Section 5: Breadth Topics

Breadth: Impact of Daylight Integration on Mechanical Load in President Office.

Introduction

The corner pavilion of the building is a prominent architectural feature of the Ballenger East Building, and the president office locates right on top of the pavilion, which also makes the special shape of the office. In the president office, there are 5 huge windows (each of about 40 ft^2 in area) facing the north-east direction. It is anticipated daylight could be an alternate light source during daytime. Yet, solar heat gain could become an issue. The façade is north-east facing, so direct sunlight should not be a problem, but the large window area (total 200 ft^2) might lead to undesirable solar heat gain a problem during the summer, while it attains the highest value with the high solar angle. Nevertheless, the solar heat gain is generally considered desirable to reduce the heating load during winter time. In other words, though the natural sunlight is a tremendous source of light and heat. But without control of natural sunlight, building performance and interior furnishings would be negatively impact, disruption and discomfort perceived by occupants are even worse. Therefore, a study would be performed to investigate how the glazing system and solar heat gain would most positively enhance the working environment in the president office.

Objectives

To investigate how the glazing system and solar heat gain affect the mechanical load.

Process

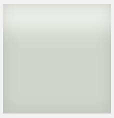
A clear glazing is selected for the existing design. Introduction of new solar systems with tint and colored glass would be avoided as it might possibly distort the architectural style of the space and image of the organization. In short, the ideal solar glazing system depends on some major properties of fenestration:

- Visible Transmittance (**T_V**) – percentage of glare-causing penetrated visible light
- Solar Heat Gain Coefficient (**SHGC**) – measures the transmittance of solar radiation
- Light to Solar Gain Ratio (**LSG**) – measures the efficiency of glazing (T_V/ SHGC)
- U value – heat transfer coefficient

- Outdoor Visible Light Reflectance (ρ_v)

Software 'Hourly Analysis Program' (HAP) is used to collect glazing data, which would be shown in the following table:

Decreasing T_V, U_{winter}, U_{summer}, SHGC

Glazing Data (PPG Architectural Glass Products)							
Glazing	Image	T_V	U_{winter}	U_{summer}	SHGC	ρ_v	LSG
Starphine, clear glass, uncoated	No image available	84%	0.47	0.5	0.82	15%	1.02
Sungate 500, clear glass, low-e coating		74%	0.35	0.35	0.62	17%	1.19
Solarban 60, clear glass, low-e coating		70%	0.29	0.27	0.38	11%	1.85
Solarban 70XL, clear glass, low-e coating		64%	0.28	0.26	0.27	12%	2.37

Decreasing LSG

The HAP analysis:

The president office is about 900 ft^2, with glasses of 200 ft^2 facing north-east and weather data would be used as input for the simulation. Only several models are selected due to their clear glass, non-tints, and acceptable visible transmittance value properties.

The results could be summarized in the following table:

Load Summary				
Glazing	Heating Load		Cooling Load	
	Btu/hr	Tons	Btu/hr	Tons
Starphine, clear glass, uncoated	25,800	2.15	19,800	1.65
Sungate 500, clear glass, low-e coating	26,100	2.18	14,860	1.24
Solarban 60, clear glass, low-e coating	26,600	2.22	12,500	1.04
Solarban 70XL, clear glass, low-e coating	27,000	2.25	11,600	9.67

Interpretation

The Solarban 70XL has the highest heating load as well as the least cooling load, because it has the highest LSG ratio and lowest SHGC value. Though it has the highest heating load, all the values are comparable among each other (within a range of about 1200 Btu/hr). However, the difference in cooling load is more significant, as the largest margin is about 8000 Btu/hr. This pronounced cooling load reduction not only save energy cost but also reduce the air-handling unit size and thus save the equipment cost as well. By summing up the additional heating and cooling, it shows Solarban 60 and Solarban 70XL have an extra load of 39,100 Btu/hr and 38,600 Btu/hr respectively. The values are quite close, and I think both models are good selections to be recommended, and it really depends on the favor of the occupant.

Breadth: Sustainable Materials on Building Envelope

Introduction

On the building envelope of the Ballenger East Building, several materials are mainly used: bricks, precast concrete, and glasses. On the north, east and west sides of the building, the windows take up 40 – 50% of surface area on the façade, and the office spaces has occupied the two upper-most floors. If natural ventilation could be manipulated through the window openings, it possibly would lead to a reduction on energy consumption for cooling load.

Objectives

(a) Estimate the number of hours of natural ventilation is available at the site
(b) How would the sustainable materials, in this case the glass, impact on the results of the estimation in (a).

Process

Software 'BinMaker' would be used to collect weather data and the data would be used in a sample of an office space to perform the study.

City Location (from BinMaker)

Richmond, Virginia

Office Space Dimension

Length: 5m (16.25 ft.)
Width: 4m (13ft.)
Height: 3m (9.75')
Room area: $20m^2$ ($211\ ft^2$)
Volume: $60m^3$ ($2060\ ft^3$)
Window orientation: 4 windows of $0.4m^2$ ($4.5\ ft^2$) each are separated 2m (6.5 ft) by height on the 4m wall.
West facing

Month

April

Assumptions

T_{in}	°C	20	ASHRAE 55, Fig 5.3 comfort zone
T_{out}	°C	14.97	Averaged value from weather data
U	m/s	4.1	Averaged value from weather data
Z	m	5	
h	m	2	
A	m^2	0.8	
V	m^3	60	
θ	°	189.56	

$$\dot{V}\mathbf{stack} = 0.6A\sqrt{gh\frac{\Delta T}{(Tout+273)}} = (0.6)\times(0.4\times2)\sqrt{9.8\times2\times\frac{20-14.97}{14.97+273}} = \mathbf{0.281}$$

$$\dot{U}local = KUcos\theta Z^a = 0.35\times4.1\times\cos(270-189.56)\times5^{0.25} = 0.356$$

$$\dot{\mathbf{V}}\mathbf{wind} = 0.1AUlocal = 0.1\times(0.4\times2)\times0.356 = \mathbf{0.0285}$$

$$\mathbf{Vtotal} = \sqrt{\dot{V}wind^2+\dot{V}stack^2} = \sqrt{0.0285^2+0.281^2} = \mathbf{0.282}\quad (m^3/s)$$

$$\mathbf{ACH} = 0.282\,x\frac{3600}{60} = \mathbf{16.95}$$

Natural ventilation could provide roughly **17 ACH** (Air Changes per Hour) in the month of April.

After calculating the air changes per hour, we would put our focus on the impact of using sustainable materials for the window opening. By doing so, two calculations would be performed. The first attempt would use materials of higher U-values (shaded in grey), the second attempt use materials of lower U-values (unshaded)

Building Material Selection

Material	Description	U value (W/kM^2)
Wall	Wood Studs 2x5, 16" o.c. with exterior air film, stucco, exterior gypsum board, interior gypsum board with air film.	**0.55**
	Wood Studs 2x6, 24" o.c. with exterior air film, stucco, continuous insulation, interior/exterior gypsum, interior air film	**0.37**
Window	Double Glazed Clear , SC =1	**3.63**
	Double Glazed Reflective , SC = 0.6	**3.63**

<u>1st Attempt</u>

From the values above and in the tables below, we could use these equations to solve for Internal Heat Gain at **1st Hour**,

Q_{wall} = U * A * (CLTD) = 0.55 x [(4 * 3) – (0.4 * 4)] * 14 = **80.08 W**

Q_{window} = U * A * (CLTD) = 3.63 x (0.4 * 4) * 1 = **8 W**

$Q_{solar\ gain}$ = A * (SC) * (SCL) = (0.4 * 4) * 1 * 3 = **4.8 W**

Therefore,

$Q_{total\ heat\ gain} = Q_{wall} + Q_{window} + Q_{solar\ gain}$ = 80.8 + 8 + 4.8

= **93.6 W**

Q_{vent} = 1.08 * CFM * (ΔT) = 1.08 * 17 ACH * (5m * 4m *3m) * (20˚C– 14.97˚C) * (1/60)

= **92.35 W**

$\Delta T = \frac{Q(\text{Total Heat Gain}) - Q(\text{Vent})}{1.08 \times CFM}$ = (93.6 – 92.35) / [(1.08 *17 ACH * (5 *4 *3) *(1/60))

= **0.068 °C**

$T_{inside} = T_{out} + \Delta T$ = 14.97 + 0.068 = **15.04 °C**

Hour	Avg DB (°C)	Avg WD	Avg WS (m/s)	CLTD (west facing)	CLTD (window)	SCL (type A, west facing)
1	11.04	166	3.51	14	1	3
2	10.68	183	3.51	11	0	0
3	10.32	186	3.51	9	-1	0
4	9.95	187	3.52	7	-1	0
5	10.15	197	3.67	6	-1	0
6	10.37	179	3.82	4	-1	38
7	10.57	172	3.99	3	-1	54
8	12.32	190	4.25	2	0	76
9	14.07	196	4.51	2	1	95
10	15.82	191	4.76	3	2	110
11	16.92	196	4.74	4	4	120
12	18.04	203	4.71	5	5	126
13	19.14	209	4.68	6	7	205
14	19.59	216	4.68	8	7	359
15	20.02	222	4.69	11	8	498
16	20.47	217	4.69	16	8	589
17	19.05	183	4.20	21	7	605
18	17.61	184	3.71	25	7	491
19	16.17	162	3.23	29	6	180
20	14.98	154	3.28	30	4	85
21	13.79	158	3.32	28	3	41
22	12.61	130	3.36	24	2	19
23	12.20	154	3.45	21	2	9
24	11.77	168	3.51	17	1	6

Hour	Q_{wall}(w)	Q_{window}(w)	Q_{solar}(w)	Total heat gain(w)	$Q_{ventilation}$ (w)	ΔT(°C)	T_{inside} (°C)
1	53.8	8	4.8	66.6	164.6	-4.69	**6.35**
2	36.6	0	0.0	36.6	171.0	-6.43	**4.26**
3	25.2	-8	0.0	17.2	177.7	-7.68	**2.64**
4	13.7	-8	0.0	5.7	184.4	-8.54	**1.41**
5	8.0	-8	0.0	0.0	180.8	-8.64	**1.51**
6	-3.4	-8	60.8	49.4	176.8	-6.09	**4.27**
7	-9.2	-8	86.4	69.2	173.1	-4.96	**5.61**
8	-14.9	0	121.6	106.7	141.0	-1.64	**10.69**
9	-14.9	8	152.0	145.1	108.9	1.73	**15.81**
10	-9.2	16	176.0	182.8	76.8	5.07	**20.89**
11	-3.4	32	192.0	220.6	56.5	7.84	**24.77**
12	2.3	40	201.6	243.9	36.1	9.94	**27.97**
13	8.0	56	328.0	392.0	15.8	17.99	**37.12**
14	19.4	56	574.4	649.8	7.5	30.71	**50.31**
15	36.6	64	796.8	897.4	-0.3	42.92	**62.93**
16	65.2	64	942.4	1071.6	-8.6	51.65	**72.12**
17	93.8	56	968.0	1117.8	17.5	52.60	**71.65**
18	116.7	56	785.6	958.3	43.9	43.72	**61.33**
19	139.6	48	288.0	475.6	70.2	19.38	**35.55**
20	145.3	32	136.0	313.3	92.1	10.57	**25.56**
21	133.8	24	65.6	223.4	114.1	5.23	**19.02**
22	111.0	16	30.4	157.4	135.6	1.04	**13.65**
23	93.8	16	14.4	124.2	143.1	-0.91	**11.30**
24	70.9	8	9.6	88.5	151.0	-2.99	**8.79**

1st attempt results

It shows that most of the heat gain is from through the wall from the calculation above, and during most of the day, the natural ventilation is not sufficient to supply cooling load for the space. From the above table, it shows solar radiation through the window contributes most for the total heat gain. Besides, we would be able to use natural ventilation **11 hours a day** (hour 1-8, 22-24, shaded orange above), and about **330 hours a month**.

2nd Attempt

Hour	Q_{wall2}(w)	Q_{window}(w)	Q_{shade}(w)	Total Q(w)	ΔT(°C)	T_{inside}(°C)
1	36.2	8	2.88	47.1	-3.64	**7.40**
2	24.6	0	0	24.6	-4.53	**6.15**
3	16.9	-8	0	8.9	-5.22	**5.10**
4	9.2	-8	0	1.2	-5.67	**4.29**
5	5.4	-8	0	-2.6	-5.67	**4.48**
6	-2.3	-8	36.48	26.2	-4.66	**5.71**
7	-6.2	-8	51.84	37.7	-4.19	**6.39**
8	-10.0	0	72.96	63.0	-2.41	**9.91**
9	-10.0	8	91.2	89.2	-0.61	**13.46**
10	-6.2	16	105.6	115.4	1.20	**17.02**
11	-2.3	32	115.2	144.9	2.73	**19.66**
12	1.5	40	120.96	162.5	3.91	**21.95**
13	5.4	56	196.8	258.2	7.50	**26.64**
14	13.1	56	344.64	413.7	12.57	**32.16**
15	24.6	64	478.08	566.7	17.54	**37.55**
16	43.9	64	565.44	673.3	21.09	**41.57**
17	63.1	56	580.8	699.9	21.11	**40.15**
18	78.5	56	471.36	605.9	17.38	**34.99**
19	93.9	48	172.8	314.7	7.56	**23.74**
20	97.7	32	81.6	211.3	3.69	**18.67**
21	90.0	24	39.36	153.4	1.22	**15.00**
22	74.7	16	18.24	108.9	-0.83	**11.79**
23	63.1	16	8.64	87.7	-1.71	**10.49**
24	47.7	8	5.76	61.5	-2.77	**9.00**

2nd attempt results

Moreover, adding reflective properties of the window or the mass onto the wall, or decreasing the U-values could decrease the overall ΔT caused by (**Q_{solar} – $Q_{ventilation}$**). We could now use natural ventilation **13 hours** (hour 1-9, 21-24, shaded blue above) **a day** and about **400 hours a month**.

Interpretation

The calculation clearly shows by using more sustainable materials of lower U-values, more natural ventilation could be manipulated. The sample office space is one of the 20 office spaces in the west side of the building. By simple estimation, a total of 8,000 hours of natural ventilation could be manipulated for the west wing in April.

However, the setback of the calculation results is, even with better hours of natural ventilation could be used, the hours covered do not include the hours with most occupancy in the office, like at 3 pm. Yet, it is believed if the test month is July instead of April, the natural ventilation results would be more pronounced.