

CONCLUSIONS AND FUTURE WORK

7.1 Guidelines for passive houses in tropical uplands

It was shown in Chapter 5, with computer simulations that the room in the upper floor of two storey house could experience a lower temperature in the night and higher temperature in the daytime than the room at a ground floor. This means that generally upper floor rooms could be better during daytime since these could experience temperatures close to the outdoor. However, there is some possibility for overheating in quite warm days. The lower fluctuation of temperature and also higher temperature during the nighttime of ground floor bed rooms indicate that these could be better during the night. Therefore, a conceptual house was proposed in Chapter 6 was proposed, which could combine the better features of ground floor and upper floor bedrooms. This house has part as two storey where the bed rooms are located one on top adopting the below passive features given below. House at tropical upland should be followed below guidelines:

Houses having an upper floor in a part of it should be constructed except under the geological and structural circumstances, financial problems or any other circumstances. Since the effect of ridge direction is insignificant, ridge of the roof should be directed to either north-south or east-west. A combination of two roof systems are also allowed. For the roof materials, the materials which have low thermal capacity and low emittance should be used. By this, heat transferring rate into the house can be increased. New GI sheets are highly recommended as a roofing material. If asbestos sheets are used they should be painted in dark colour as recommended below. Burnt clay tiles should be strictly avoided.

The orientation of the house should be faced either south or north. By this, heat transfer in to the house through glazing can be reduced. Hence overheating can be avoided. All the roofs and walls should be painted in dark colour which has higher absorptance values. The colours like Green, Blue and Grey are recommended. All the openings, doors and windows in the house should be closed at night time. The curtains should be provided from the top of the window including the lattice. The maximum effort to avoid infiltration should be taken. Ceilings should be provided to avoid cold air entering in to the house. Windows should be provided on north, east and south. West should be avoided in order to control the hot discomfort. If and only if, one of the walls are gable walls of the house, providing windows facing west is allowed. Fins, sunshades and all the types of shading devices can be removed if and only if, they are not used to divert the wind which flow in to the house.

7.2 Future work

1. The passive techniques selected to investigate the thermal performances in high altitudes of Sri Lanka were limited to few features like roofs, walls, windows and infiltration. But passive systems are quite a vast field and complex to analyse. Thus, there could be lot more features of these techniques to study, deeply and carefully.
2. In future, another problem could be the energy consumption in commercial building sector than the domestic sector. Thus, the research should be widened for the commercial building sector as well.
3. The governments of Sri Lanka has not paid much attention on the “Livability” of houses. Thus, boarder publicity will be necessary to enlighten the authorities and the general public about the importance of passive features. The government also could concentration on this broad field and prepares energy codes for both uplands and lowland.

7.3 Concluding remarks

Today, energy crisis is a major problem in Sri Lanka as well as in the world. Thus, the duty of the researcher has become more critical to determine the solutions for this acute problem. Thus, a careful attention should be given to determine the options available for energy conservations.

By going through the passive techniques, it was understood that energy used for building services can be minimized. That type of option can reduce the usage of mechanical devices like fans, heaters etc. This research has been found some design guidelines which is suitable for tropical uplands of Sri Lanka. They can be adopted by the designers, during their preliminary stage of designing so that the energy required for heating can be minimized or eliminated altogether.

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APPENDIX A

This appendix gives the data sheets used for the validation of the software.

DATA SHEET

HOUSE : *Irregation Circuit Bangalow, Bandarawela*

DATE:-

STARTED:-

FINISHED:-

HOUR	OUTDOOR TEMPERATURE °C		HUMIDITY		INDOOR TEMPERATURE, °C	OUTDOOR TEMPERAURE, °C
	Max	Min	Dry bulb	Wet bulb	Room No	C

Roof colour:-

Ceiling type:-

Roof material:-

Wall colour:- outside _____ Inside _____

Wall material:-

Window size:-

Ceiling material:-

Temperature Scales

Results

Below tables show the results presented in Chapter 4.

Table a- Flat ceiling-Maximum Indoor Air Temperature						
Case	NE- Decemb	SE- Dece	NE- June	SE- June	NE- March	SE- Marc
E-W Directed roof	21.7	22.2	25	24.7	24.4	24.5
N-S Directed roof	21.6	22.2	25.6	25.5	24.3	24.4
Flat ceiling-Minimum Indoor Air Temperature						
E-W Directed roof	18.1	18.4	21.4	21.3	19.3	19.3
N-S Directed roof	18.4	18.8	21.2	21	19.3	19.3

Table b-Sloping ceiling-Maximum Indoor air Temperature						
Case	NE- Decem	SE- Decem	NE- June	SE- June	NE- Mar	SE- Mar
E-W Directed roof	21.3	22.6	25.7	25.3	24.8	25
N-S Directed roof	21.8	21.9	25.4	25.3	24.5	24.7
Sloping ceiling-Minimum Indoor Air Temperature						
E-W Directed roof	18.1	18.6	21	20.9	19.9	19.3
N-S Directed roof	18.3	18.8	21.5	21.3	19.2	19.3

Table c- Flat ceiling-Maximum Indoor Air Temperature						
Case	NE- Dece mber	SE- Dece mber	NE- June	SE- June	NE- March	SE- March
E-W Directed roof with shades	21.7	22.2	25	24.7	24.4	24.5
E-W Directed roof with no shades	21.3	22.3	25.1	24.7	24.3	24.3
Flat ceiling-Minimum Indoor Air Temperature						
E-W Directed roof with shades	18.4	18.4	21.4	21.3	19.3	19.3
E-W Directed roof with no shades	18.3	18.8	21.5	21.3	19.2	19.3



Case	NE- Decem	SE- Decem	NE- June	SE- June	NE- March	SE- March
<i>N-S Directed roof with shades</i>	18.5	19.1	25.6	25.5	24.4	24.4
<i>N-S Directed roof with no shades</i>	18.7	19.2	25.7	25.5	24.2	23.7
Flat ceiling-Minimum Indoor Air Temperature						
<i>N-S Directed roof with shades</i>	18.4	18.8	21.1	21	19.3	19.3
<i>N-S Directed roof with no shades</i>	18.5	19.1	21.2	21	19.8	19.8

Results

Below tables show the results presented in Chapter 5.

Case	G-NE	G-SE	U-NE	U-SE
<i>Dark colour roof and walls</i>	22.7	22.8	24.7	24.8
<i>Light colour roof and walls</i>	21.9	22	24.1	24.3
Sloping ceiling-Minimum Indoor Air Temperature				
<i>Dark colour roof and walls</i>	19.9	20	19.2	19.3
<i>Light colour roof and walls</i>	19.3	19.4	18.7	18.8

Case	G-NE	G-SE	U-NE	U-SE
<i>0-24 hours- 1 ach</i>	22.1	22.3	24.4	24.7
<i>11-17 hours- 3 ach, other -1 ach</i>	22.7	22.8	24.7	24.8
<i>0.24 hours-3 ach</i>	22.4	22.5	24.4	24.6
Sloping ceiling-Minimum Indoor Air Temperature				
<i>0-24 hours- 1 ach</i>	19.9	19.9	19.2	19.2
<i>11-17 hours- 3 ach, other -1 ach</i>	19.9	20	19.2	19.3
<i>0.24 hours-3 ach</i>	18.8	18.9	18.4	18.4

Table h-Sloping ceiling-Maximum Indoor Air Temperature

Case	G-NE	G-SE	U-NE	U-SE
Windows on North-South	22.7	22.8	24.7	24.8
Additional window on East	23.2	24.8	24.8	25.1
Additional window on West	23.8	22.9	24.8	24.9

Sloping ceiling-Minimum Indoor Air Temperature

Windows on North-South	19.9	20	19	19.1
Additional window on East	19.9	20	19	19.1
Additional window on West	20	20.1	19	19.3

Results

Below table shows the results presented in Chapter 6. Operative temperature is given.

MCIRIZ1	MCIRIZ2	MCIRIZ3	MCIRIZ1	MCIRIZ2	MCIRIZ3	OUTDOOR	JCIRIZ1	JCIRIZ2	JCIRIZ3	JCIRIZ1	JCIRIZ2	JCIRIZ3	OUTDOOR
G-NW	G-NW	G-NW	U-NW	U-NW	U-NW	OUTDOOR	G-NW	G-NW	G-NW	U-NW	U-NW	U-NW	OUTDOOR
21.4	21.5	20.8	20.9	21	20.5	16.8	23.1	23.2	22.6	22.4	22.4	22	18.8
21.2	21.3	20.5	20.6	20.6	20.1	15.8	23	23	22.3	22.1	22.1	21.6	18.1
21	21.1	20.3	20.2	20.3	19.7	15.1	22.8	22.8	22.1	21.8	21.8	21.3	17.4
20.8	20.9	20.1	19.9	20	19.4	14.7	22.6	22.7	21.9	21.5	21.6	21	17.2
20.6	20.7	19.9	19.7	19.7	19.1	14.6	22.4	22.5	21.7	21.3	21.3	20.8	17.1
20.5	20.6	19.7	19.5	19.5	18.9	14.5	22.3	22.3	21.6	21.3	21.3	20.7	17
20.4	20.5	19.6	19.5	19.6	18.9	14.7	22.3	22.3	21.6	21.5	21.5	20.9	17.2
20.3	20.4	19.6	19.7	19.7	19.1	15.4	22.3	22.3	21.6	21.6	21.7	21.1	17.7
20.4	20.5	19.8	20	20.1	19.5	17.3	22.4	22.4	21.7	21.9	21.9	21.4	19.2
20.6	20.7	20.3	20.9	21	20.6	20.6	22.6	22.6	22.1	22.5	22.5	22.2	21.8
20.8	20.9	20.7	22.1	22.1	22	23.3	22.8	22.8	22.6	23.5	23.5	23.4	24
21	21.4	21	23.3	23.6	23.3	24.6	23	23.2	22.9	24.6	24.7	24.4	25.1
21.2	21.6	21.2	24.3	24.5	24.2	25.3	23.1	23.4	23.1	25.3	25.4	25.2	25.6
21.4	22	21.4	24.8	24.9	24.7	25.5	23.3	23.6	23.3	25.8	25.8	25.6	25.8
21.5	22.1	21.6	24.9	25.1	24.8	25.4	23.5	23.7	23.4	25.9	25.9	25.7	25.7
21.7	22.2	21.8	24.8	24.9	24.7	25.1	23.6	23.9	23.6	25.8	25.8	25.6	25.4
21.9	22.3	21.9	24.3	24.4	24.2	24.5	23.8	24	23.7	25.4	25.4	25.2	25
22	22.2	22	23.3	23.4	23.2	23.9	23.8	23.9	23.7	24.7	24.7	24.5	24.5
22	22.2	22	22.8	22.8	22.7	23.1	23.8	23.9	23.6	24.1	24.1	23.9	23.9
22	22.2	21.9	22.4	22.5	22.3	22.2	23.8	23.9	23.6	23.7	23.7	23.5	23.2
22	22.1	21.7	22.2	22.2	21.9	21.1	23.7	23.8	23.4	23.5	23.5	23.2	22.3

21.8	22	21.5	21.9	22	21.6	20	23.6	23.7	23.2	23.3	23.3	22.9	21.4
21.7	21.8	21.3	21.6	21.7	21.3	18.9	23.5	23.5	23	23	23	22.6	20.5
21.5	21.7	21	21.3	21.3	20.9	17.8	23.3	23.4	22.8	22.7	22.7	22.3	19.6

DC1R1Z1	G- NW	DC1R1Z2	G- NW	DC1R1Z3	G- NW	DC1R1Z1	U- NW	DC1R1Z2	U- NW	DC1R1Z3	U- NW	OUTDOOR	MC1R2Z2	G- NW	MC1R2Z3	G- NW	MC1R2Z3	U-NE	MC1R2Z3	U-NE
19.6	19.7	19.7	19.3	19.3	19.2	19.2	19.2	18.9	16.8	20.6	21.2	20.7	20.3							
19.5	19.6	19.6	19.1	19	19	19	18.7	16.2	20.3	21	20.4	19.8								
19.4	19.4	18.9	18.7	18.7	18.8	18.4	18.4	15.7	20.1	20.9	20.1	19.5								
19.3	18.3	18.8	18.8	18.5	18.6	18.2	15.4	19.9	20.7	19.8	19.2									
19.1	19.2	18.7	18.3	18.4	18	15.4	19.7	20.5	20.5	19.5	18.9									
19	19.1	18.5	18.2	18.2	17.8	15.3	19.5	20.3	19.3	19.3	18.7									
18.9	19	18.5	18.3	18.4	18	15.4	19.4	20.2	19.9	19.3	19.3									
18.9	19	18.5	18.6	18.6	18.2	15.9	19.4	20.2	20.7	20										
19	19	18.6	19	19	18.6	17.7	19.6	20.2	21.4	20.8										
19.2	19.2	19	19.5	19.6	19.4	19.3	20.1	20.5	22.4	21.9										
19.3	19.4	19.3	20.4	20.4	20.4	21.1	20.6	20.7	23.3	23.1										
19.4	19.7	19.5	21.1	21.3	21.1	21.9	20.8	21.2	24	23.8										
19.6	19.9	19.7	21.7	21.8	21.7	22.4	21.1	21.4	24.5	24.2										
19.7	20	19.8	22	22.1	22	22.5	21.2	21.6	24.6	24.4										
19.9	20.1	19.9	22.1	22.2	22.1	22.3	21.4	21.7	24.5	24.3										
20	20.2	20.1	22	22.1	21.9	22.2	21.6	21.9	24.2	24										
20.1	20.3	20.1	21.6	21.7	21.6	21.9	21.7	22	23.7	23.5										
20.1	20.2	20.2	20.9	20.9	20.8	21.4	21.7	22	23.1	22.9										
20.2	20.2	20.1	20.5	20.5	20.5	20.9	21.7	21.9	22.6	22.5										
20.2	20.2	20.1	20.2	20.3	20.2	20.3	21.7	21.9	22.3	22.1										
20.1	20.2	20	20.1	20.1	20	19.6	21.5	21.9	22.1	21.8										
20	20.1	19.8	19.9	19.9	19.7	18.9	21.3	21.6	21.8	21.4										
19.9	20	19.6	19.7	19.7	19.6	18.2	21.1	21.4	21.4	21										
19.8	19.8	19.5	19.4	19.5	19.2	17.5	20.8	21.4	21.1	20.6										


MC1R1Z2				MC2R2Z3				JC1R1Z2				JC2R2Z3			
G- NW	G- NE	U- NW	U- NE	G- NW	G- NE	U- NW	U- NE	G- NW	G- NE	U- NW	U- NE	G- NW	G- NE	U- NW	U- NE
21.5	21.8	21	21.2	20.1	20.4	19.7	19.9	23.2	23	22.4	22.3	22.6	22.4	22	21.8
21.3	21.6	20.6	20.8	19.8	20.2	19.3	19.5	23	22.9	22.1	22	22.3	22.2	21.6	21.5
21.1	21.5	20.3	20.5	19.6	20	19	19.1	22.8	22.7	21.8	21.7	22.1	22	21.3	21.2
20.9	21.3	20	20.2	19.4	19.8	18.7	18.8	22.7	22.6	21.6	21.4	21.9	21.9	21	20.9
20.7	21.2	19.7	19.9	19.2	19.7	18.5	18.6	22.5	22.5	21.3	21.2	21.7	21.8	20.8	20.7
20.6	21.1	19.5	19.7	19.1	19.6	18.2	18.4	22.3	22.5	21.3	21.3	21.6	21.7	20.7	20.7
20.5	21.3	19.6	20.4	19.1	19.8	18.3	19	22.3	22.7	21.5	21.9	21.6	21.9	20.9	21.3
20.4	21.5	19.7	21.4	19.1	19.9	18.4	19.7	22.3	22.8	21.7	22.6	21.6	22	21.1	22
20.5	21.6	20.1	22.3	19.2	20.2	18.8	20.5	22.4	22.9	21.9	23.3	21.7	22.2	21.4	22.7
20.7	22	21	23.4	19.7	20.8	19.9	21.6	22.6	23.1	22.5	24.2	22.1	22.6	22.2	23.7
20.9	22.3	22.1	24.4	20.2	21.3	21.1	22.7	22.8	23.4	23.5	25	22.6	23	23.4	24.7
21.4	22.4	23.6	25.1	20.4	21.4	22.1	23.4	23.2	23.6	24.7	25.6	22.9	23.2	24.4	25.3
21.6	22.5	24.5	25.6	20.6	21.6	22.9	23.8	23.4	23.8	25.4	26	23.1	23.4	25.2	25.7
21.8	22.6	24.9	25.7	20.8	21.7	23.3	23.9	23.6	23.9	25.8	26.1	23.3	23.5	25.6	25.9
22	22.7	25.1	25.5	20.9	21.8	23.4	23.8	23.7	23.9	25.9	26	23.4	23.5	25.7	25.6
22.1	22.7	24.9	25.1	21.1	21.8	23.3	23.5	23.9	23.9	25.8	25.7	23.6	23.6	25.6	25.4
22.2	22.7	24.4	24.5	21.2	21.7	22.9	23	24	23.9	25.4	25.2	23.7	23.5	25.2	25
22.3	22.6	23.4	23.7	21.2	21.7	22.2	22.4	23.9	23.7	24.7	24.6	23.7	23.5	24.5	24.4
22.2	22.6	22.8	23.1	21.2	21.6	21.8	22	23.9	23.7	24.1	24.1	23.6	23.4	23.9	23.9
22.2	22.5	22.5	22.8	21.1	21.4	21.4	21.7	23.9	23.6	23.7	23.7	23.6	23.3	23.5	23.5
22.1	22.4	22.2	22.6	21	21.2	21.1	21.3	23.8	23.5	23.5	23.5	23.4	23.1	23.2	23.2
22	22.2	22	22.2	20.7	21	20.8	21	23.7	23.4	23.3	23.2	23.2	22.9	22.9	22.8
21.8	22.1	21.7	21.9	20.5	20.8	20.4	20.6	23.5	23.3	23	22.9	23	22.7	22.6	22.5
21.7	21.9	21.3	21.5	20.3	20.6	20.1	20.2	23.4	23.1	22.7	22.6	22.8	22.5	22.2	22.2

DC1R1Z2				DC2R2Z3			
G- NW	G- NE	U- NW	U- NE	G- NW	G- NE	U- NW	U- NE
19.7	20	19.2	19.4	19.3	19.5	18.9	19.1
19.6	19.9	19	19.2	19.7	19.4	18.7	18.8
19.4	19.8	18.8	18.9	18.9	19.2	18.4	18.5
19.3	19.7	18.6	18.7	18.8	19.1	18.2	18.3
19.2	19.7	18.4	18.5	18.7	19	18	18.1
19.1	19.6	18.2	18.4	18.5	18.9	17.8	18
19	19.7	18.4	18.9	18.5	19	18	18.5
19	19.8	18.6	19.7	18.5	19.2	18.2	19.2
19	19.9	19	20.3	18.6	19.4	18.6	19.8
19.2	20.1	19.6	21	19	19.8	19.4	20.7
19.4	20.3	20.4	21.8	19.3	20.1	20.4	21.6
19.7	20.6	21.3	22.3	19.5	20.3	21.1	22.1
19.9	20.7	21.8	22.6	19.7	20.4	21.7	22.4
20	20.8	22.1	22.7	19.8	20.5	22	22.5
20.1	20.8	22.2	22.6	19.9	20.5	22.1	22.5
20.2	20.8	22.1	22.3	20.1	20.6	21.9	22.2
20.3	20.6	21.7	21.9	20.1	20.6	21.6	21.7
20.2	20.6	20.9	21.2	20.2	20.5	20.8	21.1
20.2	20.5	20.5	20.8	20.1	20.4	20.5	20.7
20.2	20.5	20.3	20.6	20.1	20.3	20.2	20.4
20.2	20.5	20.1	20.4	20	20.2	20	20.2
20.1	20.4	19.9	20.2	19.8	20	19.7	19.9
20	20.3	19.7	19.9	19.6	19.9	19.5	19.7
19.8	20.2	19.5	19.7	19.5	19.7	19.2	19.4

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 Dissertations



TECHNICAL GLOSSARY

1. **Absoptance** is defined as the ratio of the amount of radiant energy a particular surface absorbs to the total amount of radiant energy incident upon it.
2. **Air change** – the replacement of quantity of air in a volume within a given period of time. This is expressed in number of changes per hour. If a house has 1 air change per hour, all the air in the house will be replaced 1 in a 1-hour period.
3. **Angle of incidence** – the angle that the sun's rays subtend with a line perpendicular to a surface.
4. **Conduction** – the process by which heat energy is transferred through materials (solids, liquids or gases) by molecular excitation of adjacent molecules.
5. **Conductivity** – the quantity of heat that will flow through one square meter of material, one meter thick, in one second, when there is a temperature difference of 10C between its surfaces.
6. **Convection** – the transfer of heat between a moving fluid medium (liquid or gas) and a surface, or the transfer of heat within a fluid by movements within the fluid.
7. **Decrement factor**- ratio of the maximum outer and inner surface temperature amplitudes taken from the daily mean.  University of Moratuwa, Sri Lanka
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8. **Density** – the mass of a substance which is expressed in kilograms per cubic meter.
9. **Diffuse radiation** – radiation that has traveled an indirect path from the sun because it has been scattered by particles in the atmosphere, such as air molecules, dust and water vapour. Indirect sunlight comes from the entire skydome.
10. **Dry Bulb Temperature**:- DBT is an indicator of sensible heat or the heat content of perfectly dry air.
11. **Emissivity** – the property of emitting heat by radiation; possessed by all materials to a varying extent. "Emittance" is the numerical value of this property.
12. **Humidity**: - This refers to the water vapor contained in the air.
13. **Humidity ratio**: moisture content or mixing ratio is defined as the ratio of the weight of the water vapour to the weight of the dry air contained in a given volume of air.

14. **Temperature**:-Thermal state of matter with reference to its tendency to communicate heat to matter in contact with it. It is an index of the energy content of materials, disregarding energies stored in chemical bonds and atomic structure of matter.
15. **Relative humidity**:- Is defined as the ratio of the amount of moisture contained in the air under specified conditions to the amount of moisture contained in the air at saturation at the same temperature.
16. **Emittance** is defined as the ratio of the amount of radiant energy released by a particular surface at a specified wavelength and temperature to the emittance of an "ideal black body" at the same wavelength and temperature.
17. **Greenhouse effect** – refers to the characteristic tendency of some transparent materials such as glass to transmit shortwave radiation and block radiation of longer wavelengths.
18. **Heat gain** - an increase in the amount of heat contained in a space, resulting from direct solar radiation and the heat given off by people, lights, equipment, machinery and other sources.
19. **Heat loss** – a decrease in the amount of heat contained in a space, resulting from heat flow through walls, windows roof and other building envelope components.
20. **Infiltration** – the uncontrolled movement of outdoor air into the interior of a building through cracks around windows and doors or in walls, roofs and floors. This may work by cold air leaking in during the winter, or the reverse in the summer.
21. **Insulation** – materials or systems used to prevent loss or gain of heat, usually employing very small dead air spaces to limit conduction and/or convection.
22. **Sol-air temperature** – an equivalent temperature, which will produce the same heating effect as the incident radiation in conjunction with the actual external air temperature.
23. **Solar radiation** – electromagnetic radiation emitted by the sun. The radiation received without change of direction is called beam or direct radiation. The radiation received after its direction has been changed by scattering and reflection is called diffuse radiation. The sum of the two is referred to as global or total radiation.
24. **Specific heat** – the quantity of heat required to raise the temperature of kg of a substance 1°C .
25. **Radiation** – the direct transport of energy through space by means of electromagnetic heat.
26. **Reflectance** – the ratio of the amount of light reflected by a surface to the amount incident.

27. *Resistance* – resistance is the reciprocal of conductivity
28. *Thermal mass*- the amount of potential heat storage capacity available in a given assembly of system.
29. *Transmittance* is defined as the ratio of the amount of the radiant energy transmitted through specified thickness of a substance at specified wavelength to the total amount of radiant energy incident upon its surface.
30. *Wet Bulb Temperature*:- WBT is an indicator of total heat of the air, that of its combined sensible and latent heats.



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