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Seismic Analysis of a RCC Dome Using Staadpro - A Review

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***Abstract*: During the past four decades, the development of dome structure as a structural form has added an exciting chapter to contemporary architecture. Thin shells are an example of strength through form as opposed to strength through mass. In design, the effort is to make the shell thin as per practical requirements so that the dead load is reduced and the structural members free from large bending stresses. By this it means, a minimum of materials is used for a maximum structural advantage. STAAD PRO V8iwas used for analyzing the structure and calculating the moments and loads coming on the structure. There by, designing the components of the structure for the safe loads acting on them. The displacement at the nodes in the structure is found using this software and it is checked whether it is within the safe limits.**

***Keywords*: Dome, STAAD.pro, Shear Force and Bending Moment, Stresses, Seismic analysis.**

1. Introduction

The dome or domed shell commends itself from the architectural and aesthetic points of view and would be a comparatively inexpensive form of construction but for the practical difficulties due to the accurate erection of the curved shuttering (on both faces Where the inclination to the horizontal is greater than about 30 deg.) and the difficulty of placing the concrete. In any structure a saving of materials in the finished work due to an otherwise excellent design may be accompanied by prohibitive erection costs; in domes these cannot be ignored since the curved shuttering is expensive to make and erect and the costs of placing the concrete and steel, often at great heights, are particularly heavy. From other points of view, concrete, suitably reinforced, is advantageous since, once the erection difficulties have been solved, the wet concrete readily takes up the curvatures required in the two directions, thus avoiding the production of a series of flat surfaces which in most other materials only approximate to the curvatures of the shell. Moreover, the compression stresses in domes are small so that, particularly with the high- strength concretes now obtainable, the shell may be cast very thin, resulting in a light-weight construction. Its adaptability for receiving fixings to hold an outer covering or plaster false work and the fact that the construction is fireproof are other advantages of concrete. In practice, domes are usually spherical and are essentially sur faces of revolution about a vertical axis. A vertical section through this axis in any direction is, as a rule, an arc of a circle. Another possible form is the conical surface of a right cone with a vertical axis giving a triangular section through its axis of revolution. Other shapes, such as the spheroid giving an elliptical section through its axis of revolution, have not been adopted in this country. By employing surfaces of revolution with vertical axes and ensuring that all loading is symmetrical about these axes in every direction, only direct compression forces in the shell are required to maintain stability, provided the shell is supported in a plane at right angles to its axis of revolution, the supports being level all-round the edge. These are the conditions in the design of domes of normal proportions.

A. Aim

The aim of project is to study seismic analysis of RCC Dome by using Staadpro.

B. Research objectives

- To identify the optimal shaped dome structure that can be used in low cost housing
- To investigate the important design criteria with regard to domes
- To utilize affordable materials that can be acquired in remote area
- To investigate different methods of dome construction
- To construct a durable, architecturally and structurally efficient low cost dome auditorium.

C. Need of the study

- It is essential to design urban life spaces in accordance's to the needs of modern time
- This study will be useful where the need for low cost housing in India is large and huge percentage of population is still lingering under poverty.
- Monolithic concrete domes can serve as the safest structures in areas prone to Tornadoes and Earthquakes.

Hence, this research is aimed to study the response of a dome structure using staadpro.

D. Key deliverables (Market potential)

- In this study, the complete project work is divided in five different tasks. Within each of these tasks are a

number of key deliverables that that have been accomplished to fulfill the five objectives and are as follows:

- Project Justification and Background
- Preliminary study on current processes and practices in construction, study about the different dome structures
- Case study selection/Design/Analysis.
- Implementation of models in Staadpro
- Guidelines, Certification and recommendations.

E. Future scope

This study is undertaken only for an auditorium in Pune. Same study can be done on other type of structures in different locations.

F. Advantages of monolithic dome structure

- Cost of a dome is less.
- Require less maintenance.
- Circulation of air and heat is very good, to climate these structure are very cold.
- Protects from fire.
- Survives from earthquakes, tornadoes, hurricanes.

G. Disadvantages of monolithic dome structure

- Wasted space in narrow corners.
- Lack of seams.
- If local officials are not familiar with the monolithic dome, then Building permits may be difficult to obtain

2. Literature review

Design and Analysis of Monolithic Dome Structure – Rahul Ingale, Amol Dighe, Vaibhav Badhe Girjinath Damale, Pote R.K.

In this paper, the authors designed and analyzed the "Monolithic Dome Structure" by analytically (manually) and by using software STAAD PRO V8i. They have designed and analyzed various shapes of monolithic dome structures using STAAD PRO V8i.

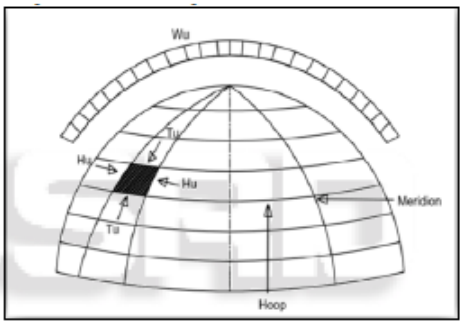

Fig. 1. Components in loading diagram

Design a reinforced concrete spherical monolithic dome roof for a planetarium of 15m internal diameter. The dome is to carry a uniformly distributed load of 1kn/m2 of the surface area. Further are the conclusions mentioned by the author for monolithic dome structures.

1. Results are approximately equal on designing it manually and with software.
2. Very nominal reinforcement required to construct the monolithic dome structure

By using analytical and software design they had compared the results of monolithic dome structure. Further, they have analyzed our findings with the results which are obtained in STAAD PRO V8i software. The authors have concluded that the results obtained by manual design and Software design are approximately equals and also very nominal reinforcement required to construct the monolithic dome structure. Hence the monolithic dome building technique is an effective alternative to conventional method.

Findings: Monolithic Dome, Hoop Force, Hoop stress, Meridional Thrust, Meridional Stress

Analysis and Design of Monolithic Domes for Low Cost Housing - Kalaiselvi M, Selvakumar T, Padmasri.

This project includes analysis and design of Monolithic Concrete Dome for low cost housing and comparing its cost and energy efficiency with a conventional building. The project emphasizes the need for low cost housing in India and providing the best solution in the form of monolithic concrete domes that not only render cost efficiency but also have proved to be disaster resistant over the years. The project also encompasses various aspects of the constructions of concrete domes which include cost efficiency, disaster resistant nature, earthquake resistant nature and energy efficiency. The design was done in accordance with the codal provisions as provided in the design of reinforced concrete structures.

As results, Monolithic Concrete Dome structures are comparatively more stable than normal conventional buildings.

Findings: Analysis and design, Monolithic Concrete Dome, Energy efficiency, Low cost housing.

Design and analysis of geodesic tunnel dome for an auditorium, Arya Abhishek, Phadtare Shubham, Patil Pratik, Tipare Harshal, Reetika Sharan

The study shows the result of static analysis and design of geodesic tunnel dome. The authors collected the dimension of an auditorium, the length is 40m & width of the inner side is 20m with the height of the crown is 10.63m. They built the model required for the project. They also calculated the forces acting (i.e. Wind load, Dead load, Live Load &, etc.) on each panel of the structures for designing purpose, this load is resisted by two hinged arches which are further transferred to the RCC column to soil strata through the foundation. Wind intensity as per (IS 875-1987 part-3) is 44 m/s.

Findings: Geodesic Tunnel Dome, Heavy Wind Load, Arch Truss, Aesthetic View, Energy Efficient, Economical, Steel tubes

Analysis and design of spherical dome structure by using STAAD.Pro, R. Madhukumar, U. Manivasan, V. S. Satheesh and S. Suresh Babu.

In this investigation by applying point loads over the nodal joints analysis and design of concrete dome structure was done using STAAD.pro. An 8.49m rise with 30m diameter dome and a support height of 14m was considered for the design. Dead load is assigned as plate load and the live load is assigned as point load over the nodal joints. The safe loads were found from the design results against various loading cases.

*Findings***:** Dome, STAAD.pro, Nodal Joint Load, Shear Force and Bending Moment.

Study of Dome structures with specific Focus on Monolithic and geodesic domes for housing: Riya Anna Abraham, G. Kesava Chandran

The literature is reviewed on Study of Dome structures with specific Focus on Monolithic and geodesic domes for housing. This paper deals with the study of the domes and dome roof comparison with flat roofs. The domes are constructed because of large space with minimum surface area. Geodesic dome can be regarded to be a portion of a geodesic sphere. The main aim of the author was to analyze the monolithic and geodesic domes. Both the domes shows various advantages which are energy efficient, eco-friendly and durable housing options. Advantages of domes provides unprecedented structures for covering areas where we have minimal interference of internal supports. Also author analyze on the failure of dome structure mentioned below,

1. Insufficient thickness
2. Buckling
3. Slope
4. The inner face
5. Cracking of domes

Geodesic domes are one of the most efficient structures due to several reasons. The triangle is a very stable configuration. Table represents the popular large geodesic domes.

Table 1
Popular large Geodesic Domes Dimensions summarised by the authors

No.	Name	Location	Diameter(m)
1	Fantasy entertainment couples	Kyosho isle, japan	216
2	Multipurpose arena	Nagoya, japan	187
3	Tacoma dome	Tacoma, WA, USA	161
4	Superior dome	Northern Michigan Univ Marquette, MI, USA	160
5	Walk up sky dome	Northern Arizona Univ. Flagstaff, AZ, USA	153

Parametric Study of Dome: A Review: M. A. Jain, C. B. Nayak, S. B. Walke.

The basic objective of this chapter is to get inside into the previous findings so that it will help to know the gap in earlier studies and to justify the research problem selected by me for the study purpose. The literature is reviewed on the Parametric Study of Dome. The main aim of the study is to analyze and design the dome using various software. The dome roofs used to cover the circular shape and are also the lightest structure. The domes are covers maximum area with the minimum surface area. Thus with the efficient shape and size the structure shows good results. The investigation of analyzing on different aspects of dome structure is processed with using different software. As per researching on various software's, the author analyzed and designed the dome by using software such as ANSYS, STADD PRO, ABAQUS, SAP etc. thus different types of domes were analyzed with this software's.

It is observed that for dome parametric study is the key for optimum configuration by overall.

A Study in Importance of Monolithic Method in Different Structures: Arun Hota, Hemlata Sahu, Nidhi Jaiswal, Nikita Patel, Pragya Mahilwar, Surbhi Shrivastava, Namrata Verma.

The literature is reviewed on the in importance of monolithic method in different structures. As per authors study, the monolithic construction method is in accordance to time is feasible method for construction of the repetitive construction work as compared to conventionally applied method of construction. The main aim of this paper is to analyze the importance of the monolithic construction work in different structure like high rise building, Domes Tunnels, Pavements helps to save Time, Money & Energy. The brief study of monolithic construction and have some advantages of this construction over traditional method for modern housing monolithic structure are most dominant. This type was construction is probably used for many types of development like Domes, Tunnels, Concrete Pavements, silos, residential building, schools, stadium, and roof of industries, nuclear reactors, pressure vessel, and auditorium. Based conclusion on this study are mentioned below,

1. It is a time efficient construction process.
2. The most important agenda of everyone, so through using this procedure, housing construction field reaches in the peak.
3. Monolithic method we use the industrial waste fly ash to replace 15-20% of the cement used in construction which also helps to save the environment and cost of construction.

Cost Analysis of Dome Structure with Ring Beam: B. H. V. Pai and B. Durga Prasad Baliga.

The literature is reviewed on the cost analysis of dome structure with ring beam. The author analyzed the dome structure where for housing form the domes are used. The cost analysis of the dome structures is also the aim of this paper. The structures deals with the shape and size of the area with this cost, time effects the construction method. The construction method varies according with the materials usage. In this paper, the design of dome deals with the compressive strength developed on the structure with ring beam, thus ring beam are provided at the base of the dome and designed to resist the tension and shear force. For the design of fome with the ring beam, Structural Design of the dome with ring beam is done in accordance to IS:456 - 2000 and IS: 2204 - 1962. The detailing of the reinforcement is done referring to Indian Standard SP: 34.

Various input values for dome construction are mentioned in

table given below,

Table 2
Various input values for dome construction

Inputs	Case 1	Case 2	Case 3
Span of the dome(m)	10	20	30
Rise of the dome(m)	1.5	3.4	5
Thickness of dome(mm)	150	200	300
Density of concrete	25	25	25
Live load	2	2	2
Floor finish	1	1	1
Grade of concrete	20	20	25
Grade of steel	415	415	415
Width of ring beam	250	350	600

Following are the conclusion mentioned by the author,

1. On the basis of table, the calculation was manual.
2. With the semi central angle, the meridional stress increases and hoop stress decreases.
3. For higher span, there is no need to increase the semi central angle.

Dynamic Characteristics of Large Reinforced Concrete Domes: J. A. Abdallaand A.S. Mohammed.

The author researched on the Dynamic Characteristics of Large Reinforced Concrete Domes. Author mentioned that there is need to analyze the characteristics of domes at seismically active area. The UAE is the one of the country comes under these areas. The investigation was done in UAE cities regarding measuring the magnitude of 5.9 Richter scale in November 27, 2005. Cities including in paper were Dubai, Sharjah and Ras Al-Khaima and sent hundreds of thousands of rattled residence to the streets. This paper presents the study of reinforced concrete domes and the effect of the variation of their thickness, height and span on their dynamic characteristics such as frequencies of vibration.

Optimization of RCC Dome: Prabhavati. P, S. B. Vankudre, Veeresh. Varur.

The literature is reviewed on the Optimization of RCC Dome. Domes are those space structures which provide large column free net precious areas. The structure of domes are like arch having different elements. The method is analysed by theory used for analysis of the dome and design is done by working stress method as per IS: 800-2007. Domes are used in variety of structures, such as (i) roof of circular areas (ii) circular tanks (iii) hangers, (iv) exhibition halls, auditoriums and planetariums' and (v) bottoms of tanks, bins and bunkers.

An optimization problem consists of maximizing or minimizing a real function by systematically choosing input values from within an allowed set and computing the value of the function.

Further table represents the results of spans of domes,
As results, domes of base diameters 6 m, 20 m, 45 m, are considered. The height of each dome varied between 1/5th to 10th of the base diameter.

The following conclusion may be made from the recent study:

1. It is possible to formulate and to obtain solution for the minimum cost design for R.C.C. Dome.
2. Significant savings in cost over the normal design can be achieved by the optimization. However, the actual percentage of the saving obtained for optimum design for R.C.C. T-beam girder depends upon the span of slab and grade of material.

Table 3
The results obtained for above spans of domes

D in meters	Wt. of steel in Kg by empirical design	Wt. of steel in Kg after optimization
6	3.5	1.4
20	36.5	18.22
45	184.5	175.26

3. Methodology

The demand of monolithic domes is increased in variety of residential, commercial and industrial projects. The main need of this study is to improvise new dimensions of domes to analyze the behavior of dome like strength variation and durability. Monolithic domes will helps in studying load analysis. All the study will implement on Staadpro v8i software to calculate the load of structure and implementing the correct sizes of columns, beams.

The project study involved two stages. The primary data was gathered through a Literature survey targeted by web searches and review of e books, manuals, codes and journal papers. After review the problem statement is defined and the selected dome model is taken up for detail study and analysis purposes. This project execution follows the flow chart given below:

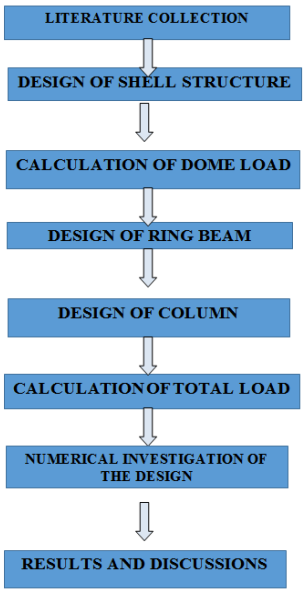

Fig. 1. Methodology

Software for Analysis:
AUTOCAD 2013

This software was used for sketching the plan, section, elevation and reinforcement details for the proposed project.

STAAD PRO V8i

This software was used for analyzing the structure and calculating the moments and loads coming on the structure. There by, designing the components of the structure for the safe loads acting on them. The displacement at the nodes in the structure is found using this software and it is checked whether it is within the safe limits.

Planning

Planning of the monolithic concrete dome plays a very important role in designing the structure. The plan of the dome, elevation is drawn in Auto cad with the considerations for an auditorium. The architectural plan selected for this analysis is shown as follows:

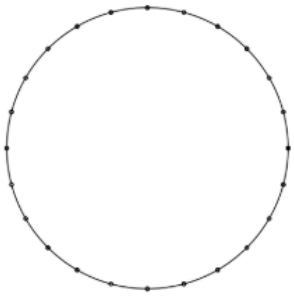

Fig. 2. Top view of dome with column positions

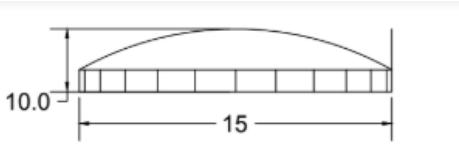

Fig. 3. Front view of dome with height

Fig. 4. Sectional view of dome

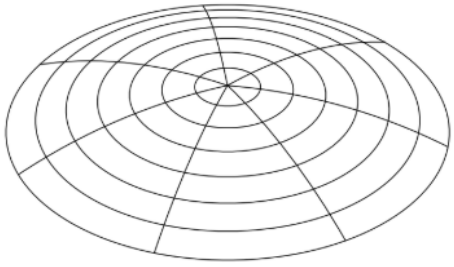

Fig. 5. Isometric view of dome with beams and columns

4. Scope of the study

This project provides a sample amount of scope for the budding engineers to enhance their knowledge in structural engineering. During the past four decades, the development of dome structure as a structural form has added an exciting chapter to contemporary architecture. Thin shells are an example of strength through form as opposed to strength through mass. The effort in design is to make the shell as thin as practical requirements will permit so that the dead load is reduced and the structural functions as a membrane free from large bending stresses. By this it means, a minimum of materials is used for a maximum structural advantage.

The scope of this research work is limited to the analysis of the models prepared in Staadpro v8 for the monolithic dome designed for an auditorium. The results of the analysis will mainly vary according to the dimensions and site conditions of the selected case study.

5. Conclusion

This paper presented an overview on seismic analysis of a RCC dome using staadpro.

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