



Environmental Impact of Biophilic Architecture on Human Health: Evidence from Residential Buildings Greater Noida, India

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ABSTRACT: The connection of human beings to nature is of utmost importance to architects and other allied professionals. Human health and social well-being are amongst the major priorities which are of utmost importance in any successful building design. The biophilic architecture looks forward to bridging the lacuna of the gap that exists between the users of the building and nature or naturally produced resources such as natural air, daylighting, vegetation, water body, and natural materials. This paper aims to explore the environmental aftermath of biophilic architecture on residents' health, well-being, and comfort of living in the context of residential buildings of Greater Noida. The study argues that some environmental biophilic elements are not given the needed justice and priority in residential building designs such as passive ventilation, daylight, etc. This results in overheating of the indoors, thus creating discomfort for the occupants. This research employs a thorough scrutiny of the three landmark residential apartments in Greater Noida (ATS Greens Paradiso, Jaypee Greens, and Purvanchal Height) and their corresponding responses biophilically to the occupants' comfort of living. One-hundred and twenty questionnaires were distributed across the three buildings in which ninety-three valid responses were recorded accordingly. The challenges that the author(s) faced were many, such as, getting the residents to respond and also quantifying the relative responses. Findings reveal that all the five elements are vital for the improvement of health status, social well-being, and quality condition of the environment. However, vegetation happened to be the prominent element in its impact which is vulnerable and common to the selected buildings based on fieldwork analysis and residents' perception results.

Keywords: Biophilic architecture, Environmental element, Green building, Healthy architecture, Human wellbeing

I. INTRODUCTION

Biophilic architecture holds the postulation of connection between humans and nature that happens to be progressively supportive throughout the life span of the buildings [1]. The idea is to encourage the incorporation of the environmental elements in biophilic architecture through these research findings, these elements include; natural lighting, passive ventilation, plants, water-bodies, and natural materials. Biophilic architecture triggers the progress of sustainable cities and buildings. However, this architectural approach contributes towards improving the quality of the residential buildings thereby promoting the occupants' health and the comfort of the environment. Architecture biophilic expresses a part of a new concept that blends with human health, ecology, and sustainability [2]. Biophilic architecture desires to bridge the lacuna between modernity and the human demands to link with the natural ecosystem. This approach focuses more on the enhancement and reinstates the vital aspects of nature in the context of the built environment, [3]. Since environmental elements were considered amongst the key factors to improve human health, it's been a trending concern for every residential building to be sustainable, both socially and economically in order to

blend with the lifestyle of the occupants and improve the ecological sense within the framework of the ecosystem, [4]. Greater Noida is a developing city with high-tech infrastructural facilities and multiple layouts for residential apartments. However, since the price is very affordable for low-income groups, it results in continuous influx of people from different parts of India looking for an affordable apartment, resulting in overcrowded apartment complexes. Most of the real-estate developers propose high rise residential apartments accompanied with environmental elements that influence the comfort of living for the residents such as plants, swimming pools, etc. The design of the apartments and the layout of these complexes takes into account the availability of land and the cost efficiency of the materials used in construction.

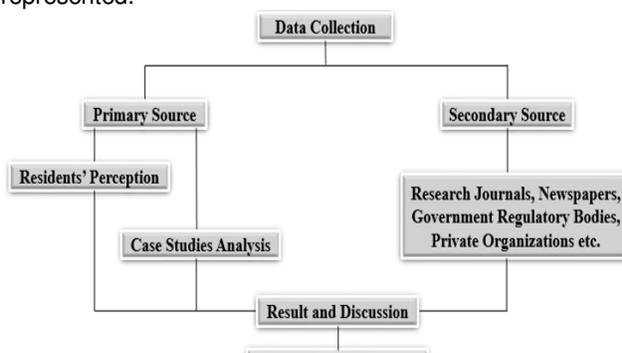
Biophilic design in architecture connects the interior and exterior space with nature; it emphasizes the temporal impact of environmental elements in preserving the sustainability of our built environment. The quality of human life and activities of the residential spaces are enhanced by the nature of the surrounding landscape. However, the impact of these factors has far-reaching effects on the health of the occupants and the overall well-being of the inhabitants, [6]. Green building is the act of triggering a superlative usage of resources, to

minimize the negative impact of building on human health during the lifespan of the building. The various factors considered while designing any green building include; vegetation, water materials etc. These factors aid in reducing buildings and the environmental impact of the built mass on the inhabitant's health [7]. In this respect, this research aims at exploring, encouraging, and improving the utilization of the environmental elements in the biophilic architecture (design) to improve the occupants' health and environmental well-being. Recent literature findings reveal some of the problems that arise due to insufficient or poor consideration of these elements. They are:

- Sick building syndrome – Insufficient Passive, Ventilation [8].
- Glary vision - caused by poor natural lighting design, [9].
- Over-heating of the indoors – associated with bad weather condition analysis, [10].

II. METHODOLOGY

This research explores the environmental benefits of biophilic architecture on inhabitants' health and comfort of their well-being. During the process of research, the basic environmental attributes were analyzed from the design analysis perspective and their response to the internal environment was recorded. Literature reviewed elaborated on their direct and indirect impact and their endowment in the immediate environment. Residents' experiences on these vital elements are captured with the aid of a questionnaire, 120 questionnaires were distributed across the three buildings and 93 responses were recorded. The first section of the questionnaire comprised of the demographic part which collects the respondent's details and the second section entailed questions on the basis of the five identified environmental biophilic elements. Each question was answered to a desired option with preference from the 5-point Likert scale, and all the residents' perceptions were collected in this manner. The data collected was analyzed and the resultant impact was graphically represented.



The conclusion from both techniques was derived from the result and discussion section where inferences and contributions were comprehensively itemized. The paper employs a thorough reconnaissance of the design analysis tool and residents' perception coupled with the work of the relevant literature.

(1). BIOPHILIC ARCHITECTURE

The term biophilic was coined from "biophilia" which means love to live. The word was first used by Enrich

Fromm in 1964 to describe the acclimatization psyche of the connection affinity of all the phenomenal impacts of living and non-living elements in our built environment. Biophilic architecture expresses the bonding and the potential empathy of linking the building users to nature through designs and integration of various natural elements that directly or indirectly impact the life of the occupants in different senses. The idea of biophilic architecture is to bring the building users more close to nature and to maximize the utilization and response to the natural landscape. This idea took effect in the pre-modern era in most the vernacular buildings, however, the technology and some materials that trigger this distinct concept were not largely pronounced, [11]. The thought of biophilia begins with the comprehension of human evolution where the historical record reveals that more than 99% of the human species were biologically adapted and linked to nature without any artificial catalyst, [12].

The biophilic design focuses on the fundamentals of connecting man with nature under the scope of some temporal goals of developing an active, sound and communicative built environment, where human biophilic inclination can find its consciousness. This contributes to ascertaining the equity between the landscape natural elements and the immediate environment, [13].

(2). PRINCIPLE ELEMENTS OF BIOPHILIC DESIGN

Biophilic design has distinctive elements that guide its success, the physical and psychological manifestation of these elements provide an integral effect and appreciation for the built environment. These idiosyncratic elements are categorized into six aspects, and their respective attributes. These were identified from a literature reconnaissance and are relevant to this paper as illustrated below.

- **Environmental Features:** These features entailed different environmental factors that are connected to the biophilic design, they are the complimentary elements in the biophilic architecture of our built environment. They comprise of natural and man-made components that strengthen the associational value of the relationship between the occupants and the natural environment they are in. Sunlight, Fresh air, Plant, Animals, Water, Soils, Geology and landscape, Habitat and ecosystem, fire, Views and vistas, Natural colors, and natural materials such as wood and stone are examples of such elements.

- **Natural Shapes and Forms:** The adoption and the adaptive re-use of the naturally existing shapes are maximally practiced in the principle of biophilic design in order to blend with the ecosystem and ecological landscape. This concept is streamlined with that of pop architecture, i.e. the architecture of symbolism of natural and artificial objects to mimic a particular element so as to define the character or identity of a place. This is popular in post-modern and contemporary architecture, [15]. These attributes include botanical Motifs, trees, and columnar support, animals (Mainly Vertebrate) motifs, shells and spirals, egg, oval and tubular forms, arches, vaults, and domes, shapes resisting straight lines and right angles, simulation of natural features, biomorphic, geomorphology, biomimicry.

- **Natural Patterns and Processes:** Functional elements found in nature are integrated and the process simulated in the biophilic design of our built environment. These patterns are vital, especially those involved in human evolution such as designs that express the variety of senses and organic growth. These attributes include: sensory variability, information richness, Age, change, and the cachet of time, growth and efflorescence, central focal point, patterned wholes, bounded spaces, transitional spaces.

- **Light and Space:** These principles have a huge impact on the biophilic architectural design, they delineate the relationship between light and space and their response to one another within and outside the living spaces. However, during the course of research, some relevant attributes of light and space were identified, they are: natural light, filtered and diffused light, light and shadow, reflected light, light pools, warm light, etc.

- **Place-Based Relationships:** This feature determines the coupling of peoples' culture with the ecological condition, in accordance with the climatic and geographical context of the site. This ensures the revelation of the intrinsic demand of the occupants to identify the previously owned boundaries for effective control. The elements defining this feature include Geographic connection to place, historic connection to place, ecological connection to place, cultural connection to place, indigenous materials, landscape orientation.

- **Evolved Human-Nature Relationships:** This element does not literally reflect the biological context of the environment, but rather it primarily defines the innate affinity of the human relationship to nature. Security and Protection, Mastery and Control, Affection and Attachment, Attraction and Beauty, Exploration, and Discovery, Information, and Cognition, Fear and Awe, Reverence and Spirituality, associational value etc.

III. THEORETICAL FRAMEWORK

Apropos to the principle elements of biophilic design discussed above which are relevant and temporal to biophilic architecture, this research is limited to five major attributes of environmental features identified as parameters for this study, which are commonly incorporated in the biophilic design of the residential buildings in Greater Noida, and how they impact to the occupants' health and comfort of living. The environmental features that have been elaborated below from literature surveys are:

A. Passive Ventilation (Fresh Air)

Natural ventilation induced by wind forces aids indoor cooling, and these forces propel the circulation of fresh air in the building. Fresh air is essential for a healthy and comfortable environment, openings provided in any design determine the effectiveness of airflow, configuration, and orientation of the building. Passive ventilation also contributes greatly to sustainable building design, most especially in energy-efficient buildings as it reduces the expenses incurred for mechanical ventilation, therefore its impact on the building is temporal and enormous, [16]. Natural ventilation has many advantages in the built environment which are both physical and psychological.

The buildings' ability to connect the indoor and outdoor air contributes towards its physical as well as sensory experiences. Temperature and pressure affect their displacement, the internal air has a high temperature which is easily replaced by the outside air that is more humid and gets triggered by the wind buoyancy into the internal environment, [17]. The demand for cool building envelope is progressively turning out to be unceasingly cherished and is a major consideration in building design. This arises as there is a pertinent need to convert internal generated heat by fresh air and thereby reserve the cooling efficiency in summer [18]. Cross ventilation is controlled by wind, pressure. The pressure difference between the windward and the leeward side of the building, with openings opposite or alternate to each other forces the flow of air to move around to cool the space, (Fig. 1).

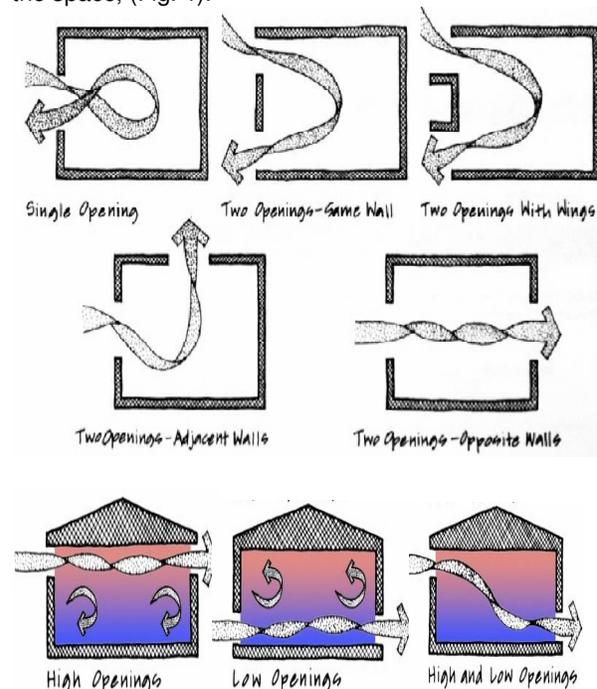


Fig. 1. Diagrams of different cross-ventilation strategy. [19].

B. Daylighting (Sunlight)

Natural day lighting is considered a phenomenal element of good residential design, it needs to be prioritized from the design inception stage to achieve effective access of natural lighting into the building for the comfort and health condition of users. Any good natural day lighting design prevents direct access to the interior spaces which may result in overheating of the indoors or causing glare, the precautions are taken to have a technical and professional way of admitting the sunlight into the building in a controlled sense through vertical and horizontal shading devices to achieve comfort level for the users, [20]. The radiation of sunlight from the sky that has direct access to the building or enters the building from an opposite reflected object is considered a major source of natural lighting within the internal environment [21]. Sunlight can transform a space that is dark and unpleasant into a bright inspired space which is vital and beneficial for the inhabitant. One of the robust benefits of admitting daylight in

residential building is the ability to save the resources for mechanical heating in winters and improve the psychological comfort for the occupants. However, despite daylighting being among the essential aspect to consider in the design, it requires careful control of having direct access into space (Fig. 2), which would discomfort the users and affect their health condition as well as the ambient light quality in living space [22].

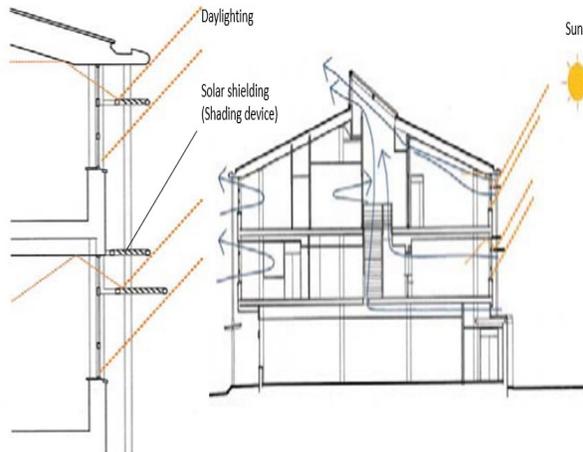


Fig. 2. Section showing the controlled day lighting access [23].

C. Plant (Vegetation)

Plants in residential buildings are attached to the interior or exterior wall either in the vertical or horizontal direction as in the green wall and green roof respectively (Fig. 3), although they can be standalone in some cases. A properly designed green building fulfills the functional and design goals supporting the life of some selected species for a specific purpose, [24]. Plants are advantageous in supplying fresh air to the surrounding environment. They keep the environment in control by creating microclimate to minimize the danger of erosion and hold the ground water, thus keeping the habitat in comfort zone and pleasant conditions [25]. The vegetation of a building envelop is a fast-growing practice in the modern world, this is one of the opportunities to practice biophilic architecture. Creating a green building helps to improve the comfort of the building users as it gives a soothing look to the built environment, at the same time, the progressive incorporation of vegetation allows the utilization of the surrounding landscape as well as in both vertical and horizontal parts of the building, [26]. The prospective of the plantation or any other vegetation type incorporated in a building design has a significant impact in minimizing the cooling load identified from different relevant works of literature, the changes in microclimate influence the sustainability potential of this approach. Therefore, the climate model and simulation are deemed to have an extreme impact on vegetation integration in our buildings and immediate environment, [27]. A green wall holds the growth of plants along the vertical axis of the wall to promote the greening effect on a building and enhance the visual appeal of the built environment [28].



Fig. 3. Internal and external incorporation of greenery. [29].

D. Water-Bodies

Water bodies have a significant impact on the life of the inhabitants as they lead to a considerable variation in the microclimate of the surrounding. Its evaporative cooling potential is one of the cognitively satisfying ways of passive cooling in residential buildings. The water body's temperature can reduce the temperature of the surrounding especially in a residence with the water body. The hot air that blows from the windward side across the building gets saturated while in contact with the element of water, [30]. Water in nature is considered as an ingenuity when designing residential and commercial buildings, its embodiment in a building design gives a fascinating look and appearance thus contributing to an aesthetic view, quality condition, and pleasant environment for the inhabitants [31]. The integration of water in our built environment, especially when it blends with the natural settings of the site gives an appealing effect to the environment. Water is mandatory for human and animals' life, provision of water body in the building or its surrounding increases the amount of positive intangible ambience and the brightness of the space thereby encouraging the inhabitants to have a long-time stay at home with reduced stress, [32]. The waterbody is one of the landscape factors with dynamic motifs, it is natural that people require water not only for consumption but rather for their daily life activities. It has a distinctive feature of variability which creates an adulation effect of the landscape (Fig. 4), [32].



Fig. 4. Water bodies in a residential landscape [32].

E. Natural Materials (Stones, Bamboo & Wood)

Natural materials in the construction industry have been flourishing before industrialization, after the emergence of new construction materials of modern movement, the utilization of these materials has reduced. However, in the post-modern era, the idea of critical regionalism came which made use of the extensive exploitation of locally sourced materials to achieve modern buildings

and revive the lost identities. The concept of sustainable buildings also brainstorm on this philosophy considering the instinctively inbuilt characteristics of these materials, [33]. Stone has some excellent advantages over the rest of the natural materials (wood, mud, bamboo, etc), used in building design. It also could create flexible functions both in internal and external spaces, such as internal and external finishes, stone walls, facades, etc. This natural material has been an inspiration in vernacular and contemporary designs as it improves the closeness of the occupants to nature [34]. The extensive use of these materials is based on easy procurement and less technical know-how of usage (Fig. 5). Although with recent technology and the modern methods, they often utilize the modern techniques to ease the process and break through the traditional difficulties (Fig. 6). Therefore, most of the low-cost housing, makes use of these local materials to construct the structure themselves. These materials are purely sustainable and universal, and they respond to both local and modern techniques of construction such as contemporary sustainable buildings, [35].



Fig. 5. Blooming bamboo home [36].

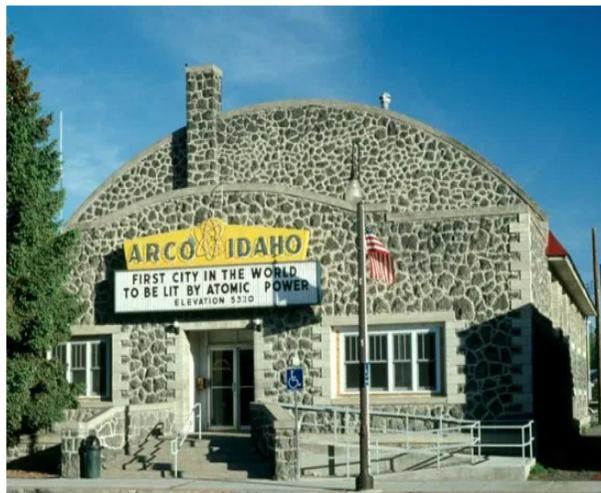


Fig. 6. Basalt stone use in construction [37].

IV. CASE STUDIES ASSESSMENT

The three eminent residential buildings were identified in Greater Noida as they exhibit the character of biophilic
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architecture. Fieldwork analysis was thoroughly conducted on each building concerning their features and responsiveness to the comfort of living for the occupants. These buildings are regarded as the pivot upon which the reliability of the research findings rest. Apropos to the analysis of these case studies the blueprint of the biophilic design in the buildings was ascertained. Their respective locations are pointed in Fig. 7 below. The buildings are:

1. ATS Greens Paradiso
2. Jaypee Greens
3. Purvanchal Height

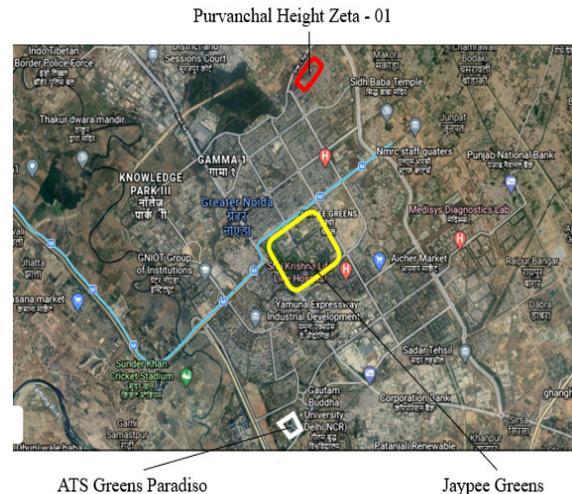


Fig. 7. Satellite Image of the Buildings' Location in Greater Noida.

1. ATS Greens Paradiso

ATS Greens Paradiso is a residential apartment located at sector CHI 4 in Greater Noida, the project was completed in 2008 by ATS Group to bridge the gaps of scarcity of the residential apartments and improve the livability index of conducive residential buildings, (Fig. 8). The site is well landscaped with greens all over, and the shape of the building which mimics the ideology of modern architecture making it aesthetically attractive and functionally conducive. The apartments provided are 3BHK and 4BHK with approximately square meters of 148.64 and 260.13 respectively. This project is distributed on a total area of 32 acres, which has 24 towers in all, comprising 14 floors each having a total of 1031 units. ATS Greens Paradiso contains some facilities like Gymnasium, Jogging track, swimming pool, etc. [38].



Fig. 8. ATS Greens Paradiso (Source: Field Work, 2020).

1a. Passive Ventilation: The amount of natural fresh air admitted in a building is determined by the openings provided and the configuration of the buildings on the site to improve the quality condition of the spaces. Passive ventilation is one of the vital attributes of biophilic architecture as it gives the residents a natural feel of fresh air as well as the sense of the outside environment. The fresh air that blows to the internal space contributes to the passive cooling in the summers and improves the conducive sense of the environment. However, ATS Greens Paradiso's apartments through the windows and the balcony connect the inhabitants to outside features and resources (Fig. 9).

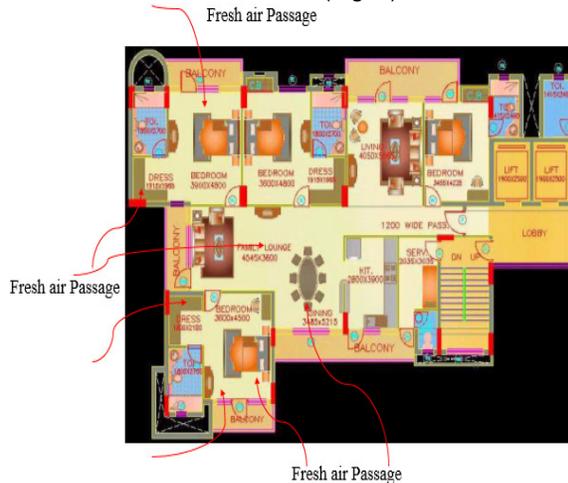


Fig. 9. Floor Plan of 4BHK Showing the Natural Ventilation Access to the Internal Spaces. (Source: Authors' Sketch, 2020).

1b. Day lighting: The orientation of a building on-site with respect to the direction of the sun is the prime determinant of the intensity of daylight received in an enclosed space [39]. ATS Greens Paradiso admits daylighting to the internal spaces through the openings, however, the direct penetration of daylighting is controlled by the shading elements for comfort of reading purpose, lighting, and improve the visibility for the inhabitants (Fig. 10).



Fig. 10. Daylighting access and control. (Source: Field Work, 2020).

1c. Plant (Vegetation): ATS Greens Paradiso is well landscaped with vegetation of different varieties. Residents of these apartments are directly connected to the landscape as well as the ecological sense of the site. In the apartment's balconies, some flower pots are arranged just to give the inhabitants a direct feel of nature. (Fig. 11). The plantation across the entire site is favorable to the inhabitants thus imparting a feel-good factor to the residential environment. ATS Greens Paradiso has done a commendable job in launching this

project into one of the most inspired green buildings through the structured plantations and they are responding to biophilic architecture as well as contributing to the relief of the occupants' stress and soothing views of the surrounding landscape (Fig. 12).



Fig. 11. Images showing flower pots and plants along the wall. (Source: Field Work, 2020).



Fig. 12. Vegetation distribution of ATS Green Paradiso (Source: Field Work, 2020).

1d. Water Bodies: The water body considered in biophilic architecture could be naturally existing water and adaptively re-used or artificially collected water. The main aim is to connect the inhabitant with the naturally existing elements, giving them a progressive feel of nature. Biophilic architecture in ATS Greens Paradiso is defined through the water body (swimming pool) situated at the center of the site imparting a sense of balance to all the occupants living in this premises, giving them an attractive view (Fig. 13). The feel of comfort is derived from this feature and the impact of this unique architecture on the occupants is quite phenomenal.



Fig. 13. The water body in ATS Greens Paradiso (Source: Field Work, 2020).

1e. Natural Materials (Stones, Bamboo, and Wood): The naturally existing materials are profane to biophilic design not only because of their impact on the comfort of living, but rather their cost efficiency, thus making them preferable for the professionals to be incorporated in different designs for different purposes. In ATS Greens Paradiso stones and bamboo were used as they complement the landscaping giving the surrounding a dynamic look with different elements (Fig. 14). The stone spread in the premises breaks the lacuna of having plants throughout, also the value addition it gives to the surrounding for the inhabitants make them generate the automatic feel of nature and enhance their comfort of mind and relieves stress.



Fig. 14. Stone and Bamboo used in ATS Greens Paradiso (Source: Field Work, 2020).

2. Jaypee Greens

Jaypee Greens has been the leading real estate developer in providing world-class residential apartments in and around Delhi NCR since 2002. It offers an environment that is incorporated with all the necessary socio-cultural activities which create a self-sufficient and sustainable environment. Jaypee Greens Greater Noida is spread across 452 acres of land and instigates the concept of Golf-centric living in India. Abundantly endowed with a fine mélange of the independent golf estate, it has resulted in a spectacular apartment complex. (Fig. 15). There are several activities, facilities, and amenities within Jaypee Greens premises to support the life of the inhabitants and improve their social well-being, they include Resort, Golf and Spa, conference & Banquet halls, the clubhouse, tempting eateries, health club, and other recreational and entertainment center to make the environment friendly and opportune [40].



Fig. 15. Jaypee Greens Apartments (Source: Field Work, 2020).

2a. Passive Ventilation: The distribution of Jaypee Greens towers was done in order to allow a free flow of natural ventilation into the internal environment. Windows and openings were adequately provided, and the configuration of the spaces was arranged to have a free flow of air without any hindrance. The positioning of the apartments concerning the windward side was done to achieve sufficient airflow and the services were located along the leeward side to define the vitality of natural ventilation in the buildings (Fig. 16). Single-aided passive ventilation was widely used in residential buildings in order to create a complex airflow pattern for the internal environment. The difficulty faced by this method is the inclination to manage the wind and temperature leading to a good indoor environment condition [41].

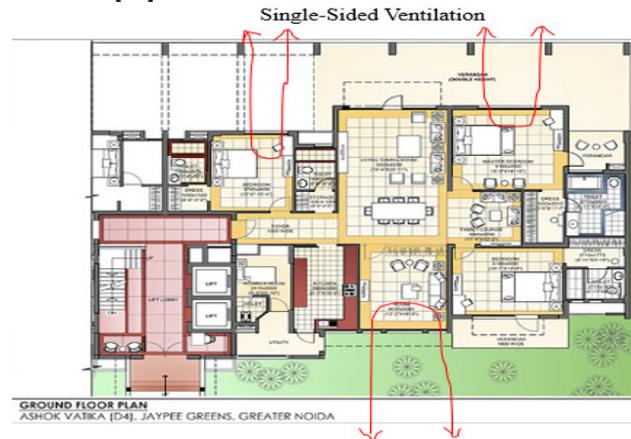


Fig. 16. Floor plan of 4BHK Apartment – Jaypee Greens (Source: Authors' Sketch, 2020).

2b. Daylighting: This is another identified biophilic element exhibited at Jaypee greens in order to improve the quality condition for the residents. Glass windows are employed in the apartments to admit natural light for quality vision, reading, and connect the occupants with the surrounding natural features (Fig. 17). In winters, the amount of daylight admitted in these apartments has a significant impact on the internal variant temperature, thereby saving the energy needed for mechanical heating.



Fig. 17. Guest room fully glazed (Source: Field Work, 2020).

Jaypee greens' orientation considers the direction of movement of the sun, giving the internal spaces a controlled way of admitting day lighting for a comfortable environment. Change of lighting condition changes the mood of the inhabitants in a building. There is no prescribed way to what lighting conditions produce a desirable mood, windows are the media through which day lighting is favored in residential apartments. However, the feeling that changes with the intensity of day lighting depend on the preference and anticipation of the occupants. Those that cherish working with day lighting find it interesting and improve their level of response to the positive mood and the comfort of their living space [42].

2c. Vegetation (Plant): Vegetation concentration in and around the building makes it more biophilic and its relevance to this distinct architecture comfort, thereby affecting the mental wellbeing of the residents. Jaypee greens as the name implies focuses on creating a greenery-friendly environment which makes the inhabitants feel at home with a constant sense of connectedness with nature. The entire site of Jaypee greens is landscaped with green features, making it one of the leading green buildings that manifest the ideology of biophilic architecture in Greater Noida. (Fig. 18). Some walls and balconies are equally attached to vegetation which contributes to the internal cooling in the summers and helps to reduce the energy needed for mechanical cooling. Vegetation is naturally captivating, its impact on the health and stress relief of the occupants is something quite exceptional. The environmental gains of the incorporated vegetation in buildings range from vision improvement, aesthetics, and social well-being of the residents. This vegetation also improves the air quality through the gaseous exchange between the occupants' exhaled air that gets absorbed by the plant for photosynthesis and releases fresh oxygen for respiration [24].



Fig. 18. Jaypee greens 4th Avenue site plan & vegetation on the wall (Source: Field Work 2020).

2d. Water Body: The water bodies found in Jaypee greens are fountains, indoor swimming pool and outdoor swimming pool. The water body is dynamically distributed across the site to serve each inhabitant the benefit of the facility and triggers their sense of connectedness with nature defining biophilic architecture. Jaypee greens provide an indoor and outdoor swimming pool for the comfort of the occupants

(Fig. 19). The aim is to keep the residents in tune with the sense of natural provision even in an enclosed space. However, it equally contributes to the interior cooling whenever the wind blows from the poolside, it alleviates the heat and dilutes the air with moisture content making it denser cooling the environment.



Fig. 19. Indoor and Outdoor swimming pool (Source: Field Work, 2020).

2e. Natural Materials (Stone, Bamboo, and Wood): Jaypee greens is completely constructed with red bricks, plastered, and has excessive incorporation of natural materials to showcase the relevance of traditional identity. Jaypee greens does not widely use natural materials in the buildings, although it is used for the final finishing in some part of the site (Fig. 20). The idea is to give the inhabitants the feel of naturally inspired materials in and around the site. "Wood is natural and healthy material by nature" [43].



Fig. 20. Natural stone used for aesthetic (Source: Field Work, 2020).

3. Purvanchal Height

Purvanchal height is located at sector Zeta 1, in Greater Noida, the project provides a sustainable and affordable residential apartment with a well-integrated idea of contemporary architecture making it unique (Fig. 21).



Fig. 21. Purvanchal height Zeta-01 (Source: Field Work, 2020).

The building was completed and ready to move in 2011 comprised of 3BHK, 4BHK, and 5BHK. Purvanchal height apartment size ranges from 170.01sqm to 372.07sqm. The project offers facilities like a gymnasium, Swimming pool, Badminton, Lawn tennis, and Jogging Track. The site location is well connected with the city, there is a very good transportation system making the site more accessible from different parts of Delhi NCR [44].

3a. Passive Ventilation: Purvanchal height employs a good design and properly positioned glass windows meant for admission of natural air to improve the indoor cooling making it more conducive in summers (Fig. 22). The building position considers the direction of the wind flow, thus offering a sense of cross ventilation among all towers. However, the spaces provided between the towers also contributes to the free flow of natural air finding its way to the interior spaces for improvement of the quality condition and providing clean air to breathe for the inhabitants (Fig. 23). The replacement of the exhausted air by the fresh air is an automatic scenario that happens either through a stack effect or wind drove ventilation. The system keeps going without any hindrance as far as there are no changes in the configuration of the internal environment [45]. In residential buildings, the design concerning the benefit of the natural world is one of the prime priorities giving the residents more chances of connecting with nature.



Fig. 22. Natural ventilation strategy in Purvanchal Height. (Source: Field Work, 2020).



Fig. 23. Site Plan of Purvanchal height showing the tower spacing for free airflow [46].

3b. Daylighting: Natural light is a part of the basic requirements of a good residential design for vision strength and temperature adjustment. The intensity of light entering the building is defined by the surface area of the medium through which the light rays penetrate. Looking at figure 22 above, natural daylighting is effectively admitted to a considerable amount because of its cogent potentials, thereby leading to improvement in the health conditions of the inhabitants. The orientation of the building was done to capture the sun rays to a controllable amount with the aid of the projected slabs as shading devices. The amount of energy used for lighting is also saved when there is a natural daylighting, its impact on the change of mood and behavior of the residents is something that holds a robust reason behind its admission. The aim of daylighting in residential buildings is to maintain a progressive balance and direction preventing glare, the aesthetic effect given by natural light create a dynamic function of views and improve the interior elegance character and comfort for the residents [47].

3c. Vegetation (Plant): Purvanchal height is ecologically sound and biophilically responsive (Fig. 23). The distribution of the green areas was done to bring nature close to the inhabitants to be inspired daily. Furthermore, it was discovered that some plants were arranged on the balconies for more closeness to nature and the feel of a relaxed mind (Fig. 24).



Fig. 24. Vegetation positioning for biophilic impact (Source: Field Work, 2020).

Vegetation is the defined biophilic element found in Purivanchal height, it has a dynamic impact on the occupants. Distribution of vegetation in Purvanchal height provides a relaxing landscape where the

inhabitants sit around and enjoy the vistas for comfort and peace of mind. Vegetation in this respect could be non-native species in as much as is serving the functions with or without human disturbance, the implication to the inhabitants remain positive [48].

3d. Water Body: The water body incorporated in Purivanchal height is the swimming pool and the fountain. The purpose is to enhance the aesthetic of the landscape as well as provide the hydrological feel of nature (Fig. 25). Waterbody improves the coolness of the entire environment through the cool breeze that substituted the lightweight air. The residents of Purvanchal heights benefit from this element for their comfort of living, beautiful vistas, and opportunities of social interactions offered by the water body.

Water is the most abundant element on the earth, it takes more than 70% of the earth giving a huge chance to be used for different applications. However, the secular aspect of integrating water in a residential apartment meant a significant concern of how valuable the element is in showcasing the identity of nature as well as its implication to the people living around [49].



Fig. 25. The water body in Purvanchal Height (Source: Field Work, 2020).

3e. Natural Materials (Stone, Bamboo, and Wood): Natural materials are other essential elements of biophilic architecture in giving a direct sense of nature and their impact on the living environment. Artificial stone and wood are found in this building surrounding landscape, to improve and compliment the sense of nature for the occupants (Fig. 26).



Fig. 26. Artificial stone and wood are used as biophilic elements (Source: Field Work, 2020).

Natural materials are less costly and they have a tremendous impact on the buildings, regardless of their biophilic application. They are equally inspired by the modern and contemporary style of architecture to improve unity. Purvanchal height incorporated the above-discussed elements alongside natural materials to make the site more biophilic, more aesthetically pleasing, and more environmentally friendly (Fig. 23).

Hundreds of researchers inferred that natural materials have a fundamental impact on the health and social well-being of the residents. Furthermore, exposure to the wood in an internal or external environment has a phenomenally positive effect on the physical freedom of space and the psychological wellbeing of the inhabitants [50].

V. RESULT AND DISCUSSION

The data collected from the inhabitants of selected case studies through the questionnaire was based on their short and long term experience with environmental attributes of biophilic architecture. The essence is to capture their feelings and comments on the impact of these elements on their health status and social well-being in their respective environment. These elements were gauged on a 5-point Likert scale (1. Excellent 2. Good 3. Fair 4. Poor 5. Very Poor) to effectively examine the performance of each determinant and its response to the environment. Male and Females respondents' experiences were captured where 84.9% and the 15.1% male and female's responses were recorded respectively (Fig. 27). However, the ages of the respondents to these questions were equally noted to have a clear picture of their age status and help to comprehend the way they perceive these elements in their environment. The age was collected on the range of 20-30, 30-40, 40-50, and 50 to above with 32.3%, 26.9%, 34.4%, and 6.5% responses respectively. (See Fig. 28)

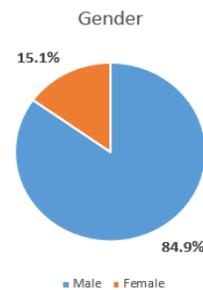


Fig. 27. Percentage of the Respondents' Gender.

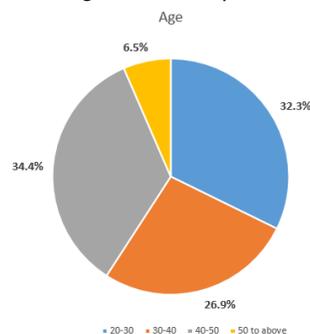


Fig. 28. Respondents' ages range.

From the table 1, on the general note it is recorded that all the five environmental elements used as parameters for this research are incomparably impacting in contributing to the occupants' health and social well-being. However, considering the excellent scale in column (1%), it is observed that vegetation contributes more to the comfort of the inhabitants with 64.2%. While water body happened to get the least percentage of

49.2% on the same column according to the respondents.

Table 1: Respondents Feedback on the Biophilic Impact of the Elements across the Three Buildings.

S/N	Elements	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
1	Passive Ventilation	49.4	39.4	7.9	2.2	1.1
2	Daylighting	53.4	36.2	9.3	0.7	0.4
3	Vegetation (Plant)	64.2	30.1	3.2	2.2	0.3
4	Water Body	49.2	37.3	10.9	2.1	0.5
5	Natural Materials	54.5	36.2	6.8	2.5	0.0

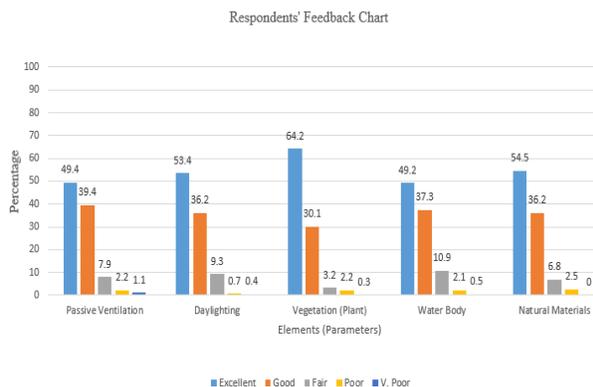


Fig. 29. Residents Perception Result on the Impact of the environmental biophilic elements on their health and social well-being across the three buildings.

The three selected buildings were assessed professionally based on the available environmental biophilic elements in each building. Similarly, the elements impact and response to the internal and external environment were acknowledged through the assessment of the buildings design and their corresponding impact to the inhabitants. On the other hand, in an attempt to compliment the findings, the questionnaire survey analysis was conducted building wise in order to collect the residents' feelings and experiences with the natural environment. However, 5-point Likert scale, open ended online questionnaire was administered to them containing the essential questions related to the environmental impact of biophilic element on the occupants' health and social well-being. Therefore, the data collected was analyzed using Microsoft excel and SPSS for the graphical representation of results and normality test respectively. From the elaborated analysis of case studies (ATS Greens Paradiso, Jaypee Greens, and Purvanchal Height) in chapter 3, the identified elements possessed by each building were thoroughly assessed as well as their impact to the building and the surrounding landscape.

VI. CONCLUSION

The incorporation of sustainable materials and techniques for the design of buildings remains a continuous routine in the construction industry. This

attempts to minimize the amount of energy consumed for the life of the building. Modern and contemporary designs employ the idea of effective integration of naturally produced resources such as natural ventilation, day lighting, water body, vegetation, and natural materials to enhance the connection of the residents with nature and improve the quality conditions and well-being of living spaces. This research looks forward to emphasizing on the impact of the environmental biophilic elements on the inhabitants' comfort of living, with evidence from the residential buildings in Greater Noida. The data gathered from each building were analyzed and the resultant effects of the data on each building in the derivation of friendly atmosphere were recorded accordingly. From the buildings' assessment, the inferences obtained on passive ventilation and daylighting were positively effective, this was discovered from the buildings orientation on-site, taking cognizance of the windward and the leeward sides as well as the sun's direction, to ascertain their performance accordingly. However, vegetation, waterbody, and natural materials were analyzed based on their location in each building and their proximity to the occupants.

On the other hand, in an attempt to obtain the robust result for this research, the residents of the identified residential buildings in Greater Noida were deeply engaged to capture their experiences with these parameters and how they respond to them. Furthermore, the data collected from the occupants through the questionnaire was analyzed and the result was represented graphically in figure 29. From the bar chart, it is inferred that the incorporation of the selected elements is temporal to the occupants' quality of living conditions. And out of the five elements used for this research, vegetation seems to be the prominent parameter that contributes a lot to the inhabitants' health and social well-being according to the residents' responses. Therefore, this research has contributions to academic literature, design professionals, and building stakeholders, first – it is apprehended that these elements perform significantly to the derivation of comfort for the occupants. Two – It helps to minimize the amount of energy needed for the enhancement of the quality condition for the residents. Three – it improves the aesthetic quality of the building and surrounding thereby giving the environment a pleasant appearance. Conclusively, from the analysis of each building and the residents' perception survey and the corresponding inferences of both tools, this paper reveals productive outcomes on the impact of these biophilic elements for the promotion of health status such as stress relief, comfortable respiration, strong vision, etc. And the improvement of quality conditions and comfort of the environment ascertained through the fieldwork analysis and residents' perception survey.

VII. FUTURE SCOPE

This research was conducted within the territory of Greater Noida India, where three land marks residential estates were used as case studies to ascertain the impact of biophilic architecture on human health. Therefore based on the findings from this study, the following future plans are proposed accordingly.

- The study encourages the incorporation of vegetation both inside and outside of the environment as it improves the comfort condition and stress relief to the inhabitants.

- It is a part of this research finding goals to disseminate the impact of these elements among the architects and stake holders to keep integrating the idea of biophilic architecture for the improvement of health, quality condition and the social environment in residential buildings.

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