STRUCTURAL STEELS

Dutch bridges point the way

DILLINGER

MODERN CONCEPTS OF STEEL

It pays off to select modern and innovative grades and high quality steels as early as the planning and design phase: this is how outstanding modern and sustainable structures engineered in steel evolve, via consistent exploitation of the potentials nowadays available thanks to smart product developments during steel production.

Modern innovations in steel permit not only more slender architectural aesthetics, but also highly efficient, cost optimized fabrication. The special benefits of these new developments in steel are summarized below and are then illustrated by a number of selected bridge projects completed in the Netherlands.

Higher strength steels

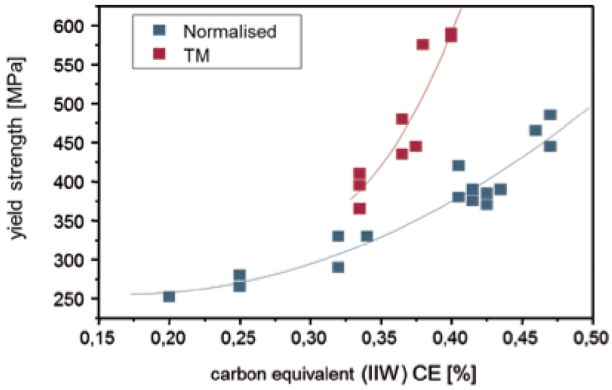
A steel with a minimum yield strength of 355 MPa (e.g. S355N) used to be classified as a higher strength steel, whereas nowadays steels of a yield strength class of at least 460 MPa and up to 690 MPa are frequently deployed. There is a good reason for this: these new “higher strength” steels permit significant savings on weight, and thus on costs, and provide an ideal example of the sustainable use of resources in bridge engineering. Up to 30% of material thickness can be saved, depending on the loading situation, when using a S460 rather than a S355, thus allowing lighter designs and longer spans.

In addition to the obvious cost benefits of using less material, higher strength steels also offer other advantages. Firstly, the lower overall weight has beneficial implications for foundation design. Secondly, welding costs are significantly lower since they decrease at a greater rate than plate thickness.
Dillinger’s S460M/ML (available as product brand DI-MC 460 B/T) is therefore an excellent alternative to a classical S355J2+N. It possesses excellent workability properties and can be used with great cost efficiency even at high thickness.
If a steel with a 460 MPa yield strength should run up against its limitations, particularly in heavily stressed components, however, the use of a S690Q/QL will open up new design potentials. Here, thanks to this steel good workability, Dillinger can provide the ideal solution for even more lightweight and filigree structures in bridge engineering – in the form of DILLIMAX 690.

SAFE AND EFFICIENT STRUCTURAL DESIGNS

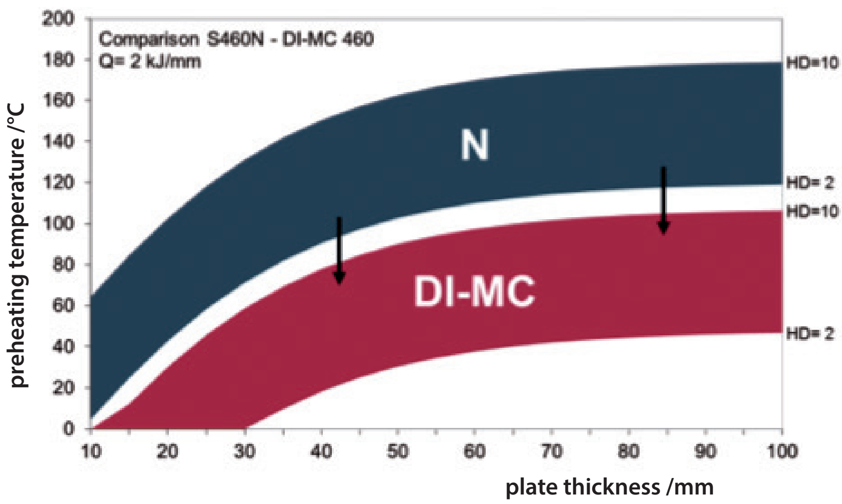
Excellent weldability

To attain higher strengths, additional elements must be alloyed into the steel, but will, however, necessitate greater care in welding. In these cases, higher strength thermomechanically rolled steels, such as S460M/ML, provide the ideal compromise between high mechanical strength and excellent weldability since the extra strength for these plates is very largely obtained by means of the special rolling process. High alloying element contents are thus avoided and an extremely low carbon equivalent is achieved.



The widely used CEV and CET carbon equivalents can in this context serve as an indicator of weldability: the lower the CEV or CET, the better the weldability. Therefore, these can be also applied to calculate the preheat temperature necessary for welding a steel.

DI-MC 460 very low carbon equivalent means that this steel can be welded at a significantly reduced preheat temperature. Correct selection of weld parameters can, in fact, make it possible to dispense with preheating entirely, even in higher plate thickness ranges. DI-MC 460 thus achieves greater strengths without loss of workability.



By producing its own feed material, Dillinger has at its disposal extremely thick, high quality slabs. Perfectly harmonized coordination with Dillinger's rolling and cooling technology thus permits production of heavy plates in the advantageous S460M/ML (DI-MC 460 B/T) grade up to a plate thickness of 150 mm - with a guaranteed low CEV carbon equivalent.

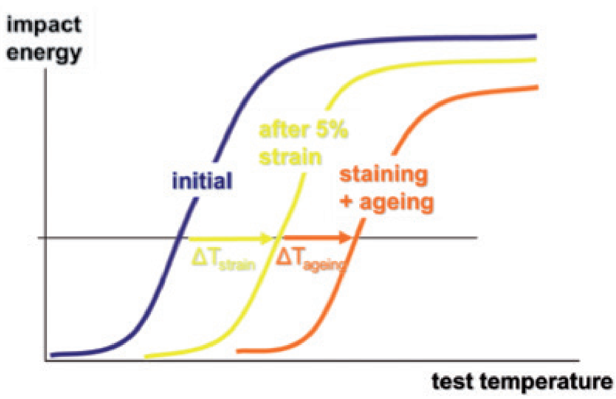
Plate thickness t [mm]	DI-MC 460 B/T typical CET [%]	DI-MC 460 B/T typical CEV [%]	DI-MC 460 B/T max. CEV [%]	See EN 10025-4 max. CEV [%]
t ≤ 16	0.27	0.38	0.40	0.45
16 < t ≤ 40	0.27	0.38	0.40	0.46
40 < t ≤ 63	0.25	0.39	0.41	0.47
63 < t ≤ 120	0.25	0.39	0.41	0.48
120 < t ≤ 150	0.26	0.40	0.43	-

Maximum toughness requirements

High material toughnesses and insensitivity to cracking are important factors in component safety for engineering structures. A crack tip opening displacement (CTOD) test determines the material resistance to crack propagation and is thus considered proof of maximum toughness. For steels in conformity to EN 10225, this test has therefore proven its value as an additional verification, particularly for offshore applications. Structural steels, such as S460ML, are nowadays also available in conformity to such test requirements. This test can be performed both on the weld (generally for prequalification of a material) or on the parent material.

Maximum cold formability requirements

In pipes or in bent and rounded shapes - versatile formability is one of the outstanding properties of steel as a material and makes possible the achievement of complex, innovative and efficient structures. Unfortunately, cold forming, in particular, results in a loss of the material toughness and thus in a shift in its transition temperature from tough (upper shelf of transition curve) to brittle material behaviour (lower shelf of transition curve).



Steels with a very low transition temperature in this context possess the necessary reserves of safety. It is now possible, for example, to produce steels which meet low temperature toughness requirements even after 10% deformation followed by ageing. Cost and time intensive normalizing of cold formed components can thus be omitted in the fabrication process. This assures efficient and dependable fabrication.

PROVEN IN IMPOSING BRIDGE PROJECTS

Zandhazenbrug

Higher strength steels | **Excellent weldability** | **Maximum cold formability requirements**

As part of the largest infrastructure project ever built in the Netherlands, the Schiphol-Amsterdam-Almere abbreviated SAAone project, the new double track arch bridge over the A1 near Muiderberg, to the east of Amsterdam, was officially opened on 26th August 2016. This mega undertaking included among others the widening of the A1 motorway from six to ten lanes. The replacement of the before existing concrete rail bridge by a longer structure was necessary to provide space for this road widening. Because of the required wide span, the most suitable solution consisted of a steel arched bridge without any intermediate supports. The resulting bridge, with a span of 255 m, a width of 17 m, a height of 55 m and a weight of 8,400 t, is one of the largest arch bridges of its type in all of Europe.
"Slender", "easy to transport" and "easy assembly on site of the prefabricated components" – these were the design requirements. In order to achieve these objectives, the designers and constructors set high demands to the materials and the welding technology to be used for the construction. Therefore, in order to reduce the weight, they selected the higher strength thermomechanically rolled steel S460M/ML. For the transverse tubes they relied on the S355NL with highest requirements on cold formability. Some 8,250 t of Dillinger steel, thereof round 7,000 t in grade S460M/ML, were used for the construction of this unique bridge.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Queen Maxima Bridge

Maximum cold formability requirements

This bascule bridge, opened to traffic on 6th April 2017, spans the Oude Rijn at Alphen aan den Rijn. The passage, even for ships with higher superstructures, is made possible by two bridge segments which can be opened and closed. In its kind, the Queen Maxima bridge is also groundbreaking: the skilful use of materials and renewable energy are the ingredients of its sustainability. Solar collectors, for example, supply the energy for the bridge opening and closing mechanisms and for the lighting and traffic signalling systems. Natural water treatment systems create a clean water zone.
Dillinger supplied 420 t of heavy plates for this very special bridge.


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MAKING THE EXCEPTIONAL POSSIBLE

Botlek Bridge Rotterdam

Higher strength steels | ***Excellent weldability*** | ***Maximum toughness requirements***

The new Botlek Bridge, a combined road/rail bridge located in Rotterdam harbour, is part of - and the core element in - the 37 km large scale upgrading of the A15 motorway from Maasvlakte to Vaanplein. It is one of the largest lift bridges in the world and is in all respects a structure of superlatives: it moves the world's largest mass, operates at the highest lift frequency and has the highest lift speed. The 1,243 m long bridge consists of six 64 m high oval reinforced concrete lifting towers and two 4,850 t steel superstructure elements, each with a span of 92 m and a width of approx. 50 m. This is equivalent to the size of a soccer pitch. Not only the moving mass (around 10,000 t, equating approximately to the total weight of the Eiffel Tower), but also the frequency and speed of opening are impressive. The bridge is raised and lowered through 30 m in less than 100 seconds once per hour, signifying a total of 9,000 opening operations per year.

Since the lift bridge, with its 100 year (or 900,000 lifting cycle) design service life, is required to withstand much more than the stresses customary in this industry, the materials and the welding technology deployed also had to meet very high standards. A high proportion of thermomechanically rolled S460M/ML steel was used, with special weldability specifications (low carbon equivalent, CTOD requirements, extra toughness), in order to reduce the structure weight.

Dillinger steel is used both in the steel superstructure elements of this bridge and in the lifting mechanism guide rails.

De Oversteek

Higher strength steels

“De Oversteek”, as the urban bridge in Nijmegen is also known, was constructed between 2011 and 2013 in order to connect the expanding suburbs on the north and south sides of the River Waal with one another. The engineering highlight of the entire structure is the modern steel arch bridge itself. This, with its spectacular basketwork superstructure, spans the navigable channel of the Waal for a length of 285 m. Dillinger supplied 1,600 t of heavy plates for this monumental structure, including approx. 320 t of the higher strength S690QL (DILLIMAX 690 T) grade.

Galecopperbrug

Higher strength steels **Maximum toughness requirements**

The Galecopperbrug is part of the A12 motorway and crosses the Amsterdam-Rhine Canal in Utrecht. It is the second most heavily frequented bridge in the Netherlands and it was renovated between 2013 and 2015. This refurbishing was necessary because the bridge had virtually reached the limits of its load bearing capacity. The renovation work was also used as an opportunity to raise the Galecopperbrug, so that the bridge now permits the passage of ships bearing four tiers of containers.

Dillinger supplied approx. 5,800 t of heavy plates of strength class S460, predominantly S460M/ML, and approx. 1,000 t of S460G2+Q, for this unprecedented bridge renovation project.

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