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HARMONIZING SUSTAINABLE PRACTICES: CLIMATE-RESPONSIVE DESIGN IN UNIVERSITY LIBRARIES

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Abstract
Consequently, this paper responds to the growing environmental issues and energy disasters by noting that human conduct needs to be adjusted to sustainable practices. With a particular interest in the Junaid Zaidi Library in the COMSATS University Islamabad (CUI), the study examines how climate-responsive design can be used to improve the level of indoor comfort and raise awareness about sustainability in educational institutions. The current conditions of the library, performance gaps, and the design strategies that can be offered to the library, such as the best orientation, passive heating and cooling methods, and the use of sustainable materials, are evaluated by studying the library with the help of observational methods, qualitative surveys, and analysis of environmental data. The results would be used to create energy-efficient, user-friendly academic spaces with minimal adverse effects on the environment. The study was carried out within a period of four months, but there might have been limitations to the study, such as the time factor and seasonal factor. However, the study offers useful design information to architects and planners to help in a wider perspective of sustainable building practices within the scope of university libraries within the twin cities of Pakistan.

INTRODUCTION

The growing pace of environmental problems and the constant energy crises observed in the global arena led to an acute necessity for a paradigm shift in human contact with the environment (Bhatti & Ghufran, 2020). With the stress on sustainable development, which the World Conservation Strategy (Nguyen, 2013) underlines, it is important to focus on social and environmental concerns, as opposed to economic progress. Sustainability has therefore become a common worldwide purpose to have a habitable planet for future generations by working multidisciplinary (Hariram et al., 2023). In such a setting, architecture contributes significantly to solving ecological problems through incorporating climate-based design principles that ensure maximum resource and energy consumption and comfort of occupants (Hafez et al., 2023). Although awareness has increased, the lack of globally acknowledged sustainability measures in architectural design has been causing a lack of contact between buildings and their natural surroundings.

This disconnect prevents society from understanding the principles of sustainable design and hinders the change in behavior to energy-conscious living. Thus, it is essential to increase the level of attention to indoor environmental performance and promote sustainable design (Bhatti et al., 2024). This gap in knowledge is addressed by the current paper, and the research evaluates the performance of collective educational spaces on the basis of the environmental performance and proposes the solutions to the climate resiliency-based design interventions to minimize energy consumption and improve comfort of users (Hasan and Panda, 2023). The concept of responsive architecture is an emerging technique that integrates technology and structural flexibility to react to the environmental conditions and user requirements (Mfonet al., 2024). The most important aspects of this strategy are daylight, ventilation, and greenery, which do not only boost the quality of indoor environmental (IEQ), but also the physical and psychological health of users (Bhatti and Iftakhar, 2023). It has been found that sustainable buildings that are moderately concerned with environmental conservation and comfort of occupants can boost productivity, health, and overall satisfaction (Kim & Kim, 2020).

A number of studies have explored the subject of climate-responsive architecture as a mechanism of harmonizing the buildings with the climatic conditions of the area. It is discovered that passive solar design may guarantee maximum energy use through maximum winter sun and minimum summer sun (Hauruna, Wakawa, & Isa, 2017). On the same note, bioclimatic building envelopes, variable shading systems, and dynamic insulation are amongst the factors that enhance year-long better thermal performance (Mukhtar et al., 2024). Green walls and green roofs also aid in further insulation of a building, heat gain, and alleviation of urban heat islands (Lin & Zhang, 2024). Natural ventilation systems have also been identified as an important measure in supporting the indoor air quality, as well as the lack of mechanical cooling dependence (Rashid et al., 2025). In addition to such architectural solutions, urban design that is microclimate-sensitive and the use of renewable energy technologies enhance the environmental performance of constructed environments (Pagori, 2022).

The present study takes Junaid Zaidi Library (JZL) at COMSATS University Islamabad (CUI) as a case study to evaluate how the principle of climate responsiveness design can contribute to the comfort of the indoor environment. Even though the library was initially built with sustainability in mind (cavity walls, solar panels, and efficient HVAC systems), the observation made by the users has found that the library has a few environmental shortcomings. These are under-ventilating the buildings, irregular temperature maintenance, lack of daylight, and excessive dependence on artificial illumination. These restrictions are hurting the comfort, concentration, and productivity of the library users, and design re-evaluation and optimization are necessary. Architectural models that are responsive to the climate play a crucial role in reducing the effects of global warming and creating awareness of sustainability in institutions. As a center of hub for sharing knowledge and admiration, libraries should set sustainability design examples with focus on environmental performance. This aims at determining the user perceptions and satisfaction with the indoor environment of the library by measuring the current state of the indoor environment of the JZL.

Moreover, the suggested study has also presented design strategies that adopt passive climatic responsiveness as a provision of comfort within the indoor environment and a reduction in the use of active energy supply regimes. Lastly, the paper will also aim at creating a model framework of climate-responsive design in higher education to demonstrate how sustainable building uses can result in comfort, energy saving, and environmental consciousness. The information learned in the JZL case study will be combined with the general discourse on sustainable educational architecture and may be applied in the future to the designing of buildings and the formulation of policies that would aid in bringing the future sustainable.

1. Materials and Methods:

The qualitative, mixed-methods approach is utilized, combining primary and secondary sources of data. Primary data will consist of field environmental measurements, user survey and librarian, faculty and student interviews. The target population was the faculty members, students, staff and the visitors who frequented the JZL regularly. Since the accessibility was limited, 100 participants have been chosen as the sample population to reflect the wide range of users. Random and stratified random sampling were used to sample the population in order to represent all of the categories of users (about 80% students, 15% faculty, and 5% administrative or miscellaneous staff). The data were measured at different times and at different days of the week with a time interval of two hours.

Structured questionnaires, interviews, and on-site observations were used to record the perceptions of the users of the comfort parameters namely temperature, humidity, lighting, ventilation, and acoustics. The relative humidity and temperature of interiors were measured with the help of hygrometers and light intensity meters, the amount of natural and artificial lighting was measured, the context was supported with the help of observation and photo records. Climate Data Analysis was done by the use of analytical tools, such as Geographic Information System (GIS) and Computer Fluid Dynamics (CFD) simulations. Collected data were compared to the international standards to determine the comfort parameters in the form of the temperature change, humidity, solar radiation, wind structure and availability of daylights. Solar radiation analysis, azimuth and altitude angle mapping and classification of climatic zone were informed by geospatial information of Google Earth and Pakistan Meteorological Department (MET).

The study suggests the design interventions based on these findings; that is, the design interventions should focus on building orientation, passive cooling and heating, optimization of shading, and natural ventilation techniques. Coding, tabulation, and analysis of data were conducted in a systematically organized manner through descriptive statistics and the comparative analysis methods. Environmental measurements patterns were compared to interview insights in order to determine areas that needed to be changed to reduce design inefficiencies.

2. Results:

3.1 Climatic Data Analysis:

The physical data retrieved by physical measurements at the study site, the weather data retrieved by local weather stations and satellite images were compared to different guidelines on psychometric chart and National International standard of study comfort levels.

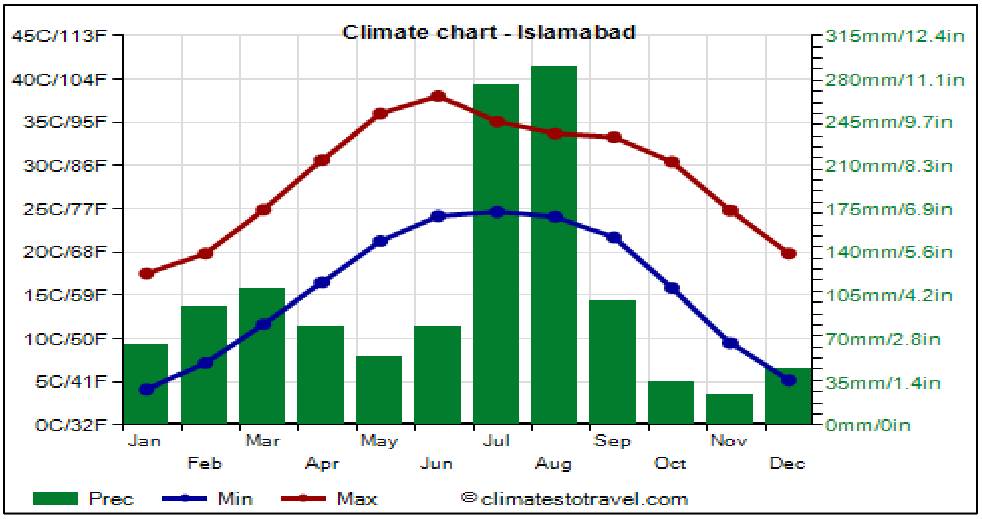

Figure 1 Temperature and Humidity of Islamabad (PMD, 2024)

This paper in relation to climatically responsive design explores JZL through an analysis of the solar data, Azimuth and Altitude at different times of the year concerning the specific site. With the climate-related software, one is able to collect data over the year hence making it simple to interpret and provide recommendations on the design strategies based on the climate conditions. Similarly, such software was used to analyse JZL.

3.2 Field Data Analysis:

The JZL features a semicircular plan, with the convex façade-oriented north and the concave side facing south (Figure 2). This configuration influences solar exposure and internal lighting patterns. While the north-facing facade benefits from diffused natural light, the south-facing courtyard experiences minimal ventilation due to limited openings and closed windows, leading to stagnant air circulation. The library's solid volumetric form demonstrates a low surface-to-volume ratio, reducing heat loss and improving thermal efficiency (Figure 3).

Figure 2: Junaid Zaidi Library Location (Right) and roof plan (Left) (Google Earth, 2024)

JZL, located at CUI, Islamabad, shares the same climatic conditions as all around Islamabad. JZL comes under a subtropical climate zone with generally warm and humid, hotter, stormier summers and with short, cooler,drierwinters.

The designed library building relies on the principle of sustainability because it has cavity wall, optimum orientation, an atrium, and a lot of openings. Nonetheless, windows covered with blinds and window opening and closing have greatly decreased ventilation and natural sunlight permeation throughout the reading sections of the building. The wind pressure affects the south wall,which is curvy, and the only opening on the ground floor is the entry point to the library. This forms negative pressure spaces between the window depths,which is two feet, and the backside, south side of the facade, by the solid surface of the building. The building is currently on HVAC system, thus the internal temperature has been kept constant, but as soon as the lightsare off or the loadshedding period occurs, the internal areas become uncomfortable.

Cross ventilation is lacking in JZL because its windows are not open all year round due to the university's rules and regulations. Nonetheless, the design of the building has provided aspects of atria windows that might help in natural ventilation by providing the pathway to air movement and convective heat transfer, yet as the windows are being closed, no air is in circulation, and proper utility is not being observed (Figure 4). Thickness walls (external cavity) of 24 inches and an air gap of 9 inches offer fundamental insulation, which is, however, suppressed by the lack of any specialized insulating materials, which reduces the thermal resistance (R-value) of the wall and leads to the variation of indoor temperatures.

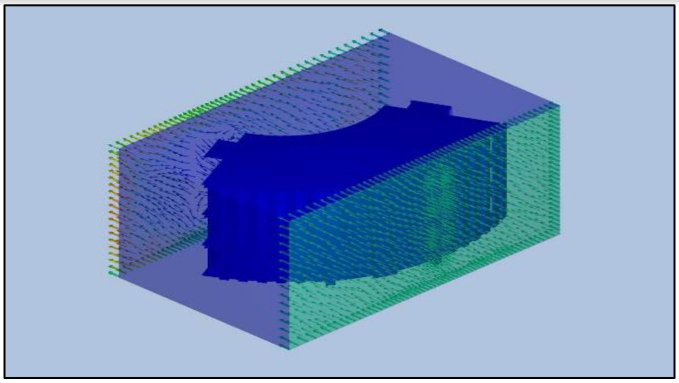

Figure 3: Massing of Junaid Zaidi Library (CFD)

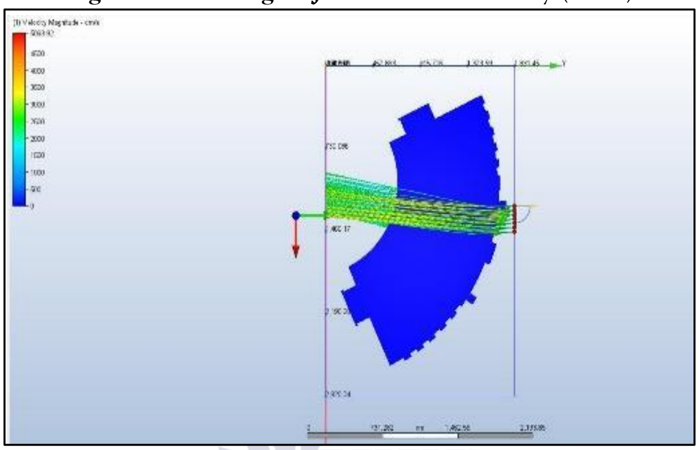

Figure 4: Inlet of Air is unidirectional (CFD)

The time frame in which the study was carried out was observedto be two weeks, with an observation period of 8.30 am to 4.30 pm, in the month of April 2024. The activities and visitor movement in the library at this time were entered in a systematic manner so that the spatial usage, peak hours, and user behavior patterns could be analyzed (Figure 5). The observations were made on the impact of environmental parameters, including lighting and ventilation, on the comfort and occupancy rate of users during the day.

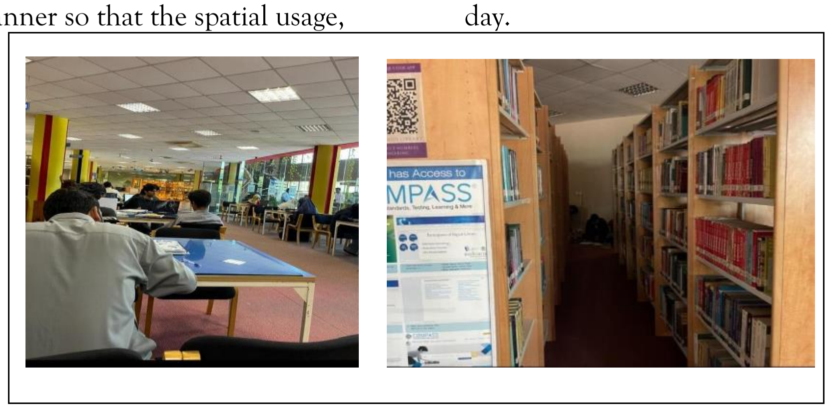

Figure 5: Internal view of Library (Reading Areas and Book Shelves)

3.3 Usage Pattern:

Identification of popular and underutilized spaces within the library was made through a survey between 8:00 am to 4:00 pm (Figure 6). It has been observed that the areas next to the windows are mostly used by the students even if there is no chair or table. Students feel comfortable in these private corners where the sound is less, where there is more privacy and light.

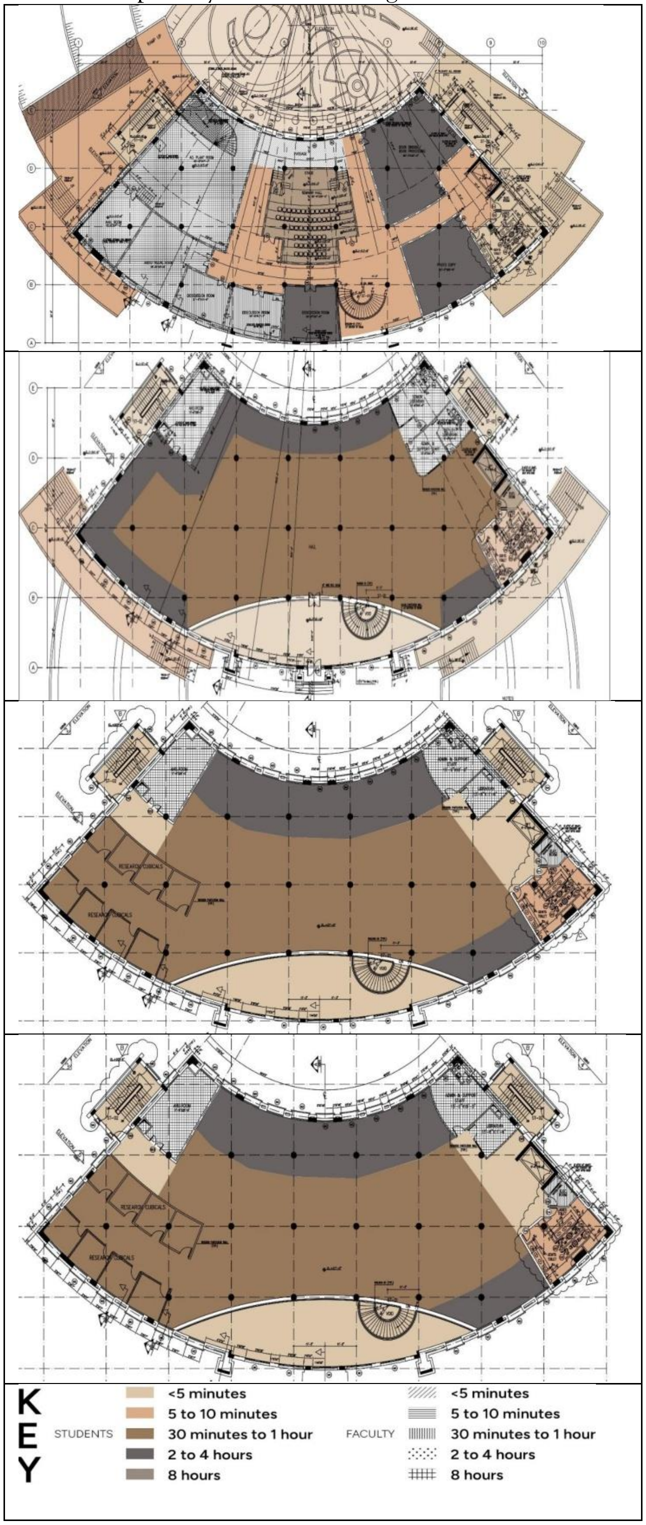

Figure 6: ColorKey for Analyzing the Usage of the Library Space of all Floor Plans

3.4 User Response:

The findings from the library user survey provide significant insights into user perceptions of environmental comfort and building performance within the JZL (Figure 7). The data indicate that while the building embodies sustainable design principles, its practical performance in maintaining user comfort remains limited.

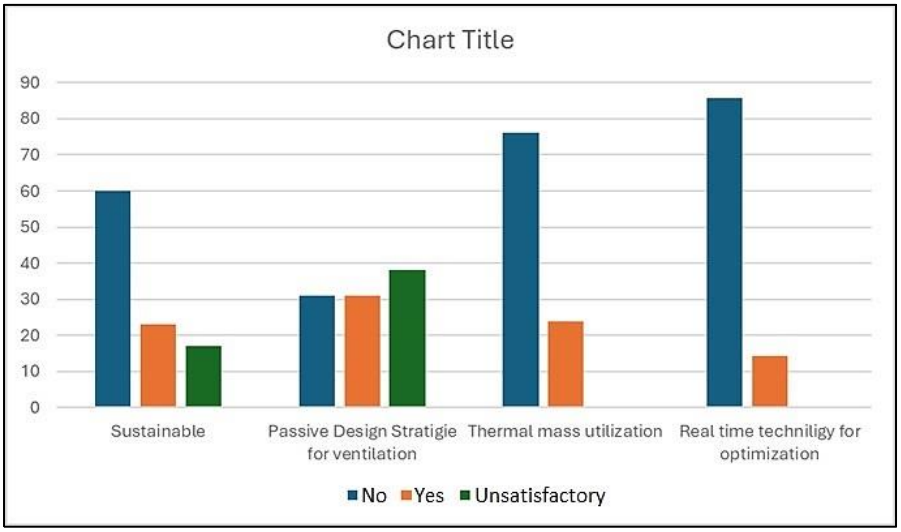

Figure 7: Graphic interpretation of User Response

Based on the user survey findings, as shown in the chart, the intentions of the sustainable design of JZL are not being entirely implemented in practice. Approximately 60 percent of the respondents believed that the building is not well-sustained, and almost the same number were not satisfied with the lack of passive ventilation measures. A large majority of approximately 70% of the respondents thought that the thermal mass of the building is not used to its full extent, as temperature comfort is highly reliant on the mechanical HVAC system. The most alarming fact is that around 85 percent of the users indicated the lack of real-time technological systems to monitor and optimize indoor environmental conditions. 60 percent of users have indicated displeasure with ventilating the JZL. Overall, the findings suggest the necessity of better natural ventilation, more intensive utilization of passive design elements, and the inclusion of intelligent monitoring devices to provide the library with the desired climatic responsiveness and physical comfort of the occupants. In general, the findings indicated in the survey suggest that passive and active design interventions, such as the improvement of the ventilation, the optimization of the day lighting, and the implementation of the real-time monitoring system, are necessary to make the JZL a truly climate-responsive, energy-saving, and people-oriented place.

3.5 Interviews:

All the interviews show how the JZL is plagued by serious deficiencies in the climatic responsiveness and comfort of its users. Both experts and users reported that even though the architectural design of the library focuses on the grandeur and space beauty, it overlooks the comfort of functionality and environmental flexibility. The dependence of the HVAC system on the thermal control of the building, the lack of natural ventilation, makes the building uncomfortable at the time of power failures, varying temperatures inside the building. Interviewees pointed out that blinds will limit daylight, and the use of artificial white, fluorescent lighting will be used, which is aesthetically unpleasant and cannot be used to read. Other issues that were raised were the lack of acoustic control in the ground floor, high noise levels caused by the open entrance, and an inappropriate color scheme whose warm colors exacerbate the feeling of discomfort in the humid climate of Islamabad.

All these findings demonstrate the necessity to improve natural ventilation, optimize the utilization of daylight, acoustically treat the building, and use climate-appropriate interior materials to improve the environmental performance of the building and the well-being of its occupants. The interviews indicate some of the major concerns about JZL design and functionality at CUI Islamabad. The library is created with the focus on the quality of the space and grandeur, yet it seems that the concept of the convenience and functionality of the users has been neglected. One of the commonly used sections is the reference section, which has poor thermal comfort as a result of convection currents because of the open ending of the grand main entrance. This causes inconvenience to the users both in winter and summer seasons, as the HVAC system finds it difficult to ensure optimal temperature in the interiors. Moreover, the lack of natural ventilation will weaken the dependence on mechanical systems during the year.

Moreover, the selection of fluorescent and rough colors is unappealing to the ambience of coziness and relaxation that is supposed to prevail in a library environment. All in all, these problems need to be tackled to develop a favorable environment where the comfort of users becomes a central point, and the usability of the library will improve. General observations illuminate the main issues concerning the interior environment situation at JZL, underlining the necessity to focus on the ventilation, lighting, and noise problems to improve the level of comfort and satisfaction among the occupants.

3.6 Thermal Comfort:

A potential solution to passive design implementation is the adoption of a surface geothermal system, which is the use of natural thermal energy of the earth to act as a source of heating in the winter and cooling in the summer. Adapted to the exact circumstances of the place of a library in Islamabad, the proposal given describes the possibility and advantages of transitioning to such a system. The design of the building is intended to achieve the best interior temperatures without excessive reliance on mechanical HVAC systems by introducing the use of thermal mass (geothermal heat exchange) and natural ventilation, e.g., air chimneys. This helps to improve the comfort of the occupants, and energy efficiency and sustainability in the library environment are promoted. Psychometrics charts are useful when determining the indoor thermal conditions of comfort in the JZL. The designers can understand the level of thermal comfort based on parameters like temperature, humidity, and air movement by measuring these. Nevertheless, the users do not report any thermal problems with the functioning of HVAC in the basement, ground, and first floor.

Nevertheless, the heating grows to an unpleasant degree during the summer, despite the HVAC being turned on/off. The second is to evaluate the response of the user to the building chosen in terms of temperature, humidity, ventilation, lighting, and comfort. The user analysis is known, and pie charts have been prepared. Hygrometers were used to give information about the environment, which helped in determining the effectiveness of the HVAC equipment andits suitability forpreservation requirements. This points out their critical importance in the realization of climate-responsive design in libraries. Unlike the Light intensity meters, which are essential elements of the design of climatic responsiveness, theyprovide accurate measurements of the levels of illumination to conduct research and data gathering. They facilitate the analysis of the environment by detecting areas that lack adequate lighting or have more lighting than is required so that the designers can offer specific solutions. The instruments were both employed to keep track of the humidity level and lighting level in the library.

3.7 Intensity of Light within the library:

Data collection, analysis, and evaluation were done by collecting climatic data at four points (Figure 8) of all four floors at various times of the day. It has been noted that the east-facing and south-facing windows that get direct sunlight during sunrise until about 2 p.m., both in summer and winter, when the screens are removed, would lead to the intensity of light of between 400 and 590 lux. Although the screens can successfully shield direct heat of the sun and the glare of the sunlight, they also restrict the supply of natural light into the space and hence the quality of daylight. The west sun is low and cuts deep into the building, particularly during winters, and achieves the required lux index without heat and glare (Figure9).

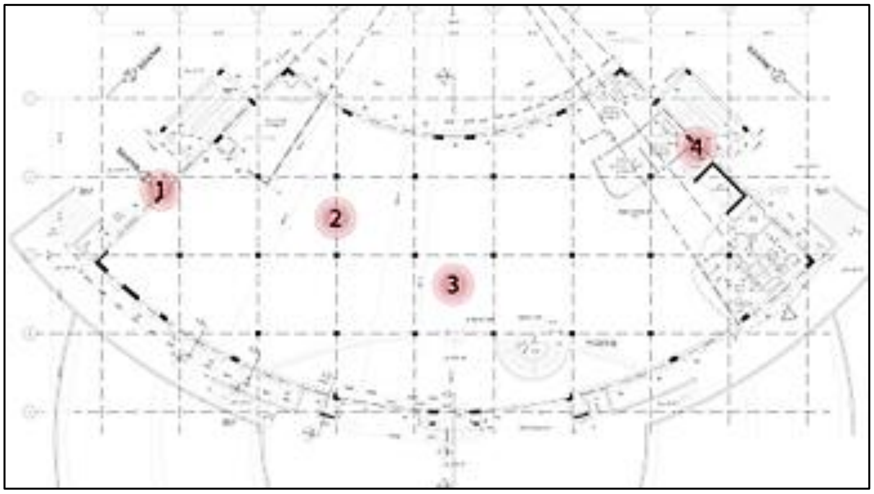

Figure 8: Points marked for Data Collection w.r.t.Light, Temperature and Humidity

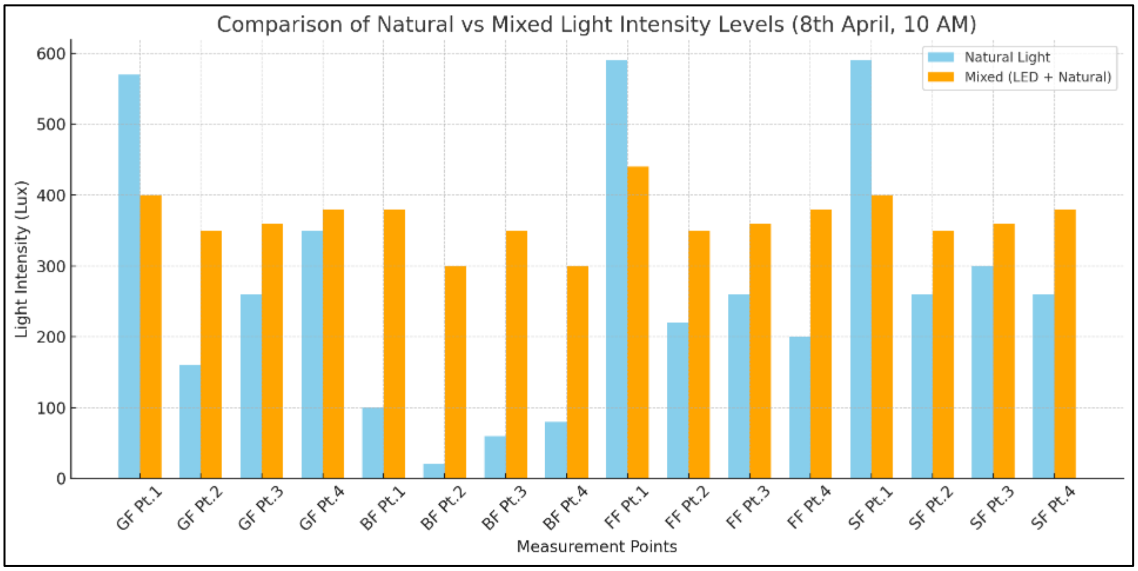

Figure 9: Light Intensity Measurement at Four Selected Points with and without LEDs

To solve this as a climate-responsive design, the other solution is to install a mixture of both vertical and horizontal louvers. Such louvers would also be able to regulate the glare and solar heat of the sun without necessarily blocking the natural lighting. Projections or louvers would assist in diffusing the sunlight and enabling more evenly spread and regular lighting in the interior. Consequently, the level of light within the rooms, which at present decreases to 160 lux in darker areas of the room, would increase to a level much higher, even during an energy failure. On the same note, light wells and skylights would be added, hence increasing light levels within the library. Vertical louvers would be utilized especially to block the low-angle morning sun, whereas horizontal louvers would control the higher midday sunlight. This would not only help make the space more comfortable for the eyes by minimizing glare but would also maximize light penetration into the space. This passive approach to designing can reduce the amount of artificial lighting required by maximizing the amount of natural light entering the structure, thus resulting

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in increased energy savings and a more comfortable interior environment with enhanced lighting. Finally, incorporating the use of vertical and horizontal louver would improve the aesthetic and functional quality of the space because it would balance the natural light, heat balancing, and visual comfort.

3.8 Temperature and Humidity:

An in-depth analysis of the temperature and humidity indicates that the temperature rates in the specified Point No. 1, which is on the east side of all floors, are considerably high because of non-energy-efficient glass. This is more evident on the second floor, where the levels of both heat and humidity tend to be above the psychometric comfort levels even with the HVAC system on. The highest discomfort is felt between 10 a.m. and 2 p.m. when the sun is at its highest position, where the glazing on the east and south facade makes 21.28 percent of the floor ratio of each floor. There is much heat on the second floor that is made worse by the fact that there isinsufficient thermal insulation of the glass and no ventilation. This is due to the heat stack effect, in which warm air rises and gets trapped, especially at the top of the atrium, which raises the temperature even more. Also, the discomfort is further exacerbated by the humid air that develops on this floor, caused by changes in temperature and the condensation of air to form a type of temperature conversion, thus making the atmosphere humid indoors (Figure 10).

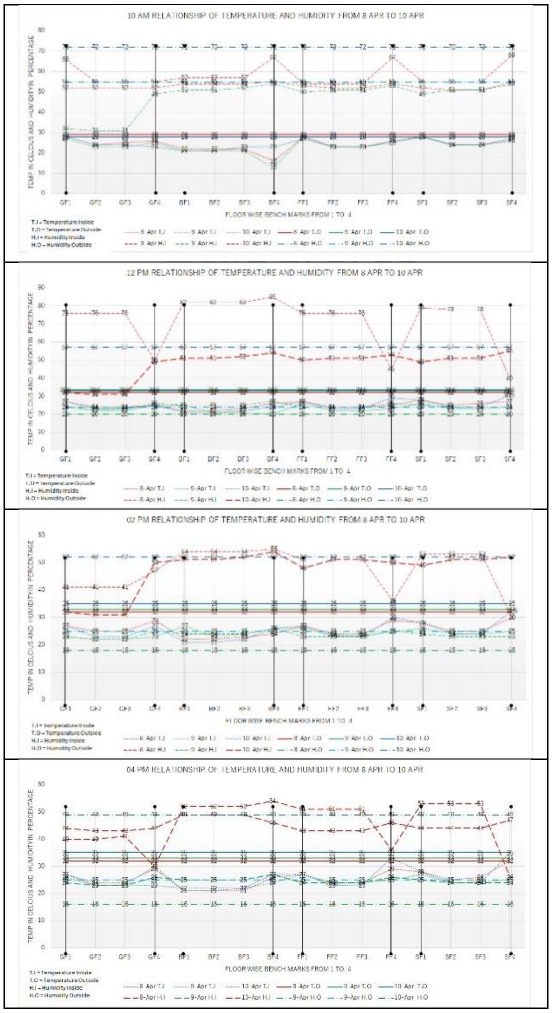

Figure 10: Temperature Humidity Graph (10 A.M., 12 P.M., 2 P.M., 4 P.M.)

Discussion:

To address and optimize natural ventilation, strategic design interventions are necessary. This includes the implementation of openings such as windows, vents, and louvers to promote cross-ventilation and enhance airflow throughout the library space (Figure 11). Also, the incorporation of features that utilize current winds can enhance the ventilation effectiveness and minimize the energy waste, which is consistent with the concept of climate-receptive construction. Daylighting design enriches penetration of natural light into interiors of buildings to minimize usage of artificial lighting, enhance visual comfort and well-being and productivity of occupants. Clerestory windows, skylights, light shelves and light tubes are some of the strategies that maximize the daylight distribution and reduce glare and the amount of solar heat gain (Figure 12).

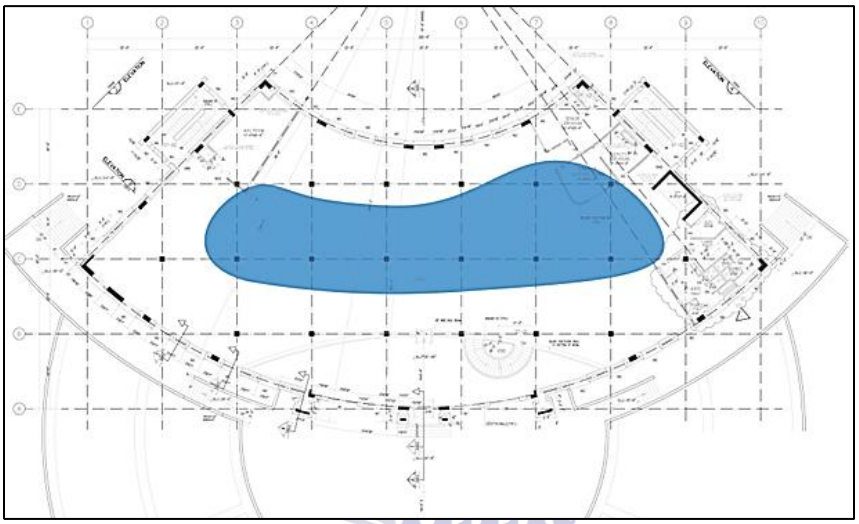

Figure 11: The Light Penetration Analysis, Blue Zone with less Light Intensity.

Figure 12:(a) Atrium at the time of electric breakdown,(b) depth of shadows at 4:00pm from the South.

In order to solve the Solar radiation problem, retrofitting the JZL to include external shading equipment like overhangs or louvers is advised to prevent direct sunlight penetration as well as minimize solar heat gain. These shading solutions are to be placed in a strategic position so that they can maximize their benefits without interfering with visual comfort and access to daylighting and views. During the winter, the solar angle is low and hence the sunlight can enter deeper into the interiors thus providing a more comfortable environment due to solar heat gain by adopting strategies. The library will be able to increase the level of its energy efficiency, improve the indoor comfort, and make the environment more sustainable and friendly to its users during the winter period, as well (Figure 13).

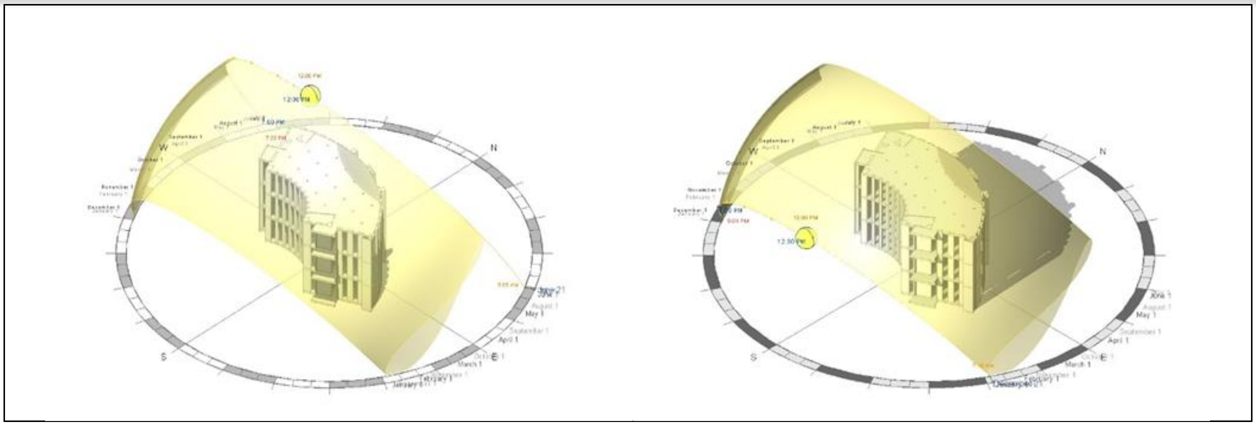

Figure 13: Solar impact on the Library for Summer and for Winter

When incorporated into building projects, the joint impact of these passive design approaches will enable the architects and designers to develop climate sensitive environments that consider the comfort of the occupants, energy efficiency, and environmental friendliness (Figure 14).

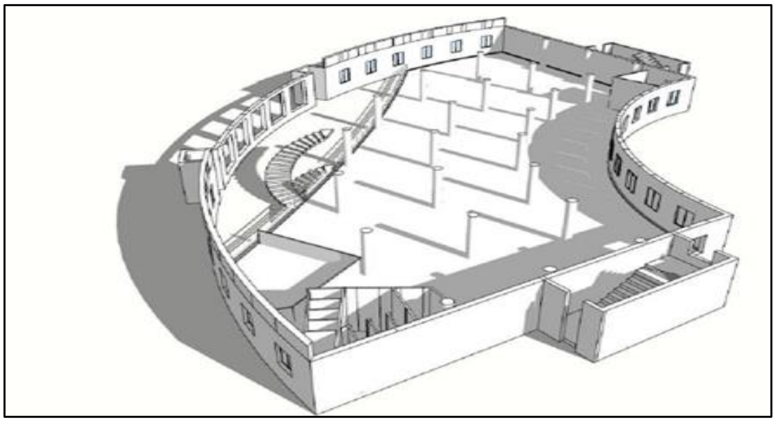

Figure 14:Light Penetration per Floor at South in Winters at 4pm

Design Proposal:

An analysis of the obtained data is conducted to reach the objectives of the climatic responsive design, and a design proposal is presented. According to this study, this proposal should make the library more climatically responsive and the library design has to be redesigned with the assistance of operable windows, louvers, and vents that are strategically located to allow cross-ventilation and airflow. The perimeter of the building may have operable windows to facilitate in the intake of fresh air and the vents or louvers may be located at strategic locations to promote airflow and circulation in the interior spaces.Using the solar chart of Islamabad, the best sizes and location of the windows can be identified to optimize on natural ventilation and minimise heat loss or gain. This includes the consideration of factors like the direction of wind and the sun angles and the orientation of the building to ensure that it maximizes the airflow patterns and reduces the discomfort that may occur because of outdoor conditions (Figure 15).

The design of the JZL and the consumption of the energy depends upon the climate aspects of temperature, humidity, solar radiation, and wind. Maximum daylighting and minimization of solar heat gain are achieved with the north-south orientation and a 9-inch gap between the cavity wall and the air which is a thermal barrier. There should be humidity control that will help avoid such problems as molds and damage to the materials, and there should be the mechanical ventilation systems and vapor barriers. Blinds help to reduce solar radiation problems, although external transfers are used to improve thermal performance and minimize the need to use mechanical cooling. The nature of the design supports wind movement but gets inhibited by the few openings and the shape of the library as it is circular in shape thus requiring the use of better airflow tactics in order to ensure comfort in the interiors.

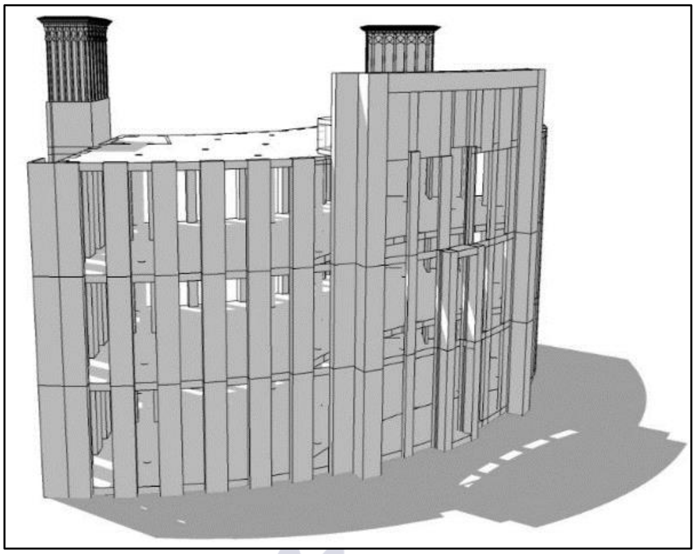

Figure 15: North Elevation of the Proposed Design

Insulation materials can be used to regulate indoor temperature will help in both reducing energy consumption and usage of energy for heating and cooling. In addition to this cavity can be used as a moisture barrier which helps maintain a dry interior environment and prevent water infiltration.Sound insulation can be improved by reducing noise from external sources and enhancing the library's ambiance. In addition to all mentioned above cavity walls can help in strengthening the integrity of walls increasing their durability and stability. Leveraging the existing cavity provides us with a sustainable and budget-friendly solution to increase the overall experience of JZL.

Ventilation systems are used for the removal of moisture and regulation of humidity levels; this is done by introducing fresh air and expelling the indoor air. This leads to the prevention of moisture buildups. For the observed building the ventilation is hindered as the HVAC system is being installed. It is recommended to enhance ventilation to produce a comfortable environment and reduce load on the HVAC system. Ventilation can be enhanced by adding wind catchers and creating a channel for air to flow (Figure 16).

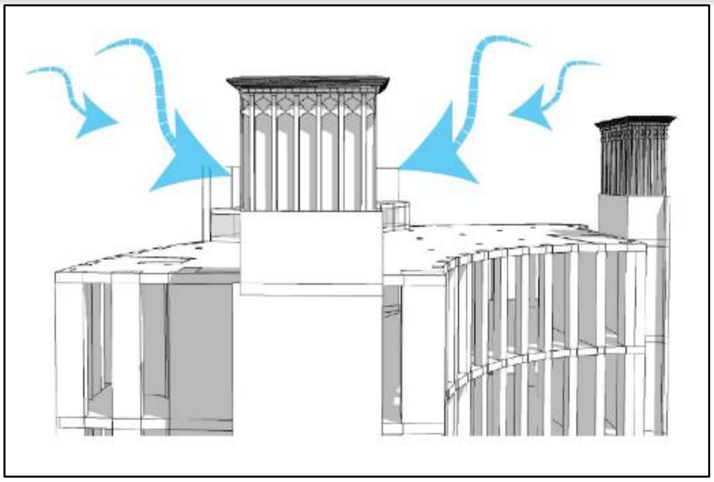

Figure 16: Enhancing Ventilation by Suggestion of Badger

The building is oriented to maximize natural daylighting and minimize solar heat gain, with large, glazed facades facing north and south.Optimize building design to maximize natural daylight penetration based on analysis of solar angles and shading patterns. Light shelves, skylights and reflective surface as design elements should be included to maximize natural day lighting in the library and reduce glare and heat gain. Thus, nowadays, blinds on the windows inhibit the direct entry of light, which prompts the necessity to use artificial lighting to comply with the requirements of reading and moving between shelves. Nevertheless, during an electric failure, the light drop to 6 X 20 Lux is insufficient in performing any activity in the library.

Therefore, integrating strategies to harness natural light effectively can enhance interior illumination levels and removal of blinds, ensuring a comfortable and functional environment even during unforeseen circumstances. The climatic analysis suggests that the windows facing south can be provided with shades (horizontal louvers) to stop direct sunlight and heat gain. Length of the louver can be calculated aligning with the solar angles. This way a design can be made where there will be lot of natural light inside the building.Further designing Light wells facilitating lights into the dark area is a creative solution. Hydroponic design with deciduous plans reduces the heat gain and reflection of glare at the south façade.The EAHE system (earth-to-air heat exchanger) is a kind of heat exchanger that can transfer heat between soil and ventilation airflow within underground buried pipes(Omidvar, Monghasemi, & Rosti, 2019). The temperature of underground soil keeps approximately constant with a low fluctuation all year round when the depth reaches to a certain degree. This makes the temperature of underground soil significantly higher or lower than the outdoor air temperature in winter or summer, respectively (Figure 17). In recent years, the energy-saving potential, optimal design, and heat transfer model of the EAHE system have been constantly investigated. (Maoz, et al., 2019; Lee & Strand, 2008) pointed out that the diameter, depth, and length of buried pipes as well as airflow velocity within pipes show significant influence on the cooling and heating capacity of EAHE systems. A depth of 3 m and a length of 50 m (Figure 18) for the buried pipe of the EAHE system considering the compromise between construction costs and energy performance is recommended.

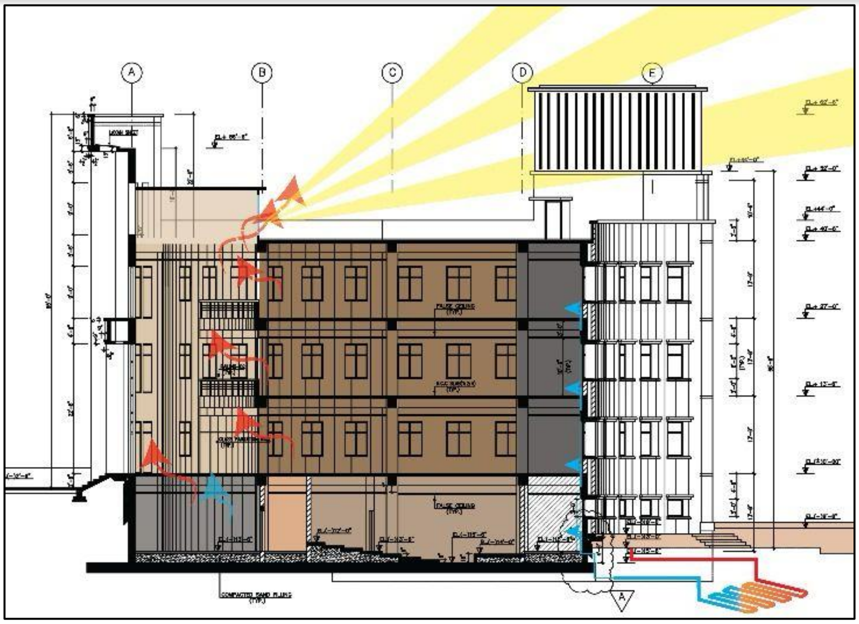

Figure 17: Geothermal Exchange along with Enhanced Stack Effect by Adding Ventilator Chimney above Atrium and Enhancing Air through wind catcher.

Islamabad gets a lot of rain, which affects how wet or dry the soil becomes. Understanding this quality of soil will help in designing systems that can work well for the library. Studies on how heat moves around in the ground (Naqash&Farooq , 2021) can be incorporated in the design to create a system that can transfer heat effectively and keep things at the right temperature around the JZL. Studying different areas around the library helped in finding the best spots to put in systems that use Earth's heat.To regulate the library's climate, a loop is installed just below the outdoor areas beside the stairs well. Further the stairwell is extended to build the wind catcher above it to enhance air flow into these ducts that lead towards the underground tubes. The underground tubes in the form of a loop. The tubes run for a length of 50 meters inside the earth picking up the earth heat. These loops transfer heat to or from the ground as needed, meaning we can heat or cool the library without relying too much on regular heating and cooling systems. The benefits are:

1. Conserving Energy: By adopting such geothermal systems we consume less energy, which is good in terms of saving our environment, and also economically we do not have to spend so much money on operational costs of running the library.
2. Going Green: By utilizing renewable energy on the planet, we are demonstrating our responsibility to the planet and construction.
3. Keeping everyone comfortable: With this type of system installed, the temperature of the library remains the same and therefore the library is a comfortable and warm environment to all the people who visit and work there irrespective of the weather outside.

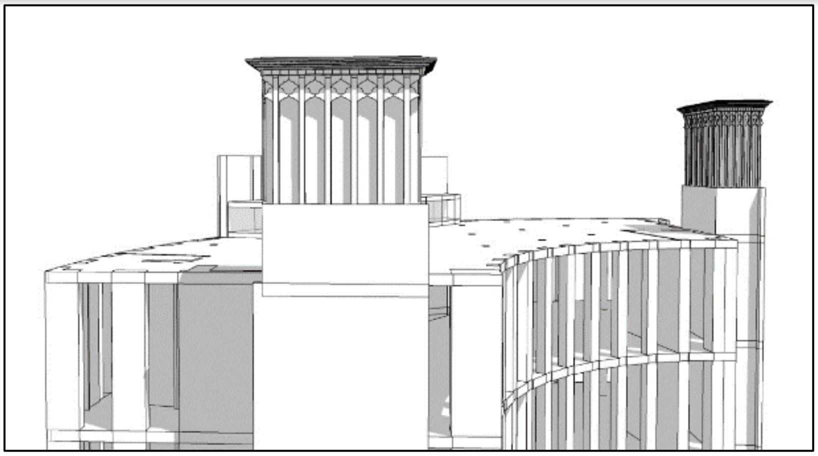

Figure 18: Adding Chimney for Air Intake

The introduction of surface geothermal in the JZL will be a viable and affordable solution in climate control. Taking advantage of the natural thermal energy of the earth, the library could become energy efficient and sustainably green as well as provide more comfort to the occupants.

Design Implementation:

The suggested design (Figure 19) will be efficient in the energy consumption, availability of daylight and comfort of the occupants. It is possible to align the completed design with the purpose of research and implementation with sustainable materials and building methods. Ongoing monitoring and evaluation of the building's performance will ensure its continued alignment with research objectives over time. At the south the building's curved form along with the projections will maximize daylight penetration while reducing the need for artificial lighting. Automated external louvers can be provided to facilitate the adjustment throughout the day to optimize daylighting and minimize glare and solar heat gain. Whereas the windows can have operable louvers at east and west to automatically adjust the penetration of light into the building. At the North side there is diffuse light present, so there is no need of louver or blind.

Operable windows above the atrium and the wind catcher tower with underground thermal tubes will facilitate natural ventilation while adjusting automatically to the climatic need and shall reduce the need for mechanical cooling. The atrium roof lifting of 5 feet for providing operable vents and tilting to make it at an angle that is 90 degrees to the solar angle of summer latitude i.e., 17 degrees for better performance and maximum heat gain to trigger stack effect for effective ventilation. This effect can be further enhanced by coloring the ceiling black from the exterior. Thermal comfort and loss of heat are minimized through high-performance insulation and triple-glazed window glasses. With the application of these passive design strategies, it is possible to have comfortable indoor environments in the buildings throughout the year with the reduction of dependence placed on the HVAC systems. This philosophy facilitates sustainability, energy efficiency, and comfort, of the occupants in a climate conscious manner.

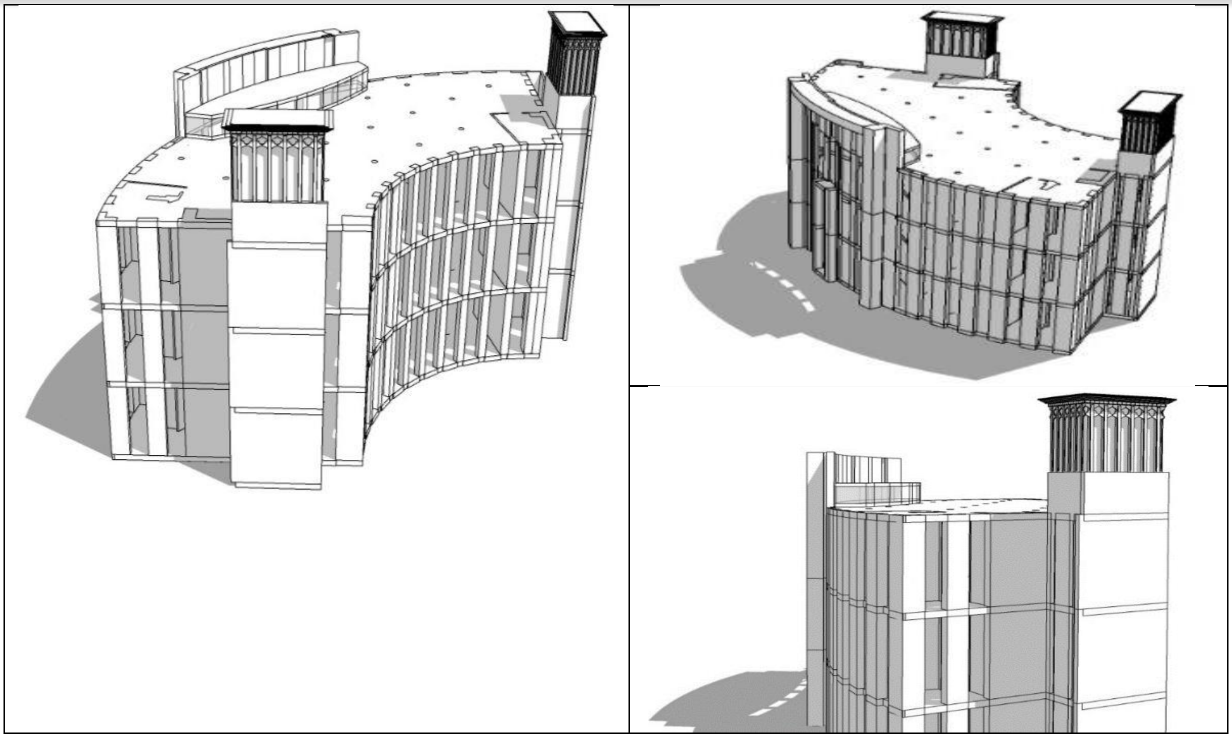

Figure 19: Designed Facade facing Southwest, North, and Detail of Badger rising above the mumty giving it the height of 64 feet (12 feet above the mumty)

Any of the following passive design strategies will ensure that the library will be a model of climatic responsive design, which will encourage energy efficiency, energy sustainability, and comfortable atmosphere throughout the year. This design can subsequently be established as a model to the ones who desire to make adjustments in their habitat as a climatic responsive design.

Conclusion:

The study of Junaid Zaidi Library (JZL) of COMSATS University Islamabad shows how essential climate-responsive design principles in infrastructural learning settings are. Although the architectural framework and the sustainability aim of the building is admirable, its inefficiency in operations especially the absence of natural air conditioning, the poor use of daylighting and reliance on mechanical HVAC controls curtails its climatic flexibility and comfort to its users. The empirical data about monitoring of the environment, surveys, and interviews with the users demonstrate that occupants feel uncomfortable with temperature systems, weak lighting balance, and auditory disturbances. All these complications reflect the disparity between the theoretical sustainability design and actual implementation.

The research suggests a general redesign framework that will entail passive solutions like operable windows, optimized louvers, wind catchers and geothermal air exchange systems. Combined with better insulation, efforts to provide strategic shading, as well as light well integration, such interventions can help significantly lower energy loads, and provide thermally and visually comfortable indoors. COMSATS University can also lead a trend on sustainable architecture in the design of educational institutions in Pakistan by turning the JZL into an example of responsive architecture. This study highlights the fact that environmentally correct architecture should be built on a balance between aesthetic appeal, environmental performance and occupant comfort to be truly sustainable.

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