R & D WORK AND CURRENT PRACTICE FOR STAINLESS STEEL STRUCTURAL DESIGN IN ITALY

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Abstract

Stainless steel is increasingly used in Italy for building construction, nevertheless the use of concrete for structural members is still largely prevalent.
Interesting perspectives are open for stainless steel cold worked sheets, plates and bars and the mechanical properties of cold worked bars are illustrated.
Current cases of construction practice using stainless steel as a structural material in Italy are shown.

1 INTRODUCTION

Italy with a stainless steel production around 1 million tons per year is an important stainless steel producer of flat (coils, foils) and long (bars, tubes, wire) products. The apparent per capita stainless steel consumption is about 19 kg/person per year - this means that Italy is an important stainless steel transformer, a field of activity where specialistic skill required to realise stainless steel components is often very high.

Stainless steel market in Italy has grown consistently and the trend is still continuously increasing. Many application segments show an appreciable increase in the last years; Fig. 1 shows that stainless steel products involved in building amount to 10% of the annual consumption, with an appreciable increase from the 4.5-5% figure reported eight years ago [1].

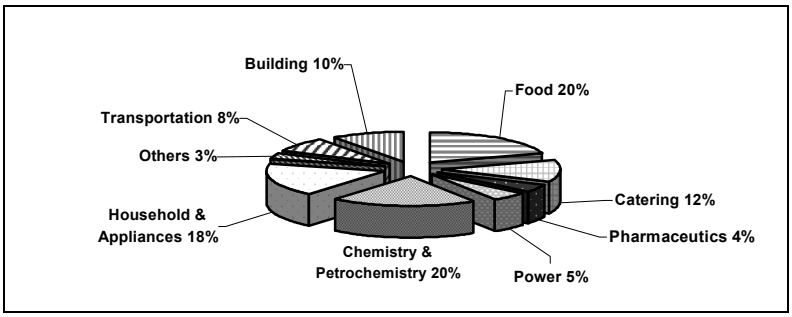

Figure 1 Distribution of the stainless steel consumption in Italy

Nevertheless, stainless steel can be found mainly in non-structural applications or in those applications where the structural properties of the component are not of primary importance, such as tinsmithing, roofing, continuous façades, railings, and handrails are typical examples in which the resistance to corrosion and the inalterability of the aesthetic aspect are the premium factors. In these applications, stainless steel is gaining consistent segments of the market.

Within this frame, wider stainless steel application in civil and industrial building is expected by the introduction into the market of the new coloured coil coated stainless steel (*). This new class of products opens new niches in roofing, façades, outdoor and indoor components, adding aesthetics and fantasy to the well recognised merits of stainless steel.

(*) VERNEST – Trade mark of ThyssenKrupp Acciai Speciali Terni

The use of stainless steel as a structural material is slowly growing and its diffusion does not correspond to the European trend: the use of concrete is still largely preferred (Fig. 2).

The majority of stainless steel used for construction is in form of flat products (coils and plates) but also bars are extensively used for braces and tie rods in building as well as for reinforcement structures in the restoration of monuments or of buildings; this applies also in case of damage by seismic events.

As examples of the growing tendency of the Italian stainless steel application in the construction segment, Fig. 3 illustrates the increase of stainless steel use in chimney flues from 1988 to 2001 and Fig. 4 reports the consumption in roofing that is almost doubled from 1998 to 2000.

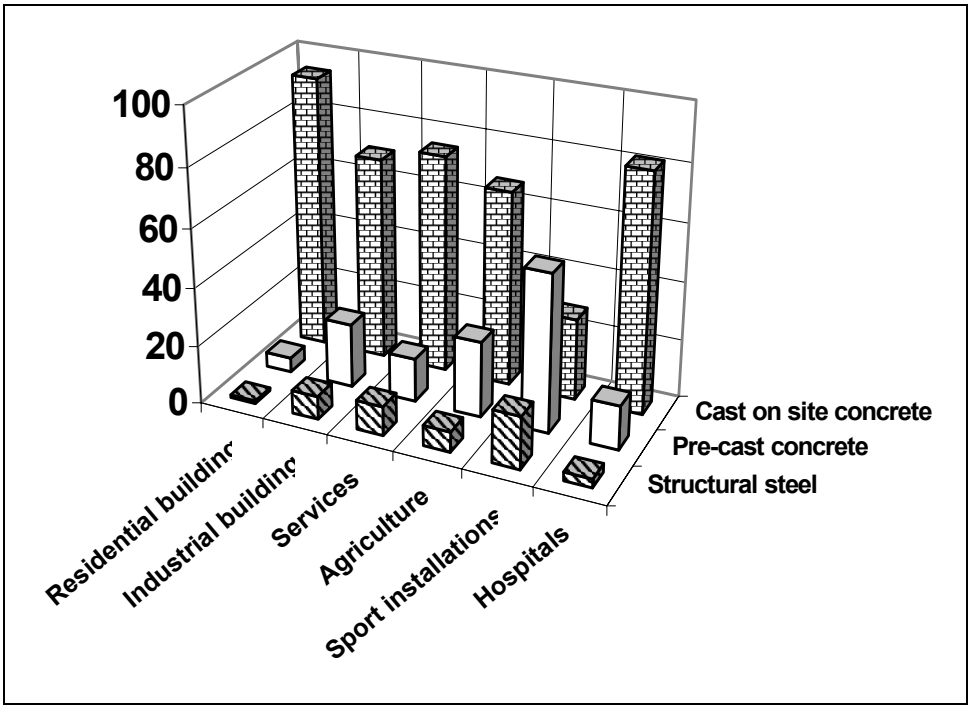

Figure 2 Share of the construction market in Italy for concrete and steel

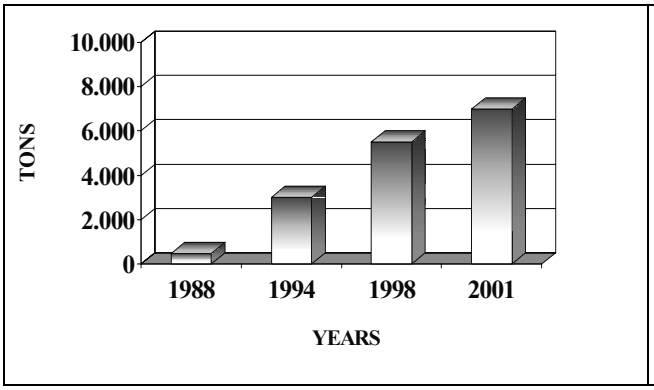

Figure 3 Growth of the stainless steel use in chimney flues

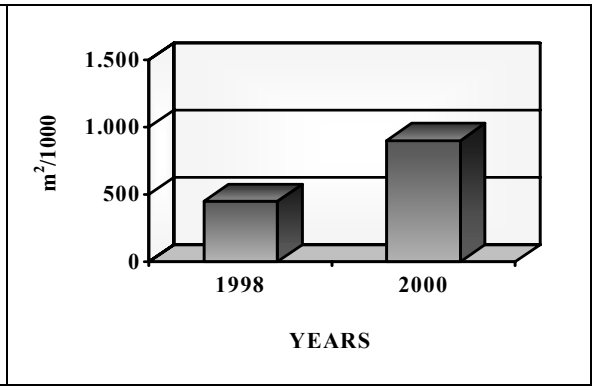

Figure 4 Growth of the stainless steel use in roofing

This paper will focus on some first results relevant to the mechanical properties of cold worked stainless steel bars, obtained in a research programme partly founded by ECSC, and then some interesting applications of stainless steel in construction will be reviewed.

2 TENSILE PROPERTIES OF COLD WORKED BARS

The structural applications of stainless steel in construction are strongly supported by the enhanced resistance to fire with respect to the traditional carbon steels or low-alloyed steels. The use of cold worked austenitic stainless steel is susceptible to further increase the range of the possible applications, but the evaluation of the decay of the mechanical strength at high temperature is a key factor for future developments in accordance with the Construction Products Directive (CPD, 89/106/EC).
In this work, the activity has been concentrated on cold worked bars. Tensile tests have been carried out on specimens obtained from 1.4404 stainless steel bars produced by Cogne (14,58 mm diameter) cold worked according to EN 10088-3:1997 standard Class 700 and Class 800 respectively.
The mechanical properties at room temperature are reported in Table 1 in comparison with the requirement of EN 10088-3. Cold worked stainless steel shows mechanical strength higher than that of the carbon steel grades used in construction, together with higher ductility (El > 30% for grade C700).

Table 1 Tensile properties of the tested cold worked bars

	$Rp_{0,2}$ (MPa)	**Rm (MPa)**	**El_5 (%)**
Experimental C700	633	837	31
EN 10088-3 C700	$\geq$ 350	700 - 850	$\geq$ 20
Experimental C800	749	912	25
EN 10088-3 C800	$\geq$ 500	800 – 1000	$\geq$ 12

To assess the performance of cold worked bars, isothermal tests were conducted from room temperature up to 800°C and the results compared with those obtained on annealed plates [2]. The results are reported in Figures 5-7.

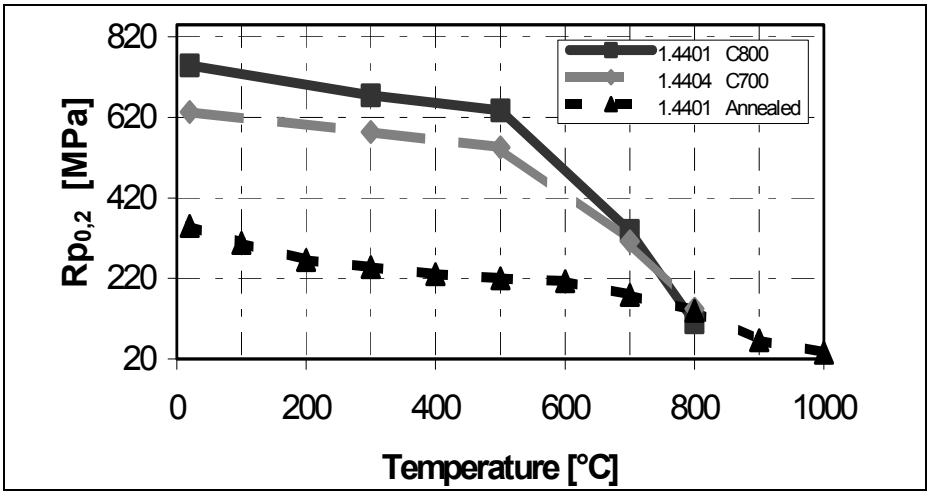

Figure 5 0,2% proof strength as a function of temperature

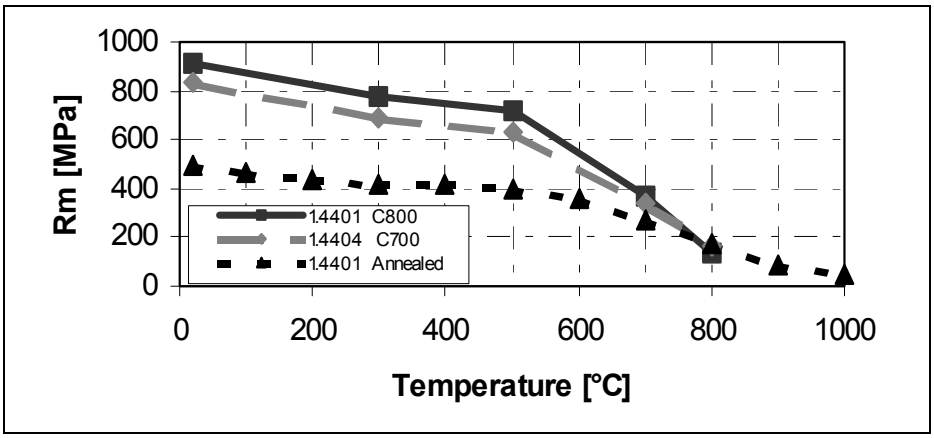

Figure 6 Ultimate tensile strength as a function of temperature

It is interesting to analyse the behaviour of the 0,2% proof strength retention factor, that is the percentage ratio between the 0,2% proof strength at temperature T and the corresponding value at 20°C. This factor is useful to evaluate how much the strength of the selected material at a given temperature deviates from the design value; its dependence from temperature is shown in Fig.7.

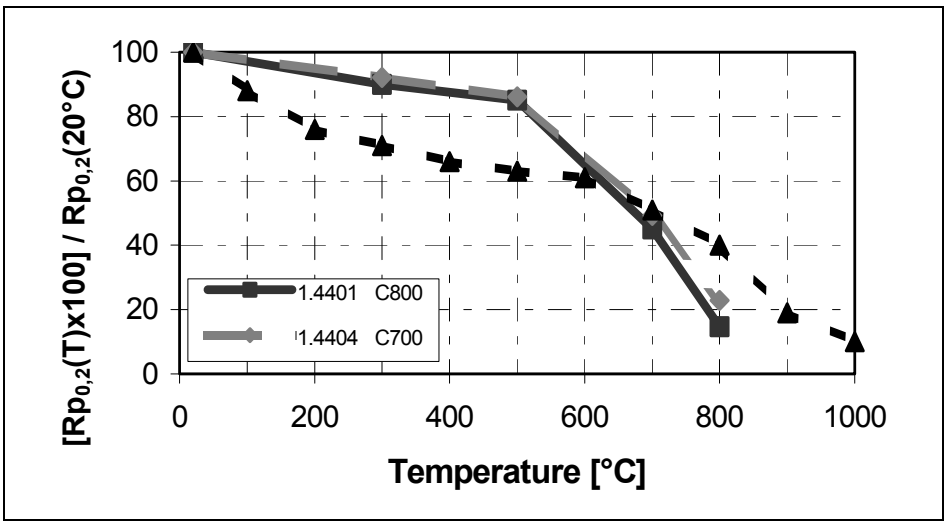

Figure 7 0,2% proof strength retention factor as a function of temperature

Some interesting suggestions can be drawn by examining Figs. 5 to 7.

The high strength is maintained also at high temperature, up to 800°C, where both 0,2% proof strength and ultimate tensile strength of cold worked bars are equivalent to those of the annealed ones. This is important when welded components are taken into account, because this means that the effect of heat input is not so strong; experiments on the fatigue behaviour of welded connections are in progress.

Also the 0,2% proof strength retention factor is decidedly higher than that of the annealed steel. At 500°C, only a decrease of 15% in 0,2% proof strength takes place; at increasing temperature, the annealing process begins to take place and, of course, the loss of mechanical strength is higher with respect to the annealed specimens.

3 EXAMPLES OF DESIGN USING STAINLESS STEEL FOR STRUCTURAL MEMBERS

3.1 Bank of Lodi

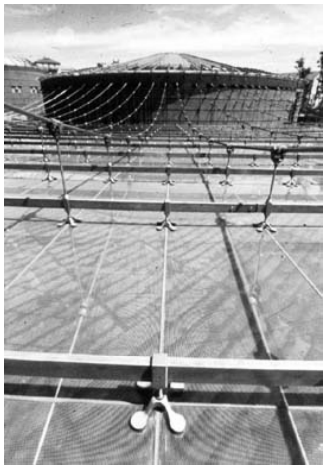

Figure 8 Bank of Lodi. View of the glass roof Anchoring and supporting elements of the tensile structure

A large complex has been built for the Bank of Lodi to house not only its head office, but also an auditorium for conventions and many other offices for various commercial activities. Four large cylindrical columns rise to form a large area that covers the building services and the convention hall. The columns are connected together, and to the main building, by an armoured glass roof supported by a tensile structure of carbon steel cables covered with stainless steel. The 38 supporting cables, both those that carry the load and those that stabilise the structure, are made from a core of galvanised steel covered by special sections of stainless EN 1.4401 (AISI 316). A complex fixing system, all stainless, provides the anchorage for the tensile structure.

Stainless steel is also used, where it cannot be seen, as the means of retaining the brickwork panels that cover the walls of all the buildings in the complex.
More than 350 tons of stainless have been used for the external and internal work.
Architectonic project and artistic director: Renzo Piano Building Workshop, Genoa – Italy

3.2 Bridge in Chiavari

Figure 9 Bridge in Chiavari

The town of Chiavari, as part of its urban restyling, has rebuilt the sea promenade, which basically posed the problem of the intersection between pedestrian traffic, parallel to the coastline, and the vehicle traffic travelling to the leisure port. The bridge was built in EN 1.4401 (AISI 316) stainless steel.

Apart from the mechanical properties of the material which allowed a restriction on the thickness of the members and hence minimal visual impact of the structure, a static solution was chosen, with girders with an “H” section, in order to allow assembly in the factory of standard production sheets to make components with guaranteed static capacity.

The bridge cost a total of € 150,000, of which € 60,000 for the structure in stainless steel (10,000 kg) and € 10,000 for the accessories, also in stainless steel.
Design: Sergio Picchio, I-16129 Genoa

3.3 Bridge in Sondrio

Figure 10 Bridge in Sondrio

The new bridge at Gombaro, situated in one of the most historic zones that characterize Sondrio, bears memory to the terrible flood of 1987 and, at the same time, illustrates the will to rebuild the Valley. Wisely chosen materials, “classic” wood and “noble” stainless steel, have been used for constructing the bridge, making it an excellent example of the use of stainless steel. The classic and noble in harmony together.

The finished bridge is both architecturally valid and technically solid and durable. Tubes, bars and sheeting of stainless steel EN 1.4301 (AISI 304) have been cleverly combined with the wood. The upper surfaces of the laminated wood arches are covered with a protecting stainless sheet. The stays, the guard and hand rails, along with various connections and fixings are also in stainless steel.
Design: Arch. P. Stefanelli and Ing. M. Erba, 23100 Sondrio - Italy

3.4 Footbridge in Terni

Figure 11 Footbridge in Terni

A new foot and cycle bridge was built in the town of Terni on River Nera. The project was based on an “arch shaped” static scheme with a suspended deck. Stainless steel was chosen to withstand the aggressive environment. The arch has a span of 32 metres and is 7 metres high. The deck is 5,25 metres long.

All building elements, included bolts and ties, are made with EN 1.4401 (AISI 316) except for arch shaped tubes and supporting tubes under the deck that are in carbon steel.
Design: Garofoli Spa – Aginox Division, 05036 Narni Scalo TR – Italy

4 CONCLUSIONS

Cold worked stainless steel can further broaden the wide range of sophisticated products offered by the steel industry for the construction of esthetical and maintenance-free structures. Cold worked bars exhibit high strength and ductility at ambient temperature as well as at temperature up to 500°C.

5 ACKNOWLEDGMENTS

The RFCS support through the RFCS Steel RTD Programme to the research project on cold worked stainless steels is gratefully acknowledged.

6 REFERENCES

[1] Barteri, M., Stainless steel as a structural material in construction: the case of Italy, Stainless Steel in Structures – An Experts Seminar, London, 21-22 September, 1998

[2] ECSC Contract No. 7210-SA/842, 903, 904, 327, 134, 425 , Development of the use of stainless steel in construction, Final Report, 2000.