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Energy Simulation in Buildings

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Chapter 1

INTRODUCTI

Background Information

This section outlines the history of building energy analysis simulation as it pertains to the work done at the Solar Energy Research Institute (SERI). The section titled, History of SERI Validation Work summarizes the factors we considered when choosing which simulations to validate.

1.1 Historical Context of Building Energy Analysis Information

Using computer programs for building energy analysis is not new. Since the late 1960s, the number of computer programs in both the public and private sectors has proliferated. Figures 1-1 and 1-2 show this development. With almost 15 years of development behind some of these programs, it is tempting to conclude that they are sufficiently accurate. This is not true for several reasons.

Until the oil embargo of 1973, these programs were used for sizing heating, ventilating, and air conditioning (HVAC) equipment or for justifying to the consumer a new piece of equipment. Little emphasis was placed on the ability to predict envelope loads accurately in other than conventional building types. Therefore, the authors of these programs made simplifying assumptions and chose solution approaches that, although quite reasonable for computational efficiency, were not adequate for innovative building designs.

In 1973, it became evident that the approach to the use of energy in buildings would have to change. At first, the trend was toward active solar systems that presented little difficulty for building energy analysis simulations (BEAS), since the solar components could be added much as another HVAC system. The original TRNSYS program was exclusively an active solar system simulation and was incorporated into such BEAS as DOE [1,2] and BLAST [3,4] without necessitating major revamping of these programs.

Chapter 2

LITRATURE REVIEW

2.1 *General*

Many developments are underway in the computer-aided building design field. As CAD systems possessing the drafting function proliferate, a demand is growing for advanced performance appraisal software. Designers will then come to rely on simulation as the means to test alternative design hypotheses throughout the design process and post occupancy. Indeed CAD system integration is perhaps the most effective mechanism for market penetration of advanced energy analysis systems. Also, as many energy sources become more expensive, and as conversion and management technologies become more complex, designers of the future will be required to focus more critically on the intimate relationship between design and performance. This will require a quantum jump in the capability and accuracy of the energy simulation techniques then on offer.

It is also likely that with the advent of powerful, integrated CAD systems, and considering the investment made in model creation and the related performance database that the design profession will seek to refine the building model and database beyond the construction phase. One possible scenario is that a client of the future will expect delivery of a computer-based model and its related performance database, in addition to the product of the design, the building. The information regarding building performance is then readily available for inspection. And, of course, the model can be used at any time as the basis for trouble shooting exercises and retrofits.

Researchers developing building performance simulation techniques can no longer afford to work as independent groups creating non-interchangeable software. Some mechanism must be found to give all developers access to the developments of others whilst retaining the flexibility to tailor a simulation system to individual needs. This is the subject matter of this paper. Developments are proposed which seek to create and order the building blocks of energy simulation. Private and public sector organizations can then use this *Kernel* to construct customized simulation systems which embody an appropriate level of detail, offer wide ranging application potential and utilize the most up-to-date techniques.

2.2 Nature of and Need for Validation

Building energy analysis simulations are used to predict energy flows in buildings. This includes temperatures, envelope losses, system performance, and electrical loads. The building in question may be an existing structure, a modification of an existing structure, or a new design. The accuracy of prediction of the building's performance depends on three main factors:

- Accuracy of the input data
- Applicability of the tool to the building and climate being analyzed
- Ability of the tool to predict real building performance when given perfect input data [1].

The accuracy of the input data is an important factor. The weather data available for the prediction are generally historical data for a site other than that of the building being analyzed. The data do not perfectly reflect the microclimate at the building site. The accuracy of the building description is constrained by the level of detail incorporated in the analysis tool, the accuracy to which the building properties are known, and the user's skill, experience, and available time.

To be truly applicable to a specific problem, the tool should predict building performance for that specific type of building in that particular climate, or it should predict performance for a statistically significant set of buildings and climates [3]. However, it is rarely feasible to collect sufficient experimental data or to apply a given analysis tool to a sufficient number and range of test cases to achieve complete confidence for all situations. Therefore, engineering judgment is commonly used to select test cases that represent typical applications of the tool. Analysis tool developers agree that models that have been verified for a few climates can be used with some degree of confidence to predict performance in other climates. However, they have less confidence in extrapolating from a single-zone structure to a multi-zone structure, and even less in predicting the performance of one building type (e.g., an indirect-gain south-aperture storage wall) based on the results of another model (e.g., a south-aperture direct-gain wall) .

The validation effort described in this report investigates the ability of the simulations to predict real building performance when given accurate input data. The four computer codes selected were: BLAST [6], DOE [7], DEROB [8], and SUNCAT [9]. For each code, some validation effort has already taken place. The remainder of this section reviews those validation studies.

2.2 Existing Validation Studies

The BLAST program was compared with empirical results from a direct gain test cell, a thermally massive building, and two Army buildings that were the size of small commercial buildings. The direct gain tests compared the hourly air temperature of the test cell to BLAST predictions. Two time periods were-compared: one in September, one in December. During the former, the average temperature difference was 0.4°C (0.7°F), during the latter 0.8°C (1.4°F). The investigators considered these results quite good. However, they identified several sources of ambiguity:

The split between beam and diffuse components of solar radiation was not measured.

Results are a strong function of the assumed infiltration rate.

The questions remaining after such a test are:

1. How well do single-zone test cell results indicate results for full-scale buildings?
2. How is the accuracy with which air temperature is predicted related to the accuracy with which thermal loads are predicted?
3. How do we explain the discrepancies that exist? (With limited experimental data taken, code valuators must speculate about the causes of differences between observed and predicted air temperatures.)

Chapter 3
CASE STUDY

3.1 General

The Building has two floors; the first floor consists of stores and eatery places and the second floor has some offices. There is no basement in the building.

3.2 *Location of the study area*

Sheridian Business Plaza (Figure 3.1) is a 1806 m2 (floor area) shopping plaza, located in Brampton

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Figure 3.1 Graphical representation of the building (Source: www.gdnlawyers.com)

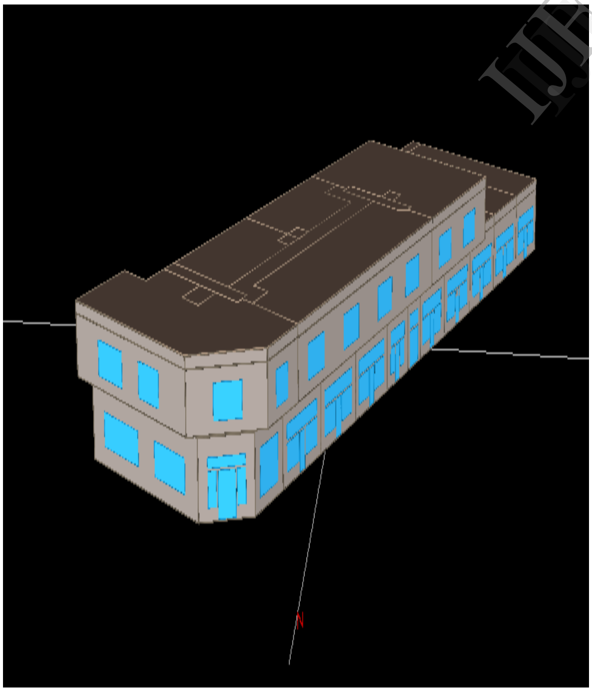


Figure 3.2 Geometrical representation of the building.

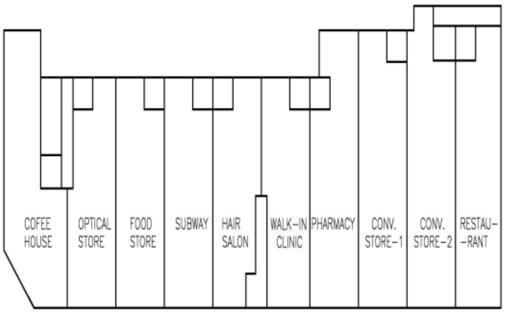


Figure 3.3 Floor Plan of First Floor (with units as zones).

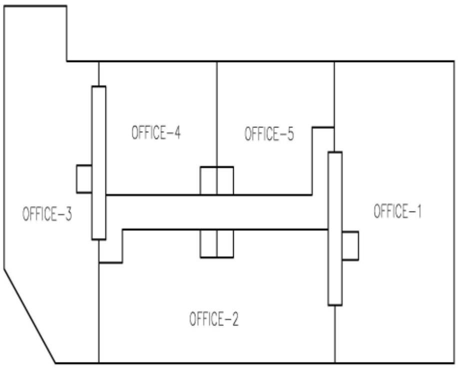


Figure 3.4 Floor Plan of Second Floor (with units as zones).

3.3 *Climate of Southern Ontario:*

The climate in Toronto is marked by cold winters and relatively warm summers. According to the Environment Canada (2008) historical data, the annual average outdoor temperature is 7.5oC and the warmest month is typically July with mean temperature of 20.8oC. The coldest months are January and February, with mean temperatures --6.3oC and ---5.4oC respectively. Heating Degree Days (HDD) is approximately 4000 K day.

Toronto is located at the south---eastern part of Ontario, and is heating dominated. According to the Natural Resources of Canada (2006), space heating accounts for 55.3% of the total energy requirement in buildings in Ontario, whereas space cooling accounts formerly 4.4 %.

3.4 *As---is case design parameters :*

This section describes the design parameters of the building in question. The details include the envelope construction, lighting, equipment and HVAC design.

3.4.1 Envelope

The envelope elements include walls, roof, floor, and fenestration. The details of each of these are described starting with wall construction.

3.4.2 External Wall construction

The different layers, from inside to outside, and their relative thicknesses are graphically represented in Figure 3.5

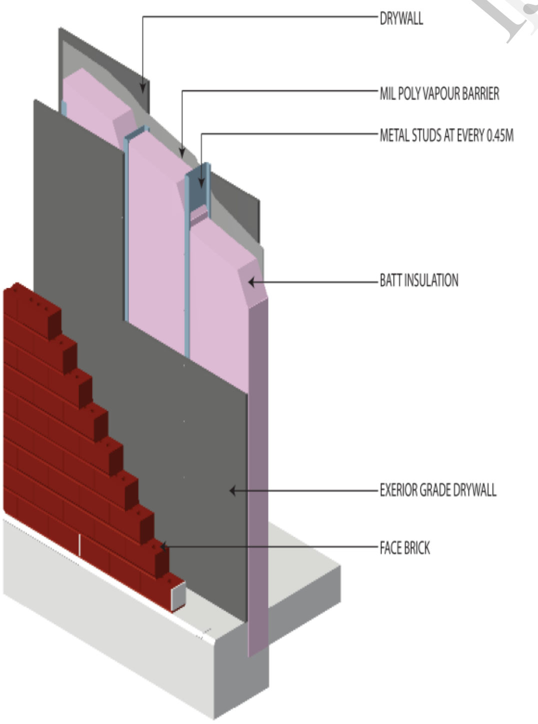


Figure 3.5 Section of the external wall of the building.

Layer	Material	Thickness (m)	Density (kg/m3)	Specific Heat (J/kg·K)	Thermal Conductance (W/m·K)
1	Face Brick	0.1016	2800	896.0	0.770
2	Air Space (at 0°)	.0508	1.293	1.005	.0243
3	Exterior Grade Drywall	0.0158	900.0	1000.0	.250
4	Batt Insulation and metal studs at every 0.45 m	0.1524	12.0	840.0	0.040
5	6 MIL Poly Vap Bar	0.1524	980.0	1800.0	0.50
6	Drywall	0.0158	900.0	1000.0	.250

Table 3.1 Properties of materials consisting of various layers of existing external wall construction (Reference: The building drawings)

Roof Construction:

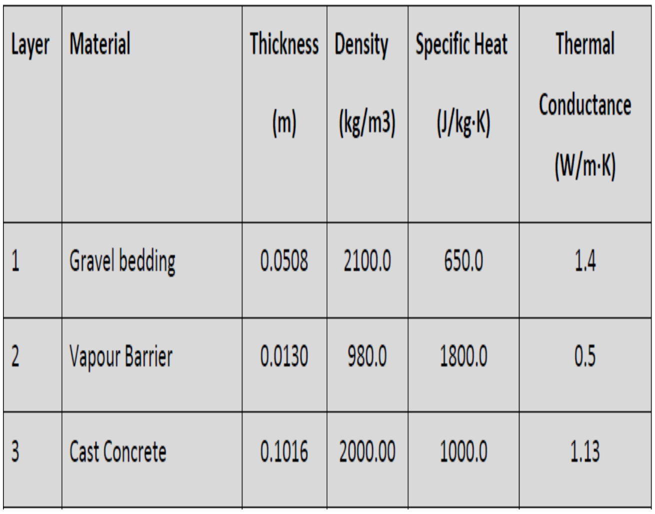
The materials and properties of different layers of the Roof, starting from outside to inside, are given below in Table 3.2.

Layer	Material	Thickness (m)	Density (kg/m3)	Specific Heat (J/kg·K)	Thermal Conductance (W/m·K)
1	Gravel Bedding	0.05	2100.0	650.0	1.4
2	4 ply Built up Felts	0.025	1100.0	1000.0	0.23
3	(R-20) Rigid Insulation	0.1016	12.0	840.0	0.04
4	Vapour Barrier	0.0130	980.0	1800.0	0.5
5	Steel Deck and Structure				

Table 3.2 Properties of materials consisting of various layers of existing Roof construction.

Floor Construction (Slab on grade)

The materials and properties of different layers of the Slab on grade, from ground to inside, are given below in Table 3.3

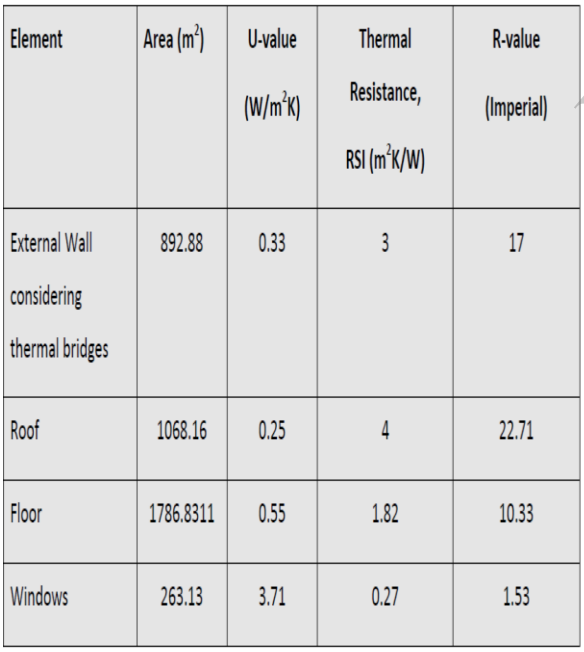


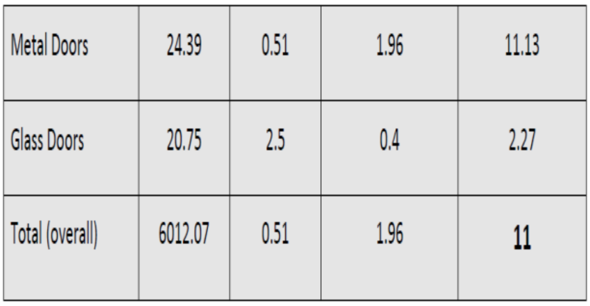
Layer	Material	Thickness (m)	Density (kg/m3)	Specific Heat (J/kg·K)	Thermal Conductance (W/m·K)
1	Gravel bedding	0.0508	2100.0	650.0	1.4
2	Vapour Barrier	0.0130	980.0	1800.0	0.5
3	Cast Concrete	0.1016	2000.00	1000.0	1.13

Table 3.3 Properties of materials consisting of various layers of existing Floor construction.

Thermal resistance of Envelope:

The overall heat flow through the building envelope depends on the overall thermal resistance of the envelope, which can be calculated area weighting of U---values of different elements. The overall resistance of the existing building has been calculated in Table 3.4.

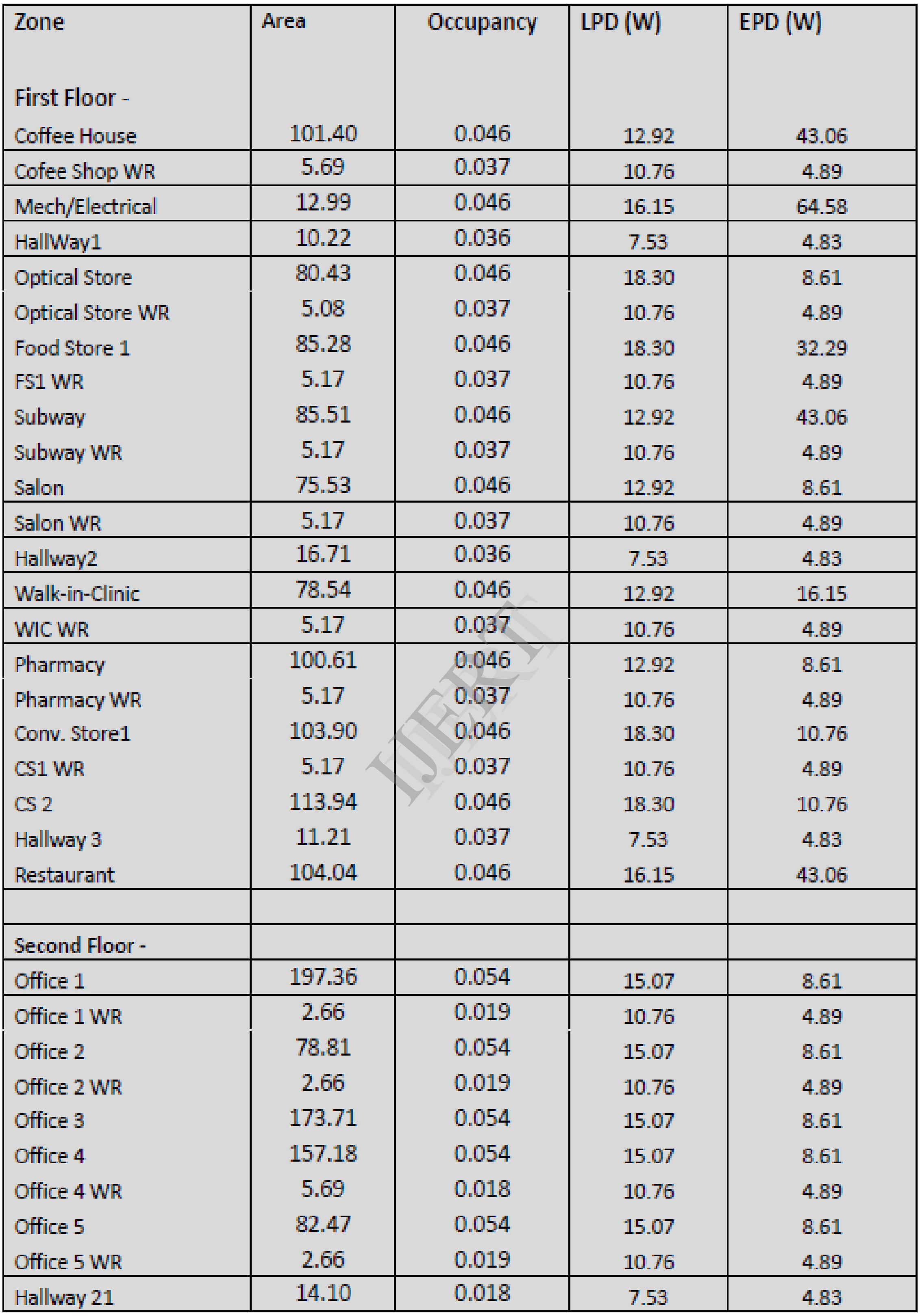




Element	Area (m^2)	U-value (W/m^2K)	Thermal Resistance, RSI (m^2K/W)	R-value (Imperial)
External Wall considering thermal bridges	892.88	0.33	3	17
Roof	1068.16	0.25	4	22.71
Floor	1786.8311	0.55	1.82	10.33
Windows	263.13	3.71	0.27	1.53
Metal Doors	24.39	0.51	1.96	11.13
Glass Doors	20.75	2.5	0.4	2.27
Total (overall)	6012.07	0.51	1.96	**11**

Table 3.4 Thermal Resistance of various elements of the existing envelope.

Occupancy, Lighting and Equipment



Zone	Area	Occupancy	LPD (W)	EPD (W)
First Floor -				
Coffee House	101.40	0.046	12.92	43.06
Cofee Shop WR	5.69	0.037	10.76	4.89
Mech/Electrical	12.99	0.046	16.15	64.58
HallWay1	10.22	0.036	7.53	4.83
Optical Store	80.43	0.046	18.30	8.61
Optical Store WR	5.08	0.037	10.76	4.89
Food Store 1	85.28	0.046	18.30	32.29
FS1 WR	5.17	0.037	10.76	4.89
Subway	85.51	0.046	12.92	43.06
Subway WR	5.17	0.037	10.76	4.89
Salon	75.53	0.046	12.92	8.61
Salon WR	5.17	0.037	10.76	4.89
Hallway2	16.71	0.036	7.53	4.83
Walk-in-Clinic	78.54	0.046	12.92	16.15
WIC WR	5.17	0.037	10.76	4.89
Pharmacy	100.61	0.046	12.92	8.61
Pharmacy WR	5.17	0.037	10.76	4.89
Conv. Store1	103.90	0.046	18.30	10.76
CS1 WR	5.17	0.037	10.76	4.89
CS 2	113.94	0.046	18.30	10.76
Hallway 3	11.21	0.037	7.53	4.83
Restaurant	104.04	0.046	16.15	43.06
Second Floor -				
Office 1	197.36	0.054	15.07	8.61
Office 1 WR	2.66	0.019	10.76	4.89
Office 2	78.81	0.054	15.07	8.61
Office 2 WR	2.66	0.019	10.76	4.89
Office 3	173.71	0.054	15.07	8.61
Office 4	157.18	0.054	15.07	8.61
Office 4 WR	5.69	0.018	10.76	4.89
Office 5	82.47	0.054	15.07	8.61
Office 5 WR	2.66	0.019	10.76	4.89
Hallway 21	14.10	0.018	7.53	4.83

Infiltration

In the absence of physical testing, it is rather difficult to decide on an infiltration level for a building. There is also very little information available on natural air exchange in commercial buildings. But whatever little there is suggests a range of 0.1 – 0.6 ACH at normal conditions. (Harvey, 2006, Section 3.7.1). For the building in question, considering the envelope design, lack of vestibules in the retail units, as well as the workmanship and construction practices, the rate of infiltration can be assumed as 0.4 ACH. After obtaining and analyzing the results, it is observed that infiltration is a vital factor affecting the heating energy use for the building, so it is critical to achieve an envelope with minimum possible unwanted air flow through it.

As---is Case Results

A model of the building was created in eQUEST by feeding the geometry of the building in question and the design details as described above and the building was simulated. The results of the simulation show that theEnergy Use Index (EUI) is 447 kWh/m2/yr and the Heating Use Index (HUI) is 320 kWh/m2/yr. The simulation results are presented in graphical form below. Figure 4.6 shows the breakdown of overall electric consumption through the year by different factors. Figure 4.7 shows the breakdown of overall gas consumption through the year by space heating and domestic hot water. Figures 4.8 and 4.8 show the breakdown of annual electric and gas consumption respectively and Figure 4.9 shows the cumulative energy use (gas and electric) through the year by various factors.

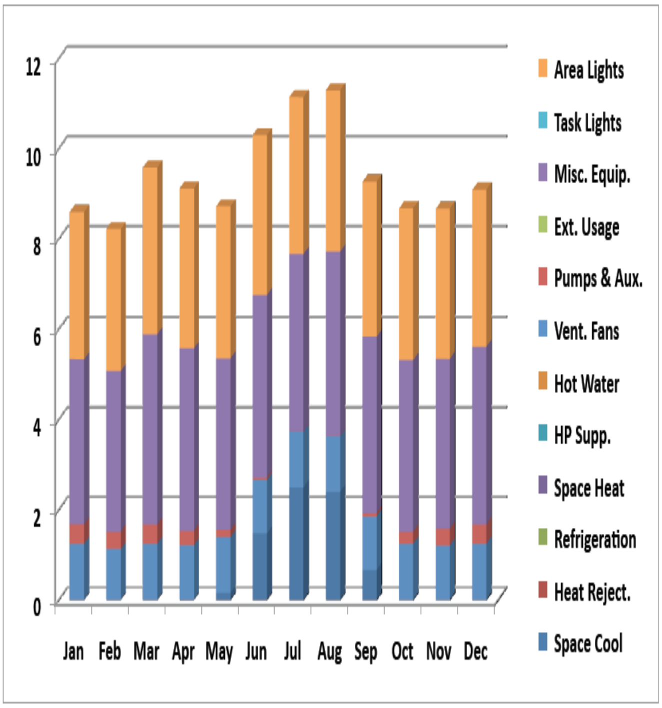


Figure 3.6 The overall electric consumption in kWh/m2/yr for the as---is case.

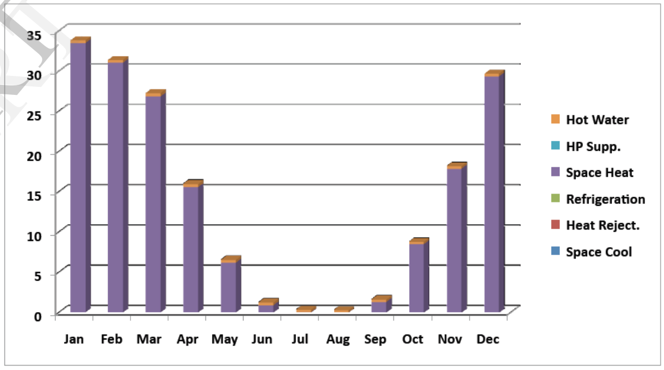


Figure 3.7 The overall gas consumption in kWh/m2/yr for the as---is case.

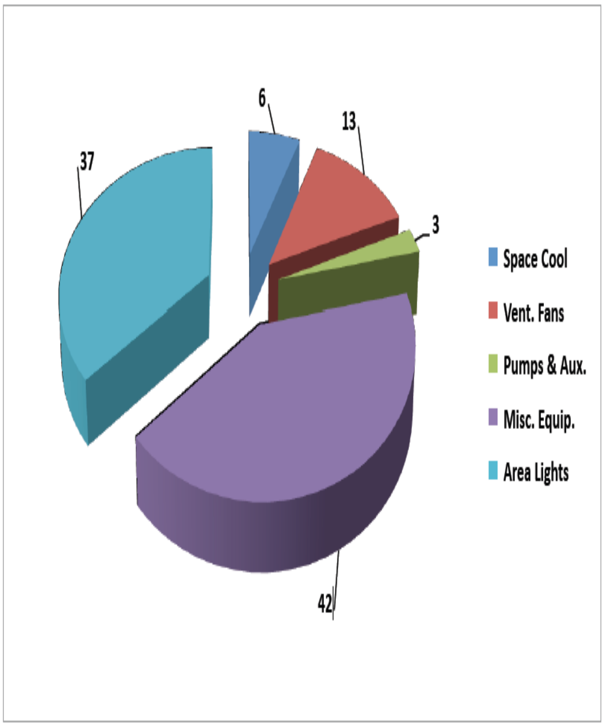


Figure 3.8 Percentage breakdown of electricity use for the as---is case.

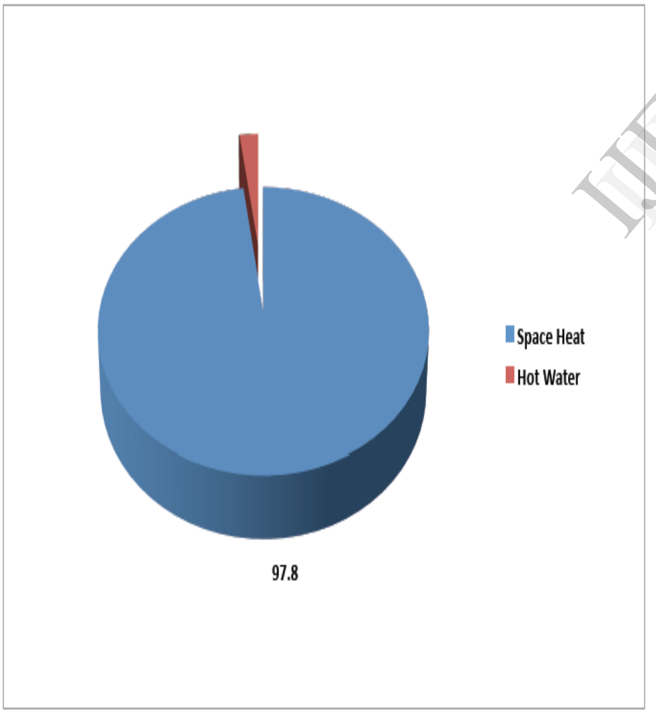


Figure 3.9 Percentage breakdown of natural gas use for the as---is case.

Analysis of As---is Case Results

According to the simulation results, heating use of the building amounts to almost60 percent of the entire energy use. Thus, heating the building is the most energy intensive process and should need maximum attention and work, in order to bring down the overall energy use dramatically. The building uses a natural gas furnace to provide for heating and domestic hot water, and out of this 98 percent of the gas is used for heating only 2 percent for domestic hot water.

Looking at the electricity usage by different factors, the three keys areas, where electricity is used, are miscellaneous equipment (16percent) and area lights (14 percent). Less than 1 percent of the electricity is used for space cooling, which is justifiable by the climate of the region. Space cooling is required mainly during the months of June, July and August.

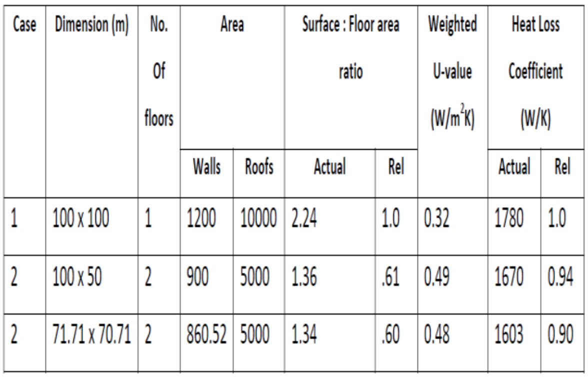
Chapter 4

METHODOLOGY

Building shape, form and orientation

Building shape, form and orientation are architectural decisions that have impacts on heating and cooling loads, day lighting, passive ventilation, solar heating and cooling, and for active solar energy systems. Building shape refers to the relative length of the overalldimensions (height, width, depth); building form refers to small---scale variations in the shape of building; and building orientation refers to the direction that the longest horizontal dimension faces. The impact of these factors is, however, small compared to the impact of more insulation, better windows, a more air---tight envelope and the use of heat exchangers to recover heat from the exhaust air in the mechanical ventilation system.

It is commonly found that minimizing the surface area to volume ratio of a building decreases the heating load for a given insulation system. Even if the thermal resistance of each element (walls, roof, floor and windows) is fixed, a change and shape f the building will inevitably be accompanied by a change in the relative proportions of the different façade elements and this Can easily outweigh the impact on heat loss due to increase in surface to volume ratio, when the building shape is altered while keeping the volume fixed. Adopting a square, rather than rectangular, floor plan for a fixed volume, reduces the heat loss coefficient byabout4percent.An example of such a calculation is shown in Table 5.1 below



Case	Dimension (m)	No. Of floors	Area		Surface : Floor area ratio		Weighted U-value (W/m^{2}K)	Heat Loss Coefficient (W/K)	
			Walls	Roofs	Actual	Rel		Actual	Rel
1	100 x 100	1	1200	10000	2.24	1.0	0.32	1780	1.0
2	100 x 50	2	900	5000	1.36	.61	0.49	1670	0.94
2	71.71 x 70.71	2	860.52	5000	1.34	.60	0.48	1603	0.90

Minimizing surface to volume ratio, specially the roof area and the area of west---facing walls, also minimizes the summer heat gain from outside. Having narrow buildings and the long axis along the east---west, would maximize glazing opportunities on the south side, thus maximizing solar heat gain in winters, which can be controlled during summer months by external shading. More details of significance of appropriate orientation are detailed on Glazing Fraction.

Chapter 5

CONCLUSIONS

Conclusions made on the analysis of all simulations done in this research work.

The results of all the simulations done in the present study have already been. Based on the analyses, the following conclusions are drawn.A reduction of 60 percent in the building energy use (not including the equipment energy) has been achieved, as compared to the existing state of the building chosen as the case for study. This building had been constructed 5 years ago and so may be considered as a fairly recent construction.

A city level research study can be carried out based on the simulation results of the modified new building designed in this study. Climate simulation tools can e used and a detailed study of possible carbon reductions by applying the new construction can be carried out.

Chapter 6

REFERENCES

1. Barney et al, 008 Guide to Energy Management (Sixth Edition) by Barney L. Capehart, Wayne C. Turner and William J. Kennedy,
2. EIA,2007 --- International Energy Statistics database (as of November2009), web site www.eia.gov/emeu/international. Projections: EIA, World Energy Projection System Plus (2012).
3. Fennell and Haehnel, 2005 --- ‘Setting air tightness standards’ by Fennell, H. C.And Haehnel,J.(2005), ASHRAE Journal,Volume 47, no. 9
4. Wouthers et al, 2013 --- ‘Classification ofHybrid Ventilation Concepts’ by P.Wouters, N. Heijmans, C. Delmotte, L. Vandaele, Belgian BuildingResearch Institute, 2013
5. Hong, 2008 --- Comparing Computer Run Time of Building Simulation Programs. BuildSimul (2008). Berkeley,: Tsinghua Press and Springer.
6. Sharma et al, 2009--- ‘Review on thermal energy storage with phase change materials and applications’ by Atul Sharma, V.V. Tyagi,C.R. Chenand D. Buddhi, Renewable and Sustainable Energy Reviews, Volume 13, Issue2, February2009