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AN EXAMINATION OF CUTTING-EDGE DESIGN AND CONSTRUCTION METHODS CONCERNING GREEN ARCHITECTURE AND RENEWABLE ENERGY EFFICIENCY FOR TIER-II CITIES OF INDIA

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SUMMARY

The growing global concern about environmental deterioration and energy consumption has made green architecture and energy efficiency essential in modern construction. To improve energy efficiency, green architecture uses a variety of creative design and construction methods, which are all thoroughly reviewed in this paper. The study explores the incorporation of sustainable design concepts and highlights the significance of reducing the environmental impact of buildings. This paper examines the traditional residential project of a Tier-II city Bhopal in exhibiting environmentally benign characteristics. In addition, the use of cutting-edge building technologies, like HVAC systems with low energy consumption and smart grids, is explored as a means of maximizing energy efficiency across a building's lifetime. The combination of these technologies not only helps to reduce greenhouse gas emissions overall but also encourages energy self-sufficiency. Hence energy efficiency in the infrastructure can be promoted along with a positive approach for the environmental issues.

Key words: *green architecture, energy efficiency, environmental protection, sustainable buildings, low carbon emission.*

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INTRODUCTION

Present-day construction activity is also dependent on stakeholders' responsibilities concerning architecture and environmental issues. The present worldwide issues like climate change and the prevention of natural resources are being given preference in terms of energy efficient infrastructures which can lead to sustainable development as well. Hence a term called "green architecture" has been devised which takes care of harmony towards ecology and saving in terms of building energy requirements. [1] The current article emphasizes on the in-depth analysis of methodologies adopted for construction and cutting-edge design via green architecture concepts. Hence the idea is to not only fulfill the requirements of occupants but also to focus on innovative design parameters taking the help of architects, engineers, and construction professionals so as to mitigate adverse impacts on the environment due to urbanization [2]. Under the aegis of the green architecture concept, the present research considers several methodologies, which range from highly advanced technologies for optimizing energy usage to passive design concepts that utilize natural features [20]. This research article considers the creative design and construction methods that develop responsible structures that are environment-friendly, use sustainable construction materials which are sustainable, adopt innovation in the construction techniques, and integrate cutting-edge technologies. [3] Green architecture also demands the use of recycled materials with the integration of renewable sources of energy [4]. The success all depends on the conceptualization and effective design of constructed buildings. [39] The major goal of this article is to enhance the education and motivation of scholars, industry experts, professionals, and policymakers of the concerned industry. This review will help in setting the stage leading to sustainability in the future taking the aid of architecture in integration with the environment and protecting the health of humans and the environment. This is all possible with the integration of knowledge related to the latest trends, challenges, and breakthroughs. [5]

ARCHITECTURAL DEVELOPMENT: MANOEUVRING THE INTERSECTION OF ENERGY EFFICIENCY AND SUSTAINABILITY

There are a lot of changes and transformations experienced in the discipline of architecture concerning the depletion of resources, climate changes, and environmental deterioration. Traditionally, architecture is associated with the creation of aesthetic and pleasing infrastructures which gives priority to both functionality and design principles. However, a significant change has emerged in the 21st century, which compelled architects along with designers to develop a more holistic approach concerning environmental accountability [6]. The global environmental crisis is directly connected to architecture; although, architecture assumes an important role in developing solutions. The appreciation related to the constructed environment influences depletion of resources, consumption of energy, and carbon emissions lay down the basis of the correlation between architecture and environmental concerns. The need for sustainable and energy-efficient infrastructures is increasing as urbanization is accelerating on a global scale [7]. The development of sustainable and energy-efficient structures within the present global context cannot be ignored. The International Energy Agency has stated that the construction sector significantly leads to greenhouse gas emissions, which is responsible for approximately 39% of total emissions globally. Along with the operational carbon emissions, the inculcated carbon of materials and energy-intensive construction techniques adversely affect the quality of the building's environment [40].

Moreover, the increasing demand for energy on one side along with the availability of conventional energy resources on a larger scale, necessitates a detailed reassessment of the planning, development, and maintenance of built environments. Sustainable and energy-efficient structures not only prevent ecological losses but also fulfill broader objectives leading to resource conservation, resilience, and energy security. They provide a mould for designing urban environments that are economically feasible and environmentally sustainable over the future term [9]. The basic aim of this paper is to provide a detailed examination of the innovative design and construction technologies employed in green architecture, particularly highlighting the capacity to improve energy efficiency [10].

The objective of this article is to provide valuable insights that may illuminate and motivate architects, engineers, policymakers, and academics by exploring all possible dimensions of sustainable architecture, which includes the incorporation of renewable energy resources [11] green architecture can help in minimizing the carbon footprints which is significant for protecting the human fraternity.

The main aim of this investigation is to promote sustainable construction methodologies considering the climatic conditions, and material properties to provide comfortable living conditions to the occupants.[41]. To optimize solar gain during winter months while minimizing it during summer, achieved through the strategic placement of windows with appropriate dimensions, overhangs, and other architectural elements to either obstruct or capture solar radiation. [13] Moreover, the infrastructure shall be so designed that it facilitates airflow without reliance on mechanical systems. This often requires the strategic positioning of windows and vents to harness prevailing winds, thereby promoting airflow and maintaining an appropriate indoor climate [42]. In passive design, materials with high thermal mass, such as stone or concrete, are employed to absorb, store, and gradually release heat. This approach aids in moderating temperature fluctuations, particularly in regions characterized by diverse climatic conditions. [15] The optimization of natural light through judicious window placement and design can significantly diminish the reliance on artificial lighting. Daylighting not only enhances occupant productivity and well-being but also contributes to reduced energy consumption [16]

The structural elements absorb and retain solar heat throughout the daytime and release it gradually during nighttime, thereby stabilizing the interior temperature and alleviating the demands on heating and cooling systems. An educational facility that prioritizes daylighting integrates large north-facing windows. [17] This design enhancement not only reduces the necessity for artificial lighting but also fosters well-lit, inviting environments conducive to student learning. The utilization of passive design constantly conserves energy by significantly reducing the dependency on mechanical lighting, heating, and cooling systems [18] [12]. Simultaneously, passive design helps in reducing carbon footprints and mitigating the environmental repercussions concerned with building operations. [19]

By maintaining constant temperatures, maximizing natural light, and improving fresh air circulation, well-implemented passive design enhances indoor comfort. The passive design efficiency is affected by factors related to the site like topography, climate, and constructions in the vicinity, which might be problematic in some areas. It might be necessary to modify conventional architectural methods in order to implement passive tactics, which would mean a paradigm shift and a learning curve for designers and builders. Although passive design frequently results in long-term cost benefits, some projects with limited funding may find it difficult to implement because of the higher initial expenses [21]. In summary, passive design ideas provide a sophisticated balance between human living and the natural environment, placing them at the forefront of sustainable building. [22]

Passive design is an intelligent use of natural features to improve energy efficiency and promote harmonious cohabitation between built environments and the ecosystems they inhabit. The many advantages of incorporating passive design principles into architecture in the future for a more resilient and sustainable built environment outweigh the problems that may arise. [23]

ECO-FRIENDLY BUILDING SUPPLIES AND TECHNIQUES

The use of sustainable building materials is essential to minimizing the negative effects of construction on the environment. One of the main components of sustainable construction methods is the utilization of recycled materials. [24] This entails recycling commodities, such as recycled steel, glass, and reclaimed wood, to keep them out of landfills and drastically reduce the need for virgin resources.

Reclaimed wood is an environmentally friendly substitute for new wood, coming from either demolished structures or other applications [25]. The construction sector can lessen its carbon impact from logging and processing new wood by recycling existing wood, thus aiding in forest conservation. The energy-intensive process of producing steel has a less negative environmental impact when recycled steel is used in buildings. [26] It is possible to melt down and reform scrap steel from abandoned buildings or end-of-life items into structural components that have less of an impact on the environment while still providing strength and durability. [27] The sustainable mindset encourages the use of resources that are readily available locally while obtaining building materials. This lowers energy use and emissions associated with transportation while also boosting local economies. [28] Long-distance transportation's negative environmental effects are reduced when local sources of stone and wood are used. Using locally sourced materials supports a connection between the built environment and its natural setting and is consistent with the ideas of sustainability [29] Sand and gravel are two common materials used in construction. Choosing aggregates that come from nearby quarries not only helps to minimize the carbon footprint associated with transportation, but it also encourages the responsible mining of these resources. [30]

A paradigm change in construction methods, modular construction places an emphasis on efficiency, decreased waste, and expedited project timeframes. [31] This method entails assembling building components on-site after they have been constructed off-site in a controlled environment [32]. Green architecture optimizes material consumption in production settings and helps in waste reduction on-site. Accurate measurements and regulated environments help in reducing the waste material and preventing the environmental losses that arise during the disposal of building-demolished waste. [33] Modern construction facilities provide a vibrant atmosphere that facilitates the consumption of optimal energy related to heating, cooling, and lighting systems. The modern construction's overall energy efficiency can be enhanced by reducing emissions associated with transportation.

Prefabrication is the process of producing building modules or components off-site, and we can minimize the risk on-site by encouraging sustainability, improving resource efficiency, and speeding the construction process. Prefabrication permits the precise cutting of materials and assembly as per the requirements, which helps in maximizing resource utilization. [34] This technique is also beneficial in reducing construction site waste and promotes a better environmentally friendly building process. The project can be completed even before the deadlines by prefabrication because we can produce several components in the desired number simultaneously. The ultimate achievement is the lowering of adverse impacts on the environment associated with the different construction phases along with the cut down in the overall construction period. The environmental issues can be solved by using sustainable methods and materials in the overall phases of the project [35]. Recycled and locally available materials are used to create an infrastructure, which lessens the industry's dependency on traditional materials and thus minimizes the emissions related to transportation as well. Simultaneously cutting-edge building techniques like prefabrication and modular construction have simplified the flow of work, improved the efficiency of resources, and highlighted that this sector is dedicated to environmentally responsible ways. A resilient and ecologically favorable built environment can be created by utilizing these sustainable materials and techniques as this construction industry develops.

CUTTING-EDGE TECHNOLOGY FOR GREEN ARCHITECTURE

The quest for sustainable design has made technical breakthroughs potent enablers for increased energy efficiency. At the forefront of this revolutionary voyage are two major innovations: building automation systems and smart grids. A paradigm shift in the production, distribution, and use of energy inside the built environment is represented by smart grids. These sophisticated electrical networks make use of cutting-edge information and communication technology to improve grid stability, optimize energy use, and smoothly incorporate renewable energy sources. Demand response systems, which allow buildings to communicate with the electrical grid dynamically, are a feature of smart grids. This makes it possible to modify energy use in real-time in response to changes in the grid, price swings, and the availability of renewable energy sources. The move to a more sustainable energy ecosystem is facilitated by smart grids, which incorporate renewable energy sources like solar and wind into the grid. Smart grid-enabled buildings can effectively distribute and use renewable energy, which lessens the need for traditional power sources. By providing centralized management over multiple building systems to maximize performance and energy efficiency, building automation systems (BAS) are a prime example of the harmonious coexistence of technology and architecture. Sophisticated energy management systems that track, evaluate, and control a building's energy use are integrated into BAS. This involves adjusting the HVAC (heating, ventilation, and air conditioning) systems according to occupancy, the time of day, and outside factors. Building automation systems employ sophisticated sensors and adaptive controls to identify occupancy levels and modify ventilation, lighting, and temperature in accordance. This leads to an interior atmosphere that is more responsive and comfortable while also improving energy efficiency [43]. In conclusion, the green architecture sector is reaching previously unheard-of levels of sustainability and energy efficiency thanks to the integration of cutting-edge technologies. The way buildings interact with energy grids is being revolutionized by smart grids and building automation systems, which optimize usage and seamlessly integrate renewable sources. These technologies have the potential to completely change the field of green architecture as they develop, providing answers that are in line with the demands of environmental responsibility and the goal of creating a more sustainable built environment.

INTEGRATION OF RENEWABLE ENERGY

As the use of renewable energy resources have increased via architectural designs, a rapid change has been observed towards a built environment that is more ecologically conscious and sustainable. The energy efficiency of the buildings can be enhanced along with the reduction in carbon emission by utilizing the renewable resources of energy. Solar panels also termed as Photovoltaic (PV) cells, are the main component of green architecture which helps in integrating renewable energy. These panels are capable of absorbing the sunlight which is constantly available in countries like India, and converting it into electricity, thereby providing a sustainable and clean energy source. These panels are installed over the infrastructures, from facades to rooftops, with the help of suitable architectural designs in a way that helps into both the functional and aesthetically pleasing components of the building. Solar integration is enhanced by building-integrated photovoltaics, which smoothly incorporates solar components into a variety of architectural features. Solar façade systems, solar roof tiles, and even solar windows are used now as an exemplary example of utilizing renewable energy resources.

In addition to producing renewable energy, solar panels enhance the overall appearance of the infrastructure. Further for integrating renewable energy, the available option is wind turbines, especially in regions with ample wind resources like the Indian conditions. [36] In alignment to capture wind from all directions in addition to its compact size and capacity, vertical axis wind turbines, or VAWTs, are becoming more and more popular for use in urban environments of the countries. Hence to take advantage of this technology, architects are continuously investigating so as to improve the aesthetic appearance of the infrastructure. They can help in saving electricity, once installed on rooftops or integrated into the building structure. Innovative designs that take advantage of wind forms incorporated into the architecture of the structure are being investigated by architects. These buildings add to the building's visual attractiveness in addition to producing electricity. This utilization of wind energy raises the possibilities of creating synergy between architecture and sustainable energy generation. These renewable energy resources improve the overall sustainability of buildings by upgrading the energy efficiency of buildings. By installing these, we can reduce our dependency on conventional energy sources and the impacts on the environment caused by the usage of fossil fuels as a source of power generation. The central government of India has also initiated a scheme called PM-Surya Ghar: Muft Bijli Yojna where in 1 crore house owners have been provided subsidies in three categories on the successful installation of solar panels over their existing buildings. For installing panels of 1 Kilo Watt (KW) efficiency a subsidy of 30000 Indian National Rupees (INR) had been provided directly to the stakeholders. For 2 KW efficient panels additional 30000 INR was also disbursed. A maximum subsidy of 78000 was provided to the houses installed with panels having an efficiency of 3 KW. (Details available on the national portal: https://pmsuryaghar.gov.in) The sole objective of the government behind this initiative was to decrease carbon emissions while producing electricity as production of the same from non-renewable resources like coal is a major source of environmental pollution. Thus, infrastructures can reduce the impact of climate change by accepting solar and wind power, thus eliminating the greenhouse gas emissions linked to the production of conventional energy.

This is in line with international initiatives to move toward a sustainable, low-carbon future.

Buildings with net-zero and positive energy can be developed through the integration of renewable energy [37]. Net-zero buildings achieve a balance between energy production and consumption by producing as much energy as they consume. Buildings with positive energy go one step further by producing more energy than they consume and returning extra energy to the grid. These initiatives specify how the infrastructures can actively participate in the energy ecosystem in addition to being energy-efficient. When traditional power systems are disrupted, buildings that are outfitted with renewable energy sources become more resilient and reliable.

Through on-site electricity generation, these buildings may sustain key functions and a certain level of self-sufficiency even in the event of a grid failure. Infrastructures may demand for initial financial burden to some extent, but in the long run, financial as well as environmental benefits are stronger. renewable energy is a financially viable option since it reduces reliance on grid electricity and offers the possibility of generating income through excess energy exports. In summary, incorporating renewable energy sources into architectural plans is a revolutionary step toward the construction of robust and sustainable structures. [8] On adopting cutting-edge technologies by using renewable resources of energy like solar panels and wind turbines along with creative architecture not only improves a building's visual appeal but also establishes it as a key player in the worldwide movement towards the adoption of renewable energy. The significance of incorporating renewable energy solutions into the architectural landscape is highlighted by the influence on overall building sustainability, which can range from decreased carbon emissions to increased energy independence. The fundamental nature of buildings could be redefined as this trend develops, moving from passive structures to dynamic contributors to a future that is more ecologically sensitive and sustainable.

CASE STUDIES

Case studies derived from real-world scenarios offer profound insights into the effective application of innovative design and construction methodologies within the realm of green architecture. By examining tangible projects, one can gain an understanding of how these methodologies transition from theoretical concepts to practical implementations, thereby influencing the development of sustainable built environments. The Vertical Forest, referred to as Bosco Verticale, serves as a prominent example of green architecture in an urban context. These residential structures, designed by the esteemed Stefano Boeri Architects, are characterized by an abundance of vegetation on each balcony, inclusive of trees and shrubs. The overarching aim of the project is to enhance biodiversity, mitigate air pollution, and address the challenges associated with urban sprawl. High-density urban settings can effectively incorporate vertical landscaping, which fosters sustainability without compromising residential spaces. The integration of greenery into building designs not only enhances air quality but also provides a habitat for urban fauna.

The long-term viability of such initiatives is often challenged by the continuous labor and resources required to sustain extensive vegetation. Collaboration and meticulous planning are imperative when addressing the balance between the weight of the vegetation and the requisite structural and engineering considerations. PLP Architecture has designed The Edge, a pioneering office edifice located in Amsterdam, which employs advanced architectural practices and technologies to exemplify energy efficiency. The structure incorporates features such as energy-efficient HVAC systems, rooftop solar panels, and adaptive LED lighting. Furthermore, it utilizes an intelligent lighting system that adjusts according to occupancy and ambient light conditions. By optimizing lighting, heating, and cooling systems in real-time, sophisticated building automation systems significantly diminish energy consumption. The sustainability of the building is augmented when renewable energy sources, such as solar panels, are strategically employed. The deployment of advanced technologies necessitates a well-integrated and user-friendly interface to facilitate efficient control and management. Although initial expenses associated with the integration of complex systems may pose financial challenges, these costs can be offset over time through energy conservation.

The aesthetic integrity of architecture and the environment is illustrated at One Central Park, a project associated by landscape architect Patrick Blanc in collaboration with architect Jean Nouvel. This residential and commercial complex feature sky gardens, green walls, and Sunglass mirrors that reflect sunlight into shaded areas. This project is aligned with the principles of biophilic design, which cultivate a deep connection between individuals and the natural environment. This project has enhanced the living and working conditions while giving due respect to the environment and contributing to the well-being of occupants.

Innovative daylighting strategies, such as heliostats, can optimize the distribution of natural light within structures. The management of vegetation within high-rise edifices and their vitality is contingent upon meticulous attention to irrigation systems, soil composition, and ongoing maintenance. The integration of heliostat systems may present engineering challenges that necessitate a comprehensive understanding of the building's orientation and its surrounding environment. A holistic approach that encompasses both functional and aesthetic considerations is imperative for the successful execution of such projects. The realization of effective green architecture demands an amalgamation of technological innovations, sustainable principles, and architectural design. The prioritization of user experience is essential. Moreover, edifices that incorporate sustainable features ought to provide their inhabitants with a comfortable, functional, and visually appealing environment while also being ecologically responsible. Empirical case studies that demonstrate success illustrate the beneficial impacts of green design on communities. Initiatives that emphasize the health of both the community and the environment contribute to the establishment of a resilient and sustainable urban fabric.

One significant impediment to innovative design and construction processes may be the initial financial investment required. Addressing this challenge will necessitate the acquisition of funding and the demonstration of long-term benefits. There exist barriers in the maintenance of energy-efficient systems, sustainable features, and advanced technologies over extended periods. To ensure the longevity and effectiveness of sustainable components, building owners and managers must develop comprehensive maintenance protocols. [38] The utilization of pioneering methods could introduce regulatory hurdles, compelling developers and architects to navigate complex permitting processes. Collaboration with local governmental bodies and regulatory agencies is crucial for the alleviation of these challenges. There is a chance of difficulty while promoting awareness regarding the benefits of green architecture and support for innovative concepts. Thus, community must be engaged and effective communication needs to be established for addressing concerns and gain benefits. The conclusion states that real-world case studies can inspire the integration of innovative design and construction methodologies within green building practices. Here an analysis of the success gained and challenges faced by projects namely Bosco Verticale, The Edge, and One Central Park, we can cultivate a detailed understanding of the challenges and potential for overcoming them to achieve sustainable design. The case studies highlight the advantages of employing a comprehensive strategy, designing as per the needs of the user, and proactively facing the challenges to shape a sustainable future where green architecture is fundamentally integrated with human well-being and environmental concerns.

CASE STUDY FROM INDIA

The project SAGE Golden Spring (SGS) is located on Ayodhya Bypass Road, Bhopal, and comprises of 3, 4 and 5 BHK Bungalows, 2 and 3 BHK luxurious flats with various modern facilities such as rainwater harvesting system, swimming pools, jogging tracks, club house, Jain temple and landscaped gardens shows in table 1 & 2.

Some of the important statistics related to the project are as follows. The details of the residential project undertaken for the study has been shown. The residential project chosen has been evaluated on the basis of parameters specified in Green Rating Integrated Habitat Assessment (GRIHA) which primarily focuses on energy efficiency of buildings, effective utilization of renewable sources of energy in collaboration with the architectural aspects of the buildings for minimizing artificial energy requirements. The current case study will help in understanding the gap between the traditional residential projects in comparison to the green ones. The progress are shows in Figure 1 – 6.

Table 1. Area statement of bungalows

Unit Type	Accommodation	Plot Size (in Ft.)	Plot Area (sq. ft.)	Built Up Area (sq.ft.)
B	5 BHK	22*60	1320	3560
C	4 BHK	22*50	1100	3000
D	3 BHK	18*50	900	2210

Table 2. Area statement of flats

Unit Type	Accommodation	Carpet Area (in Ft.)	Built Up Area (sq. ft.)	Super Built Up Area (sq.ft.)
C1	3 BHK	1080	1184	1515
C2	3 BHK	1080	1184	1515
C3	2 BHK	900	973	1275

Figure 1. Entrance view of SGS

Figure 2. Construction of multi storey Buildings in progress

Figure 3. Construction of Duplexes

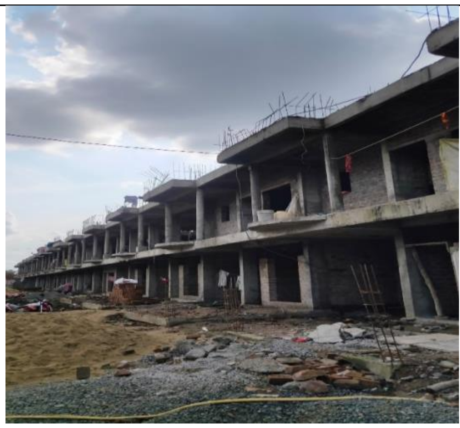

Figure 4. Ready Bungalows in campus in progress

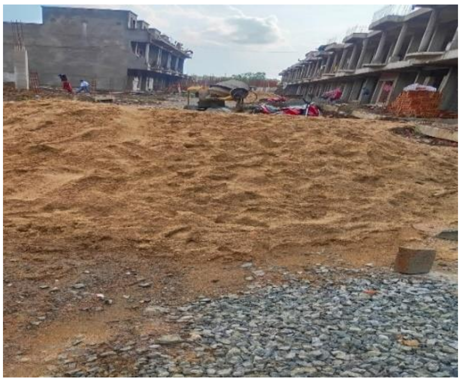

Figure 5. Post construction phase

Figure 6. Top view of site under construction (SGS)

The selected project is falling short of 1 star rating by 7 marks which can be recovered by taking suitable measures as specified by GRIHA. The table 3 & 4 below gives the Marking scheme under GRIHA checklist, for Sage Golden Spring project, evaluated based on the same [14].

Table 3. Evaluation system of GRIHA (GRIHA Manual 2019)

S. No.	Points scored	Rating
1	50-60	One star
2	61-70	Two stars
3	71-80	Three stars
4	81-90	Four stars
5	91-100	Five stars

Table 4. Marks gained by SGS as per 34 criteria of GRIHA (GRIHA Manual 2019)

Criteria			Sage Golden Spring	
S. N.	**Clause**	**Points**	**Applicable**	**Committed**
1. Selecting the site	Partly Mandatory	1	1	1
2. Landscape protection during construction/compensatory depository forestation.	Partly Mandatory If applicable	5	5	4
3. Conserving soil (post construction)	-	2	2	2
4. Designing while including existing site features	-	4	4	2
5. Reduction in hard pavements on site	Partly Mandatory	2	2	1
6. Uplifting external lighting system efficiency		3	3	1
7. Sustainable planning of utilities and optimizing on-site circulation efficiency		3	3	2

8. Providing basic sanitation/safety facilities to the construction workers	Mandatory	2	2	1
9. Minimizing air pollution while constructing	Mandatory	2	2	1
10. Reducing the water requirements of landscape		3	3	1
11. Minimizing the use of water in building		2	2	1
12. Utilizing water efficiently during construction		1	1	1
13. Designing building to reduce demand of non-renewable energy	Mandatory	8	8	3
14. Utilizing the building energy performance under specified limits of comfort	Partly Mandatory	16	16	4
15. Consumption of fly-ash in building structure		6	6	5
16. Ways of reducing construction time by utilizing technologies like pre-cast construction, RMC etc.)		4	4	2
17. Using material having lower energy in interior of buildings		4	4	2
18. Utilizing renewable energy in construction	Partly Mandatory	5	5	0
19. using hot- water system based on renewable energy		3	3	0
20. Arrangements of treating waste water		2	2	1
21. Recycling & reusing water (even rainwater)		5	5	1
22. Ways of minimizing construction waste		1	1	1
23. Segregating the construction waste		1	1	0
24. Storing and disposing construction wastes		1	1	1
25. Ways of recovering resources from waste		2	2	0
26. Using paints and products having low VOC.		3	3	2
27. Minimizing substances causing ozone depletion	Mandatory	1	1	0
28. Ways of maintaining water quality	Mandatory	2	2	1
29. Maintaining noise in interior and exterior		2	2	0
30. Neglecting use of Tobacco and smoke	Mandatory	1	1	1
31. Providing accessibility for persons with disability		1	1	1
32. Conducting audit of energy, waste and water.	Mandatory	-	-	-
33. Protocols for Operating and maintaining electrical and mechanical equipment's	Mandatory	2	2	0
34. Adopting innovative methods (beyond 100)		4	4	0
TOTAL		104	104	43

PROSPECTIVE PATTERNS AND DIFFICULTIES

The domains of energy efficiency and sustainable architecture are advancing rapidly in response to the global challenges posed by climate change and the depletion of natural resources. Emerging paradigms suggest a transformative future wherein the constructed environment will be reimagined at the confluence of innovation, sustainability, and resilience. The integration of biophilic design principles is poised to emerge as a predominant theme within the realm of sustainable architecture. Biophilic design prioritizes the incorporation of natural patterns and elements into built environments to foster a robust connection between inhabitants and the natural ecosystem. The prevalence of expansive windows, vertical greenery, and living roofs is set to increase, thereby optimizing natural light and cultivating healthier and more inspiring living and working spaces. Prospective advancements indicate that buildings achieving net-zero and positive energy outcomes will become widespread. The renewable energy utilization not only fulfils the energy requirements of infrastructure but also generates additional energy which can contribute towards the establishment of a more regenerative and sustainable energy landscape. The projections of sustainable architecture in the future will be defined by the effective exploration and consumption of innovative, sustainable materials and technologies.

The highly skilled Architects and engineers are expected to employ advanced materials which can get repaired themselves or being capable to respond during fluctuating environmental conditions, thereby helping to enhance the durability, sustainability, and efficiency of structures. The construction sector is undergoing a transformative change which is driven by continuous innovations in the construction materials such as carbon-negative concrete and transparent photovoltaic panels. The invention of digital twin technology is offering substantial opportunities for utilizing building performance throughout their expected lifespan. A digital twin thus represents a virtual counterpart of a physical building, which utilizes for monitoring, modeling, and analyzing various parameters such as energy consumption, occupancy patterns, and the soundness of the structure. The positive aspect of this technology is that it enables real-time adjustments for improving energy efficiency, the expected maintenance, and to improve the overall performance of the building. Along with the substantial progress in energy efficiency and sustainable design which is anticipated in the upcoming years, there are various challenges which must be addressed to ensure the global adoption of these transformative practices. One of the principal barrier or obstruction to the implementation of cutting-edge green technologies is the economical barrier associated with their development.

The mix of latest and advanced technologies, sustainable energy alternatives, and smart construction materials may involve a considerable initial financial outlay. A change in perspective towards the anticipation of long-term returns on investment, combined with the establishment of financial instruments to promote sustainable construction, can surmount this challenge. The only significant barrier to the extensive implementation of eco-friendly construction methodologies is the lack of clearly established frameworks and regulatory norms. The availability of diversified standards and regulations based on the different regions also aids to the complication in adopting innovative practices. Thus the solution is to develop a comprehensive and universally accepted set of policies, norms and regulations which incentivizes sustainable development. Although the public awareness is gaining momentum but still a considerable portion of population is unable to grasp the advantages and importance of green construction. The public needs to be educated and shall have acceptance for gaining the long-term benefits associated with sustainable building practices. The industry's adaptability is hindered by the rapid pace of technological advancement. The major challenge is the lack of skill among the labour force and their adaptability to understand the latest technologies easily. Thus the integration of sustainable methodologies along with the allocation of financial resources toward educational and training programs can focus on bridging this skills gap. The infrastructure can be an energy efficient and net zero energy building if it possesses a resilient and adaptive infrastructure.

One of the most challenging task to align all the stakeholders of this industry towards a single direction wherein the role of policy makers, developers, builders, labour operating on site and most importantly the buyers of these green infrastructures are knowing the long term benefits and willingly playing their individual roles. The government shall also try to promote such energy efficient infra by providing a lucrative incentive so that the technique of green technologies can be widely adopted. Inconsistent policies are actual hindrance in the path of sustainable development and widespread adoption of green architecture and energy-efficient practices. For overcoming this challenge, coordination of global policy is vital.

SUGGESTIONS AND ENDORSEMENTS

Governments and policymakers should make sincere efforts to facilitate the promotion of green architecture by implementing detailed legal frameworks and felicitation via financial incentives to the stakeholders. If we wish to accelerate the innovative design and construction methodologies, it can be achieved through the establishment of legislation, providing subsidies, and tax incentives that promote everyone to follow the sustainable practices. In lieu of enhancing the proficiency in green architecture among respected stakeholders like engineers, architects, and construction professionals, it is essential to foster educational and training programs which specifically aims at sustainable development. Also, the academic curriculum shall be integrated with the sustainable practices and innovative technologies which provides opportunities for ongoing professional development, and can ensure that the workforce is aligned in the same direction of applying the advanced methodologies. Still a few people are aware about the advantages of green construction technologies, advantages of green architecture and energy efficient buildings, hence it is equally important to improve public awareness through campaigns which can educate communities about the benefits associated with environmentally sustainable building practices. When the awareness among the public related to their health and environment will accelerate, surely the demand for sustainable construction techniques will also arise. Hence a lot of research and development is expected in the field of green architecture and green infrastructure. The human brain is expected to invest in innovative projects and research initiatives, novel materials, technologies, and construction techniques. Thus, the scope for sustainable construction and design will gain momentum. Promoting the collaborations in form of partnerships between the two academic institutes or industries or between public and private sector will aid to achieve the goals in a far better way. This will be a beneficial step to promote knowledge sharing among the stakeholders of diversified fields along with the selection of best construction practices. This will enhance the adoption of green architecture and energy efficient infrastructures.

CONCLUSIONS

It is concluded that the examination of cutting-edge design and construction methods in green architecture represents how sustainable techniques and practices can significantly alter the development of built environment in the future. This technological field of green architecture is quickly changing, from advanced technologies and integrated renewable energy to passive design principles and materials leading to sustainability. The advantages of implementing these techniques and strategies are presented by the success stories found in present-world case studies. The sustainable development can be achieved by combining aesthetics and e responsibility towards the environment, as depicted by the projects like Bosco Verticale, The Edge, and One Central Park. Future trends in green architecture comprises of digital twin technology, net-zero energy buildings, and biophilic design are gaining large attention, and the hence the path of green architecture is in the direction of a well-balanced mix of creativity, practicality, and responsibility towards environment. For achieving revolutionary changes and strategies to be globally used, it is important to address issues including financial restrictions, regulatory frameworks and requirements, increasing public awareness, integration of technology, and global collaboration.

Indian case study demonstrates that by implementing the guidelines provided in Green Rated Integrated Habitat Assessment (GRIHA) a tool for assessing green buildings, followed widely for green construction in India, the innovations and parameters associated for energy efficiency in the buildings can be adopted. Various criterion is focused specifically for improving the architecture and energy efficiency of the structures. Some of the criterion are mandatory whereas others are optional as per GRIHA. These suggestions are helpful to the interested parties in laying a supportive atmosphere which encourages the techniques required for environmentally friendly building. In broad sense energy efficiency and green architecture is a combined effort which requires cooperation and dedication of legislators, industry experts, educators, and members of the public along with architects. By following the principles of sustainable design, we can establish a physical environment which not only fulfils the demand of present world but lays a strong foundation of a sustainable and prosperous future for future generations.

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