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COMPARATIVE ANALYSIS OF BERMED HOUSE AND CONTEMPORARY HOUSE IN COMPOSITE CLIMATE

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Abstract**:** This paper addresses the study of bermed structures which act as an excellent passive adaptation strategy to reduce the adverse climatic effects and improve thermal performance of the bermed house in both HVAC and natural ventilation case in composite climate. Thus, the goal of this study is to simulate and compare the thermal performance of bermed and contemporary structures in composite climate and to study parametric optimization for the same. For that, a base scenario, a combination south facing facade with 10% WWR has been chosen by referring standards like NBC, reviewing literature and case study. Further the variation in WWR, orientation and stack effect has been performed to frame various design case and finding the optimum case for the construction of bermed structure in composite climate. The methodologies adopted are (i) the computational simulation of the EPI (ii) the quantification of the discomfort hours and PMV with the subsequent comparative analysis. The results shows that for adequate amount of natural ventilation and thermal performance, the most optimum composition for bermed structure that can be used is "vertically oriented windows with 10% WWR, facing towards south direction in natural ventilation case and north in HVAC case and bermed with minimum 0.9 m of earth mass". Also using stack effect can help in inviting cross ventilation. Nonetheless, it is shown that this passive strategy of making bermed structure works as an excellent adaptation measure to improve thermal performance and overall EPI of the building in composite climate.

***Index Terms* -** thermal performance, building simulation, global warming, EPI, discomfort hours, bermed.

1. INTRODUCTION

1.1 Background study

A bermed structure has one or more walls surrounded by outside earth, and it can be above grade or partially below grade. Both varieties typically have earthen roofs, with the possibility of vegetation covering some of the roofs to prevent erosion. Three general designs have been developed from these two fundamental types. They are the following:

- Atrium (or courtyard) plan: underground construction in which the entrance to the dwelling and the focal point of the house are an atrium;
- Penetrational plan: constructed above or partly above grade, with bermed areas to protect the outer walls not facing south;
- Elevational plan, a bermed structure that may have a glass south-facing entry. (Earth-Sheltered Houses, 1997)

The sun can heat and lighten the inside of a house by shining on its exposed front, which is typically facing south. The bedrooms and common areas of the floor plan are oriented to share the heat and light from the southern exposure. This is the most straightforward and least expensive method of constructing an earth-sheltered building. The northern sections of the house can have enough light and ventilation if skylights are positioned strategically. Except for the areas with windows and doors, the whole house is covered in earth in a penetrational bermed design. Typically, the earth is piled up (or bermed) around and on top of the ground level house. This layout provides access to natural light and cross-ventilation from multiple sides of the house. (energy saver).

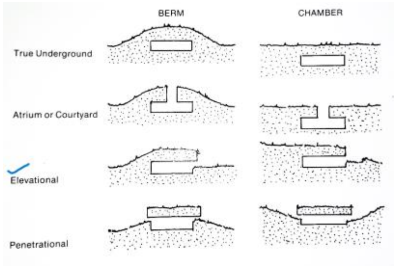


Figure 1 Types of bermed structures

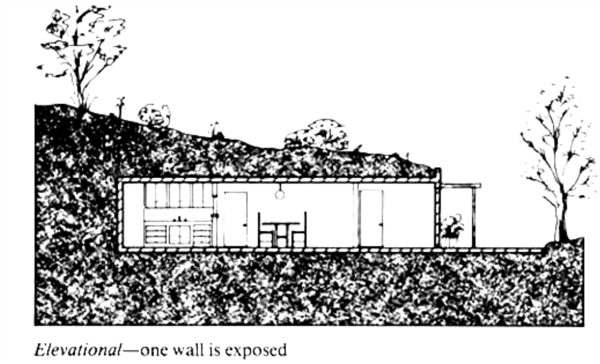


Figure 2 selected bermed structure for design case

1.2 Aim

The aim of this paper is to simulate and compare the thermal performance of bermed and contemporary structures as passive strategy in composite climate.

1.3 Objective

- To measure thermal comfort and natural ventilation of elevational bermed house.
- To study parametric optimization for bermed structure in composite climate.
- To simulate and compare the thermal performance of bermed and contemporary houses.
- To study the effect of variation in WWR and orientation in bermed structures.

1.4 Scope and limitations

- The scope of the research is to provide comparative analysis between bermed house and contemporary houses and incorporate this passive strategy in composite climate.
- This does not consider daylight and drainage. Thermal comfort and ventilation will be considered.

1.5 Methodology

1.5.1 Secondary data collection

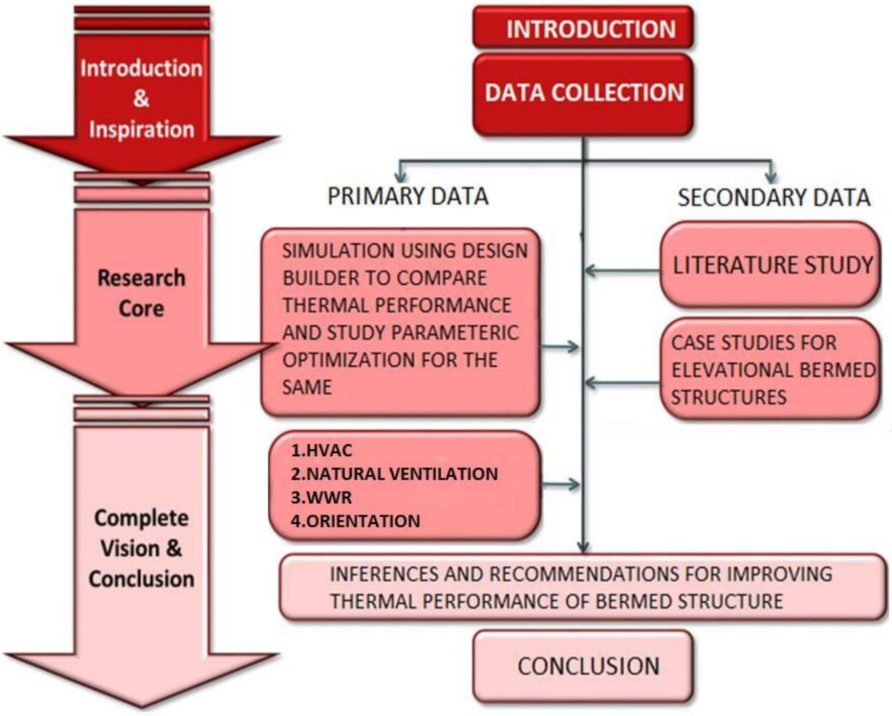
For secondary source, literature study from various research papers and case studies has been selected with elevation type bermed structures. House typology has been opted for all the data collection to match the design case with composite climate. Parameters like thermal comfort, natural ventilation, daylight is considered in this report. The case studies are compared and summarized to obtain data regarding the selected projects. The study of parametric optimization of the design variables, such as the orientation, climate, heating-cooling set point, ventilation rate, earth mass, building envelope materials, u-value, window-to-wall ratio (WWR) is analyzed.

1.5.2 Primary data collection

Simulation in design builder software has been performed between conventional house and bermed house for analysis and primary data collection. Through parametric optimization of the design variables and material selection multiples simulations is done to compare thermal performance, natural ventilation and daylight between bermed and conventional house.

1.5.3 Parameters

The values of thermal performance, discomfort hours, PMV (predicted mean vote) and EPI (energy performance index) of the buildings are compared.
For performing the simulation, suitable orientation, material, WWR, heating-cooling set points, material specification and thermal performance data have been obtained using design builder software.



2. LITERATURE STUDY

As per various study, as the building descends below 2.5 m, the energy consumption reduction varies at a very tiny rate in the southward-oriented earth-sheltered structure. As can be observed, the aboveground building's maximum and minimum temperatures are higher than the outside temperature. Nevertheless, the thermal state of the structure varies with the depth of the earth-sheltered area. These findings also show that the earth-sheltered structure's interior space experiences less temperature fluctuation. When compared to a traditional aboveground building, the earth-sheltered structure's yearly temperature fluctuation is 50% less under these conditions. Additionally, the range of annual maximum and minimum temperatures in the earth-sheltered area dramatically shrinks. The winter temperature in these buildings drops by 8°C, and the summer temperature drops by 6.8°C. (Nasrollahi, Thermal Performance of Earth-Sheltered Residential, 2014)
In the study of the thermal performance of the earth-sheltered buildings and the impact of the significant and effective factor of orientation on the residential function, it was found that southward orientation provided the least amount of energy consumption across all depths. The results show that, in comparison to conventional aboveground structures, energy efficiency increases significantly with building depth. In these situations, the yearly temperature of an earth-sheltered building is 50% lower than that of a normal above-ground building. The comfort zone is increased by fifty days because a larger percentage of the year is spent in it due to the depth of the structure's reduction in indoor temperature fluctuation. (Nasrollahi, Thermal Performance of Earth-Sheltered Residential, 2014)

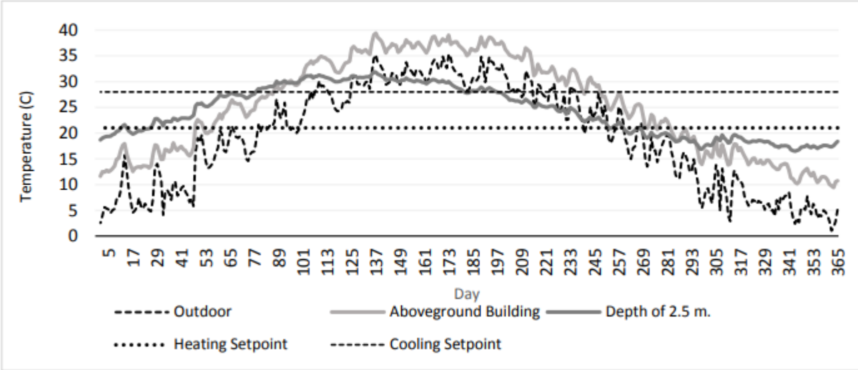
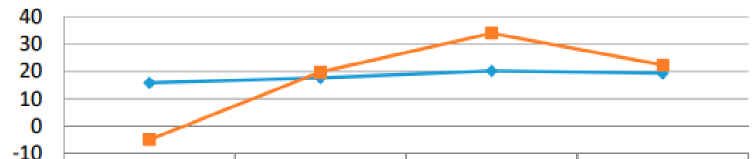


Figure 3 Comparison of temperature aboveground and underground

Between 2012 and 2016, the Dobraca bermed-earth protected house's daily temperature inside and outside was examined, with a focus on the insulation layers and wind speed. The temperature within this bermed-earth sheltered house, based on the measurement that was provided, was near to the optimal temperature that humans require—between a minimum of 15.8 ◦C and a maximum of 20.6 ◦C. (Milanovic, 2018). The temperature is 21 °c during the summer time, even if the outside temperature is above 35 °c. The green roof with just 0.4 m of soil, provides enough thickness for keeping the internal temperature stable (Milanovic, 2018)

Table 1 Quarterly measured temperature (14 h) during 2012 (Milanovic, 2018)

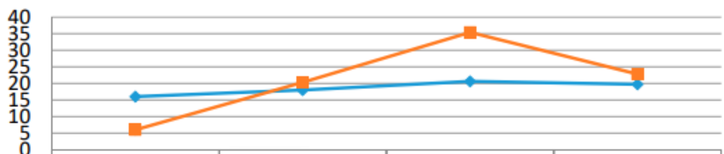
Daily temperature 2012 °C



	Jan-12	Apr-12	Jul-12	Oct-12
	1	2	3	4
Temperature inside	15.8	17.66	20.22	19.33
Temperature outside	-5	19.8	34	22.4

Table 2 Quarterly measured temperature (14 h) during 2016 (Milanovic, 2018)

Daily temperature 2016 °C



	Jan-12	Apr-12	Jul-12	Oct-12
	1	2	3	4
Temperature inside	16	18	20.6	19.72
Temperature outside	6	20.3	35.4	22.8

The other house type has an indoor temperature and humidity of 12.70°C and % 70.13 RH, whereas the underground house has an indoor mean temperature and humidity of 16.12°C and % 62.07 RH, according to an additional result in the Bakoosh paper (Bakoosh, 2020). These findings demonstrate the large differences in interior temperatures between the different types of houses; the underground house is found to be nearly 3.5°C warmer. Given that it is winter, one could argue that the interior temperature of the underground home seems to be somewhat more comfortable than that of the modern home. Furthermore, if we look at the standard deviation values, we can argue that an underground house achieves lower temperature variability, leading to a more stable and constant temperature. (Bakoosh, 2020)

The subterranean construction approach demonstrated significant cost savings achieved by these construction models in nearly all of the examples that were given. In Serbia, the most popular construction model combines bermed elevation structures with green roofs. Subterranean housing complexes typically have temperatures between 16 and 20 degrees Celsius. Bermed underground housing can be adequately served by green roofs with medium requirements, semi-intensive, as they are considered to be the kind that can yield positive results for the duration of the summer. A green layer of the roof garden, with a soil layer between 100 and 900 mm thick, yields the highest savings; - the best kind of roof garden is one with shrubbery and a 300 mm thick layer of soil; this type of garden can save up to 15% of annual energy consumption, or 79% of the energy used for building cooling. (Rudnik)

Based on utility billings for all-electric homes in Oklahoma, Boyer's research paper (Boyer) compared the monthly total energy use of earth sheltered homes with conventional above ground homes. The sample includes numerous instances of both kinds. Earth shelters use approximately 40% less energy annually overall, and their winter peak usage is cut in half. Additionally, there is a two-month shift in the timing of the demand peaks in the summer and winter. This sample's summer performance isn't very impressive. Even though both curves have similar appliance and hot water usage, there is a significant overall energy reduction visible. Even though the current earth shelters are saving a significant amount of energy, there are still plenty of opportunities to save even more. Research shows that optimally designed earth-sheltered structures can reasonably expect yearly energy use reductions of about 80% for both heating and cooling. (Boyer)

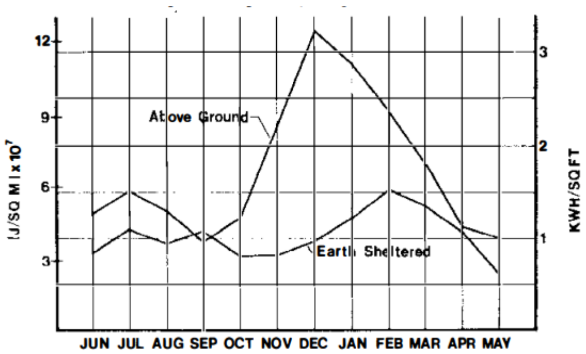


FIGURE 4 MONTHLY ENERGY CONSUMPTION IN CONTEMPORARY ABOVE GROUND AND EARTH SHELTERED HOMES

3. CASE STUDY

3.1 Selection criteria for the case studies

Case studies are selected according to the following selection criteria similar to the design case:

Table 3 Selection criteria for case studies

SR NO.	PARAMETERS	SPECIFICATIONS
1.	Climate	Composite
2.	Materials	Concrete
3.	Orientation	270°
4.	Typology	House
5.	Earth shelter type	Elevational (bermed walls and roof)
6.	WWR	10%-25%
7.	Thermal mass	Earth

The case studies are compared and summarized to obtain data regarding the selected projects.

The study of parametric optimisation of the design variables, such as the orientation, climate, heating-cooling set point, ventilation rate, earth mass, building envelope materials, u-value, window-to-wall ratio (WWR) is analyzed. The thermal performance, ventilation rate and thermal loads of the buildings are compared. From the selected case studies, suitable orientation, material, WWR, heating-cooling set points, material specification and thermal performance data have been obtained through simulation using design builder software.The selected buildings were well occupied for since the last 5 years.

3.2.1. Dobraca village house near kragujevac, Serbia

The 2008 completion of the house was followed by a quarterly monitoring program for average temperature between 2012 and 2016. (Milanovic, 2018)

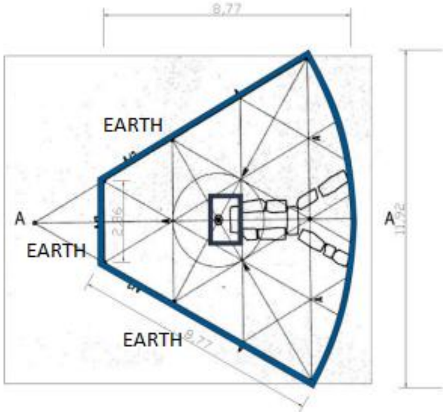
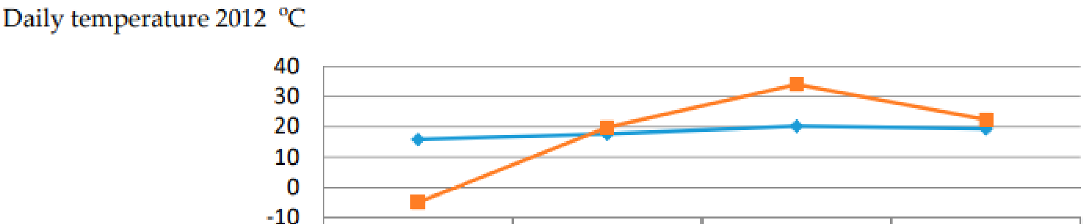


Figure 5 Floor plan of the house (Milanovic, 2018)

Figure 6 Elevation of the house (https://images.app.goo.gl/P5ovEQ8TnrKDnPy17)

Between 2012 and 2016, the Dobraca bermed-earth protected house's daily temperature inside and outside was examined, with a focus on the insulation layers and wind speed. The temperature within this bermed-earth sheltered house, based on the measurement that was provided, was near to the optimal temperature that humans require—between a minimum of 15.8 ◦C and a maximum of 20.6 ◦C. (Milanovic, 2018)

Table 4 Quarterly measured temperature (14 h) during 2012 (Milanovic, 2018)



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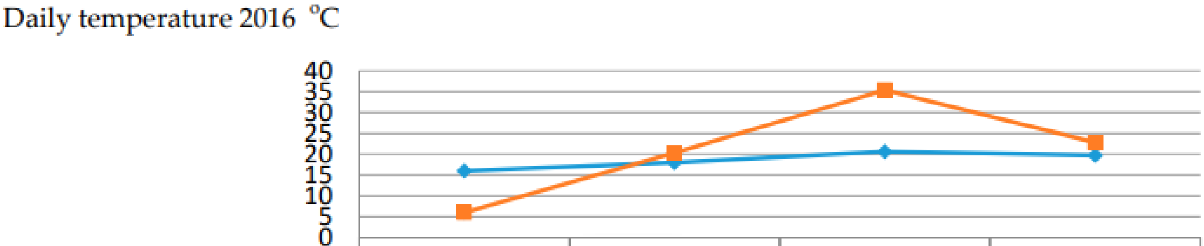
Temperature outside	-5	19.8	34	22.4

Table 5 Quarterly measured temperature (14 h) during 2016 (Milanovic, 2018)



	Jan-12 1	Apr-12 2	Jul-12 3	Oct-12 4
Temperature inside	16	18	20.6	19.72
Temperature outside	6	20.3	35.4	22.8

3.2.2. Earth-sheltered home, Korea

This study contrasts the thermal performance of a typical home with that of an earth sheltered house, which was specifically created to withstand the circumstances in Korea. The earth-sheltered home's interior temperature ranged 1.6°C in the summer and 5.4°C in the winter compared to the traditional residence's temperature range. According to measurements, the earth-sheltered home's interior temperature was more consistent than that of the traditional home. (Lee, 1988)

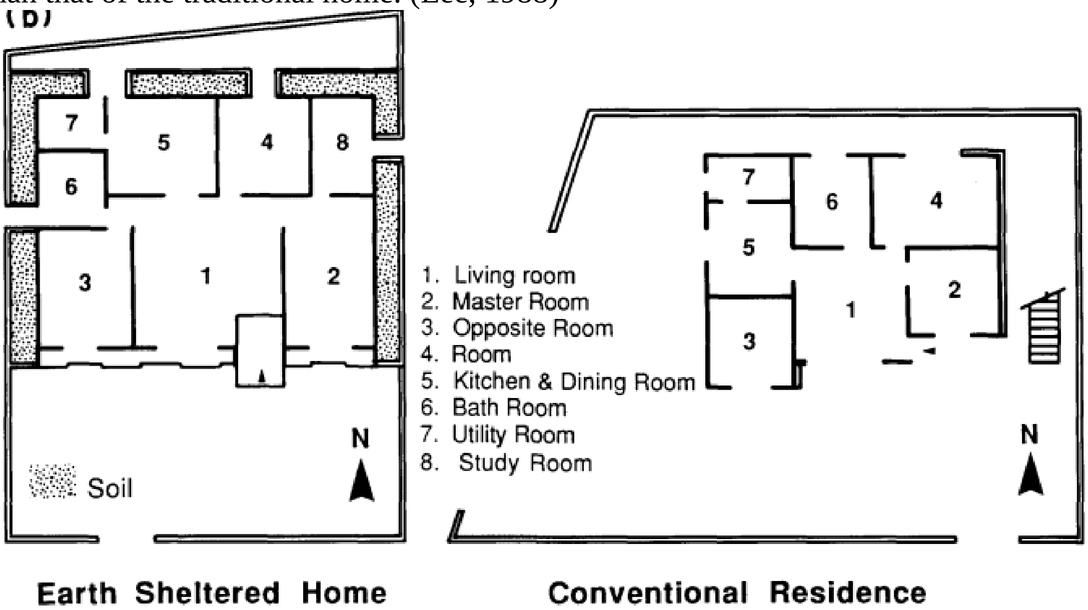


Figure 7 Left: Floor plan [or an earth-sheltered home. Right: Floor plan for a conventional house. (Lee, 1988)

The earth-sheltered home experiences a longer indoor temperature time lag in winter (77 minutes) and a longer indoor temperature time lag in summer (54 minutes) compared to the conventional residence. This indicates that the earth-sheltered home experiences a greater effect of indoor thermal lag.

Table 6 Measured indoor and outdoor temperature in both residences. (Lee, 1988)

Classification		Temperature (°C)		
		Mean *T.*	Max. *T.*	Min. *T.*
Winter	Outdoor temperature	–3.1	3.5	–8.1
	Indoor temperature of the conventional residence	3.7	8.4	0.7
	Indoor temperature of the earth sheltered home	11.5	12.9	10.6
Summer	Outdoor temperature	28.3	32.4	25.3
	Indoor temperature of the conventional residence	28.7	30.8	25.9
	Indoor temperature of the earth sheltered home	27.0	28.3	25.6

3.2.3. Earth sheltered residence on kea island, Athens

Summer time temperatures are high in Athens, with an absolute maximum temperature of 39.4C in July and an average of 25.4C. The average winter temperature is 11.2 C, with an absolute minimum of 2.0 C in February. The Average Low Temperature Is Still Rather High, At 6.6 C, Even in the Winter. The Only ‘‘Exposed’’ Part Of The Structure Is The Residence’s Facade (Benardos, 2013)

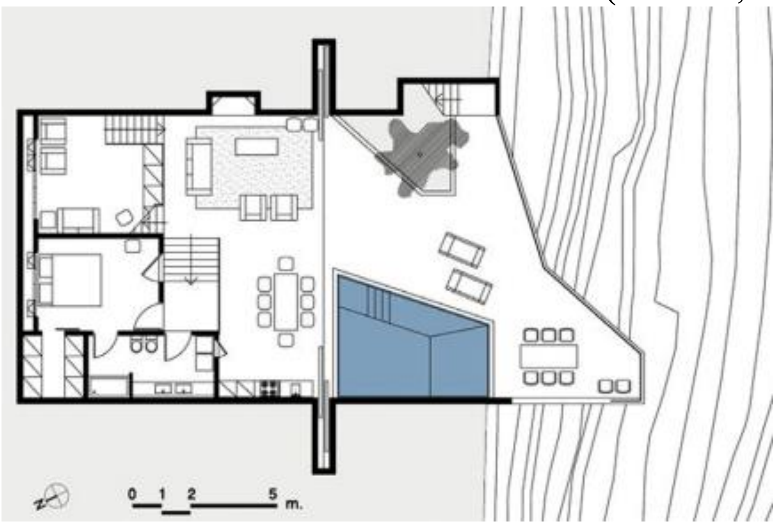


Figure 8 Plan of residence

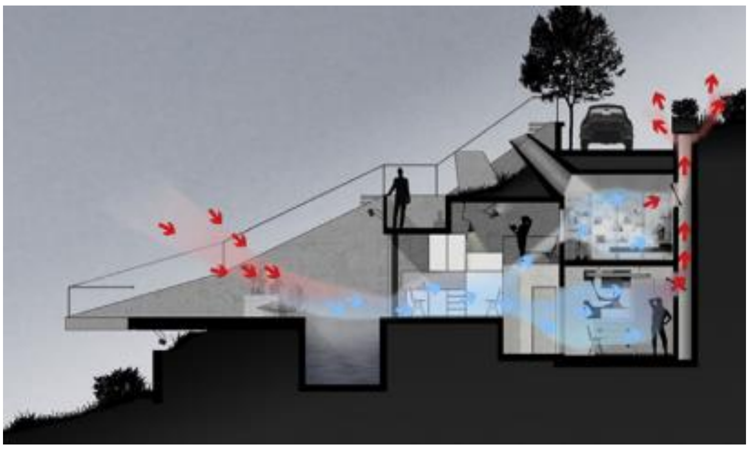


Figure 9 Section of the residence (Benardos, 2013)

Based on the information presented in Table, it can be said that the aboveground building requires 42% more energy in total, 25% more for cooling, and 250% more for thermal energy than the underground building.

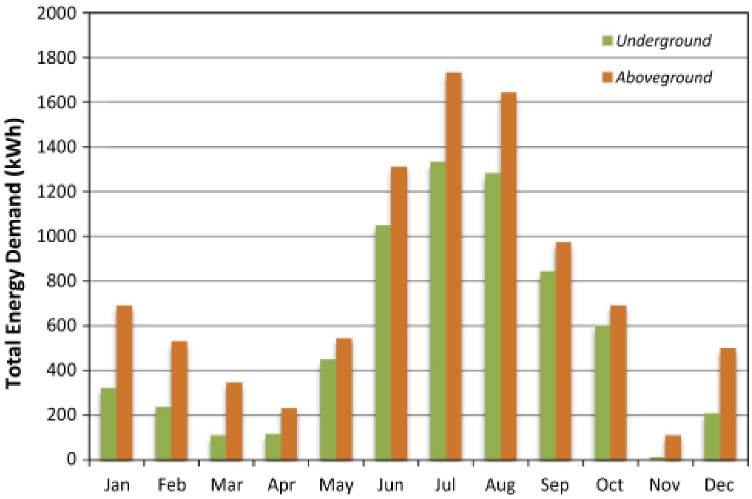
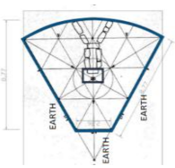
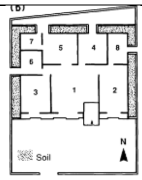
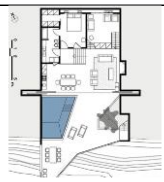


Figure 10 Total energy demand of the underground and the aboveground structure on monthly basis (Benardos, 2013)

3.3. Comparative analysis

Table 7 Comparative analysis of case studies

Sr no.	PARAMETERS	CASE-01	CASE-02	CASE-03
	PLAN			
1.	LOCATION	Serbia	Korea	Athens
2.	CLIMATE	Continental	Temperate	Mediterranean
3.	ORIENTATION	East	South	South
4.	HEMISPHERE	Northern and Eastern	Northern	Northern and Eastern
5.	NO.OF BERMED SIDES	05	05	05
6.	NO.OF FLOORS	01	01	02
7.	MATERIAL (WALL,SLAB)	Concrete	Cement brick, concrete	Reinforced concrete
8.	WWR %	10	15	20
9.	TEMP.DIFF	10-20℃	01-18℃	07-13℃

3.4. Inferences from case studies

- The suitable orientation for northern hemisphere in accordance with climate is south i.e. 270°. It is helping in eliminating the summer sun with altitude in harsh summer and gaining the winter sun with low altitude in cold. Providing shading in this orientation is very easy and can be managed by normal projections or chajjas.
- Variation in WWR from 15% to 25% has been witnessed to gain adequate amount of daylight and natural ventilation to provide necessary thermal comfort. thus opting for the given ranges of WWR with respect to climate can be beneficial for bermed structures
- The temperature difference between conventional and bermed house ranges from 7℃-20℃ due to earth acting as a thermal mass which makes it a sustainable means of construction. Also the thermal

performance of bermed house is much more effective than the conventional ones making it thermally comfortable throughout the year and reducing annual thermal load upto around 60%.

- Reinforced concrete with an additional layer of insulation can be used along with earth mass for retaining walls and roof and a clear glass of 6mm for glazing as materials.
- Roof should be covered with minimum width of 0.9 m of earth mass.

4. SIMULATION METHODS AND QUANTITATIVE ANALYSIS

4.1. Simulation methodology

- Literature study
- Case study
- Standards (NBC)

BASE CASE

I Static data
1. Shading
2. Climate
3. Area
4. Topography
5. Typology

II Dynamic data

1.Orientation
a. North
b. South
c. East
d. West

2. WWR
a. 10%
b.15%
c.25%

3. Window orientation
a. Horizontal
b. Vertical

4. Stack effect

Design case

a. Natural ventilation
b. HVAC

OPTIMUM CASE

4.2. Base case and design case specifications

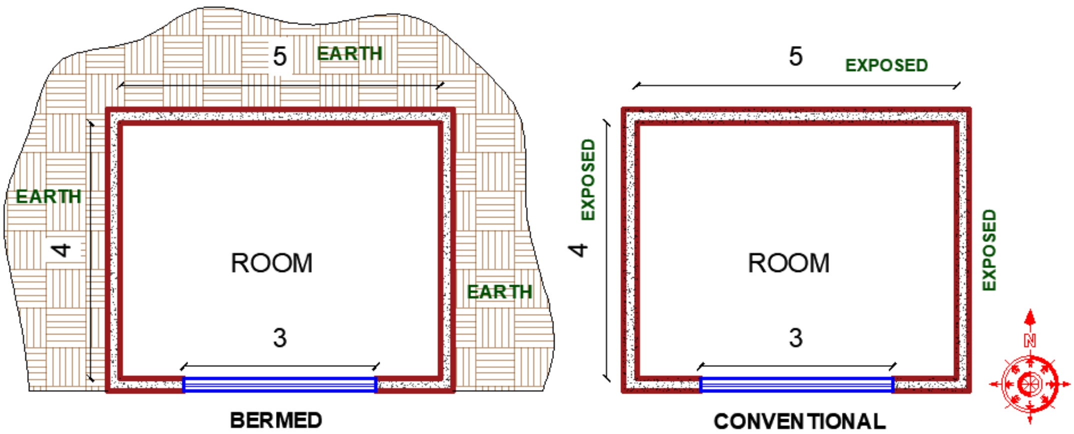


Figure 11 Plan of bermed and conventional house

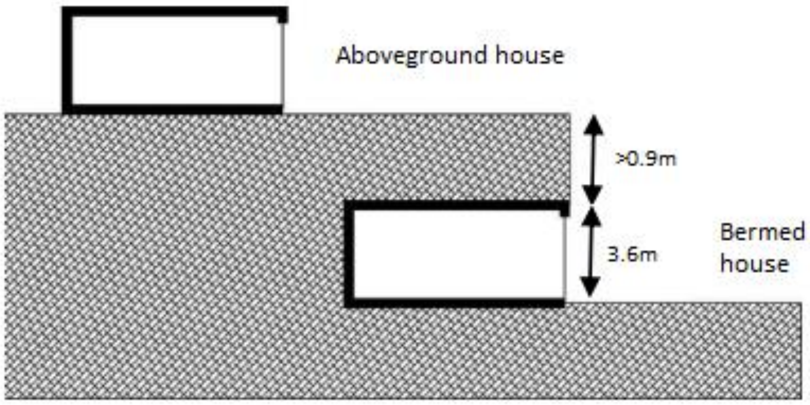


Figure 12 Section of both the cases

4.3. Quantitative data analysis

4.3.1 Physical properties for design and base case

Table 8 Physical properties for design and base case

SR.NO	VARIABLES	BASE CASE	DESIGN CASE
1.	Type	Conventional	Bermed
2.	Topography	Flat	Flat
3.	Location	Lucknow	Lucknow
4.	Climate	Composite	Composite
5.	Roof type	Flat	Bermed
6.	No. of bermed side	0	04
7.	No. Of exposed side	05	01
8.	No. Of floor	01	01
9.	Area	20sqm	20sqm
10.	Height	3.6m	3.6m

4.3.2 Parametric optimisation for simulation

Parametric optimization study has been performed using Design Builder/ Energy Plus software to reach the optimal performance of the building with the best combination of design variables.
Design Variables were the combination of 4 aspects: -

- Natural ventilation and HVAC condition, resulting in 4 cases
- Window/Wall ratio percentage, ranging from 10-25% with 3 steps increment, for the building as a target object, resulting in 24 cases.
- Orientation, ranging from 0°-270° with 90° steps increment, for the building as a target object, resulting in 24 cases.
- Horizontal and vertical window orientation resulting in 4 cases
- Stack effect resulting in 2 cases
- Total number of simulation- **58 cases**

. After the parametric optimization process, the optimal design variables combination has been chosen for the design guidelines recommendations.

Table 9 Optimisation setting for both the case

SR.NO	VARIABLES	UNIT	VALUE
1.	WWR	%	10, 15, 25
2.	Heating set point	°C	24
3.	Cooling set point	°C	27
4.	Orientation	°	0-270
5.	Ventilation rate	ACH	0.5

4.4. Material specifications for base case and design case

Table 10 Material specification for design and base case

SR.NO	ELEMENTS	MATERIAL	THICKNESS (M)		U-VALUE (W/m²K)
			Conventional	Bermed	
1.	Wall	Reinforced concrete	0.23	0.23+earth	0.659
		Plaster	0.02	0.02	
2.	Roof	Concrete	0.2	0.2+earth	0.88
3.	Thermal mass	Earth	-	1.0	-
4.	Glazing	Clear glass	0.006	0.006	5.78

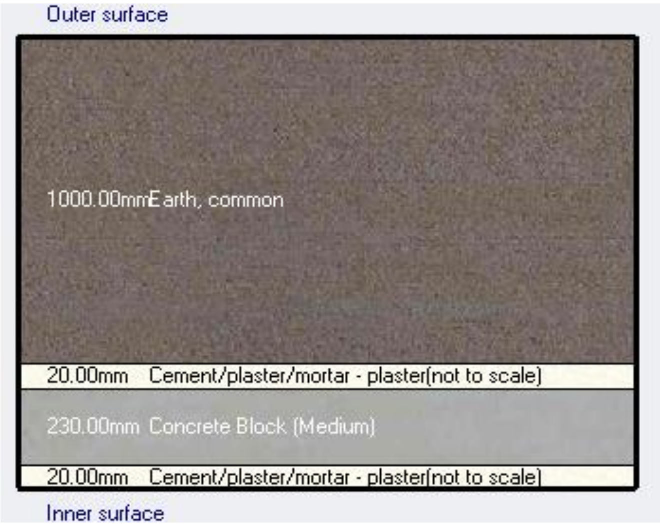


Figure 13 Section of wall assembly with earth mass (Design builder)

4.4.1 Wall assembly

For wall assembly, concrete block has been used as it is the most suitable material for making retaining structures. The thickness of wall is 0.23m with inner and outer plaster of 20mm. To berm the structure, earth mass of 1.0m has been added all the 3 sides of wall except for the exposed facade in the composition. The combined u- value of wall assembly is 0.659 W/m²K and the wall is a composition of concrete, plaster and earth mass. The property of wall for conventional house has been kept same, only the earth mass has been eliminated to keep all the sides of wall exposed to the environment.

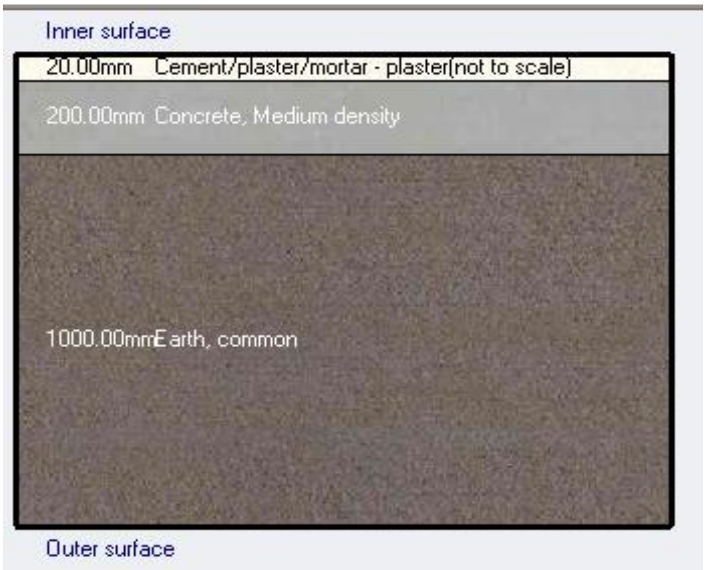


Figure 14 Section of roof assembly with earth mass (Design builder)

4.4.1 Roof assembly

For roof assembly, concrete slab has been used as it is the most suitable material for casting slab. The thickness of roof is 0.20m with inner plaster of 20mm. To berm the roof, earth mass of 1.0m has been added on the top of the roof in the composition. The combined u- value of roof assembly is 0.88 W/m²K and the roof is a composition of concrete, plaster and earth mass. Roof type is flat in both the cases. The property of roof for conventional house has been kept same, only the earth mass has been eliminated to keep the roof area exposed.

5. RESULT AND SIMULATION ANALYSIS

5.1 Case 01- Bermed VS conventional- HVAC

In this case, simulation has been performed between bermed house and conventional house in the case of HVAC to find out difference in the values of heating load, cooling load, lighting load and overall energy performance, EPI between both the cases. Static parameters are taken from NBC as per composite climate standards. South direction with 15%WWR has been fixed for design and base case.

Table 11 Simulation results in the case of HVAC for bermed and conventional house.

DATA (YEARLY)	ENERGY CONSUMPTION			
	HEATING (kwh/m$^{2/}$year)	COOLING (kwh/m$^{2/}$year)	LIGHTING (kwh/m$^{2/}$year)	EPI (kwh/m^2/year)
CONVENTIONAL	188.28	254.93	23.79	581.15
BERMED	**30.75**	**158.45**	**23.79**	**327.14**

5.1.1 Result

After simulation, the **bermed structures** were found to be the optimum case in HVAC case when compared with the conventional structure in terms of heating load, cooling load, lighting load and overall EPI.

- **Percentage (%) of annual energy saving-**

The annual energy saving in bermed house is **44.75%** more than the conventional house.

5.2 Case 02- Bermed VS Conventional- Natural ventilation

In this case, simulation has been performed between bermed house and conventional house in the case of natural ventilation to find out difference in the values of discomfort hours and PMV (predicted mean vote) between both the cases. Static parameters are taken from NBC as per composite climate standards. South direction with 15%WWR has been fixed for design and base case.

Table 12 Simulation results in the case of Natural ventilation for bermed and conventional house.

DATA (YEARLY)	THERMAL COMFORT	
	DISCOMFORT HOURS (hrs)	PMV
CONVENTIONAL	6559.33	2.04
BERMED	**6239.5**	**1.62**

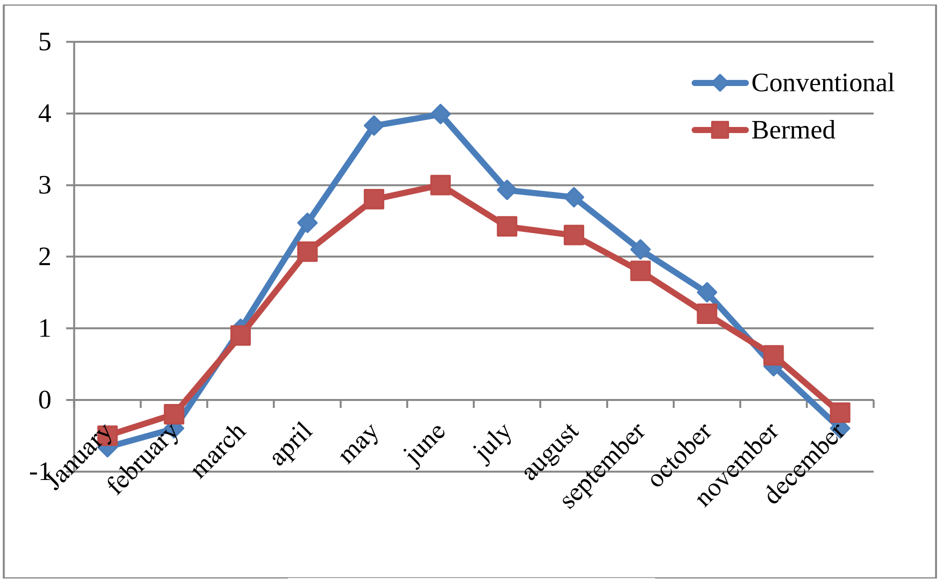
5.2.1 Result

After simulation, the **bermed structures** were found to be the optimum case in natural ventilation case when compared with the bermed structure in terms of discomfort hours and PMV.

- **Decrease (%) in discomfort hour-**

The annual discomfort hours in bermed house are **4.9%** less than the conventional house.

Table 13 PMV value comparison for bermed and conventional house



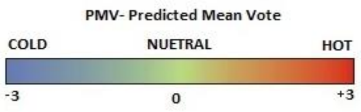


Table 14 Energy consumption comparison for bermed and conventional house (monthly)

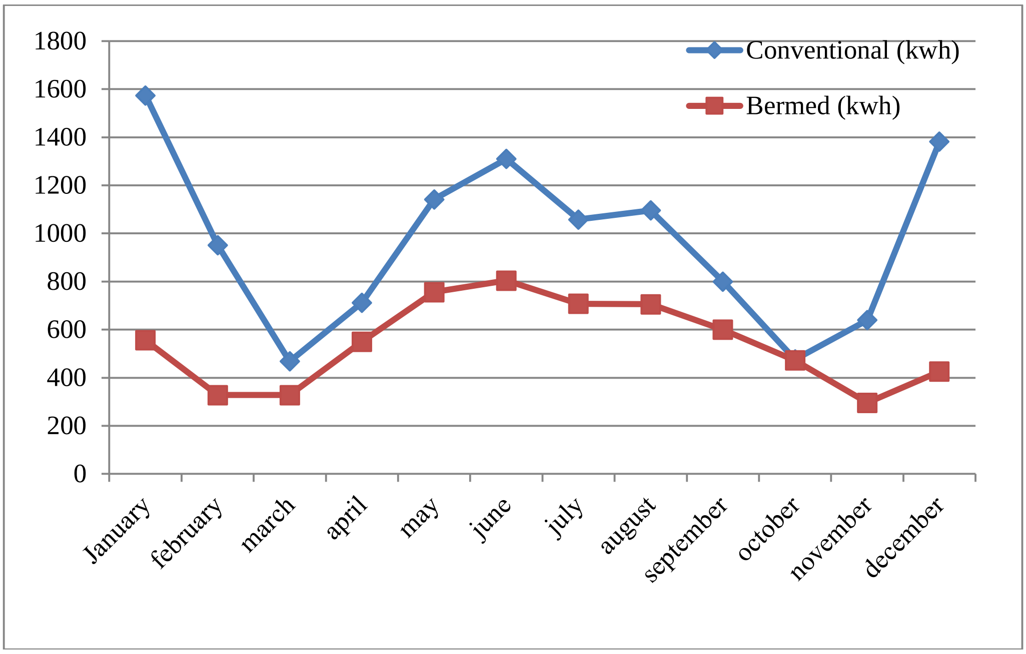


Table 15 Heating load comparison for conventional and bermed house (monthly)

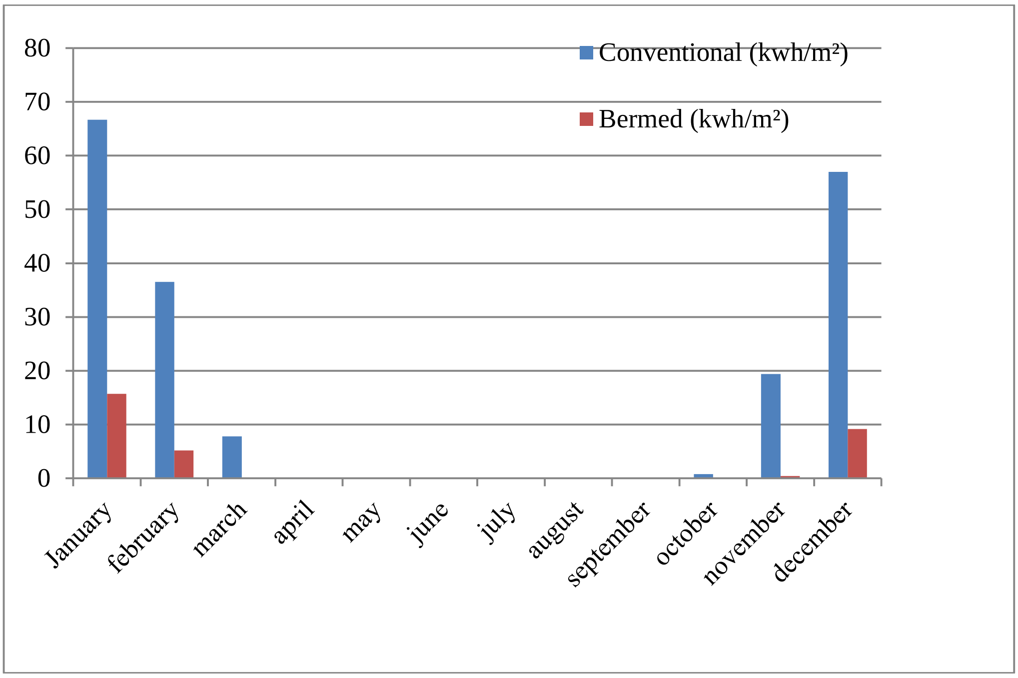


Table 16 Cooling load comparison for conventional and bermed house (monthly)

5.3 Case 03- Variation in WWR and orientation in bermed house- natural ventilation

In this case, simulation has been performed on bermed house in the case of natural ventilation by doing variation in orientation and WWR. The model has been simulated by rotating elevational facades in all the four directions i.e. north, south, east and west and changing WWR from 10%, 15% to 25% of all the walls of the block, to find out difference in the values of discomfort hours and PMV (predicted mean vote) between all the case and hence to find the optimum case. The variation in selected parameters framed 24 cases.

Table 17 Variation in WWR and orientation for bermed house (Natural ventilation)

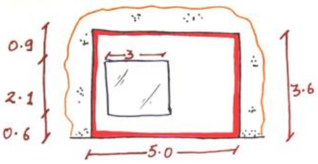
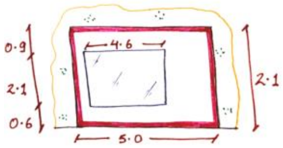
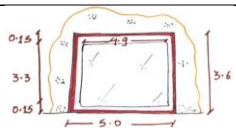
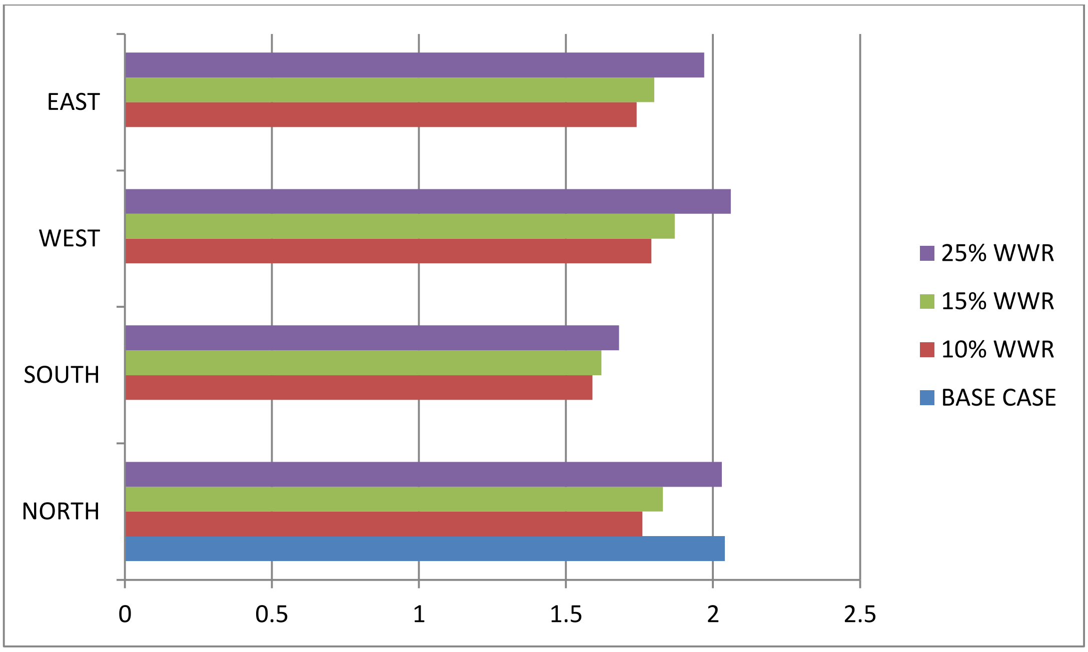
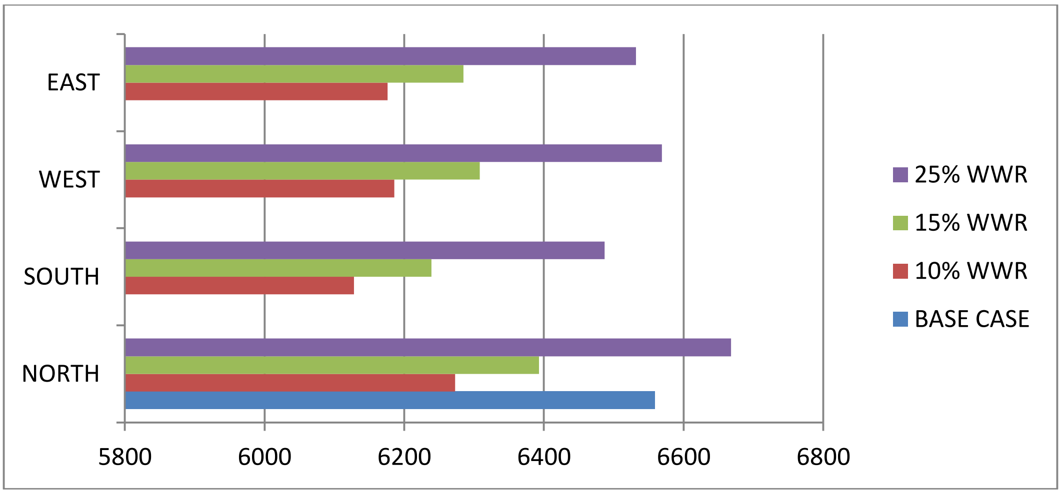
ELEVATION						
WWR (%)	**10%**		**15%**		**25%**	
DATA (YEARLY)	**THERMAL COMFORT**		**THERMAL COMFORT**		**THERMAL COMFORT**	
	DISCOMFORT HOURS	**PMV**	**DISCOMFORT HOURS**	**PMV**	**DISCOMFORT HOURS**	**PMV**
CONVENTIONAL	-	-	**6559.33**	**2.04**	-	-
NORTH	6272.66	1.76	6393.66	1.83	6668.00	2.03
SOUTH	**6128.00**	**1.59**	6239.5	1.62	6487.00	1.68
WEST	6186.5	1.79	6308.16	1.87	6569.66	2.06
EAST	6176	1.74	6285.83	1.80	6532.33	1.97

Table 18 Comparison of PMV values with variation in orientations and WWR



- **Best case- South with 10% WWR in natural ventilation**

Table 19 Comparison of Discomfort hours with variation in orientations and WWR

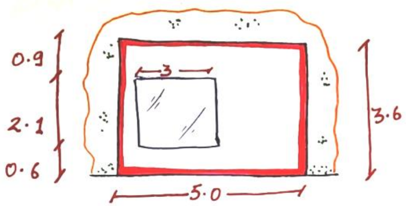
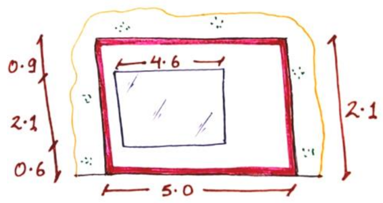
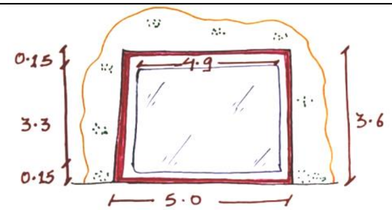


- **Best case- South with 10% WWR in natural ventilation**

5.4 Case 04- Variation in WWR and orientation in bermed house- HVAC

In this case, simulation has been performed on bermed house in the case of HVAC by doing variation in orientation and WWR. The model has been simulated to find out difference in the values of heating load, cooling load, lighting load and overall EPI between all the case and hence to find the optimum case. The variation in selected parameters framed 24 cases.

Table 20 Variation in WWR and orientation for bermed house (HVAC)

ELEVATION												
WWR (%)	**10%**				**15%**				**25%**			
DATA kwh/m²/yr	**HEATING**	**COOLING**	**LIGHTING**	**EPI**	**HEATING**	**COOLING**	**LIGHTING**	**EPI**	**HEATING**	**COOLING**	**LIGHTING**	**EPI**
CONVENTIONAL	-	-	-	-	**188.28**	**254.93**	**23.79**	**581.15**	-		-	-
SOUTH	15.54	160.09	23.64	322.42	16.61	180.48	23.48	334.72	239.85	216.73	230.44	377.90
NORTH	**27.96**	**151.80**	**24.13**	**308.03**	30.75	158.45	23.79	327.14	45.53	174.94	232.22	357.85
WEST	23.00	173.98	23.49	334.62	24.59	185.98	23.40	348.13	35.67	221.31	230.71	394.20
EAST	25.25	168.21	24.67	331.68	38.07	195.62	23.71	371.55	391.00	209.44	231.55	385.84

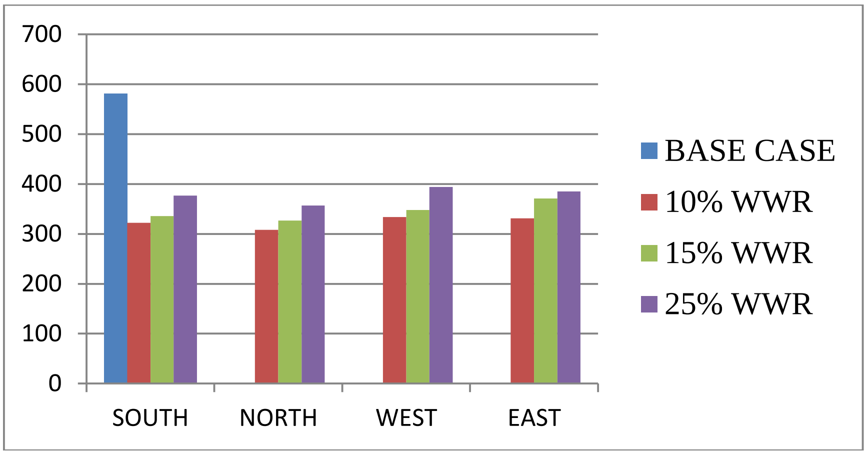
•

5.4.1 Result

After simulation, the bermed structure with **10% WWR facing towards North** was found to be the optimum case in the HVAC case when the values of heating load, cooling load, lighting load and overall EPI were compared with the variations of WWR and orientation. The annual energy saving in north facing bermed house with 10% WWR is **47.00 %** more than the conventional house (base).

Best case - North orientation with 10% WWR

Table 21 Comparison of EPI with variation in orientations and WWR

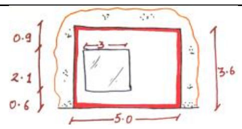
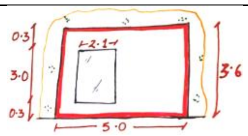


Best case- North with 10% WWR in HVAC

5.5 Case 05- Variation in orientation of North facing window in bermed house- HVAC

In this case, simulation has been performed on the above simulated optimum case i.e. north facing with 10% WWR bermed house in the case of HVAC by doing variation in orientation of window in horizontal and vertical manner. The model has been simulated to find out difference in the values of heating load, cooling load, lighting load and overall EPI between all the case to bring more accuracy in the results and hence to find the optimum case. The variation in selected parameters framed 2 cases.

Table 22 Simulation results in the case of HVAC for vertical and horizontal window orientation.

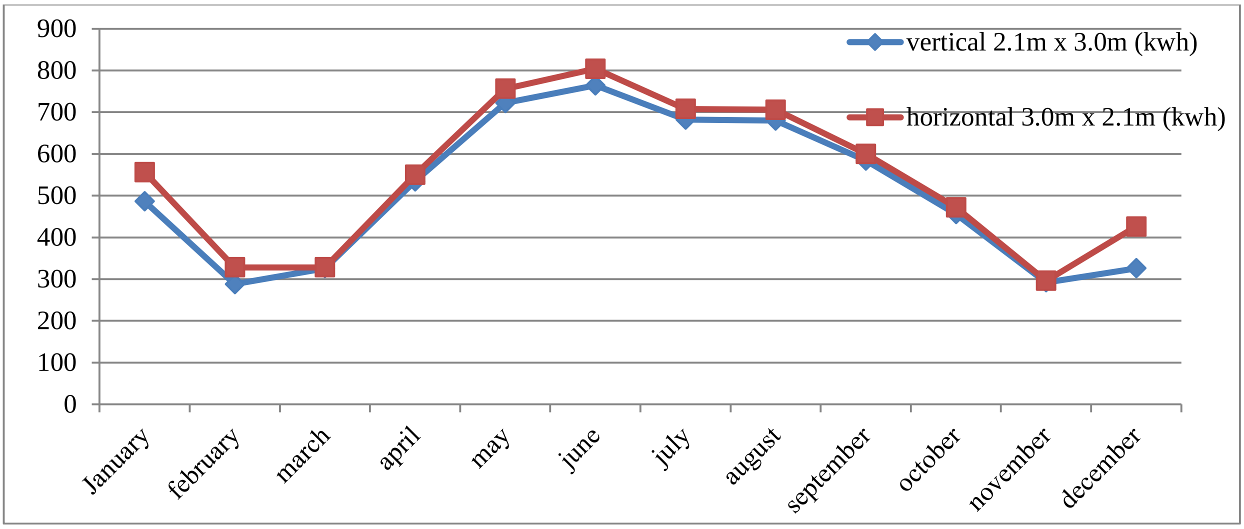
ELEVATION	WINDOW ORIENTATION	ENERGY CONSUMPTION (kwh/m$^{2/}$year)			
		HEATING	COOLING	LIGHTING	EPI
	**CASE-a. HORIZONTAL WINDOW,10% WWR**	27.96	151.80	24.13	308.03
	**CASE-b. VERTICAL WINDOW, 10% WWR**	**21.10**	**150.51**	**25.26**	**299.87**

5.5.1 Result

After simulation, the bermed structure with **10% WWR facing towards north having vertical window** was found to be the optimum case in the HVAC case when the values of of heating load, cooling load, lighting load and overall EPI were compared with the variations of window's orientation. The annual energy saving in north facing bermed house with 10% WWR having vertical window is **2.7 %** more than the north facing bermed house with 10% WWR having horizontal window.

Best case- Vertical window with 10% WWR in HVAC, north facing

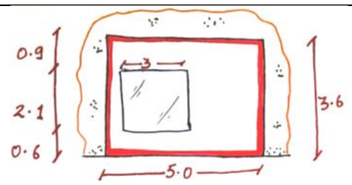
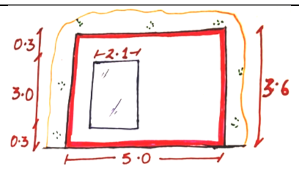
Table 23 Energy consumption comparison for vertical and horizontal window (monthly)



5.6 Case 06- Variation in orientation of south facing window in bermed house- natural ventilation

In this case, simulation has been performed on the above simulated optimum case i.e. south facing with 10% WWR bermed house in the case of natural ventilation by doing variation in orientation of window in horizontal and vertical manner. The model has been simulated to find out difference in the values of thermal comfort and PMV between all the case to bring more accuracy in the results and hence to find the optimum case. The variation in selected parameters framed 2 cases.

Table 24 Simulation results in the case of Natural ventilation for vertical and horizontal window orientation

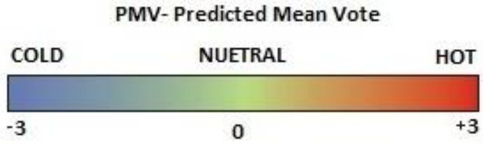
ELEVATION	WINDOW ORIENTATION (SOUTH FACING)	THERMAL COMFORT	
		DISCOMFORT HOURS (hrs)	PMV
	**CASE-a. HORIZONTAL WINDOW, 10% WWR**	6128.00	1.59
	**CASE-b. VERTICAL WINDOW, 10% WWR**	**6014.33**	**1.51**

5.6.1 Result

After simulation, the bermed structure with **10% WWR facing towards south having vertical window** was found to be the optimum case in the HVAC case when the values of of heating load, cooling load, lighting load and overall EPI were compared with the variations of window's orientation. The annualdiscomfort hours in south facing bermed house with 10% WWR having vertical window is **1.9 %** less than the south facing bermed house with 10% WWR having horizontal window.

- **Best case- Vertical window with 10% WWR in HVAC, south facing**

Table 25 PMV value comparison for vertical and horizontal window (monthly)



5.7 Case 07-Comparision with stack effect

In this case, simulation has been performed with the stack effect phenomenon to gain cross ventilation in order to enhance thermal performance. Simulation has been performed uisng optimum case i.e. south facing with 10% WWR vertical windows in the case of natural ventilation. The model has been simulated to find out difference in the values of thermal comfort and PMV due to cross ventilation. The cut out area is 5% of the room area i.e. 1.0 sqm to allow cross ventilation.

Table 26 Simulation result with stack effect.

SR NO.	WINDOW ORIENTATION (SOUTH FACING)	THERMAL COMFORT	
		DISCOMFORT HOURS (hrs)	PMV
1.	CASE-a. WITHOUT STACK EFFECT	**6137.16**	**1.51**
2.	CASE-b. WITH STACK EFFECT	**6014.33**	**0.90**

5.7.1 Result

After simulation, the bermed structure with **stack effect** was found to be the optimum case in the natural ventilation when compared the PMV value and discomfort hours.

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusion

6.1.1 Case 01- bermed vs conventional- HVAC

The **bermed structures** are the optimum case in HVAC condition when compared with the conventional structure in terms of heating load, cooling load, lighting load and overall EPI. The annual energy saving in bermed house is **44.75%** more than the conventional house.

6.1.2 Case 02- bermed vs conventional- natural ventilation

The **bermed structures** are optimum case in natural ventilation condition when compared with the bermed structure in terms of discomfort hours and PMV. The annual discomfort hours of bermed house is **4.9%** less than the conventional house.

6.1.3 Case 03- variation in WWR and orientation in bermed house- natural ventilation

The bermed structures with 10% WWR facing towards south are the optimum case in the natural ventilation condition when the values of discomfort hours and PMV are compared with the variations of WWR and orientation. The annual discomfort hours in south facing bermed house with 10% WWR is **4.9%** less than the conventional house.

Therefore **the optimum case in natural ventilation condition is - south orientation with 10% WWR**

6.1.4 Case 04- variation in WWR and orientation in bermed house- HVAC

The bermed structures with 10% WWR facing towards north are the optimum case in the HVAC condition when the values of heating load, cooling load, lighting load and overall EPI are compared with the variations of WWR and orientation. The annual energy saving in north facing bermed house with 10% WWR is **47.00 %** more than the conventional house.

Therefore **the optimum case in HVAC condition is - north orientation with 10% WWR.**

6.1.5 Case 05- variation in orientation of north facing window in bermed house- HVAC

The bermed structures with 10% WWR facing towards north having vertical window are optimum case in the HVAC case when the values of heating load, cooling load, lighting load and overall EPI are compared with the variations of window's orientation. The extra annual energy saving in north facing bermed house with 10% WWR having vertical window is **2.7 %** more than the north facing bermed house with 10% WWR having horizontal window.

Therefore **the optimum case in HVAC condition is - vertical window with 10% WWR in HVAC, north facing.**

6.1.6 Case 06- variation in orientation of south facing window in bermed house- natural ventilation

The bermed structures with 10% WWR facing towards south having vertical window are the optimum case in the HVAC case when the values of of heating load, cooling load, lighting load and overall EPI are compared with the variations of window's orientation. The annual discomfort hours in south facing bermed house with 10% WWR having vertical window is extra **1.9%** less than the south facing bermed house with 10% WWR having horizontal window.

Therefore **the optimum case in HVAC condition is - vertical window with 10% WWR in HVAC, south facing.**

6.1.7 Case 06- Comparision with stack effect

The bermed structure with **stack effect** was found to be the optimum case in the natural ventilation when compared the PMV value and discomfort hours.

6.2 Recommendation

- **WWR (all the 4 sides of wall)**

  Using 10% WWR in composite climate will give the best thermal performance for bermed structure in both HVAC and natural ventilation condition.

- **Orientation of exposed facade in HVAC condition**

  Locating the exposed facade in north direction will be the optimum orientation in HVAC condition as it will give maximum annual energy saving than any other orientation.

- **Orientation of exposed facade in natural ventilation condition**

  Locating the exposed facade in south direction will be the optimum orientation in natural ventilation condition as it will give minimum number of annual discomfort hours and near to neutral PMV than any other orientation.

- **Window's orientation**

  Orienting windows vertically will give extra 2.7% of annual energy saving and lesser 1.9% of annual discomfort hours as compared to horizontal orientation of window. Bermed house with vertical orientation of window, instead of horizontal orientation of window will be more thermally comfortable.

- **Optimum composition for bermed structures in composite climate.**
  For adequate amount of natural ventilation, and thermal performance, the most optimum composition for bermed structure that can be used is "vertically oriented windows with 10% WWR, facing towards south direction in natural ventilation case and north in HVAC case and bermed with minimum 0.9 m of earth mass".

- **Stack effect** can be introduced in order to maintain cross ventilation and improvement in thermal comfort can be felt in terms of PMV values.

REFRENCES

1. Amirreza Khaksar, A. T. (2022). Thermal comfort analysis of earth-sheltered buildings. Keai , 34.
2. Bakoosh, H. M. (2020). Comparison of temperature and humidity among traditional underground . International Journal of Advanced and Applied Sciences , 11.
3. Benardos, A. (2013). Modern earth sheltered constructions: A paradigm of green. Tunnelling and Underground Space Technology , 7.
4. Callejas, I. J. (2020). Thermal Performance of Partially Bermed . Mdpi , 13.
5. Earth-Sheltered Houses. (1997). Energy efficiency and renewable energy , 8.
6. Energy saver.(n.d.). Retrieved from energy.gov: https://www.energy.gov/energysaver/
7. Hasan, H. (2012). The Possibility of Applying the Earth-Sheltered Building Type for Housing. Research gate , 9.

HTTPS://IMAGES.APP.GOO.GL/P5OVEQ8TNRKDNPY17. (N.D.). RETRIEVED FROM WWW.GOOGLE.COM

REFRENCES

1. Amirreza Khaksar, A. T. (2022). Thermal comfort analysis of earth-sheltered buildings. Keai , 34.
2. Bakoosh, H. M. (2020). Comparison of temperature and humidity among traditional underground . International Journal of Advanced and Applied Sciences , 11.
3. Benardos, A. (2013). Modern earth sheltered constructions: A paradigm of green. Tunnelling and Underground Space Technology , 7.
4. Callejas, I. J. (2020). Thermal Performance of Partially Bermed . Mdpi , 13.
5. Earth-Sheltered Houses. (1997). Energy efficiency and renewable energy , 8.
6. Energy saver.(n.d.). Retrieved from energy.gov: https://www.energy.gov/energysaver/
7. Hasan, H. (2012). The Possibility of Applying the Earth-Sheltered Building Type for Housing. Research gate , 9.

8. Https://images.app.goo.gl/p5oveq8tnrkdnpy17. (n.d.). Retrieved from www.google.com.
9. Lee, s. W. (1988). The thermal environment in an earth sheltered home in korea. Tunnelling and underground space technology , 8.
10. Lembo, F. P. (2022). Artificiality and Naturalness: Semi-underground Houses and Their Role in the. Journal of Civil Engineering and Architecture , 14.

11. Lembo, F. (2011). Semi-underground house models as new concepts for urban . Elsevier , 10.
12. Milanovic, A. R. (2018). Earth-Sheltered House: A Case Study of Dobraca. MDPI , 15.
13. Mirrezaei, S. A. An Ecological Study on Earth Sheltered Housing in. Institute of Graduate Studies and Research.
14. Nasrollahi, N. (n.d.). Thermal Performance of Earth-Sheltered Residential. Basic Studies and new Technologies of , 11.
15. Nasrollahi, N. (2014). Thermal Performance of Earth-Sheltered Residential. Basic Studies and , 11.
16. Pearlmutter, D. (2011). Monitoring the Thermal Performance of an Insulated Earth-sheltered Structure: A Hot-arid. Architectural Science Review , 9.
17. Rudnik, A. (n.d.). EARTH-SHELTERED HOUSING BUILDINGS IN THE ENERGY EFFICIENT . 14.

Wong, l. S. (n.d.). Old Yaodong House In The Yulin Village/Shaanxi Province/Republic Of China. 10