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POTENTIAL OF EARTH SHELTERED BUILDINGS FOR THERMAL COMFORT.

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ABSTRACT

Earth is the cheapest and as well as commonly available material with enormous potential within it.
The studies have been conducted for working out the energy usage of earth-sheltered building as compare to conventional above-ground building for thermal comfort with the help of energy simulation tools.
Simulations will be focused on the influence of soil cover and the thermal insulation of building covering thickness and will be done for hot and dry climatic region. These models have been translated into computer software for excellence and efficiency in building design.
During summer due to the because of more thermal inertia of soil adjoining earth sheltered building heat losses to the ground are more which helps to cool down the air temperature naturally in a building.
The paper attempts to generate the comparative study of the earth sheltered buildings and conventional above ground buildings with the help of energy simulation softwares and select an appropriate one for simulating the various building design options for an ongoing research, "Design of Earth Sheltered Buildings".

Keywords: Earth, above ground buildings, Energy conservation, Building envelope, Thermal Comfort.

1. INTRODUCTION

In current years, the theory of sustainability has involved increasing attention within building science, for energetic, ecologic and cost-effective reasons. The declining fuel reserves demand a minimized consumption of energy and maximized application of renewable energy sources. A potential way to fulfill the requirements for habitation is the concept of earth-sheltered buildings, such buildings can be covered with earth on one or more sides or can be constructed partially or completely below the ground. The large thermal mass of the soil envelopes causes the temperature in the surrounding soil to be lower than the outdoor air temperature during summer.

This way, the temperature differences between the internal and external areas are reduced, which means that the heat conduction is lower compared to conventional above-ground buildings. The application of soil cover thus potentially cuts the required cooling loads. The research will undertake the analysis of the effect of soil cover thickness, thermal mass thickness, open area of exposed elevations and type of soil on cooling loads of earth sheltered buildings. The results will be then compared to the respective above ground buildings. Building energy simulations will be done for Jaipur climate conditions. [1], [2]

2. BUILDINGS & PROJECT DESCRIPTION

To be analyzed buildings are one-story residential houses and are nine in numbers. Buildings have a floor area of approximately 6764 sq. ft. per block. Building blocks height is 4.0 meter. Because of high soil pressures, buildings have a concrete construction with walls and a thickness of up to 30 cm and slab on the ground of 15 cm. The exposed glazing area will be around 13% for above ground buildings. Detailed material specifications will be presented in final report. Simulations of energy performance will be done for multiple thermal insulation thicknesses.

2.1 Soil

Simulations of energy performance of earth-sheltered buildings will be done for several soil thickness covers. The detail on same will be presented in final report.

2.2 Climate

Energy simulations will be done for Jaipur climatic conditions.

2.3 Interior conditions

The cooling systems are turned on when the internal air temperature rises above the maximum temperature of the comfort range. For summers the minimum and maximum air temperatures (i.e. the comfort limit) are 20 °C and 24 °C respectively. The maximum humidity in the comfort range is 60 RH.

3. NUMERICAL MODEL & SOFTWARE DESCRIPTION

As most building energy simulation models do not allow to incorporate soil cover accurately, an integrated strategy will be used to calculate soil heat transfer and building energy consumption will be calculated with eQUEST software. First the temperature of a building's envelope will be calculated, and then the results will be exported to eQUEST, where the building energy consumption will be calculated. All simulations will be performed for 8760 operating hours.

e-Quest is building energy analysis software designed and developed by DOE2 (Copyright James J. Hirsch). e-QUEST uses the DOE 2.1 Building energy simulation engine. It has the ability to explicitly model all of the following:

- 8,760 hours per year
- Hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat set-points, and HVAC system operation, defined separately for each day of the week and holidays
- Thermal mass effects
- Part-load performance curves for mechanical Equipment
- Capacity and efficiency correction curves for mechanical heating and cooling equipment.

Study will be conducted by using eQUEST – For energy simulation and ECO tect – For Day lighting and thermal comfort.

eQUEST is a refined and easy to use building energy simulation software that provides high quality results by combining a building formation wizard, an energy effectiveness measure wizard and a graphical results display module.

eQUEST was designed to perform thorough analysis of today's high-tech building design technologies using today's most sophisticated building energy use simulation techniques.

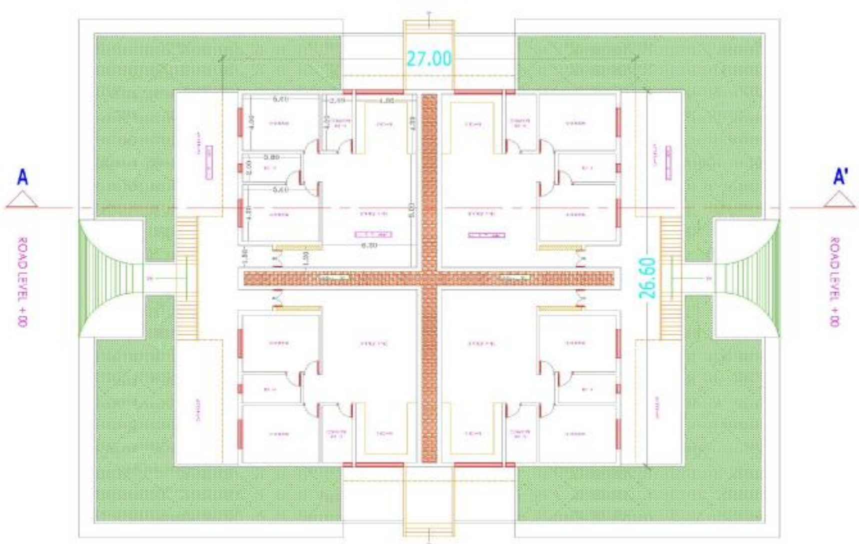
ECOTECT is conceptual design analysis simulation software that features overshadowing, shade design, lighting, sound and wind speed analysis functions.

Its simulation and analysis capabilities can handle geometry of any size and complexity. It uses CIBSE (Chartered Institution of Building Services Engineers) Admittance Method to calculate heat and cool loads for any amount of zones within a model.

It can display hourly internal temperatures and load breakdowns and also annual temperature distributions and the effects of thermal mass.
[3], [4], [5]

4. ANALYSIS PROGRESS

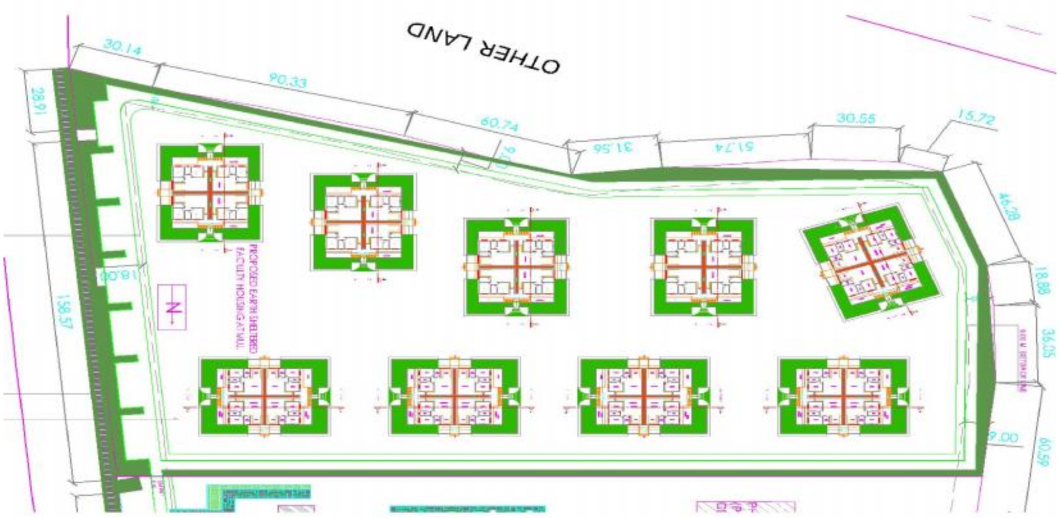
The impact of soil dampness exchange on building heat misfortune by means of the ground is researched by contrasting completely coupled recreations and straight warm reenactments. The watched impacts of coupling are (1) the bigger plentifulness of surface temperature, (2) the variety of warm conductivity with dampness substance, and (3) the shift in weather conditions of sensible warmth by fluid exchange. In a parameter study, it is demonstrated that these decisions hold for an assortment of atmospheres, soils and establishment developments. Notwithstanding, given the present precision level of standard strategies, the joining of coupling impacts in these count strategies can't be guarded. [6], [7]
Per the methodology described above, soil parameters are under analysis to get the required parameters. Detail on the same will be provided in next progress report. As the first step, zoning was done as per the architectural plans. The interior layout has been modelled as per below zoning pattern.



All blocks have been places in the same manner as designed and located in the site plan. The blocks are identical to each other. Only orientation is different for each blocks.

4.1 Base Case (Conventional - On Ground Building):

The base case was modelled on the ground keeping all façade exposed to the surrounding. For 3D energy simulation model for the building has been developed in eQUEST to calculate the energy performance of the building. Figure provided below shows the 3D structure developed in eQUEST. It accurately resembles the actual building.



Input Parameters:

Table 1 Conventional Building Input Parameters

Building Parameters	Base Case Values
Wall U Value (btu/h sqft °F)	0.096
Roof U Value (btu/h sqft °F)	0.048
WWR	13%
Clear Glass SHGC	0.8
Clear Glass U Value (W/sqmK)	6.0
LPD (W/sqft)	0.5
Equipment Load (W/sqft)	0.3
HVAC System	Packaged Singe Zone
Fan Control	Constant Flow
HVAC System Cooling Efficiency	10.25 EER
Ventilation	30 cfm/person

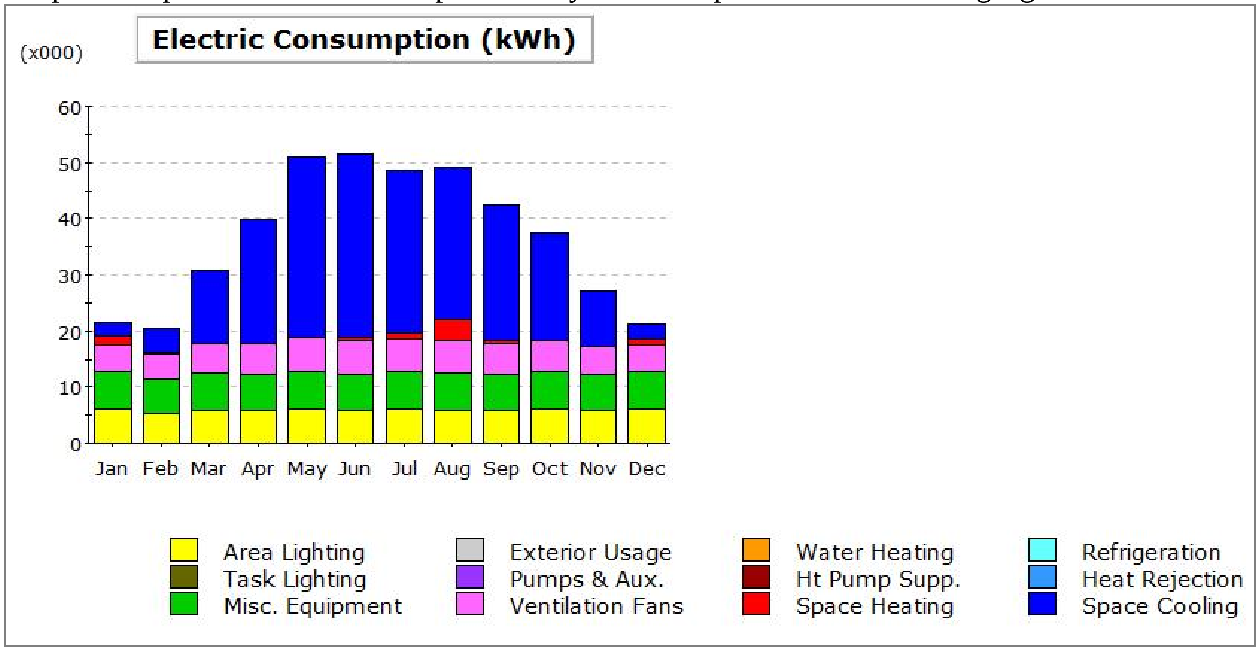
Preliminary Results

The table below shows the preliminary results of the energy simulation of all building blocks. These results provide the trend of the energy consumption of the building as per the input mentioned in the table. The final results may be defer and depend upon the input parameters and analysis work.

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	2.24	4.31	12.95	22.00	31.97	32.65	28.84	26.92	24.21	19.15	9.69	2.62	217.53
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	1.70	0.33	-	-	-	0.61	1.09	3.72	0.40	0.00	-	1.21	9.07
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	4.83	4.49	5.37	5.72	6.26	6.05	6.00	5.79	5.71	5.73	5.11	4.80	65.88
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	6.66	6.01	6.64	6.43	6.65	6.43	6.65	6.65	6.43	6.66	6.44	6.65	78.31
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	6.06	5.40	5.90	5.73	6.01	5.73	5.99	5.94	5.76	6.02	5.80	5.98	70.33
Total	21.48	20.55	30.86	39.89	50.90	51.47	48.57	49.02	42.52	37.55	27.04	21.26	441.11

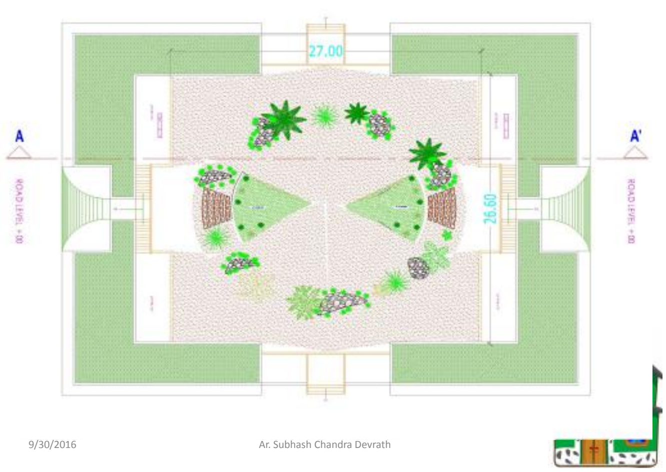
Graphical representation of these preliminary results is provided in following figure.



Considering the input parameters as mentioned in the table 1. The above results shows the annual energy consumption of above ground (conventional) building. The simulated result shows the annual energy consumption 441,110 kWh. The intent behind this research is analyzing the performance of earth sheltered buildings and comparing the same with conventional above grade building (as performed above). More than 95% of the annual hours comes under comfort range. The estimated tonnage required for the building comes up to be around 98 TR.

4.2 PROPOSED CASE 1 (EARTH SHELTERED – AIR CONDITIONED)

The proposed case was modelled under the ground keeping all façade covered with soil. For 3D energy simulation model for the building has been developed in eQUEST to calculate the energy performance of the building. Figure provided below shows the 3D structure developed in eQUEST. It accurately resembles the actual building.



Input Parameters

Table 2 Proposed Case 1 Input Parameters

Building Parameters	Proposed Case 1 Values
UG Wall U Value (btu/h sqft °F)	0.149
Roof U Value (btu/h sqft °F)	0.048
WWR	NA
Clear Glass SHGC	0.8
Clear Glass U Value (W/sqmK)	6.0
LPD (W/sqft)	0.5
Equipment Load (W/sqft)	0.3
HVAC System	Packaged Singe Zone
Fan Control	Constant Flow
HVAC System Cooling Efficiency	10.25 EER
Ventilation	30 cfm/person

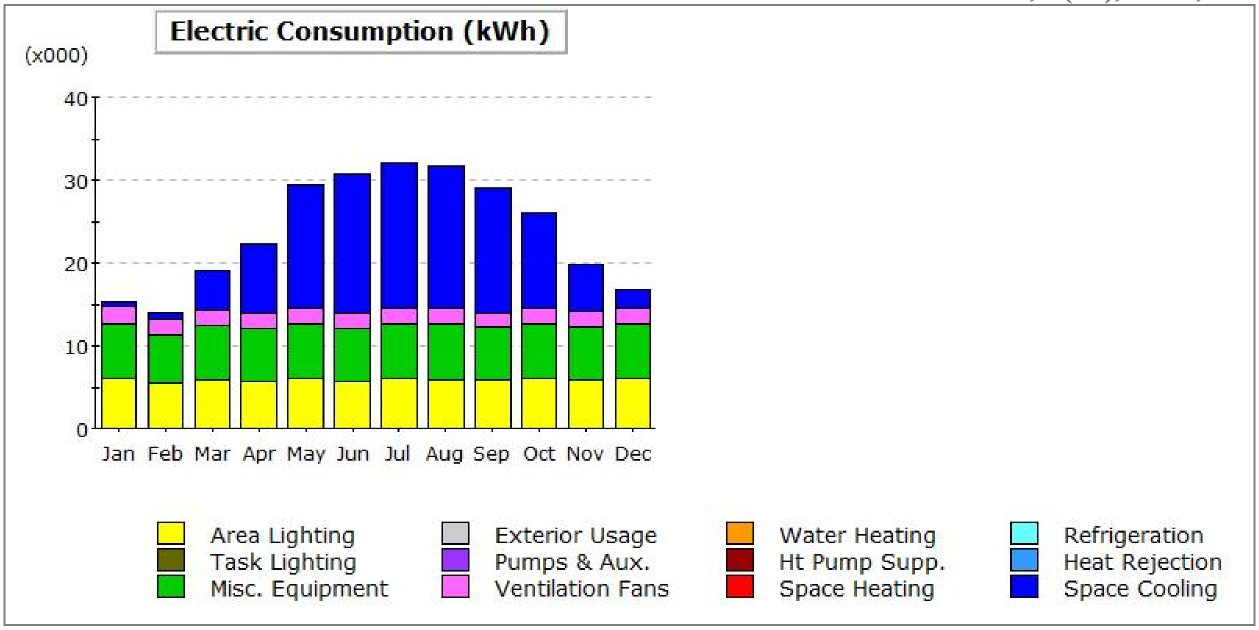
Preliminary Results

The table below shows the preliminary results of the energy simulation of all building blocks. These results provide the trend of the energy consumption of the building as per the input mentioned in the table. The final results may be defer and depend upon the input parameters and analysis work.

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.54	0.81	4.61	8.34	14.84	16.86	17.47	17.27	15.08	11.42	5.70	2.23	115.15
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.05	-	-	-	-	0.01	0.01	0.03	-	-	-	-	0.10
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.93	1.72	1.89	1.83	1.92	1.83	1.91	1.90	1.84	1.92	1.85	1.91	22.45
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	6.66	6.01	6.64	6.43	6.65	6.43	6.65	6.65	6.43	6.66	6.44	6.65	78.31
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	6.06	5.40	5.90	5.73	6.01	5.73	5.99	5.94	5.76	6.02	5.80	5.98	70.33
Total	15.24	13.94	19.05	22.33	29.43	30.85	32.02	31.79	29.11	26.02	19.79	16.77	286.34

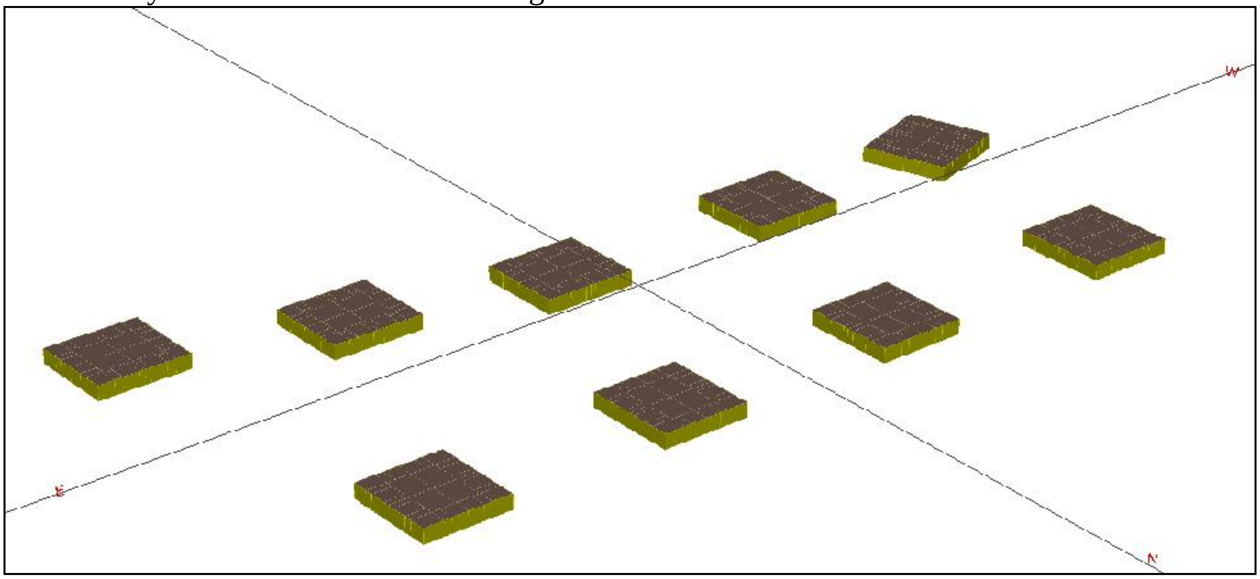
Graphical representation of these preliminary results is provided in following figure.



Considering the input parameters as mentioned in the table 2. The above results shows the annual energy consumption of underground (earth sheltered) building. The simulated results shows the annual energy consumption 286,340 kWh. There is no direct heat gains through envelope in this case. Hence the consumption is less than the base case. Considering the annual consumption, this proposed model gives 30% energy savings (if compared to the conventional building base case). The estimated tonnage required for building is around 54 TR, which is far less than base case. The comfort hours are also more than 99% in this case.

4.3 Proposed Case 2 (Earth Sheltered – Non Air-Conditioned)

The proposed case was modelled under the ground keeping all façade covered with soil. For 3D energy simulation model for the building has been developed in eQUEST to calculate the energy performance of the building. Figure provided below shows the 3D structure developed in eQUEST. It accurately resembles the actual building.



Input Parameters

Table 3 Proposed Case 2 Input Parameters

Building Parameters	Proposed Case 2 Values
UG Wall U Value (btu/h sqft °F)	0.149
Roof U Value (btu/h sqft °F)	0.048
WWR	NA
Clear Glass SHGC	0.8
Clear Glass U Value (W/sqmK)	6.0
LPD (W/sqft)	0.5
Equipment Load (W/sqft)	0.3
HVAC System	Evaporative Cooler with no Direct Cooling
Fan Control	Constant Flow
HVAC System Cooling Efficiency	NA
Ventilation	30 cfm/person

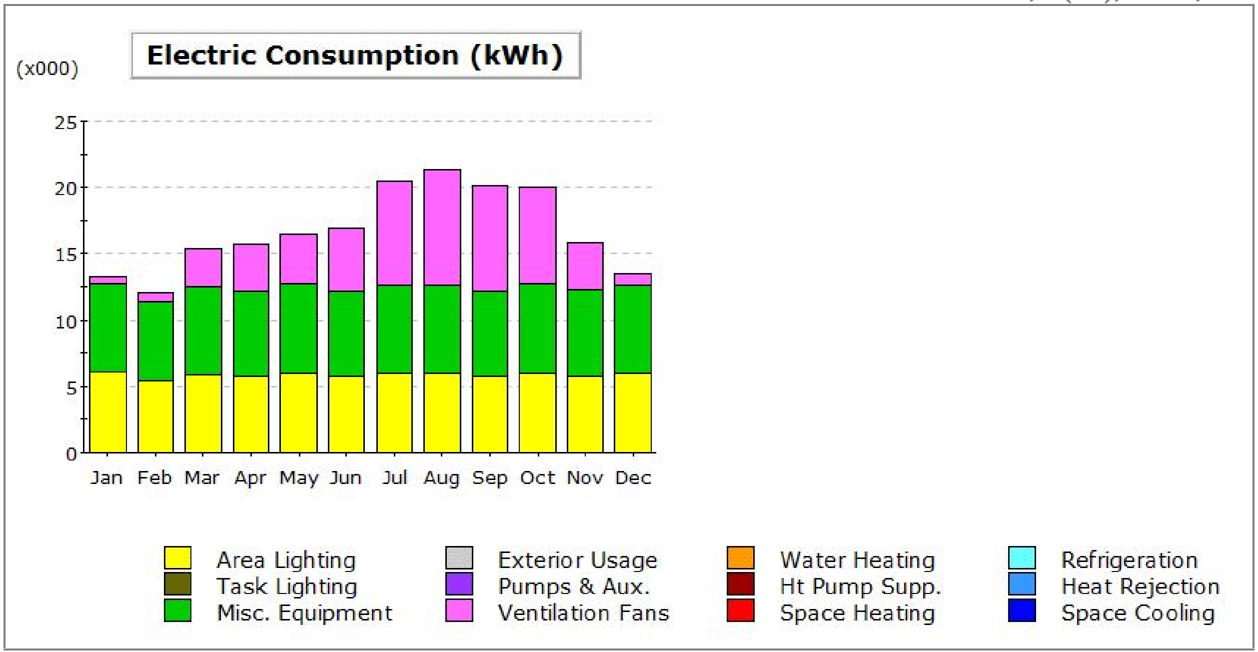
Preliminary Results

The table below shows the preliminary results of the energy simulation of all building blocks. These results provide the trend of the energy consumption of the building as per the input mentioned in the table. The final results may be defer and depend upon the input parameters and analysis work.

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.52	0.64	2.85	3.52	3.80	4.74	7.78	8.71	7.97	7.35	3.60	0.88	52.36
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	6.66	6.01	6.64	6.43	6.65	6.43	6.65	6.65	6.43	6.66	6.44	6.65	78.31
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	6.06	5.40	5.90	5.73	6.01	5.73	5.99	5.94	5.76	6.02	5.80	5.98	70.33
Total	13.24	12.05	15.40	15.68	16.47	16.89	20.42	21.30	20.16	20.02	15.85	13.52	200.99

Graphical representation of these preliminary results is provided in following figure.



Considering the input parameters as mentioned in the table 2. The above results shows the annual energy consumption of underground (earth sheltered) building with no active cooling system. The simulated results shows the annual energy consumption 200,900 kWh. There is no direct heat gains through envelope in this case. Hence the consumption is less than the base case. In this case only fans operate to meet the comfort range, but operating only fans cannot meet the purpose/comfort range inside the building. The unmet hours in this case are more than 3300, which confirms that operating only fans are not sufficient to meet all the 8760 hours, but active cooling systems are required to meet the comfort range.

5. RESULTS AND DISCUSSIONS

The paper explores the potential presents within the earth by comparing the earth sheltered building with conventional above ground building.The study gives an opportunity to designer to learn the performance of building envelope and thereby improve the thermal comfort.
Earth sheltered buildings have great advantages over conventional above ground buildings as following.

- An earth-sheltered building is less susceptible to the impact of tremendous outdoor air temperatures,
- Long life expectancy due protection from external factors.
- Low maintenance.
- Fire resistance.
- Increased comfort because of minimal temperature swings.
- Temperatures inside the building are more stable than in conventional building, and with less temperature unevenness, interior rooms seem more comfortable.
- Recycled materials may be used in their construction without problem.
- Because earth covers part or their entire exterior, earth-sheltered buildings require a lesser amount of outside maintenance, such as painting and elevation treatments.
- Constructing a building that is dug into the earth or enclosed by earth builds in some natural soundproofing.

- Earth sheltered building “blends” the landscape more harmoniously than a conventional building and as a result provide more space for landscaping.
- It provides natural safety and security to the building.
- Space above the earth sheltered buildings remains available as open space.

There are also challenges to earth sheltered building design such as day lighting and ventilation, etc,.which may be overcome by innovative layout planning and design.

The above case studies demosnstrate the enormous potential of Earth Sheltering for thermal environmental control of the building. However the quantification has not been done to provide solid design guidelines for Earth Sheltering buildings. [8], [9], [10].

6. CONCLUSIONS

As expected, the simulation results will indicate that earth-sheltered buildings outperform above ground buildings with respect to annual cooling energy consumption. Results also shows that earth is proved a very important material with thermal mass. As per initial runs, three models were performed to compare with each other. The proposed model 1 (earth sheltered with Air Conditioned) fits the requirement with better energy savings as compared to the conventional buildings.

7. Conflict of interest: None

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