SECTION 13 APPENDICES

ENERGY EFFICIENCY BUILDING DESIGN GUIDELINES FOR BOTSWANA

Sections:

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1. PROPERTIES OF BUILDING MATERIALS

	Density	Specific heat	Conductivity	Source
	kg/m^3	J/kg.K	W/m.K	
Insulating materials				
Polystyrene	15	1.4	0.037	a
Glasswool	12		0.042	e
PVC	1390	900	0.17	b
PVC floor covering			0.4	a
Woodwood cement	908		0.282	e
Concrete, brick and plaster				
Plasterboard			0.159	a
Concrete medium density	1800	1000	1.35	b
Cast concrete	2000	1000	1.13	b
Plaster (dense)	1300	1000	0.5	b
Vermiculite plaster (light)	480	880	0.144	a
Vermiculite plaster (dense)	960	880	0.303	a
Brick (average)			1.21	a

	Density	Specific heat	Conductivity	Source
	kg/m^3	J/kg.K	W/m.K	
Aggregate, rock and clay				
Granite			2.92	a
Sandstone			1.295	a
Building sand	1500	840	0.3	a
Slate	2500	750	1.4	a
Soil	1500	850	1.5	a
Clay tiles	1922	920	0.84	a
Timber				
Pine timber	500	2800	0.15	d
Hardwood (American Beech)	560 - 865	390	0.173	c
Metals				
Lead	11340	1900	34	a,c
Cast iron	7200	520	50	d
Steel	7870	4860	51.9	c
Aluminium	2698	900	210	c
Copper	8960	385	385	c
Silver	10491	234	419	c
Other				
Air	1.3	1	0.032	d
Water	998	4182	0.609	c
Concrete	2250	1000	2	d
Glass	2500	700	1	d

2. PROPERTIES OF BUILDING ELEMENTS

Construction	thickness	R value	U value	C	CR	Source
layers	mm	m^2.K/W	W/m^2.K	kJ/m^2.K	sec	
ROOF						
Galvanised roof		0.190	5.263	22.949	4.360	a
Galvanised sheet	0.6			22.949		
Galvanised roof with ceiling		0.530	1.887	27.449	14.548	a
Galvanised roof	0.6			22.949		
Ceiling	10			4.500		
Galvanised roof with 50mm insulated ceiling		2.030	0.493	27.450	55.724	a
Galvanised roof	0.6			22.949		
Fibre glass insulation	50			0.001		
Ceiling	10			4.500		
Galvanised roof with 100mm insulated ceiling		3.420	0.292	27.451	93.883	a
Galvanised roof	0.6			22.949		a
100mm fibre glass insulation	100			0.002		
Ceiling	10			4.500		
Thatch		4.500	0.222			a
Thatch	250					
Concrete tiles with underlay		0.345	2.897	56.250	19.406	b
Concrete tiles	25			56.250		
Air gap	25			0.000		
Polythene	0.1			0.000		

Construction	thickness	R value	U value	C	CR	Source
layers	mm	m^2.K/W	W/m^2.K	kJ/m^2.K	sec	
WALLS						
Solid half brick wall plastered		0.311	3.215	228.000	70.908	b
Plaster	15			19.500		
Cement brick	105			189.000		
Plaster	15			19.500		
Hollow block wall plastered 150mm		0.410	2.439	201.000	82.410	a
Plaster	15			19.500		
Hollow cement block	150			162.000		
Plaster	15			19.500		
Hollow block wall plastered 230mm		0.510	1.961	287.400	146.574	a
Plaster	15			19.500		
Hollow cement block	230			248.400		
Plaster	15			19.500		
Solid one brick wall plastered		0.394	2.538	435.000	171.390	b
Plaster	15			19.500		
Cement brick	220			396.000		
Plaster	15			19.500		
Cavity wall plastered		0.567	1.764	417.000	236.439	b
Plaster	15			19.500		
Cement brick	105			189.000		
Air gap	50			0.000		
Cement brick	105			189.000		
Plaster	15			19.500		
Cavity wall plastered with insulation		1.955	0.512	417.001	815.237	b
Plaster	15			19.500		
Cement brick	105			189.000		
Air gap	50			0.000		
Glass wool	50			0.001		
Cement brick	105			189.000		
Plaster	15			19.500		

Construction	thickness	R value	U value	C	CR	Source
layers	mm	m^2.K/W	W/m^2.K	kJ/m^2.K	sec	
FLOORS						
Concrete on DPC		0.231	4.329	200.626	46.344	b
Cast concrete	100			200.000		
PVC	0.5			0.626		

Sources:

a. Hamilton, L.B., et. al. 1984. Passive Solar Design Workbook. BRET. Botswana.

b. EECOB Report: 'Parametric simulation of the energy performance of three generic building types in Gaborone, Botswana'. Department of Energy, Government of Botswana, January 2007.

c. Matweb Material Property Data. http://www.matweb.com

d. University of Warwick. Department of Engineering. Data Book 1977

e. National Institute of Standards and Technology, USA. Standard Reference Database 81. http://srdata.nist.gov/insulation/

3. PROPERTIES OF GLASS

Description	Visible light Transmission [%]	Solar energy Transmission [%]	Visible/Solar Transmission [ratio]	Shading coefficient [ratio]	U value [W/m^2°C]
Clear float glass				1.00	
SolarVue Blue – High Light	38	47	0.81	0.54	5.8
SolarVue Blue – Extra High Light	46	53	0.87	0.61	5.8
SolarShield Blue – S10	9	25	0.36	0.28	5.8
SolarShield Blue – S20	20	33	0.61	0.38	5.8
SolarShield Blue – S30	30	41	0.73	0.47	5.8
CoolVue Clear	72	47	1.53	0.54	5.8
InsulVue Coolblue (ColourVue +12mm air gap + ClearVue)	65	61	1.07	0.71	3.2
InsulVue Blue (SolarShield +12mm air gap + ClearVue) – S10	8	16	0.50	0.19	3.2
InsulVue Blue (SolarShield +12mm air gap + ClearVue) – S20	18	24	0.75	0.27	3.2
InsulVue Blue (SolarShield +12mm air gap + ClearVue) – S30	26	31	0.84	0.35	3.2

Table 3.1. Properties of Glass (from Smart Glass Catalogue, PFG Building Glass)

Notes:

The "Shading Coefficient" is the ratio of Total Solar Energy Transmission of a glass compared to the Total Solar Energy Transmission for ordinary 3mm glass.

The ratio of Total Visible Light Transmission compared to Total Solar Energy Transmission has been included to give a comparison of which glass is most effective at transmitting maximum light with minimum energy. The higher the 'Visible Light Transmission', the clearer the glass will appear. The higher the 'Solar energy transmission', the more heat the glass is allowing into the building. Thus the ideal glass would have high Visible Light Transmission and low Solar energy transmission.

4. ASHRAE STANDARD 90.1 2001 (extract).

Extract from : ASHRAE Standard 90.1 2001 Energy Standard for Buildings except Low Rise Residential Buildings

Climate data for Pretoria are given in Table 4.1. and the corresponding values for envelope requirements are given in Tables 4.2. and 4.3.

Climate parameter	**Value**
Latitude	25.73S
Longitude	28.28E
Elevation	1,330
Heating Degree Days base 18°C	639
Cooling Degree Days base 10°C	3,238
Heating design Temp. 99.6%	4
Cooling Design Temp DB 1.0%	31
Cooling Design Temp WB 1.0%	17

Table 4.1. Climate data for Pretoria (source: ASHRAE Standard 90.1-2001 Table D3)

Opaque Elements	Non-residential		Residential	
	Assembly Max U-value [W/m^{2}K]	Insulation Min. R-value [m^{2}K/W]	Assembly Max U-value [W/m^{2}K]	Insulation Min. R-value [m^{2}K/W]
Roofs				
Metal building	0.369	3.3	0.369	3.3
Attic and other	0.192	5.3	`0.192	5.3
Walls above ground level				
Mass	3.293	NR	0.857	1.0
Metal building	0.642	2.3	0.642	2.3
Steel framed	0.705	2.3	0.705	2.3
Wood framed and other	0.504	2.3	0.504	2.3
Floors				
Mass	0.780	0.7	0.606	1.1
Doors				
Opaque hinged doors	3.975	N/a	3.975	N/a

Table 4.2 Building Envelope Opaque Elements requirements for Pretoria climate (source: ASHRAE Standard 90.1-2001 Table B-6)

Fenestration	Non-residential		Residential	
	Assembly Max U (Fixed / Operable) [W/m^{2}K]	**Assembly Max. SHGC (All Orientations / North orientated) [ratio]**	**Assembly Max U (Fixed / Operable) [W/m^{2}K]**	**Assembly Max. SHGC (All Orientations / North orientated) [ratio]**
Vertical Glazing. % of wall				
0-10.0%	Fixed 6.93 Operable 7.21	All 0.39 North 0.61	Fixed 6.93 Operable 7.21	All 0.61 North 0.61
10.1-20.0%	Fixed 6.93 Operable 7.21	All 0.25 North 0.61	Fixed 6.93 Operable 7.21	All 0.44 North 0.61
20.1-30.0%	Fixed 6.93 Operable 7.21	All 0.25 North 0.61	Fixed 6.93 Operable 7.21	All 0.44 North 0.61
30.1-40.0%	Fixed 6.93 Operable 7.21	All 0.25 North 0.61	Fixed 6.93 Operable 7.21	All 0.40 North 0.61
40.1-50.0%	Fixed 6.93 Operable 7.21	All 0.17 North 0.42	Fixed 6.93 Operable 7.21	All 0.29 North 0.41

Table 4.3. Building Envelope Fenestration Elements requirements for Pretoria climate (source: ASHRAE Standard 90.1-2001 Table B-6)

Definitions relating to tables 7.2, 7.3 and 7.4:
Roof, metal building:
a roof that is constructed with (a) a metal, structural, weathering surface, (b) has no ventilated cavity, and (c) has the insulation entirely below deck (i.e., does not include compos- ite concrete and metal deck construction nor a roof framing system that is separated from the super- structure by a wood substrate) and whose structure consists of one or more of the following configura- tions: (1) metal roofing in direct contact with the steel framing members or (2) insulation between the metal roofing and the steel framing members or (3) insulated metal roofing panels installed as described in (1) or (2).

Roof, attic and other:
all other roofs, including roofs with insulation entirely below (inside of) the roof structure (i.e., attics, cathedral ceilings, and single-rafter ceilings), roofs with insulation both above and below the roof structure, and roofs without insulation but excluding metal building roofs.

Wall, mass:
a wall with a heat capacity exceeding (1) 143 kJ/m^{2}K or (2) 102 kJ/m^{2}K provided that the wall has a material unit weight not greater than 1920 kg/m^3

Wall, metal building:
a wall whose structure consists of metal spanning members supported by steel structural members (i.e., does not include spandrel glass or metal panels in curtain wall systems).

Wall, steel framed:
a wall with a cavity (insulated or otherwise) whose exterior surfaces are separated by typical steel stud walls systems).

Wall, wood framed and other:
all other wall types, including wood stud walls.

Floors, mass:
a floor with a heat capacity exceeding (1) 143 kJ/m^{2}K or (2) 102 kJ/m^{2}K provided that the wall has a material unit weight not greater than 1920 kg/m^3

Assembly max SHGC:
solar heat gain coefficient (SHGC): the ratio of the solar heat gain entering the space through the fenestration area to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted, or convected into the space.