# Sustainable steel solutions for port infrastructure

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Steel sheet piles have been used in ports for the execution of quay walls for almost 100 years. They replaced wooden piles due to the lack in the supply of wood by the end of the 19th century.

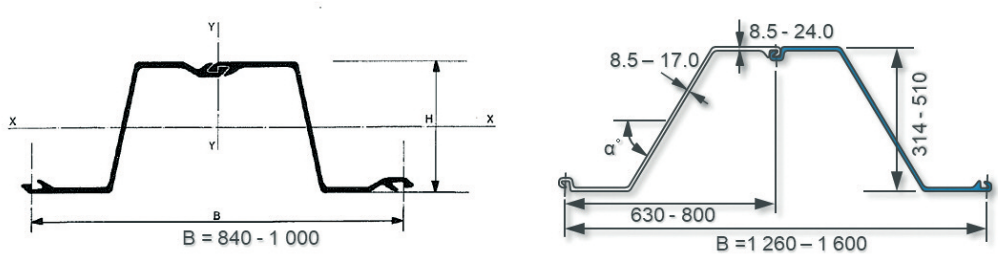
In the meantime, numerous quay walls, jetties and breakwaters around the globe have been built with steel sheet piles. The evolution of the shapes of the profiles combined with the improvement of the steel grades made it possible to design increasingly deeper maritime structures in response to the increase of the size of the vessels.

Research and development contributed to lowering the environmental impact of the steel in several ways. Firstly, by reducing the quantity of steel required to build equivalent structures, and secondly by developing new production routes that recycle steel.

Durability is an important criterion of sustainability, and one of the major challenges for maritime structures. Steel and reinforced concrete are both affected by this harsh environment. Construction industry is looking for new innovative solutions to increase the service life and reduce maintenance costs during the entire life-cycle.

The second aspect in sustainability is the environment. Financial considerations will always be a key parameter in the choice of the technical solution, but the world is changing, and in the last years, environmental aspects are gaining more and more importance in the complex decision-making process.

The inexorable advance in rolling techniques, along with the development of more efficient driving techniques pushed steel sheet manufacturers to improve the effectiveness of their products, the aim being to outperform competitors. For instance, the reduction in




**BZ** (1950's) | **AZ**® (1990 – 2004 – 2015)

| | $W_{el}$ ($cm^3/m$) | mass ($kg/m^2$) | Δ mass (%) |
|---|---|---|---|
| BZ IIR | 1 370 | 140.0 | |
| AZ 14-770 | 1 355 | 103.2 | **-26%** |
| BZ VN | 3 720 | 237.0 | |
| AZ 38-700N | 3 795 | 180.6 | **-24%** |

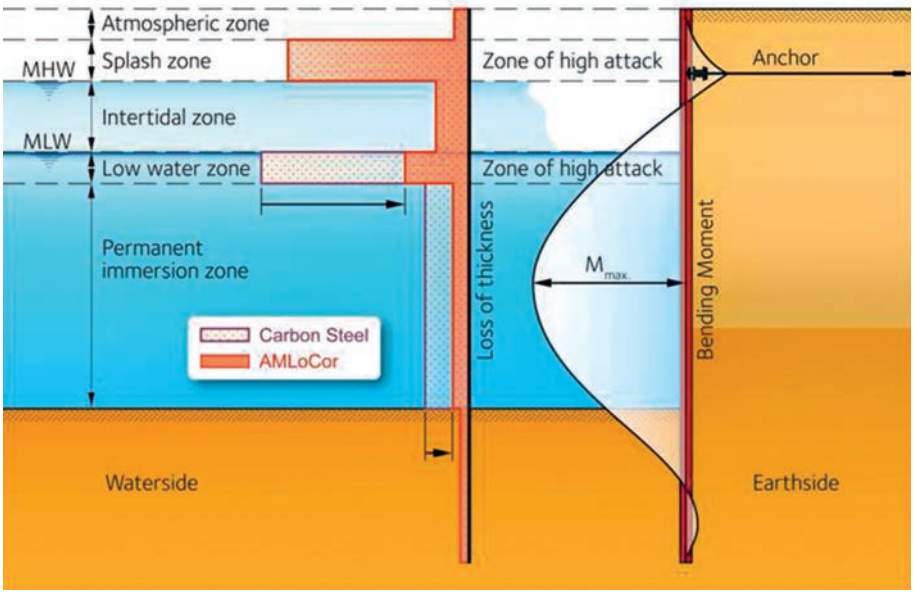
Development of Z-type sections over last decades: mass reduction (mass) for similar section properties.

weight between different generations of Z-type sheet pile sections with the same section modulus is significant: the new AZ®-800, launched in 2015, is more than 25% lighter than an equivalent BZ section from the 1950's.

Similarly, the high section modulus HZ®-M steel wall system was launched in 2008 and beats the old HZ system from the 1970's by at least 10% in weight. Its maximum resistance (maximum section modulus) was more than doubled.

Additionally, taking into account the increase of up to 30% in yield strength of current steel grades, *the mass of steel required to build exactly the same sheet pile structure has decreased in the last decades by more than 50%!*

Corrosion is one the key parameters for the optimization of a steel structure in a marine environment. It is quite difficult to estimate a reduction of thickness of a steel element in sweater, because many parameters influence the corrosion phenomenon. These parameters can also vary during the service life of the structure. To improve the durability, new steel grades emerged in the last years specifically for marine applications. Based on more than 15 years of exposure of steel samples in seawater in a UK port, measured corrosion rates of steel grade AMLoCor® in the low water zone and in the permanent immersion zone are up to 5 times smaller than the ones of standard carbon steel.




Corrosion rates measured in a port in the UK over a period of 15 years.

AMLoCor has been granted a German national technical agreement, so that even if it contains more alloys than a standard steel used in construction, it can be designed according to the international design standards for steel. For instance, approximately 4 000 tonnes of steel sheet piles in AMLoCor were installed in the new Unitterminal in the Port of Koege, Denmark, in 2016.

Unitterminal | Port of Koege | Denmark (2016). 4 000 t of AMLoCor ® steel sheet piles installed.

*Reduced corrosion rates can lead to lighter sheet pile sections,* and can avoid the need for coatings. This is a typical win-win situation for the environment.

Groins built with steel sheet piles are used to protect beaches from wave erosion, and more recently, sheet pile walls in the USA were designed to protect beach fronts from the devastation of storms and hurricanes.

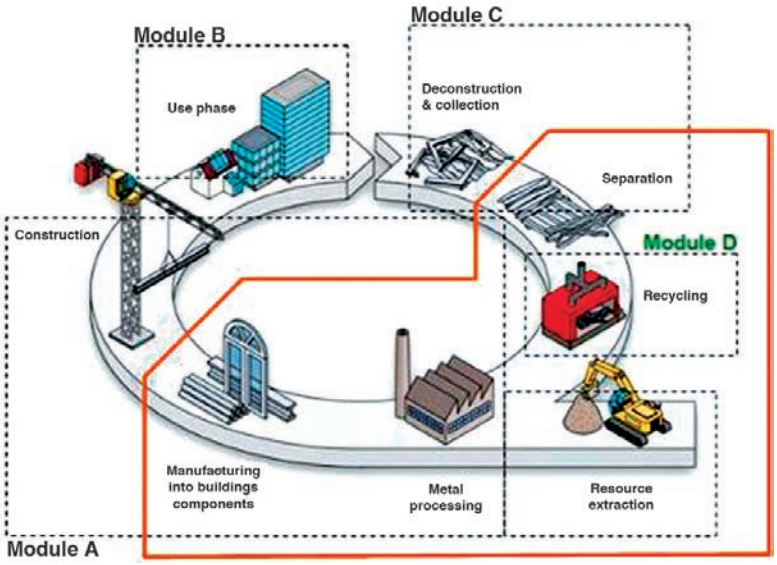
Steel is durable and resistant, but it has another outstanding property: *steel can be recycled over and over again. Recycling preserves natural resources,* and hence contributes to a more sustainable world. Steel is an environmentally-friendly material, and 100% of the steel in any structure can be recovered and recycled.

The challenge in port construction is that old structures are not always dismantled, but in a few decades, recovering the different construction materials for further processing, preferably recycling, will be a natural thought for every project owner. The building industry already takes into account environmental criteria, for instance in the certification of 'green' buildings (labels such as LEED, BREEAM,…). It is noteworthy that some European administrations already implement sustainable criteria in their tenders of public works, based on the 'Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement'. One method is to monetize the different sustainable criteria, for instance by giving credits based on an LCA (environmentally-friendly materials get more credits).

The difficulty in comparing alternative solutions from an environmental point of view is the lack of reliable information about the environmental impacts of each material. The effects of installation, its use phase, and after the service life, the recycling, are not easy to calculate. The main contributors of a structure to the environmental impact shall be analysed through a Life Cycle Assessment (LCA) according to ISO standards, taking into account every phase of the structure, including the recycling of the material.

An Environmental Product Declaration (EPD) for a specific product (specific use) simplifies such comparisons. It consists of an LCA using data provided by one or more production mills (steel mills and rolling mills) for specific products. Assumptions on reuse and recycling rates depend on the utilization of the products. Steel sheet piles can be reused several times, for temporary applications, but most of them are used in permanent structures for a service life ranging from 30 up to 100 years. Some modules, such as production from cradle-to-gate (modules A1 to A3 from EN 15804) are mandatory, others are left to the choice of the manufacturer.

ArcelorMittal leads the way by being the first manufacturer of steel sheet piles to have published a peer-reviewed EPD according to the latest ISO and EN standards for steel products in 2016, and a more specific *EPD for EcoSheetPiles™,* which are sheet piles




Modules considered in the EPD according to EN 15804.

manufactured exclusively out of scrap through an electric arc furnace (EAF) route, in June 2018.

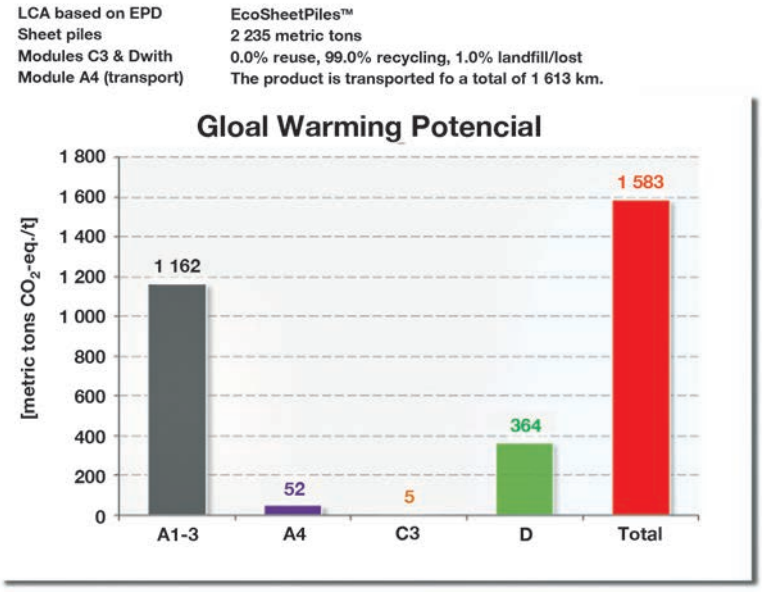
The next step in the industry should be the development of more user-friendly tools and calculators to perform the comparison of LCA's with different materials. It is important to mention that *LCA's should compare alternatives for the same functional unit.*


EPD EcoSheetPiles™ (ArcelorMittal) published by IBU e.V. in June 2018.

LCA's performed by ArcelorMittal in the past have shown that for a couple of quay wall configurations, steel has a lower environmental footprint than alternative materials, provided that steel elements are recovered and recycled after the service life of the structure.

As an example, below chart shows a simplified LCA for the parameter 'Global Warming Potential' ($CO_2$) using realistic assumptions for a project in Denmark, where 2 235 t of sheet piles manufactured in Belval, Luxembourg, were transported by rail to Antwerp, Belgium (around 328 km), and then by vessel to Kalundborg, Denmark (around 1 285 km). There can be huge differences between the EPD's and assumptions made in a LCA for a specific project. Clearly, transport has a very small impact on the overall carbon footprint of the solution. Installation, maintenance and dismantling can most of the time also be neglected (not represented on the graph). Following graph is based on a recycling rate of 99% of steel, and no reuse.

The key parameter is undoubtedly the re-use and recycling rate. The *electric arc furnace route (EAF) reduces significantly the environmental impact of a sheet pile solution*. Module D takes into account the influence of reuse and recycling of steel, but since it is not mandatory to declare it, some authorities do not consider it in the LCA. In our opinion, module D should always be considered.




LCA: global warming potential for a sheet pile project in Kalundborg, Denmark (2018).

Finally, a fashionable expression nowadays is *circular economy,* which encompasses the reuse of products and materials, consequently reducing the waste of natural resources. *Steel sheet piles have been a precursor because they can be re-used several times* for temporary excavations before being scraped, and are sometimes even re-used in permanent structures. We have seen steel sheet piles that have been used up to 10 times. Rental of steel sheet piles contributes also to the circular economy (reuse).

Sustainability is a key goal for new port infrastructures in the future. It will be a challenge, for sure, and innovative steel solutions can definitely contribute to the achievement of this crucial goal.

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