INTERNATIONAL MOLYBDENUM ASSOCIATION
THE VOICE OF THE MOLYBDENUM INDUSTRY

Molybdenum in Architecture, Building and Construction

Friends Arena, Stockholm

Molybdenum's contribution to sustainable development in:

- Stainless steels
- **Alloy steels**
- Superalloys
- Cast iron
- Mo metal
- Chemicals

MoRE FOR LESS

www.imoa.info

Molybdenum makes an important contribution to sustainable development as a metal, as an alloying element, and as a constituent of chemical products. IMOA's 'MoRE FOR LESS' case studies explore, in more depth, how molybdenum is contributing to sustainable development, a pattern of growth in which resource use aims to meet human needs while preserving the environment.

In particular we will look at how a specific use or application is contributing to the three pillars of sustainability:

ECOLOGY — Environmental performance, resource use, energy efficiency & production and recycling

ECONOMY — Supply chain, lifecycle and materials performance

SOCIETY — Health, safety and wellbeing

This case study explores the sustainability benefits of using molybdenum-containing high-strength steel (HSS) in place of conventional steel in long-span structures, using the Friends Arena in Stockholm as an example.

The Challenge

Concentrations of greenhouse gases in the atmosphere are increasing and are widely recognized for causing global climate change. The primary human activity affecting the amount and rate of climate change is the emission of greenhouse gases from burning fossil fuels[1]. The iron and steel industry has one of the largest carbon footprints of any single industrial sector due to its size and energy-intensive processes, contributing some 4% of global man-made emissions[2].

The use of HSS for structural members enables lighter structures to be built, providing the design of the members is not governed by deflection or instabilities. The CO_2 emissions resulting from the production of HSS are only slightly higher than those for conventional structural steels – there is about a 7% increase in emissions when the yield strength doubles from 350 to 690 MPa. The weight savings made possible by HSS depend on the type of member and mode of loading, but in many practical situations might range from 20–40%, leading to significant overall reductions in CO_2 emissions. Molybdenum is one of the elements used to make HSS and interestingly some 750 kg of molybdenum is contained in the HSS used in the stadium's construction.

The Friends Arena is a multi-purpose stadium with a retractable roof and a capacity for up to 65,000 people. © Sweden Arena Management

The Solution

Four 17 m-deep space trusses span the 162 m width of the stadium and carry the load of the retractable roof and were identified as having most potential to benefit from the use of molybdenum-containing HSS.

The key elements of the trusses, offering the greatest potential to exploit the advantages of HSS, were the top and bottom chords and the outer diagonal member closest to the support points. The top chords consist of S460 steel tubes with a diameter of just over a meter. The designers were able to use higher grades of HSS in the bottom chords and the outer diagonals (S690 and S900 respectively) as these are predominantly subject to tensile loading. The bottom chord was a U profile to simplify welded connections and the outer diagonal members were flat plate.

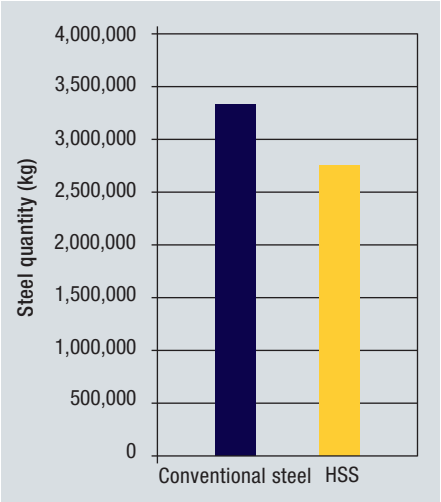

Figure 1: Weight comparison of design options

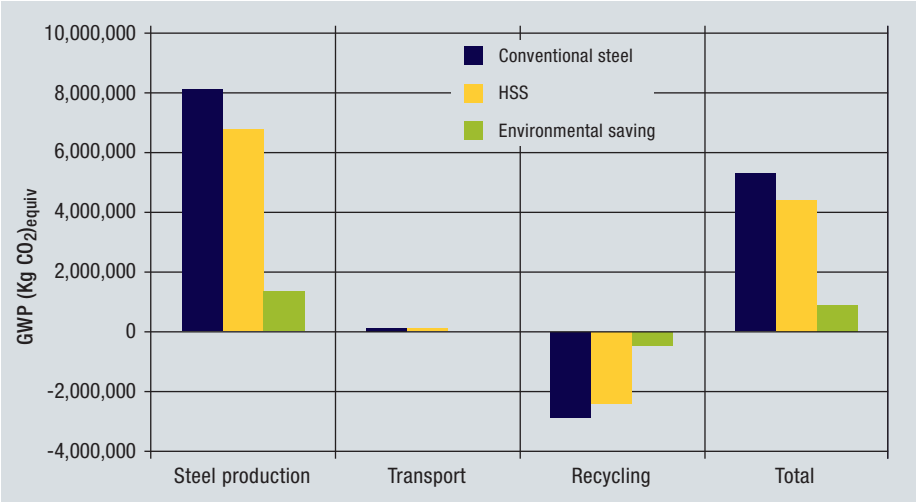

Figure 2: Global Warming Potential (GWP) comparison between conventional and high-strength steel

The use of HSS led to a 17% reduction in the weight of the roof compared to a roof made from conventional S355 structural steel (Figure 1)[3].

Although HSS is slightly more expensive than conventional structural steels, the reduced tonnage and cost of fabrication (mainly due to the reduced welding required) led to an overall cost saving. Table 1 shows that a 14.5% saving in the cost of the roof was achieved through the use of HSS.

When considering the environmental impact of a product, it is important to analyze the entire life cycle. For the roof structure, the three aspects of the life cycle assessment (LCA) which were identified as having the greatest environmental impact were steel production, transportation and recycling at end of life. The environmental impact due to the fabrication of the structure and during its operating lifetime was deemed to be negligible. Figure 2 and Table 2 compare the environmental impact of the HSS roof with a roof fabricated from conventional structural steel. The data is presented as an equivalent weight of CO_2 (kg CO_2)$_{equiv.}$ and shows that HSS led to reduction of the global warming potential of 17%.

Table 1: Cost comparison of design options

Design option	Cost
Conventional structural steel	€ 14,309,869
High-strength steel (as-built solution)	€ 12,228,959

How molybdenum can help

The yield strength (grade) of steel can be increased by adding more carbon, however this can have a detrimental effect on both ductility and weldability. With the addition of molybdenum, increased yield strength is possible without compromising weldability. Adding molybdenum also maintains toughness and improves hardenability.

In most cases molybdenum is used with comparatively small additions. Typically the quantity in HSS ranges between 0.2% and 0.5%, rarely exceeding 1%. Typical ranges of molybdenum in various steel grades are given in Figure 3.

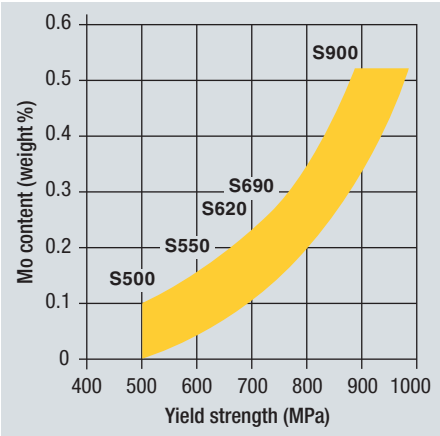

Figure 3: Yield strength of 20 mm thick plate for various HSS grades with increasing Mo content.

Table 2: Global Warming Potential (GWP) comparison between conventional and high-strength steel ((kg CO_2)$_{equiv}$)

Category	Conventional structural steel	High-strength steel (as-built solution)	Environmental saving
Steel production	8,150,707	6,802,655	1,348,052
Transport	106,250	86,000	20,250
Recycling	-2,930,735	-2,458,108	-472,627
Total	5,326,222	4,430,547	895,675

Key sustainability benefits

Benefit	Sustainability attribute		
Reduces the quantity of CO_2 produced over the life cycle of the structure	ECOLOGY		SOCIETY
Reduces the amount of steel required, saving natural resources	ECOLOGY	ECONOMY	SOCIETY
Reduces the material transportation required	ECOLOGY	ECONOMY	SOCIETY
Reduces the amount and associated cost of welding required		ECONOMY	
Reduces the construction cost due to the reduced amount of steel required		ECONOMY	
Molybdenum-containing HSS is readily recycled	ECOLOGY	ECONOMY	SOCIETY

Summary

The use of HSS in long-span structures can offer an improved sustainability performance, as demonstrated in the Friends Arena in Stockholm. Compared to a design using conventional structural steel, the use of molybdenum-containing HSS in the roof trusses contributed to the following sustainability benefits:

- A 17% saving in the quantity of steel used
- A cost reduction of over €2 million
- A reduction in greenhouse gas emissions of 17% (895,675 kg of CO_2 equivalent), when analyzed over the entire life cycle of the steel used

Molybdenum is a significant raw material in the production of HSS and its use in construction projects like the Friends Arena will increase the global contribution that molybdenum is already making to sustainable development.

1 Causes of Climate Change. United States Environmental Protection Agency (EPA) http://www.epa.gov/climatechange/science/causes.html
2 2009 EAA report No. 9. Greenhouse gas emission trends and projections in Europe 2009. Annex: Additional information on greenhouse gas emission trends and projections
3 Cederfeld, L. and Sperle, J-O: High Strength Steel in the Roof of Swedbank Arena. Savings in Weight, Cost and Environmental Impact. Nordic Steel Construction Conference 2012, Oslo Norway.

International Molybdenum Association
info@imoa.info · www.imoa.info

IMOA/07/13