Structural Engineering: An Overview of Global Directions

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Vice Chancellor for IT
Professor of Civil Engineering
Overview

- Global trends affecting education
- Technology impact on learning and behavior
- Considerations for structural education & practice
- Two examples of technology enhancements
  - FB-MultiPier
  - DIGGS
"In God we trust," she said. "All others, bring data."

~Margaret Spellings~
Secretary of Education
Industrial Value Added (% GDP)

From World Bank Data

- Germany
- India
- France
- Japan
- China
- US
Service Value Added (% GDP)
From World Bank Data
High Tech Exports (% Manufactured Exports)
From World Bank Data
Import of Goods and Services (% GDP)
From World Bank Data
Gross domestic expenditure on R&D
As a percentage of GDP, 2006 or latest available year

From Organization for Economic Co-Operation and Development (OECD)
Investment in knowledge (% GDP)
(Expenditure on R&D, Higher Ed, Software)

From Organization for Economic Co-Operation and Development (OECD)
IP Generation by Country

Balance of income on intellectual property
Royalties and licence fees, $ billions (2001)

From Hamish McRae, Futurist, UK – various talks
Ease of Starting New Businesses

Barriers to entrepreneurship

Scale of indicators

<table>
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<th>Country</th>
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</table>

Source: OECD, 1999 study

From Hamish McRae, Futurist, UK – various talks
Communication Costs Essentially Zero

The falling costs of transport and communications

Index (initial cost=100)

Sources: World Development Report / market estimates

From Hamish McRae, Futurist, UK – various talks
Work Where the Value Is

The Stan Shih Smile Curve

- Concept/R&D
- Branding
- Design
- Manufacturing
- Distribution
- Sales/After Service

Under this model manufacturing is the lowest value input

Stan Shih, Founder of Acer, Taiwan, 1992
• Grassroots Video
  ▪ Virtually anyone can capture, edit, and share video clips.

• Collaboration Webs
  ▪ Collaboration no longer calls for expensive equipment

• Mobile Broadband
  ▪ Each year more than a billion new mobile devices are manufactured

• Data Mashups
  ▪ Multiple sources of data merged together provide new insight

• Collective Intelligence
  ▪ Hive, crowd sourcing, open source,…

• Social Operating Systems
  ▪ Organize around people not content
Expect Increased Demands for Information Access and Malleability

• All time access to all your services
  ▪ Phone browsing is just the beginning
• Easy to use technology (no users manual)
• Analytics rule – predictive modeling
  ▪ Amazon “people who have … also considered…”
• Shared Data
  ▪ Interlinked/connected – Web services, Mash-ups, cloud
• Identity Management
  ▪ Know who you are and trust it is you
    o Security & Compliance, Shibboleth, grid computing, true “cloud computing”
• Outsourced components as appropriate
  ▪ Industry leads, Higher Ed embracing now – (SaaS, Google apps, MS Live, Facebook for collaboration, )
Higher Ed: What does it mean for us?

- Electronic platform delivery (growth, on-campus, flexibility)
- Focus on advanced degrees
- Educate for the “Smile”
  - Creativity as fundamental education
  - Entrepreneurs – Need to foster cognitive diversity
  - Develop champions in science (biology, nano, physics)
  - Creation of new intellectual property (innovation)
- IT as an accelerator for research
  - Collaboration
  - High performance computing in all fields
- Increased expectations for service delivery
Bloom’s Digital Taxonomy – Premium on Higher Order Skills

Bloom’s Taxonomy

From: Andrew Churches (http://edorigami.wikispaces.com/file/view/bloom%27s+Digital+taxonomy+v2.12.pdf)
Work Style of “Digital Natives”
work from Prensky, 2001

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Sharing

Communicating

Coordinating

Gartner, Inc., “IT-Based Collaboration and Social Networks Accelerate R&D” by Carol Rozwell, January 2008
Culture Change: Digital Natives

- Millennial Generation has grown up with technology, its use and on-demand access to information.
  - There is evidence that neurological changes are occurring
  - Gaming has shown improved creative thinking
- Newer generations have always adapted, taken it for granted and innovated new technologies
  - Telegraph, Dial a phone, wireless, typewriter
- Understanding of the underlying concepts of the technology and its adaptation and applications has (and will always) be the generator of change
  - As these ideas are automated and simplified, they become usable by all under the rules from which they have been developed
“Imagination is more important than knowledge.”

~Albert Einstein~
NC State University: Delivering Innovation & Positioned to Lead

• Innovative campus programs
  ▪ Centennial Campus – A model for University/Industry partnership
  ▪ FREEDOM Center, Digital Games Research Center, Entrepreneurs Program, Friday Institute, Institute for Advanced Analytics, Undergraduate Research
  ▪ Technology transfer success
    o 623 Patents, 72 Start-up companies (Company Spin offs: Red Hat, Cree, VCL (Apache.org), …

• State and Region leader in Innovation
  ▪ Research Triangle Park (Model for countries to build capacity)
  ▪ NC Government – understands and fosters Economic Development and Higher Ed linkage
NC State #11 in Grad Enrollment (2,125)

Making Progress

Graduate engineering trends continued to move in a positive direction over the past several years. Degrees at both levels increased slightly, despite a dip in master’s degrees in 2006-07. Master’s enrollment is up by 8 percent since 2005. Doctoral enrollment may be reaching its peak after growing by only 2 percent over the past two years. That’s sharply lower than the 45 percent growth from 2000 to 2005. Female representation at both degree levels is also at an all-time high, while the share of degrees to underrepresented minorities remains low.

Compiled by Michael Gibbons
Infographic Illustration by Calvin Chen
Ideas for Structural Engineering

- Engineering needs to be part of the leading trends
  - Improve teaching (relevance of place)
    - Recent articles in Structure Magazine
      - Are We Relying Too Much On Computers? (Powell)
        - *Phases: Modeling, Number Crunching and Interpretation*
        - *Too much time number crunching!*
      - Alternatives to Matrix Methods (Hoit)
  - Innovate in research
  - Partner and collaborate
  - Incorporate right brain thinking

  **Two examples:**
Example 1:
SR 20 / Apalachicola River Bridge Construction

SR 20 / Apalachicola River Construction Site
(viewed from the East, 1997)
FB-Multipier model of SR 20 / Apalachicola River Bridge

224/280/224 ft steel spans across the river
Case Study - 2550 kips at Pier 2

- Case I: Guided Bearings

Plan view shows relation of deck to substructure when bearings ARE guided. (400 kips are transferred)

Plan view of deformed bridge (scaled up 200 x)
Case Study - 2550 kips at Pier 2

- Case II: Un-Guided Bearings

Relation of deck to substructure: 130 kips are transferred to deck when bearings are NOT guided.
Barge Impact Tests at St George Island Bridge

Barge Impact Tests were conducted at St. George Island Bridge during March / April 2004. A total of 15 impact tests were conducted.

Courtesy of UF Structure Research Group, Gary Consolazio et al.
Coupled Vessel Impact Analysis of FB-Multipier

- Dynamic bridge model (FB-MultiPier)
- Simplified dynamic barge model
- Crushable barge bow section
Validation of Coupled Vessel Impact Analysis (CVIA) Models of FB-Multiplier

Impact force time history

Courtesy of UF Structure Research Group, Gary Consolazio et al.
Dynamic Amplification Effects

Courtesy of UF Structure Research Group, Gary Consolazio et al.
Simplified Superstructure Analysis Model

- Full bridge models: computationally expensive
- One-pier two-span (OPTS) model
  - Impacted pier and two adjacent spans are retained
  - Remainder of bridge modeled with springs & point masses

Courtesy of UF Structure Research Group, Gary Consolazio et al.
FB-Multipier Model Development

- CVIA and OPTS have been implemented in FB-MultiPier
- Several Florida bridge-configurations are currently being analyzed:

  - SR-20 at Blountstown channel pier
  - SR-20 at Blountstown off-channel pier
  - New St. George Island channel pier
  - New St. George Island off-channel pier
FB-Multipier Full Bridge Model

- New St. George Island Bridge (constructed: 2004): Channel pier

 Courtesy of UF Structure Research Group, Gary Consolazio et al.
CVIA output: OPTS vs. Full Bridge Analysis

- New St. George Island Bridge (constructed: 2004): Channel pier
Design Table Application (Example)
Easy Access to Critical Loadings

Tapered column and cap sections
### Display of Axial Member Forces (Text Format)

#### AXIAL FORCES AT PILE HEADS
(USE TO COMPARE TO PILE DRIVE CAPACITY)
MAXIMUM COMPRESSION AND MAXIMUM TENSION FORCES

**"STRENGTH CASES"**

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<th>PILE</th>
<th>MAX TENSION</th>
<th>COMB</th>
<th>AASHTO</th>
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**"SERVICE CASES"**

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**"EXTREME EVENT II CASES"**

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# Display of Shear Member Forces (Excel Format)

## PIER CAP SHEAR DESIGN

Maximum Shear Forces at Left and Right of Bearings and at Column Faces

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## "Service Cases"

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Example 2: Interconnecting Data, Tools and the Net

• Data Interchange for Geotechnical and GeoEnvironmental Specialists (DIGGS)

• Incorporating new IT into the Civil Engineering process
  ▪ Shared data
  ▪ Data reuse
  ▪ Web services
  ▪ Business process change
Motivation

• Need to efficiently deliver information from various and distributed resources

• Recognize the cost of site investigations, preserve assets through proper management and storage of data and documents

• Current paper-based systems are inefficient in today’s environment

• Current distributed, disconnected and inconsistent electronic systems increase confusion
Caltrans Experience

- 30,000 project files
- 2 million documents
- 300 projects/year
- 80 years of data
- Difficult to access information
Ohio DOT Experience

- 20-30 person hours per week to retrieve information
Projects or Experienced Cost Savings

- Ohio DOT:
  - 10-20% less drilling, savings $12-24M per year
- Florida DOT:
  - Fewer borings saving $250,000 - $500,000 on one project
- Missouri DOT:
  - 10-15% fewer borings per bridge
- Missouri DOT:
  - $81,000 savings per year in boring log preparation by using electronic data entry in the field
- California DOT:
  - 20% savings ($200k/year) with laboratory data management system implementation
Single Data Entry - Single Organization

Data is collected in the field electronically

Data files are transferred to a central repository
Single Data Entry - Multiple Organizations

Geotechnical Virtual Data Center
Example of Multiple Organization Collaboration
Pooled Fund Project TPF-5(111)

- DIGGS Project:
  - Develop a single international data exchange standard
  - Combine existing geotechnical data interchange standards (AGS, COSMOS, FDOT/UF, EPA)
  - Expand to include other data (i.e. geohazards, geotechnical assets)
  - Survey state DOTs and others
  - Finalize standards
Characteristics of DIGGS

• XML Schema Definition (XSD)
  ▪ Normative document
  ▪ Defines elements

• Standard for internet data transfer
  ▪ Platform independent
  ▪ Tools available for validating, querying, processing, displaying, and transforming

• Compliant with Geography Markup Language (GML)
  ▪ Allows for processing by GIS applications
  ▪ Allows for display of data over the Internet using web services
Characteristics of DIGGS

• DIGGS provides a context for different kinds of data that may be related administratively or spatially.

• Transfers data commonly reported as part of a geotechnical investigation:
  - Borehole records
  - In-situ test data
  - Monitoring data
  - Laboratory test summaries
  - Geophysical data
  - Geoenvironmental data
  - Pile design, installation, and testing data
Example 1 – Sample Taken from an Exploratory Hole

Real World

- Project
  - locations
  - samples
    - Sample ID = ABCD-12
      - Source = ABCD-1

Data Construction

- Hole ID = ABCD-1
  - Sample from Hole ID = ABCD-12
    - Source = ABCD-1

Linkages

Sample collected from exploratory hole
Example 2 – Sample Taken from an Exploratory Hole, tested for NMC, LL and PL

- **Real World**
  - Sample collected from exploratory hole
  - Sub-samples created in laboratory

- **Data Construction**
  - Project
    - locations
  - Hole
    - ID = ABCD-1
  - samples
    - Sample
      - ID = ABCD-123
      - Source = ABCD-12
    - Sample
      - ID = ABCD-124
      - Source = ABCD-12
  - laboratoryTesting
    - ID = ABCD-23456
    - Source = ABCD-124
    - MoistureContent
      - ID = ABCD-123
      - Source = ABCD-12
    - AtterbergLimits
      - ID = ABCD-23456
      - Source = ABCD-124

- **Linkages**
  - Hole
    - ID = ABCD-1
  - Sample from Hole
    - ID = ABCD-12
    - Source = ABCD-1
  - Sample from sample
    - ID = ABCD-123
    - Source = ABCD-12
  - Sample from sample
    - ID = ABCD-124
    - Source = ABCD-12
Example 2 – Sample Taken from an Exploratory Hole, tested for NMC, LL and PL

Real World

Data Construction

Project

locations

Hole

ID = ABCD-1

samples

Sample

ID = ABCD-12

Source = ABCD-1

Sample

ID = ABCD-123

Source = ABCD-12

Sample

ID = ABCD-124

Source = ABCD-12

samples

laboratoryTesting

Sample

ID = ABCD-12

Source = ABCD-1

Sample

ID = ABCD-123

Source = ABCD-12

Sample

ID = ABCD-124

Source = ABCD-12

MoistureContent

laboratoryTesting

ID = ABCD-12345

Source = ABCD-123

MoistureContent

ID = ABCD-23456

Source = ABCD-124

AtterbergLimits

ID = ABCD-12345

Source = ABCD-123

AtterbergLimits

ID = ABCD-12345

Source = ABCD-123

Sample collected from exploratory hole

Sub-samples created in laboratory

“FIELD”

“LAB”

Sample taken from exploratory hole, tested for NMC, LL and PL.
This is one example of a considerable number of complex examples that have been considered.
Supporters/Promoters of DIGGS

- The United States Federal Highways Administration
- The United Kingdom Highways Agency
- US Departments of Transportation (CA, CT, FL, GA, IN, KS, KY, MN, MO, NC, OH, TN)
- The United States Geological Survey
- The United States Army Corps of Engineers
- The United States Environmental Protection Agency
- CIRIA (the UK Construction Industry Research and Information Association)
- AGS (the UK Association of Geotechnical and Geoenvironmental Specialists)
- COSMOS (Consortium of Organizations for Strong-Motion Observation Systems)
- The University of Florida
HA (UK) Geotechnical Data Management System (HA GDMS)

• Internet-based GIS

• Stores data on:
  ▪ spatial context (mapping and aerial photos)
  ▪ assets
  ▪ reports
  ▪ boreholes

• Supports UK AGS data transfer format
  ▪ data storage/retrieval
  ▪ summary logs
  ▪ summary test sheets
EarthSoft – Equis Database

Field Data Collection

Monitoring/Instrumentation

Laboratory EDDs

Data In, Information Out

Red Means Go
Geotechnical Virtual Data Center

- Virtual gateway to data repositories from multiple agencies.
- Uses DIGGS for standardized data exchange.
Red Means Go
Borehole Previewer

- Viewer xsl, css, and javascript completed
- Viewer Application (in development)
  - DIGGS xml -> XSLT -> CosmosLog xml
  - Possible user-customized vertical scale
  - Other user-customizations possible but not planned
Summary

• Need to take advantage of technology trends and improve research innovation, teaching & learning, and professional practice
• Partner, partner, partner
• Educate for the “smile”
  ▪ Creativity
  ▪ Higher end of Bloom’s Taxonomy
"Our Age of Anxiety is, in great part, the result of trying to do today's jobs with yesterday's tools."

~Marshall McLuhan~