figure3
%figure
%plot(TIME,T1TOAgray,'r');hold on
%plot(TIME,T2TOAgray,'b');
%plot(TIME,T3TOAgray,'g');
%%%%%%%%%%%%Comparison T2 all type Wall Temp figures

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```
%figure
%plot(TIME,T2BGwhite,'r');hold on
%plot(TIME,T2BGgray,'b');
%plot(TIME,T2TOAwhite,'g');
%plot(TIME,T2TOAgray,'y');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%Comparison T1 all type Wall Temp figure4
figure
plot(TIME,T1BGwhite,'r');hold on
plot(TIME,T1TOAwhite,'g');
figure
plot(TIME,T1BGgray,'b');hold on
plot(TIME,T1TOAgray,'y');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%Comparison T3 all type Wall Temp figure6
figure
plot(TIME,T3BGwhite,'r');hold on
plot(TIME,T3TOAwhite,'g');
figure
plot(TIME,T3BGgray,'b');hold on
plot(TIME,T3TOAgray,'y');
```