Why single-storey buildings?

Particularly attractive for reclaiming and reusing structural steel:

- Use **dry and lean construction** systems that facilitate the deconstruction process (members are visually exposed);
- Most of the **building layers are easily detachable**;
- Have a **repetitive structural approach**; significant number of members with the same cross section;
- Considerable member length on its original form – **long spans** (members free of major modifications);
- Members are **easily accessible**;
- Are **readily disassembled** and can be **easily reassembled**;
- Each building component is **simple to document**;
Why single-storey buildings?

- Residential
- Buildings - Non-residential - TOTAL
- Buildings - Commercial (retail)
- Buildings - OTHERs
- Buildings - Other (health, education, leisure)
- Power generation
- Industrial
- Bridges

UK 2018

- Industrial buildings (71%)
- Office buildings (20%)
- Multi-storey residential (3%)
- Commercial buildings (6%)

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

Good practices in design for reuse

Reuse of existing steelwork
Scope of steel reuse

- All members to be reused should come from a building structure constructed after **1970**;
- **“Building”** because groups of members can be easily pointed out, based on cross section and structural application (say columns, rafters, bracings), minimizing testing costs;
- **1970 as a benchmark for current Eurocode design** rules and for tests used to specify those rules (buckling curves rely on testes from 1969-1989); material properties similar to the ones we use today;
- **Damage-free building structures**, i.e. structural members that have not been subjected to extreme-event limit state, e.g. large-scale earthquake, fire, fatigue etc.;
- Members to be reused shall **not have areas of accelerated localised corrosion** (> 5% thickness lost);
- Welded/built-up members of members with welded splices: **welds need to be tested** according to the execution standard (EN1090-2);

Most relevant barriers for reuse

1. The reclaimed material satisfies the **performance requirements**, which are the essential mechanical, physical, dimensional, chemical (CEV) and/or other relevant properties of steel to **ensure their adequacy to be used in structural design to EN 1993 (Adequacy assessment)**;

2. The salvaged material meets the **quality requirements** from nominal specifications to **ensure their reliability** to be used in the structural design to EN 1993 (Reliability assessment);

3. Relevant material properties (and fabrication procedures if needed) need to be known and documented to **achieve CE marking (documentation & certification)**;
Product conformity, quality and traceability

To which specific product standard was the material manufactured to? (say EN 10025-2 or EN10210)

- Check for **product conformity, quality and traceability:**

  - If **mill certificate/documentations is available**, it is possible to trace back the reclaimed **steel** and check if:
    - the steel meets the relevant material requirements
    - the steel meets all reliability requirements for design to EN 1993
    Note: this can be the case of a steelwork manufactured by a non-EU standard

  - **Otherwise**, the **steelwork needs to be tested to justify material properties** and show it meets all the **reliability requirements** according to Eurocodes 3 design
    Note: it is expected that the most of steelwork available to be reclaimed will fall into this category.

Good practices in design for reuse

Material performance requirements – CE Marking

- Adequacy assessment for steelwork with no documentation – EN 1090 clause 5.1

<table>
<thead>
<tr>
<th>Item</th>
<th>Property</th>
<th>To be declared</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>Strength (yield and tensile)</td>
<td>Yes</td>
<td>Determined by destructive and non-destructive tests.</td>
</tr>
<tr>
<td>b)</td>
<td>Elongation</td>
<td>Yes</td>
<td>Determined by destructive tests.</td>
</tr>
<tr>
<td>c)</td>
<td>Stress reduction of area requirements (STRA)</td>
<td>If required</td>
<td>Generally not required to be declared.</td>
</tr>
<tr>
<td>d)</td>
<td>Tolerances on dimensions and shape</td>
<td>Yes</td>
<td>Based on dimensional survey.</td>
</tr>
<tr>
<td>e)</td>
<td>Impact strength or toughness</td>
<td>If required</td>
<td>If required, determined by destructive tests.</td>
</tr>
<tr>
<td>f)</td>
<td>Heat treatment delivery condition</td>
<td>Yes</td>
<td>Conservative assumption as the default.</td>
</tr>
<tr>
<td>g)</td>
<td>Through thickness requirements (Z-quality)</td>
<td>If required</td>
<td>Generally not required to be declared.</td>
</tr>
<tr>
<td>h)</td>
<td>Limits on internal discontinuities or cracks in zones to be welded</td>
<td>If required</td>
<td>Generally not required to be declared.</td>
</tr>
</tbody>
</table>

  In addition, if the steel is to be welded, its weldability shall be declared as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Property</th>
<th>To be declared</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>i)</td>
<td>Classification in accordance with the materials grouping system defined in CEN ISO/TR 15608, or</td>
<td>Yes</td>
<td>Not applicable for reclaimed steelwork.</td>
</tr>
<tr>
<td>j)</td>
<td>A maximum limit for the carbon equivalent of the steel, or;</td>
<td>Yes</td>
<td>Maximum to be declared from manufacturer’s test certificates.</td>
</tr>
<tr>
<td>k)</td>
<td>A declaration of its chemical composition in sufficient detail for its carbon equivalent to be calculated</td>
<td></td>
<td>Determined by non-destructive and destructive tests.</td>
</tr>
</tbody>
</table>

Good practices in design for reuse
Classification of reclaimed steel

- Reclaimed steelwork classes

<table>
<thead>
<tr>
<th>Classification</th>
<th>Class A</th>
<th>Class B</th>
<th>Class C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original material test certificates are available and constitute evidence of conformity with the relevant product standard.</td>
<td>Comprehensive testing is applied.</td>
<td>Original material test certificates are not available.</td>
<td></td>
</tr>
<tr>
<td>Minimal testing if required, minimum NDT can be carried out to confirm material provenance.</td>
<td>Reclaimed steel is tested for the adequacy assessment. All required material characteristics are justified according to EN1090-2 section 6.1 shall be justified and declared.</td>
<td>No adequacy assessment.</td>
<td></td>
</tr>
<tr>
<td>Optional minimal testing. Original inspection documents are available and can be traced back to the material and ensure that it meets the relevant product standards.</td>
<td>Material re-certified. Reclaimed steel is tested and it is demonstrated that it meets all reliability requirements.</td>
<td>No reliability assessment.</td>
<td></td>
</tr>
</tbody>
</table>

Good practices in design for reuse

Sampling and material testing – SCI P427

1. **Categorise structural members by groups** (from the same building), e.g. according to size, structural function (beam columns, bracing); 20 tonnes is the maximum group weight – similar to current EN10025 requirement;

2. **100% Non-destructive testing (NDT)** for each group (hardness & spectrometer) in combination with limited Destructive testing (DT);

3. **Sampling for DT**: Regions of reduced stress to minimise the effects of reduced area, e.g. flange tips at beam ends for simply supported beams; detailed testing procedures provided and how to evaluate results;

4. **Destructive testing** for each group to confirm mechanical and chemical properties of reclaimed steel (**Class B**);
   - **CC1 and CC2**: one coupon from each test unit;
   - **CC3**: three coupons from each test unit;

5. **Guidance about how to handle test data provided**, ensuring that appropriate uncertainties from the test procedures are accounted for;
Assessment

Pre-deconstruction audit & assessment for reuse – steel building erected after 1970

Preliminary assessment

Steel can be reused?

No

Send steel elements that can’t be reused to scrap for recycling

Yes

Confirmed or amend reuse scenario

Comprehensive assessment

Steel can be reused?

No

Confirm or amend reuse scenario

Comprehensive assessment

Steel can be reused?

Yes

Limited inspection with optional minimal testing

Check for material documentation to try to implement Class A steel.

Detailed inspection and admissibility for reuse

Testing and design

Adaptability and reliability assessment
Testing protocol / documentation review

Design and reusing/fitting for reuse

Class A steel

SCI P427

Class B steel
Design overview

Partial factors for resistance:

- Reclaimed steel members are expected to perform as intended for new steel, without accounting for any material property changes (these do not deteriorate with time, as long as there is no fatigue); no concerns with cross sectional resistances.

- Although steel members have to meet the geometric tolerances from EN 1090-2, cross-sectional imperfections and member imperfections (mainly due to imprecisions during the geometric assessment) may still affect the member buckling resistance; increase reliability to account for such uncertainty; see SCI P427 for more detail; Values for UK practice are:

\[ \gamma_{M0} = 1.0 \quad \gamma_{M1,mod} = 1.15 \quad \gamma_{M2} = 1.1 \]
Design overview

Partial factors for actions:

- It is common practice to lower the required safety level when evaluating and upgrading an existing structure, as long as the human safety levels are not exceeded → shorter design life.

- If need be, assume a shorter design life for designs with reclaimed steel, say 15-30 years, and compensate for the lower partial factors by a high level of quality management and control/inspection (only recommended for scenarios where the whole structure is relocated or for existing structures)

- For reuse of existing steelwork on new structures, standard reliability levels according to Eurocode 0 are recommended; adjusting members/frames spacing of number of buckling restraints may be used to allow for reclaimed steel reuse;

Good practices in design for reuse

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Design overview

Partial factors for actions:

- **Shorter design life**, say 15 to 30 years (not 50 as usual):
  - 50 years → $\beta = 3.8$
  - 15-30 years → $\beta = 3.3$ → $K_F = 0.90$
  - Minimum for human Safety → $\beta = 2.5$ (ISO 13822)

<table>
<thead>
<tr>
<th>Reuse</th>
<th>Persistent and transient design situations</th>
<th>Permanent actions</th>
<th>Leading variable action</th>
<th>Accompanying variable actions ($i &gt; 1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-30 notional design working life ($K_F = 0.9$)</td>
<td>Eq. 6.10 (not 6.10a and 6.10b)</td>
<td>$1.215O_{k,inf}$, $1.0O_{k,inf}$</td>
<td>$1.35\Psi_{0,i}O_{k,i}$</td>
<td>$1.35\psi_i O_{k,i}$</td>
</tr>
</tbody>
</table>

- Equivalent to say that an **Utilization Factor** of ~1.11, say $1.10$, is acceptable for in situ reuse of existing buildings or for relocations;

Good practices in design for reuse
New buildings: design for reuse

Single storey buildings overview

- Structural systems: portal frames
Single storey buildings overview

- **Structural systems: trussed solutions** (longer spans; heavier loads)

Good practices in design for reuse

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Single storey buildings overview

- **SCI Publications: best practice for portals and connections**

Good practices in design for reuse
Key concepts for steel reuse

- Standardization (building geometry, detailing, etc.)
- Reduce number of interfaces (number of building layers)
- Reduce number of components (members; connections)
- Design for adaptability and relocation
- Design and detailing for construction, deconstruction and transportation

Good practices in design for reuse

Reduce interfaces

- Avoid secondary structure (if possible) – long span cladding

Reduce number of different components and materials

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

Good practices in design for reuse

Design for adaptability and relocation

- Environmental loads: snow

<table>
<thead>
<tr>
<th>Country</th>
<th>(\sigma_0) (kN/m²)</th>
<th>Country average(^a)</th>
<th>Min. European value</th>
<th>Class</th>
</tr>
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<tbody>
<tr>
<td>Finland</td>
<td>2.00</td>
<td>2.75</td>
<td>2.00</td>
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</tr>
<tr>
<td>France</td>
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<td>0.70</td>
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<td>Ireland</td>
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<td>Italy</td>
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<td>1.00</td>
<td>1.00</td>
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<tr>
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<td>S3</td>
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<td>0.40</td>
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<tr>
<td>Romania</td>
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<td>2.00</td>
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<td>0.45</td>
<td>0.65</td>
<td>0.70</td>
<td>S3</td>
</tr>
</tbody>
</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

Good practices in design for reuse
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</th>
<th>Mean V_{b,0,class} [m/s]</th>
<th>q_{b,0,class} [kN/m²]</th>
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<tr>
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<td>W4</td>
<td>23</td>
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<td>Belarus</td>
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<td>22.0</td>
<td>W4</td>
<td>23</td>
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</tr>
<tr>
<td>Belgium</td>
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<td>26.0</td>
<td>24.0</td>
<td>W3</td>
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<td>&gt; 28</td>
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<td>&gt; 28</td>
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<td>25.0</td>
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<td>21.0</td>
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<tr>
<td>Finland</td>
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<td>&gt; 28</td>
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<td>Latvia</td>
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<td>Romania</td>
<td>27.0</td>
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<td>31</td>
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<td>Russia</td>
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<td>25*</td>
<td>W3</td>
<td>26</td>
<td>0.78</td>
</tr>
</tbody>
</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

Design for adaptability and relocation

- Environmental loads: snow

<table>
<thead>
<tr>
<th>Country</th>
<th>s_{e} (kN/m²)</th>
<th>Country average(1)</th>
<th>Min. European value(1)</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland</td>
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<td>2.75</td>
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</tr>
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<td>France</td>
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<td>0.45</td>
<td>0.65</td>
<td>0.70</td>
<td>S2</td>
</tr>
</tbody>
</table>

(1) Assuming the average altitude for the less critical zone of the country
(2) Assuming the average altitude for the zone representing most area of the country
Design for adaptability and relocation

- **Design outcome:**
  - Standard section sizes (avoid tapered/welded sections)
  - Spare capacity may be available; document the spare capacity

- **Design according to Eurocode 3:**
  - Elastic global analysis is recommended
  - SLS stress checks to be performed
  - $\gamma_{M1,mod} = 1.15 \times \gamma_{M1}$ (allowing for future relocations)
  - $\gamma_M0$ and $\gamma_M2$: values from the appropriate NA to be used

Design and detailing for deconstruction and reuse

- **Detailing principles for reuse:**
  - Reduce the number of connections and connectors (simple connections);
  - Use bolts/screws instead of other solutions (specially with cladding);
    reduce welding;
  - Detail for easy access of connections;
  - Repetitive detailing (modular/standard);
  - Avoid permanent attachments (floor systems are critical).
Design and detailing for deconstruction and reuse

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

  ![Diagram of a bolted haunch](https://www.northlincsstructures.com/)

  Alternative to use intermittent welds between rafter and haunch.

  FIGURES CREDITS: [Progress; Ruukki](https://www.northlincsstructures.com/)

**Good practices in design for reuse**

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**Design and detailing for deconstruction and reuse**

- **Detailing principles for reuse: standard (expendable) components**

  - Fabricated haunch segments (2no) of length $L_h = 0.1L$ to $0.12L$, where $L$ is the overall span of the portal frame.
  - Fabricated apex segment (1no) of length $L_a = 0.1L$.
  - Beams (2no) of length $L_b = 20h_b$, where $h_b$ is the beam depth.
  - Columns (2no) of overall length $L_c = 20h_c$, where $h_c$ is the column depth.

  \[
  L = 2 \left( L_a + L_h \right) \cos \theta + L_h
  \]

  where $\theta$ is the slope of the rafter to the horizontal = 6°.

**FIGURES CREDITS:** Progress; Ruukki

**Good practices in design for reuse**
Design and detailing for deconstruction and reuse

- Detailing principles for reuse: standard components

  Rectangular modules to facilitate future reuse on different applications

  [FIGURES CREDITS: Progress, Ruukki]

Good practices in design for reuse

Design and detailing for deconstruction and reuse

- Detailing principles for reuse: mezzanines

  CLT floor system

  Precast concrete units

  [FIGURES CREDITS: https://www.kloecknermetalsuk.com]

Good practices in design for reuse
Design and detailing for deconstruction and reuse

- **Detailing principles for reuse: mezzanines**
  
  Demountable composite floor system

  ![Welded shear studs vs. Bolts](https://www.tatasteelconstruction.com)

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

  Good practices in design for reuse

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Design and detailing for deconstruction and reuse

- **Detailing principles for reuse: design for deconstruction & reuse**

  ![Quicon system](https://www.lindapter.com)

  ![Hollo Bolts and Blind Bolts](https://portal.steel-sci.com/shop.html?sku=P428)

  ![Cleated connections](https://portal.steel-sci.com/shop.html?sku=P428)

  ![Hot rolled bolted purlins](https://portal.steel-sci.com/shop.html?sku=P428)

  ![Clamped connections for purlins](https://portal.steel-sci.com/shop.html?sku=P428)

  **FIGURES CREDITS:** SCI; [http://www.lindapter.com](http://www.lindapter.com) (right)

  Good practices in design for reuse
Design and detailing for deconstruction and reuse

- Detailing principles for reuse: long span cladding cladding

**Figure Credits:** SCI, Ruukki, RWTH

Good practices in design for reuse

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Design and detailing for deconstruction and reuse

- Detailing principles for reuse: long span cladding cladding

**Figure Credits:** Ruukki

Good practices in design for reuse
Building Information Modelling - BIM

Lever of Information need (EN ISO 19650); material passport

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context</td>
<td>For each life cycle: the context/time where/when the structural member has been used.</td>
</tr>
<tr>
<td>Project actors</td>
<td>For each life cycle: actors involved from relevant disciplines;</td>
</tr>
<tr>
<td>Purpose</td>
<td>For each life cycle: the purpose of the member;</td>
</tr>
<tr>
<td>Identification</td>
<td>For each life cycle: the identity of the structural steel member and its traceability to the digital information;</td>
</tr>
<tr>
<td>Structural design</td>
<td>For each life cycle: relevant design conditions and design outcome for the building and element;</td>
</tr>
<tr>
<td>Fabrication &amp; erection</td>
<td>For each life cycle: records from fabrication and procedures and the quality of those procedures;</td>
</tr>
<tr>
<td>Provenance &amp; characteristics</td>
<td>Full traceability of the member material, including records and certificates;</td>
</tr>
</tbody>
</table>

Lever of Information need:

Permanent component tracking: bar codes, QR codes or RFID

Example of possible QR code for component tracking:

<table>
<thead>
<tr>
<th>Type: Reclaimed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin: UK, Ascot</td>
</tr>
<tr>
<td>Steel Age: 1975</td>
</tr>
<tr>
<td>ID: 010</td>
</tr>
<tr>
<td>Fabricator: Name</td>
</tr>
<tr>
<td>Designer: Name</td>
</tr>
<tr>
<td>Stockholder: Name</td>
</tr>
<tr>
<td>Stockholder Certificate: AA001</td>
</tr>
<tr>
<td>Steel Designation: S355JR</td>
</tr>
<tr>
<td>Material Standard: EN1090-2 cl. 5.1</td>
</tr>
<tr>
<td>Design Yield (MPa): 355</td>
</tr>
<tr>
<td>Design Tensile (MPa): 470</td>
</tr>
<tr>
<td>Measured Yield (MPa): 405</td>
</tr>
<tr>
<td>Measured Tensile (MPa): 520</td>
</tr>
<tr>
<td>Measured Elongation (%): 23</td>
</tr>
<tr>
<td>Measured CEV: 0.46</td>
</tr>
<tr>
<td>Profile: IPE500</td>
</tr>
<tr>
<td>Dimensions: EN 10365</td>
</tr>
<tr>
<td>Tolerances: EN 10034</td>
</tr>
</tbody>
</table>

Good practices in design for reuse

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 – Reuse of existing steelwork

1. Steel buildings, in particular single storey buildings, can be easily dismantled and their elements reclaimed; large quantities of the same cross section with a considerable length free of modifications;
2. Steel is a high reusable material; properties don’t deteriorate over time; there are opportunities for re-fabricating reclaimed steel as done for new steel;
3. Most issues can be overcome: justify material properties; documentation to CE marking
4. Design to EN 1993:
   • Restriction to elastic global analysis; no application to primary structural systems for seismic design, unless the structure is classified as low dissipative structure;
   • Reliability: use $\gamma_{M1,\text{mod}}=1.15$ and possibility of using lower partial factors for actions for existing building or relocations;

Good practices in design for reuse

<table>
<thead>
<tr>
<th>Property/procedure</th>
<th>Reclaimed steelwork class</th>
<th>Class B (no documentation)</th>
<th>Class C (no assessment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test programme</td>
<td>Class A (with documentation)</td>
<td>Comprehensive</td>
<td>No testing</td>
</tr>
<tr>
<td>Adequacy assessment</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Reliability assessment</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>% of NDT</td>
<td>10% (randomly) – with a minimum of 3 tests per group</td>
<td>100%</td>
<td>-</td>
</tr>
<tr>
<td>Minimum number of DT</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Geometric tolerances</td>
<td>Visual inspection or assessed if steelwork was previously erected</td>
<td>Assessed</td>
<td>Assessed</td>
</tr>
<tr>
<td>CE marking</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Global analysis</td>
<td>Elastic</td>
<td>Elastic</td>
<td>Elastic</td>
</tr>
<tr>
<td>Section analysis</td>
<td>Elastic/plastic</td>
<td>Elastic/plastic</td>
<td>Elastic/plastic</td>
</tr>
<tr>
<td>$k_{\text{sw}}$</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>$k_{\text{sw},1}$</td>
<td>1.00/1.151-2</td>
<td>1.152</td>
<td>1.15$^{2}$</td>
</tr>
<tr>
<td>$k_{\text{sw},2}$</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>CC1 structures</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CC2 structures</td>
<td>Yes</td>
<td>Yes</td>
<td>Not recommended</td>
</tr>
<tr>
<td>CC3 structures</td>
<td>Yes</td>
<td>Yes</td>
<td>Not recommended</td>
</tr>
</tbody>
</table>

1 – For the cases where the steelwork was never erected the value of $k_{\gamma_{M1}} = 1$ can be used.
2 – For in-situ reuse of steelwork erected after 1970, the conservative value of $\gamma_{\text{M1}}$ is not recommended (i.e. $k_{\gamma_{\text{M1}}} = 1$).
NDT – Non-destructive testing; DT – Destructive testing; CC – Consequence class according to EN 1990; $k_{\gamma_{M1}}$ – The material partial factor is adjusted with a factor $k_{\gamma_{M1}}$. $\gamma_{\text{M1,mod}}$ is obtained by $K_{\gamma_{M1}} \times \gamma_{\text{M1}}$, where $\gamma_{\text{M1}}$ shall be obtained from EN 1993-1-1 or the National Annex for use in a country.

The $k_{\gamma_{M1}}$ values can be defined for different regions/countries.

Good practices in design for reuse
Final remarks – Design for reuse

1. Small improvements to current practice for single storey buildings will have a large impact on the construction market;
2. Seek standardization as much as possible;
3. Facilitate access for all connections;
4. Design for deconstruction, not only construction;
5. Avoid permeant attachment between components;
6. Reduce number or layers, materials and components;
7. Design for relocation/adaptability, not for a single purpose and location;
8. Designers to specify allowable structural capacity to facilitate reuse;
9. Stress check, global elastic analysis and $\gamma_{M1,mod} = 1.15$.

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.