Wall/floor: 2x4 steel stud wall with R-11 insulation

Description

- ½-in. gypsum board
  - Thermal conductivity – 1.11 Btu-in/h-ft^2-F
  - Density – 50 lb/ft^3
  - Specific Heat – 0.26 Btu/lb-F
- 3.5-in. R-11 fiberglass batts
  - Thermal conductivity – 0.32 Btu-in/h-ft^2-F
  - Density – 5.3 lb/ft^3
  - Specific Heat – 0.23 Btu/lb-F
- 2x4 steel studs
  - Thermal conductivity – 314 Btu-in/h-ft^2-F
  - Density – 490 lb/ft^3
  - Specific Heat – 0.12 Btu/lb-F
- ½-in. plywood
  - Thermal conductivity – 0.8 Btu-in/h-ft^2-F
  - Density – 34 lb/ft^3
  - Specific Heat – 0.29 Btu/lb-F
- ½-in wood siding
  - Thermal conductivity – 0.5 Btu-in/h-ft^2-F
  - Density – 34 lb/ft^3
  - Specific Heat – 0.30 Btu/lb-F

Foundation

concrete
Thermal conductivity -9.09 Btu-ihn./ hft2F
Density - 140lb/ft3,
Specific heat 0.21 Btu/lbF
foam: thermal conductivity -0.2 Btu-ihn./ hft2F
density - 2.0lb/ft3
specific heat 0.29 Btu/lbF

Comment:
Total response of the thermal bridge is to be calculated by multiplying response factors or z-transfer function coefficients by the exterior surface area.

COMPUTATION RESULTS

Three-dimensional model

Table 13.1
Resistance, transmittance and capacitance of the wall

	IP		*SI*	
R-value	3.79581	ft^2 °F h/Btu	0.66806	m^2 K/W
R^{-1}	0.26345	Btu/h ft^2 °F	1.49686	W/m^2 K
Capacitance	7.80927	Btu/ft^2 °F	159.57308	kJ/m^2 K

Table 13.2
Dimensionless 3D z-transfer function coefficients

n	b_n	c_n	d_n
0	0.10985	2.69068	1.00000
1	0.12760	-4.04151	-1.14685
2	-0.14546	1.51023	0.23109
3	-0.01314	-0.07516	

$\Sigma\, c_n = 0.08424$, $E_1 = -0.06390$

Table 13.3
3D response factors calculated with the help of the finite difference computer code HEATING 7.2 [Btu/h ft^2 °F]

N	X_n	Y_n
0	7.0885577E-01	2.8939635E-02
1	-2.5177887E-01	6.6806303E-02
2	-5.4693116E-02	3.1608628E-02
3	-2.4342901E-02	1.7350862E-02
4	-1.5278667E-02	1.2818667E-02
5	-1.1613253E-02	1.0876501E-02
6	-9.6297998E-03	9.6463875E-03
7	-8.3013635E-03	8.6577751E-03
8	-7.2907369E-03	7.7902665E-03
9	-6.4652641E-03	7.0101138E-03
10	-5.7636153E-03	6.3050723E-03
11	-5.1534740E-03	5.6681536E-03
12	-4.6158573E-03	5.0936155E-03
13	-4.1384841E-03	4.5760688E-03
14	-3.7126875E-03	4.1103587E-03
15	-3.3318856E-03	3.6916099E-03
16	-2.9907876E-03	3.3152782E-03
17	-2.6849668E-03	2.9771786E-03
18	-2.4106195E-03	2.6734908E-03
19	-2.1644217E-03	2.4007475E-03
20	-1.9434377E-03	2.1558145E-03
21	-1.7450584E-03	1.9358659E-03
22	-1.5669560E-03	1.7383579E-03
23	-1.4070486E-03	1.5610030E-03
24	-1.2634717E-03	1.4017456E-03
25	-1.1345539E-03	1.2587389E-03
26	-1.0187962E-03	1.1303245E-03
27	-9.1485339E-04	1.0150129E-03
28	-8.2151860E-04	9.1146678E-04
29	-7.3770836E-04	8.1848540E-04
30	-6.6245015E-04	7.3499051E-04
31	-5.9487086E-04	6.6001400E-04
32	-5.3418668E-04	5.9268660E-04
33	-4.7969383E-04	5.3222779E-04
34	-4.3076047E-04	4.7793672E-04
35	-3.8681926E-04	4.2918408E-04
36	-3.4736079E-04	3.8540480E-04
37	-3.1192766E-04	3.4609148E-04
38	-2.8010918E-04	3.1078849E-04
39	-2.5153654E-04	2.7908671E-04
40	-2.2587859E-04	2.5061875E-04

Table 13.4
3D response factors ratio, dimensionless 3D response factors and transfer functions of the first order

n	X_n/X_{n-1}	Y_n/Y_{n-1}	$R*X_n$	$R*Y_n$	$R*X'_n$	$R*Y'_n$
0			2.69068	0.10985	2.69068	0.10985
1	-0.35519	2.30847	-0.95571	0.25358	-3.37193	0.15494
2	0.21723	0.47314	-0.20760	0.11998	0.65061	-0.10774
3	0.44508	0.54893	-0.09240	0.06586	0.09403	-0.04188
4	0.62764	0.73879	-0.05799	0.04866	0.02498	-0.01049
5	0.76010	0.84849	-0.04408	0.04129	0.00800	-0.00241
6	0.82921	0.88690	-0.03655	0.03662	0.00303	-0.00046
7	0.86205	0.89751	-0.03151	0.03286	0.00131	-0.00002
8	0.87826	0.89980	-0.02767	0.02957	0.00062	0.00006
9	0.88678	0.89986	-0.02454	0.02661	0.00031	0.00005
10	0.89147	0.89943	-0.02188	0.02393	0.00016	0.00004
11	0.89414	0.89898	-0.01956	0.02152	0.00008	0.00002
12	0.89568	0.89864	-0.01752	0.01933	0.00005	0.00001
13	0.89658	0.89839	-0.01571	0.01737	0.00002	0.00001
14	0.89711	0.89823	-0.01409	0.01560	0.00001	
15	0.89743	0.89812	-0.01265	0.01401	0.00001	
16	0.89763	0.89806	-0.01135	0.01258		
17	0.89775	0.89802	-0.01019	0.01130		
18	0.89782	0.89799	-0.00915	0.01015		
19	0.89787	0.89798	-0.00822	0.00911		
20	0.89790	0.89798	-0.00738	0.00818		
21	0.89792	0.89797	-0.00662	0.00735		
22	0.89794	0.89797	-0.00595	0.00660		
23	0.89795	0.89798	-0.00534	0.00593		
24	0.89796	0.89798	-0.00480	0.00532		
25	0.89797	0.89798	-0.00431	0.00478		
26	0.89797	0.89798	-0.00387	0.00429		
27	0.89797	0.89798	-0.00347	0.00385		
28	0.89798	0.89799	-0.00312	0.00346		
29	0.89798	0.89799	-0.00280	0.00311		
30	0.89798	0.89799	-0.00251	0.00279		
31	0.89799	0.89799	-0.00226	0.00251		
32	0.89799	0.89799	-0.00203	0.00225		
33	0.89799	0.89799	-0.00182	0.00202		
34	0.89799	0.89799	-0.00164	0.00181		
35	0.89799	0.89799	-0.00147	0.00163		
36	0.89799	0.89799	-0.00132	0.00146		
37	0.89799	0.89799	-0.00118	0.00131		
38	0.89799	0.89800	-0.00106	0.00118		
39	0.89799	0.89800	-0.00095	0.00106		
40	0.89800	0.89800	-0.00086	0.00095		

$\alpha = 0.89800$. $\tau_1 = 9.29453$

Equivalent wall model: 3 layers plane wall

Table 13.5
Structure factors and time constants

Structure factors		*Time constants [h]*	
φ_{ii}	0.23535	$R \cdot C \cdot \varphi_{ii}$	6.976
φ_{ie}	0.21726	$R \cdot C \cdot \varphi_{ie}$	6.440
φ_{ee}	0.33014	$R \cdot C \cdot \varphi_{ee}$	9.786
		$R \cdot C$	29.643

Table 13.6a
Thermophysical properties of the equivalent wall - IP units

Layer *N*	R_n ft^2-°F-h/Btu	C_n Btu/ft^2-°F	l_n in	k_n Btu-in/h-ft^2-°F	ρ_n lb/ft^3	c_{pn} Btu/lb-°F
1	1.29508	0.41667	0.5	0.38608	40	0.25
2	1.39326	6.40693	3.5	2.51209	87.866	0.25
3	1.10747	0.98569	1	0.90297	47.313	0.25

Table 13.6b
Thermophysical properties of the equivalent wall - SI units

Layer *n*	R_n m^2 K/W	C_n kJ/m^2 K	l_n m	k_n W/m K	ρ_n kg/m^3	c_{pn} kJ/kg K
1	0.22793	8.51408	0.013	0.056	640	1.048
2	0.24521	130.91780	0.089	0.362	1405.86	1.048
3	0.19491	20.14120	0.025	0.130	757	1.048

Table 13.7
Dimensionless z-transfer function coefficients and first time constants for the equivalent wall

n	b_n	c_n	d_n	τ_n
0	0.00115	3.00619	1.00000	
1	0.04705	-4.27439	-1.08029	4.835
2	0.07659	1.55383	0.22151	0.721
3	0.01277	-0.14983	-0.00350	0.244
4	0.00016	0.00192		0.131

$\Sigma\, c_n = 0.13772$, $\alpha = 0.81318$

Table 13.8
Response factors for the equivalent wall [Btu/h ft^2 °F]

n	X_n	Y_n
0	7.919756E-01	3.034399E-04
1	-2.705139E-01	1.272367E-02
2	-5.831137E-02	3.385448E-02
3	-3.977529E-02	3.711889E-02
4	-3.049358E-02	3.268812E-02
5	-2.433507E-02	2.720894E-02
6	-1.967326E-02	2.228263E-02
7	-1.596899E-02	1.815888E-02
8	-1.297843E-02	1.477614E-02
9	-1.055192E-02	1.201813E-02
10	-8.580125E-03	9.773415E-03
11	-6.977057E-03	7.947675E-03
12	-5.673517E-03	6.462907E-03
13	-4.613581E-03	5.255486E-03
14	-3.751651E-03	4.273630E-03
15	-3.050752E-03	3.475219E-03
16	-2.480797E-03	2.825968E-03
17	-2.017323E-03	2.298005E-03
18	-1.640439E-03	1.868688E-03
19	-1.333969E-03	1.519570E-03
20	-1.084749E-03	1.235679E-03
21	-8.820929E-04	1.004823E-03
22	-7.172981E-04	8.170987E-04
23	-5.832873E-04	6.644456E-04
24	-4.743170E-04	5.403105E-04
25	-3.857021E-04	4.393682E-04
26	-3.136448E-04	3.572833E-04
27	-2.550478E-04	2.905345E-04
28	-2.073986E-04	2.362556E-04
29	-1.686523E-04	1.921172E-04
30	-1.371435E-04	1.562256E-04
31	-1.115219E-04	1.270387E-04
32	-9.068695E-05	1.033046E-04
33	-7.374457E-05	8.400507E-05
34	-5.996716E-05	6.831088E-05
35	-4.876393E-05	5.554873E-05
36	-3.965362E-05	4.517101E-05
37	-3.224547E-05	3.673183E-05
38	-2.622121E-05	2.986955E-05
39	-2.132243E-05	2.428915E-05
40	-1.733890E-05	1.975137E-05

Frequency response for the three-dimensional model and equivalent wall; dimensionless amplitude and phase angle

Table 13.9a
3-D model

	Transmittance		*Admittance*	
period	amplitude	phase angle	amplitude	phase angle
48	0.70	-32°	1.46	19°
24	0.53	-38°	1.70	20°
12	0.42	-45°	2.01	22°
6	0.31	-65°	2.57	22°

Table 13.9b
Equivalent wall

	Transmittance		*Admittance*	
period	amplitude	phase angle	amplitude	phase angle
48	0.84	-44°	1.52	27°
24	0.61	-76°	1.98	26°
12	0.34	-116°	2.33	23°
6	0.15	-169°	2.66	25°