LCA of DfD Structural System

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SIMPSON GUMPERTZ & HEGER
Engineering of Structures and Building Enclosures

What is DfD?

- Deconstruction is a demolition method where a structure is carefully and methodically disassembled so as to salvage as many components as possible.
- "Design for Deconstruction" is an approach to new design that anticipates and facilitates the future deconstruction of the structure.

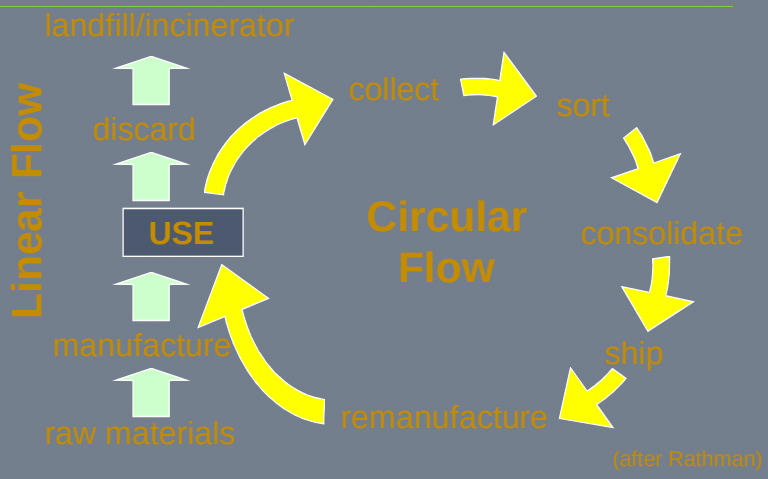
Why DfD?

- Increase salvage and recycling rates
- Increase building end-of-life value
- Reduce consumption of raw materials ("close the materials loop") and associated environmental impacts
- Reduce energy consumption
- Reduce waste and landfill demand

What is DfD *not*?

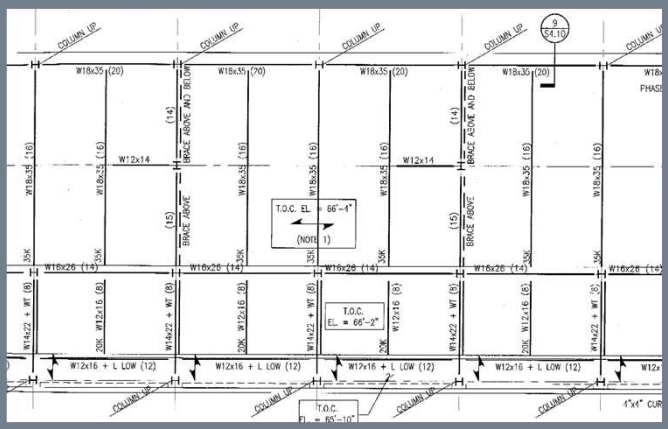
- Although DfD an excellent strategy for reducing the carbon footprint of buildings (as we will see), it is *not* a strong climate-change mitigation strategy because the benefits of DfD occur in the long-term rather than the short-term.

Closing the Materials Loop



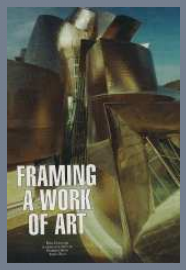
Seven Fundamental DfD Strategies

1. Simple, Regular Layout



This framing system has repeating bays with similar geometry, beam sizes, and connection types.

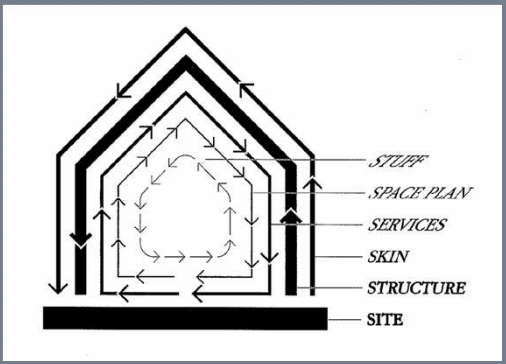
1. Simple, Regular Layout



from "Framing a Work of Art," *Civil Engineering*, March 1998

This framing system has many unique pieces that will be impossible to reuse in a different building.

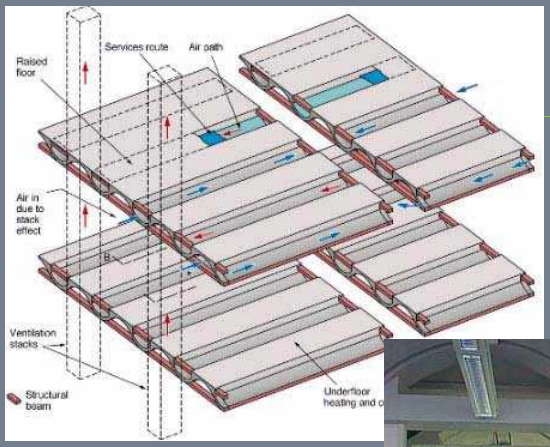
2. Layered Building Systems



from *How Buildings Learn*, by Stewart Brand (after Frank Duffy)

Building systems have different longevities. Keeping systems separate makes renovations easier, and also deconstruction.

BRE: The Environmental Building



from http:// projects.bre.co.uk/

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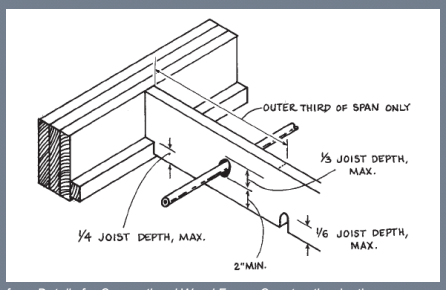
2. Layered Building Systems

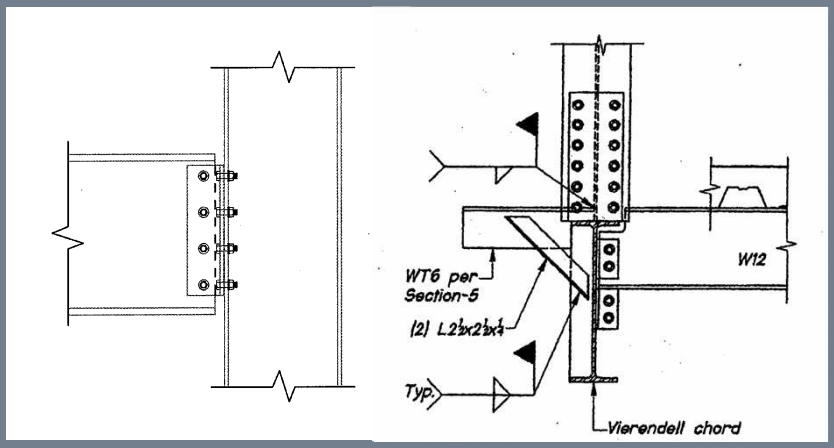


from *Details for Conventional Wood Frame Construction*, by the American Forest & Paper Association

from the Bensonwood web site, www.bensonwood.com

Conventional Wood Framing Details vs. Bensonwood Open-Built® Floor System

3. Simple, Standardized Components and Connections



Which connection would you rather take apart?

3. Simple, Standardized Components and Connections

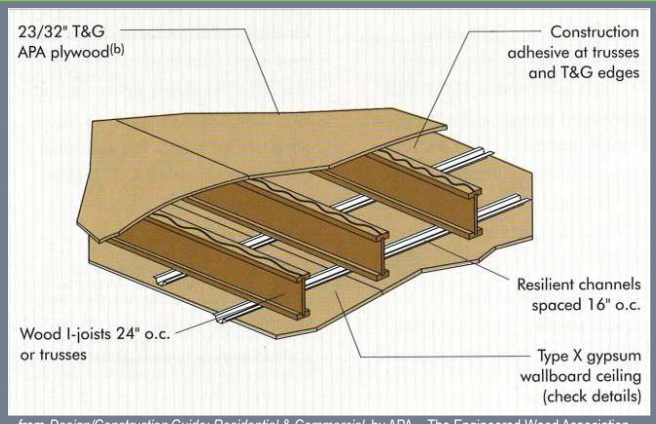
from the Quicon web site, www.quicon.com

The Quicon™ connection system uses standard interlocking connections.

from the conxtech web site, www.conxtech.com

The ConXTech connection.

4. Removable Fasteners (Avoid Adhesives and Welds)



from *Design/Construction Guide: Residential & Commercial*, by APA – The Engineered Wood Association

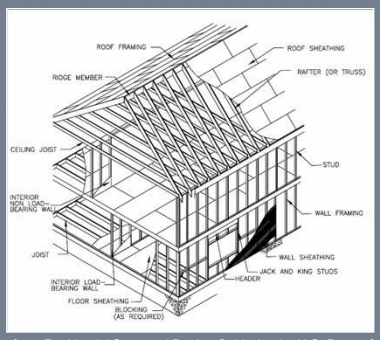
This glued plywood floor system will be virtually impossible to take apart. Use screws.

4. Removable Fasteners (Avoid Adhesives and Welds)

Lindapter Clamped Connections

5. Few Large Members vs. Many Small Members

from the Bensonwood web site, www.bensonwood.com



from *Residential Structural Design Guide*, by the U.S. Dept. of Housing and Urban Development

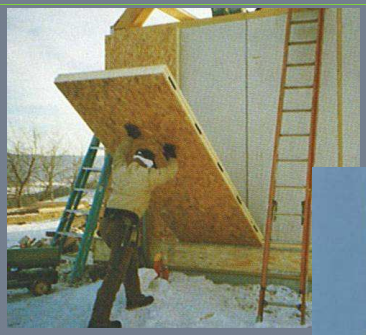
Larger members are more robust and less subject to damage during use and deconstruction. Fewer pieces to handle will likely reduce deconstruction costs.

6. Salvaged Materials

photo by Mark D. Webster

This vegetable market is constructed of salvaged timber, which will be reusable again at the end of the building's life.

7. Avoid Most Composite Systems

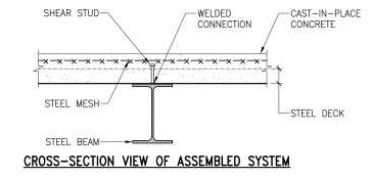


from Murus Structural Insulating Panels Brochure

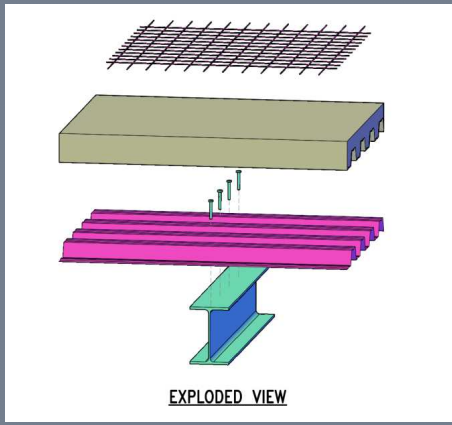
from *Stud Welding for Non-Residential Construction*, by Nelson Stud Welding

Composite systems typically increase deconstruction difficulty and reduce reuse options. Some composite systems may be reusable as assemblies.

Conventional Composite Slab

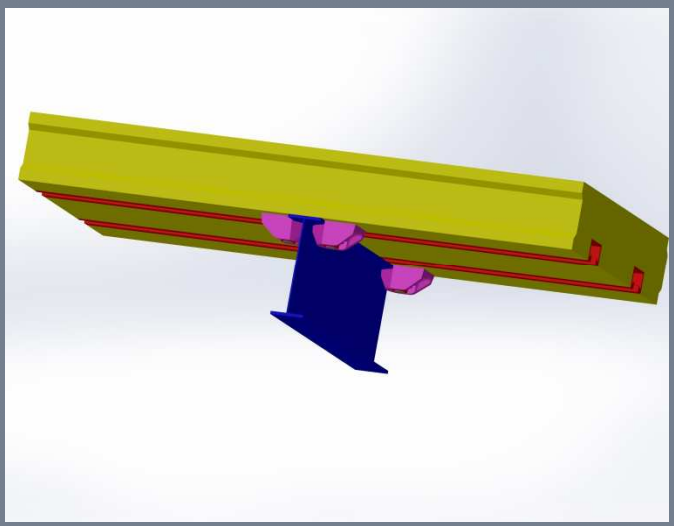


CROSS-SECTION VIEW OF ASSEMBLED SYSTEM

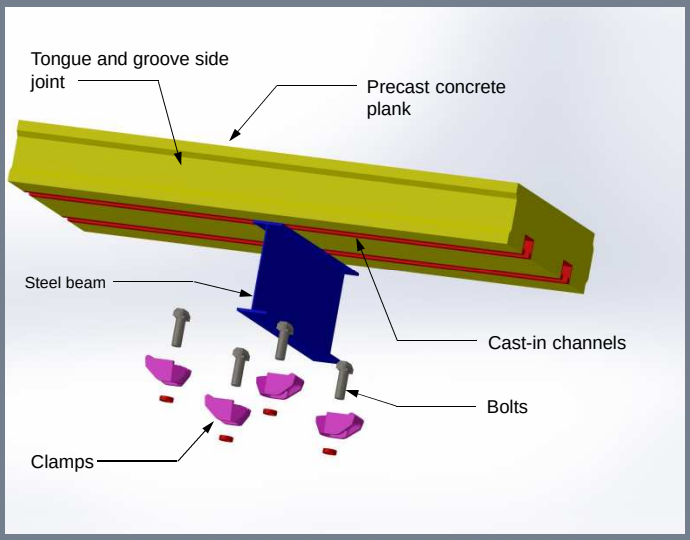

EXPLODED VIEW

- STEEL MESH, CONCRETE, & STEEL DECK NOT REUSABLE
- STEEL BEAM MAY BE REUSABLE, BUT SHEAR STUDS MUST BE REMOVED

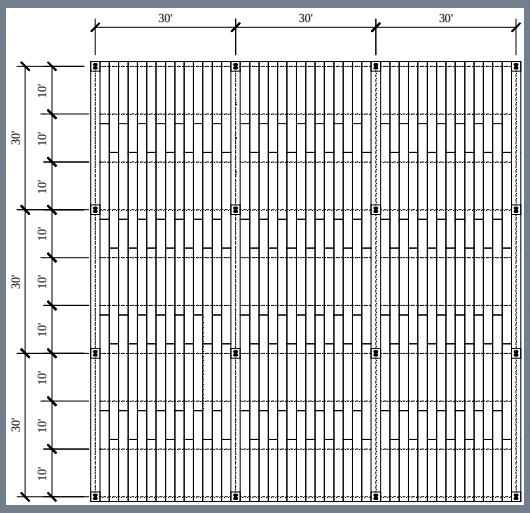
Deconstructable and Reusable Composite Slab



Deconstructable and Reusable Composite Slab



Deconstructable composite floor system



Typical floor plan for DfD system

Staggering plank pattern

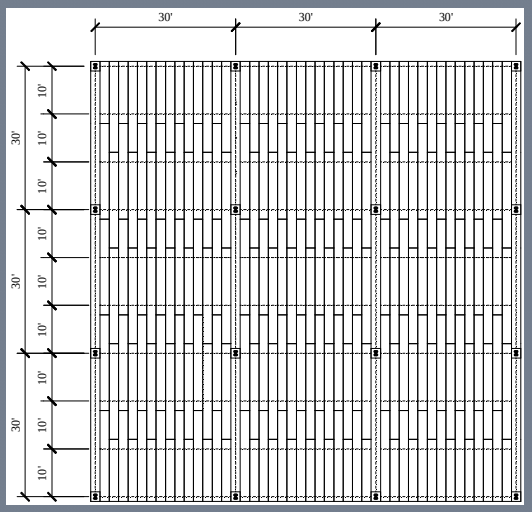
Why?

- Clamp connectors require planks being continuous over the steel beams.
- Enhanced localized stability of floor system

Benefits:

- Enables a two-plank strip to behave like a continuous beam by load transfer between the planks
- Adds flexibility to the floor plan

Deconstructable composite floor system



Typical floor plan for DfD system

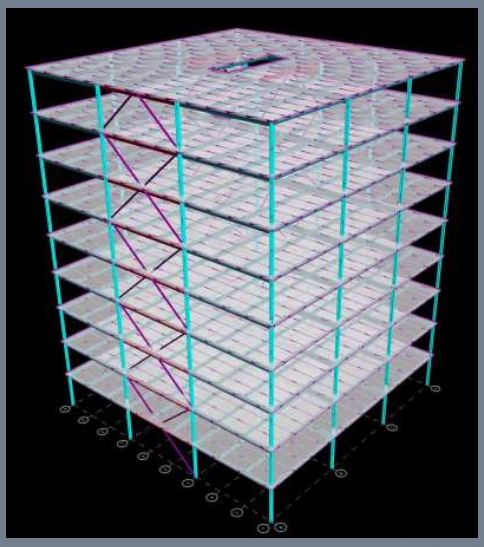
End-to-end connections:

- Located at the inflection points to reduce the load transfer between planks

Longitudinal rebar configuration in plank:

- Designed using twice the moment and shear obtained from continuous beam analysis

Archetype Office Building



- Nine Stories
- 30-Foot Bays
- Braced Frame Lateral System
- Steel Columns and Beams
- Conventional Composite Construction or Deconstructable Planks

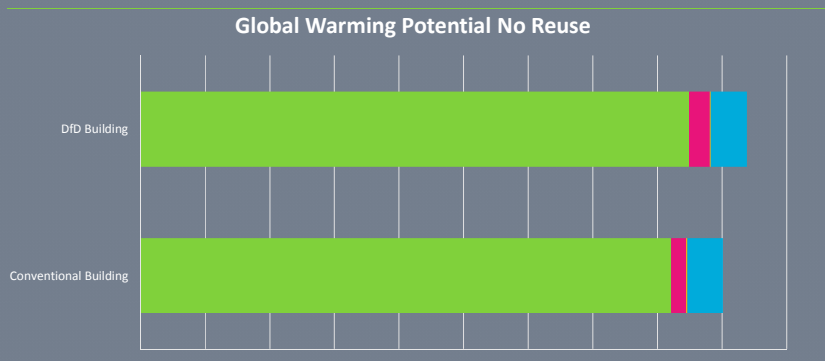
LCA Analysis

- Comparison of conventional composite construction to DfD slab construction.
- Used Simapro LCA software.
- Used U.S. Ecoinvent 2.2 and European Life-Cycle Database for material and transportation LCIs.
- Used TRACI 2.1 for environmental impact assessment.
- Modelled material transportation impacts and construction-phase labor transportation impacts.
- Assumed DfD components could be reused three times on average.

LCA Analysis

- Assumed that material and labor transportation impacts are the same regardless of whether the DfD components are new or reused.

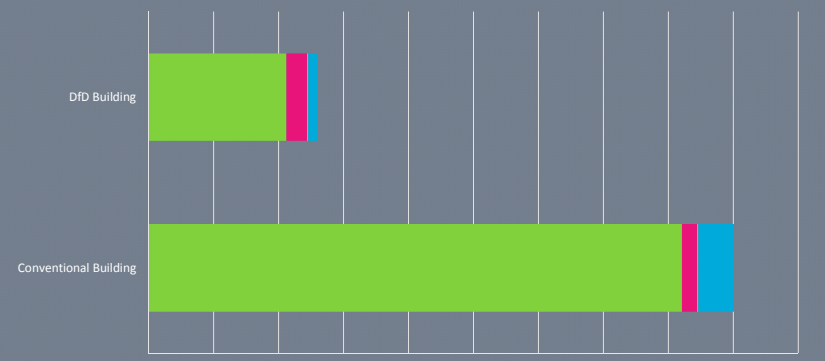
Preliminary LCA Results (No Reuse)



	Conventional Building	DfD Building
Production	821000	849000
Mat Transp	23600	32100
Worker Transp	1690	1370
Disposal	55000	56000

kg CO2 eq

Preliminary LCA Results (Reused 3x)



	Conventional Building	DfD Building
Production	821000	212250
Mat Transp	23600	32100
Worker Transp	1690	1370
Disposal	55000	14000

kg CO2 eq

Conclusions

- DfD offers tremendous environmental benefits if systems are actually reused.
- Assuming the DfD system is reused three times, it reduces carbon emissions by 71% relative to conventional composite construction.
- If reused only twice, carbon emissions are still reduced by 63%.
- If reused four times, carbon emissions are reduced by 76%.

Conclusions

- DfD requires a new mind-set for designers. We're not accustomed to thinking about the end-of-life (much less the after-life) of our building designs.
- DfD will be most successful for routine building development, such as low- to mid-rise commercial development and housing (which accounts for most construction). These buildings are the most likely to have regular, repeating floor plans, simple construction, and relatively short life-spans.

Concluding Thoughts on DfD

- DfD is attracting the attention of building designers in the North America and Europe. The Building Materials Reuse Association in the U.S. is promoting DfD, and excellent DfD guides have been published by the Canadian government, the Scottish government, and CIRIA, a British construction research and educational association.