



Reusability of existing structural steel

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Why single-storey buildings?

Particularly attractive for reclaiming and reusing structural steel:

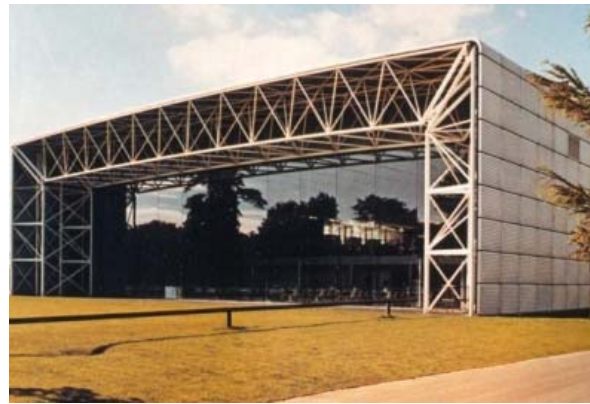
- Typically **lack fire proofing**
- Use **dry and lean construction** systems that facilitate the deconstruction system (structural members visually exposed)
- Have a **repetitive structural** approach, allowing good standardisation possibilities
- Are easily accessible at relatively safe working heights
- Are **readily disassembled** and can be **easily reassembled**
- Each building component is simple to **document**



Structural level of reuse



Constituent product (individual members)



Structural component (truss system, sandwich panel)



Whole structure or part of it



Scope of physical reuse of steel

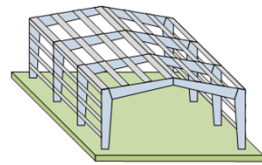
- All members to be reused should come from a building structure (never from bridge structures, in order to preclude fatigue loading history) constructed after **1970**
- **Damage-free building structures**, i.e. structural members that have not been subjected to extreme-event limit state, e.g. large-scale earthquake, fire, fatigue etc.
- Members to be reused shall not have areas of accelerated localised corrosion or show evidence of localised section loss (> 5% thickness)
- For members to be reused, they must be recovered in as much of its original intact length as possible for design freedom (design with reclaimed steel may require some modification to the overall design to make best use of available materials)



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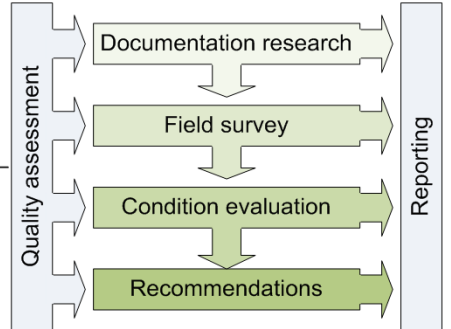
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Single-storey building erected after 1970

Pre-deconstruction audit



Steel can be reused?

No

Yes

Demolish building and send steel to scrap for recycling

Deconstruction, labelling and batching




Storage, transportation, reconditioning

Design

- Reclaimed steel usually comes with a protective coating
- Old coatings may contain banned chemicals (H&S)
- Test existing coating to determine chemical properties
- Coatings may be retained but may not be compatible with modern paints/primers

Most relevant barriers for design

- The reclaimed material satisfies the performance requirements, which are the essential mechanical, physical, dimensional, and/or other relevant properties of steel materials to ensure their adequacy to be used in structural design to EN 1993
- The salvaged material meets the quality requirements from nominal specifications to ensure their reliability to be used in the structural design to EN 1993
- Structures made from reclaimed steel have continued integrity

| | |
|---|-----------------------------|
|  | |
| 01234 | |
| Any Co Ltd, PO Box 21, B-1050 | |
| 03 | |
| 01234-CPD-00234 | |
| EN 10025-1 | |
| Hot rolled structural steel products. | |
| Intended uses: Building constructions or civil engineering. | |
| Tolerances on dimensions and shape: Plate EN 10029 Class A | |
| Elongation | |
| Tensile strength | |
| Yield strength | : Steel S355J0 – EN 10025-2 |
| Impact strength | |
| Weldability | |
| Durability: No performance determined | |
| Regulated substance: No performance determined | |

Classification of reclaimed steel (1)

1. Material performance requirements (Adequacy assessment)

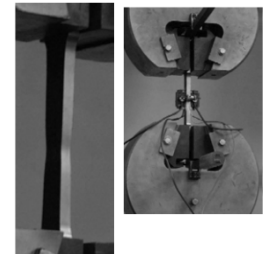
| Item | Property | To be declared | Procedure |
|------|--|----------------|---|
| a) | Strength (yield and tensile) | Yes | Determined by destructive and non-destructive tests. |
| b) | Elongation | Yes | Determined by destructive tests. |
| c) | Stress reduction of area requirements (STRA) | If required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

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

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



Hardness testing



Tensile testing



XRF spectrometer
(Chemical analysis)

Classification of reclaimed steel (2)

2. Quality assurance requirements (Reliability assessment)

To which specific product standard was the material manufactured to?

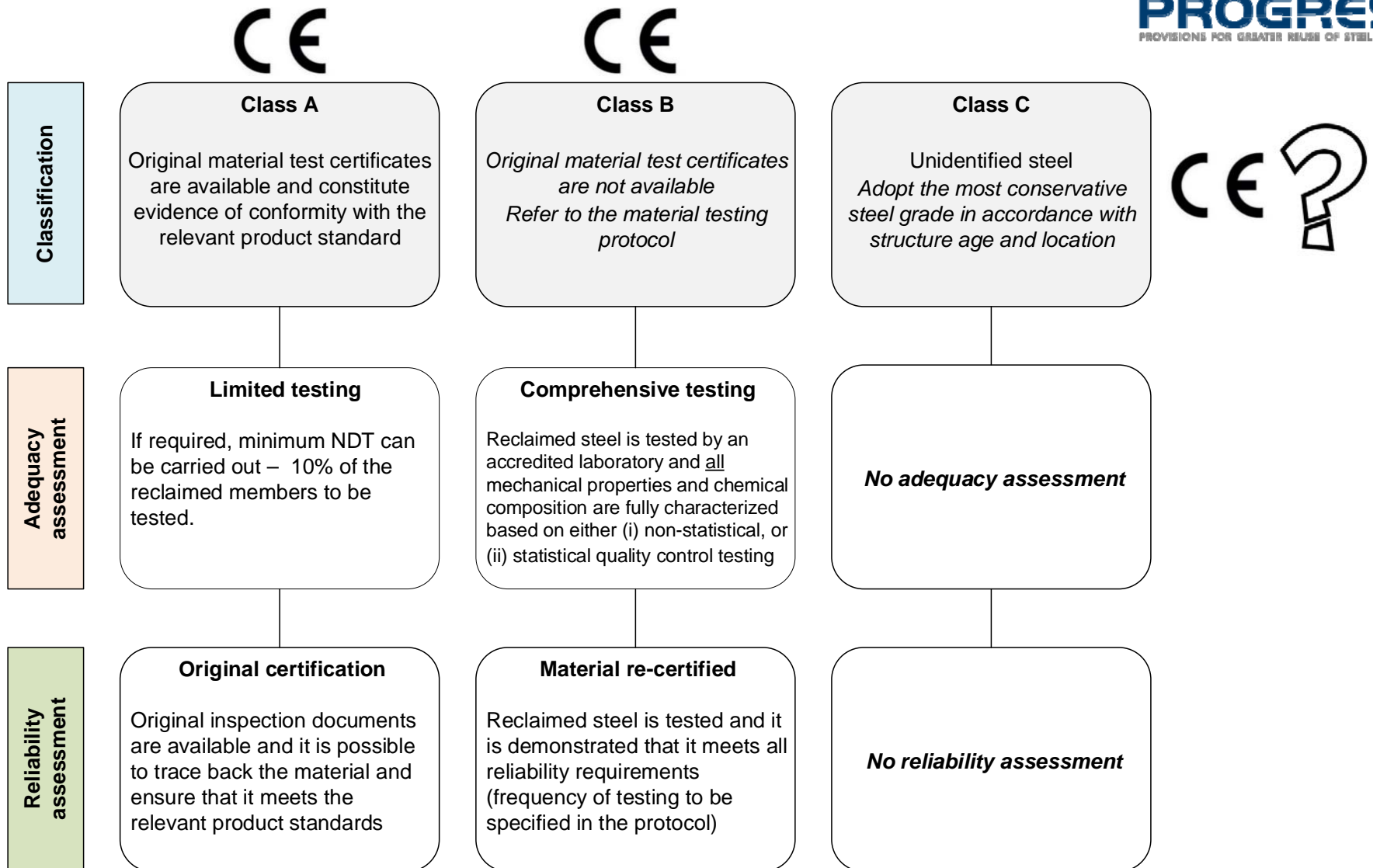
- Check for product conformity, quality and traceability
 - If mill certificates are available, it is possible to trace back the reclaimed steel and check
 - the steel meets the relevant material specifications
 - the steel meets all reliability requirements for design to EN 1993
 - Otherwise, test the steel and show it meets all the reliability requirements:

Classification of reclaimed steel (3)

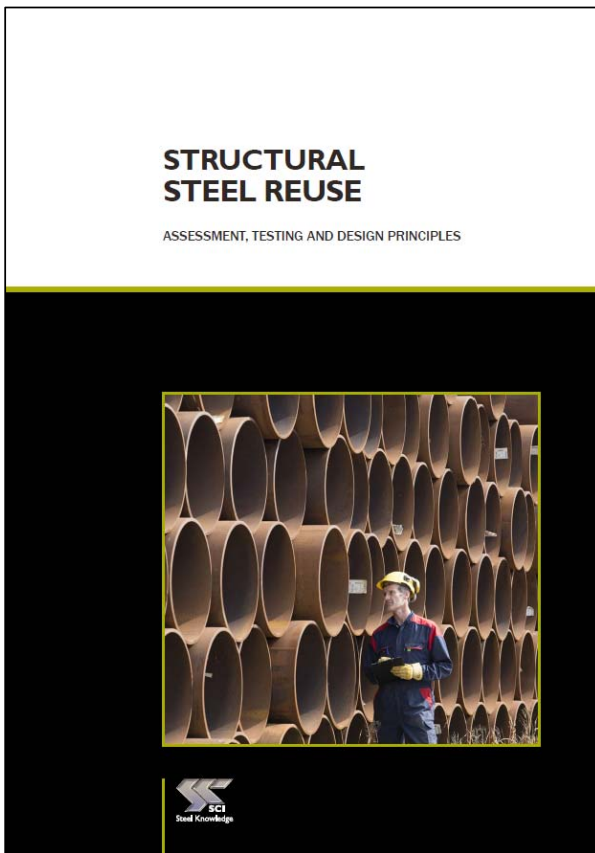
2. Quality assurance requirements (Reliability assessment) (cont'd)

- Use guidelines from RFCS *Safebricktile* project

| Steel grade | Yield strength (N/mm ²) | | Ultimate strength (N/mm ²) | | | Standard |
|-------------|-------------------------------------|------|--|------|----------------------------|---------------------------|
| | Minimum | Mean | Minimum | Mean | $f_y / f_{u \text{ mean}}$ | |
| S235 | 267 | 293 | 397 | 432 | 1.47 | EN 10025-2; EN 10219 |
| S275 | 313 | 343 | 452 | 492 | 1.43 | EN 10025-2; EN 10219 |
| S355 | 391 | 426 | 505 | 540 | 1.26 | EN 10025-2; EN 10219 |
| S460 | 490 | 529 | 560 | 594 | 1.12 | EN 10025-3/4; EN 10219 |



Sampling and material testing (1)



1. Sampling

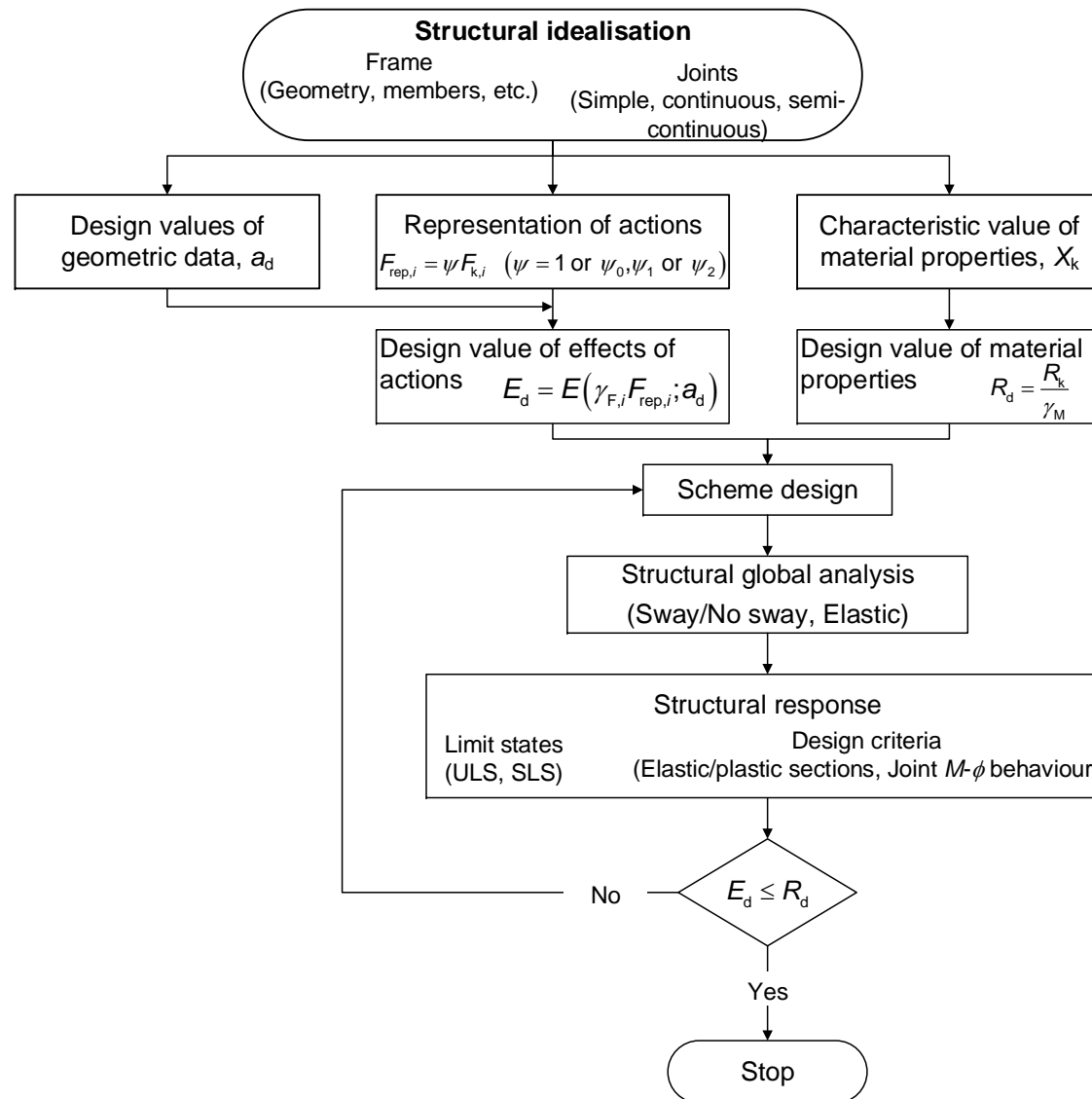
- Sampling should take place in regions of reduced stress to minimise the effects of reduced area, e.g. flange tips at beam ends for simply supported beams
- Categorise structural members by groups, e.g. according to size, structural function
- Select samples of members for destructive testing (20 tonnes)

2. Material testing: specify mechanical and chemical properties of individual members (class B)

- Frequency of testing: “lot” or “cast” – products from the same “lot” or “cast” can be treated as a test unit
 - Usual testing (CC1 and CC2): one strength coupon from each test unit
 - Comprehensive testing (CC3): three strength coupons from each test unit

Sampling and material testing (2)

| | Reclaimed steel work | | |
|---|----------------------|--|-----------------------------|
| | Class A | Class B | Class C |
| Programme of material testing | Optional | Mandatory | — |
| Non-destructive testing | 10% (randomly) | 100% | (CEV if steel to be welded) |
| Destructive testing (per test unit, 20 tonnes) | — | <ul style="list-style-type: none"> • 1 tensile coupon, CC1&CC2 • 3 tensile coupons randomly removed, CC3 | — |



Design overview (1)

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)
- Although steel members have to meet the geometric tolerances from EN 1090-2, cross-sectional imperfections may affect the member buckling resistance (therefore, change relevant γ_M or the buckling curve)

$$\gamma_{M0} = 1.0 \quad \gamma_{M1,mod} = \mathbf{1.15} \quad \gamma_{M2} = 1.1$$

Design overview (2)

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 30 years, and compensate for a slight lower partial factor by a high level of quality management and control (this may be more critical in a scenario that the whole structure is reused)

Design overview (3)

Partial factors for actions:

| CC/RC | Persistent and transient design situations | Permanent actions | | Leading variable action | Accompanying variable actions ($i > 1$) |
|-------------------------|--|-------------------------------|-------------------|---------------------------|---|
| | | Unfavourable | Favourable | | |
| 1 ($K_{FI} = 0.9$) | Eq. 6.10 | $1.2 G_{k,j,sup}$ | $1.0 G_{k,j,inf}$ | $1.35 Q_{k,1}$ | $1.35 \psi_{0,i} Q_{k,l}$ |
| | Eq. 6.10a | $1.2 G_{k,j,sup}$ | $1.0 G_{k,j,inf}$ | $1.35 \psi_{0,1} Q_{k,1}$ | $1.35 \psi_{0,i} Q_{k,l}$ |
| | Eq. 6.10b | $\xi \times 1.2 G_{k,j,sup}$ | $1.0 G_{k,j,inf}$ | $1.35 Q_{k,1}$ | $1.35 \psi_{0,i} Q_{k,l}$ |
| 2 ($K_{FI} = 1.0$) | Eq. 6.10 | $1.35 G_{k,j,sup}$ | $1.0 G_{k,j,inf}$ | $1.5 Q_{k,1}$ | $1.5 \psi_{0,i} Q_{k,l}$ |
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| 3 ($K_{FI} = 1.1$) | Eq. 6.10 | $1.5 G_{k,j,sup}$ | $1.0 G_{k,j,inf}$ | $1.65 Q_{k,1}$ | $1.65 \psi_{0,i} Q_{k,l}$ |
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Final remarks

1. Steel buildings can be dismantled like a kit of parts at the end of their life.
2. Steel is a high reuse material. There are opportunities for re-fabricating reclaimed steel.
3. Most issues can be overcome:
 - Material integrity
 - Material properties
 - CE marking
4. Design to EN 1993:
 - Restriction to elastic global analysis
 - Reliability: modify γ_{M1} and possibility of using lower partial factors for actions



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