Design of new single-storey steel buildings for reuse

Ricardo Pimentel

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Why focus on single-storey steel buildings?

Design of new single-storey steel buildings for reuse

FIGURES CREDITS: World Steel Association, European Steel Association, Primary Interviews, Grand View Research; SCI
Key concepts for steel reuse

- **Standardization**
- Reduce number of interfaces (number of building layers)
- Reduce number of different components
- Design for adaptability and relocation
- Design and detailing for construction, deconstruction and transportation
Standardization

- Structural grid
- Roof pitch
- Structural solution
- Connections
- Assemblies size (for transportation)
Reduce interfaces

• Avoid secondary structure (if possible)
  
  Roof cassette systems as an option

FIGURES CREDITS: https://www.ruukki.com; http://www.afaconsult.com;
Reduce number of different components and materials

- Fewer robust members
- Reduce number of different cross-sections
- Reduce number of materials (steel-grades, subgrades)

FIGURES CREDITS: https://www.steelconstruction.info
Design for adaptability and relocation

- **Environmental loads: snow**

<table>
<thead>
<tr>
<th>Country</th>
<th>$s_k \text{ (kN/m}^2\text{)}$</th>
<th>Country average</th>
<th>Min. European value</th>
<th>Class</th>
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</table>

\(^a\) Assuming the average altitude for the less critical zone of the country

\(^b\) Assuming the average altitude for the zone representing most area of the country

European snow load classes

FIGURES CREDITS: Progress
Design for adaptability and relocation

- **Environmental loads: wind**

<table>
<thead>
<tr>
<th>Country</th>
<th>$V_{b,0,min}$ [m/s]</th>
<th>$V_{b,0,max}$ [m/s]</th>
<th>$V_{b,0,mean}$ [m/s]</th>
<th>Class - Mean</th>
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<th>$q_{b,0,class}$ [kN/m²]</th>
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</tr>
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</table>

* - According to the most usual value defined with the national annex. Other results obtained with a weighted average: $(2*V_{b,0,min} + V_{b,0,max})/3$. Class W1: 23 m/s; Class W2: 26 m/s; Class W3: 28 m/s; Class W4: >28 m/s

**European wind load classes**
Design for adaptability and relocation

- Environmental loads: country and European load classes:
  - Define load for building locale (essentially wind and snow)
  - Compare with recommended minimum for the country
  - Compare with recommended minimum for the European class
  - Adapt design for recommended minimums country or EC loads (if economically feasible)

UF (unity factors) in practice are defined based on standard section sizes;
Spare capacity may be available;

CREDITS: Progress
Design for adaptability and relocation

- The design process:
  1. Design for allowable permanent load \((UF=1)\);
  2. Design for allowable wind load \((UF=1)\);
  3. Design for allowable snow load \((UF=1)\);

Designers may want to specify on the project documentation allowable permanent and imposed loads that lead to \(UF=1\).

Extra efforts in the design process, but more flexibility for future reuse!
Design and detailing for deconstruction and reuse

- Design according to Eurocode 3:
  - Elastic global analysis is recommended
  - SLS stress checks to be performed
  - \( \gamma_{M1,mod} = 1.15 \times \gamma_{M1} \)
  - \( \gamma_{M0} \) and \( \gamma_{M2} \): values from the appropriate NA to be used;

Reliability adjustment to cover uncertainty for different building life cycles for transportation, erection and disassembly (\( \beta = 4.3 \) for member stability). Subsequent life cycles based on visual inspection for member straightness and other geometric tolerances.
Design for adaptability and relocation

- Use reasonable loads for claddings and floor systems to allow for future adaptability based on two classes:
  - Lightweight flooring solutions (SW: 1 kN/m²);
  - Heavy flooring solutions (SW: 3 kN/m²) – clever detailing for disassembly may be needed;

Figures Credits: Progress
Design and detailing for deconstruction and reuse

- Detailing principles for reuse:
  - Reduce the number of connections and connectors (simple connections)
  - Use bolts or screws instead of other solutions; reduce welding
  - Detail for easy access of connections
  - Repetitive detailing (modular/standard)
  - Avoid permanent attachments (floors are critical)

CREDITS: Progress; SCI
Design and detailing for deconstruction and reuse

- **Detailing principles for reuse: semi-bolted haunch**

![Diagram](image)

- End plate welded to each profile segment
- Haunch length, typically span/10

**Figure Credits:** Progress; SCI
Design and detailing for deconstruction and reuse

- Detailing principles for reuse: full bolted haunch

![Diagram of full bolted haunch detail]

FIGURE CREDITS: Progress; SCI
Design and detailing for deconstruction and reuse

- Detailing principles for reuse: full bolted connections.

FIGURES CREDITS: https://www.northlincsstructures.com/
Design and detailing for deconstruction and reuse

- Detailing principles for reuse: full bolted connections

FIGURES CREDITS: https://www.northlincesstructures.com/
Design and detailing for deconstruction and reuse

- Detailing principles for reuse: full bolted connections

FIGURES CREDITS: https://www.northlincsstructures.com/
Design and detailing for deconstruction and reuse

- Detailing principles for reuse: modular truss system
Design and detailing for deconstruction and reuse

- **Detailing principles for reuse:**

  - Use of simple connections.
    - More suitable for small to medium spans.

  - Modular design concepts:
    - Use of bespoke welded standard components.
    - Repetitive detailing for a specific span and frame spacing.
    - Standard connections with standard bolt arrangements.
    - More suitable for small to medium spans.

**FIGURES CREDITS:** Progress; SCI
Design and detailing for deconstruction and reuse

- Detailing principles for reuse: mezzanines

FIGURES CREDITS: Progress; www.Steelconstruction.info; Fokker 7 Building - Schiphol Airport (right)

Design of new single-storey steel buildings for reuse

Demountable!
Design and detailing for deconstruction and reuse

- Detailing principles for reuse: mezzanines

  Bespoke SPS system

FIGURES CREDITS: [https://www.spstechnology.com/](https://www.spstechnology.com/)
Design and detailing for deconstruction and reuse

- Detailing principles for reuse: mezzanines
  
  CLT floor system

**FIGURES CREDITS:** [https://www.kloecknermetalsuk.com](https://www.kloecknermetalsuk.com)

Demountable!
Design and detailing for deconstruction and reuse

- Detailing principles for reuse: mezzanines

Demountable composite floor system

Welded shear studs vs Bolts

FIGURES CREDITS: REDUCE: Research Fund for Coal and Steel, Grant agreement No: 710040; Figure on the left: https://www.tatasteelconstruction.com

Design of new single-storey steel buildings for reuse
Design and detailing for deconstruction and reuse

- Detailing principles for reuse: bespoke connections

FIGURES CREDITS: SCI
Design and detailing for deconstruction and reuse

- Detailing principles for reuse: bespoke connections

FIGURES CREDITS: [http://www.lindapter.com](http://www.lindapter.com)
Design and detailing for deconstruction and reuse

- Detailing principles for reuse: case study

100% circular design; design for deconstruction and reuse; all structural members were designed to be disassembled; cladding with screwing fixings; BIM and Material Passport to enhance future reuse.

FIGURES CREDITS: Fokker 7 Building; Schiphol Airport
Design and detailing for deconstruction and reuse

- Detailing principles for reuse: case study

100% circular design; design for deconstruction and reuse; all structural members were designed to be disassembled; cladding with screwing fixings; BIM and Material Passport to enhance future reuse.

FIGURES CREDITS: Fokker 7 Building; Schiphol Airport
Final remarks

1. Small improvements to current practice for single storey buildings will have a large impact on the construction market (due to high market share);

2. Design for deconstruction, not only construction;

3. Reduce number or layers, materials and components;

4. Design for relocation/adaptability, not for a single purpose and location;

5. Designers to specify allowable structural capacity to facilitate reuse;
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