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Programming of Braced Domes Using Formex Algebra

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Dr. D. R. Panchal

Applied Mechanics & Structural Engineering Department, Faculty of Technology & Engineering
The M. S. University of Baroda,Vadodara-390001.

ABSTRACT *The term 'space structure' refers to a structural system that involves three dimensions. There are numerous examples of space structures that are built for sports stadiums, gymnasiums, cultural centers, auditoriums, shopping malls, railway stations, aircraft hangars, leisure centers, transmission towers. A dome configuration is most suitable in space structure. Formex algebra is a comprehensive technique for algebraic representation and rapid processing of the configuration of any type of structure. Formex algebra is a mathematical system that consist of a set of abstract objects, known as formices and a number of rules in accordance with which these objects may be manipulated. Here various configuration of braced dome structure are created using formex algebra. These configurations of domes directly utilize in any professional software and analysis & design can be done.*

INTRODUCTION

The term 'space structure' refers to a structural system that involves three dimensions. The three-dimensional includes flat surfaces with loading perpendicular to the plane as well as curve surface. the term 'space structure' is simply used to refer to a number of families of structures that include grids, barrel vaults, domes, towers, cable nets, membrane systems, foldable assemblies and tensegrity forms. Space structures cover an enormous range of shapes and are constructed using different materials such as steel, aluminum, timber, concrete, fiber reinforced composites, glass, or a combination of these. There are numerous examples of space structures that are built for sports stadiums, gymnasiums, cultural centers, auditoriums, shopping malls, railway stations, aircraft hangars, leisure centers, transmission towers, radio telescopes, supernal structures (that is, structures for outer space) and many other purposes.

Space structures may be divided into three categories, namely, 'Lattice space structures' that consist of discrete, normally elongated elements, 'Continuous space structures' that consist of components such as slabs, shells, membranes, and 'Biform space structures' that consist of a combination of discrete and continuous parts.The behaviors of three classes of structure differ and their methods of analysis are also different. Of the above three types of structure, the skeleton or braced frame are also called latticed structures or space frames or reticulated structures. The overall shape of the surface and the pattern of the individual members of these structures may greatly affect their architectural appearance.

BRACED DOME CONFIGURATION

Formex algebra is a mathematical system that provides a convenient medium for configuration processing. The concepts are general and can be used in many fields. In particular, the ideas may be employed for generation of information about various aspects of structural systems such as element connectivity, nodal coordinates, loading details, joint numbers and support arrangements. The information generated may be used for various purposes, such as graphic visualization or input data for structural analysis. Several configurations are possible for the construction of space structures. These result in different characteristics in terms of strength, stiffness, weight, member force distribution, sensitivity to local damage and geometric imperfection, reliance on joint rigidity, degree of statically redundancy, ductility and future mechanism. The result should be useful in future designs aiming for the lowest cost and higher reliability.

The term 'configuration' is used to mean an 'arrangement of parts'. The term 'configuration processing' is used to mean the creation and manipulation of configurations and the term 'formex configuration processing' is used to mean configuration processing using formex algebra. The emerging branch of geometry is formex configuration processing provides the conceptual tools for space structure configuration.

The convenient medium for using the concept of formex configuration processing is programming language 'Formian'.

The use of this programming language is illustrated through example of braced domes.

FORMEX CONFIGURATION

```
(*) Schwedler dome (*)
M=12;    (*) No of element of the ring (*)
N=5;     (*) No of element of the rib (*)
S=20;    (*) Span (*)
H=10;    (*) Rise (*)
A=2*atan|(2*H/S);(*) Sweep Angle(*)
R=S/(2*sin|A);    (*)Radius(*)
E=rinit(M,N,1,1)|{[1,0,1;1,1,1], [1,0,1;1,0,2], [1,0,1;1,1,2]};
B=rin(2,M,1)|[1,0,N+1;1,1,N+1];
D=E#B;
DD=bs(R,360/m,A/(N+1))|D;
use &,vm(2),vt(2),
vh(0,2*r,4*r, 0,0,0, 0,0,1);
clear;
draw DD;
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Consider the dome configuration on fig-1. Dome of this kind are referred as "Schwedler dome". (After the German Engineer J W Schwedler who built a

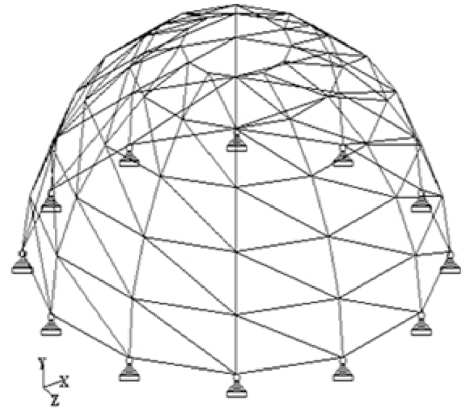

Fig 1 : Schwedler dome

number of domes of this type in the nineteenth century). In a Schwedler dome, each group of elements that forms a horizontal polygon is referred to as a 'ring' and each individual element of a ring is referred to as a 'ring element'. Also, each group of elements that lie along a meridional line between the crown and the base ring of a rib is referred to as a 'rib element'. Finally, there are the diagonally disposed elements that are referred to as 'diagonal elements'.

The most convenient reference system for the formulation of the compret of the configuration of the Schwedler dome of is a 'spherical normat'. A spherical normat may be imagined as consisting of an infinite number of concentric spheres.

In this scheme M represents the number of elements on a ring, N represents the number of elements on a rib, S represents the span and H represents the rise.

The 'sweep angle' is A =2 arctan(2H/S) = 90° The radius of the circumsphere of the dome is R= S/(2 sin A) =10m The 'central angle' of the dome is twice the sweep angle and is equal to 180°

rinit(M,N,1,1)|{[1,0,1;1,1,1],[1,0,1;1,0,2],[1,0,1;1,1,2]};
represents all the elements of the dome other than those along the base ring,
rin(2,M,1)|[1,0,N+1;1,1,N+1];
represents all the elements along the base ring and
E # B
represents all the elements of the dome.

The construct
bs(R,360/M,A/(N+1)) is a 'basispherical' retronorm. The effect of this function is to transform the spherical normat coordinates into global x-y-z Cartesian coordinates.

vm, vt, vh are used for see the different view.

```
(*)Double Layer Dome(*)

M=100; (*)No of element on a ring(*)
N=9; (*)No of element on a top rib(*)
S=75; (*)Span(*)
P=40; (*)gap(*)
D=1.5; (*)depth(*)
A=50; (*)sweep angle(*)
Rt=S/(2*sin|A); (*)Top Radius(*)
Rb=Rt-D; (*)Bottom Radius(*)
G= asin|(P/(2*Rt)); (*)Gap Angle(*)
i=(A-G)/(2*N);
                (*)Increment(*)
TOP=rinit(M,N+1,2,2*i)|[Rt,0,G;Rt,2,G]#
      rinit(M,N,2,2*i)|[Rt,0,G;Rt,0,G+2*i];
BOT=rinit(M,N,2,2*i)|[Rb,1,G+i;Rb,1,G+i]# rinit(M,N-1,2,2*i)|
[Rb,1,G+i;Rb,1, G+3*i];
WEB=rinit(M,N,2,2*i)|lamit(1,G+i)|[Rt,0,G;Rb,1,G+i];
DD=TOP#BOT#WEB;
DD=bs(1,360/(2*M),1)|DD;
use &,vm(2),vt(2), vh(0,2*Rt,4*Rt,0,0,0, 0,0,1);
clear;
draw DD;
```

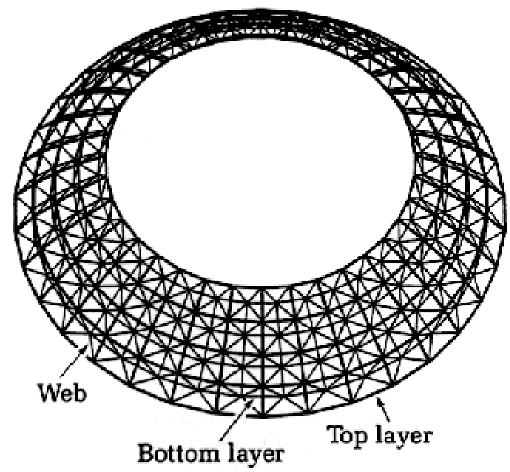

Fig 1.9.17 Perspective view of a double layer canopy dome

Fig 2. Perspective view of a double layer canopy dome

The above dome has 324 top layer elements, 252 bottom layer elements and 576 web elements. In fig. 2. the top layer elements of the dome are shown by thick lines and the bottom layer elements as well as the web elements are shown in thin lines.

Similarly, i have created different configuration for different types of braced domes.

CONCLUSIONS

1. Space structure configurations are elegant and impressive but, unless the designer is equipped with suitable conceptual tools, the task of generation of geometry is extremely difficult. Formex algebra stands alone as an algebra which provides a powerful mathematical basis for new approach to data generation. Formex configuration is emerging branch of generation of geometry of skeletal structures. It complements the human imagination and allows mentally visualized configuration to express in a concise and elegant manner & it is really proven efficient tool for modeling space structure.
2. Formian software provides a platform for formex configuration processing, generation of various types of structure like Braced Domes, Grids, Barrel Vaults, Pyramid, Towers, and Foldable System etc. This software not only generated the geometry but it is also integrated with other software like other internationally popular packages like ABACUS, LUSAS, and SAP etc. In addition to this it is also generated the data exchange file (*.dxf), which can imported in majority of CAD packages. This facility is efficiently exploited in present work.

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