



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 4, April 2024

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

A Case Study: Binishells Construction

Sawan Ramesh Patel

Students, Department of Civil Engineering, MGM's Polytechnic, Chhatrapati Sambhaji Nagar,
Maharashtra, India

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

I. INTRODUCTION

Binishells are characterized by their unique shell-like forms, crafted from reinforced concrete. What sets them apart is their construction method, which involves the inflation of a large air-supported membrane that acts as a formwork for pouring and shaping the concrete shell. Once the concrete cures, the membrane is deflated and removed, leaving behind a strikingly elegant structure.

Introduced in the mid-20th century, Binisheells quickly garnered attention for their efficiency, affordability, and versatility. Their graceful curves and organic shapes not only captivate the eye but also offer structural strength and stability. Binisheells have been utilized in a variety of contexts, from residential homes to commercial buildings, sports arenas, and even emergency shelters.

Beyond their aesthetic appeal, Binisheells represent a paradigm shift in construction methodology, emphasizing speed, cost-effectiveness, and sustainability. By minimizing material waste and construction time, they offer a compelling alternative to traditional building techniques.

In this case study, we delve into the intricacies of Binisheells construction, exploring their evolution, structural principles, applications, and the impact they've had on the architecture and construction industries. Through this exploration, we gain insight into the innovative spirit driving advancements in architectural design and engineering.

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, Zakariassen, 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]**Adeeb S M, Scholefield B W J** ; the modelling, testing, and construction of the world's first Ductal canopy. Authored by Adeeb S. M., Scholefield B. W. J., Brown T. G., Shrive N. G., Kroman J., Perry V. H., and Tadros G., the research investigates the innovative use of Ductal, an ultra-high-performance fiber-reinforced concrete, in the fabrication of a canopy structure. Through a comprehensive examination of computational modelling, material testing, and construction methodologies, the article elucidates the engineering principles, design challenges, and performance characteristics associated with Ductal canopies. The findings contribute to advancing the understanding and application of Ductal in architectural and civil engineering contexts, setting a precedent for the construction of high-performance, durable structures with exceptional aesthetic and functional qualities.[5]**D. P. Billington** ; "Thin Shell Concrete Structures" authored by D. P. Billington and published by McGraw-Hill Book Co., Inc. in 1982, is a comprehensive exploration of the design, analysis, and construction of thin shell concrete structures. This seminal work covers a wide range of topics including the historical development of thin shell structures, fundamental principles of structural mechanics, material properties, construction techniques, and case studies of notable thin shell projects around the world. With a focus on both theoretical concepts and practical applications, the book serves as an invaluable resource for engineers, architects, and students interested in understanding and implementing thin shell concrete structures in their projects. Through its extensive coverage and authoritative insights, "Thin Shell Concrete Structures" contributes significantly to the advancement of knowledge in the field of structural engineering and architectural design. [6]**Bingham, J. L.**; In this Master's thesis, authored by Bingham, J. L., and conducted at Brigham Young University, Provo, Utah, the bond strength between layers of shotcrete is investigated. Shotcrete, a versatile construction material, is commonly used for various applications including tunnel linings, slope stabilization, and structural repairs. Understanding the bond strength between layers of shotcrete is crucial for ensuring the integrity and stability of shotcrete structures. Through experimental testing and analysis, this thesis explores factors affecting bond strength such as surface preparation, mix design, application techniques, and curing conditions. The findings of this research provide valuable insights into optimizing the bond strength between layers of shotcrete, thereby enhancing the performance and durability of shotcrete structures in practical applications. [7]**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. [8]**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. [9]**South, D. B** ; Concrete International in August 1990, the economic aspects of thin shell domes are explored. Thin shell domes represent a unique structural form known for their aesthetic appeal and structural efficiency. This article delves into the economic considerations associated with the design, construction, and maintenance of thin shell domes. Through a combination of case studies, cost analyses, and economic assessments, the article evaluates the viability and cost-effectiveness of utilizing thin shell dome construction techniques compared to traditional building methods. The findings contribute to a deeper understanding of the economic implications of thin shell domes, offering valuable insights for architects, engineers, and stakeholders involved in the planning and implementation of architectural projects. [10]**South, J. P.** ; the preliminary analysis and design of large-span air-formed concrete domes are investigated. Air-formed concrete domes represent a distinctive architectural form characterized by their spanning capabilities and construction method. This

research explores the theoretical foundations, design principles, and practical applications of large-span air-formed concrete domes. Through computational modeling, structural analysis, and design considerations, the thesis examines the feasibility, structural integrity, and potential advantages of utilizing air-formed concrete technology in the construction of large-span domes. The findings contribute to advancing knowledge in structural engineering and architectural design, offering insights into innovative approaches for designing and constructing large-span concrete structures using air-forming techniques. [11] **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. [12] **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. [13] **Bologna, Alberto** ; The chapter is part of the larger work edited by Jeannette Kuo, titled "Space of Production: Projects and Essays on Rationality, Atmosphere, and Expression in the Industrial Building." Throughout the chapter, Bologna explores the interplay between rationality and expression in industrial architecture, particularly focusing on the works of Nervi & Bartoli during the specified period. The discussion extends to the innovative approaches employed by the architects in integrating structural elements with artistic expression, shaping the atmosphere of industrial spaces. Through a comprehensive analysis, Bologna elucidates the significance of structural art in the evolution of industrial architecture, shedding light on its role in creating a distinctive aesthetic identity while maintaining functional efficiency. [14] **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. [15] **Marsh, James H.** ; The Proceedings of the World Conference on Shell Structures, edited by S. J. Medwadowski, explores the construction of thin shell structures using the "lift-shape" process. Published in 1964, Marsh's paper likely presents innovative techniques for fabricating thin shell structures through a methodical process of lifting and shaping. The paper likely discusses case studies, experimental findings, and practical considerations related to the "lift-shape" process, offering insights into its applicability, efficiency, and structural integrity. Marsh's work is likely to be of interest to architects, engineers, and researchers seeking to explore alternative construction methods for thin shell structures, with potential applications in various architectural and engineering projects.

III. METHODOLOGY

Construction of Concrete Shells (BINISHELLS)

A. FOUNDATION

When it comes to the foundation of a dome, it's all about ensuring it's robust enough to handle both the expected loads and the conditions of the soil it's resting on. Typically, this 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

The concrete used in this foundation must meet specific standards, with certifications accompanying each concrete delivery. We're talking about meeting minimum compressive strength requirements, controlling aggregate size, ensuring proper air entrainment, maintaining a suitable water-cement ratio, and keeping the slump within specified

ranges. Adjustments might be necessary if the soil is particularly aggressive, requiring stronger or more chemically resistant mixes.

2. Soil Conditions

Depending on the soil conditions, different construction methods might be employed. Excavating trenches and placing concrete and reinforcing bars within is one option, but alternatives like wooden or metal forms can also be used. Ensuring that the top surface of the footing matches the dome's shape precisely is crucial for proper attachment of the inflatable form.

3. Reinforcement

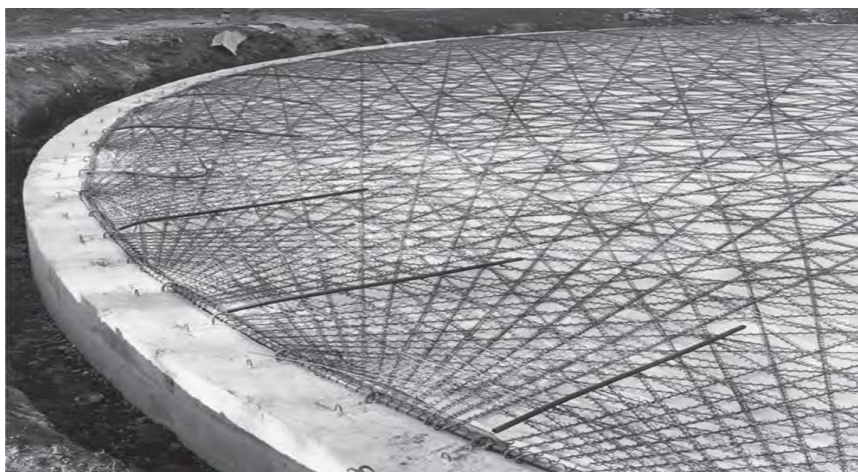


Fig No 1. Ring Beam Foundation Reinforcement

Reinforcement materials must meet stringent standards and undergo thorough inspection to ensure compliance. Usually, they're placed on cribbing within the foundation area before being covered and connected to the fabric form.

4. Anchors

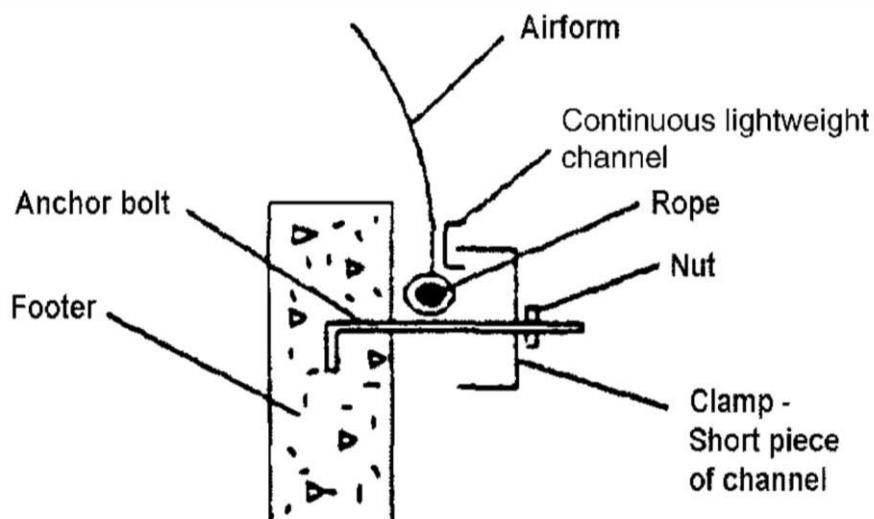


Fig No 2. Anchors System

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



Laying of the internal pneumatic form and pumping station



Fixing reinforcement of the structure at second floor



Placing concrete on top of the form at second level



Uplifting the structure



Vibration



Deflation

Fig No. 3. Inflated Forms Process of Binishell

1. Fabric Form Construction

The fabric form used in constructing concrete domes is a crucial component, as it determines the shape and size of the final structure. Here are some key points regarding the fabric form construction:

2. Material and Manufacturing

The fabric form is typically made of a single-ply membrane that stretches when attached to the foundation. Various factors, including weather and fabrication tolerances, affect the actual shape of the inflated form. Predicting the exact dimensions is impossible due to variations in the material's stretching capabilities.

3. Shape and Size

The spherical shape is the most common for inflated forms, but ellipsoids, barrel shapes, and cylinders can also be used. Sizes of domes up to 260 ft in diameter and 130 ft high have been successfully built using inflated forms. Larger domes may require additional ribs to prevent snap-through buckling.

4. Fabric

Fabrics used for inflated forms should meet strength, elongation, fabrication, ruggedness, and durability requirements. Commonly used fabrics are constructed of polyester scrim impregnated with PVC. Fabric stresses are proportional to air pressure and the radius of curvature, with allowable stress limited to 20% of the breaking strength of the fabric

5. Fabrication

Fabrication variables such as fabric stretch factors, tolerances, temperature variations, and distortions from the weight of initial shotcrete layers influence the actual size and shape of the fabric form. Anticipated stretch factors should be considered in design.

6. Field Layout and Protection

During field layout, the fabric form should be carefully unfolded and fastened to the foundation without using sharp instruments. Precautions should be taken to prevent damage to the form, and items that can damage the form should be padded. Large equipment needed inside the dome should be placed within the foundation perimeter before attaching the form.

7. Initial Stretching and Inflation

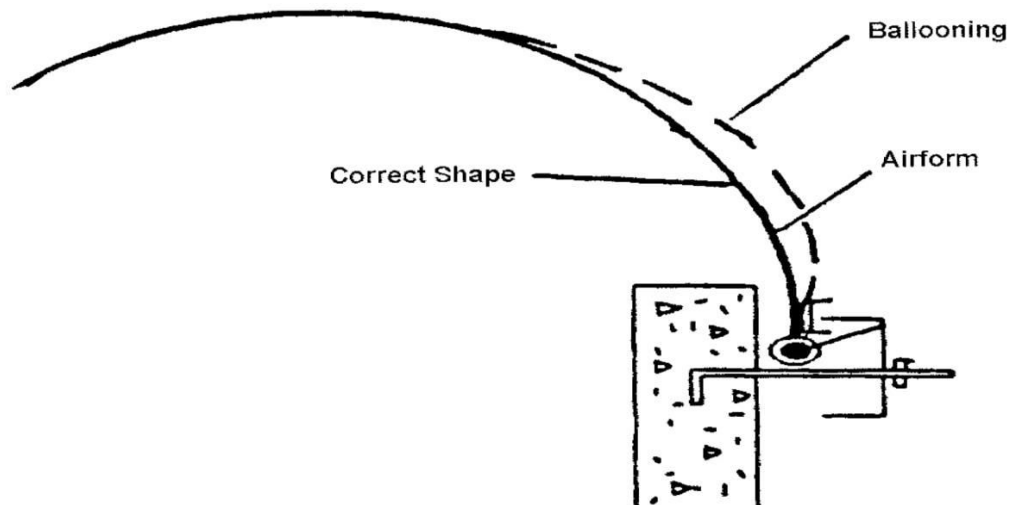


Fig No. 4. Inflated Forms Process

The fabric form undergoes significant stretching during attachment, helping minimize folds and wrinkles. It continues to acquire its final shape under consistent pressure, with diameter typically 1 to 2 inches smaller than the foundation. Inflation should be done carefully, monitoring air pressure to maintain proper shape and support construction loads.

8. Construction Tolerances and Air Pressure Maintenance

Dimensional tolerances of the inflated form should be within $\pm 3.0\%$ of the design radius of curvature. Maintaining constant air pressure is crucial to avoid deforming the dome during construction. Backup air pressure systems and monitoring mechanisms are essential for safety.

9. Collapse Prevention and Miscellaneous Connections

Care should be taken to prevent local sags that can lead to total collapse during construction. Proper design of miscellaneous connections is important to accommodate deviations in the dome's shape.

10. Fabric Form Repair and Foam Application

Tears or cuts in the fabric form can be repaired using heat welding, gluing, or riveting strips of fabric. Polyurethane foam is applied to the inside of the form to help insulate the dome, anchor reinforcement hangers, and stiffen the fabric before applying shotcrete.

11. Construction Hazards

Hazards during construction include wind, snow, and unanticipated construction loads. Proper planning and precautions should be taken to mitigate these risks.

C. SHOTCRETE

1. Shotcrete Application

- Shotcrete should be able to be pumped through the length of hose required.
- Reinforcement should be fully encased by shotcrete, meeting specified compressive strength.
- Shotcrete mixtures should contain specified proportions of Portland cement, fly ash, and water-cementitious materials.
- Shotcrete additives should be approved by the designer.



Fig No. 4. Shotcrete

2. Reinforcement

- Reinforcement material should comply with ACI 506.2.
- Maximum reinforcement size is No. 11 bar, but larger sizes can be used with preconstruction testing.
- Clear spacing between parallel bars is recommended to be 2.5 inches, adjustable based on preconstruction tests.

3. Splices and Cover

- Splices should be done using mechanical or contact lap splices, ensuring proper encasement.
- Shotcrete should provide a minimum cover of 3/4 inch between foam and reinforcement.

4. Preliminary Reinforcement Mat

- Premat of reinforcing bars can be placed in larger domes to provide additional stiffness and strength.

5. Shotcrete Compression Tests and Proportions

- Strength tests for shotcrete should be conducted according to ACI 506.2.
- Shotcrete materials and proportions should be tested and approved.

6. Field Practice

- Shotcrete should be applied in layers, with sufficient time for each layer to set.

- Thickness of shotcrete layers depends on project specific factors.
 - Gauges should be used to monitor concrete thickness during application.
7. Curing and Quality Control
- Shotcrete should be cured for at least 7 days or until specified compressive strength is achieved.
 - Quality control technicians should monitor slump and strength of shotcrete during application.
8. Shotcrete Placement Tolerance and Damage
- Shotcrete placement tolerance should be within specified limits to avoid defects.
 - Defective shotcrete should be removed and replaced as necessary.
9. Completion
- Air pressure should remain constant until the structure is self-supporting.
 - Finish work can begin after shotcrete application is completed.

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.

REFERENCES

1. Andrea Menardo, Thin Concrete Shells, Research Gate, Volume 4 Issue 3, 2021, 45-51.
2. Will Mc Lean , Building With Air, University Of Westminster , Volume 1, 1-18.
3. Dante Bini's, Dante Bini's From - Resistant Binishell, University Of Melbourne, Volume 3, 2017, 1-22.
4. Andrea Menardo, Morden Method Of Construction And Future Opportunities In The Field Of Thin Concrete Shell, Researchgate, Volume 4 Issue 3, 2021, 65-87.
5. Vincenzino E, Culham G, Perry V H, Zakariassen D, Chow T S, First Use of UHPFRC in Thin Precast Concrete Roof Shell for Canadian LRT Station, PCI Journal, Sept-Oct 2005, 50-67.
6. Adeeb S M, Scholefield B W J, Brown T G, Shrive N G, Kroman J, Perry V H, Tadros G, Modelling, testing and construction of the first Ductal canopy in the world, Canadian Journal of Civil Engineering 32, 2005: 1152-1165
7. Billington, D. P., 1982, Thin Shell Concrete Structures, McGraw-Hill Book Co., Inc., 373 pp.
8. Bingham, J. L., 1997, "Bond Strength Between Layers of Shotcrete," MS thesis, Brigham Young University, Provo, Utah, 33 pp.
9. Bini, D., 1986, "Thin Shell Concrete Domes," Concrete International, V. 8, No. 1, Jan., pp. 49-53.
10. Boyt, J., 1986, "Up, Up and Away," Concrete International, V. 8, No. 1, Jan., pp. 37-40.
11. Jacobs, S. E., 1996, "Large Diameter Low Profile Air Forms Using Cable Net Support Systems For Concrete Domes," MS thesis, Brigham Young University, Provo, Utah, 117 pp.
12. Neff, W., 1942, United States Patent No. 2,270,229. Peterson, G. P., 1998, "Pull-Out Testing of Cast in Place
13. South, D. B., 1990, "Economics and the Thin Shell Dome," Concrete International, V. 12, No. 8, Aug., pp. 18-20.
14. South, J. P., 1996, "Preliminary Analysis and Design of Large Span Air Formed Concrete Domes," MS thesis, Brigham Young University, Provo, Utah, 118 pp.
15. Howard, H. Seymour, Jr. 1966. Structure: An Architect's Approach. New York: McGraw-Hill. Isler, Heinz. 1994. Concrete Shells Derived from Experimental Shapes. Structural Engineering International 3: 142-147. Marsh, James H. 1964. Construction of thin shell structures by the "lift-shape" process, in S. J. Medwadowski (ed.), Proceedings. World Conference on Shell Structures, 447-452



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details