# A CASE STUDY: BINISHELLS (THIN SHELLS)

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**ABSTRACT**: BiniShells Construction revolutionizes architecture with an innovative blend of sustainability and aesthetics. Originating from the visionary ideas of the Bini family, the company employs reinforced concrete shells to craft resilient and visually captivating structures. Through meticulous design and assembly processes, BiniShells minimizes waste and environmental impact while ensuring structural integrity. Diverse case studies showcase the versatility of BiniShells' technology across residential, commercial, and public projects, highlighting its adaptability and impact on the built environment. Despite facing challenges, including adoption barriers, BiniShells remains steadfast in its commitment to sustainable, human-centered construction practices. Looking forward, the company aims to continue shaping a built environment that is both resilient and aesthetically pleasing, contributing to a more sustainable future for generations to come.

**KEYWORDS**: Binishell, Intricacies, Anchors, Collaboration, Tolerances, Inflation, pneumatic, impregnated

## I. Introduction

Binishells are a form of reinforced concrete thin shell structures that are lifted and shaped by air pressure. This innovative construction technology was invented in the 1960s by Dante Bini. The process involves casting thin reinforced concrete shells on the ground and then raising them with pneumatic formwork. The Binishell system has been used to construct over 1,600 structures in 23 countries.The original Binishells are typically circular in plan and can be constructed rapidly, often in less than an hour. They have been utilized for various purposes, including schools, housing, sports arenas, and even tourist villages. The technology has evolved over time, and recent advancements have been made by Dante Bini's son, Nicoló Bini, who has integrated modern materials and passive heating/cooling technologies to enhance the system's sustainability and architectural flexibility.The latest Binishell technology has moved away from relying on air pressure and instead uses tensile forces to shape the building envelope into a parabolic hyperboloid. This allows for a rectangular floor plan and multi floor capabilities, among other advantages. Binishells stand out for their speed of construction, cost effectiveness, and architectural versatility, making them a unique solution in the field of sustainable building technologies.

**Construction of Binishells**

### A. FOUNDATION

Foundation takes the form of a circular reinforced concrete ring-beam footing. This structure isn't just there to support the dome; it acts as a sort of tension ring, pushing back against both the downward and internal pressures the dome faces. Various factors come into play when designing this foundation, including the size of the dome, its intended use, local building codes, national standards, and insights from soil reports.

1. Concrete Quality
The concrete used must meet specific standards for strength, aggregate size, air entrainment, water-cement ratio, and slump. Soil conditions may require adjustments to the concrete mix for enhanced durability.

2. Soil Conditions and Construction Method
Different soil conditions may necessitate different construction methods, such as excavating trenches or using forms. Precision in shaping the top surface of the footing is crucial for proper attachment of the inflatable form.

3. Reinforcement
Reinforcement materials must meet strict standards and undergo thorough inspection. They are typically placed on cribbing within the foundation area before being covered and connected to the fabric form.

4. Anchors

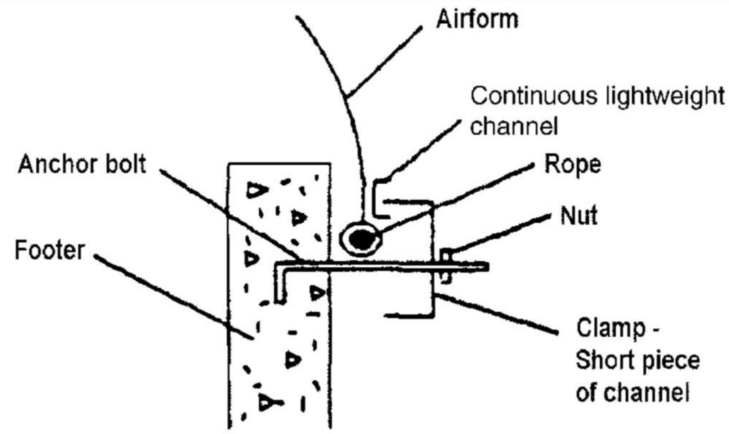


Fig No 2. Anchors System

Various anchor systems are available to secure the inflated form to the foundation ring beam, ensuring proper load transfer. Accurate positioning is crucial, as is maintaining an adequate seal to prevent air leakage.

5. Concrete Placement
Concrete placement follows specific guidelines, with attention paid to construction joints and consolidation techniques. Before applying shotcrete to the dome shell, the foundation must be cleaned thoroughly.

6. Foundation Dowels
If required, vertical dowels are bent and secured to connect the dome with the footing, ensuring proper reinforcement. Measures are taken to prevent uplift, including considerations for the dome's shape and adding ground anchors if necessary.

7. Uplift Prevention
Designing the foundation to resist uplift is essential, with factors like the concrete foundation weight and potential ground anchors taken into account. Asymmetrical shapes require additional consideration to prevent horizontal movement.

**B. INFLATED FORMS**

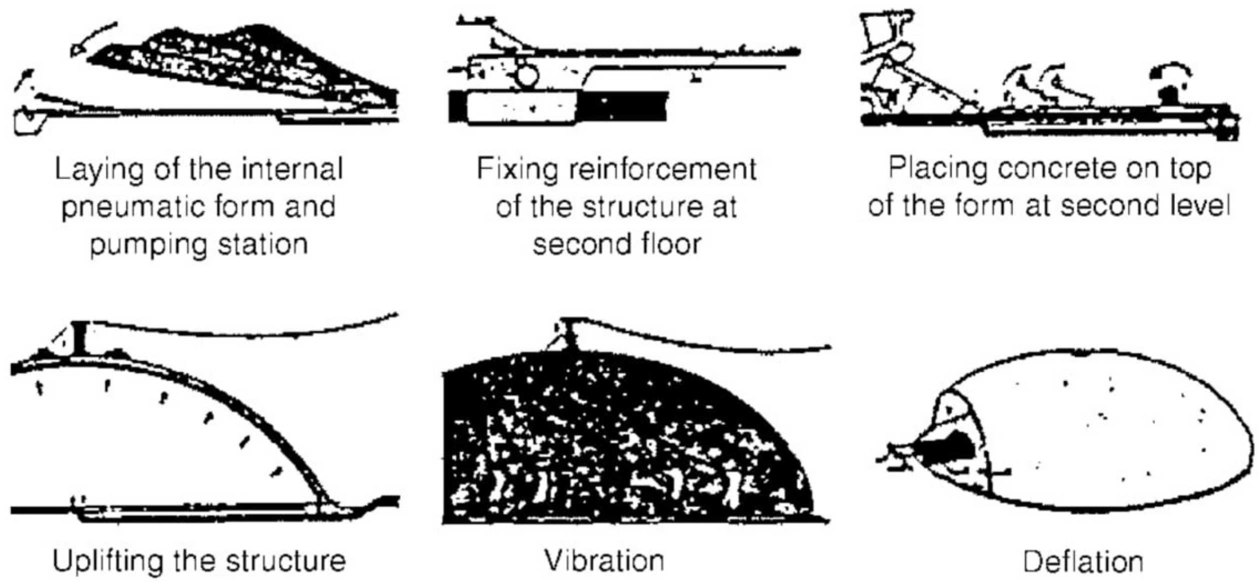


Fig No. 3. Inflated Forms Process of Binishell

1. General
- Fabric forms are single-ply membranes that stretch when attached to the foundation.
- Predicting the exact dimensions of inflated forms is challenging due to variables like weather and fabric material.
- Tolerances should be within 3% of the total height of the design.

2. Inflated Form Material and Manufacturing
- Shapes include spherical, ellipsoidal, barrel, and cylindrical. Contact the manufacturer for shape limitations.
- Sizes up to 260 ft in diameter and 130 ft high have been built.
- Common fabrics are polyester scrim impregnated with PVC, with weights ranging from 16 to 51 oz/yd2.

3. Field Layout
- Carefully unfold and fasten the form to the foundation at predetermined locations.
- Avoid using sharp instruments and unrolling on wet ground or sharp objects.

4. Form Protection
- Pad items that can damage the form. Vertical dowels should be padded.
- Equipment needed inside should be placed before form attachment and padded.

5. Initial Stretching
- Stretch the form evenly during attachment to minimize folds or wrinkles.
- Apply tension on the bottom edge to stretch the form.

6. Inflation
- Inflate the form as fast as practical, avoiding winds over 15 mph.

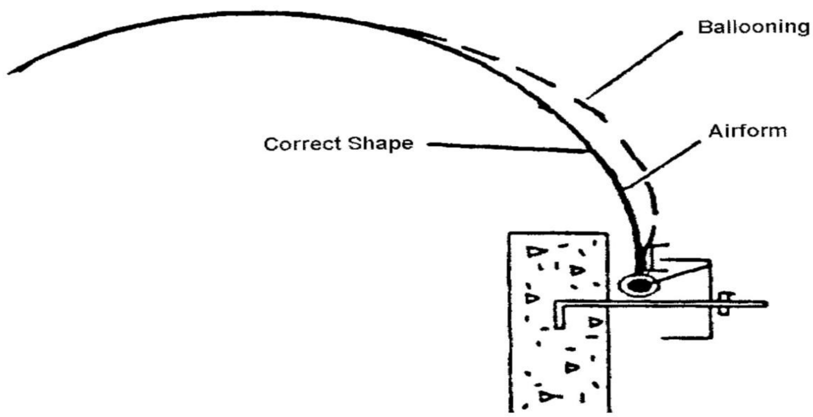


Fig No. 4. Inflated Forms Process

- Use one or more sets of inflators, monitoring and adjusting pressure as needed.

7. Construction Tolerances
- Tolerances are within ±3.0% of the design radius of curvature.

8. Air Pressure Maintenance
- Maintain air pressure within the manufacturer's recommended tolerance.
- Backup air pressure systems are recommended for safety.

9. Collapse Prevention
- Prevent local sags to avoid total collapse of the structure.
- Poor craftsmanship during the shotcrete process can lead to failures.

10. Miscellaneous Connections
- Allow for flexibility in connections to accommodate deviations from the assumed final shape.

11. Fabric Form Repair
- Tears or cuts can be field-repaired with heat welding, gluing, or riveting strips of fabric.

## C. SHOTCRETE

1. General Shotcrete Information:
   - Shotcrete is mortar or concrete pneumatically projected onto a surface.
   - It should be pumpable through the required length of hose, properly encase reinforcement, and meet project-specified compressive strength (minimum 3000 psi).

Fig No. 4. **Shotcrete**

   - Shotcrete mixture should have a maximum water-cementitious material ratio of 0.55.

2. Reinforcement Material and Size:
   - Reinforcement should comply with ACI 506.2.
   - The maximum size of reinforcement should be No. 11 (No. 36) bar.
   - Adequate encasement of bars should be demonstrated for sizes greater than No. 5 (No. 16).

3. Clear Spacing Between Bars:
   - Minimum recommended clear distance between parallel reinforcing bars is 2.5 inches (60 mm).
   - Clear spacing can be reduced if proper encasement is demonstrated by preconstruction tests.

4. Splices:
   - Splices should be done with mechanical or contact lap splices.
   - Lap splices should be firmly wired together to add stiffness to the reinforcement grid.
   - Minimum clear spacing of 2 inches (51 mm) between bars is recommended for noncontact lap splices.

5. Cover:
   - Shotcrete should provide a minimum of 3/4 inch (20 mm) cover between the reinforcement and the foam.

6. Preliminary Reinforcement Mat:
   - Premat of reinforcing bars may be placed in larger domes for additional stiffness and strength during construction.

7. Shell Reinforcement:
   - Structural dome reinforcement should be placed according to contract documents.
   - Shotcrete is applied in layers of 0.25 to 2 inches thick, allowing each layer to set before applying the next.

8. Curing:
   - Shotcrete should be kept above 40°F (4°C) and in a moist condition during the curing period.
   - Curing should continue for 7 days or until the specified compressive strength is achieved.

9. Placement Tolerance:
   - Small voids around reinforcing bars are generally tolerated, but continuous voids indicate poor shotcrete practice.

10. Damage and Repair:
   - Defective shotcrete should be removed and replaced while still plastic.
   - The designer and contractor should agree on repair methods and extent.

11. Completion:
  - Air pressure should remain constant until the structure is self-supporting.
  - Finish work can begin after completion of shotcrete operations.

## II. LITERATURE SURVEY

[1] **Andrea Menardo** ; Shells are lightweight, span long distances with minimum use of materials, provide thermal mass and are proved to have a very long design life. In an industry where sustainability has become paramount, and where architecture tends towards dynamic and fluid forms, it is imperative for the engineer to reconsider shells during the design process.The paper illustrates the latest developments in construction techniques and material sciences adopted by the modern shell builders. [2]**Will Mc Lean** ; The work of architect Dante Bini and in particular his Binishell system for lightweight 'domed' concrete shells developed in the early 1960s was technologically inventive, but remained largely a niche construction product looking for a client. It was arguably the exposure of Bini's ideas following his demonstration Binishell at Columbia University, New York that both legitimised this new technology and launched Bini's career. Throughout that career as variously an architect, inventor and builder Dante Bini has utilised the inexpensive, safe and ubiquitous material of air as a motive force and forming medium. Common to almost all his projects the use of differential air pressure as a means to lift and form heavy materials like concrete embodies an approach, which is both influenced by the great concrete craftsman architect Pier Luigi Nervi and simultaneously the "doing more with less" philosophy of Richard Buckminster Fuller. [3]**Vincenzino E, Culham G ;** This article presents the pioneering application of Ultra-High Performance Fiber-Reinforced Concrete (UHPFRC) in the construction of thin precast concrete roof shells for a Canadian Light Rail Transit (LRT) station. Authored by Vincenzino, Culham, Perry, Zakariasen, and Chow, the study details the implementation of innovative materials and construction techniques to enhance the structural performance and durability of the LRT station's roof. Through a comprehensive analysis of the design process, construction methodology, and performance evaluation, the article highlights the benefits and challenges associated with integrating UHPFRC in thin precast concrete elements. The findings contribute to advancing the understanding and application of UHPFRC in infrastructure projects, particularly in the context of transportation facilities. [4]**Jacobs, S. E**;In this Master's thesis by Jacobs, S. E., conducted at Brigham Young University, Provo, Utah, the utilization of large diameter low profile air forms employing cable net support systems for concrete domes is investigated. Concrete domes represent a distinctive architectural form known for their structural efficiency and aesthetic appeal. This research explores novel approaches to enhance the construction of concrete domes by utilizing large diameter low profile air forms supported by cable net systems. Through theoretical analysis, computational modeling, and experimental validation, the thesis examines the feasibility, structural performance, and practical implications of this innovative construction method. The findings offer valuable insights into optimizing the design and construction processes of concrete domes, with potential applications in various architectural and engineering projects. [5]**Neff, W. ;** This work investigates the pull-out testing of cast-in-place structures, aiming to assess their structural integrity and performance. The study, conducted by Neff in 1942 and Peterson in 1998, examines the methodology and results of pull-out tests applied to cast-in-place materials. Neff's patent, United States Patent No. 2,270,229, likely describes a method or apparatus related to cast-in-place construction. Peterson's paper focuses on the practical application of pull-out testing techniques and may include experimental data, analysis, and conclusions regarding the strength and behavior of cast-in-place materials under various loading conditions. The findings of these works contribute to the advancement of knowledge in the field of construction materials and structural engineering, providing valuable insights into the assessment and optimization of cast-in-place construction techniques.[6]**Bini, D ;** Bini explores the principles and applications of thin shell concrete domes. Thin shell concrete structures represent an innovative architectural form known for their structural efficiency and aesthetic appeal. Through a comprehensive analysis of design considerations, construction techniques, and case studies, the article delves into the theoretical foundations and practical implications of thin shell concrete dome construction. The findings contribute to advancing knowledge in structural engineering and architectural design, offering valuable insights for professionals and researchers interested in utilizing thin shell concrete technology in their projects. [7]**Boyt, J. ;** the construction of concrete structures utilizing innovative methods. The article likely explores advancements in construction techniques, materials, or design approaches aimed at achieving efficient and aesthetically pleasing structures. Through case studies, analysis, and practical insights, Boyt's article provides valuable information for architects, engineers, and construction professionals seeking to push the boundaries of traditional concrete construction methods. **[8] Howard, H. Seymour** ; Heinz Isler presents an exploration of concrete shell structures derived from experimental form-finding processes. Isler, renowned for his pioneering work in shell structure design, likely discusses the innovative methods he developed for generating efficient and aesthetically pleasing shell forms through physical experimentation. This article likely showcases Isler's experimental approach to shell design, highlighting case studies and projects where unconventional shapes led to structurally elegant and cost-effective solutions. Through a combination of experimental techniques, structural analysis, and construction methodologies, Isler likely demonstrates the potential of experimental form-finding in pushing the boundaries of concrete shell design. "Concrete Shells Derived from Experimental Shapes" likely serves as a valuable resource for engineers, architects, and researchers interested in exploring the creative possibilities of concrete shell structures.

## III. METHODOLOGY

### 1. Collection of Data

i. We commenced by accumulating comprehensive information pertaining to Binishells, encompassing their architectural design, construction techniques, and historical implementations.
ii. Following the initial data gathering phase, we delved into researching the advantages and disadvantages associated with Binishells. This involved a thorough examination of their structural integrity, sustainability features, cost-effectiveness, as well as any potential drawbacks or limitations.
iii. Subsequently, we meticulously compiled data concerning the current number of Binishell structures in existence up to the present date. This step provided us with valuable insights into the prevalence and adoption rate of Binishell technology within the architectural landscape.
iv. We conducted further in-depth exploration utilizing online resources such as Google and YouTube. This extended research phase enabled us to gather additional insights, case studies, and expert opinions, enriching our understanding of Binishells from diverse perspectives.

### 2. Research Paper Analysis on Binishells

i. Identified and gathered relevant research papers concerning Binishells, focusing on various aspects such as history, design parameters, and construction methodologies.
ii. Delved into the historical background of Binishells as documented in selected research papers. This involved tracing the origins, evolution, and significant milestones in the development of Binishell technology.
iii. Sifted through the research papers to extract comprehensive information regarding the design parameters essential for Binishell structures. This included factors such as structural stability, material specifications, and architectural considerations.
iv. Examined the research papers for detailed descriptions of the step-by-step construction process involved in building Binishells. This encompassed the sequential stages from initial design conceptualization to final construction execution.

### 3. Construction Process of a Mini Binishell Model

i. Compiled a detailed list of materials required for constructing the mini Binishell model.
ii. Acquired essential materials including cement, fine aggregate, plastic balls, binding wire, thin copper wire, oil, and candles.
iii. Cut the plastic ball according to predetermined specifications for the model.
iv. Marked the ball surface to indicate the placement of binding wire.
v. Utilized gauge 21 (0.71mm) binding wire for structural reinforcement.
vi. Cut binding wire to proper measurements and affixed it to the marked positions on the ball using thin copper wire.
vii. Prepared mortar with a ratio of 1 part cement to 2 parts fine aggregate.
viii. Used 43-grade cement for optimal strength.
ix. Applied the mortar mixture onto the prepared plastic ball surface.
x. Allowed the model to cure in a curing tank for a period of 24 hours.

Fig No 6.0 Mini Binishell Model

xi. Applied cement slurry to the surface to enhance smoothness.
xii. Affixed paper pieces onto the surface to achieve uniformity.
xiii. Allowed the model to dry thoroughly after surface treatment.
xiv. Colored the model to enhance its visual appeal and attractiveness.

## 4. Construction Process of a Mini Binishell Foundation Model

i. Constructed formwork using cardboard to delineate the shape of the Binishell foundation.
ii. Covered the formwork surface with cello tape to ensure waterproofing and prevent leakage.
iii. Cut binding wire according to specified dimensions for reinforcing the footing.
iv. Positioned the cut binding wire within the formwork to provide structural reinforcement.

Fig No 7.0 Mini Binishell Foundation Model

v. Prepared mortar with a ratio of 1 part cement to 2 parts fine aggregate.
vi. Applied the prepared mortar mixture into the formwork, ensuring even distribution and proper filling.
vii. Allowed the model of the footing to cure in a curing tank for a period of 24 hours.
viii. After the curing process, refined the model by removing any excess portions to achieve the desired finish and appearance.

## 5. Construction Process of Interior Design Model for Binishell

i. Upon completing the mini Binishell model with the foundation model, transitioned to preparing for the interior design model.
ii. Procured necessary materials and tools for constructing the interior design model, ensuring availability for the project.
iii. Roughly sketched the model design on paper, incorporating dimensions and layout considerations.
iv. Transferred the final design onto cardboard, marking out the required pieces for construction.
v. Using a cutter, precisely cut out the marked pieces from the cardboard.
vi. Marked the legs of the cut walls on the cardboard to serve as a stable base for the model.

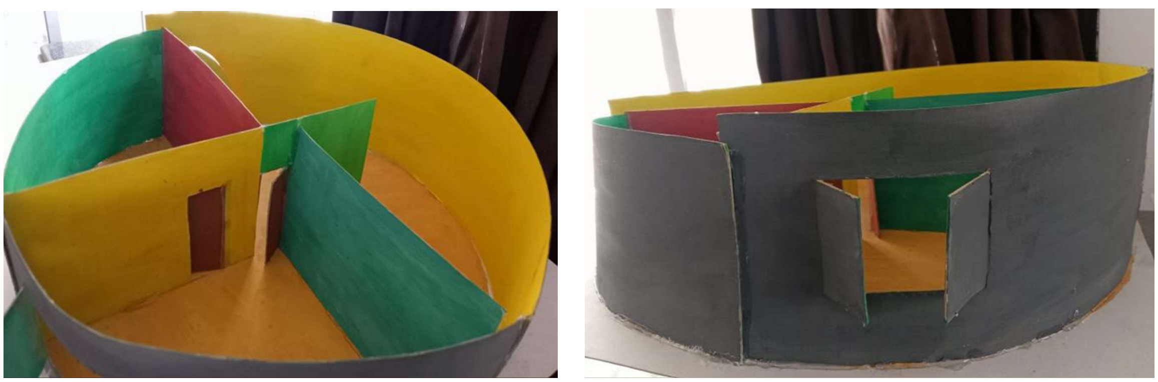

Fig No 8.0 Binishel Interior Design Model

vii. Cut out openings in the cardboard to simulate entry points for the Binishell structure.
viii. Applied coloring to the cardboard pieces to enhance visual appeal and realism.
ix. Utilizing a glue gun, assembled all the cutouts into the desired layout and configuration, ensuring structural integrity.
x. Integrated miniature furniture pieces into the model to provide a realistic representation of the interior space.

**6. Planned Furnish Binishell Modal in CAD**

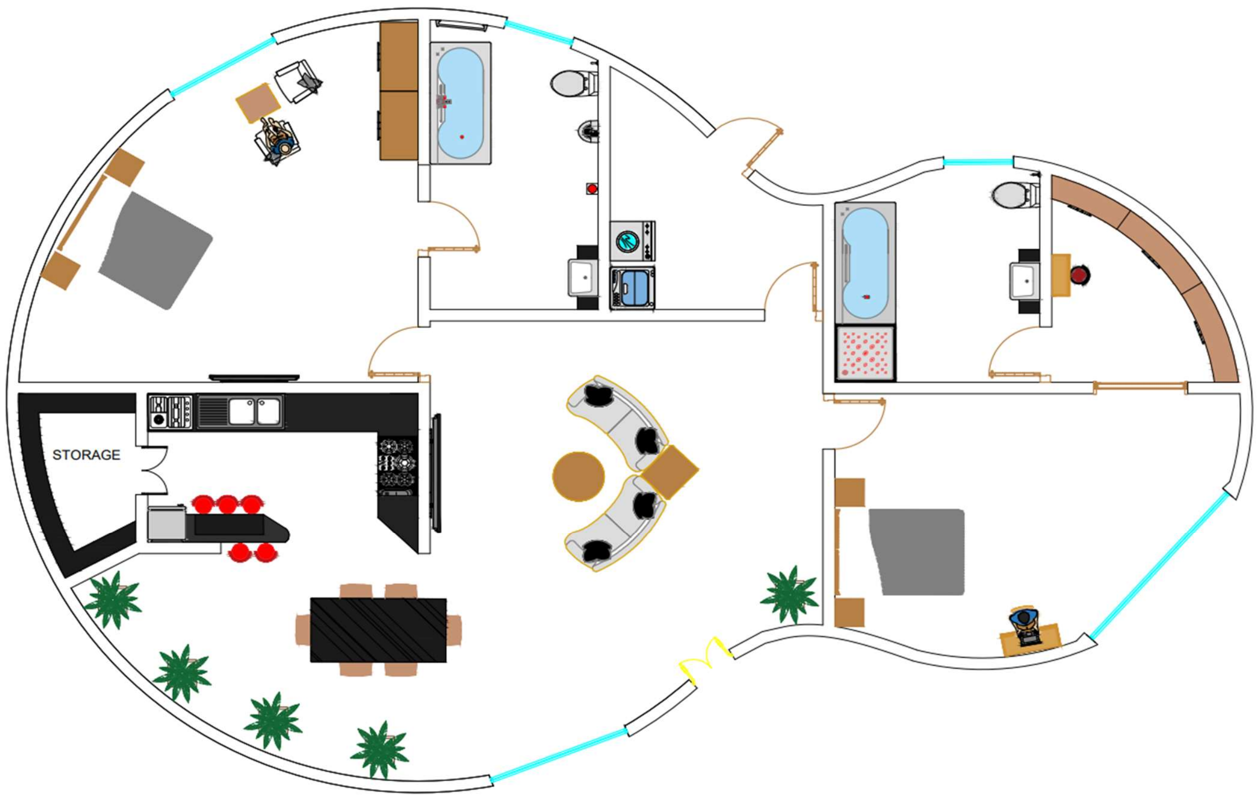


Fig No 9.0 CAD Binishell Modal

Binishell CAD plan had prepared with building principles and laws with all suitable use of furniture and fixtures.

## IV. CONCLUSION

In wrapping up our exploration of Binishell construction, it's clear that this innovative approach holds tremendous promise for the future of building. Through our examination of principles, processes, and practical applications, we've gained valuable insights. Binishells offer a unique blend of efficiency, affordability, and sustainability. Their ability to be constructed rapidly, with minimal environmental impact, makes them an appealing option for various building needs, from residential homes to disaster relief shelters. Yet, we've also encountered challenges along the way. From regulatory hurdles to design complexities, there are obstacles to overcome. Collaboration among stakeholders will be key to addressing these challenges and unlocking the full potential of Binishell construction. Looking ahead, there's great potential for further innovation and improvement in Binishell construction. Continued research and collaboration will pave the way for even more sustainable and resilient building practices. Binishell construction represents a promising path forward in the quest for sustainable and cost-effective building solutions. By embracing its potential and working together to address challenges, we can create a brighter future for construction and beyond.

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