



Article

On Hierarchical Applications of Finite Element Methods and Classical Applied Mechanics Approaches for Complex Structures

Sheldon Wang ^{1,*} , Ebot Ndip-Agbor ² and Enahó Atamenwan ³

¹ McCoy School of Engineering, Midwestern State University, Texas Tech University System, 3410 Taft Blvd., Wichita Falls, TX 76710, USA

² Austin, TX 78727, USA; ebot@u.northwestern.edu

³ R.T. Moore, Indianapolis, IN 46268, USA; eatamenwan@rtmoore.com

* Correspondence: sheldon.wang@msuutexas.edu; Tel.: +1-940-704-8436

Abstract: In this paper, hierarchical studies based on both analytical and computational approaches have been employed to validate and improve current structural designs of mud holding tanks for hydraulic fracturing in petroleum industries. Through detailed comparisons at different levels of approximations for both real world complex structural design problem and a simplified stiffened plate with extreme geometrical aspect ratios, proper design procedures have been reiterated and validated. It is highly recommended that low-dimensional structures with emphasis on classical mechanics principles should be considered before full-fledged three-dimensional computational analyses. Both Castigliano's Theorems and Galerkin methods are utilized along with simulation packages such as ADINA and Solidworks. The hierarchical approximation procedures reemphasize important subjects such as planes and shells, strength of materials, structural mechanics, asymptotic and perturbation analysis no longer required in some engineering programs, yet often necessary for the study of complex three-dimensional structural systems.

Keywords: finite element method; hierarchical; stiffener; buckling; multi-scale modeling



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1. Introduction

In today's engineering practice, analyses of very complex systems are frequently studied based on various finite element methods (FEM) and computational fluid dynamics (CFD) tools. The sophistication of these simulation packages and their direct connections with solid modeling and engineering graphics tools have inadvertently left false impressions among design engineers that the fundamentals of solid and fluid mechanics are no longer needed. In fact, some of the design engineers tend to utilize simulation packages right at the beginning stage of the design process at which the entire system and its geometries and configurations are still not finalized. As a consequence, the intricate design details and specifics which are not finalized will be entangled with the complication of meshing and multi-scale issues for both FEM and CFD analyses. In a way, this is very similar to applying high resolution or magnification lenses during preliminary search within a fairly large area, which is obviously very ineffective, inefficient, and wasteful with respect to both time and financial resources.

Wichita Tank Manufacturing LTD presented the McCoy School of Engineering with a design concern with respect to their 500 fluid barrel (BBL) holding tanks for hydraulic fracturing, as shown in Figure 1. In the United States of America, most fluid barrel apart from oil barrel has the following conversion ratio, namely, 1 BBL is equivalent to 119 liters (L) or 31.5 gallons. Initially, these tanks were designed to hold up to 15,750 gallons of water. While it is empty, the tank will be transported through highway systems to and from different locations. The problem is to determine whether or not it is safe to hold

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Table of Contents Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover

1. Understanding the eBook Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover
 - The Rise of Digital Reading Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover
 - Advantages of eBooks Over Traditional Books
2. Identifying Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover
 - 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 Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover
 - User-Friendly Interface

4. Exploring eBook Recommendations from Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover
 - Personalized Recommendations
 - Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover User Reviews and Ratings
 - Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover and Bestseller Lists
5. Accessing Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover Free and Paid eBooks
 - Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover Public Domain eBooks
 - Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover eBook Subscription Services
 - Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover Budget-Friendly Options
6. Navigating Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover eBook Formats
 - ePub, PDF, MOBI, and More
 - Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover Compatibility with Devices
 - Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover
 - Highlighting and Note-Taking Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover
 - Interactive Elements Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover
8. Staying Engaged with Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Stability Of Structures By Finite Element Methods Studies In Applied

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9. Balancing eBooks and Physical Books Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover
 - Setting Reading Goals Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover
 - Fact-Checking eBook Content of Stability Of Structures By Finite Element Methods Studies In Applied Mechanics Hardcover
 - 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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