DUPLEX WORLD SEMINAR & SUMMIT 2022

Cover Story: Outokumpu

Structures for a lifetime

Duplex as a material for bridge and storage tank construction

The Outokumpu research was conducted to establish a body of data for evidence-based alloy selection for stainless steel for structural applications.

The stainless steel industry has long believed duplex to be the perfect material for bridge and storage tank construction. That notion has now been proven by onsite inspections carried out by Outokumpu. A frontrunner in the production and promotion of duplex stainless steel, Outokumpu is leading the way in performing reality checks for these grades in structural applications. Sukanya Hägg Mameng from Outokumpu R&D has inspected bridges and storage tanks built up to fifteen years ago. In particular, she focused on the lean duplex Forta LDX 2101. In this article, Sukanya and Lead Technical Manager Andy Backhouse explain the relevance of this study, what the first results mean for duplex marketing, and how they could influence design codes such as Eurocode.

By Frank Wobbeking, Stainless Steel World

The high strength, minimal weight and long life of duplex of the Nynäshamn bridge fits with increasing focus on reducing the lifetime carbon footprint of infrastructure.

A trend supporting the use of duplex stainless steel is the global transition in urban traffic from car to public transport, walking, and cycling is forcing authorities worldwide to re-develop their city centres.

Sukanya's schedule during 2022 includes eleven bridges and six storage tanks in several countries. The first inspections have been completed, so it's time to discuss the results. "The idea of this project was to examine whether our expectations for the performance of duplex grades in different environments correspond to real-life applications," explains Sukanya. "The stainless steel industry has a lot of good atmospheric corrosion testing data from purpose-designed exposure test sites, but we wanted to check the reality."

Why is this project so important for Outokumpu? According to Andy Backhouse, the main reason is establishing a body of data for evidence-based alloy selection for stainless steel for structural applications. "Now we can provide real-world technical information to decision-makers. This enables us to significantly increase the competitiveness of these grades through optimising grade selection in external environments," he explains.

Promising circumstances

The economic circumstances for supporting the use of lean duplex grades are extremely promising. "There is an increasing awareness that construction costs are only a small part of the total cost of ownership. Stainless steel—particularly duplex grades—has an advantage in projects with high maintenance costs. "As an industry, we cannot try to replace every carbon steel installation, but we can look for places where the balance between construction costs and lifecycle costs leans in favour of stainless steel," Andy says. An example is the rail industry, which is increasingly running around the clock. "This means the opportunity for maintenance of rail infrastructure is reduced. Consequently, railway authorities are becoming increasingly interested in stainless steel structures, which need little or no maintenance," he continues.

In the case of bridges, another trend supports the use of duplex stainless steel: the global transition in urban traffic from car to public transport, walking, and cycling is forcing authorities worldwide to re-develop their city centres. "At the same time, they want their cities to look attractive, which makes stainless steel the perfect choice for new bridges and other structures. There is also increasing attention being paid to reducing the lifetime carbon footprint of infrastructure, and the high strength & minimal weight, together with the long life of duplex, fits with this philosophy."

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The combination of modern aesthetics and relatively low lifecycle costs is a convincing argument for decision-makers. Stainless steel for structural applications is recognised in design codes such as EN 1993-1-4 (Eurocode 3) and, more recently, AISC 370, helping promote adoption amongst structural engineers.

On the location

With that in mind, the inspection team hit the road, equipped with digital cameras and handheld XRF analysers. The first location of their tour was the Orrhammarvägen road bridge in Flen, Sweden. This bridge was built in 2009 and was the country's first stainless steel and concrete composite bridge. The duplex grade used was Forta LDX 2101. The R&D experts first examined the drawing of the bridge to obtain basic information about the architecture.

"As we could not cut pieces out of the bridge, we carried out a visual inspection, checked the grades used, measured the surface roughness, checked contamination and took water samples," Sukanya says. Every step was documented with digital photographs, and the samples were sent to a specialised lab.

"Excellent condition"

It may or may not come as a surprise, but the inspection results confirmed what the stainless steel industry had assumed for many years. "After thirteen years, the bridge is still in excellent condition. There are no signs of corrosion at all. We found some contamination caused by dirt and sand, but the corrosion resistance was not affected. The bridge looks perfect." The inspection results also showed that other components made of galvanised steel, such as bolts used in brackets securing an electrical cable and the roadside barrier, are in poor condition.

The contamination on the bridge beam surface was collected and transferred to a specialised laboratory. A sample of this contamination showed that O, Fe, Na, Mg, Si and Al were present on the stainless steel surface but had no adverse effect on the steel's corrosion performance.

The next bridge on the list, Nynäshamn in Sweden, was also manufactured with LDX 2101. "This bridge was built before a stainless steel material selection procedure was introduced into the Eurocode. From today's perspective, Eurocode 3 would suggest using grade DX 2205 because of the corrosive environment near the coast and the risk of corrosion from de-icing salt, so it was very interesting to see how the lean duplex has performed until now. And we can say it has performed very well," Andy states. After eleven years in service, the duplex material was in perfect shape. The Outokumpu experts detected some dirt and dust but no signs of corrosion.

Structural engineers

The first pedestrian bridge to be checked was a modular bridge over the main E4 highway in Södertälje. The result of the material analysis was particularly interesting. "You could call the bridge a stainless steel experiment," Sukanya says with a smile. Several different grades were used, with standard austenitic grades used for some non-structural components. Andy went on to give his experience of talking to bridge designers: "Construction companies are often not familiar with duplex. Structural engineers, who design bridges, are usually familiar with carbon steel. Our challenge is to ensure structural engineers, designers, and architects are aware of the advantages and the limited variety of duplex stainless steel grades that are relevant to them. Providing them with good technical information in a digestible form is an ongoing task for us."

What is the conclusion of the first inspected bridges? "Forta LDX 2101 showed good resistance to atmospheric corrosion after eleven and thirteen years in Eurocode Corrosion Resistance Class (CRC) III environments. With appropriate consideration of specific environmental circumstances, the grade might be successfully used where the conditions are slightly more harsh than CRC III describes. A very long life of the structures inspected can be anticipated, with minimal need for maintenance," the inspection team concluded. Meanwhile, the R&D experts have inspected more bridges in different European countries. As diverse as they are, the results were consistent: all bridges are still in excellent condition.

Storage tanks

The second part of the inspection project involves the performance of Forta LDX 2101 in storage tanks. The use of duplex stainless steel in storage tank constructions has increased significantly in the last twenty years, particularly for chemical, pharmaceutical or wastewater applications.

"Forta LDX 2101 has often been selected over Forta DX 2205 and Forta DX 2304 due to its exceptional mechanical properties, reasonable corrosion resistance, and lower costs. It is important to select the appropriate stainless steel grade for the intended service environment, as the price of the material generally increases with the corrosion resistance," explains Sukanya. However, there is less documented information available about the service performance of actual structures, such as the storage tanks made of Forta LDX 2101. For that reason, Outokumpu decided to inspect tanks which have been in service for years. Tanks in two locations have already been inspected, and the results were summarised in a report.

The Södertälje bridge contains several different grades of duplex, with standard austenitic grades used for some non-structural components.

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Outokumpu inspected tanks which have been in service for years to obtain documented information available about the service performance of actual structures.

Inspection procedure

The storage tanks were inspected to verify the durability of stainless steel in terms of atmospheric corrosion performance in actual service environments. The first tanks inspected were built by Oostwouder Tank & Silobouw and contained contaminated water (a mixture of oily sludge and wastewater). They are owned by ATM, a producer of circular raw materials and processor of hazardous waste streams, located near a river not far from the sea, south of Rotterdam.The choice of LDX 2101 is typically considered appropriate for the expected service conditions.

The selected tanks were respectively eight and twelve years old at the time of inspection. The procedure for each storage tank involved a visual inspection and digital photographs to identify the stainless steel elements and document the stainless steel conditions. A handheld X-ray fluorescence spectrometer was used to confirm the grade of steel used where access was possible. When interesting contamination was observed, it was transferred to an adhesive scanning electron microscope (SEM) stub. The laboratory procedure included analysis of contamination by SEM and energy-dispersive X-ray spectroscopy (EDS) to identify the nature and chemical composition.

In the ATM tanks inspected near Rotterdam, Forta LDX 2101 showed good resistance to atmospheric corrosion after eight and twelve years in the service environments.

The corrosion Resistance Class (CRC) of the inspected tanks is characterised in accordance with the standard EN 1993-1- 4:2006/A1:2015 Annex A, which provides a procedure for selecting an appropriate stainless steel grade for the service environment if structural integrity is the primary concern. The CRC system considers the risk of exposure to chlorides from saltwater or de-icing salts, the risk of exposure to sulfur dioxide, SO_2 and the cleaning regime or exposure to washing by rain.

Unsurprisingly, the results were similar to the results of the inspected bridges. "Forta LDX 2101 showed good resistance to atmospheric corrosion after eight and twelve years in the service environments. No significant difference in terms of corrosion performance was observed for the CRC II (304L/4307) and CRC III (Forta LDX 2101 and 316L/4404) grades," the report states. All grades were only susceptive to low levels of cosmetic corrosion in the most aggressive condition (CRC III), which does not affect the structural integrity of the stainless steel. This shows that Outokumpu Forta LDX 2101 is an appropriate material choice for a storage tank structure in this service environment. This grade shows excellent long-term durability, and by utilising the higher mechanical strength, it is possible to save weight compared to standard austenitic grades.

Eurocode

What does the inspection project have to do with the Eurocode design standard? "In many cases, we have shown the Eurocode material selection guidance in EN 1993-1-4 Annex A is appropriate and can be used with confidence by structural engineers who are not specialists in stainless steel. "We also checked some environments where the Eurocode may point designers towards a more highly alloyed steel than was actually used. We have shown that there is some scope, with a more detailed knowledge of a particular environment and the specific project requirements, to select a more lean alloyed steel than the Eurocode might recommend. In doing so, you can save money and make it more likely that stainless steel will be chosen. It is really good to have this information," Andy concludes.

This new evidence of real-life performance is a perfect way to spread the word about duplex stainless steel among structural engineers and architects around the world.