iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** V **Month of publication:** May 2024

DOI: https://doi.org/10.22214/ijraset.2024.62576

Green Building Innovation: Analysis and Design of Sustainable Commercial Structure by using BIM

Shruti Agarwal[1], Pawan Khandare[2], Tanmay More[3], Suraj Ninave[4], Gaurav Nivalkar[5]
Department of Civil Engineering, Zeal college of engineering and Research, Pune-411041

Abstract: This project explores the utilization of Building Information Modeling (BIM) as a cornerstone for designing and analyzing sustainable commercial structures. With a growing emphasis on environmentally responsible construction practices, BIM emerges as a pivotal digital platform facilitating the creation, analysis, and optimization of green building designs. Employing a systematic methodology encompassing data collection, market surveys, building planning, analysis and design, 3D visualization, cost comparison, and results discussion, this research investigates the efficacy of BIM in fostering sustainability within commercial construction projects.

Various software tools including AutoCAD, STAAD Pro, SketchUp, and Excel are leveraged at different stages to support the project's objectives. Through meticulous examination, the project underscores BIM's role in enabling comprehensive environmental assessment, energy simulation, safety enhancement, and integration with Internet of Things (IoT) technologies. Moreover, the study elucidates both the advantages and limitations inherent in the BIM software and analysis tools utilized, while also shedding light on external factors that may impact the applicability of the project's findings.

In conclusion, this research reaffirms BIM's potency as a robust tool for designing green buildings, offering insights into its multifaceted capabilities and its potential to drive sustainable practices in commercial construction. By delineating key findings, this study contributes to the ongoing discourse surrounding sustainable architecture and underscores the imperative role of BIM in shaping the future of environmentally conscious building design and development.

Keywords: Building Information Modeling (BIM), sustainable construction, green building design, environmental assessment, energy simulation, commercial structures, software tools, AutoCAD, STAAD Pro, SketchUp, Excel, 3D visualization, cost comparison, sustainability, IoT technologies.

I. INTRODUCTION

Building Information Modeling (BIM) is a process of creating and managing digital representations of the physical and functional characteristics of buildings and infrastructure. BIM enables collaboration, optimization, and innovation across the project life cycle, from planning and design to construction and operation 123. BIM is the foundation of digital transformation in the architecture, engineering, and construction (AEC) industry, and it has the potential to deliver better outcomes for business and the built environment.

The concept of green building, aimed at creating structures that minimize resource consumption, enhance occupant well-being, and reduce environmental impacts, has gained momentum over the past few decades. However, what truly distinguishes the current era is the seamless integration of sophisticated software tools into the heart of sustainable design and construction processes. Building Information Modelling (BIM), energy simulation software, sustainable design optimization tools, and other digital solutions have become indispensable allies for architects, engineers, and developers committed to delivering eco-conscious and high-performance commercial buildings.

Green building is a concept of constructing high-performance structures that have minimal or no negative impacts on the environment throughout the project life cycle.

Green building aims to enhance energy efficiency, limit water consumption, reduce waste generation, and use recycled, recyclable, and non-toxic materials 456. Green building is also known as sustainable building or eco-friendly building, and it is aligned with the principles of environmental, social, and economic sustainability.

The purpose of this report is to explore the relationship between BIM and green building, and to examine how BIM can facilitate the implementation of green building practices and standards.

The report will also discuss the benefits and challenges of using BIM for green building, and provide some recommendations for future research and development.

II. LITERATURE REVIEW

1) *Building Information Modelling (BIM) Applications in Smart Buildings: From Design to Commissioning and Beyond*

This paper critically evaluates the use of BIM in smart buildings across their lifecycle stages. It highlights advancements and challenges in integrating BIM with design, construction, operation, and renovation processes. Emphasis is placed on BIM's contributions to environmental assessment, energy simulation, safety, and IoT technologies. Additionally, the paper addresses data sharing challenges between BIM and other software tools, advocating for enhanced interoperability and standardization.

2) *Building Information Modeling (BIM) for Green Buildings: A Critical Review and Future Directions*

This paper presents a critical review of the relationship between BIM and green buildings, introducing the "Green BIM Triangle" framework. It categorizes this relationship based on project phases, green attributes, and BIM attributes, elucidating how BIM supports various aspects of green building development. The paper also underscores the necessity for improved interoperability, accurate prediction models, industry-wide standards, and wider acceptance of green BIM in practice.

3) *Efficiency Improvement in Polycrystalline Solar Panels Using Thermal Control Water Spraying Cooling*

This paper introduces a technique to enhance polycrystalline solar panel performance through a microcontroller-based water spraying system. It describes the method's implementation, which includes utilizing an Arduino board to monitor panel temperature and activate a water pump for cooling. Results indicate a notable efficiency improvement compared to panels without cooling, emphasizing the system's affordability, space efficiency, and ease of setup.

4) *Experimental Characterization of a Geothermal Cooling System for Enhancement of Solar Photovoltaic Panels Efficiency*

This paper presents a geothermal cooling system designed to improve solar photovoltaic panel efficiency by reducing temperature. It details the system components and testing conducted in Spain, demonstrating a substantial panel temperature reduction and efficiency improvement. The paper concludes that the system is effective, particularly in warmer regions, for enhancing solar panel performance.

5) *Green Building Assessment Tool (GBAT) for Integrated BIM-Based Design Decisions*

This research introduces an integrated approach combining BIM and a sustainable data model for designing and certifying green buildings. It describes the framework's utilization of IFC-based property sets, a green materials database, and a GBAT for streamlined documentation required for BREEAM certification. The paper validates the framework through a sample project, discussing its benefits, limitations, and potential for adaptability.

6) *Potential Features of Building Information Modeling (BIM) for Application of Project Management Knowledge Areas in the Construction Industry*

This paper explores BIM's potential to enhance project management knowledge area (PMKA) application in construction. Through a literature review, it identifies key factors and BIM features enhancing PM capabilities. The paper concludes that BIM significantly enhances construction project performance through integration, collaboration, communication, and informed decision-making.

7) *Software Module for Automating the Calculation of Building Structures*

This paper introduces a software module for automating building structure calculations, specifically focusing on multilayered monolithic reinforced concrete slabs. It describes the module's fuzzy logic and computer modeling, highlighting its potential to reduce time, labour, and financial costs while improving calculation precision.

8) *BIM-Based Surface-Specific Solar Simulation of Buildings*

This paper presents a BIM-based approach for surface-specific solar simulations of buildings, aimed at planning and designing photovoltaic (PV) modules. It utilizes BIM and CityGML to capture building properties and surroundings, offering insights for comprehensive solar panel layout planning.

9) *Recent Progress on BIM-Based Sustainable Buildings: State of the Art Review*

This paper discusses the application of BIM in eco-friendly building design, examining its collaboration with tools like Life Cycle Assessment and Energy Modeling.

It identifies challenges such as data availability, interoperability issues, and lack of standards and training, proposing future directions including adaptable models and the utilization of emerging technologies like digital twins and artificial intelligence.

III. PROBLEM STATEMENT

The problem statement is to develop effective strategies that can seamlessly integrate green design principles into the Building Information Modelling (BIM) process. The integration of green design principles into the BIM process is a challenging task that requires the development of new strategies and techniques. The aim is to create a sustainable built environment that is energy-efficient, environmentally friendly, and cost-effective. The integration of green design principles into the BIM process can help architects, engineers, and builders to design and construct buildings that are more sustainable and energy-efficient.

IV. METHODOLOGY

A. Data Collection

Green building practices prioritize creating environmentally responsible structures, incorporating features such as energy efficiency, water conservation, sustainable materials, indoor air quality, and waste reduction. These efforts are often validated through certification systems like LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method).

Building Information Modeling (BIM) plays a crucial role in facilitating efficient planning, design, and operation of sustainable buildings. BIM digitally represents a building's characteristics, encompassing 3D modeling, data integration, collaboration, and simulation. By leveraging BIM technology, project outcomes are improved, leading to optimized resource efficiency and enhanced building performance.

In sustainable commercial construction, the focus lies on minimizing environmental impact, conserving resources, and ensuring occupant health and comfort. Strategies include passive design, energy-efficient systems, water management, and the use of green materials. Financial incentives and certifications further encourage the adoption of sustainable practices.

Many green building projects worldwide have embraced BIM technology to optimize sustainability and efficiency. Notable examples include:

1) *One Central Park, Sydney:* Utilized BIM to integrate green technologies like heliostat mirrors and vertical gardens for energy efficiency and natural ventilation.
2) The Crystal, London: BIM facilitated collaboration in designing sustainable features such as solar panels and rainwater harvesting systems.
3) Shanghai Tower, China: BIM streamlined the planning and construction of this iconic skyscraper, incorporating wind turbines and energy-efficient lighting.
4) The Edge, Amsterdam: BIM enabled real-time coordination in implementing energy-efficient systems and smart controls.
5) Pixel Building, Melbourne: BIM played a pivotal role in achieving net-zero energy and carbon-neutral design through passive strategies and renewable energy systems.

Sustainable design principles encompass passive design, optimal site planning, energy efficiency, water conservation, material selection, indoor environmental quality, and life cycle assessment. Sustainable materials include recycled materials, renewable materials, low-emission finishes, high-performance insulation, sustainable concrete, and green roofing. Sustainable technologies comprise photovoltaic systems, energy-efficient lighting, smart building systems, water-efficient fixtures, passive heating and cooling, and heat recovery ventilation.

Certification standards such as LEED, BREEAM, WELL Building Standard, and Passive House evaluate buildings based on criteria such as energy efficiency, water conservation, materials selection, indoor air quality, and occupant health.

BIM software and tools are essential for sustainable construction, offering capabilities such as clash detection, energy analysis, life cycle assessment, cost estimation, facility management, and sustainability assessment. By utilizing these tools, stakeholders can optimize building performance, enhance collaboration, and achieve sustainability goals effectively.

B. Study of Green Building

Green building, also known as sustainable building emphasizes environmentally responsible and resource-efficient processes throughout a structure's lifecycle. Key features include energy efficiency, water conservation, and the use of sustainable materials, indoor air quality, and waste reduction.

The integration of green materials in construction holds tremendous potential to revolutionize building practices, offering not just environmental benefits but also economic and social advantages. Consider the following examples and their wide-ranging benefits:

1) *Recycled Materials:* Embracing reclaimed wood, recycled steel, and recycled glass not only reduces the strain on virgin resources but also diverts significant amounts of waste away from landfills, promoting a circular economy and mitigating environmental degradation.
2) *Bamboo:* This rapidly renewable resource, with its versatile applications in flooring, cabinets, and structural elements, not only provides a sustainable alternative to traditional hardwoods but also supports local economies due to its widespread cultivation in various regions worldwide.
3) *Cork:* Sourced from the bark of cork oak trees without causing harm, cork emerges as a renewable and environmentally friendly material suitable for flooring, insulation, and wall coverings. Its unique properties contribute to thermal insulation, acoustic performance, and indoor air quality enhancement.
4) *Straw Bale:* As a natural and renewable insulation material, straw bales offer exceptional insulation properties while significantly reducing environmental impact. Their use in walls and roofs not only enhances energy efficiency but also supports agricultural communities through the utilization of crop residues.
5) *Recycled Concrete:* Incorporating recycled concrete aggregate (RCA) in construction not only reduces the demand for virgin aggregates but also curtails carbon emissions associated with concrete production, fostering a more sustainable approach to infrastructure development.
6) *Fly Ash:* As a by-product of coal combustion, fly ash finds new life as a supplementary cementations material in concrete production. Its utilization not only reduces the carbon footprint of concrete but also enhances its durability, prolonging the lifespan of structures.
7) *Low-VOC Paints and Finishes:* The adoption of low or zero-VOC paints and finishes not only improves indoor air quality by minimizing harmful emissions but also safeguards the health and well-being of occupants, particularly in enclosed environments.
8) *Energy-Efficient Windows:* Installing energy-efficient windows equipped with high-performance glazing offers multifaceted benefits, from reducing heat gain and loss to enhancing occupant comfort and lowering energy consumption, thus contributing to overall sustainability goals.
9) *Green Roofs:* Green roofs, adorned with vegetation, serve as natural insulators, stormwater management tools, and biodiversity hotspots while mitigating the urban heat island effect and improving air quality, fostering healthier and more resilient urban environments.
10) *Cellulose Insulation:* Crafted from recycled paper fibbers, cellulose insulation presents an eco-friendly alternative to conventional fibreglass insulation, delivering superior thermal performance, energy efficiency, and reduced environmental impact.

C. Building Planning

For building planning AutoCAD is used.

Followings are the plans:

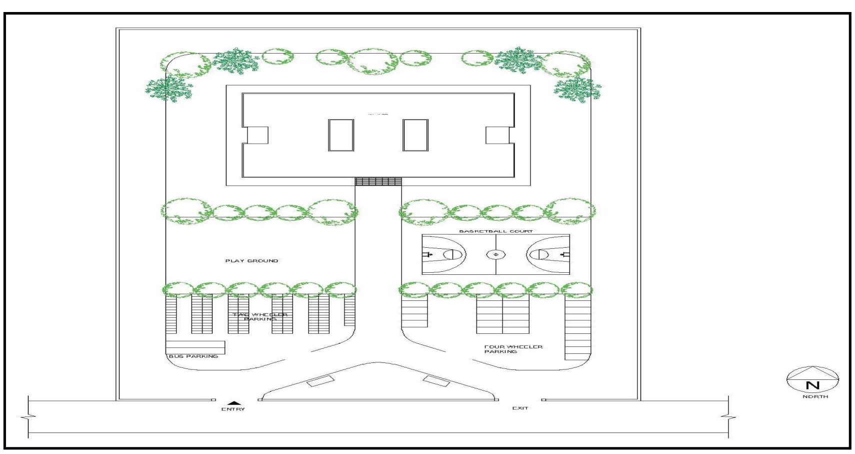


Fig 1. AutoCAD Plan

D. Material Calculations

It is done by Excel
Built-up area: 72,570.28 sq.ft
Approximate cost per sq.ft: 1,500 Rs
Total Construction Cost: 108,855,300 Rs

1) Material Requirements and Costs

a) Cement

Required: 29,028.08 bags
Cost: 17,852,269.20 Rs

b) Sand

Required: 59,217.28 tons
Cost: 13,389,201.90 Rs

c) Aggregate

Required: 44,122.68 tons
Cost: 8,055,292.20 Rs

d) Steel

Required: 290,280.80 Kg
Cost: 26,778,403.80 Rs

e) Paint

Required: 13,062.64 litters

f) Bricks

Required: 580,561.6 Pcs

g) Flooring

Required: 94,341.26 sq.ft

h) Finishers

Cost: 17,961,124.50 Rs

i) Fittings

Cost: 24,819,008.40 Rs

2) Solar Panel Calculations

Average energy consumption: 360,000 kWh per year
Monthly unit consumption: 30,000 kWh
Daily unit consumption: 1,000 units/day
Rooftop capacity: 223 kW
Number of solar panels: 670
Area required for rooftop: 21,185 sq feet (1,968.1509 sq meters)

3) Capacity of Water Tank

Water Consumption Estimate: 337,500 litters/day
Storage Tank Capacity: 1,012,500 litters
Selecting a Water Tank: 31,347 litters (for two tanks).

E. Building Description and 3D Visualization

Fig 2. 3D Front View

Fig 3. 3D Side view

Fig 4. 3D view

F. Market Survey
Most data in the construction industry is sourced through the Schedule of Rates (SoR), a comprehensive document listing the rates charged for various tasks by contractors.

However, for a more realistic understanding and enhanced accuracy, consulting with experienced project managers, who possess firsthand knowledge and expertise, adds invaluable insight.

The Schedule of Rates serves as the cornerstone of project estimation, providing a structured framework for evaluating costs across different aspects of construction.

Its meticulous categorization of tasks and associated rates enables contractors and project stakeholders to generate precise and consistent estimates, facilitating informed decision-making and budgetary planning.

Essentially, the SoR acts as a roadmap for contractors, guiding them in determining project costs and allocating resources efficiently.

By standardizing rates and procedures, it promotes transparency and fairness in the bidding process, ensuring that contractors compete on an equal footing and clients receive competitive pricing for their projects.

The Central Public Works Department (CPWD) in India, among other regulatory bodies, plays a pivotal role in formulating and disseminating SoR, alongside manuals and technical publications.

These authoritative documents serve as industry benchmarks, reflecting prevailing market rates and best practices, thus enhancing the credibility and reliability of project estimates.

Moreover, the SoR's adaptability allows for customization according to project-specific requirements and regional variations, catering to diverse construction contexts and ensuring relevance across different geographic locations.

In summary, the Schedule of Rates serves as a vital tool in the construction industry, providing a standardized framework for cost estimation, facilitating fair competition, and ensuring the accuracy and consistency of project budgets. Its collaboration with experienced project managers further enriches the data collection process, enriching it with practical insights and real-world expertise.

G. Analysis
For Analysis Etab software is used ETABS (Extended Three-Dimensional Analysis of Building Systems) is a structural analysis and design software program used by structural engineers and designers in the building industry.

It's developed by Computers and Structures, Inc. (CSI), a leading software company specializing in structural and earthquake engineering software.

ETABS allows engineers to analyze and design buildings of various sizes and complexity. Some key features of ETABS include:

1) *Three-Dimensional Modeling:* ETABS enables users to create three-dimensional models of building structures, including beams, columns, slabs, walls, and frames. The software supports various structural systems such as concrete, steel, composite, and timber.
2) *Analysis Capabilities:* ETABS provides advanced analysis capabilities for linear and nonlinear static and dynamic analysis. It can simulate the behaviour of structures under various loading conditions, including gravity loads, lateral loads (such as wind and seismic loads), and temperature effects.
3) *Design and Code Compliance:* ETABS offers comprehensive design capabilities for structural elements based on various design codes and standards, including international building codes (IBC), Euro code, ACI, AISC, and others. Engineers can perform design checks for reinforcement, member sizes, and detailing to ensure compliance with design requirements.
4) *Integrated Environment:* ETABS provides an integrated modeling and analysis environment that allows users to seamlessly transition between modeling, analysis, and design tasks. Changes made to the model are automatically reflected in the analysis results, streamlining the design process and reducing errors.
5) *Visualization and Reporting:* ETABS offers powerful visualization tools for viewing analysis results, including deformations, stresses, and mode shapes. Users can generate detailed reports, drawings, and animations to communicate their findings and design solutions effectively.

Overall, ETABS is a versatile and powerful software tool for structural engineers and designers, offering comprehensive analysis and design capabilities for building structures. It's widely used in the industry for the design of high-rise buildings, residential complexes, industrial facilities, and other types of structures

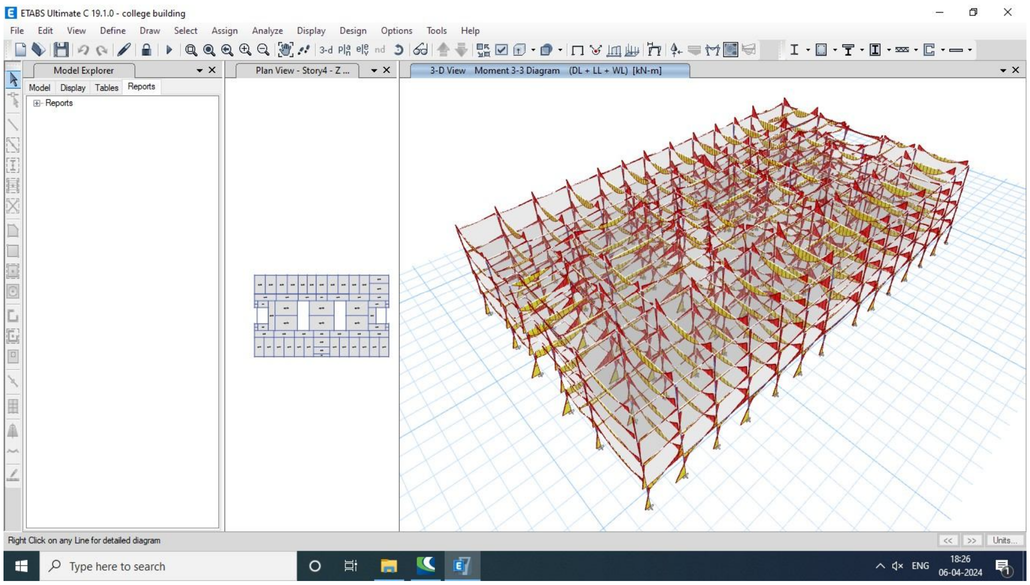


Fig 5. Etab Analysis

V. CONCLUSIONS

The adoption of Building Information Modeling (BIM) for the design and analysis of sustainable commercial structures represents a pivotal shift in the realm of green building innovation. BIM's multifaceted capabilities revolutionize traditional approaches to construction by offering a comprehensive platform for collaboration, visualization, and optimization throughout the entire building lifecycle. By harnessing BIM's power, stakeholders can seamlessly integrate sustainability principles into every phase of a project, from initial conceptualization and design to construction, operation, and eventual decommissioning.

Moreover, BIM facilitates the exploration of various sustainable strategies and technologies, allowing designers to experiment with energy-efficient systems, renewable materials, passive design principles, and more. Through detailed simulations and analyses, BIM enables stakeholders to evaluate the environmental performance of different design alternatives, identifying opportunities to enhance efficiency, reduce resource consumption, and mitigate environmental impacts. Furthermore, BIM's ability to centralize data and streamline communication fosters greater collaboration among interdisciplinary teams, including architects, engineers, contractors, and facility managers. This collaborative approach promotes knowledge sharing, innovation, and continuous improvement, driving the adoption of best practices and emerging technologies in sustainable design and construction. As sustainability continues to be a paramount concern in the built environment, the integration of BIM offers a transformative solution for addressing complex environmental challenges. By facilitating the creation of high-performance, environmentally responsible commercial structures, BIM not only meets the growing demand for sustainable buildings but also paves the way for a more resilient and resource-efficient built environment. Ultimately, the widespread adoption of BIM in green building initiatives heralds a new era of innovation, where technology and sustainability converge to shape the future of architecture, construction, and urban development.

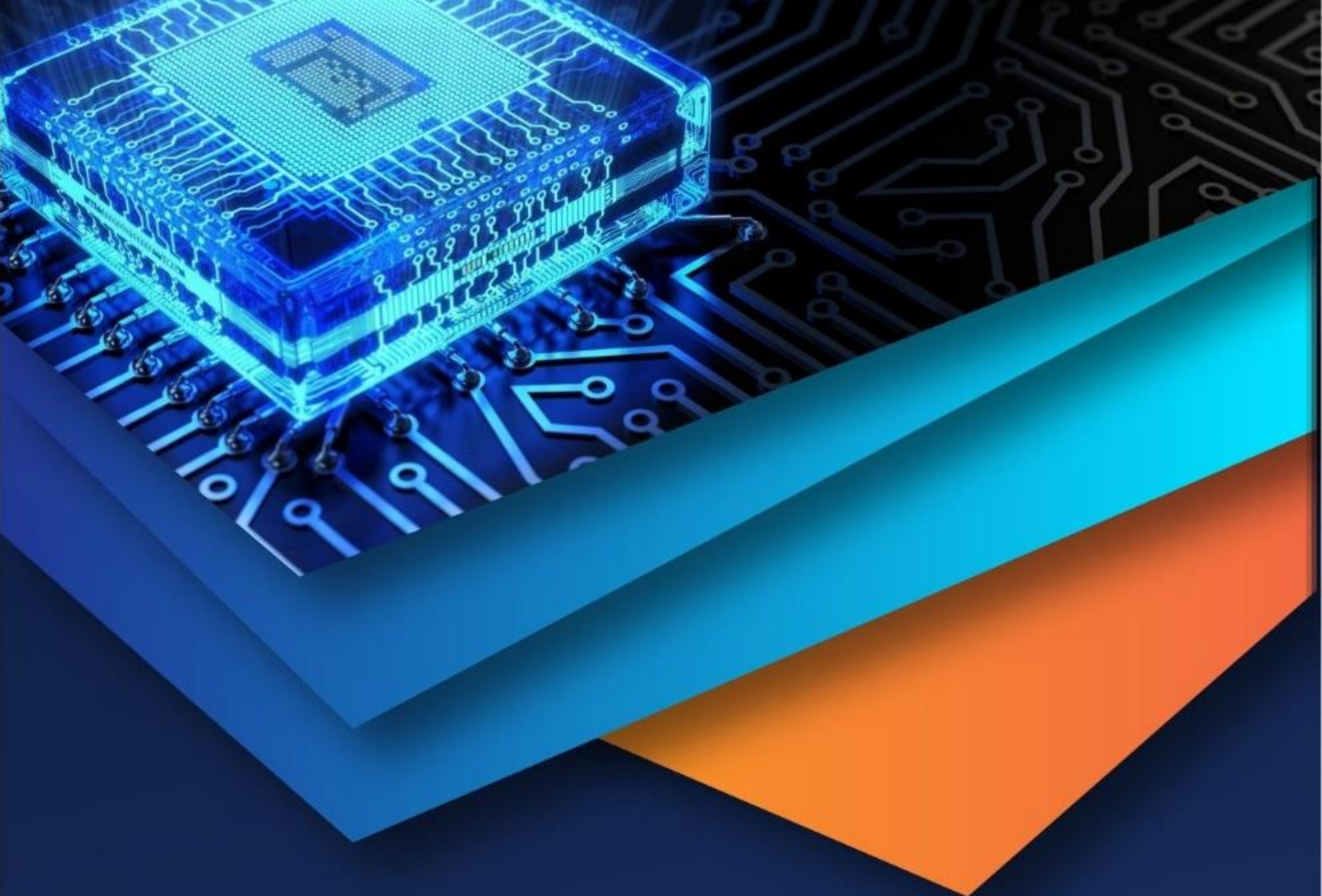
VI. ACKNOWLEDGMENT

We would like to express our deepest appreciation to all those who provided us the possibility to complete this report. A special gratitude we give to our final year project guide, PROF. S. S. Agarwal. Her direction and whole hearted in inspiration have been of the greatest help to us in bringing out this work in its present shape. The advice and route provided by him was very helpful in implementation of this project.

Many thanks go to the head of department Prof. P. P. Walvekar who allowed and motivated us to work on the topic. We have to appreciate the guidance given by other supervisors as well as the panels especially in our project presentation that has improved our presentation skills thanks to their comment and advice. We are also thankful to Principal Dr. A. M. Kate for his valuable support.

REFERENCES

[1] https://www.sciencedirect.com/
[2] https://sci-hub.se/
[3] Schedule of rate for Pune 2019-20d4f4e7f7e963905e6954e8eecb015615879b868958c2ba811869559d40e6fedd.xlsx (maharashtra.gov.in)
[4] Schedule of rate for Maharashtra 2023-24 MJP-SSR-2023-24_Final.pdf (maharashtra.gov.in)
[5] Green building - Wikipedia. https://en.wikipedia.org/wiki/Green_building.
[6] Green Building in India: Eco-friendly House Concept, Council, Materials.... https://housing.com/news/green-building/.
[7] Basic Information | Green Building |US EPA. https://archive.epa.gov/greenbuilding/web/html/about.html.
[8] Green Building Information Gateway - GBIG. https://www.gbig.org/.
[9] https://www.gettyimages.com/detail/photo/green-building-royalty-free-image/533747483.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY