# Design of new single-storey steel buildings for reuse

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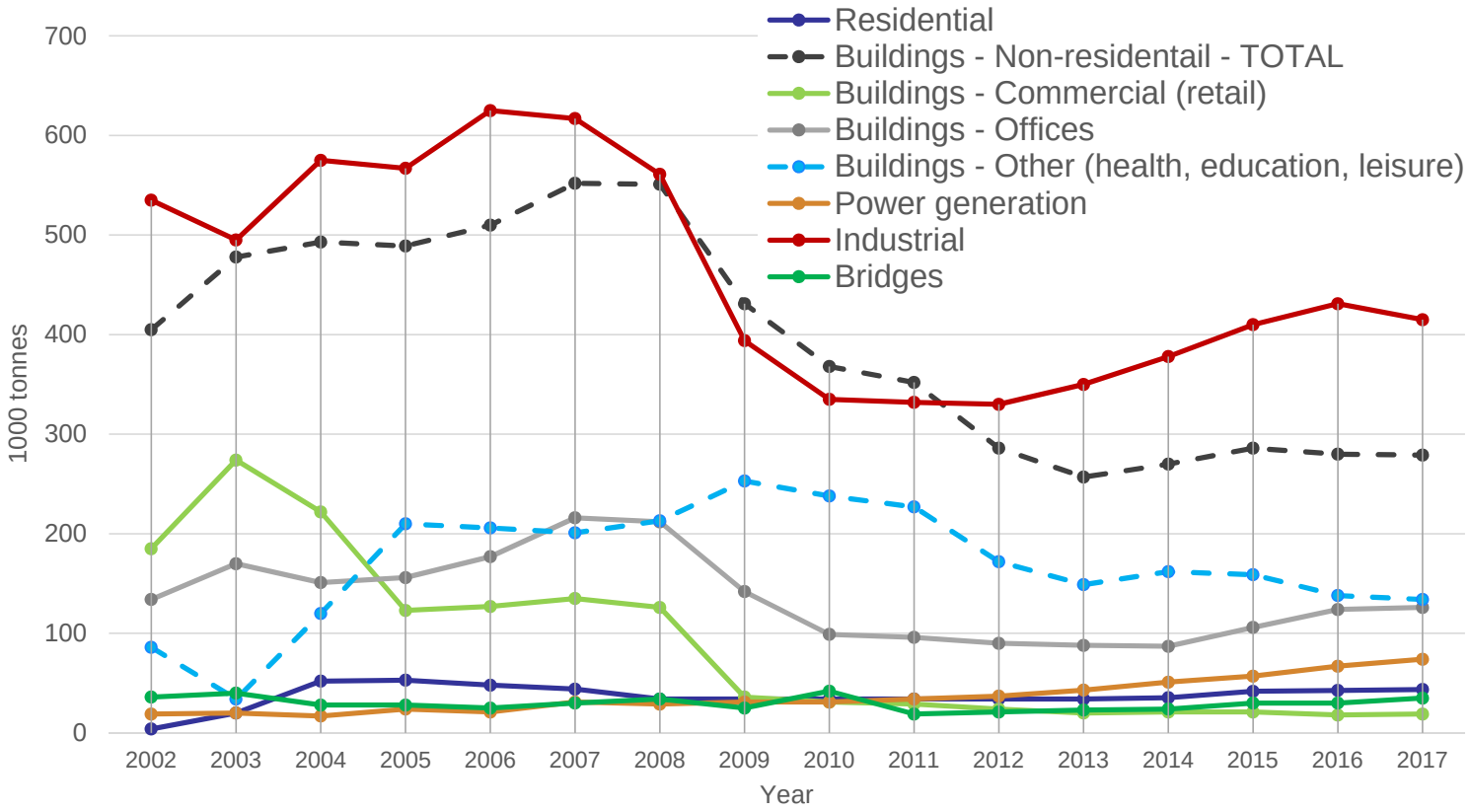
SCI Steel Knowledge

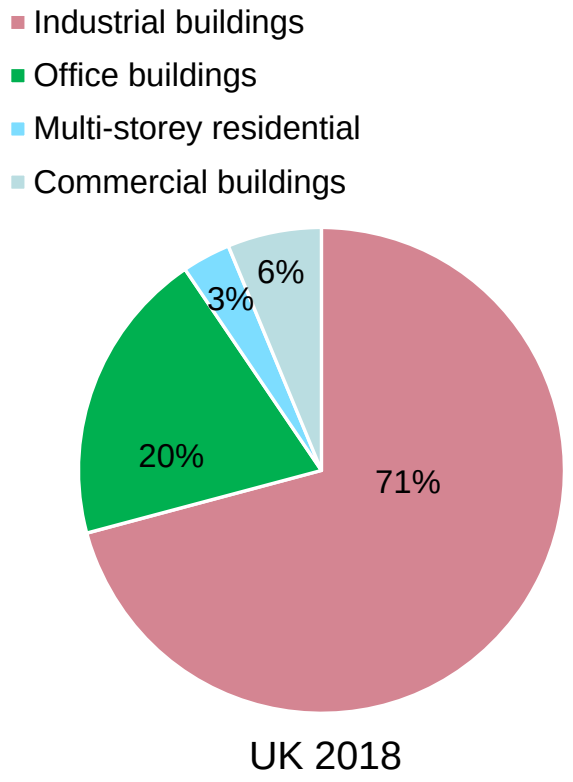
European Commission

Research Fund for Coal & Steel

2017-2020 PROGRESS PROVISIONS FOR GREATER REUSE OF STEEL STRUCTURES

# Why focus on single-storey steel buildings?




UK 2018

Hot rolled and fabricated profiles

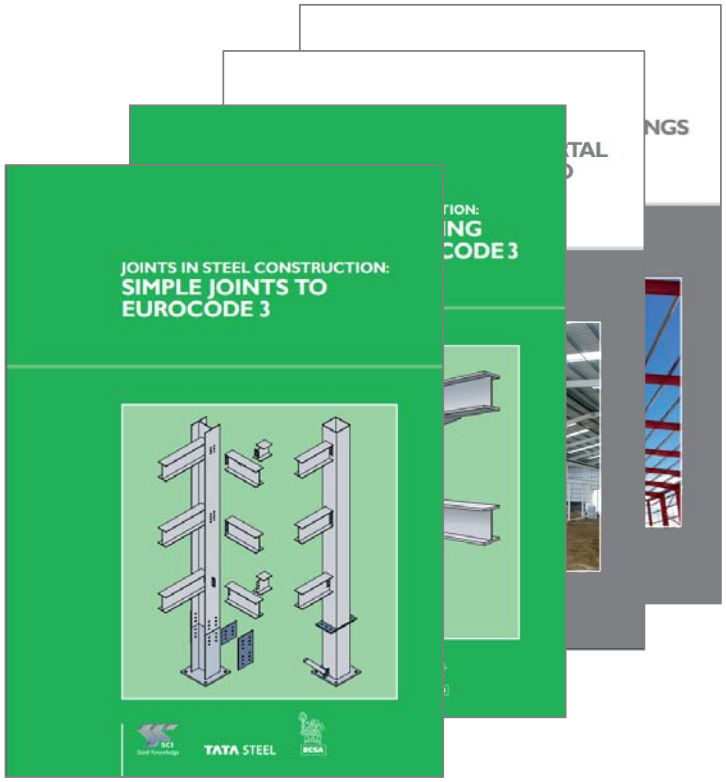
**FIGURES CREDITS**: World Steel Association, European Steel Association, Primary Interviews, Grand View Research; SCI

# 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)




FIGURES CREDITS: SCI

# Reduce interfaces

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

*Long span roof claddings (Finland)*

*Long span roof claddings (Finland)*

*Deep decking system (Portugal)*

**FIGURES CREDITS**: https://www.ruukki.com/; http://www.afaconsult.com/;

# Reduce number of diferente 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

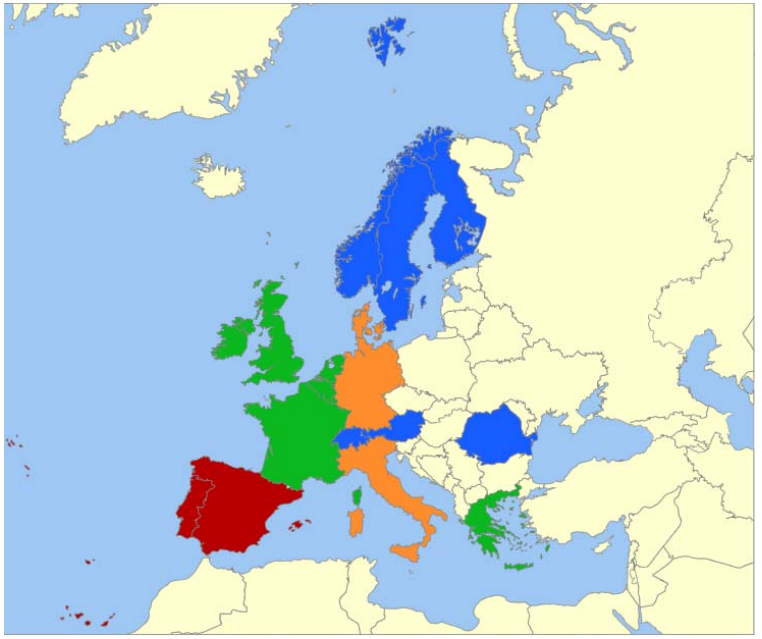
# Design for adaptability and relocation

- Environmental loads: snow

| Country | $s_k$ (kN/m²) | | | Class |
|---|---|---|---|---|
| | Min.[a)] | Country average[b)] | Min. European value | |
| Finland | 2.00 | 2.75 | 2.00 | S1 |
| **France** | 0.45 | **0.65** | **0.70** | S3 |
| Germany | 0.45 | 0.85 | 1.00 | S2 |
| **Ireland** | 0.40 | **0.55** | **0.70** | S3 |
| Italy | 0.60 | 1.00 | 1.00 | S2 |
| **The Netherlands** | 0.70 | **0.70** | **0.70** | S3 |
| Norway | 1.50 | 3.50 | 2.00 | S1 |
| Portugal | 0.10 | 0.30 | 0.40 | S4 |
| Romania | 1.50 | 2.00 | 2.00 | S1 |
| Spain | 0.30 | 0.40 | 0.40 | S4 |
| Sweden | 1.50 | 2.50 | 2.00 | S1 |
| **United Kingdom** | 0.45 | **0.65** | **0.70** | S3 |

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*

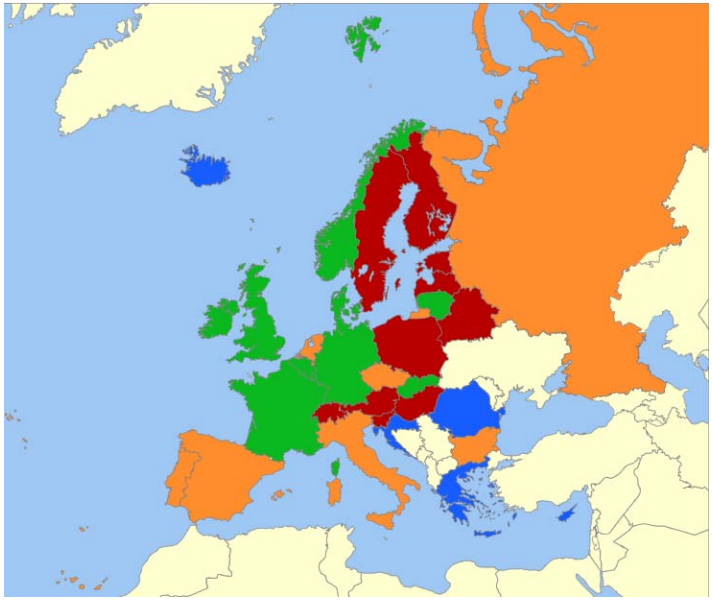
FIGURES CREDITS: Progress

# Design for adaptability and relocation

- Environmental loads: wind

| Country | $V_{b,0,min}$ [m/s] | $V_{b,0,max}$ [m/s] | $V_{b,0,mean}$ [m/s] | Class - Mean | $V_{b,0,class}$ [m/s] | $q_{b,0,class}$ [kN/m²] |
|---|---|---|---|---|---|---|
| Austria | 17.6 | 28.3 | 21 | W4 | 23 | 0.55 |
| Belarus | 22.0 | 24.0 | 22 | W4 | 23 | 0.61 |
| Belgium | 23.0 | 26.0 | 24 | W3 | 26 | 0.72 |
| Bulgaria | 24.0 | 35.8 | 27 | W2 | 28 | 0.91 |
| Croatia | 20.0 | 48.0 | 29 | W1 | > 28 | 1.05 |
| Cyprus | 24.0 | 40.0 | 29 | W1 | > 28 | 1.05 |
| Czech Republic | 22.5 | 36.0 | 27 | W2 | 28 | 0.91 |
| Denmark | 24.0 | 27.0 | 25 | W3 | 26 | 0.78 |
| Estonia | 21.0 | 21.0 | 21 | W4 | 23 | 0.55 |
| Finland | 21.0 | 26.0 | 22* | W4 | 23 | 0.61 |
| France | 22.0 | 28.0 | 24* | W3 | 26 | 0.72 |
| Germany | 22.5 | 30.0 | 25* | W3 | 26 | 0.78 |
| Greece | 27.0 | 33.0 | 29 | W1 | > 28 | 1.05 |
| Hungary | 23.6 | 23.6 | 23 | W4 | 23 | 0.66 |
| Iceland | 36.0 | 36.0 | 36 | W1 | > 28 | 1.62 |
| Ireland | 25.0 | 28.0 | 26 | W3 | 26 | 0.85 |
| Italy | 25.0 | 31.0 | 27* | W2 | 28 | 0.91 |
| Latvia | 21.0 | 27.0 | 23 | W4 | 23 | 0.66 |
| Lithuania | 24.0 | 32.0 | 26 | W3 | 26 | 0.85 |
| Luxemburg | 24.0 | 24.0 | 24 | W3 | 26 | 0.72 |
| Netherlands | 24.5 | 29.5 | 27* | W2 | 28 | 0.91 |
| Norway | 22.0 | 31.0 | 25 | W3 | 26 | 0.78 |
| Poland | 22.0 | 26.0 | 23 | W4 | 23 | 0.66 |
| Portugal | 27.0 | 30.0 | 27* | W2 | 28 | 0.91 |
| Romania | 27.0 | 35.0 | 31* | W1 | > 28 | 1.20 |
| Russia | 19.6 | 43.6 | 27 | W2 | 28 | 0.91 |
| Slovakia | 24.0 | 26.0 | 24 | W3 | 26 | 0.72 |
| Slovenia | 20.0 | 30.0 | 23 | W4 | 23 | 0.66 |
| Spain | 26.0 | 29.0 | 27* | W2 | 28 | 0.91 |
| Sweden | 21.0 | 26.0 | 22 | W4 | 23 | 0.61 |
| Switzerland | 20.0 | 24.0 | 21 | W4 | 23 | 0.55 |
| United Kingdom | 22.0 | 32.0 | 25* | W3 | 26 | 0.78 |

* - 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*

**CREDITS**: Progress

# 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!

**CREDITS**: Progress

# 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.

**CREDITS**: Progress; SCI

# 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/m$^2$);
  - Heavy flooring solutions (SW: 3 kN/m$^2$) – 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

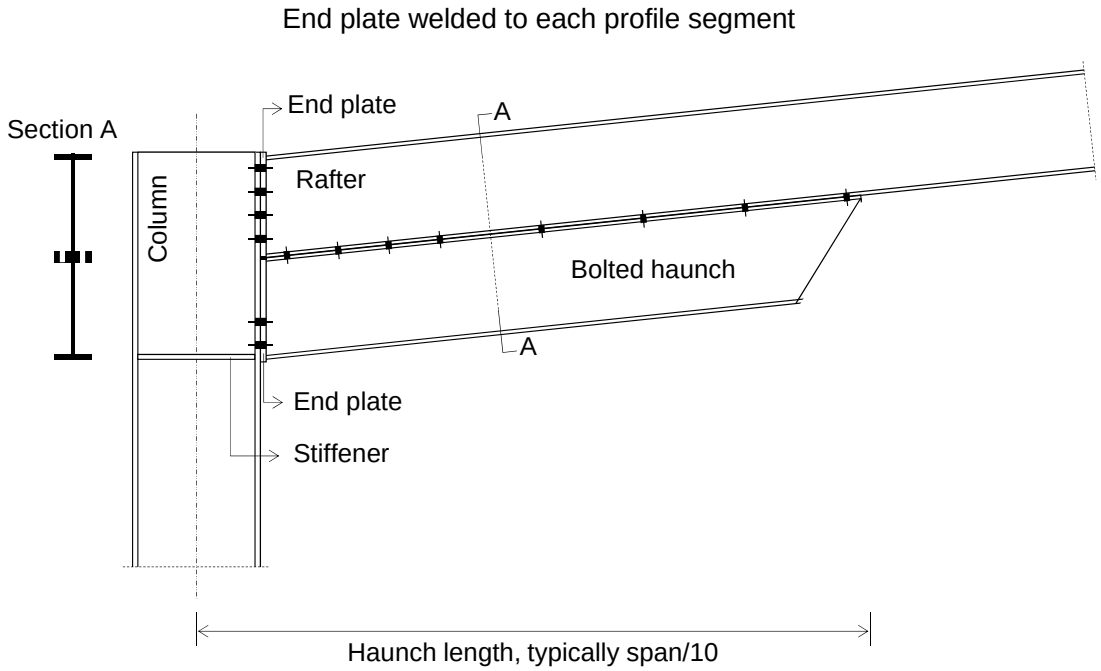



**FIGURE CREDITS**: Progress; SCI

# Design and detailing for deconstruction and reuse

- Detailing principles for reuse: full bolted haunch

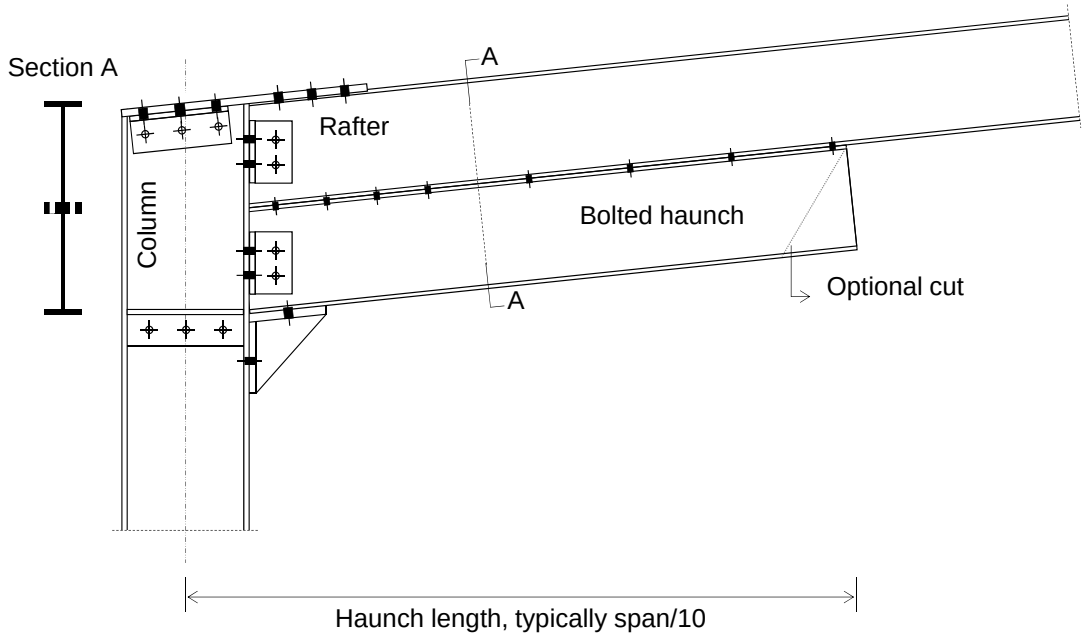



**FIGURE CREDITS**: Progress; SCI

# 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.northlincsstructures.com/;

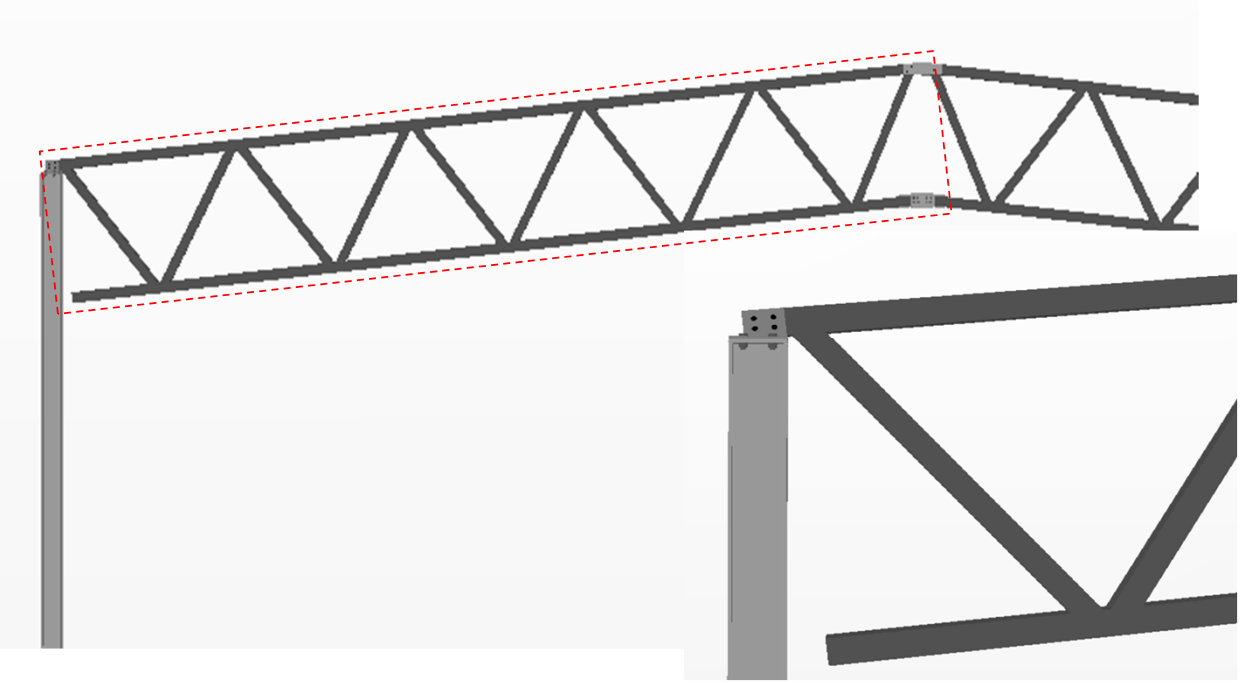
# Design and detailing for deconstruction and reuse

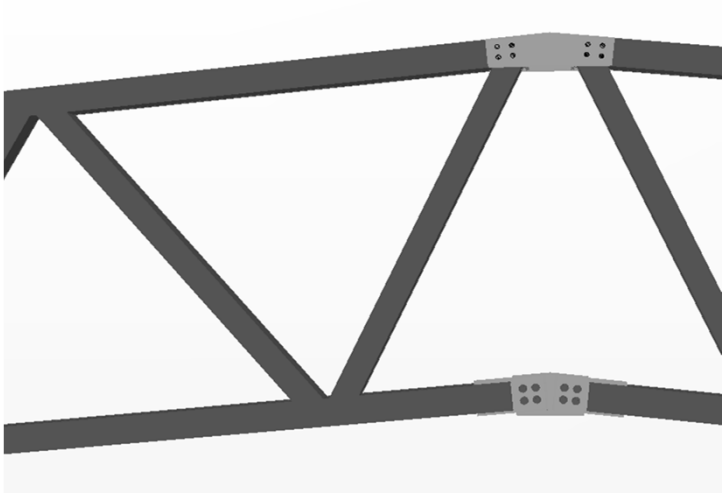
- Detailing principles for reuse: full bolted connections


**FIGURES CREDITS**: https://www.northlincsstructures.com/;

# Design and detailing for deconstruction and reuse

- Detailing principles for reuse: modular truss system

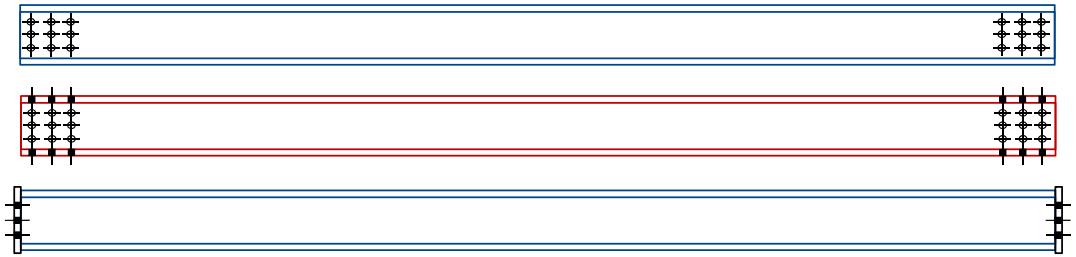




**FIGURES CREDITS**: Progress; Ruukki

# Design and detailing for deconstruction and reuse

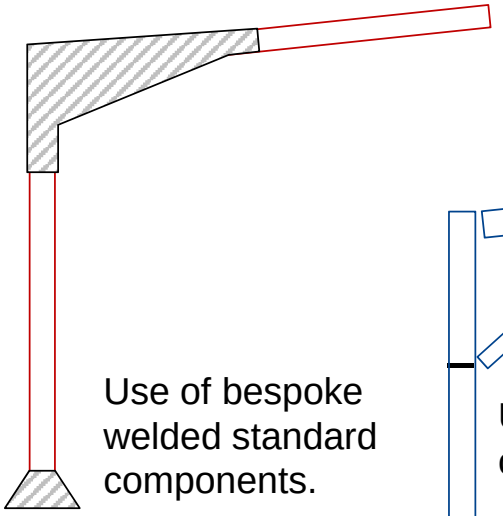
- Detailing principles for reuse:



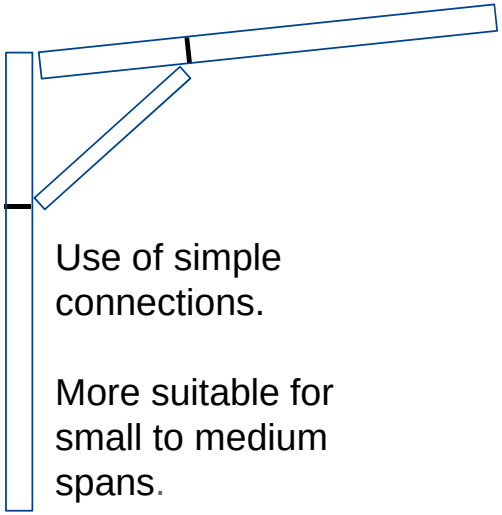
Standard connections with standard bolt arrangements.

Repetitive detailing for a specific span and frame spacing.

Modular design concepts:



Use of bespoke welded standard components.



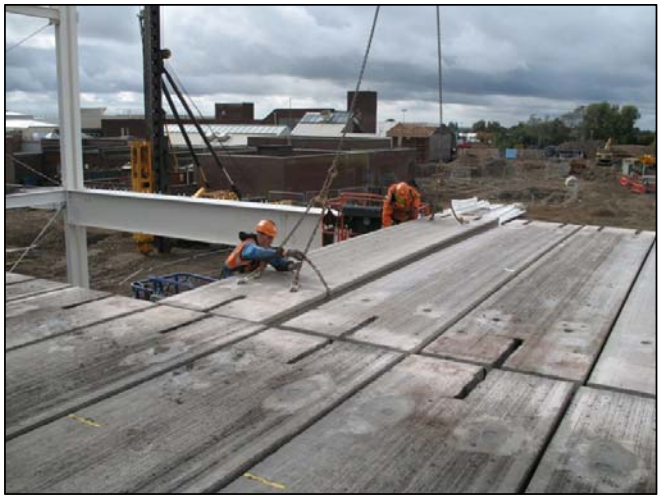
Use of simple connections.

More suitable for small to medium spans.

**FIGURES CREDITS**: Progress; SCI

# Design and detailing for deconstruction and reuse

- Detailing principles for reuse: mezzanines



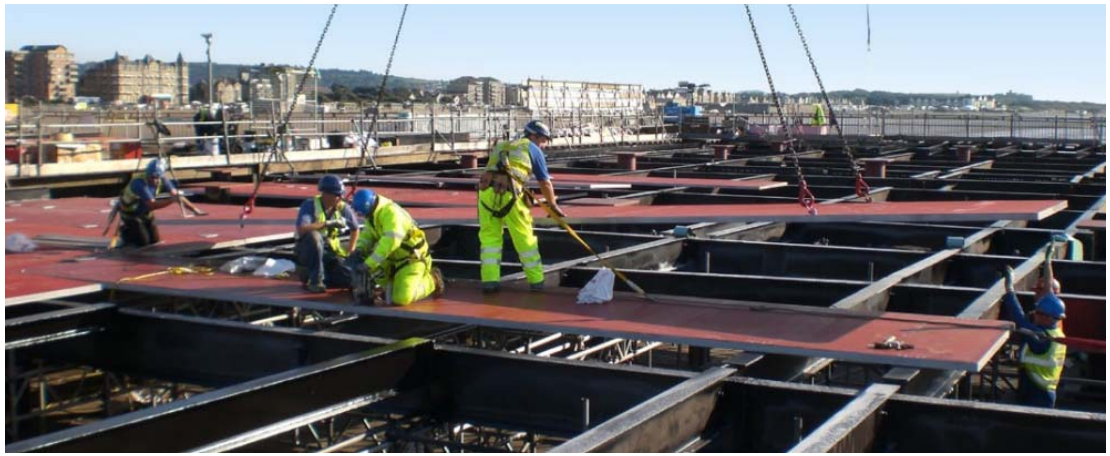
Demountable!

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

# Design and detailing for deconstruction and reuse

- Detailing principles for reuse: mezzanines

Bespoke SPS system



Demountable!

**FIGURES CREDITS**: : https://www.spstechnology.com/

# Design and detailing for deconstruction and reuse

- Detailing principles for reuse: mezzanines

CLT floor system

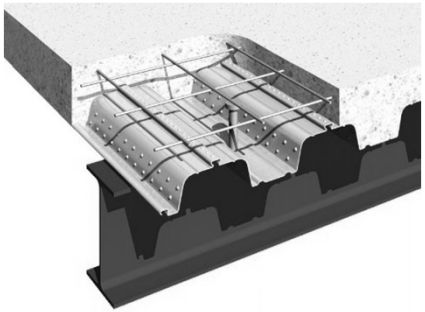
Demountable!

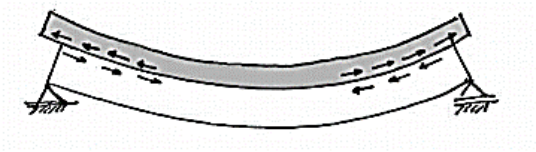
**FIGURES CREDITS**: https://www.kloecknermetalsuk.com

# Design and detailing for deconstruction and reuse

- Detailing principles for reuse: mezzanines

## Demountable composite floor system

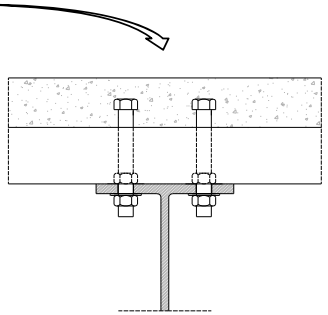





*Welded shear studs*

***vs***

*Bolts*



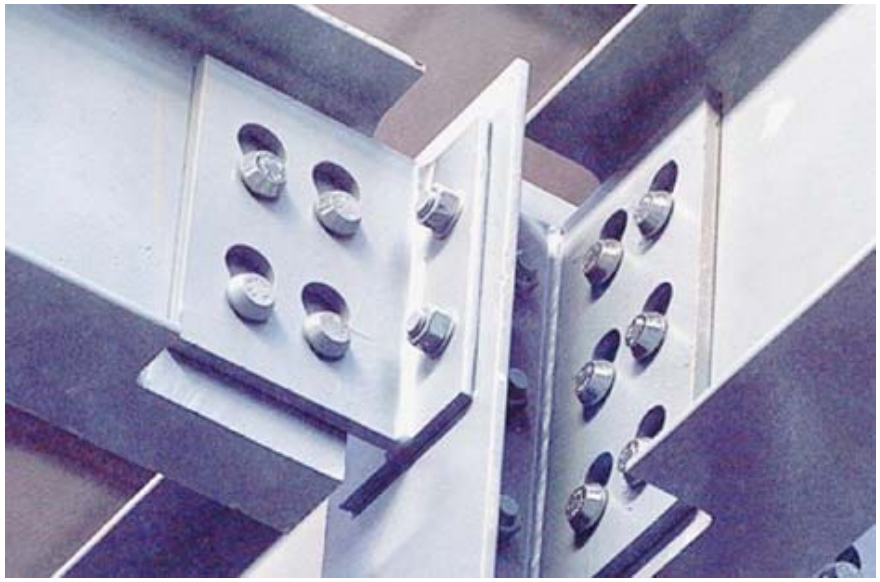
**REDUCE**

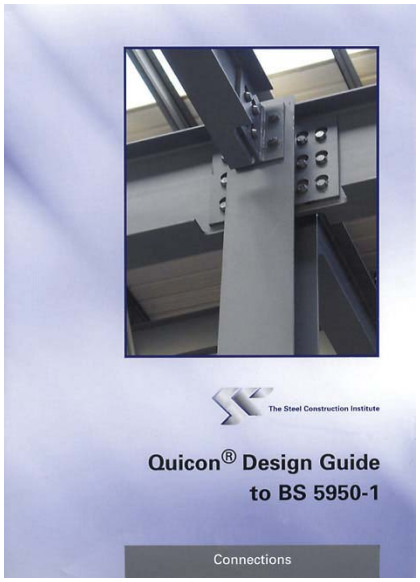
Reuse and demountability using steel structures and the circular economy

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

# Design and detailing for deconstruction and reuse

- Detailing principles for reuse: bespoke connections

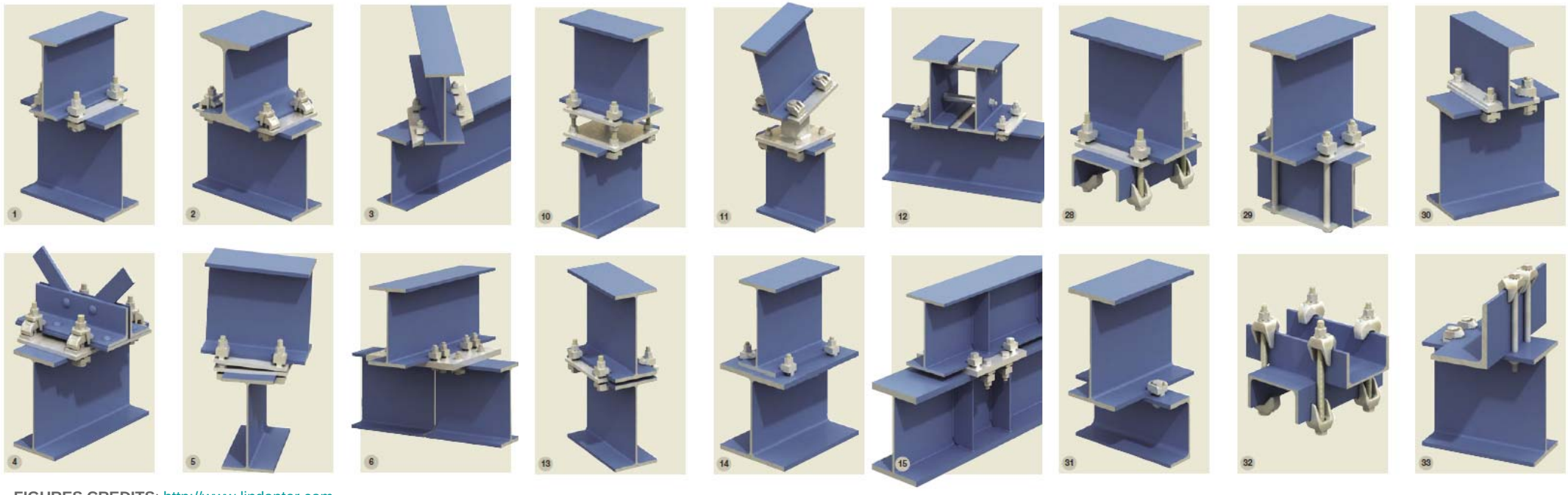





**FIGURES CREDITS**: SCI

# Design and detailing for deconstruction and reuse

- Detailing principles for reuse: bespoke connections




**FIGURES CREDITS**: http://www.lindapter.com

# Design and detailing for deconstruction and reuse

- Detailing principles for reuse: case study

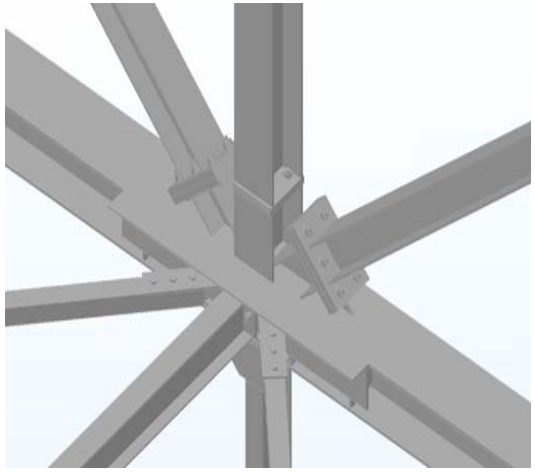


100% circular design; design for deconstruction and reuse; all structural members were designed to be disassembled; cladding with screwing fixings; BIM and Material Passport to enhance future reuse.

**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;

SCI is the leading, independent provider of technical expertise and disseminator of best practice to the steel construction sector. We work in partnership with clients, members and industry peers to help build businesses and provide competitive advantage through the commercial application of our knowledge. We are committed to offering and promoting sustainable and environmentally responsible solutions.