Conference Program

Earth and Space 2014

Engineering for Extreme Environments

October 27-29, 2014 | St. Louis, Missouri, USA

Missouri S&T University of Science & Technology

ASCE Earth and Space 2014

Organizing Committee

Conference Chair
Leslie Gertsch (gertschl@mst.edu)
Missouri University of
Science and Technology, Rolla, MO
Phone: 573-341-7278

Symposia Chairs
Symposium 1 - Granular Materials in Space Exploration
Juan Agui (juan.h.agui@nasa.gov)
NASA Glenn Research Center, Cleveland, OH
Phil Metzger (philip.metzger@ucf.edu)
University of Central Florida, Orlando, FL

Symposium 2 - Exploration and Utilization of Extra-Terrestrial Bodies
Robert P. Mueller (rob.mueller@nasa.gov)
NASA Kennedy Space Center, FL
Kris Zacny (zacny@honeybeerobotics.com)
Honeybee Robotics, Pasadena, CA

Symposium 3 - Advanced Materials and Designs for Hydraulic, Earth, and Aerospace Structures
Robert Goldberg (robert.goldberg@nasa.gov)
NASA Glenn Research Center, Cleveland, OH
Pizhong Qiao (qiao@wsu.edu)
Washington State University, Seattle, WA

Symposium 4 - Structures in Challenging Environments: Dynamics, Controls, Smart Structures, and Sensors
Ramesh B. Malla (mallar@engr.uconn.edu)
University of Connecticut, Storrs, CT
Gangbing Song (gsong@central.uh.edu)
University of Houston, Houston, TX

Student Paper Competition
Paul van Susante (pjvansus@mtu.edu)
Michigan Technological University
Houghton, MI

Sponsorships
John Koppelman
(john.koppelman@boeing.com)
Boeing Corporation, Seattle, WA

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Sue Turner (Conference Coordinator)
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Dr. Leslie Gertsch
Conference Chair

Welcome to the 14th offering of ASCE Earth and Space Conference!

The first conference of this biennial series was held in Albuquerque, New Mexico, in 1988. Since then the conference has been held in various locations, including Houston, Hawaii, and Pasadena, sharing sessions on many aspects of space exploration, robotics, advanced materials, and smart structures.

This year's ASCE International Conference on Engineering, Science, Construction, and Operations in Challenging Environments is being held in the gateway city of St. Louis, Mo., on the 250th anniversary of the city's founding.

Conference highlights include:

- Special talks on the Moon, Mars, asteroids, and smart structures.
- Nearly one hundred presentations in four concurrent symposia over two and a half days.
- Two of the many innovative robotic exploration tools being designed and built by student teams.
- Student research posters and paper contest.
- A pre-conference short course on Space Mining and Planetary Surface Construction.

Our venue is St Louis' only five-star hotel, the Four Seasons, with a mesmerizing view of the Mississippi River and its historic bridges, within walking distance of the iconic Gateway Arch.

The Committee and I sincerely hope that you enjoy your time here and find that the activities stimulate new partnerships, new ideas, and new goals. As settlers prepared in St Louis 140 years ago for their futures in the American West, so now we are preparing for our futures in even more challenging regions of the Earth and the Solar System.

Leslie Gertsch
Conference Chair

ASCE Aerospace Division Awards

Outstanding Professional Service Award for 2012
Kris Zacny, Ph.D.
Vice President and Director,
Exploration Technology Group

Outstanding Technical Contribution Award for 2012
Ramesh B. Malla, Ph.D.
Associate Professor,
Department of Civil & Environmental Engineering, University of Connecticut

Outstanding Technical Contribution Award for 2013
Hong-Nan Li, Ph.D.
Professor and Dean,
Faculty of Infrastructure Engineering
Dalian University of Technology

Thank you sponsors

On behalf of the ASCE Earth and Space Conference Organizing Committee, we would like to express our appreciation to this year's esteemed sponsors.

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www.honeybeerobotics.com

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Boardroom

Monday, October 27

7:00 a.m. – 5:00 p.m.
Registration Desk Open
Ballroom Lobby

7:00 a.m. – 8:00 a.m.
Continental Breakfast
Ballroom Prefunction

8:00 a.m. – 9:00 a.m.
Opening Plenary Session
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Fountains of the Moon
Plenary Speaker Gregg Maryniak
Speaker details on page 6

9:00 a.m. – 5:30 p.m.
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Granular Materials in Space Exploration
Laclede Room A/B
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11:00 a.m. – Regolith Geotechnics 2
1:30 p.m. – Regolith Physical Properties
3:30 p.m. – Regolith Simulants

Symposium 2:
Exploration and Utilization of Extra-Terrestrial Bodies
Gateway Room A/B
9:00 a.m. – Planetary Drilling 1
11:00 a.m. – Planetary Drilling 2
1:30 p.m. – Planetary Surface Sampling
1:30 p.m. – Regolith as Construction Material (Fontaine Room)
3:30 p.m. – Civil Engineering in Space 1

Symposium 3:
Advanced Materials and Designs
Fontaine Room
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11:00 a.m. – Mechanical Behavior of Advanced Materials 2
3:30 p.m. – Mechanical Behavior of Advanced Materials 3

Symposium 4:
Structures in Challenging Environments
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9:00 a.m. – Advances in Diagnostic and Monitoring Methods 1
11:00 a.m. – Advances in Diagnostic and Monitoring Methods 2
1:30 p.m. – Seismic, Tidal, and Artificial Loading of Structures
3:30 p.m. – Advanced Structures and Actuation Technology

10:30 a.m. – 11:00 a.m.
Break/Student Posters
Ballroom Prefunction

12:00 p.m. - 12:30 p.m.
Break for Lunch

12:00 p.m. – 3:00 p.m.
Journal of Aerospace Engineering Editorial Board
Boardroom

12:30 p.m. – 1:30 p.m.
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Advances and Applications on Structural Vibration Control of Infrastructures
Speaker Hongnan Li
Speaker details on pages 6-7

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7:00 p.m. – 9:00 p.m.
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Boardroom

Tuesday, October 28

7:00 a.m. – 5:00 p.m.
Registration Desk Open
Ballroom Lobby

7:00 a.m. – 8:00 a.m.
Continental Breakfast
Ballroom Prefunction

8:00 a.m. – 9:00 a.m.
Plenary Session
Ballroom A

Roving on Mars with Opportunity and Curiosity: Terramechanics and Terrain Properties
Plenary Speaker Raymond Arvidson
Speaker details on page 6

9:00 a.m – 5:30 p.m.
Concurrent Technical Sessions

Symposium 1:
Granular Materials in Space Exploration
Laclede Room A/B
9:00 a.m. – Mechanism-Regolith Interactions 1
11:00 a.m. – Mechanism-Regolith Interactions 2
1:30 p.m. – Regolith-Rocket Exhaust Interactions
3:30 p.m. – Rover-Regolith Interactions 1

Symposium 2:
Exploration and Utilization of Extra-Terrestrial Bodies
Gateway Room A/B
9:00 a.m. – Novel Approaches and Architectures
11:00 a.m. – Civil Engineering in Space 2
1:30 p.m. – Planetary Excavation
3:30 p.m. – Space Resources Utilization

Symposium 3:
Advanced Materials and Designs
Fontaine Room
9:00 a.m. – Structures Under Extreme Conditions
3:30 p.m. – Hydraulic Structures

Symposium 4:
Structures in Challenging Environments
Hawthorn Room
9:00 a.m. – Structures and Systems in Challenging Environments 1
11:00 a.m. – Structures and Systems in Challenging Environments 2
1:30 p.m. – Advances in Diagnostic and Monitoring Methods 3

10:30 a.m. – 11:00 a.m.
Break/Student Posters
Ballroom Prefunction

12:00 p.m. – 1:30 p.m.
Awards Luncheon
Ballroom B

ASCE Aerospace Division Awards
ASCE Columbia Award

Techno-Stories from Space
Speaker Don Pettit
Speaker details on page 7

3:00 p.m. – 3: 30 p.m.
Break/Student Posters
Ballroom Prefunction

6:00 p.m. – 7: 30 p.m.
Advanced Materials Technical Committee Meeting
Boardroom

7:30 p.m. – 9: 00 p.m.
Regolith Operations, Mobility and Robotics Technical Committee Meeting
Laclede Room

Wednesday, October 29

7:00 a.m. – 10:00 a.m.
Registration Desk Open
Ballroom Lobby

7:00 a.m. – 8:00 a.m.
Continental Breakfast
Ballroom Prefunction

8:00 a.m. – 9:00 a.m.
Plenary Session
Ballroom A

Redefining Natural Resources: The Next Audacious Step
Plenary Speaker Chris Lewicki
Speaker details on page 7

9:00 a.m. – 11:00 a.m.
Concurrent Technical Sessions

Symposium 1: Granular Materials in Space Exploration
Laclede Room A/B
9:00 a.m. – Rover-Regolith Interactions 2

Symposium 2: Exploration and Utilization of Extra-Terrestrial Bodies
Gateway Room A/B
9:00 a.m. – Asteroid Utilization

Symposium 3: Advanced Materials and Designs
Fontaine Room
9:00 a.m. – New Materials and Structures

Technical Committee Meetings

Sunday, Oct. 26

4:00 p.m. – 6:00 p.m.
Dynamics & Control Technical Committee Meeting
Boardroom

Monday, Oct. 27

12:00 p.m. – 3:00 p.m.
Journal of Aerospace Engineering Editorial Board
Boardroom

7:00 p.m. – 9:00 p.m.
Executive Committee Meeting
Boardroom

Tuesday, Oct. 28

6:00 p.m. – 7: 30 p.m.
Advanced Materials Technical Committee Meeting
Boardroom

7:30 p.m. – 9: 00 p.m.
Regolith Operations, Mobility and Robotics Technical Committee Meeting
Laclede Room

Sunday, October 26

Pre-Conference Short Course

Space Mining and Planetary Surface Construction

This short course addresses the new fields of space mining and planetary surface construction. Its objective is to reduce the technical and programmatic miscommunication that can occur when geotechnical, geological, tunneling, and mining engineers interact with aerospace engineers.

Instructors

Kwame Awuah-Offei
Missouri University of Science and Technology, Mining and Nuclear Engineering Department

Brandon Coleman
Missouri University of Science and Technology, Mechanical and Aerospace Engineering Department

Leslie Gertsch
Missouri University of Science and Technology, Rock Mechanics and Explosives Research Center

Ronaldo Luna
St. Louis University Parks College of Engineering, Aviation and Technology

Phil Metzger
University of Central Florida, Florida Space Institute

Robert P. Mueller
NASA Kennedy Space Center, Swamp Works

David A. Summers
Missouri University of Science and Technology, Rock Mechanics and Explosives Research Center

Course Schedule

Fundamentals - 12 p.m. – 1:30 p.m.
Gertsch, Coleman, Luna and Metzger

Surface Construction Engineering - 1:45 p.m. – 3:15 p.m. *Luna*

Subsurface Access - 3:30 p.m. – 5:00 p.m.
Gertsch and Summers

Mining - 5:15 p.m. – 6:45 p.m.
Awuah-Offei

Next Steps - 7:00 p.m. – 8:00 p.m.
Metzger and Mueller

Conference Plenary Speakers

Monday, Oct. 27, 2014

Opening Plenary Session

8:00 a.m. – 9:00 a.m.

Ballroom A

Speaker Gregg Maryniak

Co-founder and Secretary
of the XPRIZE Foundation

Fountains of the Moon

With almost limitless quantities of energy and materials, near-Earth space offers the promise of abundance for civilization. But true industrial activity in space is not yet commercially viable and will not succeed until three different 'streams' converge simultaneously beyond the Earth. Understanding these streams and their properties is the key to unlocking exponential abundance and preserving Earth's unique and precious biosphere.

Biography:

As Chief Executive of Princeton's Space Studies Institute, **Gregg Maryniak** led the world's largest non-governmental research program on space resources. He continues this work as Co-founder, Director and Corporate Secretary of the XPRIZE Foundation and Chairman of the Energy and Environmental Systems Track at Singularity University. He was awarded the Space Frontier Foundation's Vision to Reality award for creating the Lunar Prospector Team that ultimately discovered frozen volatiles at the lunar poles and Russia's Tsiolkovsky Medal for his work on the use of materials and energy of free space.

Tuesday, Oct. 28, 2014

Plenary Session

8:00 a.m. – 9:00 a.m.

Ballroom A

Speaker Raymond Arvidson

James S. McDonnell Distinguished
University Professor, Department
of Earth and Planetary Sciences
Washington University in St. Louis

Roving on Mars with Opportunity and Curiosity: Terramechanics and Terrain Properties

Opportunity has been roving on the plains of Meridiani and the rim of Endeavour crater on Mars since January 2004. Curiosity has been roving across the plains on Gale Crater since August 2012. Realistic mechanical models have been generated for each rover, with classical terramechanics relationships included to simulate wheel sinkage and rover-based slippage, and simulated traverses have been conducted across terrain models with topography generated from rover-based stereo images and positionally dependent bedrock and soil properties. Modeling has been used, together with analysis of engineering telemetry and image data, to retrieve surface properties, and to understand the physics of interactions among the rovers, soils, and bedrock for situations in which mobility issues have been encountered. These include high wheel sinkage and rover-based slippage while traversing the uphill sides of wind-blown ripples, and wheel wear and tear for Curiosity while traversing sharply pointed and embedded rocks.

Biography:

Raymond Arvidson received a Ph.D. from Brown University in 1974. He is presently the James S. McDonnell Distinguished University Professor at Washington University in St. Louis, focusing on teaching and research about current and past environments on the Earth, Mars, and Venus. He is a fellow of the McDonnell Center for the Space Sciences. He has been instrumental in development and implementation of both orbital and landed missions to Venus. He is also the Director of the NASA Planetary Data System Geosciences Node. He is a Fellow of the Geological Society of America and the American Geophysical Union (AGU), received the AGU Whipple Award, has been honored as the Missouri Teacher of the Year, and is a recipient of three NASA Public Service Medals.

Special Keynote

Monday, Oct. 27, 2014

Special Keynote

12:30 p.m. – 1:30 p.m.

Ballroom A

Speaker Hongnan Li

Faculty of Infrastructure Engineering,
Dalian University of Technology, China

Advances and Applications on Structural Vibration Control of Infrastructures

In recent years, much attention has been paid to research and development of structural control techniques with particular emphasis on alleviation of wind and seismic response of buildings and bridges in China. Structural control in infrastructures has been developed from the concept into a workable technology and applied into practical engineering structures. The aim of this lecture is to review state-of-the-art research and application of structural control in civil engineering in our university. It includes the passive control, hybrid control, semi-active control and active control.

Wednesday, Oct. 29, 2014

Plenary Session

8:00 a.m. – 9:00 a.m.

Ballroom A

Speaker Chris Lewicki

President and Chief Engineer
Planetary Resources

Redefining Natural Resources: The Next Audacious Step

The greatest source of natural resources is not on Earth. Near-limitless numbers of asteroids are being discovered every year. More than 1,500 are as easy to reach as the Moon and are in similar orbits as Earth. Asteroids are filled with precious resources, everything from water to platinum. Harnessing valuable minerals from a practically infinite source will provide stability on Earth, increase humanity's prosperity, and help establish and maintain human presence in space. More specifically, in the near-term, water from asteroids will fuel the in-space economy, and rare metals will increase Earth's GDP. Asteroid mining may sound like fiction, but it's just science applied to human needs. That's engineering.

Biography:

Chris Lewicki has been intimately involved with the lifecycle of NASA's Mars Exploration Rovers and the Phoenix Mars Lander. Lewicki performed system engineering development and participated in assembly, test and launch operations for both Mars missions. He was Flight Director for the rovers Spirit and Opportunity, and the Surface Mission Manager for Phoenix. The recipient of two NASA Exceptional Achievement Medals, Lewicki has an asteroid named in his honor: 13609 Lewicki. Chris holds bachelor's and master's degrees in Aerospace Engineering from the University of Arizona. At Planetary Resources, he is responsible for the strategic development of the company's mission and vision, engagement with customers and the scientific community, serves as technical compass, and leads day-to-day operations.

Biography:

Hongnan Li is a Chair Professor of Faculty of Infrastructure Engineering, Dalian University of Technology (DUT), China. He earned his Ph.D., M.S. and B.S. in 1990, 1987 and 1982, respectively. He is a Cheung Kong Scholars Program engaged professor, serves as Vice Chairman of China Panel, International Association for Structural Control and Monitoring; and Vice Chairman of Advanced Materials and Structures, ASCE Aerospace Division; Chairman of Panel of the National Natural Science Foundation of China (NSFC). His research interests are in structural control and monitoring, disaster prevention and reduction and earthquake engineering. He has received funding for more than 30 research projects, holds 24 patents, and has published seven books and 278 peer-review journal papers. He received two national awards of Science and Technology and 10 provincial awards.

Awards Luncheon

ASCE Columbia Medal Award

Recipient: Astronaut Dr. Don Pettit

Tuesday, Oct. 28, 2014

12:00 p.m. - 1:30 p.m.

Ballroom B

Techno-Stories from Space

Speaker Dr. Don Pettit

Frontiers are interesting places; they offer the possibility to make observations outside our normal range of experience. The International Space Station is such a frontier offering a local reduction in acceleration forces by nearly a factor of a million. This allows the observation of subtle phenomena that are typically masked on Earth. This orbital vantage also allows observation of Earth phenomena on the length scale of half a continent. A smattering of my observations will be presented. There will be many questions and few answers, which of course is a characteristic of being on a frontier and why we venture there.

Biography:

A veteran of three spaceflights, **Don Pettit**, PhD., has logged more than 370 days in space and over 13 EVA (spacewalk) hours. He lived aboard the International Space Station for 5-1/2 months during Expedition 6, was a member of the STS-126 crew, and again lived aboard the station for 6-1/2 months as part of the Expedition 30/31 crew.

Conference Schedule
Monday, October 27, 2014

Presentations are noted by corresponding paper number to the Abstracts listed on pages 13-28.

7:00 a.m. – 5:00 p.m.
Registration Desk Open
Ballroom Lobby

7:00 a.m. – 8:00 a.m.
Continental Breakfast
Ballroom Prefunction

8:00 a.m. – 9:00 a.m.
Opening Plenary Session
Ballroom A

Fountains of the Moon
Speaker Gregg Maryniak
Speaker details on page 6

9:00 a.m. – 5:30 p.m.
Technical Sessions
(See schedule at right)
**Student Oral Presentation*

10:30 a.m. – 11:00 a.m.
Break/Student Posters
Ballroom Prefunction

12:00 p.m. – 12:30 p.m.
Break for Lunch

12:30 p.m. – 1:30 p.m.
Special Keynote
Ballroom A

Advances and Applications on Structural Vibration Control of Infrastructures
Speaker Hongnan Li
Speaker details on page 6

3:00 p.m. – 3:30 p.m.
Break/Student Posters
Ballroom Prefunction

6:00 p.m. – 8:00 p.m.
Reception with Exhibits
Ballroom B

Mars Rover *(Missouri University of Science and Technology)*

Screw-Propelled Automated Regolith Collector (SPARC)
(Washington University in St. Louis)

Student Exhibit details on page 12

Symposium 1: Granular Materials in Space Exploration
Laclede Room A/B

Co-Chairs: Juan Agui (NASA Glenn Research Center)
Phil Metzger (Univ. Central Florida)

9:00 a.m. – 10:30 a.m.
Regolith Geotechnics 1
Session Chair: Ryan Clegg
(Washington University in St. Louis, St. Louis, MO)

- **1011 - Advances in Development of Axial-Torsional Multi-Sleeve Penetrometer for Extra-Terrestrial Studies**
- **1012 - Penetration Tests in a Mold on Regolith Quasi-Analogues at Different Relative Densities**
- **1013* - Effects of Grain Properties and Compaction on Single-Tool Normal Indentation of Granular Materials**

11:00 a.m. – 12:00 p.m.
Regolith Geotechnics 2
Session Chair: Chris Dreyer
(Colorado School of Mines, Golden, CO)

- **1021 - Evaluating Geotechnical Characterization Methods for NEOs**
- **1022* - The Study of Power Consumption During Radial and Axial Segregation in Horizontal Rotating Cylinders**

1:30 p.m. – 3:00 p.m.
Regolith Physical Properties
Session Chair: Chris Dreyer
(Colorado School of Mines, Golden, CO)

- **1031 - Characterizing the Physical and Thermal Properties of Planetary Regolith at Low Temperatures**
- **1032 - Contact Behavior of Lunar Materials and Their Simulants: Experimental Observations and Model Developments**
- **1033 - Particle Grading Effect on Mechanical Properties of Lunar Soil Simulant FJS-1**

3:30 p.m. – 5:30 p.m.
Regolith Simulants
Session Chair: Juan Agui
(NASA Glenn Research Center, Cleveland, OH)

- **1041 - Development and Application of Martian Regolith Simulant Using Volcanic Material From Banks Peninsula, New Zealand**
- **1042 - Properties of Korean Lunar Soil Simulant KOHLS-1**
- **1043 - Anm Model Approach for Lunar Soil Simulant Properties Study**
- **1044 - Characterization of Fillite as a Potential Martian Regolith Simulant**

Symposium 2: Exploration and Utilization of Extra-Terrestrial Bodies
Gateway Room A/B

Co-Chairs: Robert P. Mueller (NASA Kennedy Space Center)
Kris Zacny (Honeybee Robotics)

9:00 a.m. – 10:30 a.m.
Planetary Drilling 1
Session Chair: Robert P. Mueller
(NASA Kennedy Space Center, Cape Canaveral, FL)

- **2011 - Development and Testing of a Lunar Prospecting Drill (LPD) to Search for Water-Ice**
- **2012 - Testing of Mars-Prototype Drills at an Analog Site**
- **2013 - Auto-gopher - A Wireline Deep Sampler Driven by Piezoelectric Percussive Actuator and EM Rotary Motor**

11:00 a.m. – 12:00 p.m.
Planetary Drilling 2
Session Chair: Yoseph Bar-Cohen
(Jet Propulsion Laboratory, Pasadena, CA)

- **2021 - Novel Concept and Design of Ultralight Mobile Drilling System Dedicated for Planetary Environment**
- **2022 - Accessing, Drilling and Operating at the Lunar South Pole: Status of European Plans and Activities**

1:30 p.m. – 3:00 p.m.
Planetary Surface Sampling
Session Chair: Raymond Arvidson (Washington University in St. Louis, St. Louis, MO)

- **2031 - Sampling of Regolith on the Moon and Mars Utilizing Electrostatic Force and Mechanical Vibration**
- **2032 - MicroDrill Sample Acquisition System forSmall Class Exploration Spacecrafts**
- **2033* - Sampling of Regolith on Asteroids Utilizing Electrostatic Force**

1:30 p.m. – 3:00 p.m.
Regolith as Construction Material
(This session is being held in the Fontaine Room)
Session Chair: Robert P. Mueller (NASA Kennedy Space Center, Cape Canaveral, FL)

- **2041 - Manufacturing of Lunar Concrete by Steam**
- **2042* - Solidification of Polymer Concrete Using the Artificial Lunar Soil**
- **2043* - Protein-Regolith Composites for Space Construction**

Symposium 2: Exploration and Utilization of Extra-Terrestrial Bodies *Continued...*

Gateway Room A/B

3:30 p.m. – 5:30 p.m.

Civil Engineering in Space 1

Session Chair: A. Scott Howe (NASA Jet Propulsion Laboratory)

2051 - **Modular Additive Construction Using Native Materials**

2052 - **A Civil Engineering Approach to Development of the Built Martian Environment**

2053 - **Mass Drivers for Space Construction**

2054 - **Dust Tolerant Commodity Transfer Interface Mechanisms for Planetary Surfaces**

Symposium 3: Advanced Materials and Designs

Fontaine Room

Co-Chairs: Robert Goldberg (NASA Glenn Research Center)
Pizhong Qiao (Washington State University)

9:00 a.m. – 10:30 a.m.

Mechanical Behavior of Advanced Materials 1

Session Chair: Wieslaw Binienda (University of Akron, Akron, OH)

3011 - **Analyzing the Bending Ability of ZBLAN Optical Fibers**

3012 - **Thermal Conductivity across a Bolted Joint**

3013 - **Fatigue Behavior of Boron Nitride Nanomodified Carbon Epoxy Composite**

11:00 a.m. – 12:00 p.m.

Mechanical Behavior of Advanced Materials 2

Session Chair: Robert Goldberg (NASA Glenn Research Center)

3021 - **Effective Mesomechanical Modeling of Triaxially Braided Composites for Impact Analysis with Failure**

3022 - **Thermomechanical Modeling of Cone Sample of ZrB2-SiC Ceramic Under Arc-jet Conditions**

3:30 p.m. – 5:30 p.m.

Mechanical Behavior of Advanced Materials 3

Session Chair: Wieslaw Binienda (University of Akron, Akron, OH)

3031 - **Processing and Mechanical Characterization of Polyurea Aerogels**

3032 - **Crashworthiness and Impact Simulation using Tabulated Thermo-Viscoplastic Material Model of LS-DYNA**

Symposium 4: Structures in Challenging Environments

Hawthorn Room

Co-Chairs: Ramesh Malla (Univ. of Connecticut)
Gangbing Song (Univ. of Houston)

9:00 a.m. – 10:30 a.m.

Advances in Diagnostic and Monitoring Methods 1

Session Chair: Ramesh Malla (University of Connecticut, Storrs, CT)

4011* - **Seasonal Ground Freezing and Thawing Monitoring using Piezoceramic based Smart Aggregates**

4012 - **Displacement Monitoring of Structures Using Laser Image Displacement Method**

11:00 a.m. – 12:00 p.m.

Advances in Diagnostic and Monitoring Methods 2

Session Chair: Ramesh Malla (University of Connecticut, Storrs, CT)

4021 - **Cracking Monitoring of RC Joints under Cyclic Loadings Based on Wavelet Packet Analysis on Embedded PZT Measurements**

4022 - **Damage Status Identification of Piezoelectric Concrete Frame Structure Based on Fuzzy Comprehensive Evaluation**

1:30 p.m. – 3:00 p.m.

Seismic, Tidal, and Artificial Loading of Structure

Session Chairs: Bin Xu (Hunan University, Changsha, Hunan, P.R. China); Shi Yan (Shenyang Jianzhu University, Changsha, Hunan, P.R. China)

4031 - **Dynamic Response of Bridge Expansion Joints Under Vehicle Pounding**

4032 - **Reliability Analysis on Sluice Gate in Cao'E River Dam Under Tidal Bore Loads**

4033* - **Response Modeling of Scoured Bridges Under Near-Fault Ground Motions**

3:30 p.m. – 5:30 p.m.

Advanced Structures and Actuation Technology

Session Chairs: James Dabney (University of Houston - Clear Lake, Houston, TX); Zhen Sun (Jiangsu Transportation Institute, Jiangning KeXueGuan NanJing, P.R. China)

4041 - **Experiment Investigation for a New Type of Piezoelectric Friction Damper**

4042 - **Labs-to-go Actuation Experiments and Extensions**

4043 - **Scavenging Energy From Ambient Vibrations Using Oscillators With Asymmetrical Potential Wells**

**Student Oral Presentation*

Conference Schedule

Tuesday, October 28, 2014

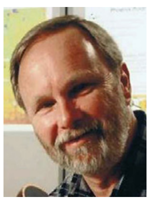
Presentations are noted by corresponding paper number to the Abstracts listed on pages 13-28.

7:00 a.m. – 5:00 p.m.
Registration Desk Open
Ballroom Lobby

7:00 a.m. – 8:00 a.m.
Continental Breakfast
Ballroom Prefunction

8:00 a.m. – 9:00 a.m.
Plenary Session
Ballroom A

Roving on Mars with Opportunity and Curiosity: Terramechanics and Terrain Properties
Speaker Raymond Arvidson



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9:00 a.m. – 5:30 p.m.
Technical Sessions
(See schedule at right)
**Student Oral Presentation*

10:30 a.m. – 11:00 a.m.
Break/Student Posters
Ballroom Prefunction

12:00 p.m. – 1:30 p.m.
Awards Luncheon
ASCE Columbia Award
ASCE Aerospace Division Awards
Ballroom B

Techno-Stories from Space
Speaker Don Pettit

Speaker details on page 7

3:00 p.m. – 3:30 p.m.
Break/Student Posters
Ballroom Prefunction

Symposium 1: Granular Materials in Space Exploration
Laclede Room A/B

Co-Chairs: Juan Agui (NASA Glenn Research Center)
Phil Metzger (Univ. Central Florida)

9:00 a.m. – 10:30 a.m.
Mechanism-Regolith Interactions 1
Session Chair: Phil Metzger
(University of Central Florida, Orlando, FL)

1051 - DEM Analyses of Soil Cutting Test in Lunar Ground

1052 - Laboratory Studies of Physical Interactions of Exploration Hardware with Surfaces of Airless Bodies

1053 - Dome Pressurization and Regolith Porosity

11:00 a.m. – 12:00 p.m.
Mechanism-Regolith Interactions 2
Session Chair: Phil Metzger
(University of Central Florida, Orlando, FL)

1061 - On Modeling Sample Acquisition from Granular Media

1062 - Leak Rate Performance of Silicone Elastomer O-Rings Contaminated with JSC-1A Lunar Regolith

1:30 p.m. – 3:00 p.m.
Regolith-Rocket Exhaust Interactions
Session Chair: Juan Agui
(NASA Glenn Research Center, Cleveland, OH)

1071* - Comparing Rocket Exhaust Effects across Lunar Landing Sites Using LRO Narrow Angle Camera Images

1072 - Image Analysis Based Estimates of Regolith Erosion Due to Plume Impingement Effects

1073 - Lunar Cold Trap Contamination by Landing Vehicles

3:30 p.m. – 5:30 p.m.
Rover-Regolith Interactions 1
Session Chair: Ryan Clegg
(Washington University - St. Louis, St. Louis, MO)

1081 - Roving on Mars with Opportunity and Curiosity: Terramechanics and Terrain Properties

1082 - Curiosity's Traverse from the Kimberley to the Base of Mt. Sharp: An Orbital Data Perspective

1083 - Discrete Element Method Simulations of Mars Exploration Rover Wheel High-Slip Mobility Tests

1084* - Experimental Study on Driving Wheel's Performance for Lunar Exploration Rovers

Symposium 2: Exploration and Utilization of Extra-Terrestrial Bodies
Gateway Room A/B

Co-Chairs: Robert P. Mueller (NASA Kennedy Space Center); **Kris Zacny** (Honeybee Robotics)

9:00 a.m. – 10:30 a.m.
Novel Approaches and Architectures
Session Chair: Paul van Susante
(Michigan Technological University, Houghton, MI)

2061 - Oilfields in the Sky - A Different Race

2062* - Expanding Mineral Resources: Technical Considerations for Extraterrestrial Mining

2063 - HALE: A Flexible Approach to Settlement of the Solar System

11:00 a.m. – 12:00 p.m.
Civil Engineering in Space 2
Session Chair: Tony Muscatello
(NASA Kennedy Space Center, Cape Canaveral, FL)

2071 - The Advantages of Continuous Excavation in Lightweight Planetary Operations

2072 - Additive Construction using Basalt Regolith Fines

1:30 p.m. – 3:00 p.m.
Planetary Excavation
Session Chair: Krzysztof Skonieczny
(Concordia University, Montreal, Canada)

2081* - Longitudinal Impact Force on a Special Drill for Planetary Exploration

2082* - Microwave Assisted Rock Breakage for Space Mining

2083 - Some Considerations for Excavation in Martian Aquifers

3:30 p.m. – 5:30 p.m.
Space Resources Utilization
Session Chair: Leslie Gertsch
(Missouri University of Science and Technology, Rolla, MO)

2091 - Comparative Specific Heat Capacity Analysis for Lunar In-Situ Manufacture of Thermal Energy Storage

2092 - Atmospheric Processing Module for Mars Propellant Production

2093* - Microwave Heating Applications for In-Situ Resource Utilization and Space Mining

2094 - Wells for In-situ Volatile Extraction From Regolith

Symposium 3: Advanced Materials and Designs

Fontaine Room

Co-Chairs: Robert Goldberg (NASA Glenn Research Center)
Pizhong Qiao (Washington State University)

9:00 a.m. – 10:30 a.m.

Structures Under Extreme Conditions

Session Chairs: Shi Yan (Shenyang Jianzhu University & School of Civil Engineering, Changsha, Hunana, P.R. China); Pizhong Qiao (Washington State University, Pullman, WA)

3041 - **Analysis on Failure Modes of Light Steel Columns with Different Cross Sections Under Fire and Explosion**

3042 - **Numerical Analysis of Honeycomb Sandwich Collision Protection Systems for RC Beams**

3:30 p.m. – 5:30 p.m.

Hydraulic Structures

Session Chairs: Shi Yan (Shenyang Jianzhu University & School of Civil Engineering, Changsha, Hunana, P.R. China); Pizhong Qiao (Washington State University, Pullman, WA)

3051 - **Multi Scale Information Fusion Predicating Model of Gravity Dam Deformation**

3052 - **Inverse Analysis on Thermal Parameters of Lock Head Floor Based on BP Neural Network**

3053 - **Flow-Induced Vibration of Stilling Basin in One of Giant Hydropower Stations**

3054 - **Research on Non-contact Measurement Method for Topography Around Hydraulic Structure Model**

Symposium 4: Structures in Challenging Environments

Hawthorn Room

Co-Chairs: Ramesh Malla (Univ. of Connecticut)
Gangbing Song (Univ. of Houston)

9:00 a.m. – 10:30 a.m.

Structures and Systems in Challenging Environments 1

Session Chairs: Gangbing Song (University of Houston, Houston, TX)
Olga Bannova (University of Houston, Houston, TX)

4051 - **Effects of Temperature Gradients on the Design of a Frame-Membrane Lunar Habitat**

4052 - **Architectural Engineering Approach to Developing a Matrix for Planning in Extreme Environments**

11:00 a.m. – 12:00 p.m.

Structures and Systems in Challenging Environments 2

Session Chairs: Gangbing Song (University of Houston, Houston, TX);
Olga Bannova, University of Houston, Houston, TX

4061* - **Parametric Modeling of Soil-Structure Oscillators for Rapid Coastal Disaster Response**

4062 - **Smart Trusses for Space Applications**

1:30 p.m. – 3:00 p.m.

Advances in Diagnostic and Monitoring Methods 3

Session Chairs: Hong-Nan Li (Dalian University, P.R. China)
Tianyong Jiang (Changsha University of Science and Technology, Dalian, P.R. China)

4071 - **Investigation and Application on Monitoring the Compactness of Concrete-Filled Steel Tube Structures with Ultrasonic Wave**

4072* - **Damage Diagnosis Under Environmental and Operational Variations Using Improved Restoring Force Method**

4073 - **Icing Monitoring for a Wind Turbine Model Blade with Active PZT Technology**

**Student Oral Presentation*

Conference Schedule

Wednesday, October 29, 2014

7:00 a.m. – 10:00 a.m.
Registration Desk Open
Ballroom Lobby

7:00 a.m. – 8:00 a.m.
Continental Breakfast
Ballroom Prefunction

8:00 a.m. – 9:00 a.m.
Plenary Session
Ballroom A

Redefining Natural Resources: The Next Audacious Step
Speaker
Chris Lewicki
Speaker details on page 7

Technical Sessions
9:00 a.m. – 11:00 a.m.
(See schedule at right)
**Student Oral Presentation*

Symposium 1: Granular Materials in Space Exploration
Laclede Room A/B

Co-Chairs: Juan Agui (NASA Glenn Research Center)
Phil Metzger (Univ. Central Florida)

9:00 a.m. – 11:00 a.m.
Rover-Regolith Interactions 2
Session Chair: Chris Dreyer
(Colorado School of Mines, Golden, CO)

1091 - **Prototype of Environment Analytics Driven Autonomous Vehicle**

1092 - **Push-Pull Locomotion for Vehicle Extraction**

Symposium 2: Exploration and Utilization of Extra-Terrestrial Bodies
Gateway Room A/B

Chair: Kris Zacny (Honeybee Robotics)

9:00 a.m. – 11:00 a.m.
Asteroid Utilization
Session Chair: Paul van Susante
(Michigan Technological University, Houghton, MI)

2101 - **Concepts of Operations for Asteroid Rendezvous Missions Focused on Resources Utilization**

2102* - **Modeling Asteroid Deflection Induced by Subsurface Blasting**

2103 - **Discrete Element Method Simulation of a Boulder Extraction from an Asteroid**

2104 - **Modeling and Simulation of Dynamics on the Surface of Phobos**

Symposium 3: Advanced Materials and Designs
Fontaine Room

Co-Chairs: Robert Goldberg (NASA Glenn Research Center); **Pizhong Qiao** (Washington State University)

9:00 a.m. – 11:00 a.m.
New Materials and Structures
Session Chair: Robert Goldberg
(NASA Glenn Research Center, Cleveland, OH)

3061 - **Structural Analysis of Tensegric Structures for Space Applications**

3062 - **Effect of Aluminum Tri-Hydrate Filler on Mechanical Properties of Glass Fiber-Reinforced Polymer Materials**

3063 - **Design Requirements of Fiber-Reinforced Polymer Materials for Building Applications**

**Student Oral Presentation*

Monday, Oct. 27, 2014

6:00 p.m. – 8:00 p.m.
Student Design Teams Exhibits
Ballroom B

WUSTL SPARC Robot

The SPARC (Screw-Propelled Automated Regolith Collector) robot from Washington University in St Louis (WUSTL) consists of a high-speed bucket-conveyor excavator mounted on an Archimedes-screw-drive propulsion system, based on old Soviet cosmonaut recovery vehicles. The team consists of nine undergraduate and three graduate students representing the WUSTL mechanical, electrical, computer, and software engineering programs along with Earth and planetary sciences. Their work was sponsored in part by Residue Solutions, the McDonnell Center for Space Sciences, and the NASA Missouri Space Grant Consortium. The SPARC robot competes in the NASA Robotic Mining Competition held annually at Kennedy Space Center, Florida.

S&T Mars Rover

The Mars Rover Design Team, from Missouri University of Science and Technology (S&T), has over 40 active student members from 14 science and engineering disciplines. The team competes in the annual University Rover Challenge, which is hosted every summer by The Mars Society at their analog Mars Desert Research Station near Hanksville, Utah. The competition goals are to “design and build … rovers that will one day work alongside human explorers in the field.” The rovers tasks include collecting samples, delivering payloads, surveying areas, and operating tools in support of suited humans on planetary surfaces. The student-designed and -built remote-controlled robot on display at the conference contains few off-the-shelf parts.

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1011 - Advances in Development of Axial-Torsional Multi-Sleeve Penetrometer for Extra-Terrestrial Studies

David Frost and Alejandro Martinez (Georgia Institute of Technology, USA)

Recent advances in the development of a subsurface characterization device that combines axial and torsional loadings are presented in this paper. The multi-sleeve penetration system uses interchangeable friction sleeves with a controlled surface roughness that provides unique information regarding geotechnical properties such as shear and interface behavior of granular media. Experimental laboratory tests performed in an axisymmetric device allow for both axial and torsional loading modes to be investigated without the disturbance effects of the penetration process. Studies of the global behavior in both axial and torsional shearing directions allow for direct comparison and fundamentally robust interpretation of the results. Furthermore, micro-scale studies provide useful information regarding the interface shear behavior of the granular media during testing. The results show the potential of the axial-torsional multi-sleeve device to provide information about soil and regolith properties such as shear strength, structure and state of stress as well as practical issues such as ease of excavation and mobility of vehicles.

1012 - Penetration Tests in a Mold on Regolith Quasi-Analogues at Different Relative Densities

Christos Vrettos, Andreas Becker, and Kai Merz (Technical University Kaiserslautern, Germany); Lars Witte (German Aerospace Center (DLR), Germany)

Know-how from terrestrial geotechnical engineering may be applied for a variety of space problems such as the prediction of the soil mechanical response of extra-terrestrial soils, the exploration of near-surface planetary soil, and the movement of vehicles. Penetration testing constitutes a well-established method for the back-calculation of the soil properties. In an initial study, indentation of a rod into granular material placed within a mold has been investigated for variable density states. Regolith simulants, natural soils, and glass have been considered. The test results are presented and key features are elucidated.

1013* - Effects of Grain Properties and Compaction on Single-Tool Indentation of Granular Materials

Dennis Duru and Leslie Gertsch (Missouri University of Science and Technology, USA)

People have been digging in dirt for hundreds of thousands of years, gaining much experience thereby. Yet we are always searching for more efficient, more effective methods. And when we begin digging on the surfaces of bodies other than Earth, such as the Moon and Mars, we must resort to a higher degree of automation and remote operation than many construction and mining engineers are comfortable with. This is made more difficult by the inherently uncertain and variable nature of dirt, soil, and regolith. This paper reports on the beginning of a sensitivity study of some of the important factors that control the excavatability of natural granular materials. Initial results reveal a complex interplay of behaviors affected by grain shape and compaction. These factors must eventually be understood more directly in space operations.

1021 - Evaluating Geotechnical Characterization Methods for NEOs

Christopher Dreyer and Logan Knowles (Colorado School of Mines, USA); Otis Walton (Grainflow Dynamics, Inc, USA); Daniel Scheld, Robert Gamber David Hall and Jeffrey Hayden (N-Science Corp, USA)

Tools and method to characterize the geotechnical properties of NEOs are needed to advance exploration, science, planetary defense planning, and resource exploitation of these bodies. We are evaluating several methods to characterize NEO geotechnical properties. In this paper we focus on a dart or kinetic impact approach. We have used empirical correlations developed to predict the depth of penetration of kinetic impactors into a variety of terrestrial surfaces, called the Young penetration equations. The Young equations predict penetration of a dynamic cone penetrometer reasonably well. The largest uncertainty in designing a NEO geotechnical evaluation tool is the lack of information on expected NEO geotechnical properties. In the approach presented here this translates to selecting an appropriate Penetrability (also known as S-number) of the NEO surface. We evaluate the problem over the full range of Young penetration equation penetrability: equivalent to dense cemented sand to soft marine sediments. The utility of the Young penetration equations.

1022* - The Study of Power Consumption During Radial and Axial Segregation in Horizontal Rotating Cylinders

Amin Amin and Walter Boles (Middle Tennessee State University, USA)

When a binary mixture of two granules with different material properties is rotated in a horizontal rotating drum the granules often segregate. The smaller particles move towards the radial core within the first seconds. Depending on granular properties, drum speeds, and drum dimensions, axial segregation can follow. When axial segregation occurs, energy dissipation is observed. Contrary to previous research we show that axial segregation can occur with two granules with similar angles of repose and two granules with different angles of repose. When there is a substantial difference in density axial segregation does not occur. The size of the granules is also critical. Lastly granules “bounce” differently when they collide with different size granules. When a large granule falls onto smaller granules it tends to not move as much, but when a small granule falls onto bigger granules it moves much farther. This coefficient of restitution suggests that the smaller particles move farther and more freely in the drum.

1031 - Characterizing the Physical and Thermal Properties of Planetary Regolith at Low Temperatures

James Mantovani, Adam Swanger, and Gregory Galloway (NASA Kennedy Space Center, USA); Ivan Townsend (ESC–Craig Technologies, USA); Laurent Sibille (ESC–EASI, USA)

The success or failure of in-situ resource utilization for planetary surface exploration – whether for science, colonization, or commercialization – relies heavily on the design and implementation of systems that can effectively process planetary regolith and exploit its potential benefits. In most cases, this challenge necessarily includes the characterization of regolith properties at low temperatures (cryogenic). None of the nearby solar system destinations of interest, such as the moon, Mars and asteroids, possess a sufficient atmosphere to sustain the consistently “high” surface temperatures found on Earth. Therefore, they can experience permanent cryogenic temperatures or dramatic cyclical changes in surface temperature. Characterization of physical properties (e.g., specific heat, thermal and electrical

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conductivity) over the entire temperature profile is important when planning a mission to a planetary surface; however, the impact on mechanical properties due to the introduction of icy deposits must also be explored in order to devise effective and robust excavation technologies.

1032 - Contact Behavior of Lunar Materials and Their Simulants: Experimental Observations and Model Developments

David Cole (ERDC-CRREL, USA)

The modeling and simulation of lunar surface and sub-surface activities requires an understanding of the mechanical behavior of the regolith and of the terrestrial materials used to simulate its various components. The discrete element method is frequently applied to model regolith mechanics and this approach requires realistic contact models for the subject materials. In support of this approach, we have conducted grain- to -grain contact experiments on lunar materials and their simulants and herein report on several advancements in this effort. The paper describes a time-based, hereditary integral approach to model anelastic deformation, experimental evidence for nonlinear creep behavior in shear is examined and modeled, and the contact behavior of two lunar materials (plagioclase and pyroxene) are compared to that of their terrestrial simulants. Although as demonstrated in our previous work, space weathering substantially degrades the contact behavior (e.g., lower stiffness and increased frictional loss) of individual mineral grains, reasonably good agreement is found in the contact behavior.

1033 - Particle Grading Effect on Mechanical Properties of Lunar Soil Simulant FJS-1

Takashi Matsushima (University of Tsukuba, Japan)

This paper presents some mechanical test results of a lunar soil simulant, FJS-1, to clarify the effect of grain size distribution on bulk mechanical properties of lunar surface soil under low confining pressure. The samples used are the original FJS-1 imitating an average grading of lunar soil, two sieved FJS-1 samples, whose grain sizes are less than 0.1mm and from 0.1 to 0.4mm, respectively. First, the maximum and minimum void ratio tests of those samples revealed both pore-filling effect and inter-granular adhesion effect of fines. Next, according to small-scale triaxial compression tests and self-standing height tests, the internal friction angle ranges from 30 to 50 degrees, and the bulk cohesion is about 0-175(Pa) depending on the void ratio, which are consistent with the previous estimation of typical lunar soil. Finally, based on the experimental results, we propose a simple micromechanics model that describes the experimental results in a consistent manner.

1041 - Development and Application of Martian Regolith Simulant Using Volcanic Material From Banks Peninsula, New Zealand

Allan Scott and Chris Oze (University of Canterbury, New Zealand); Yifei Tang (URS, New Zealand); Amy O'Loughlin (Holmes Consulting, New Zealand)

Martian regolith and rock may one day be used for building material to support long-term habitation on Mars. Despite several martian simulants being available, the capability of accurately matching a wide variety of reported grain size distributions coupled to the regolith's chemical character for specific sites on Mars needs to be advanced before producing large quantities of material for material synthesis experimentation on Earth. Here, we use volcanic material (i.e. olivine basalt and basaltic glass) from Banks Peninsula, New Zealand, to demonstrate an applied approach to matching reported size distributions on Mars. The olivine basalt and basaltic glass were crushed, washed and combined to produce a particle size distribution representative of the Columbia Hills region of the Gusev Crater. As New Zealand has a wide variety of geologic material similar to Mars, we are in the process of acquiring rocks ranging from extrusive volcanics to serpentinites with the intent to provide 'tailored' simulant to aid in civil engineering applications.

1042 - Properties of Korean Lunar Soil Simulant KOHLS-1

Tai Sik Lee and Byung Chul Chang (Hanyang University, Korea); Bonnie Cooper (Hanyang University & International Space Exploration Research Institute (ISERI), Korea)

Korea is planning for an unmanned Lunar Exploration on year 2020. To success the mission, studies on mechanical interaction between the Lunar regolith with rover wheels and lander are required. Thus, the first Korean Lunar simulant, Korea Hanyang Lunar Simulant – 1 (KOHLS-1) has been created by International Space Exploration Research Institute (ISERI) of Hanyang University.
Part of the properties of KOHLS-1 has been already reported. However, for a thorough understanding of the simulant, KOHLS-1 is now on reinvestigation. This paper presents the properties of the prior KOHLS-1. The findings of the reinvestigation and issues to modify for the KOHLS-2 will be presented at the conference.

1043 - Anm Model Approach for Lunar Soil Simulant Properties Study

Yang Lu and Stephen Thomas (Boise State University, USA)

In this paper, the upgraded Anm model (Lu et al. 2014; Qian 2012), which places multiple particles into a 3D unit cell, was used to study the microstructural properties of lunar soil simulant. A statistical analysis was performed to study the packing density and shape effects with a large number of modeled particles. The lunar soil simulant JSC-1a was developed to study simulant soil behaviors for large and medium scale engineering studies in support of future human activities on the Moon. Parameters such as particle size distribution, specific gravity, angle of internal friction, and cohesion have all been investigated (Arslan et al. 2008; Jiang et al. 2012). However, no research has been performed to explore the microstructural behaviors and their influences on the engineering properties as a whole.
As such, Anm model can provide us a useful approach to investigate microstructural features of lunar simulant, e.g. charge contact, lofting, transport, stratification and adsorption.

1044 - Characterization of Fillite as a Potential Martian Regolith Simulant

Michael Edwards, Mandar Dewoolkar and Dryver Huston (University of Vermont, USA)

The strength properties of every Lunar or Martian soil simulant are greatly affected by Earth's gravitational field. The stronger gravitational pull has made it difficult to effectively simulate high sinkage scenarios in any laboratory environment. Researchers at the NASA Glenn Research Center developed a large test bed called the "sink tank" specifically to test rovers in high sinkage/high slip situations. The material Fillite was chosen as the test bed material. Fillite exhibited the desired properties of being light weight, soil like in composition, and capable of being collected in mass quantities. The focus of this study was to determine index and mechanical properties of Fillite to aid in the analysis of rover testing. These properties were found to compare well with what is known about Martian and Lunar regoliths, and also matched closely with some frequently used Martian and Lunar simulants.

1051 - DEM Analyses of Soil Cutting Test in Lunar Ground

Mingjing Jiang, Banglu Xi, Zhifu Shen and Yongsheng Dai (Tongji University, P.R. China)

In future lunar exploration activity, ground excavation is required in construction of permanent lunar outpost and In-Situ Resource Utilization processes, which are important long-term goals of space program. In this paper, the Discrete Element Method (DEM) was employed to simulate horizontal lunar regolith excavation process. For this purpose, a high-efficient contact model was implemented into the DEM. The evolution of excavation resistance, slide surface and stress path are studied. Then the effects of excavation depth and rate, attack angle on the excavation resistance were analyzed under the terrestrial environment. The effects of gravity were also investigated. The simulation results show that the excavation resistance first increases rapidly to a peak and then drops to a stable value quickly. With further increase of the excavation zone, the excavation resistance again increases gradually mainly due to the accumulation of soil in front of the blade. The excavation resistance is greater under larger excavation depth.

1052 - Laboratory Studies of Physical Interactions of Exploration Hardware with Surfaces of Airless Bodies

Christopher Dreyer and Angel Abbud-Madrid (Colorado School of Mines, USA)

In situ resource utilization in space will add new manned and robotic exploration capabilities. Uncertainties exist regarding the interaction of exploration hardware with surfaces of airless bodies, particularly where volatile resources may be present such as asteroid surfaces, permanently shadowed craters on the Moon, and the Martian moons Phobos and Deimos. We present a plan to study the interaction of idealized probes with analog regolith surfaces over a range of water ice content. The proposed tests are described as fundamental physical-sciences experiments that isolate a specific interaction of a technological component with the space environment. This work is in the beginning stages of the recently selected Institute for Modeling Plasma, Atmospheres, and Cosmic Dust, a member of the NASA Solar System Exploration Research Virtual Institute at the University of Colorado at Boulder, in which the authors at the Colorado School of Mines are co-investigators.

1053 - Dome Pressurization and Regolith Porosity

Edward Patrick, Donald Hooper and Marius Necsoiu (Southwest Research Institute, USA); Samuel Ximenes (XArc Exploration Architecture Corporation, USA)

Long term settlement of lunar or Mars caves or subsurface features on planetary bodies where large pit openings exist provide an opportunity to substantially increase livable volume areas and allow inhabitants freedom from confines of living in modules or enclosed in a cave environment. Various studies centered on enclosing a lunar skylight pit with a pressurized dome are under investigation by the authors. An intuitive approach of merely placing a dome cap over the skylight pit is fraught with a number of issues. Accomplishing this in a practical fashion without having the seal independent of the regolith surface is a challenge for understanding the porosity of the lunar regolith along the pit walls and outer rim of the pit. Not least among these issues is prevention of the regolith from consuming too much gas and never reaching an equilibrium pressure. Essentially, what happens to gas pumped into the dome? How much of it will simply pass into the surrounding desiccated regolith?

1061 - On Modeling Sample Acquisition from Granular Media

Rudranarayan Mukherjee (Jet Propulsion Laboratory, California Institute of Technology, USA); Ryan Houlihan (Temple University, USA); Robert Bonitz (JPL, Caltech, USA)

This paper summarizes the methodology and findings of Discrete Element Method (DEM) based modeling of sample acquisition from granular media. This work was conducted concurrently with physical testing in laboratory setting for developing and validating the predictive DEM model of sample acquisition for use in parametric studies in extra-terrestrial environmental conditions. The paper presents an overview of the modeling methodology and discusses steps taken to numerically create a bed of granular media analogous to the physical test bed. This includes steps taken to ensure that polydispersion of granular media, packing ratio, bulk density and other parameters of the numerical simulation are consistent with those used in physical testing. The paper then presents simulation results of insertion and withdrawal of mechanical tools into and out of the granular media. The results were obtained for two different types of sampling tools. Good agreement is found between the numerical results and the physical test results, thereby validating the models.

1062 - Leak Rate Performance of Silicone Elastomer O-Rings Contaminated with JSC-1A Lunar Regolith

Heather Oravec (The University of Akron & NASA Glenn Research Center, USA); Christopher Daniels (The University of Akron, USA)

Contamination of spacecraft components with planetary and foreign object debris is a growing concern. Face seals separating the spacecraft cabin from the debris filled environment are particularly susceptible; if the seal becomes contaminated there is potential for decreased performance, mission failure, or catastrophe. In this study, silicone elastomer O-rings were contaminated with JSC-1A lunar regolith and their leak rate performance was evaluated. The leak rate values of contaminated O-rings at four levels of seal compression were compared to those of as-received, uncontaminated, O-rings. The results showed a drastic increase in leak Rate after contamination. JSC-1A contaminated O-rings lead to immeasurably high leak rate values for all levels of compression except complete closure. Additionally, a mechanical method of simulant removal was examined. In general, this method returned the leak rate to as-received values.

1071* - Comparing Rocket Exhaust Effects across Lunar Landing Sites Using LRO Narrow Angle Camera Images

Ryan Clegg and Bradley Jolliff (Washington University in St. Louis, USA)

High-resolution Lunar Reconnaissance Orbiter (LRO) Narrow Angle Camera (NAC) images are used to study the effects of rocket exhaust on lunar soil reflectance properties at the Apollo, Luna, Surveyor, and Chang'e 3 landing sites. Areas disturbed by rocket exhaust appear as photometric anomalies in NAC images and are preserved owing to the lack of weathering processes on the Moon. Destruction of fine-scale surface structure, smoothing of the surface, and/or redistribution of fine particles created high-reflectance areas around the landers that we refer to as blast zones. Reflectance profile shapes are consistent across all landing sites and reflectance changes are similar in magnitude (12-16% increase) across all sites, indicating that these lunar surface features are not erased on the order of decades. Blast zone area scales exponentially with lander mass and thrust, although variations arise owing to differences in engine configuration and descent trajectories.

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1072 - Image Analysis Based Estimates of Regolith Erosion Due to Plume Impingement Effects

John Lane (ESC-Easi, Kennedy Space Center, USA); Philip T. Metzger (Florida Space Institute & University of Central Florida, USA)

A method to estimate the optical extinction coefficient of dust above the lunar surface during Apollo lunar module (LM) landings is presented. This approach uses image frames acquired from the LM cockpit video camera. Previous methods relied on comparing specific features in clear versus dusty images which severely limited ability to analyze video frames. An improved method is constructed by defining an optical extinction model, using a dust thickness (extent along optical axis) model that is based on the tilt of the camera and height of the dust layer above the surface. The dust thickness model is used to account for the distance light travels through the dust for every image pixel. Dust can be artificially removed or added to images using the extinction model. Then by comparing and matching image luminosity histograms of similar dusty images to similar clear images, and by equating histograms mean and standard deviations, a histogram matching method (HMM) is able to estimate the extinction coefficient associated with the dust cloud.

1073 - Lunar Cold Trap Contamination by Landing Vehicles

Scott Shipley and John Lane (ESC-Easi, Kennedy Space Center, USA); Philip T. Metzger (Florida Space Institute & University of Central Florida, USA)

The emerging interest in lunar mining poses a threat of contamination to pristine craters at the lunar poles, which act as “cold traps” for water and may harbor other valuable minerals. The KSC Granular Mechanics and Regolith Operations Lab tools have been expanded to address the probability for contamination of these pristine “cold trap” craters. Trajectory simulations of rocket plume ejecta have been mapped onto cold trap craters to predict deposition for expected lunar landings. The processes addressed are now expanded to address the migration of volatiles over the lunar surface, and deposition into cold traps assuming that the collection efficiency of the 40K cold trap surfaces is 100%. Landing nearby such a crater will result in the deposition of significant exhaust plume gas into the cold trap portion of the crater, and may also create an unnatural atmosphere over the volatile reservoirs that are to be studied.

1081 - Roving on Mars with Opportunity and Curiosity: Terramechanics and Terrain Properties

Raymond Arvidson (Washington University in St. Louis, USA)

Opportunity has been roving on the plains of Meridiani and the rim of Endeavour crater on Mars since January 2004. Curiosity has been roving across the plains on Gale Crater since August 2012. Realistic mechanical models have been generated for each rover, with classical terramechanics relationships included to simulate wheel sinkage and rover-based slippage, and simulated traverses have been conducted across terrain models with topography generated from rover-based stereo images and positionally dependent bedrock and soil properties. Modeling has been used, together with analysis of engineering telemetry and image data, to retrieve surface properties, and to understand the physics of interactions among the rovers, soils, and bedrock for situations in which mobility issues have been encountered. These include high wheel sinkage and rover-based slippage while traversing the uphill sides of wind-blown ripples, and wheel wear and tear for Curiosity while traversing sharply pointed and embedded rocks.

1082 - Curiosity’s Traverse from the Kimberley to the Base of Mt. Sharp: An Orbital Data Perspective

Abigail Fraeman (Washington University in St. Louis & California Institute of Technology, USA); Raymond Arvidson (Washington University in St. Louis, USA); John Grotzinger (California Institute of Technology, USA)

Orbital data over Gale Crater are used for selecting traverses that visit scientifically interesting locations while maintaining rover safety. Here we focus on predictions for Curiosity’s traverse to Mt. Sharp using along-track oversampled (ATO) Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) datasets. The high spectral and spatial resolution of these datasets provides important information about terrain physical properties and surface composition. Spectral variability along the traverse is dominated by variations in the flux of dark sand versus bright dust, and spectral differences among aeolian material are likely due to variations in dust cover on darker aeolian material. We focus our investigation of CRISM data over the small-scale aeolian features along Curiosity’s traverse, and we couple this analysis with in situ data gathered during drives to determine the degree to which the variations in compositions and physical properties of Aeolian materials influence the degree of rover slip and wheel sinkage when crossing these bedforms.

1083 - Discrete Element Method Simulations of Mars Exploration Rover Wheel High-Slip Mobility Tests

Jerome B. Johnson, Anton V. Kulchitsky, and Paul Duvoy (University of Alaska, Fairbanks, USA); Karl Iagnemma and Carmine Senatore (Massachusetts Institute of Technology, USA); Raymond Arvidson (Washington University in St. Louis, USA); Jeffery Moore (NASA Ames Resrarch Center, USA)

Mars Exploration Rovers (MERs) experienced mobility challenges when crossing wind-blown ripples and deformable sands while exploring Martian terrain. Analysis of MER wheel mobility using a 3D discrete element method (DEM) model indicate three stages of mobility: (1) low slip (< 30% slip) defined by soil strength, (2) intermediate slip (30-60% slip) defined by residual soil strength and (3) high slip > 60% slip) defined by residual soil strength and depth of wheel sinkage. MER wheel sinkage and drawbar pull increased then decreased during contact between soil and the wheel tie-down patch, compared to wheel cleats, in high slip conditions, but had little effect on overall wheel mobility. DEM simulations well describe intermediate and high slip average wheel sinkage and replicate the signature of drawbar pull and sinkage for the tie-down patch, but not its magnitude. Improved DEM simulation accuracy can be achieved by using smaller polyhedral particles to represent soil.

1084* - Experimental Study on Driving Wheel’s Performance for Lunar Exploration Rovers

Shin Hyunjoon (Hanyang University, Korea)

This paper is a preliminary study to adapting terra-mechanics, analyze the mutual motion between lunar rover wheel s and lunar soil, and select an wheel design which has the best performance. To understand the lunar exploration rover wheel performance, lunar regolith simulant, lunar surface analogue test-bed, and single wheel test-bed have been developed.

1091 - Prototype of Environment Analytics Driven Autonomous Vehicle

Rich Lee (National Taipei University of Technology & IBM, Taiwan)

Exploring the soil information of an unknown terrain on the extraterrestrial is one of the major missions of space exploitation and human colonization. Using the autonomous vehicle to facilitate the soils sampling process is an emerging technology; it has been applied many times in the previous missions of Moon and Mars. This paper takes advantage of the nature of soil-zonality to propose a novel algorithm to traverse an area to save time and energy of the autonomous vehicle. Three searching tactics to suggest the vehicle to move next location, including: (1) fundamental –based on the patterns of soil map; (2) density – based on the higher scale first principle; and (3) statistical – based on the soil information gathered from the previous scan. This paper also argues using the statistical analysis as the soil properties sample comparison tool will be less cost from present practice – visually remote controlled and grabbing the samples back for later analysis.

1092 - Push-Pull Locomotion for Vehicle Extraction

Colin Creager and Kyle Johnson (NASA Glenn Research Center, USA); Scott Moreland (NASA Jet Propulsion Laboratory, USA); Krzysztof Skonieczny (Concordia University, Canada); Mark Plant (Youngstown State University, USA)

For applications in which unmanned vehicles must traverse unfamiliar terrain, there often exists the risk of vehicle entrapment. Typically, this risk can be reduced by using feedback from on-board sensors that assess the terrain. This work addresses the situation where a vehicle has already become immobilized or the desired route can't be traversed using conventional rolling. Specifically, the focus is on using push-pull locomotion in high sinkage soil. Push-pull locomotion is an alternative mode of travel that generates thrust through articulated motion, using vehicle components as anchors to push or pull against. It has been revealed through previous research that push-pull locomotion has the capacity for generating higher net traction forces than rolling, and a unique optical flow technique indicated that this is the result of a more efficient soil shearing method. It has now been found that push-pull locomotion results in less sinkage, lower travel reduction, and better power efficiency in high sinkage soil as compared to rolling. Even when starting from an "entrapped" condition, push-pull locomotion was able to extricate the test vehicle. It is the authors' recommendation that push-pull locomotion be considered as a reliable back-up mode of travel for applications where soil entrapment is a possibility.

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(*denotes Student Oral Presentation)

2011 - Development and Testing of a Lunar Prospecting Drill (LPD) to Search for Water-Ice

Kris Zacny, Gale Paulsen, Bolek Mellerowicz, Daniel Kim, Phil Chu, and Chris Follette (Honeybee Robotics, USA); Julie Kleinhenz (NASA Glenn Research Center, USA)

There are at least two approaches in searching for water-ice in lunar regolith: indirect and direct. In the indirect method, neutron spectrometer can be used to capture epithermal and thermal neutrons – signature of Hydrogen and hence possibly water. If a neutron spectrometer is integrated inside a drill string, as the drill penetrates subsurface it can determine water concentration at different layers. In the direct method, a sample is captured at depth and transferred to a Gas Chromatograph Mass Spectrometer (GCMS) for analysis. The indirect method is simpler as it does not require sample transfer, however the direct method provides higher fidelity data. This paper focuses on the direct method. The Lunar Prospecting Drill (LPD) has been tested in frozen NU-LHT-2M with 5wt% water and in dry NU-LHT-3M. The drill captured sample in 10 cm intervals, called bites. The mass of each bite varied from 20-40 grams for 5wt% simulant and from 10-20 grams for dry simulant.

2012 - Testing of Mars-Prototype Drill at an Analog Site

Brian Glass and Sarah Huffman (NASA Ames Research Center, USA); Alexander Wang and Kris Zacny (Honyebee Robotics, USA); Pascal Lee (SETI Institute, USA)

Exploring and interrogating the shallow subsurface of Mars from the surface will require some form of excavation and penetration, with drilling being the most mature approach. The latest LITA drill, designed for use at the Atacama Desert Chilean analog site, was recently tested at the same Arctic site (Haughton Crater) as have a series of past NASA drill prototypes since 2004. Unlike previous tested prototypes, the smaller LITA did not demonstrate a capability of penetrating hard rock or ice-consolidated material at the Drill Hill test site.

2013 - Auto-gopher - A Wireline Deep Sampler Driven by Piezoelectric Percussive Actuator and EM Rotary Motor

Yoseph Bar-Cohen Mircea Badescu, Hyeong Lee, Stewart Sherrit, Luther Beegle and Xiaoqi Bao (JPL, USA); Kris Zacny and Gale Paulsen (Honeybee Robotics, USA);

A drilling system that is a rotary hammering mechanism called the Auto-Gopher was developed to establish the capability to reach below the surface of Mars, a surface that is unprotected from cosmic ray (predominately protons and atomic neculi) and solar (predominately UV) radiation. The hammering mechanism is driven by piezoelectric stack while the rotation is actuated by an electromagnetic motor. In order to meet this need, the drilling operation parameters were optimized with a lab version of Auto-Gopher system by varying the duty cycle, weight-on-bit, and power of the percussive mechanism. A full wireline Auto-Gopher system was then designed and fabricated, and the drilling performance was investigated by drilling in gypsum and limestone substrates, reaching a depth of 3 meters, which is 1.5x drill's length. The results demonstrate the potential capability to reach many meters deep without considerable increase in the drill mass, size or power. The average drilling power that was used has been in the range of 100-150 Watt, and the penetration rate has reached 15-30 mm/min when operated as a rotary-percussive drill.

2021 - Novel Concept and Design of Ultralight Mobile Drilling System Dedicated for Planetary Environment

Karol Seweryn, Kamil Grassmann, Tomasz Kucinski, Jakub Lisowski, Konrad Rutkowski, and Roman Wawrzaszek (Space Research Centre of the Polish Academy of Sciences, Poland); Stanisław Bednarz, Tomasz Buratowski, Grzegorz Chmaj, Michał Ciszewski, Alberto Gallina, Andrzej Gonet, Wojciech Teper, Tadeusz Uhl, and Adam Zwierzynski (AGH University of Science and Technology, Poland);

In this paper the design of the ultralight mobile drilling system (UMDS) dedicated for planetary environment is presented. The main features of the system are connected with its mobility by integration with a rover, and the special design of support module which take advantage of tubular booms to guide the drilling subsystem. The latter is designed to reduce the path for cuttings and to be applicable for operation in vacuum conditions. At the system level, UMDS was designed to reduce the mass and power consumption in each operational phase.

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Special care was applied to minimize the cross contamination of the gathered core by volatiles as well as to reduce the influence of heat dissipation during the drilling process. The system is also considered for terrestrial applications and testing with UAV helicopter is foreseen.

2022 - Accessing, Drilling and Operating at the Lunar South Pole: Status of European Plans and Activities

Richard Fisackerly, James Carpenter, Gianfranco Visentin, Bérengère Houdou, and Bernardo Patti (ESA-ESTEC, The Netherlands); Francesco Rizzi, Alessandro Fumagalli, and Piergiovanni Magnani (SELEX-ES, Italy)

Exploration of the Moon is considered a high priority in the overall strategy of the European Space Agency (ESA), together with activities in Low Earth Orbit and missions to Mars. The Lunar South Polar region presents key opportunities for scientific discovery and advancement of exploration capabilities, but is also a uniquely challenging operational environment for robotic missions and for human explorers. ESA has placed accessing this environment and the surface material found there as a high priority. In this context ESA is discussing with international partners, in particular with ROSCOSMOS, how these ambitions might be realised in cooperation. To support this work ESA is engaged in a range of mission level activities with ROSCOSMOS on the Luna-27/Luna-Resurs Lander mission as well as Lunar Polar Sample Return (LPSR). In addition to this ESA is undertaking, with European institutes and industries, a set of specific development activities which seek to address the challenges of operating in the challenging environment of the Lunar South Pole.

2031 - Sampling of Regolith on the Moon and Mars Utilizing Electrostatic Force and Mechanical Vibration

Hiroyuki Kawamoto, Akira Shigeta and Masato Adachi (Waseda University, Japan)

To realize reliable and autonomous sampling of regolith on the Moon and Mars, the authors have developed a unique sampling system that employs electrostatic capture and mechanical vibration transport of particles. A high ac voltage is applied between parallel screen electrodes mounted at the end of the sampling tube. Regolith particles on the surface are captured after they are passed through the openings in the screen electrodes by means of an electrostatic force. The captured particles are then transported through a tube against gravity and transferred to a capsule utilizing mechanical vibration. Experiments demonstrated that some amount of regolith is sampled for a short period, even in the 1-G environment on the Earth if the end of the screen electrode is in contact with the regolith layer. Because the gravities on the Moon and Mars are one-sixth and three-eighths, respectively, of that on the Earth, the process of sampling particles on the Moon and Mars will be easier than on the Earth. Not only simulant particles but also crushed ice can be sampled using this system.

2032 - MicroDrill Sample Acquisition System for Small Class Exploration Spacecrafts

Kris Zacny, Erik Mumm, Drew Neal, Justin Spring, Gale Paulsen, Phil Chu, Bolek Mellerowicz, and Magnus Hedlund (Honyebee Robotics, USA); Robert P. Mueller, Tom Ebert and Michael Dupuis (NASA Kennedy Space Center, USA)

The paradigm for space exploration is changing. Large and expensive missions are very rare and the space community is turning to smaller, lighter, and less expensive missions that could still perform great exploration. These missions are also within reach of commercial companies such as the Google Lunar X Prize teams that develop small scale lunar missions. Recent commercial endeavors such as “Planet Labs Inc.” and Sky Box Imaging, inc. show that there are new benefits and business models associated with miniaturization of space hardware. The MicroDrill is part of the ongoing effort to develop “Micro Sampling” systems for deployment by these small spacecrafts with limited payload capacities. The ideal applications include prospecting missions to the Moon and Asteroids. This paper describes development and testing of the “MicroDrill” system. The MicroDrill is a rotary-percussive coring drill that captures cores 7 mm in diameter and up to 2 cm long. The drill weighs approximately 1 kg and can capture a core from a 40 MPa strength rock within a few minutes, with less than 10 Watt power and less than 10 Newton of preload.

2033* - Sampling of Regolith on Asteroids Utilizing Electrostatic Force

Masato Adachi, Hiroki Maezono, and Hiroyuki Kawamoto (Waseda University, Japan)

To achieve reliable and autonomous regolith sampling on asteroids, we have developed a unique sampling system that utilizes electrostatic force. When a rectangular high voltage is applied between parallel screen electrodes, the resultant Coulomb force and dielectrophoresis force act on particles in the vicinity of the electrodes, and some particles are captured passing through the openings of the screen electrodes. The sampling system is simple, has low power consumption, and has no mechanical moving parts. It was demonstrated that a lunar regolith simulant can be captured in a zero-G environment reproduced by the parabolic flight of an aircraft. As predicted by a numerical calculation utilizing a hard sphere model of the three-dimensional Distinct Element Method, a large amount of lunar regolith simulant, approximately 900 mg, was successfully sampled. The captured regolith particles contained not only small particles but also large particles more than 0.5 mm in diameter. Moreover, it was predicted by the numerical calculation that the sampling system would perform much better in a vacuum than in air.

2041 - Manufacturing of Lunar Concrete by Steam

Sebastian Wilhelm and Manfred Curbach (Technische Universität Dresden, Germany)

This paper describes a method of manufacturing concrete under vacuum conditions, based on an enhancement of the Dry-Mix/Steam-Injection method (DMSI) by T. D. LIN. The aim is the production of concrete elements for the construction of modular protective structures on the moon. Due to the vacuum, manufacturing by wet mixing of cement, aggregate and water is not possible, because the unbound water would quickly evaporate. In initial experiments it was shown that the water demand for concrete mixtures with a high content of fine particles can be greatly reduced with the help of the DMSI method leading to nearly equal compressive strength in shorter hardening time.

2042* - Solidification of Polymer Concrete Using the Artificial Lunar Soil

Tai Sik Lee, Ki Yong Ann, Byung Chul Chang and Jaeho Lee (Hanyang University, Korea); Dongcheol Choi (Hanyang University & International Space Exploration Research Institute, Korea)

The present study concerns a production of lunar concrete using the artificial lunar soil and thermoplastic polymeric material as binder. The lunar soil was cast with the polymer in a cubic mould (50x50x50 mm) in a lunar environment-mimic chamber. Prior to solidification of the lunar soil mixture, the chamber was evacuated by a vacuum pump to 0.1-0.2 torr, followed by preheating by an electric heater placed inner

wall of the chamber to sustain the internal room temperature at 123˚C. Then, a heat plate, of which the surface temperature accounts for 230˚C, was attached in one dimension for 5.0 hours on the top of the specimen in the mould to melt the polymer embedded in the mixture then to bind artificial lunar soil. Simultaneously, a specimen was in the equated condition except for the preheating process; the room temperature was about 15˚C at the onset of plate-heating and instead the heating duration lasted 24 hours to compensate for preheating benefit. As a result it was found that the specimen subjected to preheating was mostly solidified, of which solidified depth accounted for about 49.2 mm, whilst non-preheated specimen was only partially solidified in the vicinity of the top, where the heat plate was directly attached. It implies that preheating of the mixture would be more effective in melting the polymer and thus binding lunar soil then to form a solid body, even in a shorter heating duration. Without preheating, the melting efficiency of the polymer was marginal to solidify the lunar soil in a relatively long heating (i.e. 24 hours).

2043* - Protein-Regolith Composites for Space Construction

Henning Roedel and Michael Lepech (Stanford University, USA); David Loftus (NASA Ames Research Center, USA)

Identified as critical to lunar or Martian exploration, stabilized regolith can be used as a foundational construction material for key infrastructure systems. These infrastructure systems include stabilized landing pads, pavements, and protective structures that can shield humans from exposure to high energy radiation. Current approaches to regolith stabilization, however, require large amounts of energy or binder mass, and thus require significant upstream infrastructure to produce the stabilized regolith. This paper presents a novel approach to the production of stabilized regolith by binding regolith within a protein matrix. The constituent materials, processing techniques, and experimental mechanical performance of Regolith Biocomposite (RBC) material are described. Further, the mechanical performance, material requirements, and energy requirements for in situ fabrication of RBC are compared to other regolith stabilization methods found in literature. Results indicate that RBC material properties are on par with the other techniques, and that energy and binder requirements for in situ fabrication are lower than other regolith-based materials.

2051 - Modular Additive Construction Using Native Materials

A. Scott Howe, Brian Wilcox, Christopher McQuin, David Mittman, Julie Townsend, Raul Polit-Casillas and Todd Litwin (Jet Propulsion Laboratory, USA)

Using modular construction equipment and additive manufacturing (3D printing) techniques for binding, mission support structures could be prepared on remote planetary surfaces using native regolith. Material mass contributes significantly toward the cost of deep space missions, whether human or robotic, due to the resources needed to lift each kilogram of equipment out of Earth's gravity well. Proposing the modular Freeform Additive Construction System (FACS) concept, using the reconfigurable All-Terrain Hex-Limbed Extra-Terrestrial Explorer (ATHLETE) robotic mobility platform, a variety of walls, berms, vaults, domes, paving, and thick radiation shielding could be prepared in advance of crews and mission assets to help reduce the material needed to be brought from Earth. This paper discusses the current ATHLETE technology, and describes how flexible mission elements could be derived using a combination of three dimensional additive construction and in-situ manufacturing technologies using native regolith.

2052 - A Civil Engineering Approach to Development of the Built Martian Environment

Brett Schock (Transystems, Inc., USA); Cheng Lok Hing (Michael Baker Jr. Inc., USA)

A discussion of the concepts that civil engineers and planners can bring to the table in the development of a Mars built environment, this paper focuses on the civil engineering challenges and differences of Mars and presents recommendations for the planning and engineering of a Mars colony. The basics of terrestrial civil engineering for undeveloped areas are discussed from an American perspective. A contrast is shown between the anticipated conditions on Mars and those on Earth. Attention is drawn to the assumptions of modern infrastructure development, based on millennia of human history and Earth conditions and which could or should be modified for Martian environmental challenges. A concept is discussed for mimicking the development and civilization of terrestrial life for a Martian settlement, taking into account these environmental challenges, differences in basic design assumptions and correction of existing development patterns which are inefficient and unnecessary on Mars.

2053 - Mass Drivers for Space Construction

Ray Leonard (A Different Race, LLC & University of New Mexico, USA)

All space development efforts are hindered by the cost of placing payloads in orbit. Reducing launch costs allows more mass to be placed into orbit for a given budget. Most of the weight (mass) in any rocket is used to launch the fuel and not the payload. Electromagnetic (EM) railguns or mass drivers would avoid that problem. A major assumption made in the paper is that construction materials including solar panels do not have the same accelerations limits as humans.

2054 - Dust Tolerant Commodity Transfer Interface Mechanisms for Planetary Surfaces

Robert P. Mueller and Gabor Tamasy (NASA Kennedy Space Center, USA); Ivan Townsend (ESC–Craig Technologies, USA); Matthew Nugent (ESC- Sierra Lobo, USA)

Regolith is present on most planetary surfaces such as Earth's moon, Mars, and Asteroids. If human crews and robotic machinery are to operate on these regolith covered surfaces, they must face the consequences of interacting with regolith fines which consist of particles below 100 microns in diameter down to as small as sub-micron scale particles. Such fine dust will intrude into mechanisms and interfaces causing a variety of problems such as contamination of clean fluid lines, jamming of mechanisms and damaging connector seals and couplings. A dust tolerant, hand held "quick-disconnect" cryogenic fluids connector housing has been developed at NASA KSC which can be used by astronaut crews to connect flex lines that will transfer propellants and other useful fluids to the end user. In addition, a dust tolerant, automated, cryogenic fluid, multiple connector, power and data interface mechanism prototype has been developed, fabricated and demonstrated by NASA at Kennedy Space Center (KSC). The design and operation of these prototypes are explained and discussed.

2061 - Oilfields in the Sky - A Different Race

Ray Leonard (A Different Race, LLC & University of New Mexico, USA)

The concepts in this paper are presented as an evolutionary path: a) the creation of a semi-automated construction system that allows for the very economical construction of large terrestrial solar arrays; b) the integration of the SPS rectenna with the terrestrial array;

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c) using array power to synthesize liquid fuels thus providing a transition path to a hydrogen economy, d) providing a market for competitively priced synthetic fuels; and e) an economic analysis of both power from space and synthetic fuels using energy from space. Finally, a top level economic and environmental comparison of alternatives is made with the conclusions being drawn that there are no easy choices left and that it is up to us.

2062* - Expanding Mineral Resources: Technical Considerations for Extra-terrestrial Mining

Erin McCullough, Paul Jewell and Purushotham Tukkaraja (South Dakota School of Mines and Technology, USA)

It is well-understood that natural resources are scarce and that the world's population is predicted to climb exponentially. As the global population continues to grow, demand for consumer goods including food, hygiene, and technology will increase accordingly. Part of this problem is that mineral resources are becoming increasingly difficult to find and extract profitably. The necessity to consider the feasibility of resource extraction in new locations is paramount to our continued prosperity. Although mining in outer space is not considered a conventional solution to the growing mineral shortage, extraterrestrial environments are becoming particularly attractive due to increasing rates of mineral depletion, government regulations, and capital costs here on earth. Successful mine designs in space must address a wide array of challenges including mineral exploration, determining economic recovery rates, safety practices, equipment maintenance, materials handling and transportation, and mineral processing. There is not a cut and dry approach to mine design because a variety of methods exist for specific conditions.

2063 - HALE: A Flexible Approach to Settlement of the Solar System

Tom Matula (Great Basin Comm. College, USA); Kevin Greene (Astrosettlements, USA)

The Solar System has vast resources that have the potential to greatly benefit humanity. But developing those resources presents major challenges ranging from the limitations of human physiology to the lack of celestial bodies suitable for human habitation. The Habitat Automatous Locomotive Expandable (HALE) is offered as one solution to these challenges. Built initially at the Earth-Moon Lagrange Points, the HALE will be capable of reaching the most remote reaches of the Solar System where it will supply stable and safe habitation and major capabilities, for both scientific research and resource development.

2071 - The Advantages of Continuous Excavation in Lightweight Planetary Operations

Krzysztof Skonieczny (Concordia University, Canada); David Wettergreen and William Whittaker (Carnegie Mellon University, USA)

This research introduces novel experimentation that for the first time subjects excavators to gravity offload (a cable pulls up on the robot with 5/6 its weight, to simulate lunar gravity) while they dig. Excavating with gravity offload underestimates the detrimental effects of gravity on traction, but overestimates the detrimental effects on excavation resistance. Though not ideal, this is a more balanced test than excavating in Earth gravity, which underestimates detrimental effects on both traction and resistance. A 300 kg excavator offloaded to 1/6 g successfully collects 0.5 kg/s using a bucket-wheel, with no discernable effect on mobility. For a discrete excavator of the same weight, production rapidly declines from the initial rate of 0.5 kg/s as rising excavation resistance stalls the robot. The experiments presented in this work demonstrate that continuous excavation fares better than discrete excavation when subjected to comparable reduced gravity circumstances. In Earth gravity, on the other hand, both the continuous and discrete configurations operated successfully.

2072 - Additive Construction using Basalt Regolith Fines

Robert P. Mueller, Paul Hintze, Thomas Lippitt, and James Mantovani (NASA Kennedy Space Center, USA); Matthew Nugent (ESC- Sierra Lobo, USA); Laurent Sibille (ESC–EASI, USA); Ivan Townsend (ESC–Craig Technologies, USA)

This paper summarizes activities at KSC regarding the utilization of BP-1 basalt regolith and comparative work with lunar basalt simulant JSC-1A as a building material for robotic additive construction of large structures. In an effort to reduce the import or in-situ fabrication of binder additives, we focused this work on in-situ processing of regolith for construction in a single-step process after its excavation. High-temperature melting of regolith involves techniques used in glassmaking and casting (with melts of lower density and higher viscosity than those of metals), producing basaltic glass with high durability and low abrasive wear. Most Lunar simulants melt at temperatures above 1100°C, although melt processing of terrestrial regolith at 1500°C is not uncommon. These temperatures are achievable by laser heating or by using solar concentrators. Similar to volcanic magma, the cooling rate determines the crystallite size – slower cooling develops larger crystals, and rapid quenching can result in fully amorphous glass.

2081* - Longitudinal Impact Force on a Special Drill for Planetary Exploration

Luis Vila and Ramesh Malla (University of Connecticut, USA)

Special percussive mechanisms, e.g. Auto Gopher and Ultra Sonic/Sonic Driller/Corer (USDC) have been developed by NASA Jet Propulsion Laboratory and Honeybee Robotics Spacecraft Mechanisms Corporation to explore the Lunar, Martian, and other planetary subsurface and extract soil (regolith)/rock samples for further study. The percussive mechanism consists of an ultrasonic horn, a free mass (hammer) and the drill rod. This paper presents an analytical methodology to analyze the dynamic and contact analysis of the longitudinal impact of the free mass and the drill rod including the effects of structural vibration. The contact force due to impact is obtained using Hertz force-indentation relation coupled with the structural vibration obtained using mode superposition method. Numerical solution, with equilibrium iterations, of the equations of motion is implemented. The contact force was observed to follow a sinusoidal like shape, consistent with results available in literature for similar problems.

2082* - Microwave Assisted Rock Breakage for Space Mining

Pejman Nekoovaght Motlagh, Nima Gharib, and Faramarz Hassani (McGill University, Canada)

With the new advancements in space technology and also involvement of private sectors in space programs, space mining became an attractive subject either in In-Situ Recourse Utilization (ISRU) on the moon or mineral extraction from an asteroid. One can imagine that excavation and breakage technique that will be used will mainly be affected by the terrestrial methods which has been tested, tried and proved reliable. Drilling rocks is the first stage in order to extract the resources. It mainly relies on the mass of the drill and the reactive force that comes from the gravity. On the moon or an asteroid, where the gravitational force is one sixth or negligible, the drilling performance would not be equivalent to that on the earth. In this study, employment of microwave as a mean to reduce strength of the rocks before drilling is investigated. A magnetron can be installed on the drill and emit microwaves on the rock surface.

2083 - Some Considerations for Excavation in Martian Aquifers

Azupuri Kaba (Halliburton Energy Service, USA); Leslie Gertsch (Missouri University of Science and Technology, USA)

This study evaluated the effect of water saturation on the behavior of porous rock during mechanical excavation, such as drilling. Such understanding will increase the ability to design robust and flexible tools for drilling in liquid-water aquifers in the martian shallow crust. This capability will be crucial to sustaining the exploration of Mars, and ultimately of other places where liquid water occurs near the surface. The experiment controlled speed of indentation of the rock (by an indenter of a typical shape for drill bits), and the state of saturation of the rock samples. The indentation speeds were expected to bracket the threshold between drained and undrained conditions. Specific energy of indentation increased with saturation during high-speed indentation, but no other experimental parameters gave clear results. Further tests are needed.

2091 - Comparative Specific Heat Capacity Analysis for Lunar In-Situ Manufacture of Thermal Energy Storage

Aaron Clarke Bonanno (University Of New South Wales & Global Sustainable Energy Solutions (GSES), Australia); Leonhard Bernold (Universidad Tecnica Frederico Santa Maria, Chile)

Exploring and mining on the Moon is dependent on the availability of sufficient power to drive essential equipment and tools. One sustainable source of direct energy is the sun during a lunar day. However, energy required for manufacturing during the lunar night, lasting 17 Earth days, will require a means of storing this daytime energy. The focus of this thesis is to compare the thermal energy storage capabilities of sulphur concrete, polymer concrete and sintered Australian Lunar Regolith Simulant (ALRS-1). Experimental procedures were developed that allowed the calculation of heat loss in hollow cylinders made of predefined; sulphur, polymer and sintered ALRS-1 material recipes. The velocity of the heated air as well as the changing temperatures inside and around the sample was measured. This data was then used to determine the thermal energy storage properties of each sample. Four sulphur concrete samples were cast with inner pipe diameters of 2.5cm and 3.5cm, and sulphur contents of 45% and 55% respectively.

2092 - Atmospheric Processing Module for Mars Propellant Production

Anthony Muscatello (NASA Kennedy Space Center, USA); James Captain (QinetiQ North America, USA); Robert Devor (Qinetic North America, USA)

The multi-NASA center Mars Atmosphere and Regolith COllector/PrOcessor for Lander Operations (MARCO POLO) project was established to build and demonstrate a methane/oxygen propellant production system in a Mars analog environment. Work at the Kennedy Space Center (KSC) has focused on the Atmospheric Processing Module (APM). The purpose of the APM is to freeze carbon dioxide from a simulated Martian atmosphere at Martian pressures (~8 torr) by using dual cryocoolers. The resulting pressurized CO2 and hydrogen are fed to a Sabatier subsystem to make methane and water vapor. This paper covers (1) the design and selection of major hardware items, such as the cryocoolers, pumps, tanks, chillers, and membrane separators, (2) the determination of the optimal cold head design and flow rates needed to meet the collection requirement of 88 g CO2/hr for 14 hr, (3) the testing of the CO2 freezer subsystem, and (4) testing of the Sabatier subsystem.

2093* - Microwave Heating Applications for In-Situ Resource Utilization and Space Mining

Houshin Nejati and Peter Radziszewski (McGill University, Canada)

The microwave-assisted method can be used in mechanical breaking machinery, such as full face tunnel boring machines and road headers on earth. This paper discusses the potential and advantages for using microwaves in space applications such as In Situ Resource Utilization (ISRU), sampling and In-Situ material analysis. This paper first compares the mineralogical compositions and dielectric properties of the terrestrial basalts used in this research with the properties of lunar basalts. Comparison of mineralogical composition of lunar and terrestrial basalt shows the lunar basalts contain high proportions of glass and higher percentage of absorbent minerals than terrestrial basalts, therefore, it is expected that they will be more susceptible to microwave fracturing. Microwave depth of penetration and the magnitude of heat generation (microwave power dissipation) are frequency dependent, which could be advantageous for space mining applications. Frequency adjustment is a means to localize microwave absorption at desirable depth for material extractions, and control the magnitude of the heat generation (temperature) and material phase (solid, molten).

2094 - Wells for In-situ Volatile Extraction From Regolith

Otis Walton, Yunwei Sun and Hubert Vollmer (Grainflow Dynamics, Inc, USA)

This paper describes a proposed method for extracting frozen volatiles from subsurface (especially lunar) regolith and outlines steps that can be taken to evaluate the feasibility of the method, along with appropriate enhancements to simulation models, and terrestrial studies that could assist in optimization of the process. The basic premise of this concept is that after a well bore is drilled, a heat source and an extraction tube could be inserted into the bore hole to the depth of the desired resource; and a seal achieved around the extraction tube near the entrance (e.g., with an inflatable bladder or grout). Heat introduced in the well-bore would radiate/conduct into the surrounding material and vaporize the frost closest to the bore-hole. As the frost heats and sublimes, the pressure in the production region would increase and the vapor would flow to a lower pressure region (hopefully/presumably) into the open well-bore leading to the collection tube near the well entrance.

2101 - Concepts of Operations for Asteroid Rendezvous Missions Focused on Resources Utilization

Robert P. Mueller (NASA Kennedy Space Center, USA); Laurent Sibille (ESC–EASI, USA); Gerald Sanders (NASA Johnson Space Center, USA); Christopher Jones (NASA Langley Research Center, USA)

Several asteroids are the targets of international robotic space missions currently manifested or in the planning stage. This global interest reflects a need to study these celestial bodies for the scientific information they provide about our solar system, and to better understand how to mitigate the collision threats some of them pose to Earth. Another important objective of these missions is providing assessments of the potential resources that

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Symposium 2

Exploration and Utilization of Extra-Terrestrial Bodies

(*denotes Student Oral Presentation)

asteroids could provide to future space architectures. In this paper, we examine a series of possible mission operations focused on advancing both our knowledge of the types of asteroids suited for different forms of resource extraction, and the capabilities required to extract those resources for mission enhancing and enabling uses such as radiation protection, propulsion, life support, shelter and manufacturing. An evolutionary development and demonstration approach is recommended within the framework of a larger campaign that prepares for the first landings of humans on Mars.

2102* - Modeling Asteroid Deflection Induced by Subsurface Blasting

James Veerkamp and Leslie Gertsch (Missouri University of Science and Technology, USA)

Asteroid deflection through explosive blasting provides an avenue to achieve significant changes in velocity for a given explosive yield, enabling deflection of bodies on a collision course with Earth much closer to time of impact. In this analysis, a number of computational numerical methods have been applied to outstanding problems of determining the change of velocity induced to an asteroid, the uncertainty distribution within the model, and the impact deflection that a modeled change in velocity would induce in a hypothetical test case. The results from this modeling support the utility of further research and small-scale testing, and suggest that blasting has the capacity to redirect asteroids less than a year before the time of impact in many cases. Filling this capacity is essential, considering the potentially short detection interval compared to the times necessary for many other deflection strategies.

2103 - Discrete element Method Simulation of a Boulder Extraction from an Asteroid

Anton V. Kulchitsky and Jerome B Johnson (University of Alaska Fairbanks, USA); David Reeves (NASA Langley Research Center, USA); Allen Wilkinson (NASA Glenn Research Center, USA)

The force required to pull 7t and 40t polyhedral boulders from the surface of an asteroid is simulated using the discrete element method considering the effects of microgravity, regolith cohesion and boulder acceleration. The connection between particle surface energy and regolith cohesion is estimated by simulating a cohesion sample tearing test. An optimal constant acceleration is found where the peak net force from inertia and cohesion is a minimum. Peak pulling forces can be further reduced by using linear and quadratic acceleration functions with up to a 40% reduction in force for quadratic acceleration.

2104 - Modeling and Simulation of Vehicle Dynamics on the Surface of Phobos

Marco Quadrelli (California Institute of Technology & Jet Propulsion Laboratory, USA); Jonathan Cameron, Abhinandan Jain, Bob Balaram, Steven Myint and Avinash Devalla (Jet Propulsion Laboratory, USA)

This paper describes recent work done in modeling and simulation of vehicle dynamics on the surface of Phobos. This effort is part of a larger systems engineering capability developed at JPL to answer key questions, validate requirements, conduct key system and mission trades, and evaluate performance and risk related to small body operations for any proposed human or robotic missions to a asteroids and small bodies [Balaram et al.]. As a precursor to landing a human on Mars, NASA is interested in developing a capability to deliver humans, performing experiments, and then returning safely from the surface of Phobos. The study focused on three aspects of the problem: a) Orbital dynamics near the surface; b) Modeling of the interaction between the footpad and regolith material, and c) Analysis of system level effects relating to the hopper configuration geometry.

Symposium 3

Advanced Materials and Designs for Hydraulic, Earth, and Aerospace Structures

(*denotes Student Oral Presentation)

3011 - Analyzing the Bending Ability of ZBLAN Optical Fibers

Anthony Torres (Texas State University, USA)

The bending ability of an optical fiber is determined by the inherent micro-structural properties of the fiber. The major differences between the properties of an amorphous glass and a glass containing small amounts of microcrystals is that these inherent flaws play a strong role in the handling and bending ability of optical fibers, particularly in ZBLAN fibers. ZBLAN, a formulation from the ZrF4-BaF2-LaF3-AlF3-NaF system is the most stable glass for mid-infrared (IR) optical fiber applications, such as application in mid-IR sensors, radiometry, and laser power delivery. However, microcrystals formed during the fiber drawing process make this fiber a difficult material to handle and often fails when collected around the take-up reel. This study analyzes the bending ability of ZBLAN optical fibers by subjecting samples to heat-treatments and incremental bending radii of curvature. The results show that a fiber drawing take-up reel needs to be at least 15.24 cm (6.0 in.)

3012 - Thermal Conductivity across a Bolted Joint

Arup Maji and Prakash Guntuku (University of New Mexico, USA)

Satellite structures are still primarily aluminum, connected with bolted joints. Thermal management of satellites is challenging due to the large temperature excursions in space as the satellite goes from sunlight to darkness. For smaller satellites the thermal conductivity across a joint can be a significant contributor to the overall thermal gradient in the structure. Thermal conductivity across a lap joint, i.e. thin Aluminum plates connected with a single bolt in the center of the plates was investigated via analysis and testing. Plates with different surface roughness at the interface are considered. Thermal contact resistance at the interface is determined by constantly monitoring temperature at different locations of the plates using thermocouples. The applied torque on the bolt is varied to determine how thermal conductivity can be affected by the tightness of a bolted connection. Different diameter bolts were also considered.

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Advanced Materials and Designs for Hydraulic, Earth, and Aerospace Structures

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3013 - Fatigue Behavior of Boron Nitride Nano-Modified Carbon Epoxy Composite

Mahdi Ghazizadeh, Ghazizadeh and Ajit Kelkar (Joint School of Nanoscience and Nanoengineering, USA)

The behavior of nano-modified carbon-epoxy laminates under tension-tension fatigue has been investigated. Epoxy resin system comprising of Epon 862 and hardener DETDA W was modified with Boron Nitride nanoparticles. Comparison of number of cycles survived before fatigue failure indicates that at highest stress level (90 % of ultimate tensile strength) control specimens exhibited better performance under fatigue loading while at 80 %, the nano particle modified samples survived slightly higher number of fatigue cycles. Although these differences have been observed, the overall performance of the two laminates were similar under tension-tension fatigue loading. The study of the facture surface indicates failure in nano-modified specimens is caused by sudden breakage of fibers while in absence of nanoparticles, damage was progressive and was in the form of damaged and broken fibers.

3021 - Effective Mesomechanical Modeling of Triaxially Braided Composites for Impact Analysis with Failure

Walter Nie and Wieslaw Binienda (The University of Akron, USA)

A finite element analysis (FEA) based mesomechanical modeling approach suitable for two-dimensional triaxially braided composite (TDTBC) materials and structures under high speed impact was developed. This new modeling approach is capable of considering the braiding geometry and architecture as well as the mechanical behavior of fiber tows, matrix, and the fiber tow interface, making it feasible to study the details of localized behavior and global response that happen in the complex constituents. Additionally, it is capable of simulating inter-laminar and intra-laminar damage and delamination of braided composites subjected to dynamic loading. With high fidelity in both TDTBC architecture and mechanical properties, it is well suited to analyze high speed impact events with improved simulation capability in both accuracy and efficiency. Special attention was paid to the applicability of the method to relatively large scale components or structures.

3022 - Thermomechanical Modeling of Cone Sample of ZrB2-SiC Ceramic Under Arc-jet Conditions

Lokeswarappa Dharani and Jun Wei (Missouri University of Science and Technology, USA)

The effects of oxidation on mechanical behavior of a cone sample of ZrB2-SiC ceramic under arc-jet test conditions is studied by a finite element (FE) model. First a steady-state heat transfer FE method was employed to conduct the thermal analysis and obtain the temperature distribution in the inner body of the cone. Then, resulting temperature distribution is applied to the thermomechanical finite element analysis to calculate the thermal stress distribution in the cone body. Due to the mismatch of material properties between the bulk ZrB2-SiC and its new products after oxidation, the outer oxide layers constrain the thermal deformation of the inner bulk ZrB2-SiC thereby putting it in compression and outside oxide layers in tension. The stress concentrations occur at the pore tips in the pore area due to the geometric heterogeneity.

3031 - Processing and Mechanical Characterization of Polyurea Aerogels

Victoria Prokopf, Jared Loebs, Lokeswarappa Dharani and Nicholas Leventis (Missouri University of Science and Technology, USA)

The polyurea aerogels (PUA) were created by reacting triisocyanate Desmodur N3300a and water using triethylamine as a catalyst in a solution of acetone. Three PUA with densities 0.12 g/cm3, 0.17 g/cm3 and 0.33 g/cm3 were fabricated tested and used in model simulation. Quasi-static testing was conducted for mechanical strength in tension, compression, and shear. Testing was also conducted in dynamic tension and bending. Simulations were performed to develop a better understanding of structure-property response of PUA. Micro-scale effects such as particle stiffness, bond strength, and particle frictional coefficients were incorporated into the macro-scale structure-property relationship for the prediction of the Young's modulus. The results indicate that polyurea aerogels are not particularly sensitive to various mid-range frequencies. The change in storage modulus across the tested range was minimal. The 0.17 g/cm3 damped the oscillatory motion more effectively in tension than the other two densities. Compression simulations using PFC3D were completed using the PUA model.

3032 - Crashworthiness and Impact Simulation using Tabulated Thermo-Viscoplastic Material Model of LS-DYNA

Wieslaw Binienda (The University of Akron, USA); Chao Zhang (University of North Carolina at Charlotte, USA)

Aluminum alloys are still heavily used in aerospace industry. Recent advances in testing allowed to generate stress-strain characteristics under various strain rate conditions and under various temperature of the environment. Special attention has been devoted to aluminum alloy 2024-T351. New tabulated material model MAT224 for LSDYNA3D has been utilized experimental data both for the deformation and failure surface in terms of stress triaxiality and Lode Angle parameters for 3D brick and 2D shell elements. Development of new experimental test specimen will be demonstrated for determination of plastic failure strain under negative triaxiality condition and negative Lode Angle. Results of structural level impact experiments using thin wall sabot specimens made of Al2014-T351 aluminum alloy will be presented and results of numerical simulations will be used to demonstrate accuracy of the MAT224.

3041 - Analysis on Failure Modes of Light Steel Columns with Different Cross Sections Under Fire and Explosion

Baoxin Qi, Shi Yan, Wenxin Zhang and Xuelei Jiang (Shenyang Jianzhu University & School of Civil Engineering, P.R. China)

At present, light steel structures for residential buildings are widely constructed. Light steel columns used as important supporting members are often applied in practical engineering. These columns are very sensitive to blast and fire which may occur together. The bottom column failure may lead to progressive collapse of the structure under fire and explosion. In this paper, light steel columns with different sections of H-type, rectangle and round are numerically analyzed to clarify influences of different temperatures and blast loading on the dynamic responses and failure modes. The element model of light steel columns considered high temperature thermal and high strain rate coupling effects is established by finite element software ANSYS/LS-DYNA. Dynamic responses and failure modes of light steel columns are numerically analyzed to develop mechanical behaviors and failure mechanism. The results show that the

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light steel column with rectangle section has better capacity under fire and explosion than that of others, and the light steel column with H-section is the weakest among them.

3042 - Numerical Analysis of Honeycomb Sandwich Collision Protection Systems for RC Beams

Pizhong Qiao (Washington State University, USA)

Bridge damage due to impact loads from over-height vehicle collisions is a major issue occurring throughout the transportation network. In this study, the numerical finite element modeling of reinforced concrete (RC) beams protected with and without honeycomb sandwich panels is conducted to simulate the over-height vehicle impact, and the numerical results are compared with the available experimental data. The numerical parametric study is conducted, and it is then employed to investigate the effects of the design parameters, such as the projectile speed and mass, sandwich panel parameters, etc., on the effectiveness of the over-height vehicle honeycomb sandwich collision protection system. The observed phenomena from the numerical parametric study shed light on the behavior of honeycomb sandwich collision protection systems for RC beams and help develop design guidelines for improving the efficiency of vehicle collision protection.

3051 - Multi Scale Information Fusion Predicating Model of Gravity Dam Deformation

Erfeng Zhao (Hohai University, P.R. China)

Taken gravity dam deformation as random variables, multi-scale manifestation has been taken on deformation to build multi-scale statistical model based on multi-scale system theory. Then dam monitoring system has been transformed to integrate deformation monitoring information in the multi-scale domain. Furthermore, the multi scale information fusion estimation model has been established. At last, the predicating model of gravity dam deformation has been built with EWKHEFA algorithm using standardized Kalman filter. These methods have been applied into an actual project and the result shows that the model can be used into gravity dam deformation prediction effectively.

3052 - Inverse Analysis on Thermal Parameters of Lock Head Floor Based on BP Neural Network

Chao Su, Lu Wang and YiJia Dong (HOHAI University, P.R. China)

Subjected to construction situations, engineers of some lock head projects do not perform adiabatic temperature rising test to determine thermal parameters of concrete. To solve this problem, this paper proposed an inversion analysis method of lock head thermal parameters based on BP neural networks. First, combinations of concrete thermal parameters were constructed based on uniform design theory and thermal FEM analyses using these parameters were performed to generate a series of samples. Then a BP neural network was trained by these samples. After entering the measured temperature, the neural network would output the result of inversion analysis. The future temperature curve was obtained using the inversion result and was compared to the measured temperature. The result showed the reasonability and efficiency of this method, and the rate of convergence of the BP neural network was improved by uniform design, and the accuracy of this method can meet engineering requirements.

3053 - Flow-Induced Vibration of Stilling Basin in One of Giant Hydropower Stations

Xin Wang (Nanjing Hydraulic Research Institute, P.R. China)

Multi-layer and multi-strand energy dissipation by hydraulic jump was adopt to discharge flood by one giant hydropower station to avoid the atomization effect. The safety of the stilling basin structure was critical for whole project, therefore, the flow-induced vibration characteristics of the stilling basin was studied by the combined method including model test, numerical prediction and field monitoring in this paper. Pulsation pressure characteristics on the discharge chute, bottom plate and guide wall was obtained from model test. In the frequent flood condition, the main pulsation pressure was located at the end of the chute, while that of the bottom plate and guide wall was slightly smaller and reducing along the stilling basin. The main frequency of the pulsation pressure was 1.5~3.5Hz. Based on the pulsation pressure from the model test, stilling basin structure vibration responses were predicted numerically, and different vibration characteristics were shown among the chute wall, guide wall and bottom plate.

3054 - Research on Non-contact Measurement Method for Topography Around Hydraulic Structure Model

Cheng Chen, Ziyang Li and Xin Wang (Nanjing Hydraulic Research Institute, P.R. China)

Hydraulic model test is a very important method for research on large hydraulic structure under complex and extreme environments such as floods. To measure the topography around hydraulic structure model, a non-contact measurement method with laser and ultrasonic has been developed. Besides little disturbance to flow and river bed, this method makes it possible to simultaneously and quickly measure the land topography and underwater topography. The measurement system is composed of plane positioning mechanism, measuring devices with laser and ultrasonic, system of control and data acquisition. The measurement accuracy of the system is ±1mm, which was tested by experiments with different water depth and sediment concentration. The measurement system was well applied to measure the variation of topography around a bridge at the downstream of a sluice.

3061 - Structural Analysis of Tensegric Structures for Space Applications

Y. Cengiz Toklu (Bilecik Seyh Edebali University, Turkey); Fatih Uzun (Yeditepe University, Turkey); Gabriel Bekdas and Rasim Temur (Istanbul University, Turkey)

The objective of this paper is to show that the analysis of tensegric structures can be performed as a black-box application of Total Potential Optimization using Metaheuristic Algorithms (TPO/MA) in the most general way. The named method is based on the well-known minimum energy principle. It has been shown through examples on truss-like structures that, in combination with meta-heuristic algorithms, this principle per se can be used very efficiently in static analysis problems involving material and geometric non-linearities. In this study, a meta-heuristic optimization method proposed as an alternative to deal with that problem. Genetic algorithm metaheuristic optimization method is used to search best solution by mimicking the process of natural evolution. In the case of optimization problem, a genetic algorithm optimization code is developed for structural analysis that minimizes the total potential energy of the structure.

3062 - Effect of Aluminum Tri-Hydrate Filler on Mechanical Properties of Glass Fiber-Reinforced Polymer Materials Michaela Petersen, Mark Roll and Sj Jung (University of Idaho, USA); An Chen (Iowa State University, USA)

Aluminum Tri-hydrate (ATH) can be effectively used to increase fire resistance of Fiber-Reinforced Polymer (FRP) materials. This paper studies the effect of ATH filler on mechanical properties of Glass FRP (GFRP) material, based on compression, tension, and shear test results from three types of GFRP materials with the amount of 0% (control), 25%, and 50% ATH filler by weight of the resin. It can be concluded that adding ATH generally decreases the strength and increases the stiffness, making FRP more brittle. The performance of 25% ATH is comparable to the control, while 50% ATH has a more significant effect on the mechanical properties of the GFRP. The data presented in this paper can be used to develop fire-resistant FRP systems.

3063 - Design Requirements of Fiber-Reinforced Polymer Materials for Building Applications
Michaela Petersen (University of Idaho, USA); An Chen (Iowa State University, USA)

Fiber-Reinforced Polymer (FRP) has been increasingly used in civil infrastructure and is a promising material for building applications. Extensive studies have been conducted to evaluate the strength of FRP structures. However, buildings have performance requirements which are as important as strength but have received less attention. Based on International Building Code and other specifications, this paper systematically examines these requirements, including fire rating, smoke and toxicity, flame spread, water resistance, flood resistance, etc., according to the FRP's target applications as load-bearing members, interior finishes, exterior finishes, or roofings; and their corresponding ASTM standards. The requirements presented in this paper can be used to develop suitable FRP materials for building applications.

Symposium 4:

Structures in Challenging Environments: Dynamics, Controls, Smart Structures, and Sensors

(*denotes Student Oral Presentation)

4011* - Seasonal Ground Freezing and Thawing Monitoring using Piezoceramic Based Smart Aggregates Qingzhao Kong, Gang-bing Song (University of Houston, USA); Ruolin Wang (Wuhan University, P.R. China); Zhaohui Yang (College of Engineering, University of Alaska Anchorage, USA); Yuqian Wu (University of Houston, USA)

Knowledge gained from frozen ground real-time monitoring is crucial in understanding the freeze/thaw status of the ground, which is important for applications such as construction and agriculture. The traditional monitoring of frozen ground is based on temperature measurement using thermocouples or other commercial tools. However, the inhomogeneous composition of the ground can cause uneven freezing and thawing across the field. In this paper, an active-sensing method was applied to quantitatively evaluate the soil freeze-thaw degree using piezoceramic based smart aggregate (SA) transducers. A pair of SAs with a pre-determined distance apart were embedded the soil specimen. One SA was used as an actuator to generate stress wave and the other one was used as a sensor to detect the propagated stress wave. The change of the mechanical properties of the soil greatly affected the SA-generated stress wave propagation through the soil during the freeze-thaw process. To quantitatively identify the soil freeze-thaw condition, a wavelet packet-based ground freeze-thaw indicator was applied to extract the degree of soil freeze-thaw condition.

4012 - Displacement Monitoring of Structures Using Laser Image Displacement Method
Hao Liu, Ruicong Han, Yutong Wei, Xuefeng Zhao (Dalian University of Technology, P.R. China)

Based on image processing technology, a laser spot identification method of bridge displacement monitoring was proposed. Fixed laser device on the measurement object and the laser device project the laser spot onto a projection panel. When the object moves, the laser device and the laser spot moving along with it .The motion trail of the laser spot on the projection panel is recorded by a webcam. The displacement of the object is obtained by analyzing the motion trail of the laser spot. Many experiments had been conducted; the results show that this method has high accuracy. We hope to find a low-cost and high accuracy method for bridge displacement monitoring by means of these preliminary efforts.

4021 - Cracking Monitoring of RC Joints under Cyclic Loadings Based on Wavelet Packet Analysis on Embedded PZT Measurements
Bin Xu, Yujing Wang and Tingjian Huang (Hunan University, P.R. China); Shirley Dyke (Purdue University, USA)

The integrity of beam-column joints plays key roles in the earthquake resistant design of reinforced concrete (RC) frame structures. In post seismic behavior evaluation, it is still a challenging task to efficiently monitor the crack initiation and development of RC joints due to inaccessibility. In this study, an active cracking damage initiation and propagation monitoring approach for RC joints using embedded piezoelectric lead zirconate titanate (PZT) based functional elements as both actuators and sensors is proposed. Laboratory test on an exterior beam-column joint specimen subjected to incremental cyclic loadings is performed and the corresponding responses of different sensors are recorded when a certain designated embedded PZT actuator was excited with sweep sinusoidal signals. A health indicator based on the wavelet packet energy (WPE) of embedded PZT sensor measurements was defined to monitor initiation and propagation of cracks in different parts of the RC joint under various loading levels. The monitoring results agree well with the actual crack initiation and propagation pattern observed and the proposed approach by the use of embedded PZT based functional elements can be implemented in practice for the monitoring of RC joints in frame building structures under earthquake loadings.

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Symposium 4

Structures in Challenging Environments: Dynamics, Controls, Smart Structures, and Sensors

(*denotes Student Oral Presentation)

4022 - Damage Status Identification of Piezoelectric Concrete Frame Structure Based on Fuzzy Comprehensive Evaluation

Shi Yan, Cuijie Wang and Tingjian Huang (Shenyang Jianzhu University & School of Civil Engineering, P.R. China); Gangbing Song (University of Houston, USA)

Many kinds of uncertainties exist in in-situ structure performance assessment and damage detection in structure health monitoring (SHM). At present, most research in SHM field focuses on statistical analysis, data acquisition, feature extraction and data reduction. A method is introduced in the paper to improve pattern recognition and damage detection by supplementing intelligent structure health monitoring (ISHM) with fuzzy sets. Based on the developed method, a multi-class fuzzy comprehensive evaluation method (MFCEM) is used to identify the damage status of piezoelectric concrete frame structure during the service. First, a multi-level fuzzy comprehensive evaluation model and index system of the reinforced concrete frame structure is established according to the fuzzy evaluation theory. Second, the fuzzy evaluation matrix of the target system is obtained and the weight coefficient of index is reasonably determined. In the end, the evaluation result of each layer for the system is calculated by the fuzzy theory.

4031 - Dynamic Response of Bridge Expansion Joints Under Vehicle Pounding

Zhen Sun, Yufeng Zhang (Jiangsu Transportation Institute, P.R. China)

Due to increasing traffic on long span bridges, behavior of expansion joints is believed to be largely influenced by pounding impact from passing vehicles. In order to understand the behavior of expansion joint under vehicle impact loading, a new analysis scheme is proposed which incorporates interaction between vehicle and expansion joint. Mathematical model of vehicle is established and solved with Newmark method in Matlab. Expansion joint is modeled with refined solid element in Finite element software ABAQUS. Based on modular expansion joint used in Jiangyin bridge, numerical analysis with proposed scheme is conducted to investigate effects of expansion joint surface roughness, vehicle weight and vehicle speed. The analysis result indicates that vehicle loading can induce large dynamic response of expansion joint. Several countermeasures are proposed to mitigate the vehicle-induced dynamic response.

4032 - Reliability Analysis on Sluice Gate in Cao'E River Dam Under Tidal Bore Loads

Ziyang Li, Xin Wang, Cheng Chen (Nanjing Hydraulic Research Institute, P.R. China)

Tidal bore loads are the main control loads for Sluice gate of Cao'e River dam. Tidal bore loads are complex and influenced by many random factors, thus the Monte Carlo method is adopted to conduct a stochastic simulation analysis on such loads. Firstly, the procedure of Monte Carlo stochastic simulation analysis on structural reliability is studied, and the random variable sampling method with improved Two-Dimensional Logistic Map is introduced in our study. Then, random analysis are made for the selected typical tidal bore parameters based on field observed data, including tidal bore height, velocity and flow direction. Our random analysis results indicate that the tidal bore height and velocity follow normal distribution, and the flow direction obeys uniform probability distribution. In the end, the tidal bore loads are simulated using Monte Carlo method based on our rapids vibration test data, hence allowing the impact loads of the sluice gate to be investigated. The reliability assessment of the sluice gate is conducted finally base on sampling analysis results.

4033* - Response Modeling of Scoured Bridges Under Near-Fault Ground Motions

X Guo and ZhiQiang Chen (University of Missouri-Kansas City, USA)

This paper identifies near-fault pulse and non-pulse like ground motions based on the relative energy of velocity pulse and the peak velocity of pulse. An ANOVA analysis is performed to distinguish between main characteristics of pulse and non- pulse like ground motions, suggesting that the PGV-to-PGA ratio, energy, and peak displacement of pulse like ground motions are greater than that of non-pulse like ground motions. This paper also investigates the response of a three-span continuous reinforced concrete bridge supported by pile foundations under near-fault pulse and non-pulse like ground motions. Numerical results indicate that near-fault pulse like ground motions generate stronger response than do near-fault non-pulse like ground motions. In addition, this paper finds that scour depth have great influence on the response of the structure. Finally, based on statistical analysis, this paper proposes an efficient parameter which performs better in reflecting the structural response to near- fault pulse like ground motions.

4041 - Experiment Investigation for a New Type of Piezoelectric Friction Damper

Dahai Zhao (Yanshan University, P.R. China); Hongnan Li (Dalian University of Technology, P.R. China); Gangbing Song (University of Houston, USA); Hui Qian (Zhengzhou University, P.R. China)

Based on the shortcoming of the passive friction damper that the friction force cannot be adjusted during working, a new type of piezoelectric variable friction damper that the friction force can be adjusted by piezoelectric actuator was developed. The energy dissipation capacity of the damper under cyclic loading was investigated by Material Testing System. The energy dissipation performance of the damper was also analyzed by the preload, loading frequency and displacement amplitude. The experimental results indicate that the proposed piezoelectric variable friction damper has both stable hysteretic performance and good energy dissipation capacity. The energy performance of the damper varies with preload and excitation amplitude. The excitation frequency has little effect on the energy dissipation of the proposed piezoelectric variable friction damper.

4042 - Labs-to-go Actuation Experiments and Extensions

James B Dabney (University of Houston - Clear Lake, USA); Gangbing Song (University of Houston, USA)

Labs-to-Go (LTG) is an inexpensive dynamics and control experiment toolkit suitable for take-home laboratory projects, in-class work, demonstration in lectures, and outreach to K-12 and the general public. The LTG kits consist of a set of smart beam elements, assembly hardware, interface circuitry, a digital signal processing subsystem, and support software. The LTG kits enable take-home labs which reduce the need for our students to commute to campus for labs (40% of UH students commute more than 30 minutes one-way). This paper extends previous work on LTG take-home experiments and introduces the active control experiments. We also describe use of the kits to support other academic disciplines, introductory engineering courses, and outreach.

4043 - Scavenging Energy from Ambient Vibrations Using Oscillators with Asymmetrical Potential Wells

Hui Zhang and Tian-wei Ma (University of Hawaii at Manoa, USA)

In this study, the potential of using nonlinear oscillators with asymmetrical potential wells to scavenge mechanical energy from ambient vibrations is investigated. Mechanical energy of ambient vibrations is normally distributed in a spectrum of frequencies. To scavenge such energy, methods using linear and nonlinear oscillators have been proposed. In these existing methods, however, the potential wells of the oscillators are symmetrical with only one frequency dominating in the free-vibration response. Such dominance of a single frequency indicates that in the zone of resonance, the response of the oscillator will likely be dominated by a single frequency. Thus, such oscillators do not perform well if there are multiple dominating frequencies in the vibration. To overcome such limitation, a method based on nonlinear oscillator with asymmetrical potential well is proposed. An asymmetrical potential well supports multiple frequencies in the response, as demonstrated by the multiple-frequency dominance in the free-vibration response. As a result, it is more effective in scavenging energy from vibrations of multi-frequency content.

4051 - Effects of Temperature Gradients on the Design of a Frame-Membrane Lunar Habitat

Kevin Brown, Ramesh Malla (University of Connecticut, USA)

The extreme hot and cold temperatures present on the surface of the Moon bring about one of the most important design challenges when considering a lunar habitat for use in a long-term colonization mission. Within this paper, the analytical determination of the lunar surface temperature within a one-meter regolith shield is presented. It was found that the surface temperature on the structure built at the lunar Equatorial surface could reach temperatures as high as 457 K (183.85ºC) during the day while dropping to 183 K (-90.15ºC) at night. Secondly, the initial static analysis, including the determination of both member stresses and nodal deflections due to the applied internal pressure and the aforementioned temperature profile, is presented. The added mass of the regolith shield helped to reduce both the stress and deflection magnitudes throughout the structure. The high daytime temperatures resulted in increased nodal deflections due to thermal expansion, while the cold nighttime temperatures had an inverse effect.

4052 - Architectural Engineering Approach to Developing a Matrix for Planning in Extreme Environments

Olga Bannova (University of Houston & Chalmers University of Technology, USA); Maria Nystrom (Chalmers University of Technology, Sweden)

Extreme environments on Earth share similar facilities and operations, design and planning challenges. Each environment presents special lessons regarding housing design, crew/staff operations and training, and equipment and logistical requirements for human activities. The paper discusses these challenges and lessons. Recurrent and specific to environment and conditions events are outlined and categorized based on case studies reviews and literature summary. Understanding of relationships and influences between different facets of human society and architecture can help to find a design approach which would optimize needs and requirements for various types of people living in different environments, societies and cultures. Environmental conditions affecting architectural requirements include form developing factors, site orientation and circulation, and budget considerations. They have to be addressed at the programming design stage in order to avoid costly adjustments at later development stages. It is even more critical in case of designing for challenging environments.

4061* - Parametric Modeling of Soil-Structure Oscillators for Rapid Coastal Disaster Response

Rahul Tripathi, ZhiQiang Chen, Jerry Richardson (University of Missouri-Kansas City, USA)

Recent coastal disasters, such as the 2012 Hurricane Sandy, have afflicted millions in the coastal communities and resulted in billion dollars of property losses. In the meantime, much of losses in civil infrastructure and coastal structures were severely damaged or destroyed largely due to extreme impacts from storm surges. To estimate losses due to storm surges at a geospatial scale, numerical tools based on effective damage models, which correlate hazard parameters to degree of damage, are entailed for rapid loss estimation (e.g. as employed in the MH – Hazus framework). However, the existing damage models for coastal surge induced damage are not based on mechanics-based modeling but over-simplified empirical relations between inundation depth and damage states. Therefore, they are not intrinsically adequate for characterizing storm surge parameters with severe damage, such as partial or full system-level collapse. This paper first provides a review of observed storm-surge damage to coastal buildings and revealed the underlying complex force and scour effects, including hydrostatic, hydrodynamic and scouring effects.

4062 - Smart Trusses for Space Applications

Y. Cengiz Toklu (Bilecik Seyh Edebali University, Turkey); David Arditi (Illinois Institute of Technology, USA)

One way of having resistant structures in space with limited amount of materials is to make them smart. In this manner, the shape of the structure will adapt itself to the best configuration such that the stresses created will be diminished as compared to the passive structures with an invariable shape. The active structures thus designed, will take the best shape smartly relative to the type, direction and magnitude of the loads acting on them. With the current level of technology, such structures have become feasible. Indeed, the use of sensors, processors and actuators already play an important role in the modern world. In this study, a specific type of structure, namely trusses are considered. It is shown that by changing the lengths of the members, the member forces may be manipulated in any direction. The analysis of these structures can be carried out by the application of the method called Total Potential Optimization using Metaheuristic Algorithms (TPO/MA).

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Symposium 4

Structures in Challenging Environments: Dynamics, Controls, Smart Structures, and Sensors

4071 - Investigation and Application on Monitoring the Compactness of Concrete-Filled Steel Tube Structures with Ultrasonic Wave

Tianyong Jiang, Zhoutao Luo, Zhongchu Tian (Changsha University of Science and Technology, P.R. China)

Five full-scale specimens of the Ganhaizi long-span bridge, which is concrete-filled steel tube (CFST) truss structure, were fabricated to simulate the potential defects, such as debonding, void, mortar, etc. The specimens were tested using the ultrasonic wave based method. The relevant regularity and evaluation standards for identification of defects were obtained from the test results. The ultrasonic wave based method was also applied to the Ganhaizi long-span bridge for checking the pouring quality of CFST structure. The measured data not only demonstrated the accuracy of the relevant evaluation standards, but also proved that the ultrasonic wave based method researched in this paper is an effective method to detect the compactness of CFST structures.

4072* - Damage Diagnosis Under Environmental and Operational Variations Using Improved Restoring Force Method

Yabin Liang, Dongsheng Li and Hongnan Li (Dalian University of Technology, P.R. China); Gangbing Song (University of Houston, USA)

Time-varying environmental and operational conditions such as temperature and external loading may produce an adverse effect on damage detection with the structure exposed to these changes. In fact, these effects can often mask more subtle structural changes caused by damage. Therefore, in order to achieve successful structural health monitoring goal, a new data normalization technique based on the improved restoring force model (IRFM) is proposed in this paper to distinguish the effect of damage from those caused by environmental and operational variations. Firstly, a special training data set, whose IRFM coefficients are closest to the IRFM coefficients from the testing data, is determined and selected by a Euclidean distance measure. The IRFM coefficients of this training data are then applied to calculate the residual errors of this special training data and the testing data for the respective IRFM approximations to these measured time histories. Finally, the ratio of the variance of the residual errors is defined as the damage-sensitive feature and used in the outlier detection process. The usefulness of the proposed approach is demonstrated using an experimental study tested at Los Alamos National Laboratory.

4073 - Icing Monitoring for a Wind Turbine Model Blade with Active PZT Technology

Bin Xu and Xueyi Guo (Hunan University, P.R. China); Lu Fang (Hunan University, P.R. China); Shirley Dyke (Purdue University, USA)

The development of efficient ice monitoring methodologies is critical for the exploitation of wind energy in cold regions. In this study, an icing monitoring approach for a wind turbine model blade using active piezoelectric lead zirconate titanate (PZT) patches acting as actuator and sensors is proposed. Experimental study on a model blade covered with different thickness of ice is carried out and the corresponding responses of different sensors are recorded when a certain designated actuator was excited with sweep sinusoidal signals. The wavelet packet analysis on the measurement and the corresponding wavelet packet energy (WPE) of the measurement is determined. Results show that the WPE of the measurement of the same PZT patch is related to the increase of ice thickness. The proposed method based on the WPE can monitor the icing conditions of the tested specimen and has the potential application in practice for the ice monitoring for wind turbine blades operating in cold regions.

Student Posters

Symposium 1

ARTEMIS Simulations of Curiosity and Opportunity Rover Traverses Across Dingo Gap

Nathaniel Stein and Raymond Arvidson (Washington University in St. Louis, USA); Paolo Bellutta, Matthew Heverly (Jet Propulsion Laboratory, USA)

This paper describes work on characterizing the traverse of the Curiosity and Opportunity rovers across the Dingo Gap wind-blown ripple crossed by Curiosity on Sols 533 and 535 and understanding the performance of both rovers on ripples as a function of wheel size, material properties, and attack angles. The Dingo Gap ripple traverse was simulated using ARTEMIS (Adams-based Rover Terramechanics and Mobility Interaction Simulator), a software tool consisting of realistic mechanical models of the rovers, a wheel-terrain interaction module, and terrain models. ARTEMIS simulations using soil parameters similar to those of the sand at Dumont Dunes, California yielded slip values near those of Curiosity crossing the Dingo Gap ripple, including skid on downslope portions of the ripple. Simulated torque on the rear drive actuators during the ripple ascent was significantly higher than that of the middle and front drive actuators, consistent with higher loading on the rear wheels. The simulated traverse of Opportunity showed that the rover would have failed to pass over the ripple, approaching 100% slip before reaching the crest. In addition to simulations, mobility tests of SSTB-lite and Scarecrow, Opportunity and Curiosity engineering test rovers, respectively, were performed on sand dunes at Dumont Dunes. SSTB-lite approached 100% slip on a Dingo Gap analog before embedding near the ripple crest while Scarecrow successfully traversed steep manmade sand ripples with pitch approaching 20^0.

Symposium 2

Numerical Simulation of Pneumatic Excavation and Conveying of Lunar Regolith Simulant JSC-1A

Yanlong Zheng, Yun Bai (Tongji University, Australia); Guo-Dong Cai (Tongji University, P.R. China))

The pneumatic excavation and conveying of particles in hard vacuum on the moon can be treated as fast fluidization or slug flow depending on the operating conditions. The mechanism of the pneumatic excavation and conveying has not been successfully understood and simulated. This paper examines the velocity field of jet flow of compressed gas into hard vacuum through theoretical aerodynamics analysis and 3D computational fluid dynamics simulation. It then calculates the minimum and maximum fluidization velocity of irregular particles in hard vacuum based on Llop's research and points out the limitation of the most commonly used Zimmermann modification method for the Syamal-O'Brien drag model. A new method to modify the Syamal-O'Brien drag force based on minimum fluidization velocity and drag coefficient is proposed. The 3DEulerian-Eulerian model integrating the kinetic theory of granular flow for gas-solid flow is then performed in CFDs software of FLUENT to simulate the excavation and conveying processes. The phenomena observed are in high agreement with those observed in the experiments.

Washington University in St Louis' Screw-Propelled Automated Regolith Collector (SPARC) Robot

Michael Zanetti (Washington University in St Louis & McDonnell Center for Space Sciences, USA); Nathaniel Stein, Bradley Settle, Adam Mendelsohn, Rowan Meara, Hans McConnell, Pradosh Kharel, Dagmawi Gebreselasse and Adam Cooperberg (Washington University in St Louis, USA)

The Screw-Propelled Automated Regolith Collecting (SPARC) robot is Washington University in St. Louis' (WUSTL) inaugural entry into NASA's annual Robotic Mining Competition. The robot's driving platform is based on an Archimedes screw-pontoon system that provides mechanical advantage in low cohesion materials like terrestrial planet regolith. In this paper we give an overview of the SPARC robot, designed by a group of volunteer undergraduate and graduate students, and particularly the design and testing of the screw-drive mobility system. Competition results and mobility testing indicate that the screw-drive system is a viable mobility option for regolith applications, where it may outperform wheeled and tracked vehicles.

Symposium 3

Study and Application on Parameters of Extraneous Pre-stressed Concrete Designing for Preventing Temperature Cracks of Lock Chamber Concrete

Yang Su and Chao Su (Hohai University, P.R. China)

Temperature crack has been a quality hazard to large volume concrete hydraulic structure. The site of chamfer of lock chamber is a kind of long thin-walled structure. At the early stage of the placement of the concrete, temperature cracks easily appear due to the temperature stress, which influences the safety of the structure. In this paper, the extraneous pre-stressed method is used to control the cracks in the chamfer concrete, and a systematic study is developed on the parameters, including the layout, the time and the value of the extraneous pre-stressed concrete.

Scheme Research of Sheet Pile Wharf Design in Soft Foundation

Yangyang Zhang and Chao Su (Hohai University, P.R. China)

Sheet pile wharf is one of the three forms of wharf structures, however, constructing sheet pile wharf in soft foundation usually has the problems such as large deformation and outstanding stability problem. Currently, plane calculation method written in specification such as vertical elastic foundation beam method has been used in wharf structure design. Without mature design specifications and rich design experience in soft foundation wharf, its structural optimization design can solve the problem of building wharf in soft foundation effectively. Using a wharf of Yangtze River basin as the example, preliminary design of utilizing concrete beam to form a unitary wharf structure and enhance stability of front wall. Finite element analysis is completed by software ABAQUS simulating wharf and foundation system. Comparison among layout with steel rod and different concrete beam position is carried out, its stress and deformation variation is summarized to select

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Student Posters

the best sheet-pile wharf design scheme in soft foundation. At the same time, stability analysis is considered so as to provide engineering reference for optimum wharf design in soft foundation.

Numerical Simulation of Failure Process of Embankment Founded on Soft Sensitive Soils

Yong Xia, Chao Su and Yang Su (Hohai University, P.R. China)

This paper presents that using the strength reduction finite element method for the analysis of the process of yield failure of unreinforced flood embankments founded on soft sensitive soil. Terrible soil conditions usually cause quality problems of project most directly. However, limit equilibrium methods for slope stability analysis, widely used today in industry, cannot capture the process of instability failure, which may result in unconservative factors of safety. This paper presents a case study to solve a stable problem of practical engineering. The job will use finite element methods to simulate the process of plastic failure of soil and give the distribution of stress and strain on composite foundation, which contribute to help us to make precautionary measures. Besides, The method is based on the incremental strain theory, the precision of calculation has been improved. On the basis of this, the factor of dilatancy angle impact on stability has been discussed. Above all, this research will be a useful application for slopes stability. Based on general software ABAQUS, Several numerical examples are presented to validate the proposed method.

Bearing Capacity Analysis of Jacked PHC Pipe Piles in Double-Layered Ground Based on Data Mining

Jun Yang and Min Yang (Tongji University, P.R. China); Qingqing Zhang (Oriental Sheet Piling (Shanghai) Leasing Co., Ltd, P.R. China)

In this paper two data-mining technologies based on different calculation principles are used to analyze correlation between ultimate bearing capacity of jacked PHC pipe piles and several influencing factors in typically double-layered ground, combined with data from geological investigation, pile foundation construction and pile static load test. Through this way, several critical factors which influence on vertical bearing capacity of piles are determined, regression formula for predicting ultimate bearing capacity is obtained and calculation values are evaluated with measured results. Analysis shows that data mining technology has attractive capabilities and advantages to analyze importance of parameters influencing on ultimate bearing capacity of PHC pipe piles. In this soil layer ultimate bearing capacity of pile is mainly provided by tip resistance and closely linked to final pressure in pile construction, which is totally different from experiences in South China. The regression equation presented can be used to evaluate ultimate bearing capacity of test piles and computational accuracy can fill requirements in engineering practice.

Symposium 4

Review of Lunar Base Construction and Design of Structure Forms

Guo-Dong Cai and Yanlong Zheng (Tongji University, P.R. China); Yun Bai (Tongji University, Australia)

A lunar base is an outpost and transfer point for deep space exploration. Constructing a lunar base with a life support system and complete ecological system is the most important task for people to continue space exploration. The lunar base can also provide a place for mining, transportation, material processing, scientific experiments, astronomy, and a launch site for spacecrafts; however, the Moon's extreme environment is challenging. Based on the analysis of the Moon's environment, we point out several factors that must be considered during the construction of the lunar base and summarize lunar base structures that have been put forth. Combining a lunar rigid structure with a flexible structure, which can be placed on the lunar surface securely with the help of pneumatic theory is proposed in this paper for providing the reference for the future construction of a lunar base.

Dynamic Response Analysis of Long-Span Continuous Bridge under Earthquake and Train Loads

Xinjun Gao and Hui Qian (Zhengzhou University, P.R. China)

A lunar base is an outpost and transfer point for deep space exploration. In this paper, the dynamic response analysis of long-span continuous bridge under earthquakes and train load simultaneously were performed. In order to consider the coupled vibrations of vehicles and highway long-span continuous bridge, a numerical model involving soil foundation under inclined seismic wave was established using finite element software. The dynamic response of the bridge with different incidence angles of seismic waves and the different train speeds were calculated and analyzed. The results show that seismic wave incident angles have a significant effect on the dynamic response of the bridge, and with the increasing of the incident angle, the vertical displacements, velocity and accelerations of mid-span constantly increase. While the train speeds have a slightly effect on the dynamic response of the bridge under earthquake, and the dynamic response of the bridge reach maximum at a certain speed.

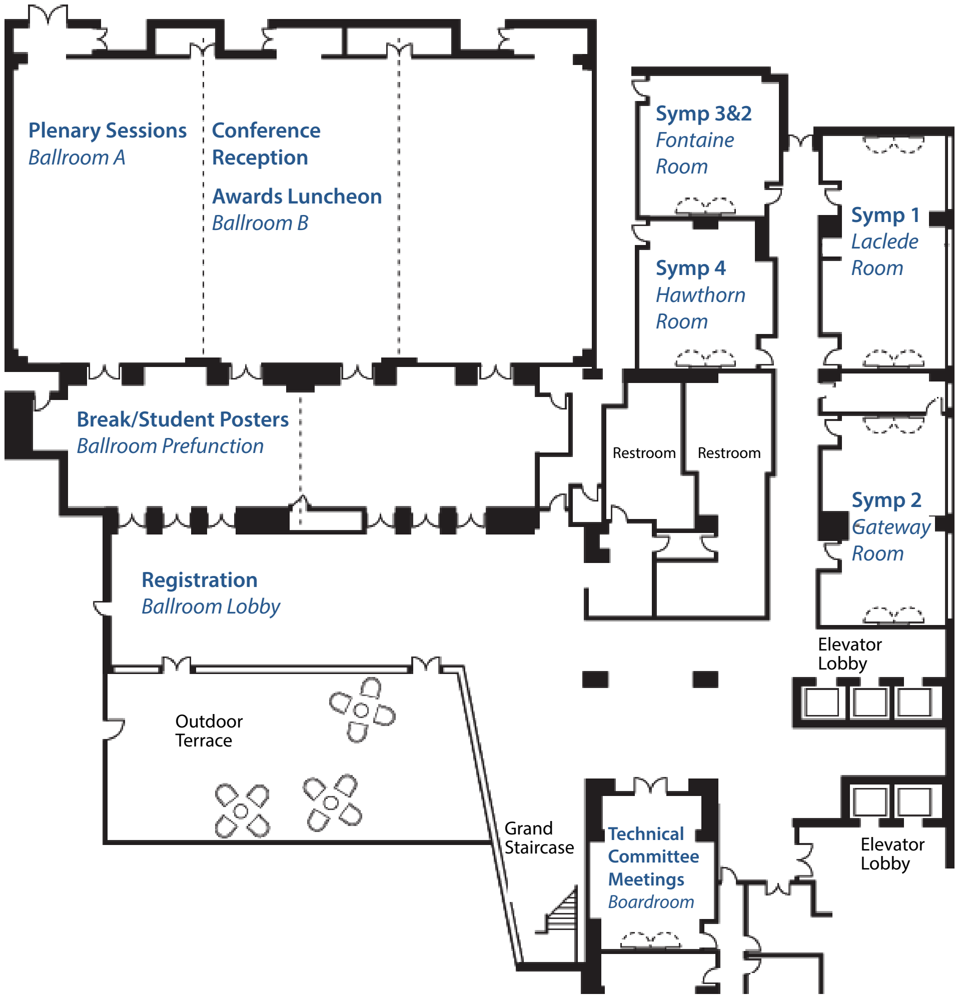
Pounding Effect on Isolation Effectiveness for Classic Simply Supported Bridges Under Strong Earthquakes

Mingyan Zheng (College of Engineering, University of Alaska Anchorage, USA); Shihao Yang (Faculty of Engineering, China University of Geosciences, P.R. China); Zhaohui Yang (College of Engineering, University of Alaska Anchorage, USA)

Most newly built bridges employ isolation bearings. In public opinion, appropriate isolation devices can improve the performance of bridges under small or medium earthquakes. For large earthquakes, more nonlinear properties should be considered, including pounding between decks or deck and abutment. It is not clear how the pounding action affects bridge isolation effectiveness under large earthquakes. In this paper, a classic three-span simply supported hybrid isolated bridge is taken as an example. When the simply supported isolated bridge is subjected to large earthquake, pounding between decks or deck and abutment occurs. The pounding effect on bridge isolation effectiveness is investigated by conducting a full nonlinear dynamic time history analysis using a refined model including material nonlinearity, bearing nonlinearity, soil-structure interaction and pounding between decks or deck and abutment. The results show that, when pounding is considered, whether in non-isolated or isolated bridges, shear force, bending moment of column beneath the bearing generally increase in the longitudinal direction but only change slightly in the transverse direction. As for isolation effectiveness, pounding makes the seismic isolation more effective in pounding direction, namely the longitudinal direction. However, the bridge responses are slightly amplified in the transverse direction.

Map of Four Seasons Hotel

Conference Meeting Rooms



Technical Sessions

Symposium 1:
Granular Materials in Space Exploration
Laclede Room A/B

Symposium 2:
Exploration and Utilization of Extra-Terrestrial Bodies
Gateway Room A/B
Fontaine Room for 1:30 p.m. session on Monday only

Symposium 3:
Advanced Materials and Designs
Fontaine Room

Symposium 4:
Structures in Challenging Environments
Hawthorn Room