BROMMA

Fossil-free steel

a viable way to significantly reduce the carbon footprint of spreaders

White Paper

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Contents

About Bromma
Bromma is the industry market leader in ship-to-shore spreaders, mobile harbour crane spreaders, and yard crane spreaders. A pioneer in the container handling industry, Bromma is focused on lifting the productivity of its customers through more reliable spreaders. Bromma has delivered crane spreaders to 500 terminals in 90 nations on 6 continents, and Bromma spreaders are in service today at 99 out of the world's largest 100 container ports. Bromma's industry-leading all-electrics spreaders and recent products such as the Spreader Monitoring System are part of this continuing effort.

Executive summary

Bromma has verified, through both theoretical and empirical studies, that fossil-free steel—specifically HYBRIT technology from SSAB—is a viable material for spreader manufacturing. It performs on par with conventional high-strength steel while enabling significant reductions in carbon emissions.

Key finding: the use of fossil-free steel in spreader manufacturing reduces the manufacturing carbon footprint by up to 94%, and by up to 60% across the product's full life cycle.

This White Paper provides the context, process, and results from Bromma's transition journey and testing of fossil-free steel.

Below is the structure of this White Paper:

Sections 1–2:	Bromma's broader climate commitments and carbon footprint assessments
Section 3:	The role of fossil-free spreader materials
Section 4:	Technical validation of fossil-free steel and its performance
Section 5:	Conclusion

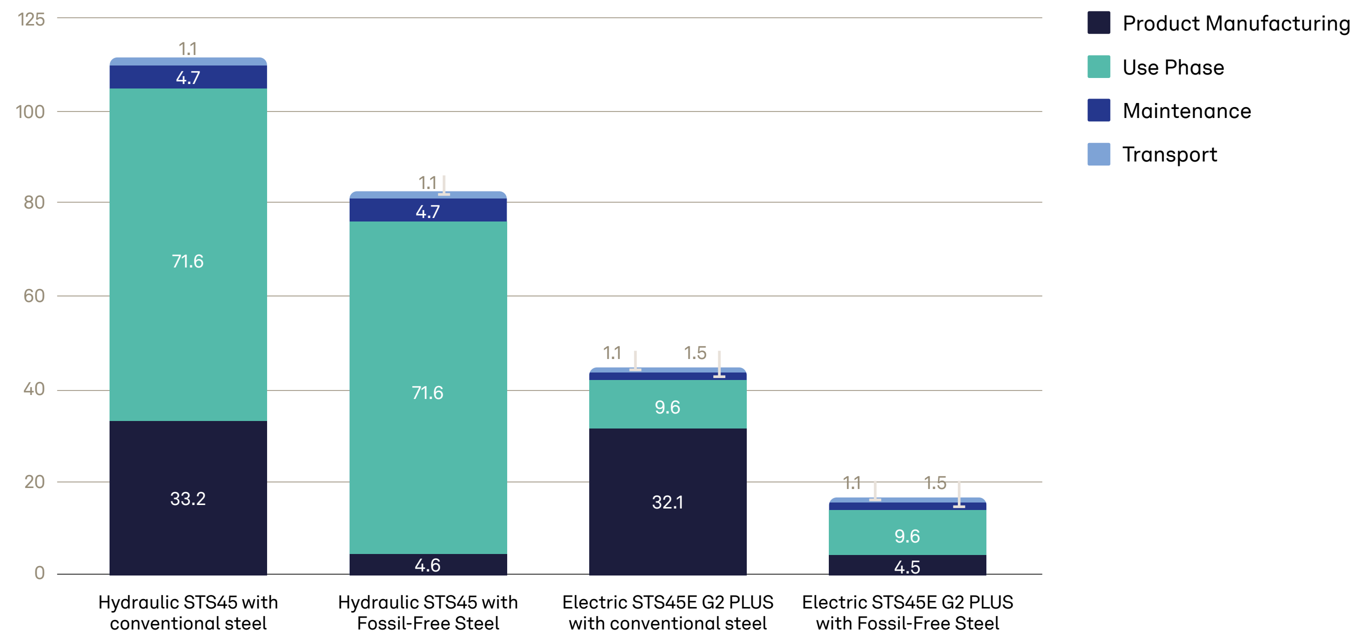
Bromma's commitment to sustainability

Sustainability is at the core of our business and we are constantly looking for ways to minimise our negative impacts on the environment, while we simultaneously strive to optimise our positive ones.

Bromma solutions and actions help build a world where global warming stays below 1.5°C and a circular economy replaces the wasteful linear one. We do this by solving our customers' sustainability challenges with our solutions. We address environmental, social, and governance (ESG) aspects across our value chain—from design and sourcing to usage and end-of-life.

This white paper outlines one of the key steps in our sustainability journey: our collaboration with Swedish steel manufacturer SSAB to explore the use of fossil-free steel in our spreaders. This initiative represents a significant milestone in our commitment to reducing emissions and advancing toward a sustainable future.

Figure 1. Projected life cycle greenhouse gas emissions: current vs. potential fossil-free spreader models



Carbon Footprint Declaration and comparative analysis

As part of our climate commitment goals, Bromma has completed detailed Life Cycle Assessment (LCA) calculations for numerous spreader models [1-4]. These calculations, based on the ISO 14067 standard, provide a comprehensive evaluation of greenhouse gas (GHG) emissions associated with the production, use, transportation, and maintenance of Bromma spreaders. By using this standardized methodology, we ensure consistency and reliability in assessing the environmental performance of our products.

The comparison results of LCA for Bromma STS45 and STS45E G2 PLUS [as shown in Figure 1] spreader models, demonstrates that greenhouse gas emissions of the all-electric STS45E G2 PLUS are significantly lower, resulting in a total **reduction of 60%** over the full life cycle when compared to the Hydraulic STS45 [5].

The analysis also highlights that the manufacturing phase is a major contributor to the carbon footprint of our products, with the core structure being the most significant factor. The core structure, typically made from high-quality, high-strength European steel, accounts for 86% of the carbon emissions from the manufacturing of an STS45 spreader and as high as 94% of the emissions from manufacturing all-electric yard spreader. By transitioning to materials with a lower carbon footprint, such as fossil-free steel, we can further reduce GHG emissions from our products, as illustrated in Figure 1.

Enabling change: integrating fossil-free steel

It is estimated that road transport accounts for about one-fifth of the EU's CO_2 emissions, making it a significant contributor to global warming. Studies indicate that a 10% reduction in vehicle weight can lead to a 6% improvement in fuel economy [10]. While comparable data for the lifting industry is not widely reported, Section 2 of this White Paper highlights that spreaders also contribute to CO_2 emissions.

To reduce industrial emissions, new regulations, such as the Carbon Border Adjustment Mechanism (CBAM) [11], have been introduced in Europe, encouraging industries to adopt low-carbon materials and minimize their carbon footprint. In response, **Bromma is investigating how to reduce the weight of its spreaders while incorporating steel with a lower CO_2 footprint, such as fossil-free steel.**

The Role Of Fossil-Free Steel
Since the input materials account for a significant portion of emissions, using fossil-free steel can substantially reduce the total environmental impact of spreader production. Fossil-free steel, such as that produced by SSAB using HYBRIT (Hydrogen Breakthrough Ironmaking Technology) technology, eliminates the use of fossil fuels in steel production, significantly lowering CO_2 emissions compared to standard steel. This transition can support Bromma's sustainability goals while maintaining the structural performance required for spreaders.

However, adopting fossil-free steel requires rigorous testing and validation to ensure that it meets the same performance standards as standard steel. At Bromma, we anticipate a growing demand for spreaders with a lower carbon footprint in the future. Since 2021, we have been collaborating with SSAB to explore the feasibility of using fossil-free steel in our products. A key focus of our evaluation **is assessing whether steel produced using HYBRIT can deliver the same performance as standard steel**. A crucial question we seek to answer is whether simply replacing the material is sufficient, or if additional verification is necessary to ensure its reliability in real-world applications.

We have conducted an analysis comparing a box welded structure – a common component in spreaders – made partly of fossil-free steel with one made of standard steel. This evaluation is a critical step in ensuring the reliability and performance of fossil-free steel in our products.

Performance testing: fossil-free steel in box welded structures

Box welded structures are a common component in spreaders, and their strength is influenced by several factors. Whether a spreader is designed for static strength or fatigue strength, understanding the behavior of the materials used in its components is critical. In this section of the White Paper we will present the results of the structural integrity tests conducted on the box welded structures.

Static strength

Static strength is important for ensuring the safe working load requirements of spreaders. To evaluate the performance of fossil-free steel, Bromma conducted tests comparing it with standard steel. The results are summarized below:

Figure 2 compares the average mechanical properties of test specimens made of fossil-free steel with those of standard steel

Table 1 summarizes the chemical composition analysis of the materials.

The findings in Figure 2 and Table 1 reveal that the strength as well as chemical composition of fossilfree and standard steel **are very similar**.

Figure 2. **Comparison between average mechanical properties test specimens made of fossil-free steel with those of standard steel**

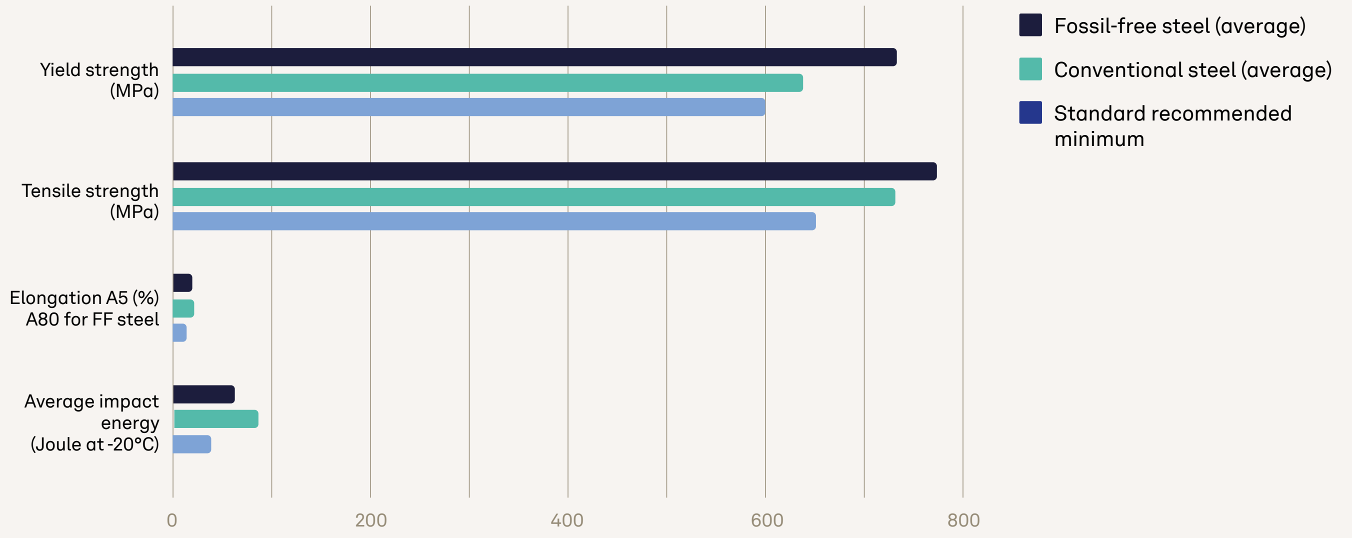


Table 1. **Comparison of chemical composition - fossil-free vs. standard steel**

ELEMENT	STANDARD SPECIFICATION RANGE	FOSSIL-FREE STEEL (%)	CONVENTIONAL STEEL (%)
C	Min (-)- Max (0.12)	0.064	0.076
Si	Min (-) - Max (0.50)	0.109	0.02
Mn	Min (-) - Max (1.90)	1.4	1.32
P	Min (-) - Max (0.025)	0.0081	0.012
S	Min (-) - Max (0.015)	0.00078	0.004
Cr	Min (-) - Max. (-)	0.077	0.03
Mo	Min (-) - Max (0.50)	0.02	0
Ni	Min (-) - Max. (-)	0.078	0.04
Cu	Min (-) - Max. (-)	0.053	0.02
Al	Min (0.015) - Max (-)	0.04	0.051
B	Min (-) - Max (0.005)	0.00067	0.0001
Nb	Min (-) - Max (0.09)	0.049	0.043
Ti	Min (-) - Max (0.22)	0.122	0.089
V	Min (-) - Max (0.20)	0.0078	0.012

Additionally, **Figure 3** and **Figure 5** illustrate the stress-strain curves and hardness measurements for steel produced using HYBRIT (Hydrogen Breakthrough Ironmaking Technology). These results align closely with those observed for steel manufactured using traditional technologies [16].

Figure 3. **Stress vs machine piston displacement of fossil-free steel test specimens**

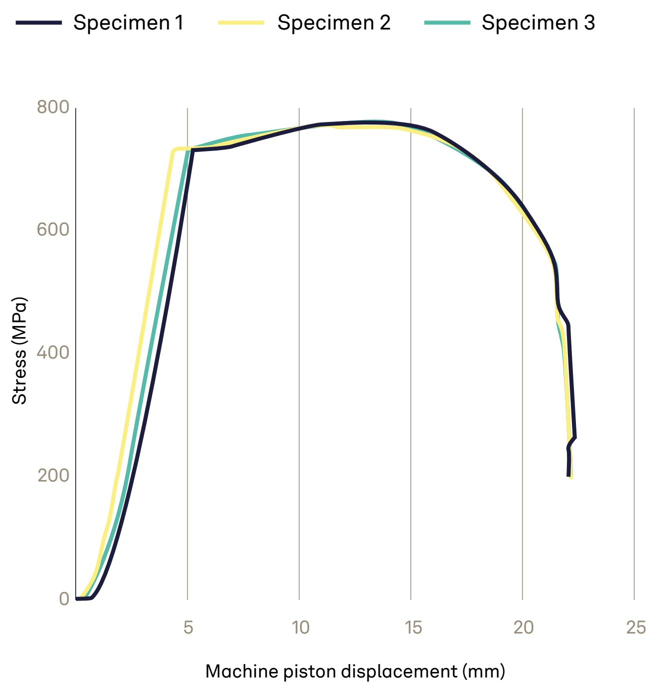


Figure 4. **Tensile testing setup of fossil-free steel specimens**

Figure 5. **Hardness measurements fossil-free steel**

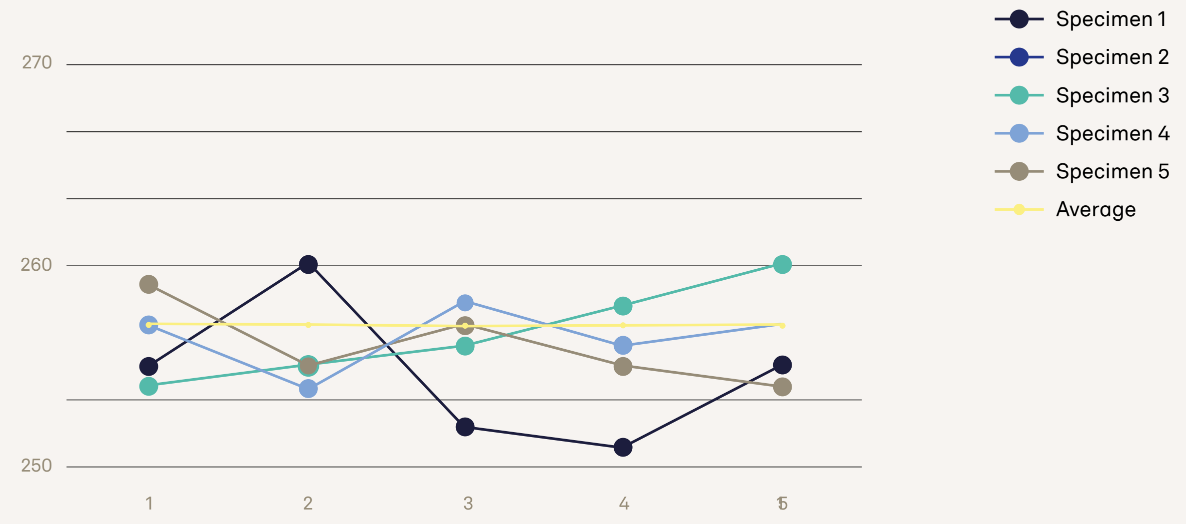


Figure 6 and **Figure 7** shows hardness measurement results for fossil-free steel welded to standard steel. These results were generated as part of establishing welding procedure specifications for welding box structure. **It can be seen that the hardness values are according to the expected limits i.e. comparable to hardness of standard steel.** The effect on hardness measurements at the heat affected zone can also be observed. In Figure 6, it can also be observed that the hardness measurement of standard and fossil free steel are similar. There is some scatter observed which is quite normal in such experiments and can be connected to production of steel at different times or manufacturing of the test pieces.

Figure 6. Comparison of hardness measurements S600MC fossil free steel and standard steel welded to S690QL

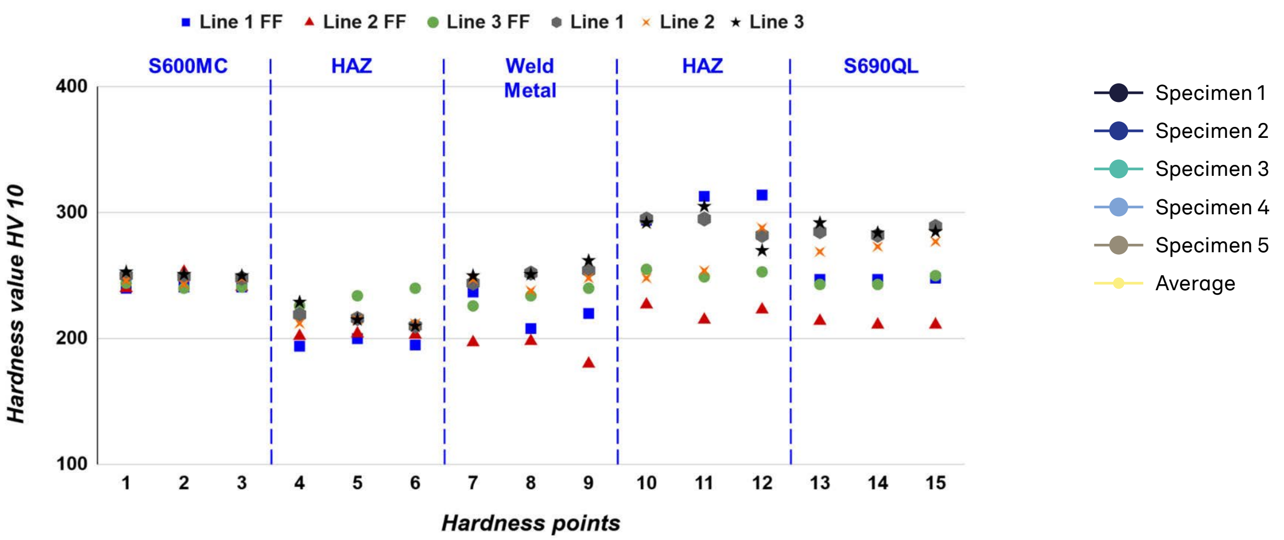
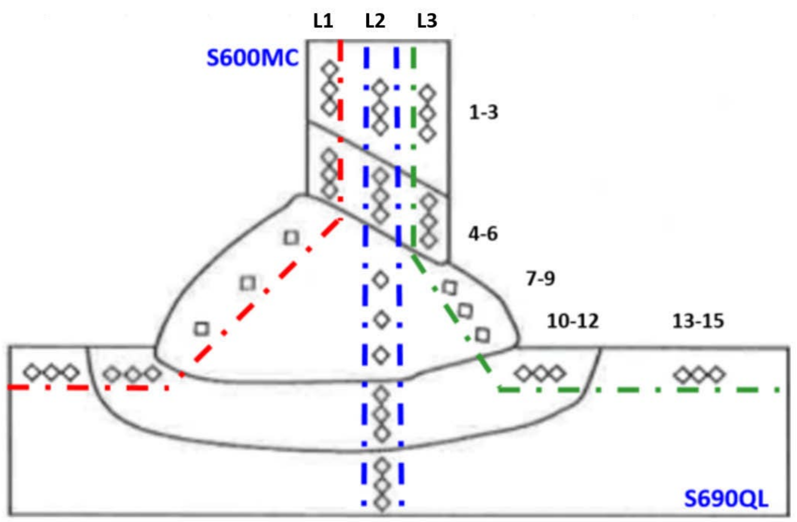


Figure 7. Schematic of hardness measurements in Figure 6



Fatigue strength

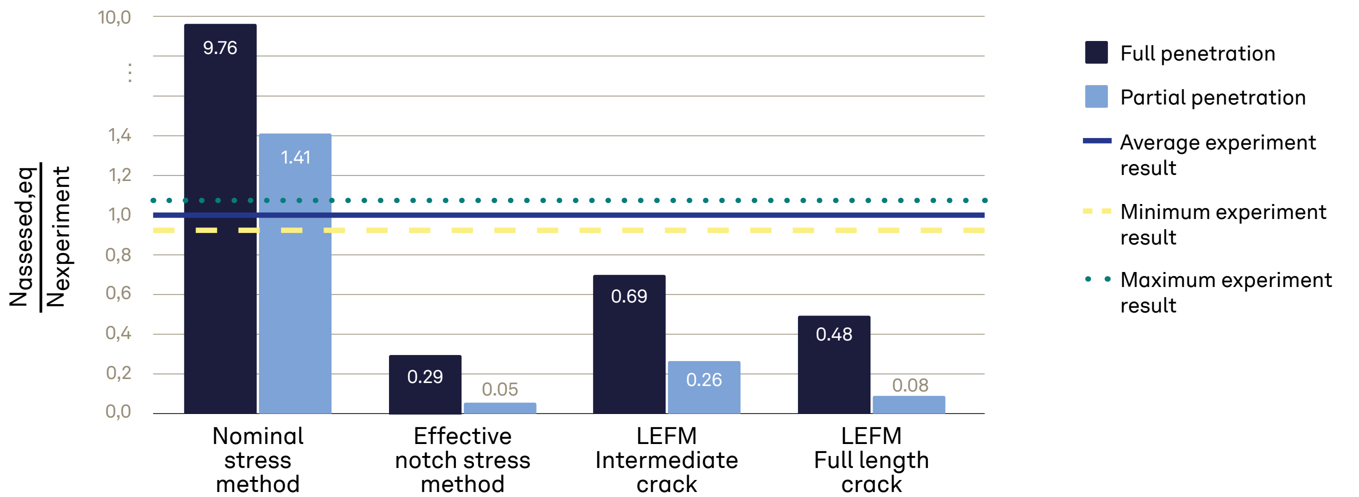
The fatigue strength of box-welded structures was analyzed as part of a project funded by Sweden's Innovation Agency, Vinnova, titled Varilight – Reduced Variation in Manufacturing Processes Enabling Lightweight Welded Structures (Grant Number 2016-03363). The project evaluated fatigue strength using various assessment methodologies. Bromma manufactured and tested the same components, and a round-robin study was conducted within the project to assess different fatigue strength methodologies and study the scatter in results [12].

The fatigue strength assessment results for the welded box structure are shown in **Figure 8(a)** and **(b)**. In these figures, the black line represents a 100% accurate life estimation compared to experimental results. The analysis reveals that:

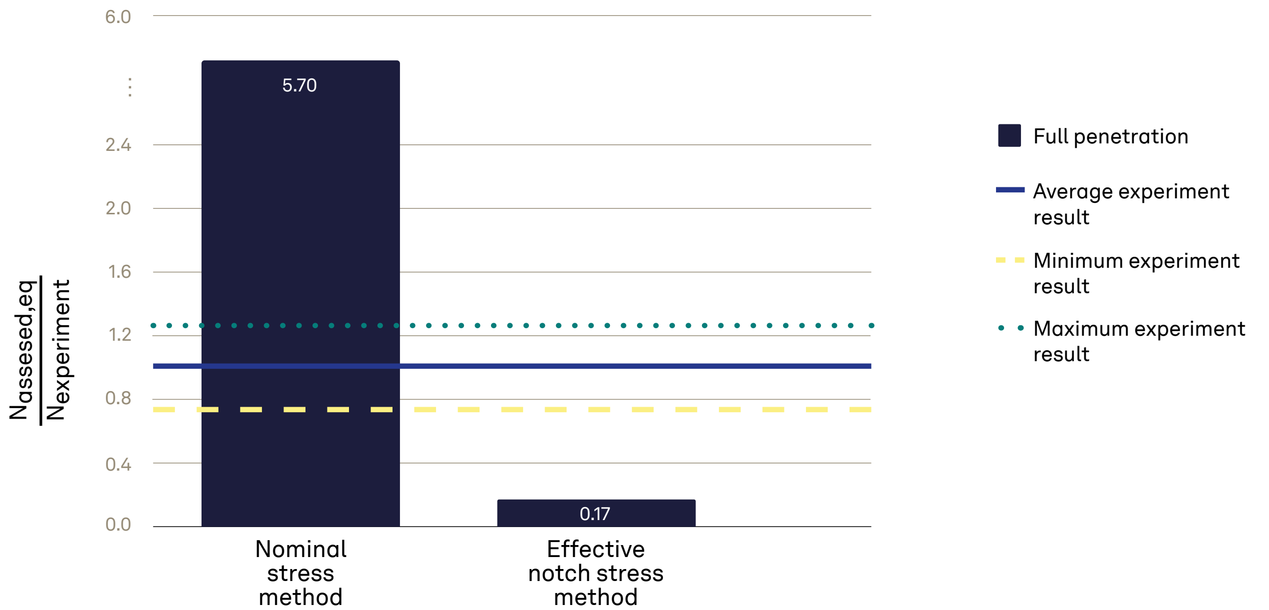
- Simple calculation methods, such as those recommended by standards like EN13001 [6-8],tend to overestimate fatigue strength for this specific component.
- Advanced methodologies, such as effective notch stress and linear elastic fracture mechanics(LEFM), provide more conservative and reliable life span estimates [12-15].

The assessment also considered the effect of residual stresses, which were studied both experimentally and through computational weld mechanics techniques [13]. Based on the observations in Figure 8(a), advanced methods are safer and more reliable, while the nominal stress method requires careful application.

Figure 8. (a) Experimental vs estimated fatigue lives for box welded structure made from standard steel



(b) Experimental vs estimated fatigue lives for box welded structure made partly from fossil free steel



Testing fossil-free steel components

Bromma recently tested the same component manufactured partially from fossil-free steel. The results, presented in Figure 8(b), include only welded boxes with full penetration welds. The weld strength was evaluated using the nominal stress and effective notch stress methods. While LEFM was not included, the trend is assumed to be similar to that observed in Figure 8(a).

The fatigue testing results for box-welded structures made from standard and fossil-free steel show some scatter, but the differences are not significant:

Average fatigue life:

- standard steel: 865,914 cycles
- Fossil-free steel: 858,335 cycles

Standard deviation:

- standard steel: 350,070 cycles
- Fossil-free steel: 226,687 cycles

These results indicate that the fatigue behavior of welded box structures made from fossil-free steel is comparable to those made from standard steel.

Strain gauge measurements

Figure 9 shows strain gauge measurements taken on a fossil-free steel box-welded structure to verify test loads and procedures. The data reveals that strains on Side 3 and Side 4 drop around 700,000 cycles, which are also the sides where cracks appeared after fracture. A similar trend was observed in box-welded structures made from standard steel [12].

To further validate the performance of fossil-free steel in welded box structures, a series of visual and experimental analyses were conducted:

- Figure 10 illustrates the modeled welded box, providing a detailed representation of thecomponent design.
- Figure 11 shows the test setup used for evaluating the fatigue strength and structural integrityof the welded boxes.
- Figure 12 displays the broken fossil-free steel welded boxes after testing, highlighting thefailure points and providing insights into the material's behavior under stress.

These visual and experimental results complement the numerical and analytical findings, offering a comprehensive understanding of the performance of fossil-free steel in real-world applications. Microstructure comparison of fossil free and standard steel was out of the scope of this study. Therefore it is not presented here, however it will be investigated in the future.

Figure 9. Strain measurements on box welded structure during fatigue testing

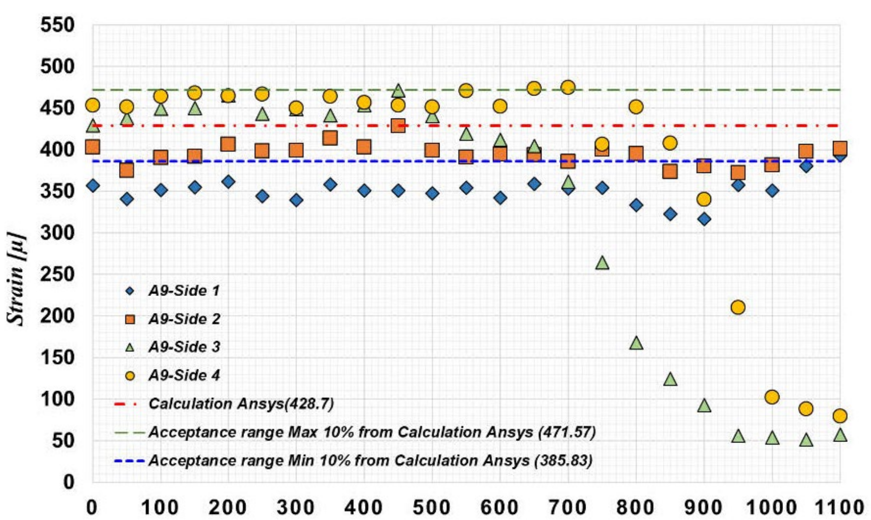


Figure 10. A) Box welded structure, (B) Meshed, (C) Deformation plot

Figure 11. Fatigue testing of partially fossil free steel box welded structures

Figure 12. Broken fossil free steel box welded structures

Conclusion

The results from material and component-level testing demonstrate that the performance of fossil-free steel components are similar to the components made with steel produced with standard technology. These findings support the viability of using fossil-free steel in Bromma's spreader manufacturing process.

The comparative tests conducted on box-welded structures—one of the core elements of a spreader—show minimal differences in performance between standard and fossil-free materials. From static load behavior to fatigue life and welding consistency, fossil-free steel meets Bromma's high standards for product quality and safety.

Beyond technical readiness, the environmental benefits are substantial. Transitioning to fossil-free steel can reduce the carbon footprint from the spreaders manufacturing phase by up to 94%, and lower the total life cycle emissions by up to 60%. These reductions are essential in helping both Bromma and our customers meet their sustainability commitments and regulatory requirements.

Most importantly, the results confirm that fossil-free steel is not only feasible for prototyping or experimentation—it is ready for commercial application. Bromma is now prepared to integrate fossil-free steel into future spreader models and bring these low-carbon solutions to market.

We will continue to monitor long-term performance and deepen our knowledge through further field data, but our current **results confirm that fossil-free steel qualifies today as a reliable, responsible, and forward-looking material for spreader production.**

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