Finite Element Modeling of Army Airbeam Structures

May 4, 2005
JOCOTAS – Port Hueneme, CA

U.S. Army RDECOM - Natick Soldier Center Collective Protection Directorate, Fabric Structures Team
Karen Santee – Project Engineer
Report Documentation Page

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE
   04 MAY 2005

2. REPORT TYPE

3. DATES COVERED
   00-00-2005 to 00-00-2005

4. TITLE AND SUBTITLE
   Finite Element Modeling of Army Airbeam Structures

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER
5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
   U.S. Army Research, Development and Engineering Command, Natick, MA, 02154

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR’S ACRONYM(S)

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
   Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:
   a. REPORT
      unclassified
   b. ABSTRACT
      unclassified
   c. THIS PAGE
      unclassified

17. LIMITATION OF ABSTRACT
   Same as Report (SAR)

18. NUMBER OF PAGES
   19

19a. NAME OF RESPONSIBLE PERSON

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18
Agenda

- Brief Overview of Airbeams
- Engineering Process
- Modeling Approaches
- Fabric Airbeam Models
- Modeling Technical Barrier
- Cavity Filled Membrane Models
- Airbeam and Fabric Membrane Models
- Application of Modeling
- Center of Excellence
- Current Small Business Innovative Research Projects
Brief Overview of Airbeams

- Load Bearing Pressurized Fabric Structures
- Pressurization pre-tensions the fibers, creating a structure that is rigid under design loads, but deflects without damage when overloaded
- Outstanding strength-to-weight ratio
Engineering Process

Textiles
New High Strength Seamless Manufacturing Technology

Modeling
Establish and Verify Analytical Techniques

Airbeams
Rapid Deployment Reduced Manpower Lightweight

Mechanical Systems
Rapid Inflation Integral Power/ECU

System Issues
Textile/Hardware Interfaces Deployment Technique Airbeam/skin integration Anchoring techniques

04 May 2005
Modeling Approaches

Airbeam Fabric

Cavity Filled Membrane

Airbeam & Fabric Membrane

04 May 2005
Fabric Airbeam Models

Finite Element Results for Shear

Experimental Results for Shear

04 May 2005
Barrier:
Test method to evaluate structural properties of fabrics subjected to combined multi-axial tension and shear loads for design purposes

Problem:
Fabric elastic modulus & shear stiffness are dependent on:
- Fiber Directions
- Fabric Construction
- Tow Density Ratios (TDR)
- Coatings
- Inflation Pressure
- Structural Loads

Solution:
A new test apprentice that can determine the pressure dependent elastic modulus and pressure dependent shear modulus.

Patent Awarded
Cavity Filled Membrane Models

- Model results based on changes in cavity volume and inflation pressure
- Has begun to be explored and is in process of validation
Airbeam and Fabric Membrane Models

Pressurized beam theory
Straight lines (typ)
Measured Curved lines (typ)

Displacement (inches)
Total Load (lbs)

12 psi
22 psi
32 psi
42 psi

0 0.5 1 1.5 2 2.5 3
0 50 100 150

04 May 2005
Application of Modeling

Deployable Airbeam Fender System for the Joint High Speed Connector

Deflated  Inflated
Verification of Model

Side View ~ 50% Compression

04 May 2005
Model Variations

Scaled Prototype Model

Partial Air and Water Model

Side View of Pinch Point

Partial Compression

04 May 2005
Center of Excellence
Inflatable Composite Structures

Increase durability, reliability and affordability

Establish predictive design tools and models

Market and Document Technology

Partner with DoD and government agencies, industry, and academia

Broaden inflatable structure applications and commercialize the technology

Vision

Deliver new inflatable technology into the hands of warfighters and commercial users.

(Established in 2001 at the Natick Soldier Center in Natick, MA)

04 May 2005
Small Business Innovative Research Project

• Flexible Display
  – Physical Optics Corporation

• Solid State Lighting
  – Space Hardware Optimization Technology
  – Physical Optics Corporation

• Photovoltaic Power Shade
  – Iowa Thin Film Technologies

• Insulation
  – Aspen Aerogels
  – L’Garde, Inc.
Flexible Display

Capabilities:

- Ultra thin (<1 mm), flexible (6-10 cm bending radius), high-resolution (100 mm pixel size, total up to 640 x 480 pixels)
- Lightweight (<0.5 g per 1 cm² of display area, <100 g for electronics)
- Full-color, real-time (30-60 Hz refresh), high-optical-contrast (>100:1) display
- Scalability in the display area (from 1 cm² to 1 m² active area)
- Visual images, such as maps and drawings, will be displayed on shelter fabric
Solid State Lighting

Capabilities

– Evenly illuminates floor level (one fixture for 1 m²) 3 m² in near future
– Permanently attached to shelter (deployed together)
– Operates from outside power or from battery 100,000 hr. lifetime
– Runs 6 hr. on 5 AA batteries with power shutoff
– 10 times longer life than fluorescent light
– Compact, lightweight (100 g fixture)
– All light is directed to the floor (no dispersed light)
– Solar spectrum
– Low cost in mass production ($5/fixture)
Photovoltaic Power Shade

“Power Shade”

**Application:**
- Solar shade w/ integral PV power
- Provides 1 Kw of PV power, reduces solar load 80% – 90%
- Design to fit over: MGPTS small, 16’ TEMPER
- Modular expandability

**Specifications**
- Dimensions: 22’ x 20’ x 10’9” – 14’6”
- Power: ~1 Kw
- Operating Voltage: 12V
- BOS required
  - PV combiner boxes
  - Master disconnect switch
  - Charge controllers
  - 12V Deep cycle batteries
  - Inverter for 120 VAC use

Application:
- Solar shade w/ integral PV power
- Provides 1 Kw of PV power, reduces solar load 80% – 90%
- Design to fit over: MGPTS small, 16’ TEMPER
- Modular expandability

04 May 2005
Insulation

• Aspen Aerogels
  – 85% Packing Cube Reduction
  – R-value > 6 °F·ft²·hr/Btu
  – Flame Resistance
  – 99% Open Porosity
  – Noise and IR Suppression
  – Phase II partner with Johnson Outdoors

• L’Garde
  – Phase III
  – R-value > 6 °F·ft²·hr/Btu
  – Weight < 20 oz/yd²
  – Demonstrated 65% reduction in heating/cooling power requirements
  – Automated fabrication
  – Adjustable to fit multiple shelter geometries

MIL-C-44154B Aspen Insulation

04 May 2005
Thank You