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RELEVANCE OF SHELL AND DOME STRUCTURES IN MODERN APPLICATIONS OF CIVIL ENGINEERING CONSTRUCTION

Dr. Engr. Gana .A.J[*1]
[1*] COREN Regd, MNSE, MNICE,Istructe Lond (U.K,) ICE Lond (U.K) Civil Engineering Department College of science and Engineering Landmark University Omu-Aran, Kwara state..
*Correspondence Author: **Dr. Engr. Gana .A.J**

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Abstract

Shell and Dome structures are structural elements of members with curved surface that are capable of transmitting loads in more than two directions to support loads. They are highly efficient structural when they are well shaped, proportioned, and supported by transmitting the applied wads without any form of twisting or bending. The modern applications of shell and Dome structures in civil Engineering construction has increased the benefits of enclosed space and span distances by these two structures. This paper examined the relevance of shell and Dome structures in this present modern Application of civil Engineering construction.

Introduction

Shell and dome structures often offered many of the attributes that the architects and engineers are looking for in an ideal structure. A shell and dome structure provides only a few centimeters thick, which can cover very. Large spans, singly and in combination are practically numberless. Shell and dome are in thin in thickness because they are curved in such a fashion as to keep bending stresses to a minimum. The extent of their economy, value of aesthetic, effects, suitability to functional requirements, and how well their structural behavior is understood. Therefore shell and dome structure offer new solutions for the designed of enclosed space and span distances, with the economy of materials in view and freedom of forms.

Material and Method

The adopted method for this paper was through visits to places where there are already existing buildings with the construction of Dome like mosques of similar purpose and uses within kwara state; public Government offices with walk ways in public institutions and places where the construction and application of shell structures and obtained.

Historical Application of shell and Dome structures World Wide

Shell and Dome structures are among the oldest means of enclosing large spaces, especially from the Hajia Sophia in Instanbul, to the classical era of cathedral Architecture. Shell and Dome structures have been used over many centuries in civil Engineering construction Worldwide. The records shown below are notable applications of these structures in different parts of the world.

Table 1. Dimension of several shell and structure (1)
The structures with bold names are described in these notes.

Structure	Location, year, architect	Geometry	Dimensions	Radius a	Thickness t	Ratio a/t
Chicken egg	150 10^6 BC	Surface of revolution	60 mm length	20 mm minimum	0.2-0.4 mm	100
Treasury of Atreus	Moknves Greece 1100 BC	Surface of revolution	14.5 m diameter	16 m	=0.8m	20
pantheon	Rome 126 A D	Hemisphere	43.4 m diameter	2.17 m	1.2 m at the top	18
Viking ship oseberg	Tonsberg Norway 800 A D	Ellipsoid part	21.58 m long 5.110 m wide			
Basilica difirenze	Italy 1420 Brunelleschi	Octagonal dome	44 m diameter	22 m		
St. Paul's cathedral	London 1679 wren	Cone and hemisphere	35 m diameter	15.25m		

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Jana planeta	Germany 1923 dischinger, finterwakder	Hemisphere	25 m Diameter	12.5m	0.06m	200
Jana factory	Germany 1923	Spherical cap	40 m Diameter	28.28m	0.06m	470
Algeciras market hall	Spain 1934 Torroja	Spherical cap on 8 supports	47.6 m Diameter	44.1m	0.09	490
Beer can	1953	Cylinder	66 mm diameter	33 mm	0.08mm	410
Hibbing water filer plant	Minnesota 1939 Tadesko	Elipsoid of revolution	45.7 m Diameter	47.24-5.33m	0.09-0.15 m	35-525
Bryn mawr factory	Pennysylvania 1947	Elpar on a rect. Plan	48.0 m between supports	34.0m	0.065m	300-400
Auditorium MIT	Cambridge 1955 Saarinen	Segment Of A Sphere On 3 Point	48.0 m between supports	34.0m	0.065m	520
Kanehoe shopping center	Hawali 1957	Intersection of 2 tori on 4 supports	39.9 x 39.0 m between supports	30.9-78.0m	0.076-0178m	500-100
palazzetto	Rome 1957	Spherical cap	58.5m	30.9m	0.12m shell	
Delllo	Nervi	With ribs	Diameter		0.33m ribs	
CNIT	Paris 1957 Esquilan	Intersection of 3 cylinders on 3 supports	219 m between supports	89.9-420.0m	1.91-2.74 m total 0.06-0.12 outer layer	47.153
Ferrybridge cooling tower	Ferrybridge Uk 1960	Hyperboloid	Height 155 m	44m	0.13 m repaired 0….m	350
Apollo rocket	Houston USA 1961-1972	Cylinder + stiffeners				
Tucker high school	Henrico USA 1965	4 hypars	47 x 49 m	127 m	0.09 m	1400
Savill building	Windsor UK 2005	Freeform	Length 98 m width 24 m	143 m	0.30 m	41
Sillogue Water Tower	Dublin 2007 collins	Surface of revolution	Height 39 m top diameter 38 m	24.8 m	0.786 m	32

Discussion

Shell: - a shell is a thin, rigid, three dimensional structural form taken by the enclosure of a volume bounded by a curved surface. The surface of a shell can assume any shape. The common forms of shell include rotational surfaces generated by the rotation of a curve about it axis, e.g. spherical elliptical, conical, and parabolic surfaces, translational surfaces that is generated by sliding one curve, over another plane curve, e.g. cylindrical and elliptical, paraboloid surfaces, and ruled surfaces generated by sliding the two ends of a line segment on two individual plane curves, e.g. hyperbolic and parabolic surfaces and also a wide variety of complex surfaces that is formed by various combinations of rotational, translation, and ruled surfaces. A shell can assume any of these forms. It is the construction considerations that usually limit the range of form options chosen.

Types of shell

Shell are of different types both in shapes and in construction. The common types are briefly discussed below:-

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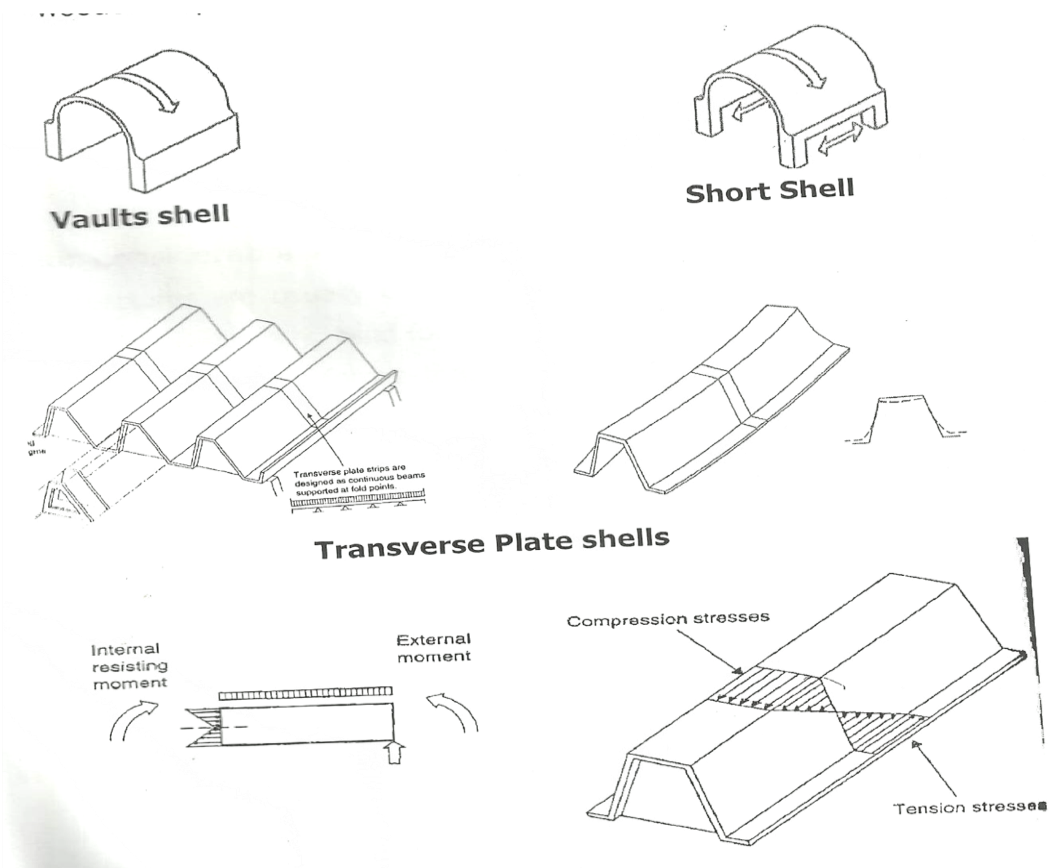
1) Cylindrical or barrel shells: - the surfaces of these shells are obtained by sliding a horizontal straight line (known as generator) along a vertical curve, (known as directory) at right angles to it. The curve may be a circle, Ellipse, parabola, a catenary or any other shape. The curve may have its curvature drawn upward. Cylindrical shells can be supported in a variety of ways, and their behavior depends upon the mode of support. If it is supported along the edges, it will behave like an arch and will develop bending stresses. If the shell is supported at its two curved ends, it will stiffen.
2) Shell of revolution:- the surfaces are obtained by rotating a curve of shape around a fixed vertical axis. The section of the surface, though passing through a plane, the axis will be the same as the rotating curve. The curve may be circular, elliptical, parabola, inclined straight line or any other curve. Shells of revolution like that of domes have long been used with thick reinforced concrete materials. It can support the loads by stresses only. Bending stresses will come into play only when the supports are not able to adjust themselves to the deformation of the shells. This shell can be used as a roof or as a bottom of tank. Half conical shell is used as a cantilever root where the axis of the dome is horizontal
3) Shell of Translation:- this is a type of shell that is obtained by moving a curve parallel to itself along another vertical curve, usually in a plane at right angles to the plane of the sliding curve. A cylindrical shell is a special kind where the sliding curve is a straight line. The sliding and the curve may have only geometrical shape. One of the surfaces best adopted due to a number of a reason is hyperbolic paraboloid. This is obtained by sliding a vertical parabola upward curvature on another parabola with downward curvature in a plane right angle to the plane of the first
4) Shells of ruled surfaces: - such a shell is obtained by moving a straight line that its ends lie on two fixed vertical curves. These two curves may be the same of different types. A cylinder is also a shell of this type, in which the two curves are of similar nature. The ruled shells are very important because their formwork can be made straight of wooden stripe. The common type of shapes are shown below:



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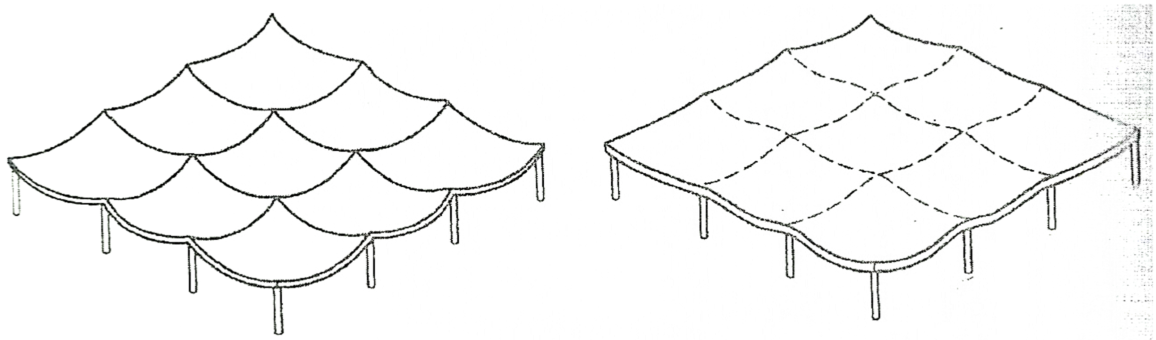

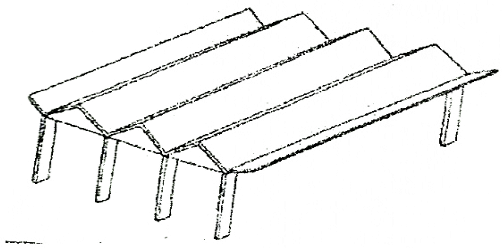

Folded plate shells

Design considerations for shell structures

Shell structures are usually designed to withstand loads, other than those acting vertically. Usually, wind forces are not too critical in the design of shell structures. Earthquake forces that also act laterally can cause extremely design problems. Where such loadings appear, special care should be taken with the design of the support conditions that are available.

Loads on shell structures

The loads applied to the surfaces of shells are carried to the ground by the development of compressive, tensile, and shear stresses acting in the plane direction of the surface. The thinness of the surface does not allow the development of the appreciable bending resistance. Shell structures are uniquely suitable for loads, and they equally have wide applications as roof structures in building. They are, however, not suitable for carrying concentrated loads.

As a result of their carrying loads by in-plane force (primary tension and compression), shell structures can be very thin and can span long and great distances.

Forces acting on shell structures

The two types of forces acting on shell structures are:-

i. Meridional forces and
ii. Hoop forces

Meridional forces have compressive forces in upper zone, while Hoop forces in the upper zone, and in tensile in the lower zone as shown in the sketches below:

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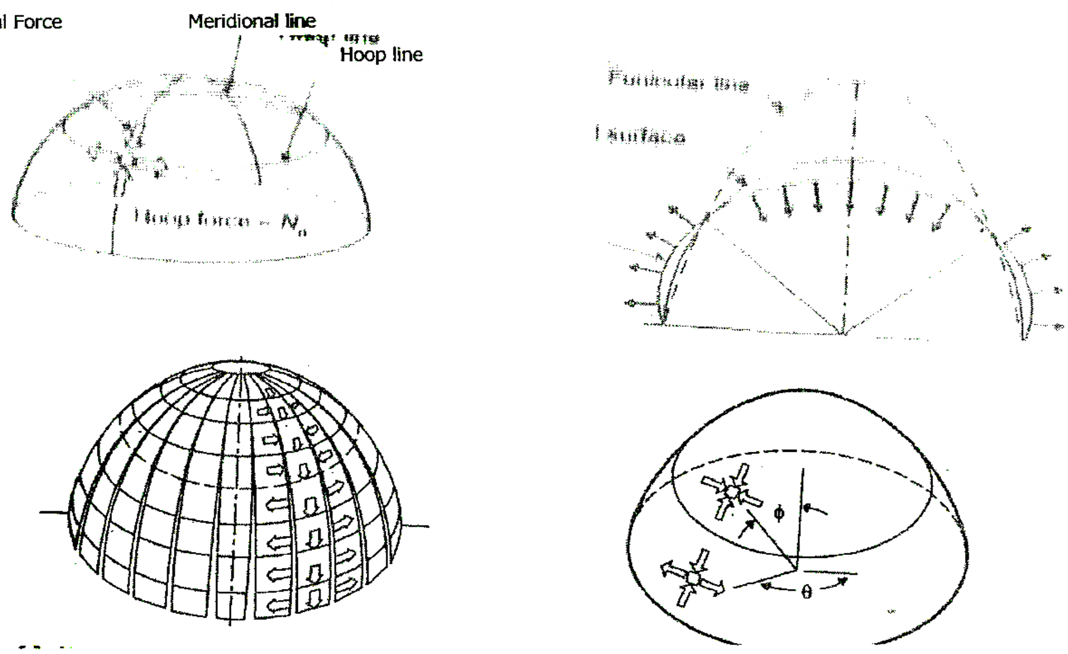

Support conditions for shell structures

Fixed Edge

Generally, the support conditions for shell structures can be any of the three below. The support conditions should be such that they do not tend to cause any bending to be developed in the shell structures. Fixed edge condition should not be allowed for reason stated below:

The roller edges are desirable in that they allow movements to occur more freely, but are very difficult to construct.

Construction Reinforcement for Shell Structures

The construction reinforcement for shell structures should be controlled by using reinforcement of different lengths, in order to check the shell surface. In practical construction considerations, some bending is often allowed to develop at the shell edge for the sake of easy constructions. The shell should be stiffened by increasing its thickness around the edge and reinforced for bending.

DOME

A dome is a three dimensional space structure, which is used to provide an easy and economic method of roofing to a large area. It also improves the appearance of the structure. When a dome is to be provided as the roof, a well is usually kept in the building. The well may be of a shape, such as a square, hexagonal, octagonal, etc. but the top of the dome is converted into a circular shape by a suitable formwork. The height of spring level of a dome above ground level is always kept at least equal to three storeys to present a passage appearance. The diameter of a dome may vary from 12 meters to 20 meters or even more for a particular design. The common types of shapes are shown below:

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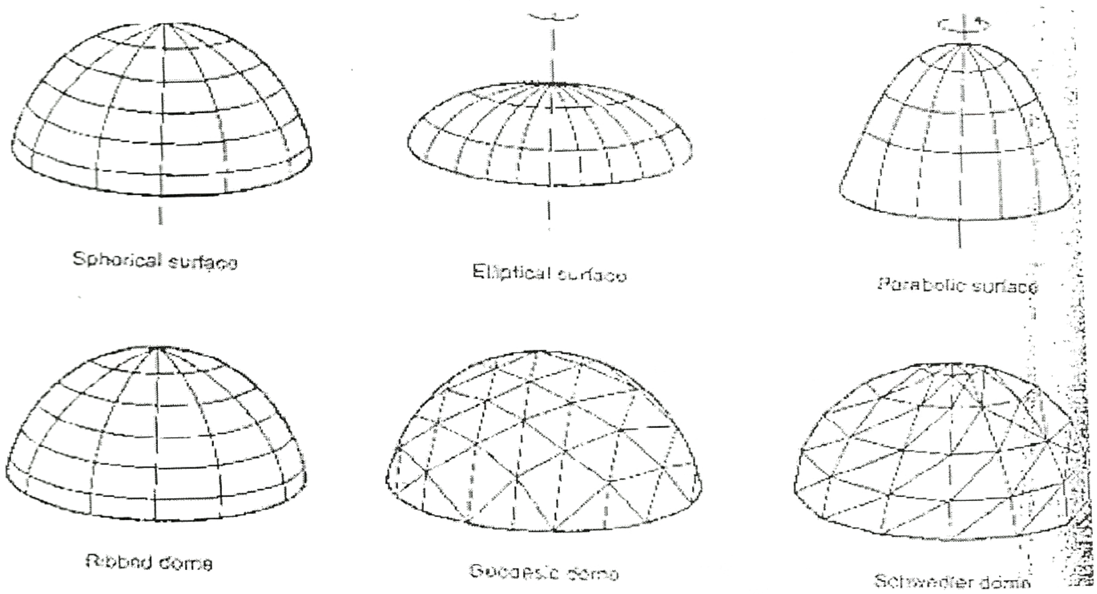

Construction of Domes

Domes are generally constructed in reinforced concrete. The construction of Domes required the design and applications of form work. The types of formwork required for Domes construction are:-

i. Solid formwork: - in case of solid formwork, the posts are carried from plinth up to the springing. Level of the Dome. This present a passage appearance type of formwork is used when there are projections around the Dome solid walls. Suitable cross-section preferably at each floor level may be provided to increase the rigidity of the formwork.
ii. Suspended formwork:- The skeleton of formwork is suspended from the spring level of the Dome. This type of formwork is adapted when solid walls are available at the springing level of Dome. The formworks are supported on these solid walls.

Formwork detailed Construction Procedures

The following procedures are usually adopted for the construction of Domes.

1. The formwork is brought up to the springing level of the dome. With this construction, the joists are fixed on the standards and smaller joists are closely arranged over these joists.
2. With the completion of the working platform, the trusses are placed over it to support the formwork. These trusses are constructed on the ground by drawing full size sections of the dome at the points where they are to be set up. The trusses are then dismantled, carried on the platform and again fitted and erected on it. The trusses are never allowed to rest directly on the platform, but on the jacks. When the trusses are finally adjusted to the true level of the jacks; they are then removed, and the blocks of hardwood are inserted in place of Jacks.
3. One vertical pole is fixed permanently at the centre during the construction of the formwork for the Dome.
4. A rotating swinging formwork is mounted on the central vertical pole. The shape of the rotating arm usually corresponds to the shape of the Dome, and hence this arrangement is used to check up the formwork for the Dome. The arm is then rotated and the portion of the formwork which does not correspond to the shape of the Dome is adjusted by the proper manipulation or adjustment of the jacks.
5. For hoisting or raising purposes, suitable equipment is erected near the Dome.
6. On the top of trusses, the purlines, rafters, and lagging are provided. The rafters are shaped to the shape of the Dome over the laggings, and the galvanized iron sheets or wooden boards are fixed to finished up the formwork. The final shape is then checked by the rotating formwork.

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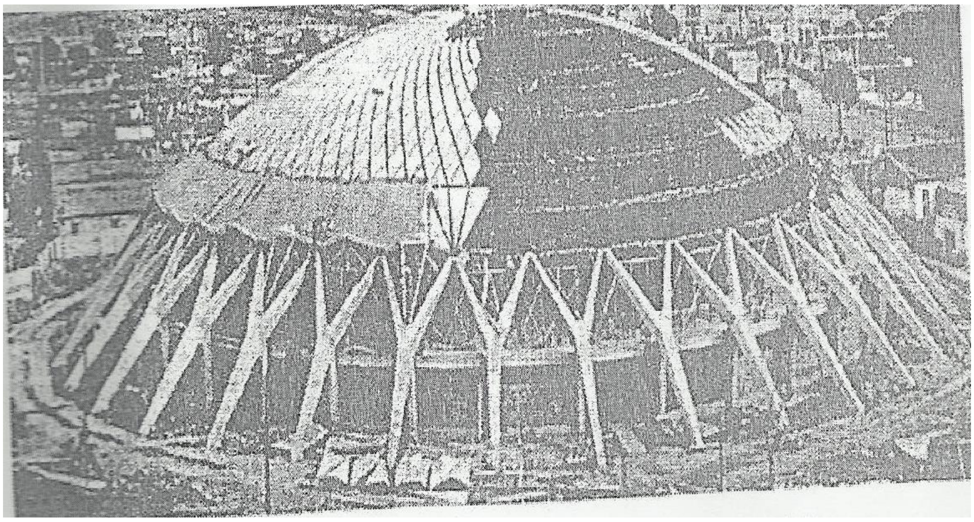
7. The construction of the Dome is then commenced by placing the concrete mixed materials. With the fixing of the Reinforcement arrangement in its proper positions. Proper care should be taking to preserves the shape of the formwork during its construction.
8. The dismantling of the formwork is finally carryout after the casting of the concretes. It is usually done after 3 or 4 days of the Dome construction.



Typical view of Dome during construction

Conclusion

Shells and Domes are generally called surface structures that are usually constructed from materials having a very small thickness, compared to its other dimensions. Sometimes, these materials may be very flexible and can be in any form. Shells and Domes can also be made from rigid materials such as reinforced concrete, which can also be shaped as folded plates, cylinder or even in hyperbolic shape, which provides aesthetic appearance for shells and Domes. The construction of these structures should be encouraged, especially on buildings, bearing in mind of the beauty they add to buildings generally.

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