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Day Light Analysis 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 the earth-sheltered building as compare to a conventional above-ground building for thermal comfort with the help of energy simulation tools. The effect of soil cover and the thermal insulation of building envelop thickness, for the hot and dry climatic region will primarily be simulated. These models have been translated into computer software for excellence and efficiency in building design. During summer because of the more thermal inertia of soil, adjoining earth-sheltered building heat dissipation to the earth is much more which helps the air temperature to cool down naturally inside a building. The paper attempts to analyze the day lighting inside the building at different levels due to the presence of the windows on the wall. Demonstrate the lighting levels in the living spaces through computer simulations. The simulation is to be carried out at a particular sky condition on September 21 at 12. Also to do the analyze of glare in the case if the daylight is more than the required.

Keywords: Building Envelope, Day Light, Earth, Energy conservation, Thermal Comfort.

****The paper is an outcome of the ongoing doctoral study being pursued by the author at the Center of Excellence, Faculty of Design, Manipal University Jaipur, Jaipur, Rajasthan, India.***

I. INTRODUCTION

In recent years, the concept of sustainability has drawn in escalating attention within building science, for ecologic, active, and cost-effective reasons. The dilapidated fuel reserves stipulated a minimized use of energy and maximized the relevance of sources of renewable energy.

An appropriate and potential way to accomplish the requirements for habitat 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 huge thermal mass of the soil covering cause the high temperature in the adjacent soil to be lower than the outdoor air temperature for the summer.

Like this, the temperature variations between the external and internal areas are reduced, which shows that the heat transmission is lower compared to traditional above-ground buildings. Therefore the application of soil envelopes thus potentially reduces the cooling load's requirements.

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The research will undertake the analysis of the effect of thermal mass thickness, soil envelopes thickness, openings of the exposed elevations and the soil type, on the cooling load's of earth-sheltered buildings. Energy simulations will be conducted for the buildings located in the climatic conditions of Jaipur. [1], [2].

II. BUILDINGS & PROJECT DESCRIPTION

The case study model of earth sheltered building is nine storey's below the ground floor level. The project is proposed in Jaipur at Manipal University Jaipur campus and this report contains the result of day lighting analysis of the living areas in the staff residence or faculty housing. This analysis will help us to understand how the project floor plate and interior layouts are designed with respect to daylight. To enhance the daylight in the inner spaces, provision of ventilation shaft has been provided.

The project is in Jaipur, and this report contains the result of day lighting analysis of the living areas in the staff residence or faculty housing. This analysis will help us to understand how the project floor plate and interior layouts are designed with respect to daylight. To enhance the daylight in the inner spaces, solar chimney provision has been provided.

All calculations are based on the interior layout drawings provided.

A. Soil

Daylight performance simulations of earth-sheltered buildings will be done for numerous soil covering thickness. The detail on the same will be presented in the final report.

B. Climate

Daylight simulations will be done i.e., for Jaipur climatic conditions.

C. Interior Conditions

Assuming that when the inside air temperature rises more than the maximum temperature limit of the comfort range, the cooling systems are turned on. 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.

III. NUMERICAL MODEL & SOFTWARE DESCRIPTION:

Ecotect, an Autodesk product has been used to simulate the living spaces to check the illuminance falling on the workplace in the living spaces.

Ecotect from Autodesk is an environmental investigation tool to simulate building performances, which permits and helps designers from the earliest stages of conceptual design. It presents analysis functions along with an interactive display which directly presents investigative results in the building model context. It **gives** real-time results of the illuminance inside the building due to day lighting. ECO tect – For Day lighting and thermal comfort.

Simulation software, ECOTECT is conceptual design investigation software that features shadow design, over shading, illumination, and echo and wind speed analysis functions.The simulation and investigation property of the software is capable of handling the geometry of any size and complication. 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.

Inner temperatures and load breakdowns can be displayed on an hourly basis, along with the effects of thermal masses and annual temperature distributions done. [3], [4], [5]

IV. ANALYSIS PROGRESS

Step 1: The zoning was done as per the plan provided below, and the model was built in the software.

Step 2: Windows with 1600 mm height were inserted. The location and length were considered as per the provided plan.

Step 3: Orientation was set.

Step 4: Weather file was introduced in the software.

Step 5: Glass property of Single Glazed Clear Glass was entered.

Step 6: Wall/Ceiling/Slab reflectivity was assigned.

Step 7: Performed Simulation for the lowest habitat floor and analyzed the results with the help of Solar Path and Shading Pattern. The living spaces (Regular Occupied Spaces) were considered for the analysis purpose.

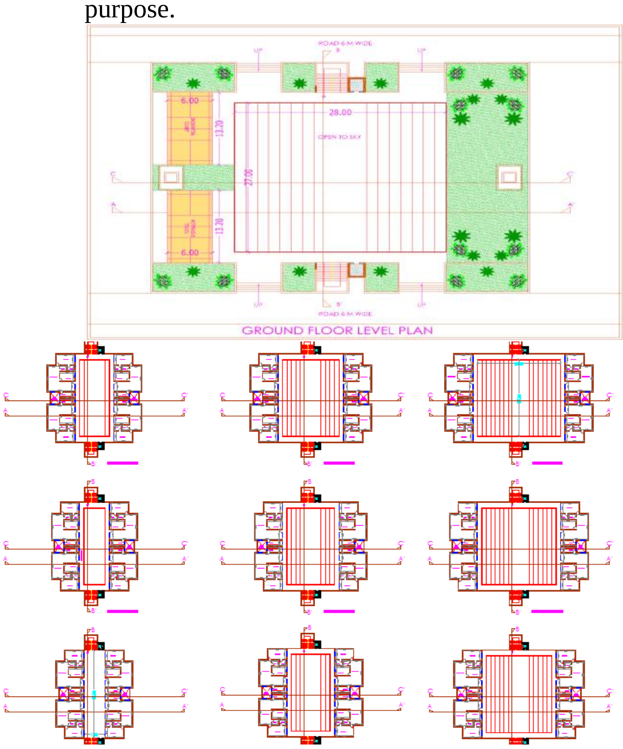


Fig. 1: All level Plans

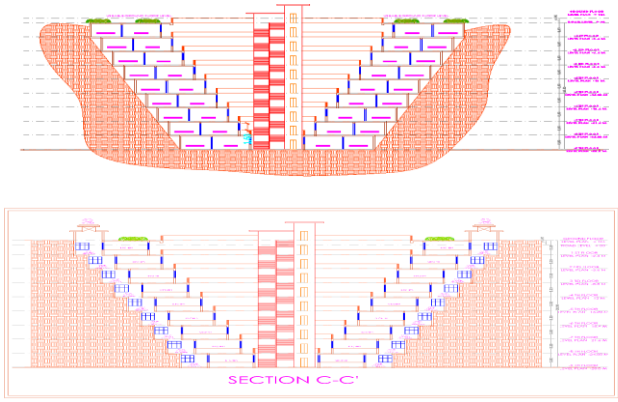
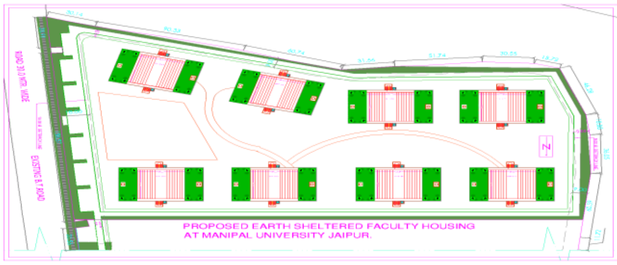


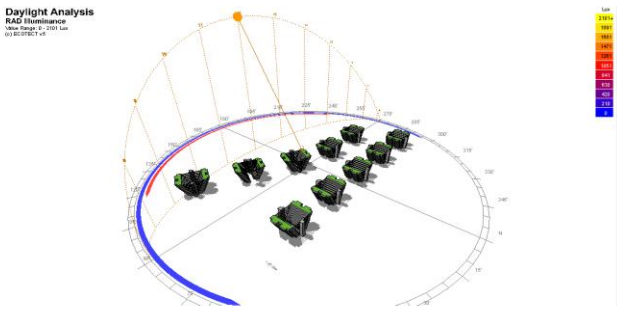
Fig. 2- Elevations

Site Layout with North:

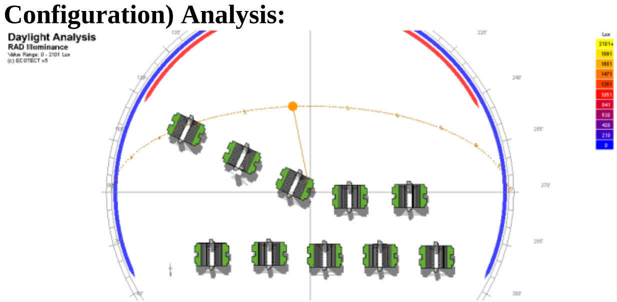
Note: Please refer the below image to understand the configuration of the blocks only. For the floor plan or floor plate layout, please refer to Image 1:



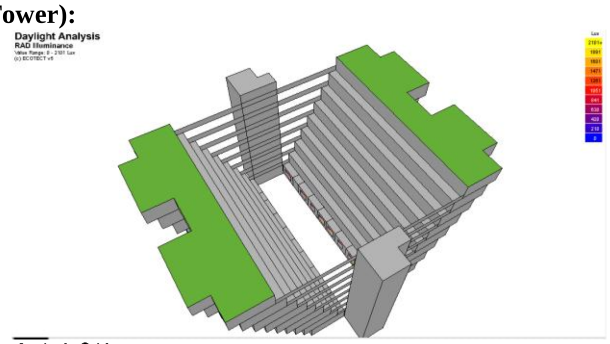
Site Layout in 3D:

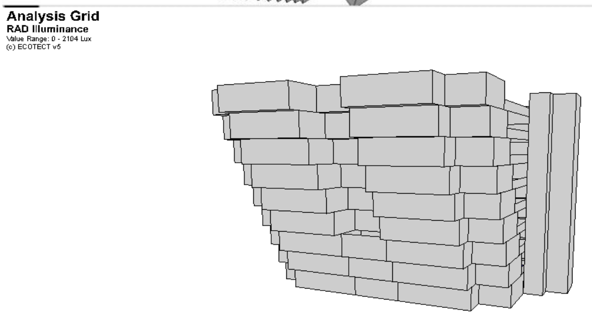


Earth Sheltered Housing Complex (Stepped Configuration) Analysis:



Earth Sheltered Housing Complex Analysis (Single Tower):



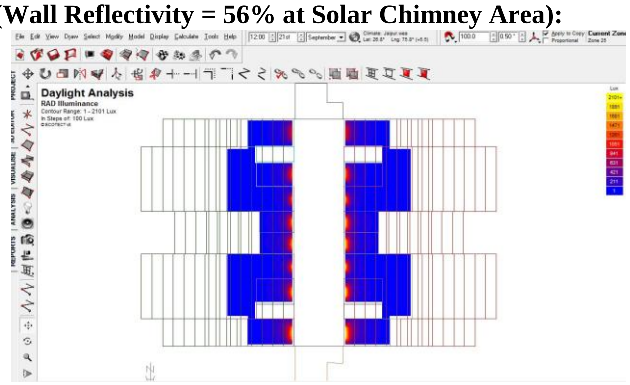


V. RESULTS AND DISCUSSIONS

S.No.	Input Parameters	Values
1	Orientation	As per Plan
2	No. of Floors	S + 9 F (Earth Sheltered)
3	Weather File	Jaipur.wea
4	Timing for Simulation	On 21st September at 12 pm
5	Simulation Tool	Ecotect with Radiance
6	Glass Properties	Clear Glass without shading effect SHGC (Solar Factor) – 0.9 VLT (Visible Light Transmittance)– 0.74
7	Wall Reflectivity (Inner Surface)	56% and 80%
8	Ceiling Reflectivity (Inner Surface)	70%
9	Slab Reflectivity (Inner Surface)	59%

The simulation was carried for the lowest habitable floor. The output report showing the lux levels were also analyzed. Generated contour wise lux level report has also been provided below for detailed results.

Earth Sheltered Housing Complex - Illuminance Pattern (Wall Reflectivity = 56% at Solar Chimney Area):



Average Lux Level: 188.4 Lux

Earth Sheltered Housing Complex - Daylight Levels (Wall Reflectivity = 56% at Solar Chimney Area):

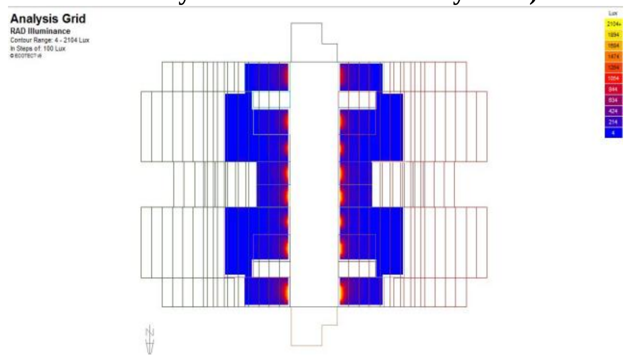
SC

Contour Band (from-to)	Within Pts	Within (%)	Above Pts	Above (%)
0-100	1994	55.89	3568	100.00
100-200	814	22.81	1574	44.11
200-300	298	8.35	760	21.30
300-400	132	3.70	462	12.95
400-500	81	2.27	330	9.25
500-600	50	1.40	249	6.98
600-700	33	0.92	199	5.58
700-800	26	0.73	166	4.65
800-900	20	0.56	140	3.92
900-1000	19	0.53	120	3.36
1000-1100	24	0.67	101	2.83
1100-1200	14	0.39	77	2.16
1200-1300	11	0.31	63	1.77
1300-1400	10	0.28	52	1.46
1400-1500	5	0.14	42	1.18
1500-1600	8	0.22	37	1.04
1600-1700	8	0.22	29	0.81
1700-1800	8	0.22	21	0.59
1800-1900	8	0.22	13	0.36
1900-2000	2	0.06	5	0.14
2000-2100	3	0.08	3	0.08

end of report

Around 44 % area is qualifying for 100 lux and more.

Earth Sheltered Housing Complex - Luminance Pattern (Wall Reflectivity=80% at Solar Chimney Area):



Average Lux Level: 227.1 Lux

Earth Sheltered Housing Complex - Daylight Levels (Wall Reflectivity=80% at Solar Chimney Area):

RAD Illuminance

Contour Band (from-to)	Within Pts	Within (%)	Above Pts	Above (%)
0-100	1549	43.41	3568	100.00
100-200	1046	29.32	2019	56.59
200-300	442	12.39	973	27.27
300-400	176	4.93	531	14.88
400-500	90	2.52	355	9.95
500-600	51	1.43	265	7.43
600-700	38	1.07	214	6.00
700-800	28	0.78	176	4.93
800-900	24	0.67	148	4.15
900-1000	16	0.45	124	3.48
1000-1100	28	0.78	108	3.03
1100-1200	13	0.36	80	2.24
1200-1300	13	0.36	67	1.88
1300-1400	9	0.25	54	1.51
1400-1500	8	0.22	45	1.26
1500-1600	7	0.20	37	1.04
1600-1700	8	0.22	30	0.84
1700-1800	7	0.20	22	0.62
1800-1900	10	0.28	15	0.42
1900-2000	2	0.06	5	0.14
2000-2100	3	0.08	3	0.08

Around 56 % area is qualifying for 100 lux and more

VI. CONCLUSIONS

Under this research work the daylight reach for the earth-sheltered houses has been analyzed at a particular depth. As expected, the simulation results indicate that earth-sheltered buildings outperform and the achieved lux levels with adequate levels as compared to the local standards and green building standards for residential space type.

By following the below mentioned parameters are necessary for designing a good Earth Sheltered Building.

1. Increase the reflectivity of the inner surfaces (wall/ceiling/slab) of the housing units. More the bright colors, more the reflectivity it would be. Reflectivity value 0 depicts absolute dark, and 1 depicts absolute white color.
2. Increase the reflectivity of the exterior wall at the courtyard area to allow adequate reflection of light which can travel maximum to the bottom floor. Note-Very high reflection should be avoided.

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3. The brighter the wall color would be in this shaft of solar chimney area, more the daylight shall pass through it and shall reach the bottom floor area.
4. Glass selected for simulation was single glazed – clear glass. Hence reflected coatings or double glazed units may decrease the lux levels inside the housing units, which is not recommended. Overhangs may be introduced if the heat gain is high through the fenestration.

ACKNOWLEDGMENT

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