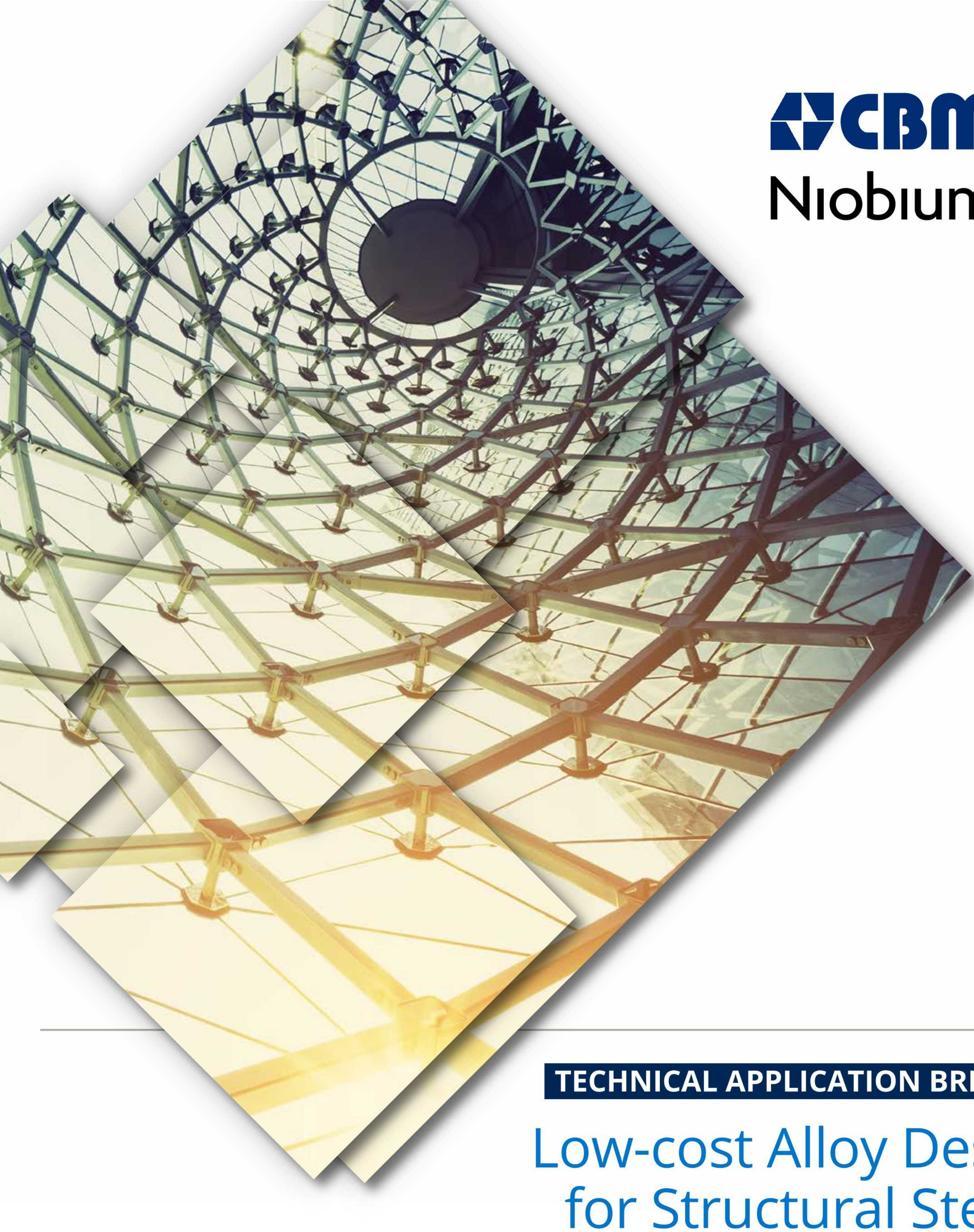

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TECHNICAL APPLICATION BRIEFING

Low-cost Alloy Design for Structural Steels: A New Approach

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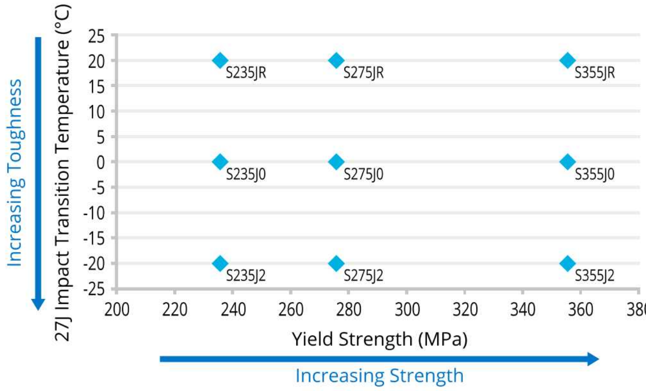


Figure 1. Toughness and yield strength of commonly applied grades.

Un-alloyed, carbon-manganese steels are used extensively in the construction and infrastructure sectors worldwide, and in 2017 over 500 Mt were produced with yield strengths ranging from 235 MPa to 355 MPa [1].

In Europe, the most widely employed grades meeting EN10025-2:2004 are S235, S275 and S355. Their product analyses can contain carbon up to 0.23%, 0.25% and 0.27% and manganese up to 1.5%, 1.6% and 1.7% respectively. The ASTM-A572-18 (North American) and GB/T 1591-2018 (Chinese equivalent) specifications rely on similar levels of these two elements.

Major international structural steel standards generally offer grades with a range of yield strengths and associated levels of toughness for use according to the demands of the intended application. Figure 1 shows strength/toughness combinations available for material in thicknesses up to 16 mm in EN10025-2:2004.

Carbon and manganese have historically been the basic building blocks of structural steels. Carbon is generally regarded as the single most important element because, at minimum cost, it adds hardness, strength and hardenability to the range of steels of interest. However, it also tends to make steels more brittle and less weldable. In steelmaking terms it costs money to reduce carbon significantly and this approach is therefore only used for classes of steel where weldability is of critical importance.

Manganese can help to offset some of the negative effects of carbon through lowering of the austenite to ferrite transformation temperature (Ar_3) and also contributing to solid solution strengthening.

As worldwide alloy costs fluctuate from time to time, opportunities to consider alternative compositional approaches become attractive. At present there is an opportunity for the cost effective substitution of some of the manganese with niobium to enhance properties.

	%C	%Mn	%Nb	YS (MPa)	TS (MPa)	El. (%)	C+Mn/6*
Traditional alloy design	0,15	1,20	–	356	499	26,0	0,35
New lean alloy design	0,15	0,80	0,010	359	481	27,0	0,28

Table 1. Example of the Application of the New Alloy Design for Structural Steel.

**See Lloyd's formula overleaf*

Whilst for example, a reduction in manganese of 0.4% as suggested in Table 1 would, without compensation, reduce yield strength by approximately 14 MPa [2] with a corresponding effect on tensile strength, the presence of 0.01% niobium can offset this loss (Figure 2).

This specific attribute of niobium at such a small addition derives principally from its ability to significantly inhibit austenite grain coarsening during reheating and subsequent processing resulting in a finished product with a fine ferrite grain size. This not only dramatically increases yield strength but, significantly, contributes to an improvement in toughness.

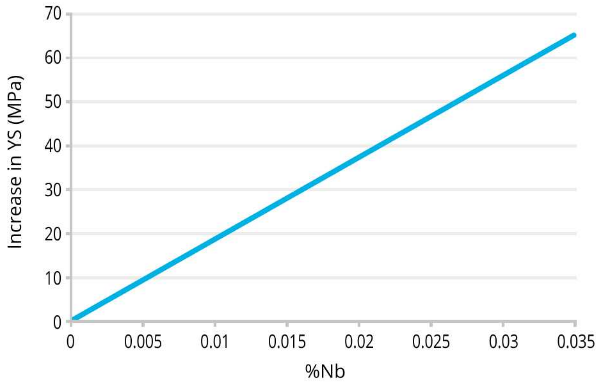


Figure 2. Effect of niobium content on yield strength in as-rolled low carbon steel strip. Adapted from [3], [4].

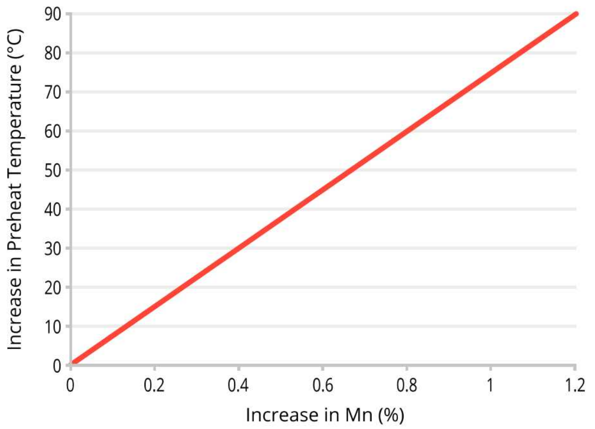


Figure 3. Effect of changing manganese levels on preheat temperature, derived from [5].

Substitutions, at this level, could potentially save steel production costs of US$ 3-5 per tonne (depending on the relative prices of ferromanganese and ferroniobium) [6].

The production cost savings are augmented by other advantages of this 'New Approach'.

Structural grades meeting EN10025-2:2004 and their ASTM and Chinese equivalents all require to be welded and the thicker the section the more pre-heat is generally required. Heat costs money and if pre-heat can be avoided or reduced this provides a further incentive for the alloying approach described above.

The weldability of structural steels is predicted by the **Lloyd's Formula**:

$$CE = C + \frac{Mn}{6} + \frac{(Cr+Mo+V)}{5} + \frac{(Cu+Ni)}{15}$$

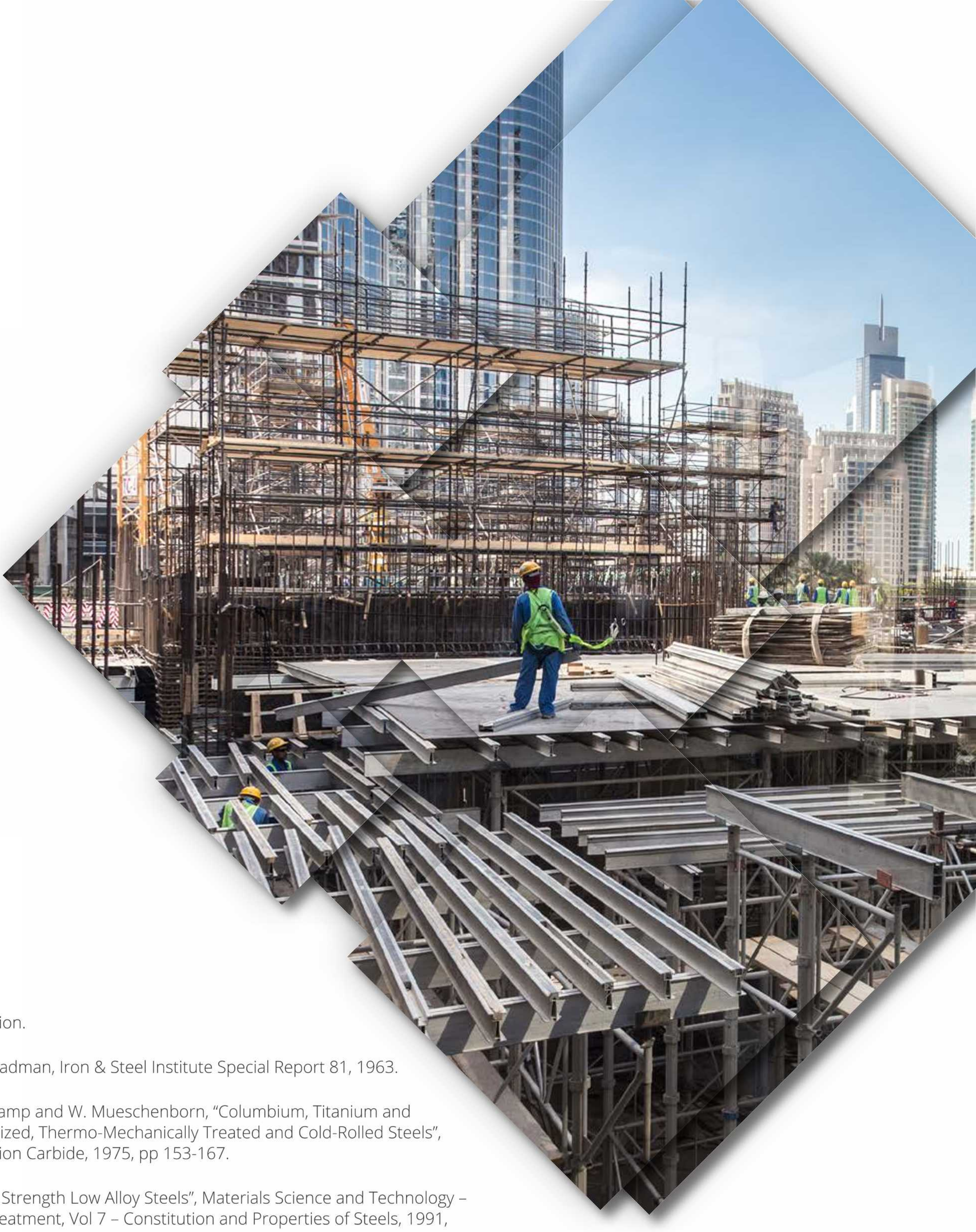
The higher the Carbon Equivalent (CE) the more pre-heat is required to avoid hydrogen induced cracking during fabrication.

The elements carbon and manganese make the largest contribution to CE in these structural steels and it follows therefore, that reducing manganese must be a major benefit to weldability. An estimate of the effect of manganese level on preheat is shown in Figure 3.

For the example illustrated in Table 1, the reduction in manganese from 1.2% to 0.8% would reduce the required preheat, to avoid hydrogen cracking, by about 30 °C.

In conclusion, the new low-cost alloy design uses very modest niobium additions to allow a reduction in the amount of manganese required. It can be applied to various hot rolled structural steel products including rebar, sections and plates.

This approach can provide equivalent or even superior mechanical properties with the bonus of improved weldability, resulting in lower fabrication costs.



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