Sustainably produced hot-rolled sections in sustainable buildings

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1. INTRODUCTION
The construction industry bears considerable responsibility for implementing the principles of sustainable development in the man-made environment.

Within this presentation, sustainability aspects of hot rolled steel sections will be addressed in detail. Steel beams, the world's most recycled products, not only allow to design sustainable buildings but also suit aesthetic criteria and provide speed of implementation, flexibility, lightness as well as safety.

Before recycling, buildings with steel structures can be readily designed to facilitate reuse or dismantling and reconstruction at the end of their useful lives. As an example, the extension project of the new Luxembourg Chamber of Commerce has given the ecologically-responsive architect and designer the opportunity for achieving a sustainable construction by incorporating steel framed structures in the building environment. Also, the stripping down to its bare structure and the subsequent renovation of the original Chamber of Commerce building has demonstrated the flexibility and adaptability of steel structures for retrofitting.

2. ENVIRONMENTALLY-FRIENDLY PRODUCED OF HOT ROLLED SECTIONS
Nowadays, most Western European producers of hot rolled structural sections are committed to sustainable development and to continuously improving their environmental performance. Focused on the production of long products like beams, merchant bars, piling sections, rebars and special sections, the world’s largest manufacturer ProfilARBED extensively renewed its production facilities in the mid to late 90s. The integrated steel mills, using the limited resources of local iron ore, were converted to the electric arc furnace (EAF) route, based on recycled ferrous scrap as sole raw material (Figure 1). The determination in maintaining and improving the high level of quality of its long products while simultaneously satisfying the toughest environmental requirements led to the use of the best available technology in its production facilities.

3. PRODUCING STEEL BEAMS FROM SCRAP
The new mills all operate according to the following process route:
• collection of raw materials,
• scrap-based electric arc furnace steel-making,
• continuous casting of near net shapes (beam blanks),
• rolling sections to final shape.

3.1 Collection of raw materials
The major part of the raw materials used for the steel production process consists of disused steel products, ranging from radiators, furnishings, and car bodies to sections from dismantled buildings and structures. Painted and zinc-coated scrap can also be processed. The scrap originates within a radius of a few hundred kilometres from the production plants. It is brought by barge, by train and, to a lesser extent, by truck. Each single load of scrap is checked for radioactivity before being processed, thus avoiding the possible contamination of the production installations and ensuring the production of clean, non-hazardous hot rolled sections.

3.2 Scrap-based electric arc furnace steel making
The technology for melting scrap in state-of-the-art electric arc furnaces considerably enhances productivity and reduces all types of emissions. The modern electric arc furnaces (Figure 2) are highly automated and computer-controlled. They are equipped with oxygen and carbon injection lances for slag foaming and high power sidewall burners to assist the melting process. The final steel grade is adjusted in an intermediary electric ladle furnace by adding small amounts of alloying elements.

Also, the modern electric arc furnaces are designed to guarantee a high degree of environmental protection and optimal working conditions. The furnace halls are completely enclosed and soundproofed; all emissions are filtered in a high performance bag house. The primary waste gas is cleaned by a complete combustion followed by quick cooling, and collected dust is recycled in the non-ferrous industry to recover zinc. The minimal quantity of slag, produced within the EAF route, is used as a high quality aggregate for road surfacing.

3.3 Continuous casting of near net shapes
Typically, the modern plants are equipped with state-of-the-art near net shape casters. For the efficient production of beams, the continuously cast semi-products are H-shaped beam blanks (Figure 3). All structural steels, including top quality offshore grades, can be produced via EAF and beam blank continuous casting. Thanks to this technology, additional energy savings are achieved in the rolling process.

3.4 Rolling of the section to final shape
The careful design of the beam blank shapes and the roll pass schemes results in a considerably simplified rolling process, thus combining high productivity with substantial energy savings in modern rolling mills (Figure 4). Moreover, sections rolled from beam blanks show excellent surface quality and internal soundness as well as good mechanical properties.
The recent development of the Quenching and Self-Tempering (QST) process allows the production of high strength beams in HISTAR grades with outstanding mechanical and technological properties. This in-line heat treatment operates without external supply of energy and substantially limits the use of alloying elements in the steel. In fact, the QST process allows to further up-cycle steel scrap as the constructional performance of a beam in HISTAR steel grade is by far superior to the performance of a standard beam.

4. THE WORK TOWARDS THE PROTECTION OF THE ENVIRONMENT
Traditional steel production was generally associated with emissions of dust and waste gas, and high energy consumption. The introduction of the EAF route has dramatically changed this situation. Taking both the emissions and the primary energy input of the new installations into account, their environmental benefits are clearly demonstrated in Figure 5. In Luxembourg, the recent launch of a highly efficient combined cycle energy plant, located in the vicinity of the steel plants, allows for a further reduction of primary energy use.

Within the different steps of the steel making process, water is needed for cooling. As it circulates in a closed loop, the water consumption of these new melt shops is small and does not constitute a significant environmental issue.

Another advantage of producing hot rolled sections from scrap is that less than 50% of the original terrain surface area is needed to manufacture the same quantity of hot rolled sections. The land freed by this process is thus available for urban development. With respect to Europe’s industrial heritage, some of the original production facilities like the blast furnace installations are preserved as historical monuments.

5. HOT-ROLLED STEEL SECTIONS FOR SUSTAINABLE CONSTRUCTION
The shapes of hot rolled structural sections are mostly standardised and produced with minimal tolerances. In perfect harmony with the requirements of architects and contractors, these sections feature the following advantages:
• they can be processed by local steel fabricators for the construction of multi-storey and industrial buildings, bridges, etc.,
• they enable a high degree of prefabrication, facilitating fast and clean erection with minimal waste and loss of material at the construction site.
the use of prefabricated building elements in steel structures substantially enhances the construction speed,  
prefabricated steel elements allow for easy dismantling and re-erection of the structure once the building no longer meets construction requirements. Reintegrating the steel elements into other structures is also an option. In case the steel elements no longer fulfil a useful part in a structure, they are recycled as scrap.

The development of high performance structural steels with yield strengths up to 460N/mm², such as the HISTAR grades, enables the building industry to:
- reduce its overall steel consumption,  
- reduce the impact of transportation of materials due to lower weight,  
- design slender load carrying elements occupying less space in a building,  
- design bold and outstanding structures.

Nowadays, improvements in the development of protective coatings, fire-resistant insulation materials and new design methods based on the Natural Fire Safety Concept allow a realistic and economical design of steel structures, thus minimising the environmental impact of the resources used.

5.1 Energy input in sustainable buildings

Hot rolled beams satisfy the demands of the 21st century. They comply with environmental standards, suit aesthetic criteria, and allow speed of implementation, flexibility, lightness and safety. Steel is more than a product; it is a concept that meets the requirements of both people and environment. The ecological development in building construction incorporates the building environment as well as innovative systems for optimising the building services. Performance can be established by the Life Cycle Assessment, which monitors:
- the embodied energy of the structural system,  
- the embodied energy of the secondary construction materials,  
- the energy used for climate control based on a mechanical Supply & Extract service system.

Typically, the embodied energy of the considered steel structures is very small when compared to total energy consumption of a building over its whole lifetime. The following conclusions are significant when selecting the materials for a low-energy, multi-storey building:
- there is no operational energy benefit in the passive thermal performance of conventional office buildings compared to modern steel-framed buildings. Massive structures are not required to exploit the benefits of energy storage in office buildings,  
- the relative values of embodied energy as compared to operational energy have been assessed showing that, on average, maintenance and use are responsible for about 75% of environmental impact throughout a building’s service life. The embodied energy of the building structure itself (steel frame + concrete floors) represents typically ~6%.

5.2 Flexibility and adaptability

Well-designed steel frame buildings are extremely versatile and can be easily altered to suit other functions and activities. One example out of many is represented by the 5 storey building of the Luxembourg Chamber of Commerce, which has been stripped down to the bare structure before being renovated in the frame of a large extension project (Figure 6, Figure 7).
Thanks to their low weight and adaptability, steel structures are usually chosen for the renovation of old buildings. Supporting frames are easily adjusted within the original façades or extra floors are added.

![Image](image1.png)

**Figure 6** Luxembourg Chamber of Commerce in 2001 (left); stripped for renovation (right)

![Image](image2.png)

**Figure 7** Artist’s view of the new Luxembourg Chamber of Commerce complex

### 5.3 Health
Iron is required daily by the human body. Likewise, steel is not a health hazard. It does not emit volatile, hazardous or allergenic substances, which further enhances its suitability as a construction material. Also, structural steel has no own electric or magnetic field. The influence of steel beams on electromagnetic fields within buildings is insignificant with respect to any harmful biological effects on human beings and animals. Opting for a steel load-bearing structure is the first step for sustainable construction. Steel framed buildings achieve good thermal isolation as well as heat storing capacity, thus providing optimal working and living conditions for their occupants.

### 5.4 Closing the loop
Once steel framed buildings no longer fulfil a useful purpose at their original location, they can be dismantled and their structure reused either as a whole or as individual components. It is indeed beneficial for the environment to preserve the value added by manufacturing the steel sections.

Steel-framed car parks for instance have demonstrated their usefulness as temporary structures. At the German airport Munich-Riem, some of the existing multi-storey car parks were no longer required when the airport went out of operation. One structure was dismantled and split to be rebuilt in two halves in Cologne and in Essen. Other examples can be found in all European metropolitan areas. They cover different building types, ranging from residential buildings to schools, exhibition halls and churches.
Once the steel components no longer fulfil a useful purpose, they can easily be scrapped and recycled.

6. SUMMARY
Sustainable Development is defined in the Brundtland Report as ‘a development that meets the needs of the present without compromising the ability of future generations to meet their own needs.’ The new electric arc furnace route allows to fulfil the requirements of this principle as the whole range of structural sections is produced from indefinitely recyclable scrap. Also, the concept of sustainable development involves all the decision-making players in the environmental policy, which ensures that main attention is paid to the environmental issues.

The hot rolled steel sections are produced from the world’s most recycled material and thus contribute to a sustainable society. Their use in construction limits the usual nuisances caused by building sites, where reduction of emissions such as noise and dust as well as smaller working areas involved help to restore a favourable environmental balance. The long-life steel sections satisfy the demands of the 21st century: they allow for optimised material strategies in steel-framed structures such as reduction of material input, prefabrication, reuse or reintegration of the sections, and finally of recycling.

Studies on the life cycle assessment of office buildings demonstrate that there is no significant difference between the environmental performance in terms of the embodied and operational energy of steel framed buildings compared to similar buildings framed with other materials. In addition, human beings, animals and vegetation are not affected when exposed to steel.

Using the steel sections from the EAF route enables architects and designers to swiftly construct safe, long-lasting and aesthetic buildings at competitive prices. The fact is highlighted that steel construction is also an ecological responsible choice, enabling the decision makers in the building industry to be fully in line with the principles of Sustainable Development.

7. REFERENCES
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