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Binishell Construction with Integration of BIPV System

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Abstract: *This project presents an innovative Binishell Construction System integrated with Building Integrated Photovoltaics (BIPV) to achieve sustainable, economical, and energy-efficient building construction. Binishell technology utilizes pneumatic formwork to create dome-shaped shell structures, reducing construction time, material consumption, and overall cost while providing improved structural stability and earthquake resistance. A 3D model was developed using Revit, and structural analysis was performed using STAAD.Pro to evaluate safety and performance. The integration of BIPV panels enables on-site renewable energy generation, enhancing the environmental sustainability of the structure. The results indicate that the proposed system offers significant advantages over conventional RCC construction in terms of construction speed, cost-effectiveness, and energy efficiency, making it a promising solution for modern sustainable infrastructure development.*

Keywords: Binishell Construction, Building Integrated Photovoltaics (BIPV), Sustainable Buildings, Pneumatic Formwork, Renewable Energy, STAAD.Pro, Revit, Energy-Efficient Construction

I. INTRODUCTION

The construction industry is continuously seeking innovative techniques that can reduce construction time, material consumption, and environmental impact while maintaining structural safety and durability. Conventional reinforced concrete construction methods often require extensive formwork, labor, and resources, resulting in increased project costs and longer construction periods [1]. As sustainable development becomes a global priority, alternative construction technologies that improve efficiency and support renewable energy integration are gaining significant attention [2].

Binishell construction is an advanced building technique developed by Dante Bini that utilizes pneumatic formwork to create thin-shell concrete structures. In this method, a flexible membrane is inflated using air pressure to form a dome shape, after which reinforcement and concrete are applied to create a strong and lightweight shell structure [3]. Due to its curved geometry, the Binishell system provides excellent load distribution, structural stability, and resistance to seismic forces while requiring less construction material than conventional buildings [4].

The dome-shaped architecture of Binishell structures offers several advantages, including reduced construction time, lower maintenance requirements, improved thermal performance, and enhanced structural efficiency [5]. These characteristics make Binishell technology suitable for residential buildings, schools, disaster-relief shelters, industrial facilities, and other infrastructure projects where rapid and economical construction is required [6].

Simultaneously, the increasing demand for clean and renewable energy has encouraged the adoption of Building Integrated Photovoltaics (BIPV). BIPV systems integrate photovoltaic panels directly into building components, enabling structures to generate electricity while serving as part of the building envelope [7]. Unlike traditional rooftop solar installations, BIPV systems improve architectural aesthetics and optimize the utilization of available surface area for energy generation [8].

The integration of Binishell construction with BIPV technology creates a sustainable building solution that combines structural efficiency with renewable energy production. The large curved surface area of the dome provides an opportunity for installing photovoltaic panels to generate electricity and reduce dependence on conventional energy sources [9]. This approach contributes to energy conservation, reduction of carbon emissions, and promotion of environmentally responsible construction practices [10].

II. PROBLEM STATEMENT

The construction industry faces significant challenges related to high construction costs, lengthy project completion times, excessive material consumption, and increasing environmental concerns. Conventional building methods often rely on energy-intensive materials and non-renewable power sources, which contribute to higher operational expenses and carbon emissions. There is a growing need for a construction approach that is structurally efficient, cost-effective, and environmentally sustainable. Binishell technology offers a promising solution through its lightweight dome-shaped shell structure, while the integration of Building Integrated Photovoltaics (BIPV) enables on-site renewable energy generation. Therefore, this project aims to develop and analyze a Binishell construction system integrated with BIPV technology to achieve faster construction, reduced resource utilization, improved structural performance, and enhanced energy sustainability.

III. OBJECTIVES

- To study the concept and construction methodology of Binishell technology.
- To develop a 3D model of the Binishell structure using Revit software.
- To perform structural analysis of the proposed system using STAAD.Pro.
- To integrate Building Integrated Photovoltaics (BIPV) for renewable energy generation.
- To evaluate the structural efficiency and sustainability of the proposed system.

IV. LITERATURE SURVEY

Bini (1967) introduced the Binishell construction technique, which utilizes pneumatic formwork to create thin-shell concrete structures. The study demonstrated that dome-shaped shells can be constructed rapidly with reduced material usage while maintaining structural strength. This innovative approach significantly decreased construction time and labor requirements compared to conventional methods.

Bini and Salvadore (2014) examined the evolution and modern applications of Binishell technology. Their research highlighted the structural efficiency, durability, and sustainability of shell structures, particularly in regions prone to earthquakes and extreme weather conditions. The study also emphasized the potential for large-span construction with minimal material consumption.

Shaikh, Patel, and Tam (2024) presented a case study on Binishell thin-shell structures and analyzed their construction methodology and performance. The authors reported that Binishell buildings offer better load distribution and reduced dead load compared to traditional RCC structures, making them economical and structurally efficient.

Patel (2024) investigated the practical implementation of Binishell construction techniques. The study concluded that pneumatic formwork technology simplifies the construction process and reduces overall project costs. However, specialized expertise and careful execution are required to ensure quality and structural safety.

Serretta, Bonomo, and Frontini (2017) studied Building Integrated Photovoltaics (BIPV) as an effective solution for sustainable building design. Their research showed that integrating photovoltaic panels into building envelopes enables renewable energy generation while maintaining architectural functionality, thereby reducing dependence on conventional energy sources.

Mellone, Taldeo, Berto, and Di Resta (2024) analyzed the structural behavior and architectural significance of Binishell structures. The study highlighted the advantages of combining innovative shell construction with modern sustainable technologies such as BIPV systems, resulting in energy-efficient, environmentally friendly, and economically viable building solutions.

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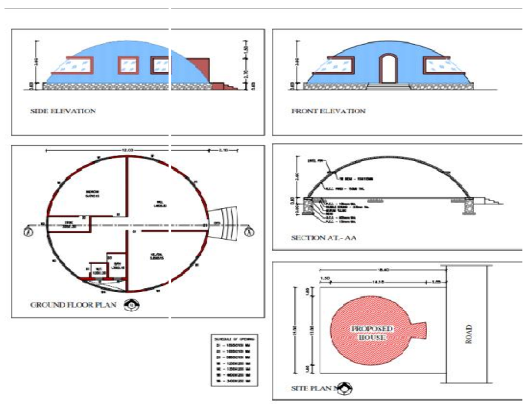
Comparison Table

Author & Year	Method Used	Advantages	Limitations
Bini (1967)	Pneumatic formwork-based Binishell construction	Fast construction, reduced material use	Requires specialized equipment
Bini & Salvadore (2014)	Analysis of modern Binishell applications	Lightweight and earthquake-resistant structures	Limited awareness and adoption
Shaikh et al. (2024)	Case study of Binishell thin-shell structures	Better load distribution, lower dead load	Skilled labor required
Patel (2024)	Binishell construction technique evaluation	Cost-effective and time-saving	Quality control is critical
Serretta et al. (2017)	Building Integrated Photovoltaics (BIPV) analysis	Renewable energy generation, sustainability	High initial installation cost
Mellone et al. (2024)	Structural analysis of Binishell systems	Energy-efficient and eco-friendly design	Complex design and analysis process



V. WORKING OF SYSTEM

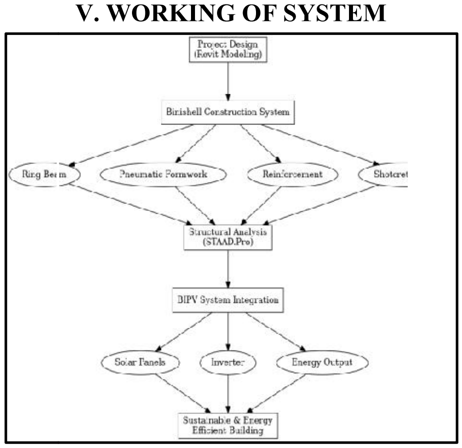


Fig 1: Design of the system

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1. Project Design (Revit Modeling)

The process begins with the development of a three-dimensional model of the proposed Binishell structure using Revit software. The architectural and structural components are designed to visualize the dome geometry, dimensions, and placement of Building Integrated Photovoltaic (BIPV) panels. This stage helps in planning and coordination before actual construction.

2. Binishell Construction System

The Binishell construction system forms the core of the project. It uses a pneumatic formwork technique to create a dome-shaped shell structure that is lightweight, strong, and economical. The construction process consists of the following components:

a) Ring Beam

A circular reinforced concrete ring beam is constructed at the foundation level. It acts as the base support and provides stability to the entire dome structure by transferring loads safely to the ground.

b) Pneumatic Formwork

A flexible membrane is attached to the ring beam and inflated using air pressure. The inflation process lifts the membrane into the desired dome shape, eliminating the need for conventional formwork.

c) Reinforcement Placement

After achieving the required dome shape, reinforcement bars or mesh are placed over the inflated membrane. The reinforcement provides the necessary tensile strength and structural stability to the shell.

d) Shotcrete Shell Formation

Concrete is sprayed over the reinforced membrane using the shotcrete technique. Once hardened, it forms a thin-shell dome structure capable of carrying various structural loads efficiently.

3. Structural Analysis (STAAD.Pro)

The completed structural model is analyzed using STAAD.Pro software. Different loading conditions such as dead load, live load, and wind load are applied to evaluate stresses, deflections, and overall structural performance. The analysis ensures that the structure remains safe and stable under operating conditions.

4. BIPV System Integration

After validating the structural safety, Building Integrated Photovoltaic (BIPV) panels are installed on the dome surface. The curved shell provides sufficient area for solar energy harvesting while maintaining the architectural appearance of the building.

a) Solar Panels

The photovoltaic panels capture solar radiation and convert it into direct current (DC) electricity. These panels serve as both building components and energy-generating elements.

b) Inverter

The generated DC power is supplied to an inverter, which converts it into alternating current (AC) suitable for operating electrical appliances and building loads.

c) Energy Output

The converted electrical energy is utilized within the building or supplied to the grid. This reduces dependence on conventional electricity sources and lowers operating costs.

5. Sustainable and Energy-Efficient Building

The integration of Binishell construction and BIPV technology results in a sustainable building system. The structure offers reduced construction time, lower material consumption, improved structural efficiency, renewable energy generation, and long-term economic benefits. The final system provides an environmentally friendly solution for modern infrastructure development.

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VI. SYSTEM DESIGN

1. Project Design (Revit Modeling)

The system design starts with the creation of a 3D model using Revit software. The architectural layout, dome geometry, and structural components are planned and modeled to visualize the proposed Binishell structure before construction.

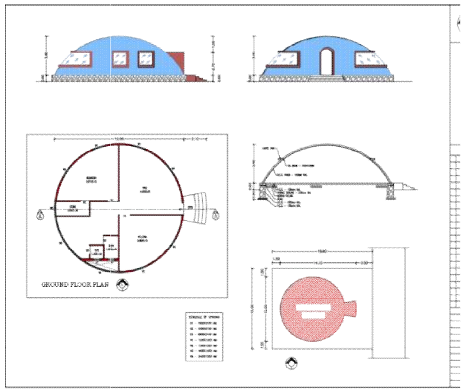

Fig.2. 3D view

2. Binishell Construction System

The Binishell construction system forms the primary structural framework of the building. It consists of the following sub-components:

a) Ring Beam

A reinforced concrete ring beam is constructed at the base level to provide support and stability for the dome structure. It acts as the foundation element that transfers loads safely to the ground.

b) Pneumatic Formwork

A flexible membrane is attached to the ring beam and inflated using compressed air. The inflated membrane creates the required dome shape and serves as temporary formwork during construction.

c) Reinforcement

Steel reinforcement mesh is placed over the inflated membrane. The reinforcement improves the strength and durability of the shell and helps resist tensile stresses.

d) Shotcrete Shell

Concrete is sprayed over the reinforced membrane using the shotcrete method. After curing, a thin-shell concrete dome is formed, providing structural stability and efficient load distribution.

3. Structural Analysis (STAAD.Pro)

The completed Binishell model is analyzed using STAAD.Pro software. Various loading conditions such as dead load, live load, and wind load are applied to evaluate stresses, deflections, and overall structural performance. This step ensures the safety and reliability of the structure.

4. BIPV System Integration

After structural validation, Building Integrated Photovoltaic (BIPV) technology is incorporated into the dome structure. The BIPV system consists of the following components:

a) Solar Panels

Photovoltaic panels are installed on the dome surface to capture solar radiation and generate direct current (DC) electricity.

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b) Inverter

The generated DC electricity is supplied to an inverter, which converts it into alternating current (AC) electricity suitable for household and commercial applications.

c) Energy Output

The converted electrical energy is used to meet building energy requirements or can be supplied to the power grid, reducing dependence on conventional energy sources.

5. Sustainable and Energy-Efficient Building

The final output of the system is a sustainable building that combines the structural advantages of Binishell construction with renewable energy generation through BIPV technology.

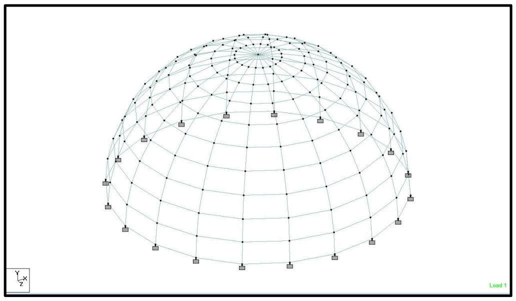
VII. RESULTS

1. Revit 3D Model Development

The proposed Binishell structure was successfully modeled in Revit software. The 3D model represents a dome-shaped residential building with integrated doors, windows, and ventilation openings. The model demonstrates the architectural feasibility of Binishell construction and provides an accurate visualization of the final structure. The dome geometry ensures efficient space utilization and improved structural stability.

Fig.3.3D Model

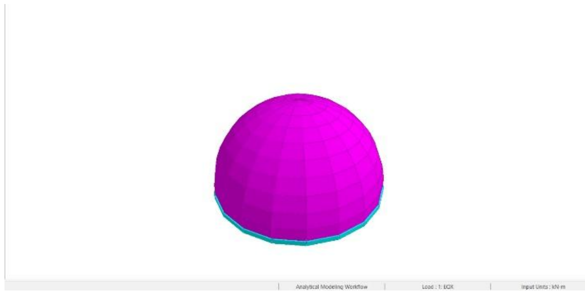
2. Structural Modeling and Analysis



The developed Binishell dome was Designed into STAAD.Pro for structural analysis. A finite element mesh was generated over the shell surface to simulate the structural behavior under loading conditions. The dome structure was supported on peripheral nodes representing the ring beam foundation. The analysis model confirmed proper load transfer from the shell surface to the supports through the curved geometry of the dome.

3. Structural Performance

The STAAD.Pro analysis indicated that the dome shell remained stable under the applied loading conditions. The curved shell geometry distributed loads uniformly across the structure, minimizing stress concentration and reducing bending effects. No significant structural instability or excessive deformation was observed during the analysis, confirming the safety of the proposed design.



4. Architectural and Functional Performance

The Revit model showed that the Binishell structure can accommodate essential residential spaces while maintaining an aesthetically pleasing appearance. The provision of windows and openings ensured adequate natural lighting and ventilation within the structure. The dome form also contributes to improved thermal performance compared to conventional buildings.

5. Cost and Time Comparison

The proposed Binishell construction system demonstrated considerable savings in construction time and cost when compared with conventional RCC construction.

Parameter	**Binishell Construction**	**Conventional RCC Construction**
Built-up Area	114 sq.m	114 sq.m
Total Cost	□17,81,830	□22,80,000
Construction Time	60–90 Days	120 Days

The results indicate a cost reduction of approximately **21.85%** and a significant reduction in project completion time.

6. BIPV Energy Generation Performance

The integration of Building Integrated Photovoltaic (BIPV) panels enhanced the sustainability of the proposed system.

Parameter	**Value**
Dome Area	114.93 sq.m
Number of BIPV Panels	115
Theoretical Output	23 kWh/hour
Actual Output	10–12 kWh/hour
Daily Energy Generation	60 Units
Monthly Energy Generation	1800 Units
Monthly Income (@ □3/unit)	□5,400
Monthly Savings (@ □10/unit)	□18,000

The results demonstrate that the BIPV-integrated Binishell can generate substantial renewable energy, reducing dependence on conventional electricity sources and lowering operational costs.

VIII. CONCLUSION

The present study successfully demonstrated the design and analysis of a Binishell Construction System integrated with Building Integrated Photovoltaics (BIPV) for sustainable and energy-efficient building development. A 3D model of the dome structure was developed using Revit, and structural analysis was carried out using STAAD.Pro to evaluate its performance under loading conditions. The analysis confirmed that the dome-shaped shell structure provides efficient load distribution, structural stability, and safe performance. Compared to conventional RCC construction, the proposed system offers reduced construction time, lower material consumption, and significant cost savings. The integration of

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BIPV panels enables renewable energy generation, reducing dependence on conventional power sources and improving the overall sustainability of the building. Therefore, the Binishell with BIPV system can be considered a practical, economical, environmentally friendly, and innovative solution for modern construction requirements.

IX. FUTURE SCOPE

The future scope of the proposed Binishell Construction with BIPV System is significant in the field of sustainable infrastructure development. Advanced materials such as fiber-reinforced concrete and high-performance composites can be incorporated to further enhance structural strength and durability. The system can be integrated with smart building technologies, IoT-based energy monitoring, and automated energy management systems for improved operational efficiency. Future research can focus on optimizing the placement and efficiency of BIPV panels on curved dome surfaces to maximize energy generation. The Binishell concept can also be expanded for large-scale applications such as residential townships, educational institutions, commercial buildings, disaster-relief shelters, and industrial facilities. Additionally, the integration of energy storage systems, rainwater harvesting, and green building technologies can transform the proposed structure into a self-sustaining and environmentally responsible building solution for future smart cities.

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