Sustainable Design:
The Role of Individuals

John Ochsendorf
Sept 29, 2004
First three lectures

1) Global challenges (9/15)

2) Construction industry (9/22)

3) Individuals (9/29)
In a forceful recent speech before business leaders in London, Mr. Blair, in many other respects a Bush loyalist, called global warming "the world's greatest environmental challenge," implicitly rebuking the administration for its repudiation of the Kyoto Protocol on climate change. Mr. Blair said he would put the issue near the top of the agenda at next year's G-8 meeting of industrialized nations, over which Britain will preside.
In hearings last week, Mr. McCain called the administration's generally passive approach "disgraceful" and warned that future generations would pay a heavy price for continued inaction now. Mr. McCain, a co-sponsor with Senator Joseph Lieberman of a bill to impose mandatory caps on industrial emissions of carbon dioxide, the main global warming gas, also ventured where few politicians have dared to go, drawing a link between this calamitous hurricane season and climate change.
Conclusions

- Construction industry is the biggest consumer of energy and materials
- Each material has environmental advantages and disadvantages
- Embodied energy is only one of many considerations
- Energy intensive materials like steel and concrete can be used more efficiently
- Alternative materials should be explored

Must consider site and building orientation to optimize daylight, ventilation, thermal insulation, etc.

www.bedzed.org.uk
Or you could treat architecture as sculpture...

Consideration of site and building orientation to optimize daylight, ventilation, thermal insulation, etc.???
The Rural Studio by Samuel Mockbee

Image courtesy of structurae.de.
Today’s Lecture: The Role of Individuals

- Introduction: Rural Studio

- Impermanence
  - How to plan for the end of life of a design?

- Examples

- LEED Rating system for buildings

- Conclusions
EFFICIENCY IS IMPORTANT: New materials in construction, such as wrought iron and steel, lead to greater concern for efficiency.
20th Century Design Concern

MAINTENANCE IS IMPORTANT: The initial design is important, though we must also design for maintenance throughout operating life.
21st Century Design Concern

“END OF LIFE” IS IMPORTANT: Waste from the construction industry is a vast consumer of natural resources on a global scale

- **19th Century:** Efficient use of materials
- **20th Century:** Maintenance matters
- **21st Century:** End of life matters
Case Study: Williamsburg Bridge

- Opened in 1903 as longest span in the world
- Designed with the elastic theory of suspension bridge design, which did not account for the stiffening effect of a cable
- Boasted to be the “strongest” suspension bridge at the time

Williamsburg Bridge, 1904
Regarded as the ugliest suspension bridge (doesn’t help that it is next to the stunning Brooklyn Bridge)
Williamsburg Bridge

- Carried traffic and trains throughout the 20th century
- But maintenance was neglected entirely for decades
- In 1988 the poor condition of the bridge became an emergency
Decay of Williamsburg Bridge

- Main cables were corroded badly (not galvanized)
- Pin joints in the main trusses were corroded
- Rusted girders
How to replace the Williamsburg Bridge?

- A vital link to Manhattan: the bridge could not be taken out of service
- Must use the same site: property for new approach spans is too expensive
Conclusion: Williamsburg Bridge Stays

At least 100 more years of service
1990-2005: Rebuilding the Williamsburg Bridge

- New cables, new girders, new roadways, new bearings, new paint, etc...
- Cost approximately $1 billion; more than a new bridge

*The Williamsburg Bridge is ranked as the most structurally deficient bridge in the USA carrying more than 50,000 cars per day.*

Rebuilding the Williamsburg Bridge: Technical Problems

- How to replace main cables?
  - One strand bundle at a time

- How to replace deck while traffic flows?
  - Lightweight orthotropic steel deck placed at night

- How to protect river and traffic from lead paint on the bridge?
  - Contain large areas with plastic
Designing for Maintenance

- Develop a maintenance plan for your structure

- Design components which are accessible and replaceable

- Avoid toxic materials which are hazardous for future maintenance operations
Design Matters

- 19th Century: Efficient use of materials
- 20th Century: Maintenance matters
- 21st Century: End of life matters

But how to design for the end of a structure’s life?
Demolition: Lessons from History

- Sustainable structures must consider the “end of life” of the structure

- ~24% of solid landfill waste in the US is generated by the construction industry

- Up to 95% of construction waste is recyclable, and most is clean and unmixed

Source: 2002 Buildings Energy Databook
http://buildingsdatabook.eren.doe.gov/
Use Materials with Low Environmental Impact During Their Life Cycle

Example: Interface Carpets

- Interface carpet is committed to closing the loop in manufacturing.
- Interface can be reprocessed into new carpet.
- The company is also working towards a zero-emissions manufacturing process which relies on renewable energy sources.

www.interfaceinc.com
www.interfacesustainability.com
Two Extreme Approaches to Sustainable Structures

1. Permanence: Very high quality construction, with materials which can be reused in future construction

Designing for Permanence: The Roman Tradition

Pons Fabricius in Rome, 62 BC
Inca Bridge Construction:
An Annual Festival

Day 1: Ropes made from local grass or plant fibers

Day 2: Old bridge is cut and new ropes are installed

Day 3: Roadway and handrails are added and bridge is complete
Grass Bridge Has Survived for 500 Years

- Maintenance plan is tied to the community
- Materials are locally available and environmentally sound
# Two Sustainable Bridge Types

<table>
<thead>
<tr>
<th>Inca suspension bridge</th>
<th>Roman arch bridge</th>
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<tbody>
<tr>
<td>High stresses</td>
<td>Low stresses</td>
</tr>
<tr>
<td>High maintenance</td>
<td>Low maintenance</td>
</tr>
<tr>
<td>Short lifetime</td>
<td>Long lifetime</td>
</tr>
<tr>
<td>Low initial cost</td>
<td>High initial cost</td>
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<tr>
<td>Renewable materials</td>
<td>Reusable materials</td>
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<tr>
<td>Low load capacity</td>
<td>High load capacity</td>
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</table>
The Structure of the Future?

- Efficient: Materials are recycled, reusable, or low-energy
- Maintainable: components can be replaced or improved or reused
- Adaptable: Can respond to changing needs and loads throughout its lifetime

Image courtesy of structurae.de.

Traversina Bridge, Jorg Conzett
Japanese Pavilion, Germany, 2000

- Recycled paper tubes
- Minimal foundations
- Recycled at end of the Expo

Images courtesy of structurae.de.
Stansted Airport Terminal

- Steel tubes can be disassembled
- Modular system for adaptation
- Can be recycled or reused at end of life

Image courtesy of structurae.de.
The Importance of History

- Case studies can illustrate successful and unsuccessful designs
- The designs of yesterday are the problems of today
- How do we design with the future in mind?
Design Questions to Consider

- In choosing structural system(s):
  - Flexibility of plan?
  - Can your building be adapted for alternative layouts?
  - Is the structural system economical?
  - Does it utilize local expertise?
  - How does the system help with natural lighting, natural ventilation, or thermal performance?
Design Questions to Consider

- In choosing materials:
  - What is the source for the materials?
  - What happens at the end of life of the materials?
  - Do the materials contribute to your other design goals? (transparency, thermal mass, etc.)
Conclusion

In choosing a structural system and the materials for a building, consider:

1. CONSTRUCTION
2. OPERATION
3. DEMOLITION
‘Architects and engineers are the ones who deliver things to people’

- “We can only get there...if the key professionals who deliver things to people are fully engaged... [architects and engineers], not the politicians, are the ones who can ensure that sustainable development:
  - is operational
  - is made to work for people
  - delivers new ways of investing in our infrastructure, new ways of generating energy and providing a built environment
  - delivers new ways of using consumer durables.

- There is no point along the sustainable development journey at which an engineer will not be involved.

Royal Academy of Engineering, UK, June 2001
LEED:

Leadership in Energy & Environmental Design™

A leading-edge system for designing, constructing, operating and certifying the world’s greenest buildings.

USGBC’s flagship rating system is LEED for New Construction and Major Renovations (LEED-NC)
The nation's foremost coalition of leaders from across the building industry working to promote buildings that are environmentally responsible, profitable, and healthy places to live and work.

The organization’s purpose is to:

- *Integrate* building industry sectors
- *Lead* market transformation
- *Educate* owners and practitioners
U.S. Green Building Council

- National nonprofit organization based in Washington, DC
- Diverse membership of organizations
- Consensus-driven
- Committee-based product development
- Developer and administrator of the LEED™ Green Building Rating System
What is “Green” Design?

Design and construction practices that significantly reduce or eliminate the negative impact of buildings on the environment and occupants in five broad areas:

- Sustainable site planning
- Safeguarding water and water efficiency
- Energy efficiency and renewable energy
- Conservation of materials and resources
- Indoor environmental quality
Benefits of Green Building

Environmental benefits
• Reduce the impacts of natural resource consumption

Economic benefits
• Improve the bottom line

Health and safety benefits
• Enhance occupant comfort and health

Community benefits
• Minimize strain on local infrastructures and improve quality of life
Economic Benefits

Competitive first costs
  - Integrated design allows high benefit at low cost by achieving synergies between disciplines and between technologies

Reduce operating costs
  - Lower utility costs significantly

Optimize life-cycle economic performance
Productivity Benefits

Improve occupant performance
- Estimated $29 –168 billion in national productivity losses per year
- Student performance is better in daylit schools.

Reduce absenteeism and turnover
- Providing a healthy workplace improves employee satisfaction

Increase retail sales with daylighting
- Studies have shown ~40% improvement
West Bend Mutual Insurance
(West Bend, WI)

Productivity

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<th>Old Building</th>
<th>Move</th>
<th>New Building</th>
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<tbody>
<tr>
<td>Productivity in</td>
<td>100</td>
<td>70</td>
<td>116</td>
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<tr>
<td>Productivity During Move</td>
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<tr>
<td>Productivity in New</td>
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Why Was LEED™ Created?

- Facilitate positive results for the environment, occupant health and financial return
- Define “green” by providing a standard for measurement
- Prevent “greenwashing” (false or exaggerated claims)
- Promote whole-building, integrated design processes
Why Was LEED™ Created?

- Use as a design guideline
- Recognize leaders
- Stimulate green competition
- Establish market value with recognizable national “brand”
- Raise consumer awareness
- Transform the marketplace!
LEED-NC® Market Transformation

- Registered Projects by State - Top 10

As of 09.20.04

All statistics exclude pilot projects.
Technical Overview of LEED®

- Green building rating system, currently for commercial and institutional new construction and major renovation.
- Existing, proven technologies
- Evaluates and recognizes performance in accepted green design categories
- LEED product development includes existing buildings, commercial interiors, multiple buildings, core & shell, and homes
Technical Overview of LEED®

- Whole-building approach encourages and guides a collaborative, integrated design and construction process
- Optimizes environmental and economic factors
- Four levels of LEED-NC certification:
  - Certified Level 26 - 32 points
  - Silver Level 33 - 38 points
  - Gold Level 39 - 51 points
  - Platinum Level 52+ points (69 possible)
LEED: Green Building Rating System

- Advantages:
  - Agreed standard for “green” building
  - Constantly being improved and updated
  - Widely accepted by all parties (clients, architects, engineers, contractors, etc.)
  - Developed by an independent non-profit organization (US Green Building Council)
LEED: Green Building Rating System

- Disadvantages:
  
  - No penalties (can only gain points, not lose them)
  
  - May encourage consumption in some cases (could add extra recycled materials just to get points)
  
  - Offers points for some aspects of normal practice (encourages the use of steel since it is highly recycled)
  
  - No measure of scale (could build a glass building from here to Chicago and it could be *platinum*)
Conclusions

- Buildings consume enormous quantities of energy and produce enormous waste annually
- Individual designers can reduce this impact significantly
- Technology and knowledge exists: requires leadership and vision to implement “green building”
- Great demand for green architects and engineers
Conclusions

- Each material has environmental advantages and disadvantages: good design is local

- Recycle or reuse materials to decrease waste

- Consider end of life in the initial design

- History suggests sustainable solutions: Inca structures (temporary) and Roman structures (permanent) can both be sustainable
Future Challenges

- Education of architects and engineers
  - Sustainability as a core principle
  - Environment as a design constraint, not an opponent

- Education of clients and general public

- Reversal of trend towards greater consumption
Further Information

US Green Building Council:
www.usgbc.org

Department of Energy:
www.sustainable.doe.gov
Credits

Lectures prepared by Prof. John Ochsendorf
with the assistance of:

Prof. Charles Ainger
Cambridge University, UK
Centre for Sustainable Development