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Corus Construction & Industrial

Steel the safe solution

Realising steel's potential

This brochure is written for steelwork designers to acquaint them with the essentials of how steel erection interfaces with design. It identifies key issues that ensure safe site erection.

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Acknowledgement

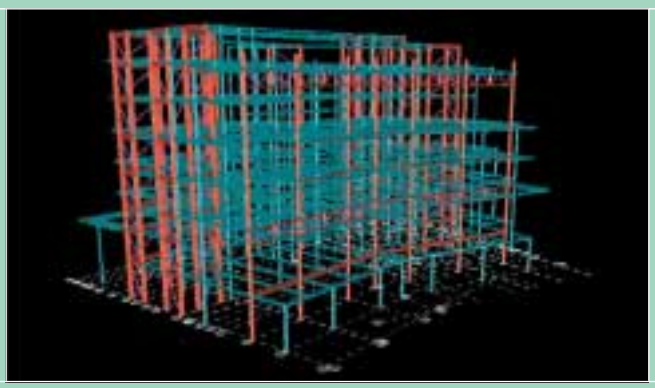
This publication is based on the paper 'Health & Safety and Erection' by Dr Roger Pope (Roger Pope Associates), Technical Consultant to the British Constructional Steelwork Association, that forms part of the Corus / SCI 'Steel in Construction' seminars.

Far right:
Trial erection aids 3D fit-up
Right:
The virtual reality model aids erection planning
Below:
Steelwork is standardised and prefabricated off site

The safe choice
For safety steel is the natural choice.

Designers are obliged to consider whether their schemes can be safely built. The choice of building materials has a major influence on what is achievable. When undertaking structural design, steel construction can be considered the most safe solution. It is inherently safer than alternative structural solutions for the following combination of reasons:

- Steelwork is pre-engineered in a way that makes pre-planning of operations easier and more certain.
- A virtual reality model of the steel frame can be built in three dimensions in the computer thus facilitating detailed planning of the erection procedure.
- Steelwork is prefabricated offsite, which makes it accurate and less liable to errors that would generate site hazards.



- Steelwork is standardised in a way that leads to repetition of site tasks and hence greater certainty of safe practice.
- Steelwork provides a framed solution that can be self-stable with immediate availability of the full strength of the material.
- Safe access to working positions can immediately be gained using already erected parts of the steel structure.
- Where necessary, steelwork can be trial erected to establish the best method of safe erection on site.
- Steelwork is easily modified if necessary during maintenance or refurbishment.
- Steelwork is readily demountable should demolition be necessary.

Default solutions

The basic concepts behind steelwork erection are easily understood in terms of default solutions.

For single storey construction:
- Start by erecting a braced bay to provide stability
- Use a mobile telescopic crane that can traverse the site
- Gain access to working positions using mobile elevating work platforms – the MEWP or ‘cherry picker’

For multi-storey construction:
- Use a stair core to provide stability
- Lift and place steelwork with the tower crane
- Gain access from metal decking or precast planks already placed on the floor below

When installing the metal decking or precast planks:
- Ensure the steel frame is aligned and stable to receive decking or planks
- Integrate the sequence of installation with the progress of steelwork erection
- Provide nets and edge barriers for general protection

The designer has obligations concerning the three safety objectives that underpin these default solutions:

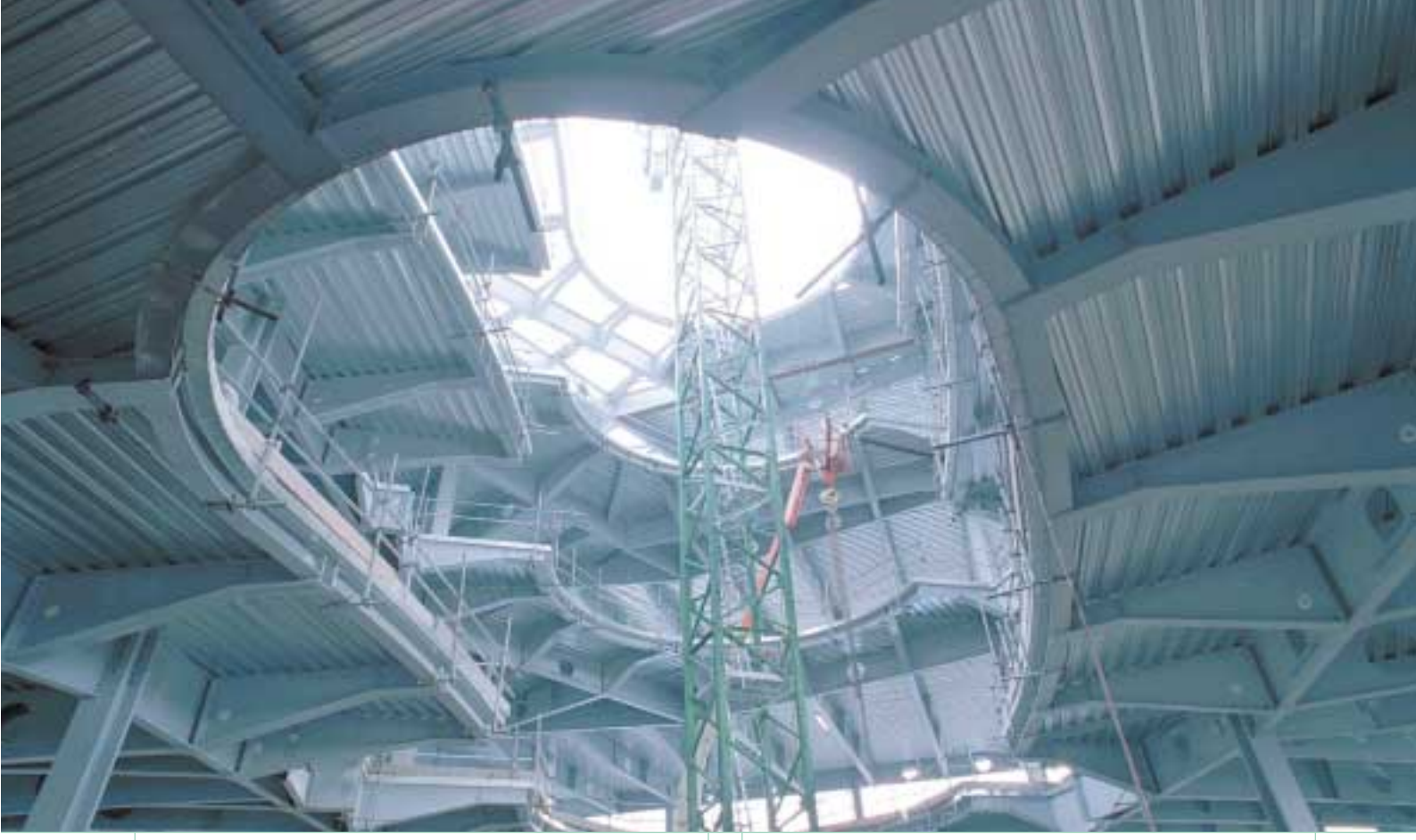
How can stability of the part-erected structure be maintained?
- This the designer MUST address as errors in ensuring that the steelwork contractor has a clear understanding of the designer’s stability concept would generally rebound on the designer.

What craneage is needed for lifting and placing the steelwork?
- Whilst the designer would not ultimately select the crane, clear assumptions on lifting capabilities should underlie the choices made in the scheme design (eg about splice positions and hence piece weights).

How can safe access to and at working positions be arranged?
- Often the designer would have no more than a general awareness about access provision – enough to confirm that the general assumptions in the default solutions are valid.

Far left:
Decking showing nets and edge protection
Left:
Multi-storey construction showing stair core, tower crane and metal decking

Above:
Single storey construction showing braced bay, telescopic crane and MEWP
Below:
How is the stability maintained?



Above:
Where can the crane be placed?
Below:
How can access be provided?

Hazard, risk and competence

Proper management by a competent steelwork contractor will ensure that risks are removed or controlled.

It is a common but unfounded view that steel erection is risky. Statistics show that neither steel erection nor falls from steel are near the top of the worst offences lists.

The hazards arise from three of steel construction's inherent characteristics:

- Large, heavy components must be lifted and placed into position
- The structure can be unstable in the part-erected condition
- Each project is different

To ensure that these hazards are safely dealt with, the risk assessment at design stage should conclude that a competent steelwork contractor must be chosen. To assist the choice, the Register of Qualified Steelwork Contractors [RQSC] classifies all its contractors against two criteria:

- For what categories of work (eg high rise buildings) does the contractor have a proven track record?
- What is the recommended maximum size of contract that can be safely resourced and managed by the contractor?

Right:
Large, heavy components
Below:
RQSC Classifications

Buildings Scheme
A – All forms of steelwork (C-N inclusive)
C – Heavy industrial plant structures
D – High rise buildings
E – Large span portals
F – Medium / small span portals and medium rise buildings
H – Large span trusswork
J – Major tubular steelwork
K – Towers
L – Architectural metalwork
M – Frames for machinery, supports for conveyors, ladders and catwalks
N – Grandstands and stadia
S – Small fabrications

Bridgeworks Scheme
FG – Footbridges and sign gantries
PT – Plate girders (>900mm deep), trusswork (>20m long)
BA – Stiffened complex platework in decks, box girders, arch boxes
CM – Cable-stayed bridges, suspension bridges, other major structures (>100m)
MB – Moving bridges
RF – Bridge refurbishment
X – Unclassified

RQSC

The categories of work used by RQSC are general and the precise scope of work demanded by each project will differ. Thus, the first priority for competent contractors is to ensure that the scope of work can be safely undertaken with the resources of know-how, manpower, equipment and finance at their disposal. For this purpose two checklists of competences (see pages 10-11) have been prepared:

- Normal steel construction activities that steelwork contractors should be competent to undertake with their own personnel
- Special activities that steelwork contractors should be able to manage using specialist subcontractors as necessary

Left:
Placing precast flooring is in the Normal scope of work
Right:
Large scale site assembly is in the Special scope of work

Having checked at tender stage what a project demands, steelwork contractors should warn designers if they are unable to undertake any of the normal activities, and designers should check beforehand whether a steelwork contractor is willing to undertake any of the special activities.

RQSC – Normal scope of competence

Normal steel construction activities that steelwork contractors should be competent to undertake with their own personnel.

1. Slinging, handling, lifting and positioning steelwork.
   - Steelwork includes fabricated hot rolled and cold-formed steel sections.
2. Aligning, levelling and plumbing steel frames.
3. Securing and bolting up steelwork.
4. Operating the necessary mobile elevating work platforms [MEWPs]
5. Setting out.
6. Acting as a banksman.
7. Caring for and use of lifting tackle:
   - Purpose-made lifting tackle, such as lifting beams and bracings to stabilise frameworks during rearing and lifting, may need to have their capacity proof tested.
8. Use of jacks.
9. Welding and cutting:
   - The use of burning equipment and welding equipment (with or without pre-heat) is 'hot work' and particular fire precautions are always needed.
   - The Commentary on the NSSSBC lists factors to be considered when undertaking site welding, of which the six listed below relate to safe practice:
   - Floor by floor completion to give good working areas.
   - Use of light easily erected working platforms.
   - Protection from inclement weather.
   - Careful detailing to ensure downhand welding.
   - Use of details and techniques to avoid the necessity for excessive pre-heating.
   - Provision of temporary means of support and stability until welding is complete.
10. Drilling or reaming using power tools:
    - The use of power tools operated by electricity should follow the advice given in the HSE's PM series of guidance notes.
11. Installing HSFG bolts:
    - If preloaded bolts - previously termed HSFG bolts - are used, there is a possibility for the bolt to break during tightening and for part of the bolt to shoot off (eg when the threads are in poor condition). Personnel should be careful not to stand in line with the bolts or in areas where the parts could fall.
12. Painting:
    - Site treatment can include site blasting as well as site painting. Additional precautions, such as the regular examination of air receivers, may be needed when using equipment powered by compressed air.
    - Additional precautions may be needed where paint coatings are heated by burning or welding operations.
13. Erection of metalwork items such as catwalks or metal flooring
    - The erection of all metalwork items - including railings, balustrades, stairs, walkways, ladders, catwalks, steel flooring of open-mesh or plate - may involve the need to manhandle items.
14. Placing precast flooring:
    - Whilst it is a normal steel construction activity to install precast planks on steel frameworks, the erection of precast concrete frameworks generally is not.
    - The placing of precast planks may result in large point loads, and precautions are needed to ensure that the local and general stability of the part-erected framework is not jeopardised.
    - The sequence of placing the planks needs to be carefully planned to preserve access for lifting and positioning subsequent items.
15. Drilling concrete.
16. Installing expanding/chemical anchors.
17. Guiding site visitors.
18. Refurbishment work:
    - The retention of elements of the existing building usually interferes with the provision of craneage for lifting and positioning operations. Hence there is a greater likelihood of manual handling for positioning.
    - Construction hoists are commonly provided for vertical lifts, and it can be hazardous if long components need to be moved in hoists.
    - The route selected for lateral movement needs to take account of the strength of the existing structure and its stability under surge induced by braking the movement of heavy components.
19. Work on a contoured site:
    - Dangers associated with operating cranes over contoured ground - especially for crawler cranes travelling under load - are described in CIRIA's *Crane stability on site*.
    - The same precautions apply to the operation of MEWPs over contoured ground.
20. Work on city centre sites:
    - Erection in city centres usually takes place on sites that are of a very restricted size, and public access is usually very close - sometimes being through part of the site plan zone. The customary designation of a "sterile zone" - accessible only to the steel contractor's personnel during erection - is often impossible, and site workers can be working underneath other workers. Hence risk, being the potential harm from hazards, increases.
    - It is more common for nets and fan scaffolds to be used on such sites. See BS EN 1263 *Safety Nets*.
    - The proximity of the public and adjacent buildings can also affect choice of craneage, limitations on noise, and permitted hours of working.
21. Connecting to an existing structure:
    - There are stability considerations for the designer to consider if connections are needed between a new structure and an existing one, and these determine the safe sequence of work.
    - The site may be traversed by members of the "public" - in the form of the client's personnel working on the site or in the adjacent building. This affects the potential for hazards to cause harm.

RQSC – Special scope of competence

Special activities that steelwork contractors should be able to manage using specialist subcontractors as necessary.

1. Grouting bases.
2. Placing bearings that allow movement.
3. Installing a scaffold platform.
4. Assisting second or third party inspection:
   - Personnel working for second or third parties may need to undertake inspections or witness tests. Additional precautions may be needed to ensure that their presence in the area designated for erection does not cause added risks.
   - Whilst ultrasonic inspections would be considered special, steel constructors would not normally undertake radiographic inspection at all.
5. Use of special fasteners and fixing proprietary items:
   - Special fasteners are proprietary products for which no British Standard exists - *Lindaptors* and crane rail fixings are examples. The manufacturer's recommendations for installation should be reviewed against the requirements for safe erection - checking back directly with the manufacturer's technical staff if the written instructions are not sufficient.
   - Similar precautions apply to installation of proprietary items such as *Halfen* channels.
6. Work on decking for composite steel and concrete structures:
   - For metal profiled steel decking, the SCI's *Good practice in composite floor construction* should be followed. Arrangements for edge protection and safety precautions along the leading edge of the work front need to be agreed.
   - Particular care is needed during the stage when the steel frame and decking are loaded with wet concrete.
   - Stud welding and shot firing are operations for which the equipment manufacturers issue guidance on suitable safety precautions. The use of cartridge operated tools should follow the advice given in the HSE's PM series of guidance notes. These operations can also require additional noise protection.
7. Work in artificial light:
   - Shift work can also involve additional precautions.
8. Extensive temporary works:
   - Whilst many temporary bracing and restraint requirements are relatively simply executed (eg wire rope guys, *Acrow* props or added strut-tie braces), extensive temporary works will require consideration of the guidance in BS 5975 *Code of practice for falsework*.
9. Large scale site assembly "on the ground":
   - Assembly on site before lifting of the sub-assembly into its final erected position can be chosen as the most appropriate safe method of construction. However, the large scale of some sub-assemblies will require provision for safe access during assembly ‘on the ground’ if working positions are at heights of more than 2 metres off the ground.
   - Any jigs or stillages used to support or stabilise the sub-assemblies need to be treated in the same way as temporary works supporting the structure in its final erected position.
10. Lateral movement of heavy loads:
    - CIRIA's *Lateral movement of heavy loads* provides guidance on sliding, winching and braking operations.
11. Work in a confined space:
    - HSE's GS 5 (rev) *Entry into confined spaces, and Confined spaces* [CIS no 15] provide suitable guidance.
12. Work over water, over a railway or airside at an airport:
    - Clients and Principal Contractors should determine the appropriate additional precautions to be followed in these and other especially hazardous environments - such as mines, quarries and oil or chemical refineries. This would normally include permit-to-work procedures.
13. Work on tall structures over 45m high:
    - Methods of achieving all three safety objectives are different on structures over 45 metres high, compared to those used on the most common type of steel structure - single storey sheds. For example, the influence of wind is much more significant.

Other activities related to steel construction that steelwork contractors would not necessarily undertake and about which specific prior negotiations should take place to establish the competences necessary, the methods to be used and the consequent risks involved.

1. Radiography or assisting radiographic inspection by third parties.
2. Site blasting and use of compressed air equipment.
3. Fixing preglazed frameworks.
4. Erecting precast concrete frames.
5. Using bonding adhesives.
6. Fixing roof or wall cladding.
7. Proof testing to commission runway beams etc.
   - Commissioning of runway beams involves proof loading which should be done under the direct instruction of a suitably qualified engineer.

Method statement development

Design decisions are often made before the appointment of a competent steelwork contractor that affect what erection methods can or must be used.

These may emerge in the development of the Pre-Tender H&S Plan or in the steelwork design process itself that depends on an assumed outline method of erection.

Items to be considered in defining the site conditions suitable for safe erection

- Access to the site and within the site.
- Limitations on dimensions or weights of components that can be delivered onto the site.
- Soil conditions affecting the safe operation of plant.

Left:
Access within the site for deliveries, cranes and MEWPs

- Provision and maintenance of hard standing for cranes and access equipment.
- Details of underground services, overhead cables or site obstructions.
- Special environmental and climatic conditions on and around the site.
- Particulars of adjacent structures affecting or affected by the works.
- Possible settlement of supports to the structure during erection.
- Availability of site services and prearranged procedures for cooperating with other contractors.
- Value of construction and storage loads allowed on the steelwork.
- Concrete placement during composite construction.

Above:
Hard standing for cranes in lay-down and erection areas
Below:
Cooperation with following trades by providing fixing points for safety netting

Further items to be considered in developing the design-basis outline method of erection

- The position and types of site joints.
- The maximum piece size, weight and location.
- The sequence of erection.
- The stability concept for the part-erected structure including any requirements for temporary bracing or propping.
- Propping or other actions necessary to facilitate subsequent concreting of composite structures.
- Conditions for removal of temporary bracing or propping, or any subsequent requirement for destressing of permanent bracing.
- Features which would create a hazard during construction.
- Timing and method of grouting foundation connections.
- Camber and presets required including values to be checked at fabrication stage.
- Use of profiled steel sheeting to ensure stability.
- Use of profiled steel sheeting to provide lateral restraint.
- Possible method of providing safe working positions.

Below:
Safe access using pre-installed edge protection

Above:
What is the stability concept for the part-erected structure?

Later, the steelwork contractor will develop the full erection method statement as part of the Construction H&S Plan. This will tackle:

- Experience from any trial erection undertaken.
- The restraints necessary to ensure stability prior to welding and to prevent local movement of the joint.
- The lifting devices necessary.
- The necessity to mark weights and/or centres of gravity on large or irregularly shaped pieces.
- The relationship between the weights to be lifted and the radius of operation where cranes are to be used.
- The identification of sway forces, particularly those due to the forecast wind conditions on site during erection, and the exact method of maintaining adequate sway resistance.
- Exact methods of coping with any safety hazards.
- Exact methods of providing safe access to positions of work and safe working positions.

Stability

Designers must chiefly be concerned with ensuring stability as only they have full knowledge of the concepts upon which the design is based.

Other key issues – to consider are craneage and access. The concern is for stability during all stages of erection:

- of the assembled structure in its final condition,
- of assembled portions in the part-erected condition,
- of individual components during lifting and after placing in position, and hence
- for specifying the brief for any temporary works necessitated by the scheme design.

For individual members:

- Are any members susceptible to instability when being lifted and placed?
- How could the need for lateral restraint be engineered?
- What restrictions might there be on rigging arrangements during lifting (eg for attachment of guys to members)?

Issues for the designer to consider are:

In the final condition:

- Will stability be by means of permanent steel bracing or sway frames, or will it depend on other construction elements such as concrete shear walls?
- Where will the permanent bracing be located?
- Will metal decking etc be used as diaphragms?
- How are load paths between components engineered?

In the part-erected condition:

- How will potential frame instability be overcome?
- How will the construction sequence dictate when load paths can be established?
- What construction loads will be permitted?

For temporary works:

- Does the scheme necessitate any bracing or propping?
- What forces and moments will develop in the temporary members?
- How will forces in tension members be developed?
- How will members be secured during site welding?
- Are there restrictions on how the temporary members might be connected?

Steelwork contractors are responsible for designing the actual temporary works to be used as they must match their chosen erection methods, but they need a clear brief specified by the steelwork designer.

Often the steelwork contractor will undertake the design of connections, and there can be an interaction between the selection of connection types and the need for temporary bracing or the sequence of erection. For instance a fin plate would be less robust in the part-erected condition than a welded full-depth end plate. Similarly the choice of a column splice location could influence whether the column required stabilising by temporary guys when first erected. This in turn could depend on the design of the foundation itself and the column base connection.

In general, it is likely that the steelwork contractor would prefer to use standard details from the 'Green Books' published by SCI/BCSA, and the designer should be safe in the assumption that a competent contractor would be fully familiar with how to fix such connection types and their implications on connection stability.

The corollary of the default assumption noted previously, is that any special connection types should be given particular attention in terms of their implications for safe erection. For example, pin connections can give rise to a mechanism in the part-erected condition. This would need to be noted as a feature which would create a hazard during construction by whoever made the decision to select that connection type.

Far left:
Decking as a construction load
Left:
Slender rafters may be unstable until secured by purlins
Below:
Temporary tensioning arrangements

Dialogue

Communication between the designer and the contractor is crucial for safe steelwork erection.

Just as with all aspects of realising the designer's scheme in terms of practical details, the secret is to promote a dialogue about such issues between designer and contractor, and this need for dialogue extends to several factors that contribute to developing a safe erection method.

There are many competent steelwork contractors, and, on behalf of the client and themselves, designers should check that the principal contractor is taking suitable steps to select one.

The market place also provides a wide choice of equipment for the contractor in terms of craneage and access. What is in relatively short supply, however, is good technical understanding of the implications of structural behaviour on erection methods – and it is this knowledge that the designer provides through the design-basis outline method of erection and the subsequent dialogue with the chosen contractor.

Below:
A wide choice of access equipment

Further advice

Free advice is available from every steel construction site that one passes or sees in photographs, such as those illustrated in this brochure.

In this way lessons can be learned from the experience of others. Contacting the steelwork contractors involved can also be a mine of advice and the contact details for BCSA members can be found on the BCSA's website www.steelconstruction.org.

BCSA has published codes of practice for erection of steel structures and metal decking.

Also available there are downloadable documents about best practice, tips for safer steel erection and copy of BCSA's *Safe Site Handover Certificate*. The SCI website www.steel-sci.org is a further source where details about publication P-162 *The Construction (Design and Management) Regulations 1994: Advice for designers in steel* may be found. Finally, BSI publishes BS 5531 *Code of practice for safety in erecting structural frames*.

Left:
Meccano for grown-ups!

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