Sustainable Modular Construction Using B-CORE Stainless Steel

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***Abstract*—Stainless Steel is one of the most sustainable and durable construction materials as measured in its Life-Cycle Assessment (LCA). Sustainability can be measured in three key LCA metrics: Durability, performance, and recyclability. The BROAD Group has conducted research into the use of stainless steel to improve the safety and durability of high rise buildings. The research has proven the unique properties of austenitic and duplex stainless steels in particular, including the "B-CORE" sandwich structure stainless steel construction material developed by the BROAD Group, make stainless steel excellent for use in all structural load bearing members of buildings.**

***Keywords*—stainless steel, sustainable, B-CORE.**

I. Introduction

A key challenge the construction industry has faced is how to design and construct buildings that have a longer service life, and can better withstand severe weather and seismic events. Conventional mid and high-rise buildings made from reinforced concrete and carbon steel have exhibited a limited service life averaging 50-75 years due to deterioration and obsolescence that sets in due to corrosion among other factors.

The BROAD Group underwent a 13 year research project to develop a construction material that is more durable, safer, and more sustainable. The result of their research has shown that stainless steel delivers a far longer service life with superior durability, and is more sustainable than other construction materials as measured in its Life Cycle Assessment (LCA).

Stainless Steel has been used for nearly a century in building facades around the world, including the iconic stainless steel cladding on the spire of the Chrysler Building in New York City in 1930, which was the first major building to use stainless steel in construction. Architects of the many buildings that have employed stainless steel chose the material in large part due to its anti-corrosive features, and the stainless steel used in these buildings has demonstrated excellent durability. What these buildings worldwide have in common is that stainless steel was used mainly on the exterior of the building for its aesthetic properties and low maintenance. However, the research conducted by BROAD Group shows that the unique properties of stainless steel, including the sandwich structure "B-CORE" stainless steel developed by the BROAD Group, also make stainless steel excellent for use in the structural load bearing members of buildings as well. This improves both the service life and the safety of tall buildings.

II. Sustainability and Properties of Stainless Steel for Modular Construction

Stainless Steel is one of the most sustainable construction materials as measured in its Life-Cycle Assessment (LCA). The LCA is a method to measure the impact of a material on the environment throughout its lifecycle, from manufacture to obsolescence which in construction, is demolition. Sustainability can be measured in three key LCA metrics: Durability, performance, and recyclability.

- Durability: Depending on the grade and in particular the 300 series of austenitic stainless steels, stainless steel is from 30-95% more resistant to corrosion than carbon steel. Stainless steels must contain at least 10.5% chromium, and the 300 series of austenitic stainless steels typically contain about 18%. Chromium reacts to oxygen and forms a protective layer that makes stainless steel highly resistant to corrosion and rust. A whole building Lifecycle Assessment performed on the BROAD stainless steel Holon Building [1] shows a lifespan 20 times longer than a conventional reinforced concrete building which is typically 50-75 years. A building that uses stainless steel for its load bearing structural members therefore has an indefinite service life. Extending the service life of a building better protects the investment in the structure, and avoids the demolition and reconstruction cycle which wastes resources, and is environmentally unsustainable with ever increasing use of landfill following demolition.
- Performance: Stainless steel has a very high ductility. Ductility is measured in % elongation before fracture during tensile testing. Elongation is deformation that occurs before a material eventually breaks. Stainless steels have a dramatically greater elongation than carbon steels, and austenitic stainless steel elongation rates are generally $\geq$ 40% [2]. Carbon steels are harder than stainless steels, but are less ductile. In the construction of tall buildings, ductility, or the ability to handle tensile load stress including seismic events, and to deform without fracture, can be a more relevant measurement of strength than hardness. In addition, stainless steels exhibit superior performance at high temperatures: Austenitic stainless steels retain a higher proportion of their strength above approximately 1,020 °F (550 °C) than carbon steel [3].

- Recyclability: Stainless steel is 100% recyclable and has one of the highest recycling rates of any material. It is estimated that 85% of stainless steels are recycled at the end of their life [4], without degradation in strength regardless how many times the process is repeated. Upon demolition, 92% of the stainless steel used in construction is recycled back into new metal [5]. It is an indefinitely recyclable resource with one of the highest recycling rates of any material. "Taking into account its entire lifecycle, stainless steel has one of the lightest impacts on the Earth of all known engineering materials. And at the end of its long life, all stainless steel can be recycled to create new stainless that is as strong and long-lasting as the original [6]."

Given the sustainability of stainless steel as measured in the key LCA metrics of durability, performance and recyclability, stainless steel was chosen by the BROAD Group for all structural load bearing members of their modular buildings. While applying stainless steel to a building façade has aesthetic value and the benefit of low maintenance, applying stainless steel to the building load bearing members including floor systems, columns and beams, gives the building a longer service life and greater safety in the event of seismic or high wind events that can cause tensile stress to the buildings' load bearing components. BROAD Group is the first to construct a high rise building solely from stainless steel, with no carbon steel or concrete above the foundation.

The first all stainless steel high-rise building was erected in 2019. The "F Tower" on the BROAD Group campus in Changsha, China is 16 stories, 81,000 sf, and took 43 days to erect. Stainless steel gave the architects of the F Tower the ability to cantilever the wings of the building, while occupying a very small footprint.

Fig. 1. BROAD F Tower: the first all stainless steel high-rise building

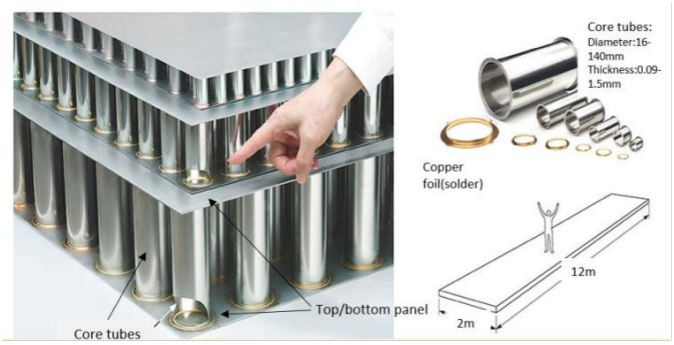

Fig. 2. BROAD B-CORE Slab

III. B-CORE Sandwich-Structure Stainless Steel

BROAD Group has innovated a new type of stainless steel material, the B-CORE Slab, which is a sandwich- structure material composed of core stainless steel tubes brazed between two stainless steel plates. The core tubes are 304L stainless steel, and the plates are a new type of austenitic stainless steel, QN1804. A hot air copper brazing process is used to braze the core tubes to the plates. As copper has a lower melting point than stainless steel, it was deemed to be the most effective brazing method. The sandwich structure is brazed in a special kiln at 1100°C (2012°F) which imbues the material with greater strength to compliment its non-corrosive and ductile properties.

As the brazing material, copper has a lower melting point than the base stainless steel, and is therefore deemed to be the most effective brazing method. The spaces between the B-CORE tubes allow the hot air to melt the copper during the brazing process. The hot air is blown into the ovens at a very high speed, which heats the B-CORE slabs uniformly. This ensures high performance under tensile stress conditions.

The inspiration for the development of the B-CORE slab was the honeycomb panels used in the outer shells of spacecraft. Conventional honeycomb panels used in spacecraft are air tight, and brazing is achieved through thermal radiation which is a slow process with a production cost up to 20 x higher per sq m than the hot air brazing process used in fabrication of the B-CORE slab.

The ends of the B-CORE tubes are flanged, making the brazing surface 10× larger to fuse the B-CORE slabs and plates solidly. Even if a tube snaps, the brazed parts of the sandwich structure slab do not separate. The core tubes are 304L stainless steel, and the plates are a new type of austenitic stainless steel, QN1804.

B-CORE is lighter than carbon steel, and has superior structural strength (rigidity). This lightness and strength of B-CORE slab is illustrated in the cantilevered wings of the "F Tower." B-CORE slab enables cantilevering up to 17 m (55 ft).

The B-CORE Slab is used as the flooring system of the BROAD Holon Building, while duplex stainless steels are

Fig. 3. B-CORE production line: B-CORE is made by AI manufacturing

used for columns and beams. Duplex stainless steels have a structure that is about 50% austenitic and 50% ferritic. This austenitic-ferritic blend gives duplex stainless steels a range of attractive properties: In terms of strength, duplex stainless steels have a higher strength than carbon steel and are as much as twice as strong as regular austenitic or ferritic stainless steels [7]. Duplex stainless steels are more ductile than ferritic stainless steels, though the ductility may not reach the level of some austenitic grades such as 304. Duplex stainless steels can match the corrosion resistance of 300 series austenitic stainless steels, and can have superior stress corrosion cracking resistance. Duplex stainless steels can be lower in cost than austenitic stainless steels as it has a lower nickel and molybdenum composition.

The range of austenitic and duplex stainless steels available enabled BROAD Group to select the best grade for each structural member, with the result that B-CORE and duplex stainless steels used in place of concrete and carbon steel deliver greater durability and superior ductility while being more environmentally sustainable. This reduces the carbon footprint of the building throughout its lifecycle.

IV. Conclusion

The B-CORE slab developed by BROAD Group, and austenitic and duplex stainless steels are ideal for the structural load bearing members of a building due to the key metrics in their LCA of durability and performance, and being 100% recyclable, are among the most environmentally friendly of all construction materials. These properties make the B-CORE Slab and other stainless steels a superior and sustainable construction resource.

Fig. 4. BROAD Holon Building: Prefabricated stainless steel buildings produced to industrial scale

Fig. 5. BROAD Holon Home Garden Building: All load bearing structural members are composed of stainless steel

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