AD 491: Hydrogen embrittlement in structural bolting assemblies - effects and remedies

Introduction

Hydrogen embrittlement is a mode of failure that can affect high strength structural steel bolts. It is a reduction in the ductility of steel due to absorbed hydrogen making the steel less able to support the imposed stresses which can lead to the development of micro cracking and eventually failure.

This mode of failure is not well understood by engineers and specifiers, as all too often high strength steel bolts are specified without considering the implications of hydrogen embrittlement. This technical note briefly explains the three factors that need to be present to trigger this mode of failure and how this can be avoided.

What triggers hydrogen embrittlement failure?

For this mode of failure to occur the following three factors must be present:

- The steel must be a high strength steel, typically above 1000 N/mm², this includes property class 10.9 bolts and above, and
- There must be a tensile stress in the steel (due to the preload in a bolt or externally applied loads), and
- The steel must have absorbed atomic hydrogen. This is explained in more detail in the next paragraph.

A more detailed explanation of hydrogen embrittlement in structural fasteners is given in *Hydrogen Embrittlement - Its effect on Structural Bolting Assemblies*, which is available at: *www.steelconstruction.info/Fabrication#Resources*.

Sources of absorbed hydrogen

Absorbed atomic hydrogen can come from two sources:

- From the manufacturing process – i.e. Internal hydrogen embrittlement
- From the environment – i.e. Environmental hydrogen embrittlement

Studies have shown that hydrogen can be absorbed during manufacture, e.g. certain types of heat treatment and surface coatings. To avoid this, the manufacturing process must be carefully controlled. The necessary controls and tests are given in the *'BCSA Model Specification for the Purchase of Structural Bolting Assemblies and Holding Down Bolts'* (MPS), and high strength bolts should be specified in accordance with this specification. The MPS is also available at: *www.steelconstruction.info/Fabrication#Resources*.

Environmental hydrogen occurs when the steel is subject to corrosion from the environment. This can be avoided by designing the connections of a structure in such a way that they do not put high tensile strength bolting assemblies into areas where water or other electrolytes are allowed to collect and remain. Both coated and uncoated fasteners are susceptible to environmental hydrogen embrittlement.

Conclusion

By following the recommendations below, the risk of hydrogen embrittlement can be significantly reduced:

- Structural bolting assemblies should be obtained from approved suppliers certified to National Highways Sector Scheme 3 (NHSS3) and that bolts conform to the BCSA MPS. A list of Approved Suppliers can be found on the LANTRA Schedule of Suppliers website and a list of the BCSA suppliers of structural fasteners complying with NHSS3 and the MPS can be found in the 'Industry members' listing at the back of New Steel Construction or on the BCSA website *www.steelconstruction.org*
  and,
- Ensure that the design of the connections does not put high strength steel bolting assemblies into areas where water or other electrolytes are allowed to collect and remain. This applies to both coated and uncoated fasteners

Contact: Ana M. Girão Coelho
Email: ana.girao-coelho@steelconstruction.org

New and revised codes and standards

From BSI Updates July and August 2022

BS EN PUBLICATIONS

BS EN ISO 9016:2022
Destructive tests on welds in metallic materials. Impact tests. Test specimen location, notch orientation and examination
supersedes BS EN ISO 9016:2012

BS EN ISO 22057:2022
Sustainability in buildings and civil engineering works. Data templates for the use of environmental product declarations (EPDs) for construction products in building information modelling (BIM)
no current standard is superseded

CORRIGENDA TO BRITISH STANDARDS

BS EN ISO 18203:2022
Steel. Determination of the thickness of surface-hardened layers
Corrigendum, June 2022

BRITISH STANDARDS REVIEWED AND CONFIRMED

PD ISO/TR 16576:2017
Fire safety engineering. Examples of fire safety objectives, functional requirements and safety criteria

PD ISO/TR 24679-2:2017
Fire safety engineering. Performance of structure in fire. Example of an airport terminal

NEW WORK STARTED

EN 1991-1-1
Eurocode 1. Actions on structures. General actions. Specific weight of materials, self-weight of construction works and imposed loads for buildings
will supersede BS EN 1991-1-1:2002

EN 1991-1-3
Eurocode 1. Actions on structures. General actions. Snow loads
will supersede BS EN 1991-1-3:2003+A1:2015

EN 1991-1-4
Eurocode 1. Actions on structures. General actions. Wind actions
will supersede BS EN 1991-1-4:2005+A1:2010

EN 1991-1-5
Eurocode 1. Actions on structures. General actions. Thermal actions
will supersede BS EN 1991-1-5:2003

EN 1991-1-6
Eurocode 1. Actions on structures. General actions. Actions during execution
will supersede BS EN 1991-1-6:2005

EN 1991-1-7
Eurocode 1. Actions on structures. General actions. Accidental actions
will supersede BS EN 1991-1-7:2006+A1:2014

EN 1994-1-1
Eurocode 4. Design of composite steel and concrete structures. General rules and rules for buildings
will supersede BS EN 1994-1-1:2004

EN 1994-2
Eurocode 4. Design of composite steel and concrete structures. General rules and rules for bridges
will supersede BS EN 1994-2:2005