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Optimization of Shell Structure Using Genetic Algorithm

Dr. R. J. Fernandes[1], Sushmita Yadahalli[2]

[1]Assistant Professor SDM college of Engineering and Technology, Dharwad, Karnataka, India

[2]PG Scholars, SDM College of Engineering and Technology, Dharwad, Karnataka, India

Abstract: ***Shell structures are used efficiently and also economically in many fields of architecture and engineering. Shell roofs are made from structural 'skins' where the shell material is thin in section relative to the other dimensions of the roof and undergoes relatively little deformation under load. They are commonly used where a building interior needs to be free from intermediate walls or columns that might support a more conventional flat or pitched roof. Shells provide an aesthetic view. In this paper, optimization is carried out for different grades of concrete keeping thickness, chord length, and semi-central angle variable, whereas in a shell roof with an edge beam width of the beam is constant and the depth of the beam varies. A computer program is written in MATLAB software for the optimization process using the genetic algorithm method, and analysis results are retrieved from SAP2000 software to carry out the optimization process.***

Keywords: shell structure, genetic algorithm, shell roof, edge beam, concrete

1. Introduction

Large span constructions with a single storey, such as assembly halls, amusement centers, theatres, factories, research labs, etc., are covered with shell roofs. Because shell roofs are aesthetically pleasant, they are frequently utilized in public buildings. The shell roof is far more practical than a flat or even a pitched roof when the interior of the structure must be open with no walls or pillars. The roofs made of shells are lighter and require less concrete and steel for reinforcement.

The two forms of shell roofs are single-curved shell and doubly-curved shell. Single-curved shells must have a minimum thickness of 5 cm. Structure-wise; double curved shells are superior to single curved shells.

In shell roof construction, the roof's slope and arc's curvature must be properly planned in order to keep the building stable. As the entire roof structure must be constructed at one level, shell roofs are not suited for situations where the roof must be at various levels. Lighting and ventilation setups are challenging to establish in shell roof construction.

The design of a shell roof is challenging, expensive, and requires knowledgeable personnel. A shell roof can be built without support beams and is quite thin. Materials for these kinds of roofs are less expensive than those needed for flat or pitched roofs.

2. Modeling and Analysis of Shell Structure

The analysis of shell structure is carried out by using CSI SAP2000 software.

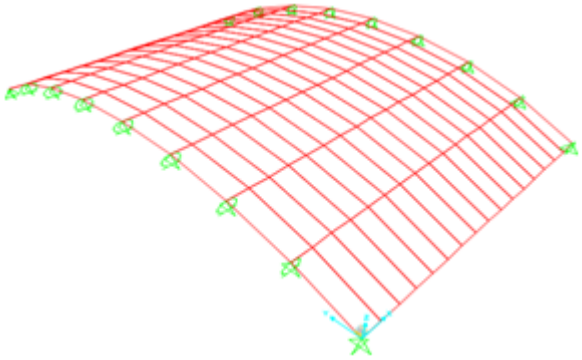

Figure 1: Shell structure model

Data used in the analysis is as follows

Chord length – 8m to 12m

Span – 8m

Thickness – 75mm to 200mm

Semi central angle (T) – 30^0 to 45^0

$$\text{Radius} = \frac{\text{Chord length}}{2*\sin T}$$

Width of beam - 230mm

Depth of beam - 230mm to 450mm

3. Results

In this chapter we study on process of optimization of shell structure of M30 grade of concrete is carried out and keeping length 8m and the following inputs are listed below and results obtained for the same are as follows.

a) Objective function = minimization of weight for the shell structure
b) No of variables 4 =X1, X2, X3,X4
c) No of constraints

Stress - $\frac{\sigma}{\sigma_a}$ -1< 0 where, σ = stress, σ_a = allowable stress

Deflection - $\frac{\Delta}{\Delta_a}$ -1<0 where, Δ = deflection, Δ_a = allowable deflection

Allowable stress for M30 concrete = 30N/mm^2
Permissible deflection = Span/360

d) No of individuals per population 20
e) Maximal Number of Generations 20
f) Generation Gap 0.8
g) Displacement being constant 10mm
h) Lower limit of variable
X1 - 30^0
X2 - 75mm
X3 - 8m
X4 – 230mm
i) Upper limit of variables
X1 - 45^0
X2 - 200mm
X3 - 12m
X4 – 450mm

X1, X2, X3 and X4 are semi central angle, thickness, chord length and depth of beam respectively.

Shell Roof without Edge Beam

S. No	Grade of Conc.	X1(DEGREE)	X2(M)	X3(M)	Weight(KN)
1	M20	45	0.091	9	17.58
2	M30	36	0.108	8	17.78
3	M40	40	0.075	8	12.5
4	M50	30	0.083	8	13.40

Shell Roof with Edge Beam

S. No.	Grade of conc.	X1(DEGREE)	X2(M)	X3(M)	X4(M)	Weight(KN)
1	M20	41	0.0833	8	0.266	16.31
2	M30	35	0.075	9	0.356	16.95
3	M40	36	0.075	9.5	0.410	18.25
4	M50	38	0.075	11	0.392	20.52

4. Conclusion

In this work, optimization of shell is carried out by genetic algorithm method. Optimization is carried out for different grade of concrete keeping chord length as variable, so that an optimum value of weight of the shell structure is determined. In this present work, optimization of shell structure is carried out by applying uniformly distributed loads throughout the shell structure. . From the results it is found that

a) Genetic algorithm as a method of optimization is satisfactorily applied to shell structures.
b) As the chord length is increased the values of optimum weights also increases.
c) From the result it is observed that for different grade of concrete different optimum values are obtained.

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