National Exams May 2011

07-Bld-A7, Building Envelope Design

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is a CLOSED BOOK EXAM. A Casio or sharp approved calculator is permitted.
3. FIVE (5) questions constitute a complete exam paper. The first five questions as they appear in the answer book will be marked.
4. Each question is of equal value.
5. For questions that require an answer in essay format, clarity and organization of the answer are important.
6. Equations and data required for calculations are provided in the appendix of this exam booklet.

Question 1 (20 marks)

A 2x6 wood-frame brick veneer wall is made up of the following components:

- 100mm exterior brick (RSI 0.13)
- 25mm air space (RSI 0.22)
- one layer of Tyvek weather-barrier membrane, 0.2mm
- 12.5 mm plywood sheathing (RSI 0.11)
- 140mm glass fiber insulation (RSI 3.67)
- 6 mil polyethylene as vapour and air barrier
- 12.5mm gypsum board (RSI 0.08)

The interior surface resistance is RSI 0.12 and the exterior surface resistance is RSI 0.03. The indoor conditions are kept at 22°C dry-bulb and 30%rh and the average outdoor temperature in January is at -10°C for Toronto.

1) Calculate the effective RSI value of the wall assembly using Parallel method. The wood stud spacing is 16" at centre, and assume the thermal conductivity of the wood stud is 0.11W/m•K. The actual dimension of 2x6 wood stud is 38mm by 140mm.
2) Although polyethylene is used as air barrier, the contractor did not seal well the penetrations i.e. electric outlet, as a result air exfiltrates through the wood-frame walls. Would there be any condensation within the wall assembly due to air exfiltration? If so, where would the condensation occur? How would you suggest avoiding the problem if you were to re-design the wall assembly? Support your solution with calculations.

Question 2 (20 marks):

The typical above-grade wall assembly in Part 9 low-rise residential building is 2x6 wood frame construction. To improve the energy efficiency of homes, the thermal resistance of walls, roofs, and below grades will need to be significantly improved. Should the higher energy efficiency standard requires to build above grade walls with an effective thermal resistance of R30 (RSI5.28)

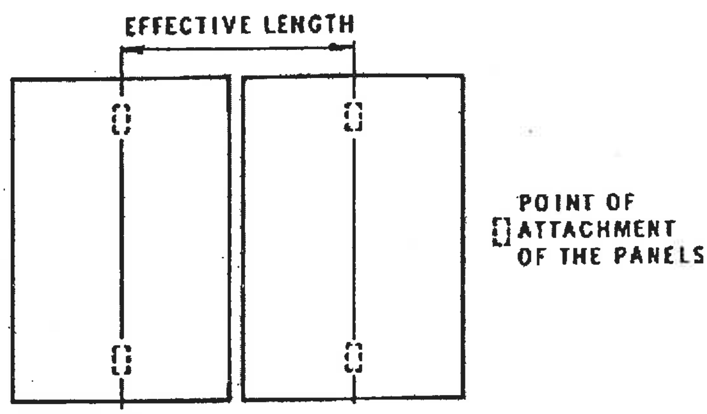
1) propose one solution that meet the thermal requirements. Use the wall assembly in Q1 as the base case.
2) Comment on the moisture performance of your solution in comparison to the conventional 2x6 wood-frame wall shown in Q1.
3) Sketch a typical floor/wall junction with the wall construction you have chosen. On your drawing, label and trace the air barrier, vapour barrier, water resistive barrier, and rain shedding surface.

In your calculation, you can assume a RSI 0.12 for the interior surface thermal resistance, a RSI 0.03 for the exterior surface thermal resistance, and a RSI 0.22 for the thermal resistance of rainscreen air cavity. Rrefer to Table 4 from ASRHAE Fundamentals Ch. 26 for the thermal conductivities of commonly used building materials and Table 8 for vapour permeability of commonly used building materials. These tables are provided in the appendix.

Question 3 (20marks)

Five-meter wide, dark gray, precast concrete spandrel panels are to be used on a building with allowance made for lateral expansion and contraction. The panels are anchored at the middle point, as shown in the Figure below. This building is located in Toronto.

1) What is the maximum surface temperature experienced by the concrete panel? Assume the wall receives 600W/m^2 solar radiation in a summer day with outdoor temperature of 32°C. The soar absorptivity of the dark gray surface is 0.8 and the outdoor heat transfer coefficient is 20W/m^{2o}C for a calm day.
2) What is the maximum movement this concrete panel experiences? Assume the design winter temperature is -20°C. The coefficient of linear thermal expansion and contraction of concrete is 11.7 x10^{-6}/°C.
3) What would be the minimum vertical joint width if a sealant having a movement capacity of ±20% is proposed and the sealant is applied at the mean temperature.
4) Sketch the vertical joint, label the components and the relative dimensions (joint width and depth), and explain the function of each component.



(a) PANELS FIXED AT MID-POINT

Question 4 (20 marks)

Part A (5 marks):

Figure a) below shows the design of a basement. Identify the mistakes in the design and comment on solutions.

Part B (5 marks):

Figure b) shows the grade connection of a metal curtain wall. Identify the mistakes in this design and provide the correct connection details.

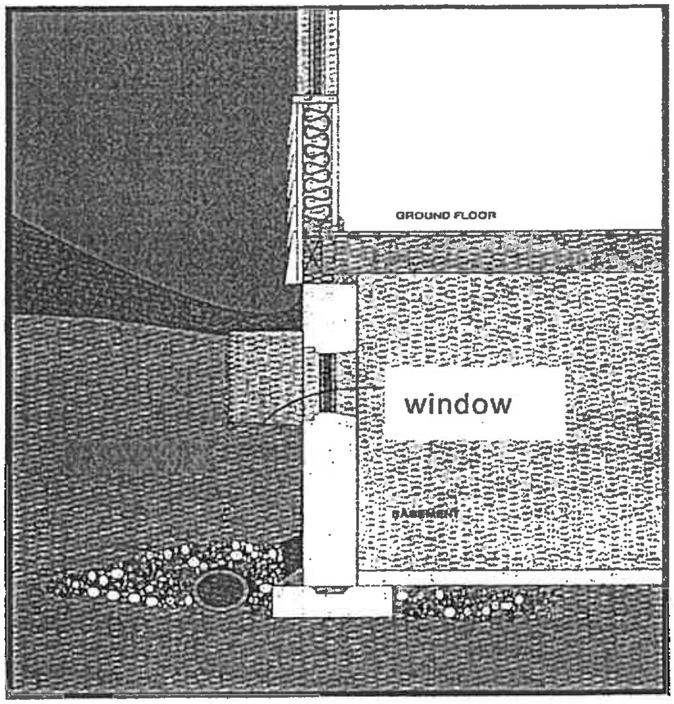


Figure a)

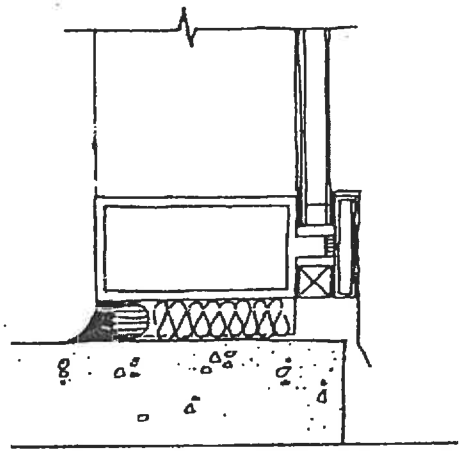


Figure b)

Part C (10 marks):

The deteriorated brick shown in photo A was found under the coping in photo B. The cross section of the coping is shown in photo C.

a) Explain the cause and mechanism which led to this deterioration of the brick,
b) Outline the deficiencies of the design detail of this coping, and
c) Draw the cross section of an effective coping and parapet.

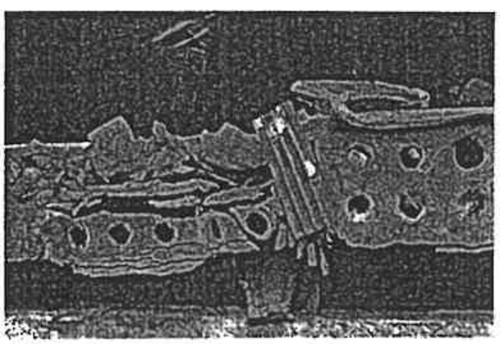


Photo A

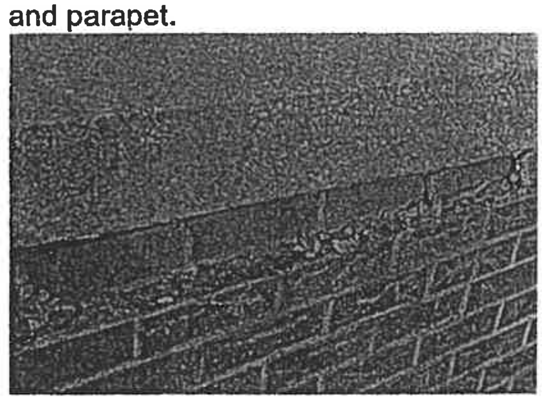


Photo B

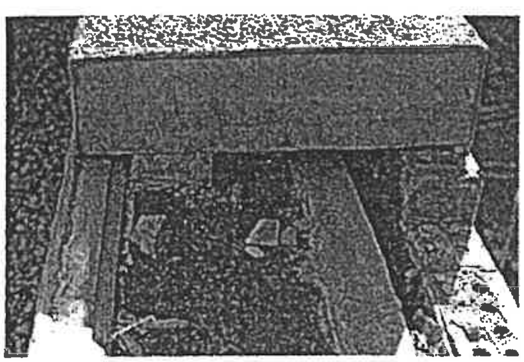
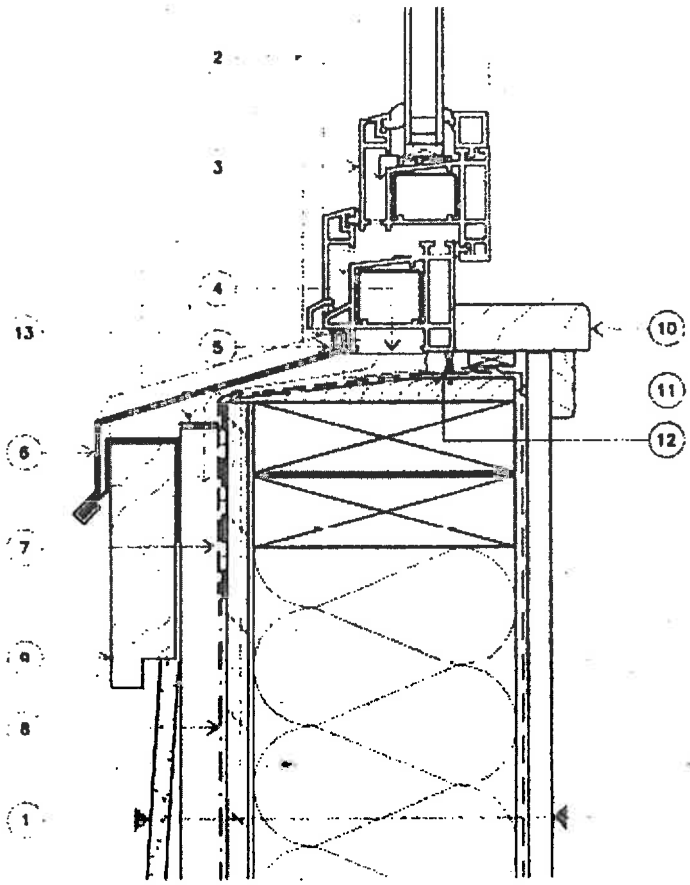


Photo C

Question 5 (20 marks):

1) List three commonly used air barrier systems and provide examples
2) Explain how to avoid roof uplift
3) Explain why a soft joint is normally required between the top of the brick veneer and the bottom of the shelf angle supporting the bricks of the next storey in a multi-story building.
4) Explain the difference between an expansion joint and a control joint with the help of sketches.
5) Figure below shows a typical window/wall connection detail. Explain how the rainwater is managed in this design.



LEGEND

1. Wall Assembly
   - Cladding (cementitious siding)
   - 19mm (¾") wood strapping (p.t.)
   - Vapour permeable sheathing membrane
   - Sheathing
   - Wood framing 38x140mm (2x6) with batt insulation
   - Polyethylene
   - Gypsum board
2. Sealant beyond
3. Window assembly
4. Intermittent shim
5. Sealant
6. Pre-finished metal flashing with end dam
7. Foil-face membrane
8. Vapour permeable sheathing membrane
9. Exterior wood trim
10. Interior window trim
11. Sloped blocking
12. Sealant & backer rod
13. Insect screen

Question 6 (20 marks)

Design a low-slope, exposed membrane roofing assembly for a warehouse building located in Toronto. The primary membrane is to be Modified Bitumen (SBS).
1) Sketch the roof section and label the main components
2) Draw a roof plan and show the location of drainage and the detailing of drainage
3) List the potential failures of a low-slope roof with Modified Bitumen membrane and elaborate on how to prevent these failures.

Material properties can be found in the appendix.

Appendix: equations

- Vapor flow equation:

$$W = MA\theta(p_1 - p_2) \quad (1)$$

where:

W = total mass of vapor transmitted, ng

M = permeance coefficient, ng/(s·m^2·Pa), $M = \frac{\bar{\mu}}{l}$

θ = time during which flow occurs, s

l = thickness, m

$\bar{\mu}$ = average permeability, ng/(s·m·Pa)

A = cross-section area of the flow path, m^2

$(p_1 - p_2)$ = vapor pressure difference applied across the specimen, Pa.

- Conductive heat transmission equation

$$\frac{q}{A} = U(t_i - t_o) \quad (2)$$

where

q/A = heat-flow rate, W/m^2

U = overall coefficient of heat transmission, W/(m^2·K)

t_I, t_o = inside and outside temperature, K

- Thermal resistance of composite section

$$R = \frac{1}{U} = R_1 + R_2 + R_3 \quad (3)$$

- Average U-value by parallel method (area-weighted average)

$$U = \frac{A_1}{A_1 + A_2}U_1 + \frac{A_2}{A_1 + A_2}U_2 \quad (4)$$

- Solar air temperature on vertical surfaces

$$t_e = t_o + \frac{\alpha I}{h_o} \quad (5)$$

where,

t_e=solar air temperature, in °C

t_o=outdoor air temperature, in °C

α, solar absorptance;

I, solar radiation intensity, in W/m^2;

h_o, the exterior surface heat transfer coefficient, W/m^2°C

- Humidity ratio

$$W = \frac{p_w}{p_a} \times 0.622 = \frac{0.622 p_w}{p_t - p_w} = \frac{0.622 \times RH\% \times p_{sat}}{p_t - RH\% \times p_{sat}} \quad (6)$$

p_w=partial water vapour pressure, Pa

p_{sat}=saturated water vapour pressure at temperature °C, Pa

p_t=atmospheric pressure, 101325Pa at sea level;

- Density

$$\rho_a = \frac{p_a}{R_a T} \quad , R_a=287.1\ J/(kg{\cdot}K) \qquad (7)$$

$$\rho_w = \frac{p_w}{R_w T} \quad , R_w=461.5\ J/(kg{\cdot}K) \qquad (8)$$

- Conversion from volume flow to mass flow

$$m = \frac{L}{\upsilon}$$

where, L is volume flow, m^3/s;
υ is specific volume, kg/m^3.

- Dimension change due to thermal expansion

$$\Delta L = C_t \times L \times \Delta t$$

$$J_t = \Delta L / S_m \qquad (9)$$

where, C_t is the coefficient of linear thermal expansion, in $10^{-6}/^{o}C$;
L is the effective length of panel, m
Δt is the temperature differential, ^{o}C
S_m is the sealant movement capacity, %
J_t is the width of the joint, m.

Table 1:

Water-Vapour Pressures at Saturation at Various Temperatures over Plane Surfaces of Pure Water and Pure Ice

Temp., °C	Pressure, Pa Over ice	Pressure, Pa Over water	Temp., °C	Pressure, Pa Over ice	Pressure, Pa Over water	Temp., °C	Press., kPa	Temp., °C	Press., kPa
−50	3.935	6.409	−22	85.02	105.4	5	0.8719	33	5.031
−49	4.449	7.124	−21	93.70	115.0	6	0.9347	34	5.320
−48	5.026	7.975	−20	103.2	125.4	7	1.001	35	5.624
−47	5.671	8.918	−19	113.5	136.6	8	1.072	36	5.942
−46	6.393	9.961	−18	124.8	148.8	9	1.147	37	6.276
−45	7.198	11.11	−17	137.1	161.9	10	1.227	38	6.626
−44	8.097	12.39	−16	150.6	176.0	11	1.312	39	6.993
−43	9.098	13.79	−15	165.2	191.2	12	1.402	40	7.378
−42	10.21	15.34	−14	181.1	207.6	13	1.497	41	7.780
−41	11.45	17.04	−13	198.4	225.2	14	1.598	42	8.202
−40	12.83	18.91	−12	217.2	244.1	15	1.704	43	8.642
−39	14.36	20.97	−11	237.6	264.4	16	1.817	44	9.103
−38	16.06	23.23	−10	259.7	286.3	17	1.937	45	9.586
−37	17.94	25.71	−9	283.7	309.7	18	2.063	46	10.09
−36	20.02	28.42	−8	309.7	334.8	19	2.196	47	10.62
−35	22.33	31.39	−7	337.9	361.8	20	2.337	48	11.17
−34	24.88	34.63	−6	368.5	390.6	21	2.486	49	11.74
−33	27.69	38.18	−5	401.5	421.5	22	2.645	50	12.33
−32	30.79	42.05	−4	437.2	454.5	23	2.809	51	12.96
−31	34.21	46.28	−3	475.7	489.8	24	2.983	52	13.61
−30	37.98	50.88	−2	517.3	527.5	25	3.167	53	14.29
−29	42.13	55.89	−1	562.3	567.8	26	3.361	54	15.00
−28	46.69	61.39	0	610.8	610.8	27	3.565	55	15.74
−27	51.70	67.27	+0.01	Triple point of water		28	3.780	56	16.51
−26	57.20	73.71	1	—	656.6	29	4.006	57	17.31
−25	63.23	80.70	2	—	705.5	30	4.243	58	19.15
−24	69.85	88.27	3	—	757.5	31	4.493	59	19.02
−23	77.09	96.49	4	—	812.9	32	4.755	60	19.92

Table 4 Typical Thermal Properties of Common Building and Insulating Materials: Design Values[a] (Continued)

Description	Density, kg/m³	Conductivity[b] k, W/(m·K)	Resistance R, (m²·K)/W	Specific Heat, kJ/(kg·K)	Reference[c]
Finish Flooring Materials					
Carpet and rebounded urethane pad .... 19 mm	110	—	0.42	—	NIST (2000)
Carpet and rubber pad (one-piece)............ 9.5 mm	320	—	0.12	—	NIST (2000)
Pile carpet with rubber pad............ 9.5 to 12.7 mm	290	—	0.28	—	NIST (2000)
Linoleum/cork tile............ 6.4 mm	465	—	0.09	—	NIST (2000)
PVC/Rubber floor covering............	—	0.40	—	—	CIBSE (2006)
Rubber tile............ 25 mm	1900	—	0.06	—	NIST (2000)
Terrazzo............ 25 mm	—	—	0.014	0.80	
Insulating Materials					
Blanket and batt[c,d]					
Glass-fiber batts .... 85 to 90 mm	10 to 14	0.043	—	0.84	Kumaran (2002)
.... 50 mm	8 to 13	0.045 to 0.048	—	0.84	Kumaran (2002)
Mineral fiber............ 140 mm	30	0.036	—	0.84	Kumaran (1996)
Mineral wool, felted............	16 to 48	0.040	—	—	CIBSE (2006), NIST (2000)
....	65 to 130	0.035	—	—	NIST (2000)
Slag wool	50 to 190	0.038	—	—	Raznjevic (1976)
....	255	0.040	—	—	Raznjevic (1976)
....	305	0.043	—	—	Raznjevic (1976)
....	350	0.048	—	—	Raznjevic (1976)
....	400	0.050	—	—	Raznjevic (1976)
Board and slabs					
Cellular glass............	130	0.048	—	0.75	(Manufacturer)
Cement fiber slabs, shredded wood with Portland cement binder............	400 to 430	0.072 to 0.076	—	—	
with magnesia oxysulfide binder............	350	0.082	—	1.30	
Glass fiber board............	160	0.032 to 0.040	—	0.84	Kumaran (1996)
Expanded rubber (rigid)............	70	0.032	—	1.67	Nottage (1947)
Expanded polystyrene extruded (smooth skin)............	25 to 40	0.022 to 0.030	—	1.47	Kumaran (1996)
Expanded polystyrene, molded beads............	15 to 25	0.032 to 0.039	—	1.47	Kumaran (1996)
Mineral fiberboard, wet felted	160	0.038	—	0.84	Kumaran (1996)
core or roof insulation............	255 to 270	0.049	—	—	
acoustical tile[f]............	290	0.050	—	0.80	
....	335	0.053	—	—	
wet-molded, acoustical tile[f]............	370	0.061	—	0.59	
Perlite board............	160	0.052	—	—	Kumaran (1996)
Polyisocyanurate, aged					
unfaced............	25 to 35	0.020 to 0.027	—	—	Kumaran (2002)
with facers............	65	0.019	—	1.47	Kumaran (1996)
Phenolic foam board with facers, aged............	65	0.019	—	—	Kumaran (1996)
Loose fill					
Cellulosic (milled paper or wood pulp)............	35 to 50	0.039 to 0.045	—	1.38	NIST (2000), Kumaran (1996)
Perlite, expanded............	30 to 65	0.039 to 0.045	—	1.09	(Manufacturer)
....	65 to 120	0.045 to 0.052	—	—	(Manufacturer)
....	120 to 180	0.052 to 0.061	—	—	(Manufacturer)
Mineral fiber (rock, slag, or glass)[d]............					
............approx. 95 to 130 mm	10 to 30	—	1.92	0.71	
............approx. 170 to 220 mm	10 to 30	—	3.33	—	
............approx. 190 to 250 mm	10 to 30	—	3.85	—	
............approx. 260 to 350 mm	10 to 30	—	5.26	—	
............90 mm (closed sidewall application)	30 to 55	—	2.1 to 2.5	—	
Vermiculite, exfoliated............	110 to 130	0.068	—	1.34	Sabine et al. (1975)
....	64 to 96	0.063	—	—	(Manufacturer)
Spray-applied					
Cellulosic fiber............	55 to 95	0.042 to 0.049	—	—	Yarbrough et al. (1987)
Glass fiber............	55 to 70	0.038 to 0.039	—	—	Yarbrough et al. (1987)
Polyurethane foam (low density)............	6 to 8	0.042	—	1.47	Kumaran (2002)
....	40	0.026	—	1.47	Kumaran (2002)
aged and dry............ 40 mm	30	—	1.6	1.47	Kumaran (1996)
.... 50 mm	55	—	1.92	1.47	Kumaran (1996)
............120 mm	30	—	3.69	—	Kumaran (1996)
Ureaformaldehyde foam, dry............	8 to 20	0.030 to 0.032	—	—	CIBSE (2006)

Table 8 Water Vapor Permeability of Building Materials at Various Relative Humidities

Material	Permeability at Various Relative Humidities, $ng/(Pa \cdot s \cdot m)$ 10%	30%	50%	70%	90%	Water Absorption Coefficient, $(kg \cdot s^{1/2})/m^2$	Mean Air Permeability, $kg/(Pa \cdot s \cdot m)$	References/ Comments
Building Board and Siding								
Asbestos cement board, 3 mm thickness		← 0.66 to 1.37 →		← N/A →				Dry cup*
with oil-base finishes		← 0.05 to 0.09 →		← N/A →				
Cement board, 13 mm, 1130 kg/m^3	7.4	7.4	9.3	12	16	0.013	3×10^{-8}	Kumaran (2002)
Fiber cement board, 8 mm, 1380 kg/m^3	0.21	0.58	1.6	4.7	14.8	0.025	3×10^{-12}	Kumaran (2002)
Gypsum board		21		23	30			Kumaran (1996)/NRC
asphalt impregnated			← 0.038 →					
Gypsum wall board, 13 mm, 625 kg/m^3	23.4	27.2	31.9	37.6	44.7	0.0019[c]	4.2×10^{-9}	Kumaran (2002)
with one coat primer	6.83	14.9	22.0	28.9	35.9	N/A	2.2×10^{-8}	Kumaran (2002)
with one coat primer/two coats latex paint	1.1	2.1	4.0	8.0	16.5	N/A	2.5×10^{-9}	Kumaran (2002)
Hardboard siding, 11 mm, 740 kg/m^3	3.92	4.28	4.67	5.10	5.58	0.00072	4.5×10^{-9}	Kumaran (2002)
Oriented strand board (OSB), 9.5 mm, 660 kg/m^3	0.0064	0.177	0.487	1.35	3.83	0.0016	1×10^{-9}	Kumaran (2002)
11.1 mm	0.026	0.60	1.23	2.30	4.08	0.0022	2×10^{-9}	Kumaran (2002)
12.7 mm	0.044	0.344	0.90	1.70	2.75	0.0016	1×10^{-9}	Kumaran (2002)
Particleboard		4.4	6.0	10.2	15.2			Kumaran (1996)
Douglas fir plywood, 12 mm, 470 kg/m^3	0.19	0.59	1.46	3.19	6.50	0.0042[d]	4×10^{-11}	Kumaran (2002)
15 mm, 550 kg/m^3	0.15	0.41	1.09	2.91	7.99	0.0031	1×10^{-9}	Kumaran (2002)
Canadian softwood plywood, 18 mm, 445 kg/m^3	0.06	0.57	2.28	6.12	13.30	0.0037	2×10^{-11}	Kumaran (2002)
Plywood (exterior-grade), 12 mm, 580 kg/m^3	0.21	0.36		0.80	8.62			Burch et al.
Wood fiber board, 11 mm, 320 kg/m^3	12.4	13.6	15.0	16.4	18.1	0.00094	2.5×10^{-7}	Kumaran (2002)
25 mm, 300 kg/m^3	71.5	58.4		86.7	77.2			Burch and Desjarlais (1995)
Masonry Materials								
Aerated concrete, 460 kg/m^3	11.2	15.9	22.9	33.4	50	0.036	5×10^{-9}	Kumaran (2002)
600 kg/m^3	18	21.6	22	42	63			Kumaran (1996)
Cement mortar, 1600 kg/m^3	13.6	16.5	20.1	24.5	30.2	0.02	1.5×10^{-9}	Kumaran (2002)
Clay brick, 100 by 100 by 200 mm, 1980 kg/m^3	4.14	4.44	4.77	5.12	5.50	0.17	2 to 5×10^{-10}	Kumaran (2002)
Concrete, 2200 kg/m^3		1.26	1.4	2.5	6.5			Kumaran (1996)
Concrete block (cored, limestone aggregate), 200 mm			← 27.4 →					
Lightweight concrete, 1100 kg/m^3		12.3		11.4	18.7			Kumaran (1996)
Limestone, 2500 kg/m^3	0.26	0.26	0.26	0.26	0.26	0.00033	negligible	Kumaran (2002)
Perlite board		28		33	82			Kumaran (1996)
Plaster, on metal lath, 19 mm			← 16.3 →					
on wood lath			← 12.0 →					
on plain gypsum lath (with studs)			← 21.7 →					
Polystyrene concrete, 530 kg/m^3		0.88		1.1	2.7			Kumaran (1996)
Portland stucco mix, 1985 kg/m^3	0.81	1.15	1.63	2.31	3.26	0.012	1×10^{-11}	Kumaran (2002)
Tile masonry, glazed, 100 mm			← 0.69 →					
Woods								
Eastern white cedar, 20 mm, 360 kg/m^3 (transverse)	0.013	0.078	0.48	3.05	20.9	0.0016	negligible	Kumaran (2002)
Eastern white pine, 19 mm, 460 kg/m^3 (transverse)	0.47	0.17	0.67	2.58	10.2	0.0066	1×10^{-12}	Kumaran (2002)
Pine	0.35	0.51	1.1	3.1	6.3			Kumaran (1996)
Southern yellow pine, 20 mm, 350 kg/m^3 (transverse)	0.12	0.404	1.37	4.7	16.9	0.0014	3×10^{-11}	Kumaran (2002)
Spruce (longitudinal)	53	74	84	86	87			Kumaran (1996)
20 mm, 400 kg/m^3 (transverse)	0.37	1.08	3.13	9.27	29.5	0.002	5×10^{-11}	Kumaran (2002)
Western red cedar, 18 mm, 350 kg/m^3 (transverse)	0.106	0.228	0.491	1.06	2.29	0.001	$<1 \times 10^{-12}$	Kumaran (2002)
Insulation								
Air (still)			← 174 →					
Cellular glass			← 0.0 →					
Cellulose insulation, dry blown, 30 kg/m^3	112	140	156	168	178	0.1	2.9×10^{-4}	Kumaran (2002)
Corkboard		3.0 to 3.8		14				
Glass fiber batt, 11.5 kg/m^3	172	172	172	172	172	N/A	2.5×10^{-4}	Kumaran (2002)
Glass-fiber insulation board, 24 mm, 120 kg/m^3		238			152			Burch et al.
facer, 1.6 mm, 880 kg/m^3	0.004	0.00251		0.0184	0.0389			Burch et al.
Mineral fiber insulation, 30 to 190 kg/m^3		70		88	250			Kumaran (1996)
Mineral wool (unprotected)			← 245 →					

Table 8 Water Vapor Permeability of Building Materials at Various Relative Humidities (*Continued*)

Material	Permeability at Various Relative Humidities, ng/(Pa·s·m) 10%	30%	50%	70%	90%	Water Absorption Coefficient, $(kg \cdot s^{1/2})/m^2$	Mean Air Permeability, kg/(Pa·s·m)	References/ Comments
Phenolic foam (covering removed)	←		38		→			
Polystyrene								
expanded, 14.8 kg/m^3	2.85	3.36	3.96	4.66	5.50	N/A	1.1×10^{-8}	Kumaran (2002)
extruded, 28.6 kg/m^3	1.22	1.22	1.22	1.22	1.22	N/A		Kumaran (2002)
Polyurethane								
expanded board stock [(R = 1.94 $W/(m^2 \cdot K)$]		0.58 to 2.3						
sprayed foam, 39.0 kg/m^3	2.34	2.54	2.75	2.97	3.22	N/A	1×10^{-11}	Kumaran (2002)
6.5 to 8.5 kg/m^3	87.5	87.5	87.5	87.5	87.5	N/A	4.2×10^{-9}	Kumaran (2002)
Polyisocyanurate insulation, 26.5 kg/m^3	4.04	4.56	5.14	5.80	6.55	N/A		Kumaran (2002)
Polyisocyanurate glass-mat facer, 0.8 mm, 430 kg/m^3	0.49	0.90		1.30	2.29			Burch et al.
Structural insulating board, sheathing quality	←		29 to 73		→			
interior, uncoated, 13 mm	←		37.2 to 67		→			
Unicellular synthetic flexible rubber foam		0.029						
Foil, Felt, Paper								
Bituminous paper (#15 felt), 0.72 mm, 515 g/m^2 (transverse)	0.29	0.29	0.29	0.40	1.17	0.0005	2.5×10^{-6}	Kumaran (2002)
Asphalt-impregnated paper								
10 min rating, 0.2 mm, 170 g/m^2 (transverse)	0.24	0.43	0.78	1.48	3.06	0.001	1.1×10^{-6}	Kumaran (2002)
30 min rating, 0.22 mm, 200 g/m^2 (transverse)	0.44	0.74	1.28	2.31	4.67	0.093	6.6×10^{-6}	Kumaran (2002)
60 min rating, 0.34 mm, 280 g/m^2 (transverse)	1.51	1.91	2.44	3.18	4.24	0.0011	7.1×10^{-6}	Kumaran (2002)
Spun bonded polyolefin (SBPO)								
0.14 to 0.15 mm, 65 g/m^2 (transverse)	4.37	4.37	4.37	4.37	4.37	0.00031	4.6×10^{-7}	Kumaran (2002)
with crinkled surface, 0.1 to 0.11 mm, 67 g/m^2 (transverse)	3.17	3.17	3.17	3.17	3.17	0.00024	3×10^{-7}	Kumaran (2002)
Wallpaper								
paper		0.12		1.2 to 1.7				Kumaran (1996)
textile		0.05		0.74 to 2.34				Kumaran (1996)
vinyl, 0.205 mm, 170 g/m^2 (transverse)	0.08	0.14	0.21	0.32	0.46	0.00025	5×10^{-9}	Kumaran (2002)
Other Construction Materials								
Built-up roofing (hot-mopped)	←		0.0		→			
Exterior insulated finish system (EIFS), 4.4 mm acrylic, 1140 kg/m^3	0.09	0.09	0.09	0.09	0.09	0.00053	0	Kumaran (2002)
Glass fiber reinforced sheet, acrylic, 1.4 mm	←		0.01		→			
polyester, 1.2 mm	←		0.035		→			

*Historical data, no reference available

N/A – Not applicable