SIMPSON GUMPERTZ & HEGER

Engineering of Structures and Building Enclosures

Life Cycle Assessment of Deconstructable Floor Systems

Research Team:
Simpson Gumpertz & Heger Inc.
- Clayton Brown
- Mark D. Webster

Northeastern University
- Professor Jerome F. Hajjar
- Professor Matthew Eckelman
- Lizhong Wang

Work supported by:
National Science Foundation
American Institute of Steel Construction
Halfen
Lindapter
Reinforced Concrete Construction Committee
Capone Iron

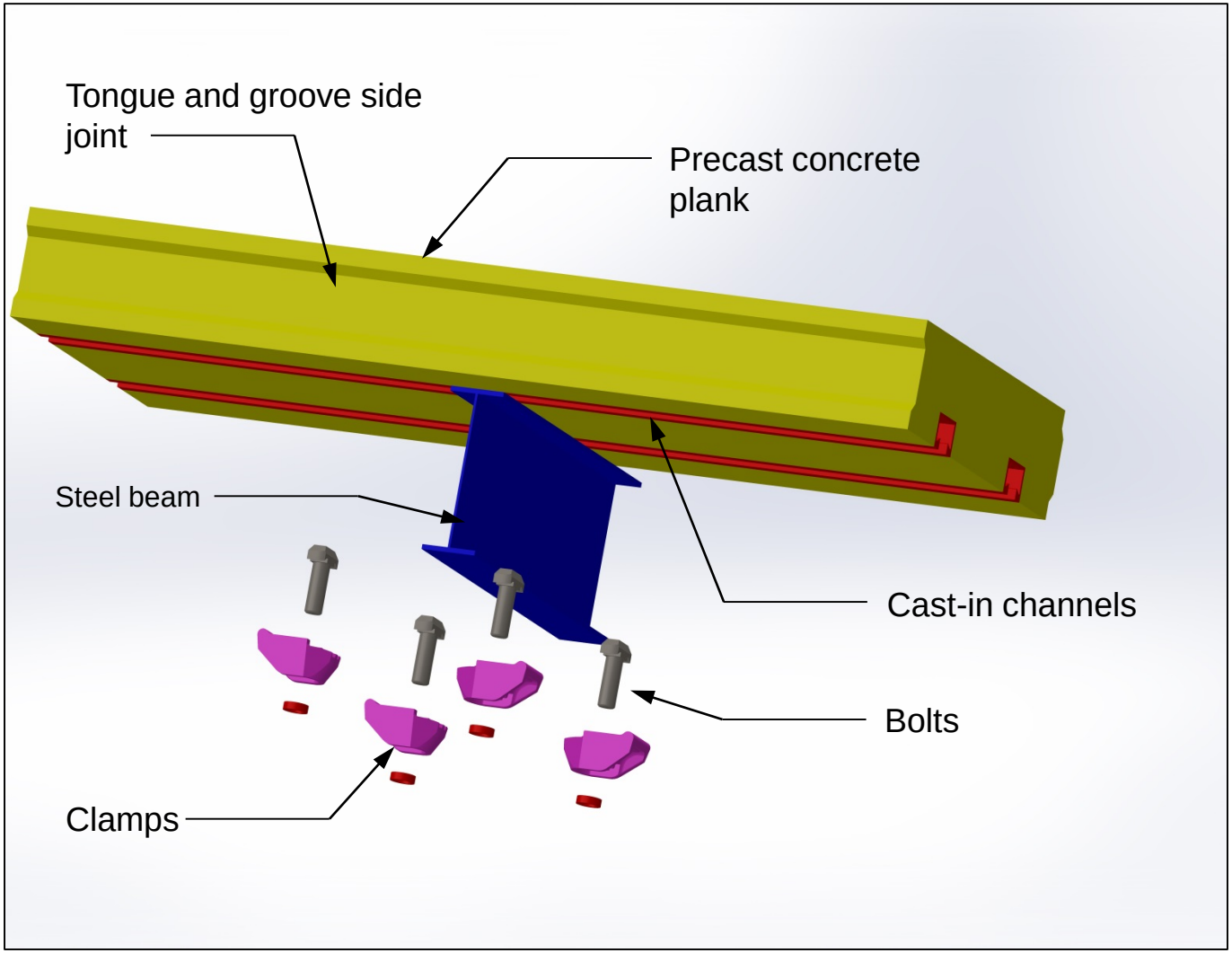
What is Design for Deconstruction (DfD)?

- Deconstruction is the process of careful demolition of a structure with the intent to salvage and reuse as much of the structure as possible.
- Design for Deconstruction is a design approach that anticipates and facilitates future deconstruction of the structure.
- i.e. – use bolted connections instead of welded connections

Why promote DfD?

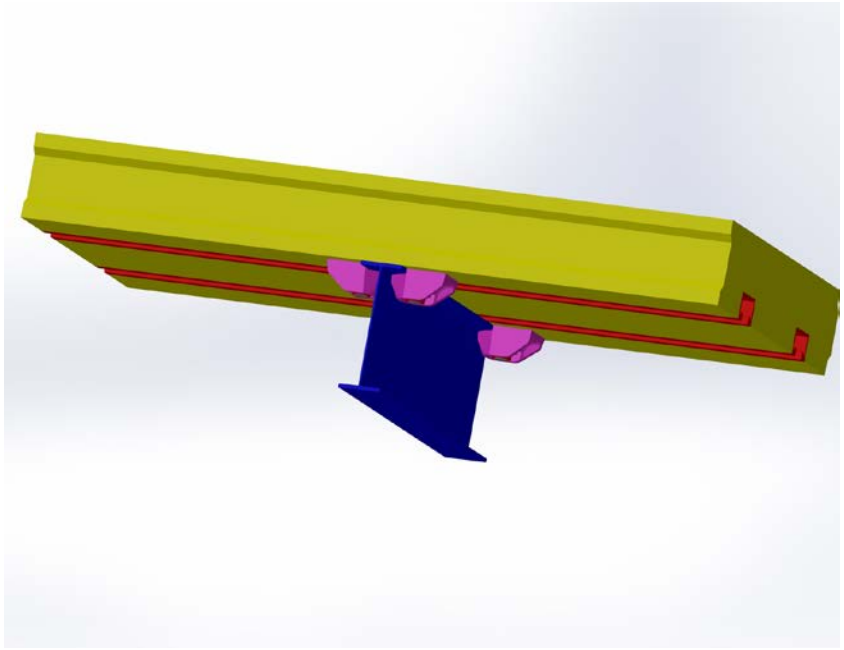
- Reduce costs and environmental impacts associated with:
  - Production
  - Disposal
  - Structural adaptation
- Reduce material waste
- Reuse is superior to recycling and down-cycling

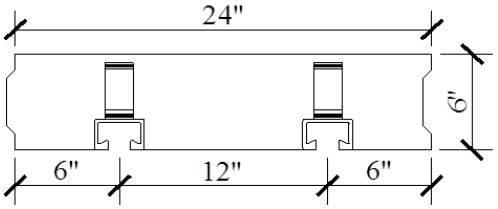
Deconstructable Composite Planks



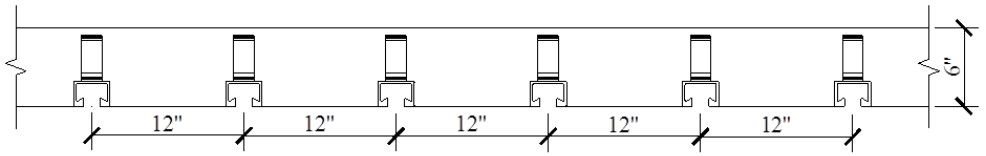
Exploded View

Deconstructable Composite Planks





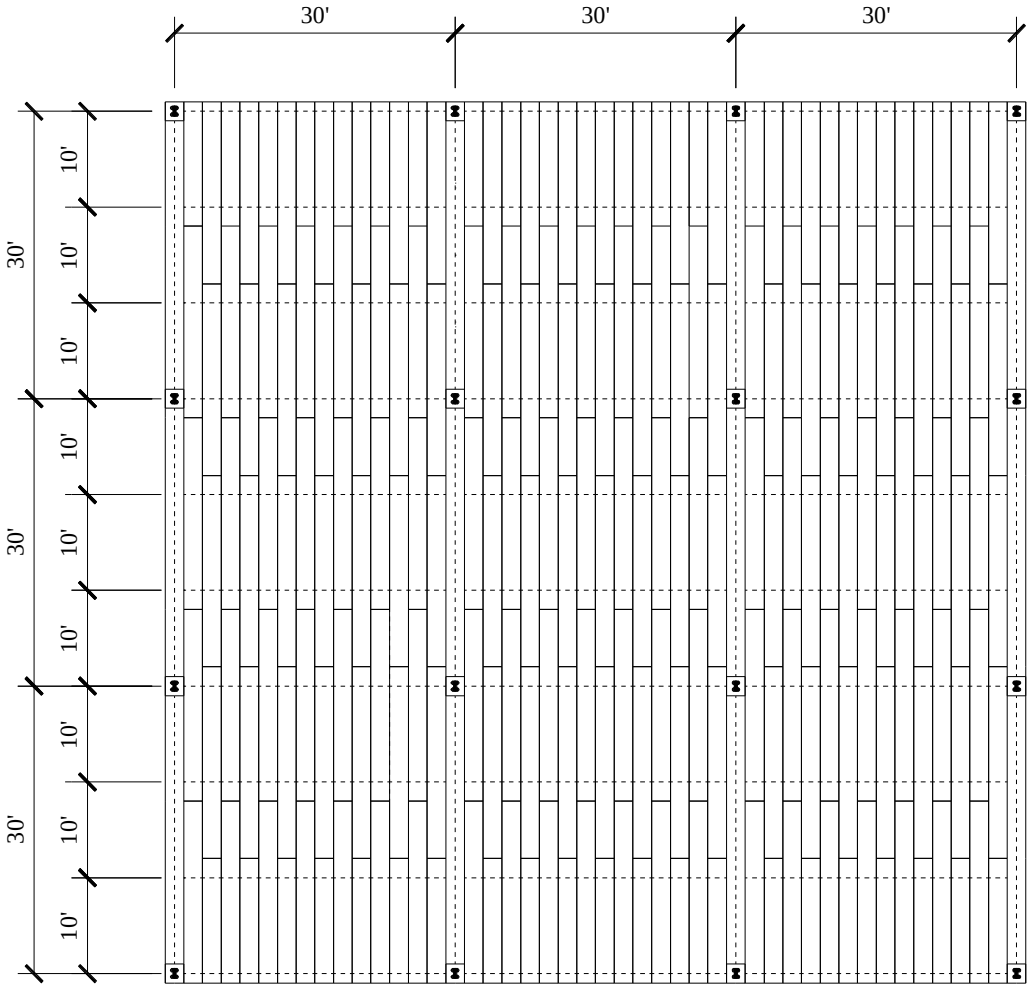
a) Plank perpendicular to the steel beam



b) Plank parallel to the steel girder

Precast concrete plank cross section

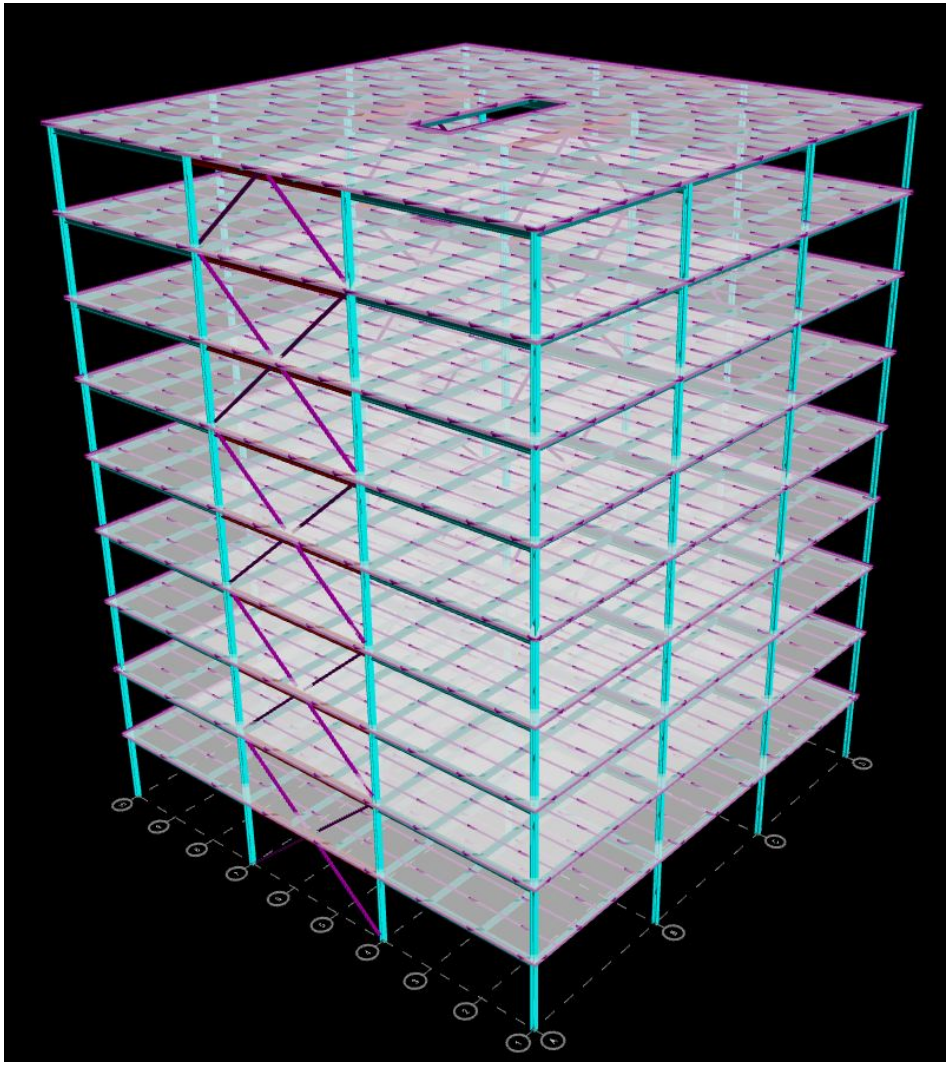
Deconstructable Composite Planks



Typical floor plan employing DfD planks

- Staggered layout of planks
- Provides enhanced localized stability of the floor system
- Allows load transfer between adjacent planks, allowing them to act as a continuous beam
- End-to-end connections located at inflection points to reduce load transfer between planks
- Longitudinal rebar designed using twice the moment and shear obtained from continuous beam analysis

Archetype Buildings



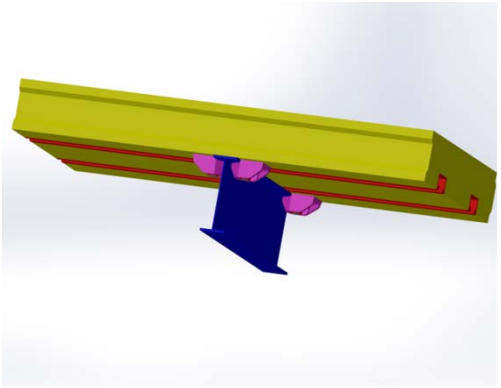
- Three or nine stories
- 3x3-20 or 30 foot bays
- 6” or 8” floors
- Steel columns and beams
- Braced frame lateral system
- Two designs:
  - Conventional composite construction
  - Deconstructable planks

What is Life Cycle Assessment (LCA)?

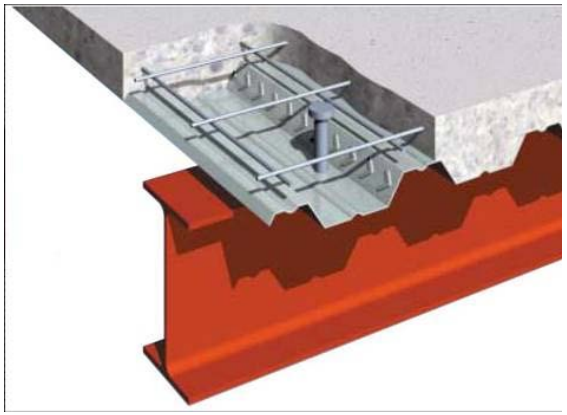
- "A technique to assess the environmental aspects and potential impacts associated with a product, process, or service" –US EPA
- ISO Standards
  - ISO 14040:2006 and 14044:2006
- Compile life cycle inventories (LCI) of:
  - Energy inputs
  - Material inputs
  - Environmental outputs
- Evaluate the potential environmental impacts associated with the LCIs
  - Life cycle impact assessment (LCIA)
  - Variety of LCIA methods in different regions
  - EPA's Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI 2.1)

LCA of DfD Planks vs. Conventional Floor

- Used SimaPro 8.0.2, LCA software developed by PRé Consultants – Netherlands
  - Transparent tool
  - User control
- LCI databases:
  - U.S. Ecoinvent 2.2
  - European Life-Cycle databases
- LCIA: EPA's TRACI 2.1



DfD Plank



Conventional Floor

Image from nexus.globalquakemodel.org

LCA of DfD Planks vs. Conventional Floor

- Material inventory
- Material transportation
- Labor force transportation during construction and deconstruction phase
- End of life impacts
- Uncertainties applied to most inputs
  - Steel and concrete plant locations
  - Storage locations
  - Distance to clamp and channel suppliers
  - Recycling percentage of concrete

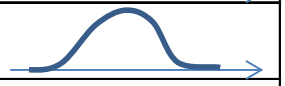
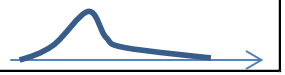
Distribution Types Supported by SimaPro		
Distribution Type	**Required Data**	**Graphical Presentation**
Range	Min and max values	
Triangular	Min and max values and best guess	
Normal	Standard deviation and best guess	
Lognormal	Standard deviation and best guess	

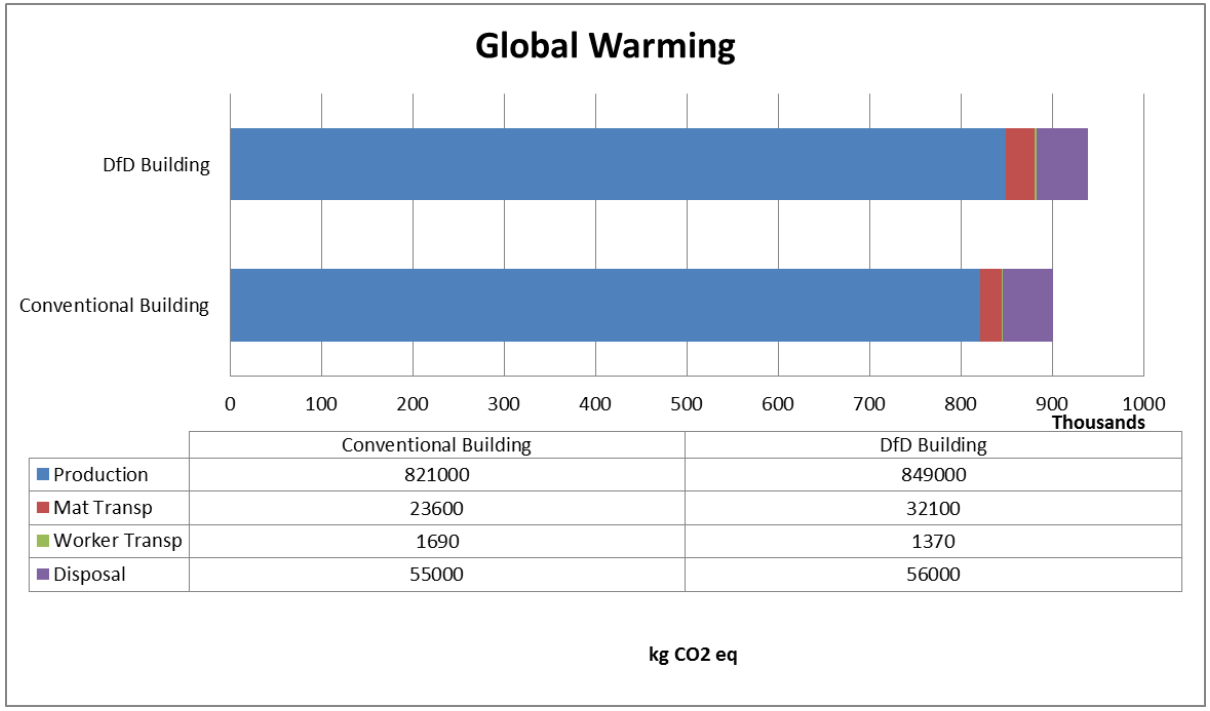
Table reproduced from *SimaPro 8 Introduction to LCA*, Pré Consultants 2014

Assumptions of Study

- Three levels of DfD component reuse
  - 66%, 75%, or 80% reuse
  - i.e. two, three, or four reuses
- In addition to the floor planks, steel components of the DfD building are also reused
  - Beams, columns, braces
- There are no inherent impacts in the storage of deconstructed components
  - The impacts of transporting materials to and from storage is considered
- All materials are transported by truck only
- Proprietary clamps are modelled as cast iron

Preliminary Results of LCA (Without Deconstruction)

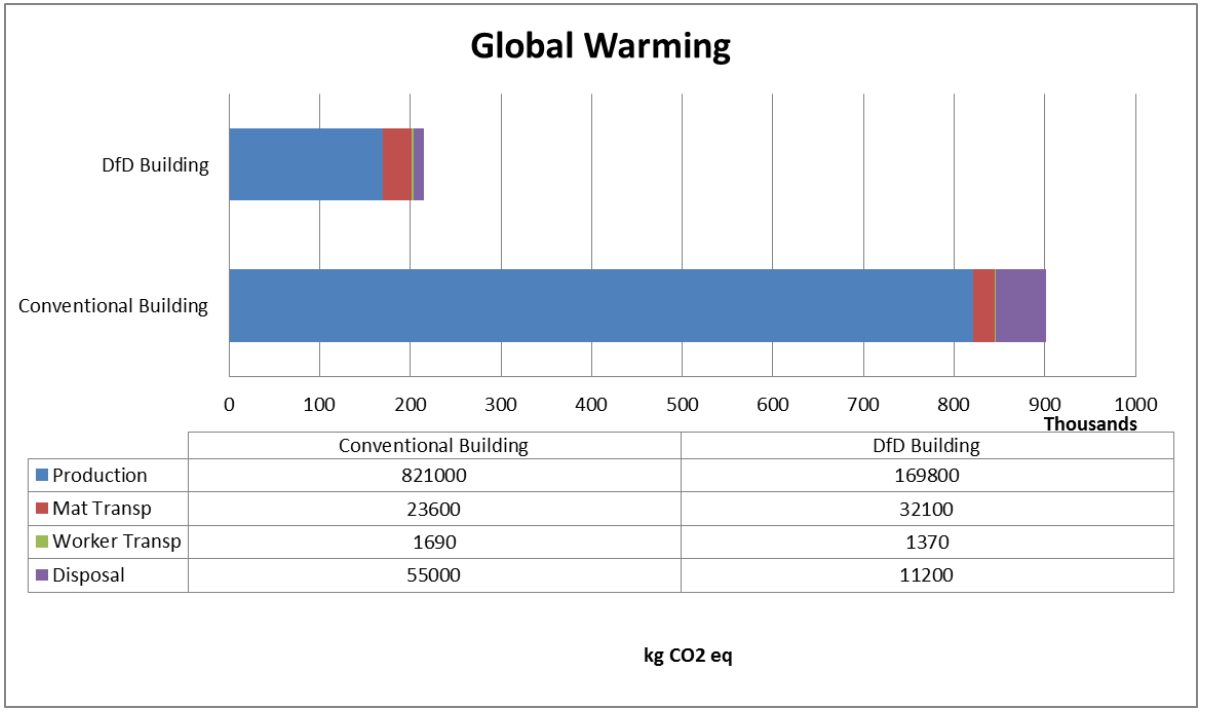
- Assume no deconstruction of the DfD building
- Provides baseline comparison of global warming impacts
- Life cycle impacts broken out by category



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

Results of LCA

- One scenario: assume 33% of the DfD structure is not salvaged
  - i.e. 66% of the DfD structure may be reused in a future structure
  - Or, on average, each DfD component may be reused twice



	Conventional Building	DfD Building
Production	821000	169800
Mat Transp	23600	32100
Worker Transp	1690	1370
Disposal	55000	11200

Results of LCA

- DfD structures may have different initial material needs compared to traditional composite structure
  - Higher environmental impact if not deconstructed and reused
- Reusing DfD components twice (66% reuse) reduces carbon emissions by 63%
- Reusing DfD components three times (75% reuse) reduces carbon emissions by 71%
- Reusing DfD components four times (80% reuse) reduces carbon emissions by 76%

Conclusions

- Even a moderate amount of reuse can provide significant environmental benefits
- Some projects are more suited for DfD
  - Low- to mid-rise
  - Repetitive, simple construction
  - Short life span

DfD and LCA in the Industry

- LCA is becoming more widely used
  - LEED
  - PCR – product category rules
  - EPD – environmental product declarations
    - NRMCA, AISC, Steel Framing Association, CRSI
- The Canadian government, Scottish government, and CIRIA (British construction and research educational association) have released valuable DfD guides

Questions?