

STRUCTURAL ANALYSIS AND OPTIMIZATION OF CONCRETE SPHERICAL AND GROINED SHELLS

Ivana Mekjavić, Srećko Pićulin

Subject review

An understanding of successful shells of the past combined with modern structural analysis methods can aid engineers in designing efficient thin shell-concrete structures. This paper presents structural analyses and the optimization study of several notable concrete shells around the world. The finite element analysis using Sofistik software was found to give results close to those from shell theory and to be more powerful when complicated real-life examples were presented. In structural optimization of the concrete spherical and groined shells an attempt is made to reduce overall tensile stress, deflection and reinforcement to the system while changing the limits of the structure's shape. The structural optimization study of these shells shows that a distributed concrete thickness reduces shell stresses, deflections and reinforcements.

Keywords: concrete shells, groined shell, spherical shells, structural analysis, structural optimization

Statika analiza i optimizacija betonskih sfernih i svodastih ljusaka

Pregledni članak

Razumijevanje ranijih uspješnih ljusaka kombinirano sa suvremenim metodama proračuna konstrukcija može pomoći inženjerima u projektiranju efikasnih tankih betonskih ljuskastih konstrukcija. U ovom radu je prikazana statička analiza i optimizacija nekoliko značajnih betonskih ljusaka u svijetu. Analiza pomoću metode konačnih elemenata upotrebom programa Sofistik dala je rezultate bliske onima prema teoriji ljusaka te se pokazala moćnijom za prikazane složene izvedene primjere. Pri optimizaciji konstrukcije betonskih sfernih i svodastih ljusaka nastojalo se reducirati ukupno vlačno naprezanje, progib i armatura u sustavu uz mijenjanje granica oblika konstrukcije. Optimizacija konstrukcije ovih ljusaka pokazala je da raspodijeljena debljina betona reducira naprezanja, progibe i armaturu ljusaka.

KLjučne riječi: betonske ljuske, optimizacija konstrukcije, sferne ljuske, statička analiza, svodaste ljuske

1 Introduction Uvod

Analytical procedures of thin shell analysis generally require the solution of ordinary or partial differential equations, which are not usually obtainable for complex structures. Hence, numerical methods are relied upon, such as the finite element method, for acceptable solutions. Engineering judgment and experience may be guides as reliable as analytical procedures based on simplifying assumptions. Factors such as size, geometry of the shell, especially the type and amount of curvature, boundary conditions, and load distribution must be considered collectively by the designer in the choice of analytical procedures.

The widespread use of large-scale computer programs for structural analysis has reduced reliance on classical methods, provided insight into previously unsolved problems and held out the hope for automatic optimized design.

Design by membrane theory provided essentially a correct basis for design in the hands of experienced shell designers; but bending theory gotten from computer-based numerical solutions gives the inexperienced engineer the opportunity to explore the behaviour of various different forms.

2 Comparison between shell theory and finite-element analysis for a spherical dome

Usporedba teorije ljusaka i metode konačnih elemenata za sfernu kupolu

A comparison of a spherical dome was made between

the Sofistik finite element analysis results and shell theory equations using an example found in [1].

The rigidly supported spherical dome of Fig. 1 is analyzed for uniform gravity load over the dome surface. The parameters of the problem are: $r = 28,80$ m (94,5 ft), constant shell thickness $h = 10,2$ cm (4 in), $\alpha = 28^\circ$, parallel circle radius at springing $r_s = r \sin \alpha = 13,49$ m (44,25 ft), Poisson's ratio $\nu = 1/6 = 0,167$, $q = 2,55$ kN/m² (dead load) + $1,76$ kN/m² (live load) = $4,31$ kN/m² (90 psf). Concrete class is C30/37, concrete strength is $f_{ck} = 30$ N/mm² and modulus of elasticity $E = 32000$ N/mm².

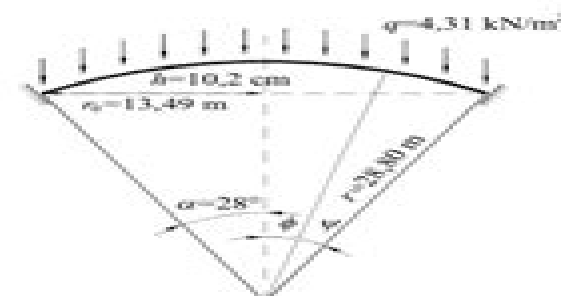


Figure 1 Fixed spherical dome for comparison between finite element analysis and analytic example

Slika 1. Sferna kupola na opetnim osloncima za usporedbu između metode konačnih elemenata i analitičkog primjera

The forces were computed on the basis of the membrane theory, where meridional force is

Structural Analysis Of Shells

E. H. Baker, L. Kovalevsky, F. L. Rish



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 - The Rise of Digital Reading Structural Analysis Of Shells
 - Advantages of eBooks Over Traditional Books
2. Identifying Structural Analysis Of Shells
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Structural Analysis Of Shells
 - User-Friendly Interface
4. Exploring eBook Recommendations from Structural Analysis Of Shells
 - Personalized Recommendations
 - Structural Analysis Of Shells User Reviews and Ratings
 - Structural Analysis Of Shells and Bestseller Lists
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 - Structural Analysis Of Shells Enhanced eBook Features
- 7. Enhancing Your Reading Experience
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 - Highlighting and Note-Taking Structural Analysis Of Shells
 - Interactive Elements Structural Analysis Of Shells
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 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Structural Analysis Of Shells
- 9. Balancing eBooks and Physical Books Structural Analysis Of Shells
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Structural Analysis Of Shells
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Structural Analysis Of Shells
 - Setting Reading Goals Structural Analysis Of Shells
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Structural Analysis Of Shells
 - Fact-Checking eBook Content of Structural Analysis Of Shells
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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