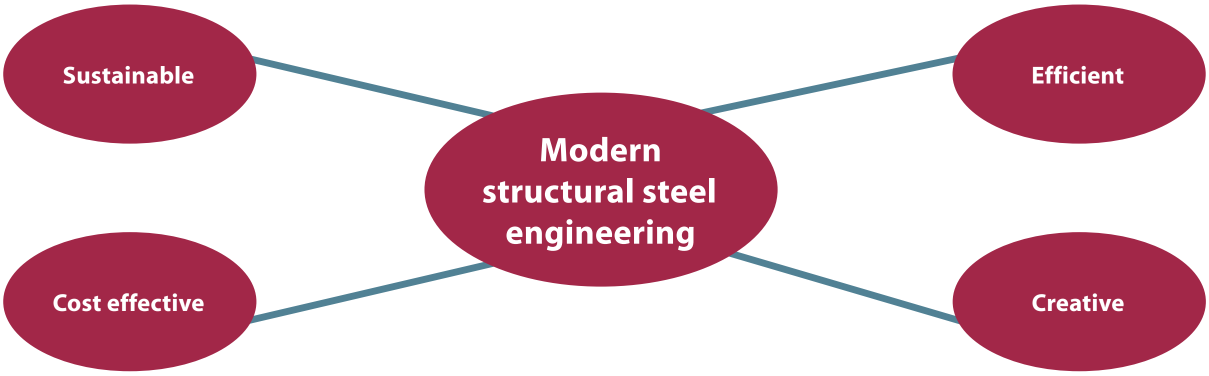
DI-MC

Simply convincing

DILLINGER

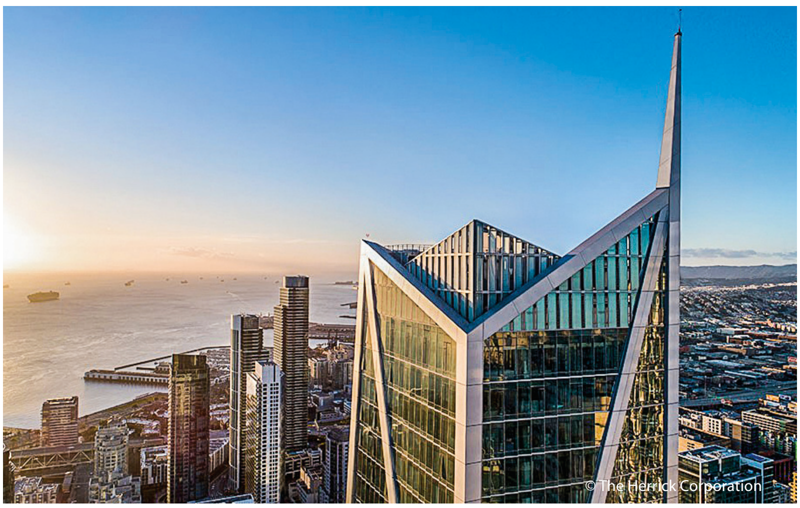
DI-MC CONVINCES



You - a successful structural steel or design engineer - know exactly what is needed.
You know, on the one hand, the enormous technological capabilities of steel, the material that combines cost efficiency, safety and sustainability like no other. And, on the other hand, you make virtuoso use of the freedoms that steel as a material provides for creative architectural and/or high efficiency design. The results are structures that impress again and again with their elegance and daring.
The boundary conditions that shape steel structure engineering are also exceptionally ambitious: only maximum efficiency production and fabrication orientated at all times around absolute process reliability are capable of assuring the targeted on-time completion with simultaneous maximization of cost effectiveness. In such an efficiency dominated environment, steels of dependable high quality are the first priority.
Dillinger has proven its strengths as a competent and dependable supplier of steel at its customers' side in innumerable highly demanding construction and energy projects over periods of many years. In DI-MC, Dillinger supplies a proprietary steel which, being a

- premium Dillinger product and
- a combination of the very best mechanical properties and excellent workability characteristics

convincingly meets the steel construction growing demands.



CONVINCINGLY EFFICIENT…
…AND LEAN

Like all thermomechanically rolled steels, DI-MC grades essentially achieve their strength properties thanks to their special production process, permitting the use of a moderate, “lean” alloying concept. The result is the combination of optimum mechanical materials properties with outstanding workability characteristics and, above all, excellent weldability. The use of DI-MC steels, for example, permits significant reduction - or even the complete omission - of the preheating of components for welding. This allows accelerated fabrication and achieves not only greater cost effectiveness but also improved logistics for the entire fabrication process.

In addition, the higher strength properties attained thanks to thermomechanical rolling - with no sacrifice of the steel’s extremely good workability - also make it possible to reduce the plate thicknesses needed from a structural analysis point of view. More filigree designs, increasingly frequently encountered in modern architecture, become feasible. The thus reduced plate cross sections in the design then have multiple beneficial effects on the cost and ecological balances of the structure:

- Lower material and welding costs,
- Lower component weights and as a consequence of this
- Significantly diminished transportation cost and complexity.

These form the basis for high cost efficiency in fabrication and installation. DI-MC thus explicitly meets the fundamental concepts for resource conserving sustainable construction in the materials cycle based on the “3R” principle: reduce – reuse – recycle.

A REAL CHAMPION …AND A WORLD RECORD

The world's longest cable-stayed bridge, France's Viaduc de Millau - was constructed using around 18,000 t of DI-MC 460 grade steel supplied by Dillinger.

Mecca's Royal Clock Tower incorporates 1,500 t of DI-MC 460.

DI-MC is not only used in numerous record breaking structures, such as the Viaduc de Millau, Shanghai's Financial Tower or the Royal Clock Tower in Mecca - no, DI-MC also sets its own records.

- Dillinger's thermomechanically rolled DI-MC plates, with a plate thickness of 150 mm, are currently the world's thickest TM plates.
- The largest TM plate ever rolled in the world, with a plate weight of > 45 t, was produced during the summer of 2017.

The world´s largest TM plate - a DI-MC 355 T

THE DI-MC FORMULA

The production of high quality thermomechanically rolled steels necessitates sophisticated technology, in which every individual production operation is carefully harmonized with the next.
The creation of a DI-MC plate therefore starts as far "upstream" as Dillinger's steelmaking plant.

The steelmaking plant – from hot metal to plate

The precise adjustment of the steel's chemical composition to accord with design specifications is one of the most important steps in the production of DI-MC grades.
Thermomechanically rolled steels are characterized by their extremely low carbon contents and by the use of microalloying elements. DI-MC is also additionally noted for its ultra low sulphur and phosphorus contents and for its excellent non-metallic cleanness. These are achieved by desulphurizing the steel even at the hot metal stage, and by subjecting it later to a special vacuum treatment during so-called secondary metallurgy.

Table 1 shows a comparison of typical heat analyses for DI-MC against comparable normalized structural steels. The permissible maximum for the individual alloying elements in DI-MC grades can be found in the corresponding Dillinger materials data sheets.

	Plate thickness	C	Si	Mn	P	S	Nb	V	Ni	Cu	Cr
S355J2+N	50 mm	0.17	0.45	1.50	0.012	0.002	-	-			-
	100 mm	0.17	0.45	1.50	0.012	0.002	-	-			-
DI-MC 355	50 mm	0.09	0.36	1.53	0.012	0.001	Low alloying with one or more elements				
	100 mm	0.06	0.34	1.55	0.012	0.001	Low alloying with one or more elements				
S460NL	50 mm	0.17	0.30	1.65	0.015	0.003	-	0.17	0.17	max. 0.08	-
	100 mm	0.17	0.30	1.65	0.015	0.003	-	0.17	0.17	max. 0.08	-
DI-MC 460	50 mm	0.07	0.39	1.64	0.013	0.0008	Low alloying with one or more elements				
	100 mm	0.07	0.39	1.64	0.013	0.0008	Low alloying with one or more elements				

Table 1: Typical data for alloying elements in %wt. in DI-MC 355 and DI-MC 460 at a plate thickness of 50 mm and 100 mm, compared to conventional Dillinger structural steels

TM ROLLING IS THE SECRET

Thermomechanical rolling

Thanks to the moderate alloying concept, the variables used to describe the weldability of a steel (e.g. the carbon equivalents CEV and CET, and the critical metal parameter [P_{cm}]) are significantly reduced in DI-MC steels. Typical data for CE, CET and P_{cm} in a DI-MC 355 and a DI-MC 460 steel are shown as a function of plate thickness in Table 2.

Plate thickness	50 mm	100 mm
DI-MC 355		
CEV [%]	0.33	0.33
CET [%]	0.21	0.21
P_{cm}	0.18	0.17
DI-MC 460		
CEV [%]	0.37	0.39
CET [%]	0.25	0.25
P_{cm}	0.19	0.19

Table 2: Typical data for CE, CET and P_{cm} in a DI-MC 355 and a DI-MC 460 steel

Unlike the classical rolling processes, thermomechanical (TM) rolling is used not only as a shaping procedure, but also for systematic adjustment of combinations of mechanical properties. Rolling must feature the greatest possible deformation, in order to achieve homogeneity of these properties. At Dillinger, slabs of up to 600 mm in thickness and originating from continuous casters using the vertical continuous casting process are available as the feed material.

TM rolling is defined as a process which

- aims at the achievement of a microstructure with a fine effective grain size,
- permits a useful combination of in-service properties,
- is harmonized with the composition of the steel and
- incorporates a sequence of the following operations controlled on the basis of time and temperature:
  - **Slab heating:** with a defined discharge temperature;
  - **Rolling:** using a defined rolling-pass schedule, with finish rolling in the non-recrystallizing austenite or ferrite two-phase region;
  - **Cooling:** down to a defined end-of-cooling temperature, either in air, in a stack or accelerated cooling on the cooling line. Dillinger's production facilities for TM plates are equipped with ultra modern water cooling lines for accelerated cooling (ACC). The use of these facilities permits the production of high quality TM heavy plates in thicknesses of up to 150 mm.
  - Additional **heat treatment** (tempering) if necessary.

DI-MC – in demand around the world: The Shanghai World Financial Center, constructed using 23,000 t of steel from Dillinger, including 7,700 t of DI-MC

Actual rolling in Dillinger's rolling mills takes place on especially powerful four-high reversing stands.

With low end-of-rolling temperatures, they apply the high torques and rolling forces necessary to permit maximum deformation per rolling pass. Fast and precise process regulation and control assure maximum quality and repeatability in the results of the rolling process.

The diagram 1 shows a schematic of the TM rolling process.

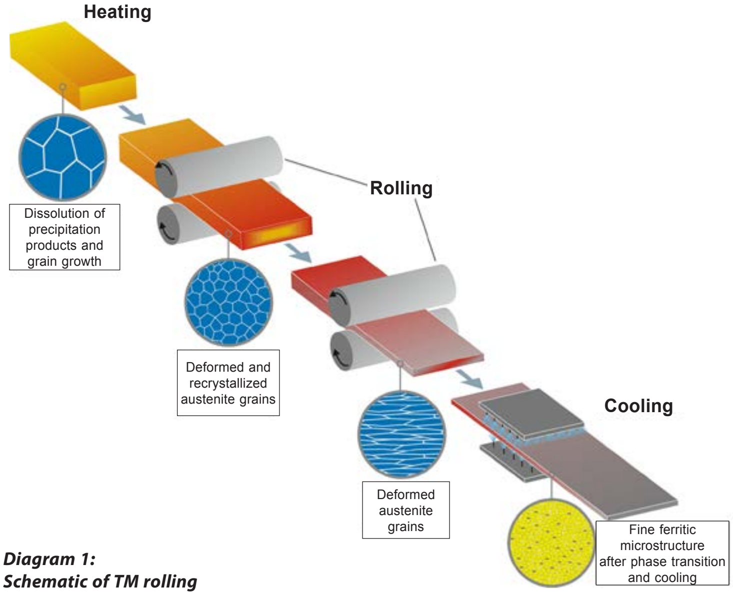


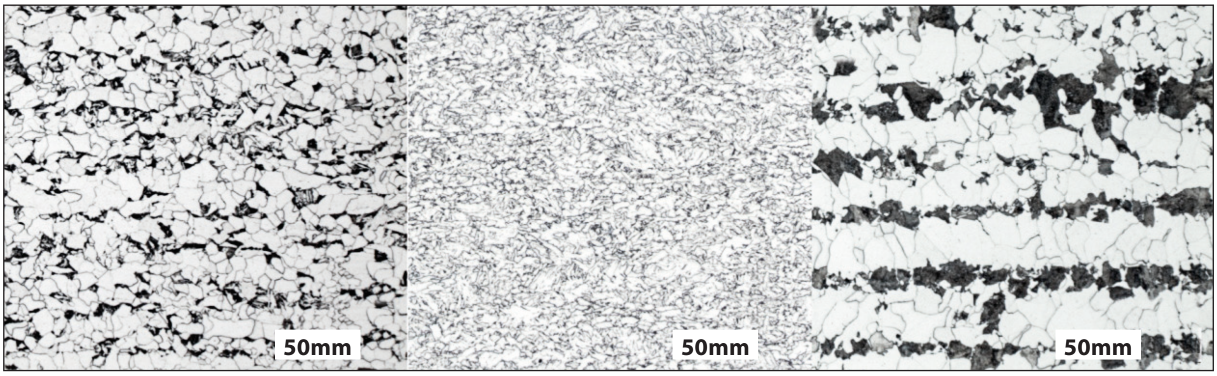
Diagram 1: Schematic of TM rolling

CONVINCINGLY FINE GRAINED

Fine microstructure - the guarantor of optimum property combinations

Thermomechanical rolling results in an extremely fine grained low pearlite microstructure in the steel. This microstructure, typical of TM steels, is the guarantor of an optimum combination of toughness and mechanical strength. The specimen comparison of the microstructure of an air cooled DI-MC 355 and an accelerated cooled DI-MC 460 against the microstructure of a comparable normalized structural steel clearly illustrates the characteristic differences in grain size and pearlite content (areas shown in black).

a) **b)** **c)**



The microstructure of a TM-rolled DI-MC 355 (a) and of a DI-MC 460 (b) compared to a normalized microstructure (c)

DI-MC – the reliable footing for renewable energy: the Thanet Offshore Wind Farm, constructed using thermomechanically rolled steel supplied by Dillinger

THE MATERIALS PROPERTIES...

Modern extra high tensile strength structural steels assure benefits not only in the form of cost efficient sustainable construction. They are, classically, also used, above all, where materials are exposed to high stresses and a special level of reliability is needed for steel structures. This is why the widely used codes and standards, such as EN 10025, Part 4, for example, define minimum mechanical and technological requirements for such steels. In DI-MC, Dillinger has succeeded in not only meeting these requirements, but instead, in many respects, in achieving even better properties than specified.

Mechanical strength

The minimum figures for yield strength of DI-MC proprietary steels are stated in Table 3. DI-MC steels not only meet the requirements of EN 10025, Part 4, they can actually perform even better than this standard requires. Up to a plate thickness of 150 mm, for example, DI-MC steels can optionally also be supplied with enhanced mechanical strength properties (e.g. a minimum yield strength of 355 MPa or 460 Mpa, irrespective of plate thickness).

The complex control of the entire TM rolling process at Dillinger, and accurate control of temperature, in particular, assures extremely uniform cooling of the plates across their length, width and thickness. Such precision control is vital for attainment of excellent homogeneity of the mechanical properties of DI-MC steels.

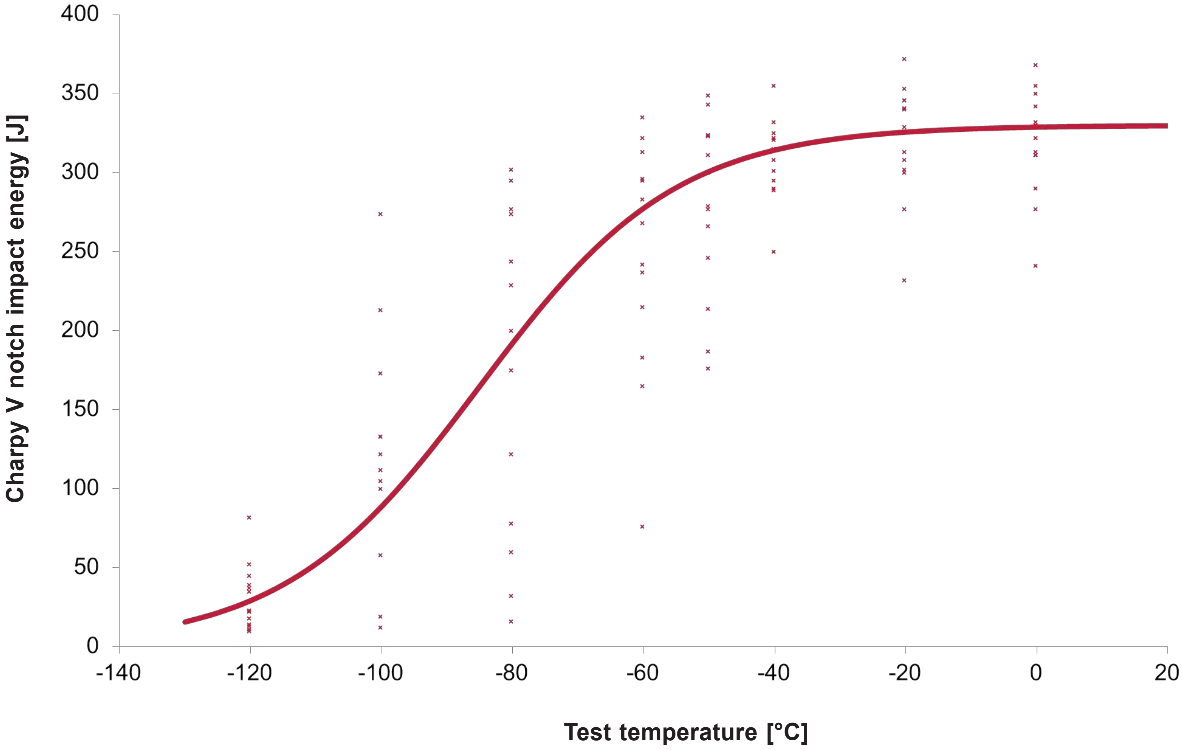
	Yield strength $Rp_{0.2}$ [MPa] Plate thickness [mm]					
	d≤16	16<d≤40	40<d≤63	63<d≤80	80<d≤100	100<d≤150
DI-MC 355	355	345	335	325	325	320
DI-MC 355 + Order Option 1	355					
DI-MC 460	460	440	430	410	400	385
DI-MC 460 + Order Option 1	460					

Table 3: Minimum values for yield strength, as a function of plate thickness

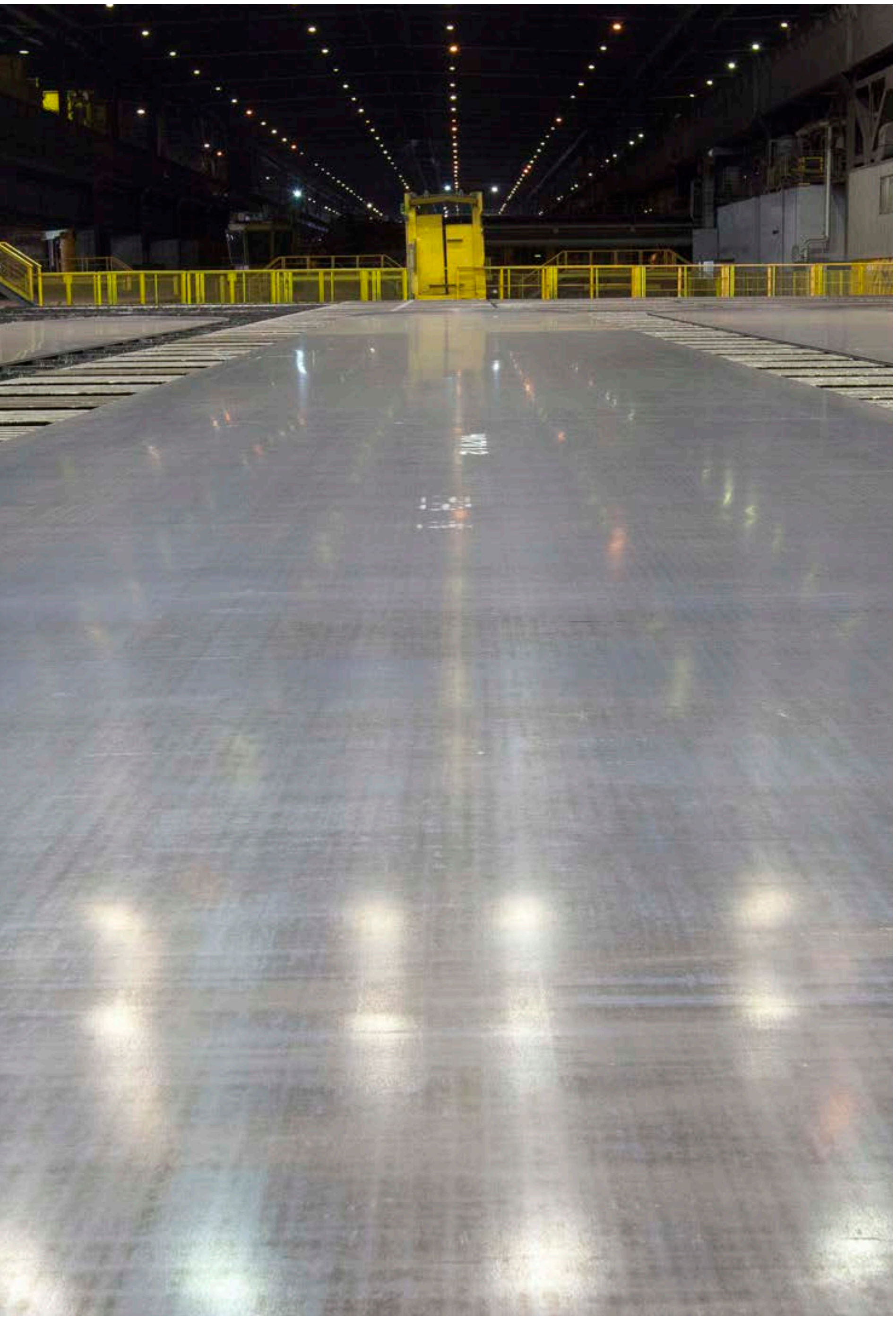
…ARE MORE THAN CONVINCING

Toughness

Excellent toughness properties that go significantly beyond the minimum requirements set out in EN 10025, Part 4, are a further important feature of DI-MC steels. This is demonstrated by these steels' high scores for Charpy V notch impact energy, which are retained deep into the low temperature range. The pronounced high level and the low transition temperature (T_{27J} or T_{40J}) are, above all, conspicuous in DI-MC steels. Production and fabrication operations such as welding, cold forming, etc., generally result in an increase in transition temperature, and these reserves of toughness in DI-MC steels assure a high level of safety both during component fabrication and subsequent service.



Typical Charpy V notch impact energy/temperature curves for 50 mm thick DI-MC 355 T plates



Surface properties

DI-MC steels convince not only with their “inner” values. Thermomechanically rolled plates also exhibit significantly improved surface properties compared to furnace normalized plate material. In normalized plates, for example, the coarse layer of scale generated by oxidation in the normalizing furnace spalls off at isolated points, leaving a rough and uneven surface. The surface of a thermomechanically rolled plate is notable, on the other hand, for its fine and smooth rolling “skin”. This facilitates further working and fabrication, and permits more rapid component completion.

DI-MC – brilliantly in form: the surface of a thermomechanically rolled plate

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