Part I: Course Outline

1. Introductions
2. Principles
3. Scope
4. Values to instill
5. Intended Results
6. Course Logistics, Schedule, Grading, etc.

Part II: Development of Construction Technologies

- Innovation in Construction
- Obstacles and Drivers

Part III: Elements of Building

1. Building Systems
   i. Definitions
   ii. CSI Division placement

Image:

Renzo Piano Building Workshop: Fondation Beyeler, Basel, Switzerland, 1999.

These notes are a test.

Prof. John E. Fernandez
Building Technology Group
Off. Hours: by appt.

Images:

LFA: Case Residence, New York, 1999.

Polshek and Partners: Hayden Planetarium, New York, 2000.

Part I: Course Outline

Principles

1. **Cultural Context**: Technology exists within a cultural context. Therefore, contemporary building technology derives of a rich historical and cultural evolution of technique and form that augments the ability to design intelligently.

2. **Holistic Building**: Understanding individual building components and the details necessitates understanding the guiding architectural intentions, performance requirements, process of manufacture and assembly, and systematic organization of various building assemblies.

3. **Invention**: Architectural invention is the medium for the determination of form at all scales and permeates the physical architectural result. The making of details is *not a deterministic* process that seeks to optimize a singular solution. Be careful of optimization. “Il n’y a pas de detail dans la construction”

Image:

Hartman & Fernau, 1998.

Scope of Course

1. History and Theory of Building Systems and Architectural Components
2. Statics of architectural structures
   - i. Structural Morphology
   - ii. Basic structural elements and force systems
   - iii. Equilibrium equations
   - iv. Material behavior
3. Building Systems
   - i. Performance requirements
   - ii. Identification and specification of elements
4. Sustainable Strategies
   - i. Best practice
   - ii. Resource efficiency
5. Materials: New and Old
6. Systems Integration

Values to instill

1. Possibility of Invention: both for engineers and architects

2. Craft of New and Old Technologies: good practice and new processes

3. Critical View of Product-Driven Design

Foster and Partners: Reichstag, Berlin, 1999. Image courtesy of Karl Doeringer and Structurae.

Intended Results

1. Familiarity with requirements of architectural assemblies
2. Understanding of broad range of “good” solutions
3. Understanding of contemporary issues in the design of architectural assemblies
4. Understanding of design process
5. Understanding of construction process
6. Identification of opportunities for “invention”
7. The initiation of a career-long study of the expressive potential inherent in the solution of technical assembly and construction situations.
8. Development of strategies for collaboration between disciplines

Course Logistics

Schedule and Grading

Part II: Development of Construction Technologies

Drivers for Innovation: 1900-1980

1. **Industrialization and Standardization**
2. **Modularization of Buildings and Building Components**
3. **Materials Science**
4. **Computational Technologies**
5. **New Structural Morphologies**
6. **Mathematical Analysis Techniques**
7. **Systems Isolation and Development**

Images:

Jean Prouve

Obstacles for Innovation: 1900-1980

"Fragmented" industry

"Fragmented" process

- Design: the rise of the specialized consultants
- Construction: numerous trades/subcontractors, the rise of the construction manager

Primary Research Interests: 1980

Coordinating resources and interests of fragmented industry

Computational modeling and controls

Technology Transfer from Materials Research

- Polymers (Albert Kahn, Eero Saarinen)
- Composites
- "High Performance" materials
  - Alloys
  - Ceramics
  - Etc.

Successes: 1900-1980

- Polymers (sealants, coatings, membranes, adhesives, nonwoven fabrics)
- Metals (especially thin films, Low-e glass)
- Composites: FRPs, GFRP, CFRP
- Digital Technologies: CAD/CAM, Simulation Software, Project Management, etc.
- Cable net and Fabric Structures (with limited use)

Kresge Auditorium at MIT. Image courtesy of HABS and Structurae

Failures

- Modular Building (except at the very low end of the market)
- Concrete Shells and Hyperbolic Paraboloids (new morphologies)
- “Fordist” Mass production and assembly
- High Performance composites (that is, carbon and glass reinforced materials)

Drivers for Innovation Now → Future Developments

Global Economy
- Competition and Alliances across sovereign borders
- New Markets (esp. China,rest of Asia, and former Soviet Republics)

Sustainable Strategies
- Energy Efficiencies
- Materials Acquisition and Processing (Resource Efficiencies)
- End of Life Materials Reuse (Life Cycle Costing)

Technological Advance
- Improved Technology Transfer (Process Engineering, simulation technologies, Management Technologies etc.)
- Materials Science
- Digital Technologies

Materials
- The integration of various materials together into premanufactured assemblies and composites
- Specification by performance

Processes
- Removing as much specialized "expertise" (knowledge) from the construction site as possible

Morphologies
- Inventing new forms that use materials more efficiently and employ time-saving construction methods (Pantograph example)
- Integrating building systems together in a synergistic way (German Parliament Building)

Obstacles for Innovation: 2001

- "Fragmented" industry
- "Fragmented" process
  - Design: numerous consultants and project components
  - Construction: numerous trades/subcontractors
- Relatively Low R&D investment by construction related Industries
- Continuing underestimation of the level of investment necessary for "real" innovation, proof of concept and market entry
- Continuing disciplinary specialization of the various scientific, professional and business interests all involved in the construction process

- Average time period necessary for a technical advance (from lab) to reach market = 17 years in the U.S.

- Easier (in terms of regulatory hurdles) to insert new materials into the human body than into buildings.

- For every $1 of laboratory research conducted,
  $10 must by spent for proof of concept and product development and,
  $100 dollars must be spent for industrial retooling and market entry.

- Average level of Research and Development for all U.S. industries approaches 5% of gross revenue.

- The construction industry only invests 0.5% of annual gross revenue.

- Currently the construction industry in the U.S. accounts for 8% of annual GDP.

Energy

Total energy use for buildings in developed nations at an historical high.

Overwhelming reliance on fossil, nonrenewable fuels.

Little domestic incentive to reduce energy consumption by buildings.

Little domestic incentive to increase material use efficiency.

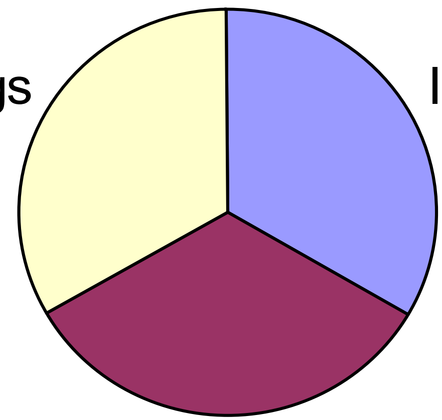
Facts:

Buildings now account for ½ of energy consumption in the western world.

Buildings now account for 1/3 of energy consumption in the entire world.

¾ of the world's energy output is consumed by ¼ of the world's population.

70 % of domestic (U.S.) materials consumption attributed to construction industry (by weight).



Materials

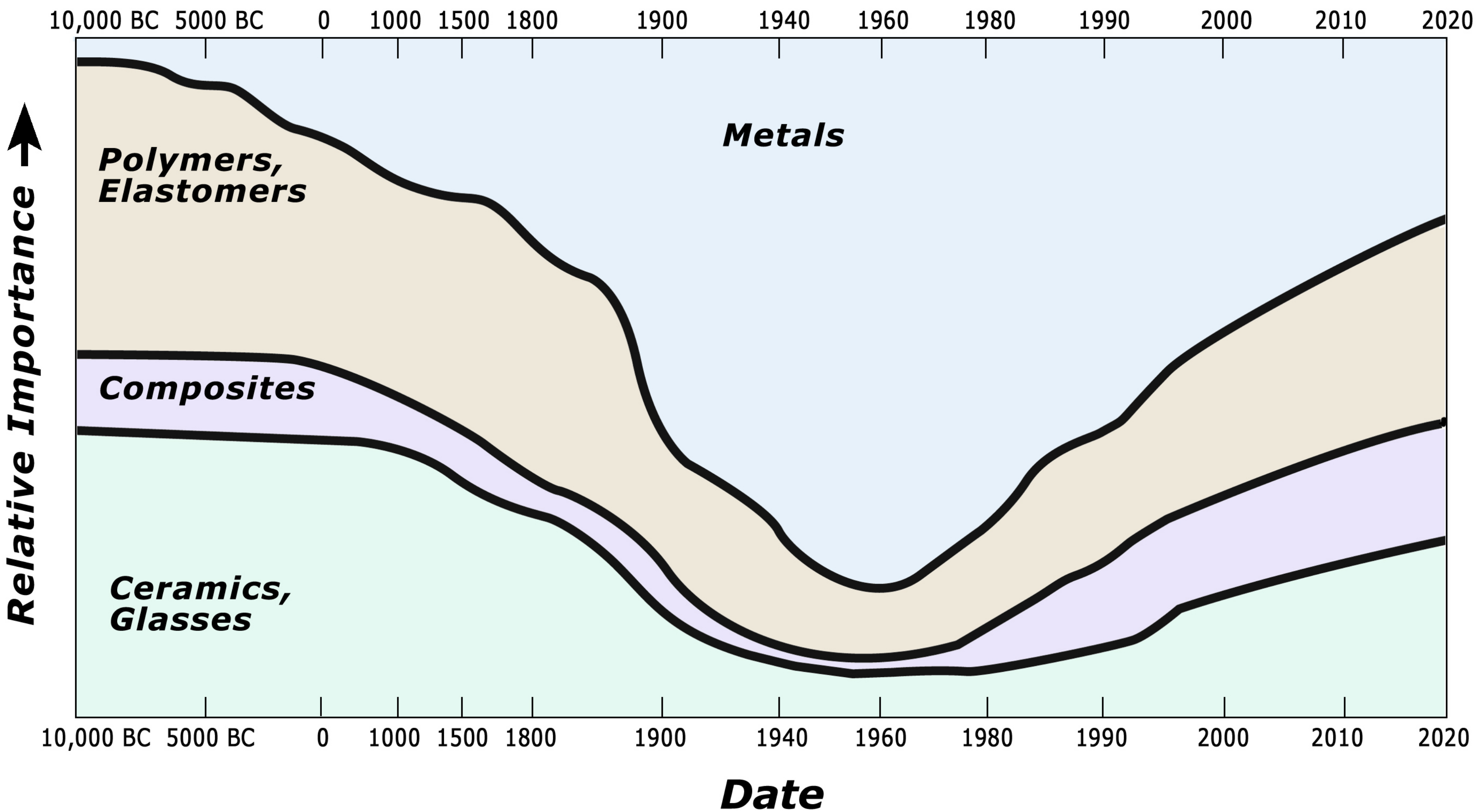


Image by MIT OCW.

Materials

- Smart and lightweight materials (tessellated fabric example)
- Appropriate technologies
- Responsive, polyvalent materials
- Micro and nano devices and assemblies
- Composites (GFRPs, glass laminars, coatings)

Processes

- Intelligent tools and systems for improved decision-making processes
- Computational and other Digital Technologies
- Large Scale Construction Methods
- Robotics and Artificial Intelligence

Morphologies

- More complex composite and hybrid structures and intricate interior-exterior interfaces (thermal, solar radiation and mass transfer dynamics)
- Panel technologies: ultrathin
- Integrated structure and exterior wall assemblies

Part III: Elements of Building

1. Building Systems
2. Cost
3. Lifetimes/Durability
4. Performance Requirements
5. Integration of Building Systems

Systems

- Foundations
- Superstructure
- Exterior Envelope
- Interior Partitions
- Mechanical Systems

Image:

Renzo Piano Building Workshop: Fondation Beyeler. Basel, Switzerland, 1999.

Building Systems: Definitions

1. Foundation/Subgrade *(SITE)*
2. Superstructure *(STRUCTURE)*
3. Exterior Envelope *(SKIN)*
4. Interior Partitions *(SPACE PLAN)*
5. Mechanical Systems *(SERVICES)*
6. Furnishings *(STUFF)*

Source: Stewart Brand,
How Buildings Learn.

Images:

Daly, Genik: Valley Center, CA, 2000.

Bensonwood Timber Frame: 1996.

Building Systems: Definitions

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Source: Rush, Richard
The Building Systems Integration Handbook.

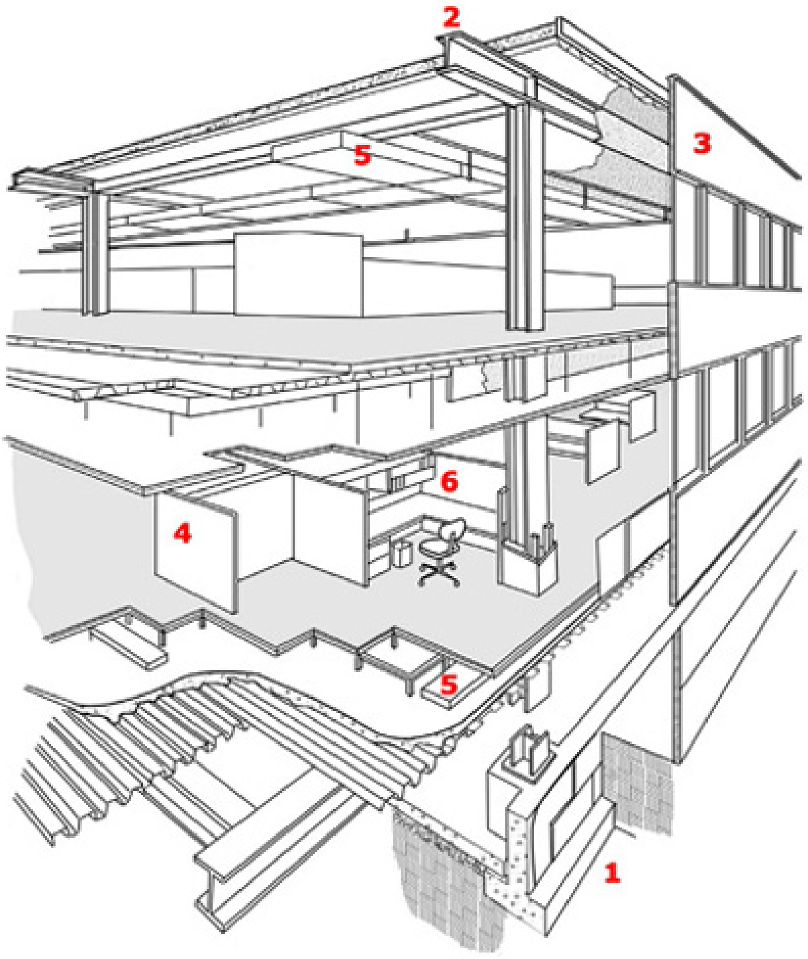


Image by MIT OCW.

Curtainwall and raised floor construction.

Cost over time

1. Foundation/ Subgrade structure 10%
2. Structure (superstructure) 30-40%
3. Exterior Wall 10-20%
4. Interior Partitions 10%
5. Mechanical Devices 30-40%

Lifetimes

		Years
1.	Foundation/Subgrade	50-100+
2.	Superstructure	50+
3.	Exterior Wall	25+
4.	Interior Partitions	10-30
5.	Mechanical Devices	20

Sir Norman Foster and Partners, Hong Kong Bank. 1995.
Image courtesy of Nicolas Janberg of Structurae

Performance Requirements

1. Foundation/ Subgrade structure
   i. Dead and live load transfer
2. Superstructure
   i. Dead and Live load transfer
   ii. Lateral force resistance and stability
3. Exterior Wall
   i. Maintenance of interior environment
4. Interior Partitions
   i. Programmatic spatial definition
   ii. Acoustic separation
5. Mechanical Devices
   i. Maintenance of interior environment

Image:

Glenn Murcutt, House, Australia.

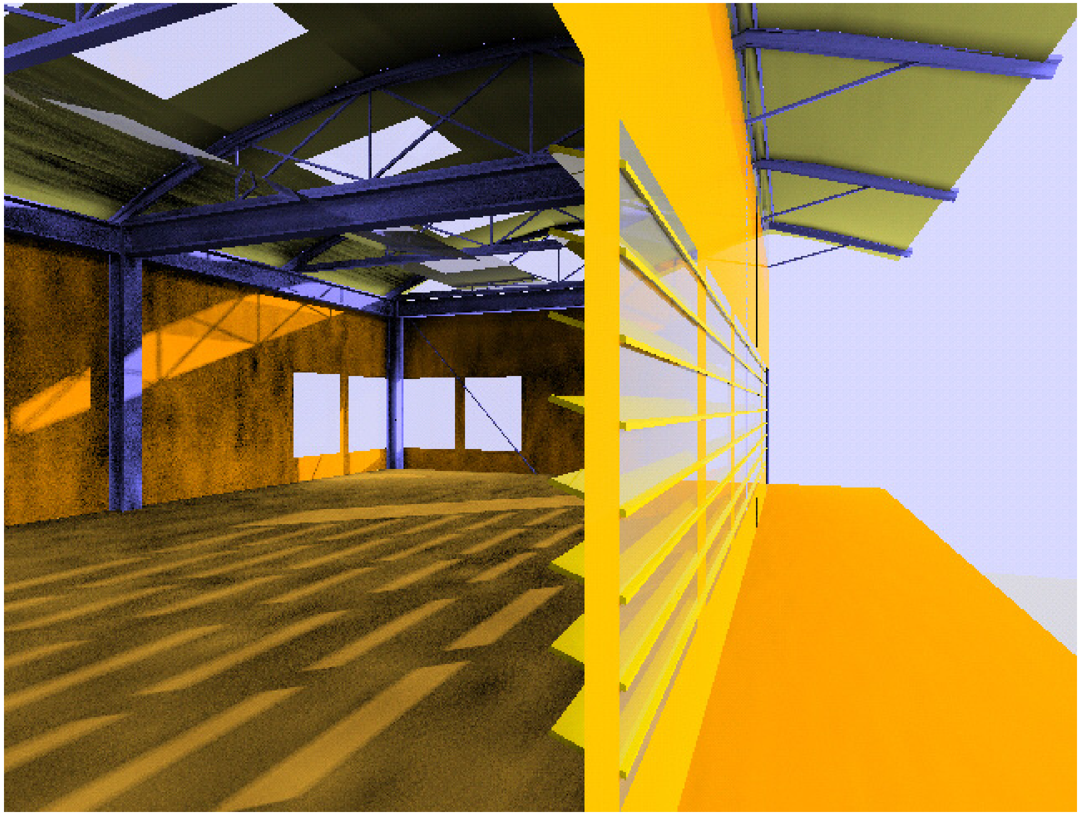
Integration of Building Systems

1. Foundation/ Subgrade structure
2. Structure (superstructure)
3. Exterior Wall
4. Interior Partitions
5. Mechanical Devices

Six General Performance Mandates

1. Spatial Performance
2. Thermal Performance
3. Air Quality
4. Acoustical Performance
5. Visual Performance
6. Building Integrity

From Rush, *The Building Systems Integration Handbook*



Student Project: Integrated Building Systems: 4.455

Building Systems: *C S I Division Specifications

1. Foundation/Subgrade *(SITE)*
2. Superstructure *(STRUCTURE)*
3. Exterior Envelope *(SKIN)*
4. Interior Partitions *(SPACE PLAN)*
5. Mechanical Systems *(SERVICES)*
6. Furnishings *(STUFF)*

* Construction Specifications Institute

System 1: Foundations/Site

Spec. Divisions

Dependent on material

Div. 2 site work, Div. 3 concrete, Div. 4 masonry, Div. 5 metals, Div. 6 Wood and plastics.

Images:

F.L. Wright: Johnson Wax, 1944

Fabric foundation wall

FRP caisson cover

System 2: Superstructure

Spec. Divisions

Dependent on material

Div. 3 concrete, Div. 4 masonry, Div. 5 metals,

Div. 6 Wood and plastics.

Images:

Eladio Dieste

System 3: Exterior Envelope

Spec. Divisions

Dependent on material, but also identified in

Div. 7 thermal and moisture protection, Div. 8 doors and windows

Images:

Thomas Herzog, Aerogel Exterior Envelope System

System 4: Interior Partitions

Spec. Divisions

Dependent on material, but also identified in

Div. 9 finishes

Image:

Rick Joy House

System 5: Building Services

Spec. Divisions

Div. 11 equipment, Div. 13 special construction, Div. 14 conveying systems, Div. 15 mechanical, Div. 16 electrical

1. HVAC
2. Plumbing
3. Electrical
4. Fire Alarm System
5. Communications/Data
6. Audio Visual