STRUCTURAL STEEL
CASE STUDY: P425 3

SCI
Steel Knowledge

STIGA Sports Arena Eskilstuna, Sweden

Figure 1 STIGA Sports Arena Eskilstuna
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Summary

STIGA Sports Arena complex is located in the Munktellstad district of Eskilstuna, about 110 km west of Stockholm, and was opened in 2017. The arena complex is used for sporting events, concerts, large conventions and fairs. The main arena comprises 3,700 seats for sporting events and approximately 5,000 seats for concerts. In total it has three individual sports halls.

Steel is, by some margin, the most commonly used material to construct indoor arenas due to its engineering, aesthetic, economic and environmental attributes. In the STIGA Sports arena, long span steel roof trusses provide the large open plan areas required for unimpeded spectator viewing.

Trusses (frameworks of members in which loads are resisted primarily by axial forces in the individual members) are generally more economical than standard steel I- beams over relatively large spans. The selective use of high strength steels for the elements in the trusses that are not governed by instabilities led to a significantly lighter structural solution than that using conventional strength steel.

Key aspects of the design of the arenas included flexibility of the space, acoustics, energy efficiency and sustainability criteria, as well as optimised building services solutions. The complex was awarded a Gold Certificate by the Swedish Green Building Council, due both to the choice of construction materials with low environmental impact and the low energy consumption of the building during service.

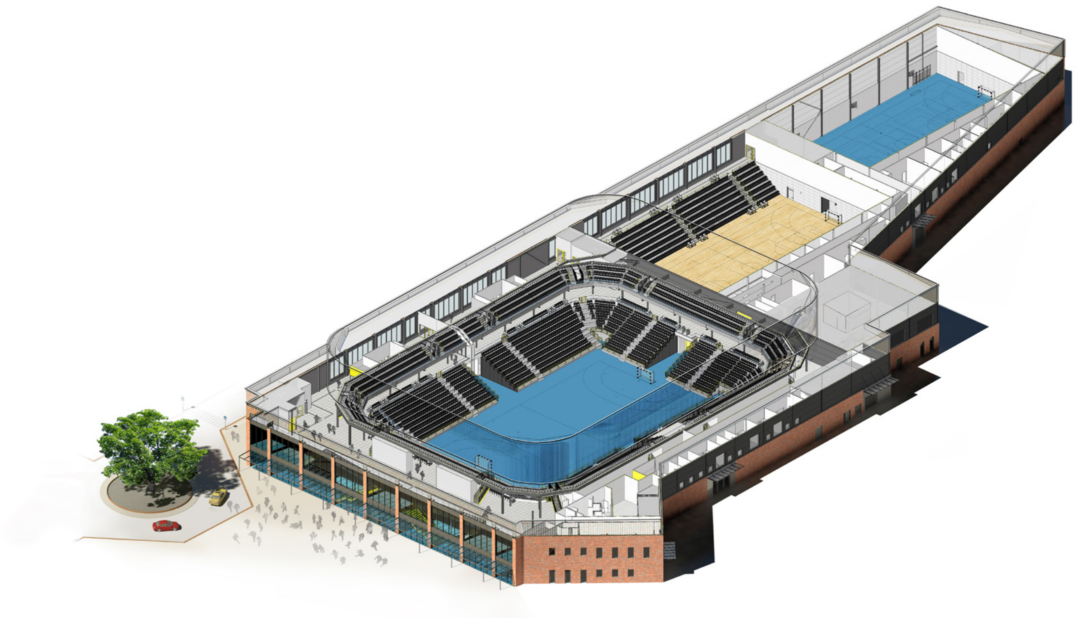

Figure 2 Schematic of the STIGA sports arena complex
Courtesy: Eskilstuna Municipality, Sweden

Figure 3 Main arena roof trusses
Courtesy: Svante Lundbäck SE

Material selection

The roof trusses for the main arena were made up from cold formed rectangular and square hollow sections: hollow sections are usually selected for trusses with very long spans due to their structural efficiency and attractive appearance. In order to optimise the design of the roof trusses, three grades of steel were used: S355, S420 and S700. Table 1 gives their mechanical properties.

The S355 and S420 steels were Domex® Tube Double Grade, produced by SSAB, which meets or exceeds the requirements of EN 10219:2006 for both steel grades S355J2H and S420MH.

The material certificates for both steel grades are provided to the customer.

EN 10219 currently only covers steels up to and including S460. The S700 steel (SSAB Strenx® Tube S700MC) used in the trusses was delivered in accordance with EN 10419-2, which is the standard covering steels for roll forming into profiles. This standard covers thermomechanically rolled steels from S315 to S960. However, the forthcoming revision of EN 10219 will cover steels up to S960, which reflects the growing demand for high strength steel structural sections.

It is important to note that these modern high strength steels are typically of a low carbon content and microalloyed with up to 0.070% niobium by weight (depending on the final strength requirements), primarily to aid grain refinement. This combination enables both strength and toughness requirements to be easily achieved, as well as improved cold formability. Furthermore, due to their low carbon equivalent, they possess excellent weldability and may require no or significantly less pre-heating prior to welding.

	SSAB Domex® Tube Double Grade		SSAB Strenx® Tube
Steel grade designation	S355J2H	S420MH	S700MC
Minimum yield strength (MPa)	355	420	700
Minimum tensile strength (MPa)	470-630	500-660	750-950
Minimum elongation A^5 (min %)	20	19	12
Minimum impact toughness at -40°C (test carried out on a 10x10 mm test specimen) (J)	40	40	27
Maximum Carbon Equivalent Value (%)	0.39	0.39	0.39

Notes
J2 = Specified impact properties at -20 °C | H = Hollow section | M = Thermomechanically rolled | C = Suitable for cold forming

Table 1 Mechanical properties of steel grades

Design

The STIGA sports arena complex comprises three separate sports halls - the main arena and two smaller arenas. For the main arena, an open plan area of approximately 52 m x 70 m is required to accommodate the sports floors and spectator seating. Although the other arenas are smaller, they still require large open plan areas. Part of the complex comprises offices and a restaurant. The intermediate floor of the offices and restaurant is a hollow-core slab and functions structurally as a stiff diaphragm.

The structural steel frame is formed from steel columns, trusses, beams and bracing members. Bracing at roof level and also in the vertical plane provides stability, resists lateral wind loads and distributes loads to the foundations. Profiled steel cladding is used for the roof and insulated steel sandwich panels for the walls. The connections between the truss and the supporting columns are pinned and hence do not resist bending moment. The column bases are also pinned.

For the main arena, each truss spans 52 m between columns and is approximately 4 m deep at the midspan. The spacing of the trusses is between 7 m and 9 m. The columns are tall enough to provide at least 15 m of clear headroom in the arena. All the steel sections for the trusses, columns and bracing are square hollow sections (SHS) and rectangular hollow sections (RHS).

Figure 4 Main arena columns and roof trusses
Courtesy: Svante Lundbäck SE

To optimise the structural efficiency of the frame, careful consideration was given to the choice of steel grade for each component of the steel frame. Depending on the loading mode in a structural member, a higher strength steel can enable the use of a smaller section profile. This results in a lighter structure, thereby minimising the quantity of steel used, the cost for the steel material, its transportation, fabrication and thus the overall environmental profile of the building.

For trusses, most of the weight lies in the chord members - using high strength steels in the chords can therefore lead to significant weight and cost savings. On the other hand, the diagonal members represent much less of the total weight, although cutting and welding them contributes to most of the fabrication costs. An optimisation process showed that the most cost effective solution for the STIGA main arena was to use conventional strength steel S355 for the braces. S700 steel was chosen for the bottom chord, which is predominantly in tension and so the benefit of high strength steel could be fully exploited. The top chord is mainly in compression, so it was not possible to fully exploit the benefits of a higher strength and the use of S420 gave a satisfactory compromise. The total weight of the trusses was 100 tonnes, notably lighter than the solution using conventional strength steel. Table 2 gives the section sizes used in the main arena.

For the trusses in the other smaller arenas, grade S355 steel was used for the diagonals and grade S420 steel for the top and bottom chords.

Member	Steel Grade	Section Size
Truss: Top chord	S420	Typically 300 x 300 x 10 mm (RHS)
Truss: Diagonal	S355	140 x 80 x 5 mm RHS, 140 x 140 x 5 mm SHS and 160 x 160 x 10 mm SHS
Truss: Bottom chord	S700	200 x 200 x 10 mm RHS
Column	S355	300 x 300 x 12.5 mm SHS
Bracing (wall and roof)	S355	150 x 150 x 5 mm SHS

Notes RHS = Rectangular hollow section | SHS = Square hollow section

Table 2 Section sizes for the structural steel members in the main arena

Fabrication and installation

Construction commenced in May 2015 and was completed in April 2017. The installation of the main steel frame and roof took approximately 3 months (Figure 5).

The structural steel members for the frame, steel sandwich panels and profiled steel cladding were produced by Ruukki Construction Oy in Finland and Poland. Installation of the building frame was carried out by Ruukki.

To make the manufacture and the transportation of the steel frames easier, each long span roof truss was fabricated in two pieces. Once delivered separately to site, the two truss sub-assemblies were connected together using bolted splice connections, located mid-span at the top and bottom chords of the truss.

To compensate for deflections arising from the self-weight of the trusses, the truss chords were fabricated with a pre-camber, hence once in-place, any member sag was not visible.

Figure 5 Main arena roof trusses spanning 52 m being installed
Courtesy: Ruukki

Figure 6 A handball match in the main arena
Courtesy: IamTimEre, licensed under CC BY-SA 4.0

References

EN 10219-1:2006 Cold formed welded structural hollow sections of non-alloy and fine grain steels. Technical delivery requirements.
EN 10149-2:2013 Hot rolled flat products made of high yield strength steels for cold forming. Technical delivery conditions for thermomechanically rolled steels.

Parties involved

Client	Eskilstuna Municipality
General Contractor	Peab Sverige AB
Structural steel design	Ruukki Construction, Design Service
Steel construction	Ruukki Construction
Steel producer	SSAB

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