

Research on Carbon Emission of Steel Structure During Production Process

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Abstract. In recent years, there has been increasing global concern about climate change and sustainable development. At the same time, there is a growing awareness of environmental responsibility in civil and construction projects. In this paper, two different types of steel materials are discussed. Then, comprehensive assessments of the environmental impact of their production processes have been carried out, with special emphasis on carbon emissions. These analyses highlight the ecological impacts associated with each material type, which also facilitates subsequent comparative assessments aimed at identifying potential ways to reduce environmental impacts. The investigation shows that there is a significant negative correlation between the tensile strength of steel and the volume of the material used, which in turn leads to a proportional reduction in carbon emissions. The research results can show the environmental benefits of improving the compositional integrity of steel. This paper hopes to make some theoretical contributions to the global mission of reducing carbon emissions.

Keywords: Environmental impact; Carbon emission; Steel structure.

1. Introduction

Carbon emissions refer to the greenhouse gases produced by humans because of an activity, and the total weight of these greenhouse gases is called carbon emissions. As early as the last century, the United Nations noted that reducing carbon emissions is an essential development goal in the future, and in 1992, the UN made a treaty called *United Nations Framework Convention on Climate Change* and called on all countries to stabilize the concentration of greenhouse gases in the atmosphere so that greenhouse gases do not harm the climate system and ecosystems can naturally adapt to climate change. The reason why carbon emissions are so important is that carbon emissions, which are growing too fast, have a huge impact on the planet. These include: increasing greenhouse gases, accelerating the rate of global warming, increasing global average temperature, rising sea levels and increasing climate extremes. Hotter summers, more intense typhoons, and expanding deserts are all the result of accelerating global warming. The most direct and effective way to reduce the impact of global warming on the planet is to reduce greenhouse gases, that is, to reduce carbon emissions. This article will focus on carbon emission of steel structure during production process.

2. Literature Review

In the early 1980s, environmental issues gradually attracted the attention of the international community, and people's awareness of the environmental impact of buildings and infrastructure gradually increased. In 1998, life-cycle environmental impact assessment was first applied to bridge research, attracting the attention of scholars at home and abroad. Subsequently, Ma et al. [1] developed a motion-based comprehensive Life-cycle assessment (LCA) model for assessing the environmental sustainability of bridges. The results showed that the production and processing stage of raw materials had the greatest impact on the environment. As shown in Fig. 1, according to the entire process of its construction and use, the life cycle of a bridge can be simply divided into the five stages: (1) bridge design, (2) production of bridge structural materials, (3) construction and installation of Bridges, (4) operation and maintenance of Bridges, (5) dismantlement of Bridges at the end of their service life [2].



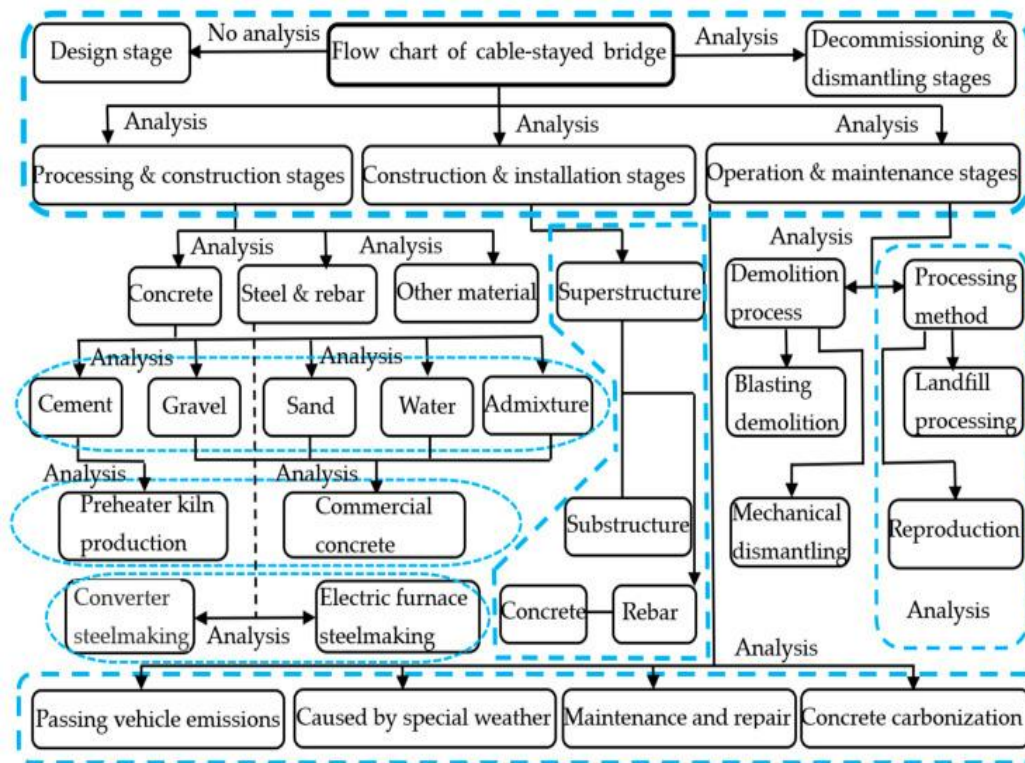


Figure 1. LCA analysis flow chart of the three-tower cable-stayed bridge

From the middle of 2000 to the beginning of 2010, international standards and guidelines for carbon emissions from construction and infrastructure began to be formulated, and research on carbon emissions from bridge engineering was gradually systematized and standardized. In 2010, researchers paid more attention to the micro level, focusing on specific cases of different bridge types, material choices, construction techniques, and so on.

2.1. Researches of Carbon Emission on Construction Field

Radhi [3] used simulation studies and energy analysis to study the energy consumption of buildings and the most effective measures to deal with the potential impact of global warming. It concluded that global warming could increase energy consumption used to cool buildings by 23.5%, with a temperature increase of 5.9°C, and CO₂ emissions could increase by about 5.4% over the following decades.

Cuéllar-Franca and Azapagic [4] introduced the three most common types of houses in the UK: detached, semi-detached and terracing houses, considering the environmental impact of residential construction at all stages of the life cycle, use and demolition after 50 years. The results show that the use stage contributes the most to the environmental impact. Of these, 50-year-old detached houses emitted 455 tons of CO₂ equivalent, semi-detached houses 374 tons and terraced houses 309 tons. The recycling of building materials contributes to the overall reduction of greenhouse gases.

Zhang [5] conducted life cycle assessment analysis and basic data statistics on buildings in Taiwan and established the assessment process and calculation formula for the assessment of life cycle carbon emissions of buildings in Taiwan, which can be used to predict the carbon emissions of reinforced concrete buildings of different sizes and building types. The impact of buildings on environment is discussed by carbon emission. In the analysis of the actual case, it is found that the carbon emission of the new construction process is lower than that of the existing construction, and the carbon emission generated by the daily energy source is higher than that of the example. The key measure to reduce the emission of building life cycle is daily energy saving.

Zhang [6] adopted the life cycle assessment method to conduct a more comprehensive analysis of the environmental impact of the whole life cycle of prefabricated steel structure residential buildings. Compared with traditional reinforced concrete structure buildings, they concluded that the global warming potential (GWP), resource depletion potential (RDP), acidification potential (AP) of steel structure buildings are more efficient and photochemical ozonation. There are obvious advantages in the four aspects of POCP, which are 47%, 78%, 48% and 54% of the steel-mixed buildings, and the comprehensive evaluation results are 57% of the steel-mixed buildings, and the influence of the recycling level of building materials on the ring construction performance of prefabricated steel residential frame structures is analyzed.

2.2. Researches of Carbon Emission on the Bridge

Liu et al. [7] studied the environmental impact of bridge engineering construction, adopted the improved analytic hierarchy process, and analyzed the established multi-level comprehensive evaluation index system. At the same time, the fuzzy evaluation theory was used to analyze the evaluation results, and it was concluded that the production and processing of raw materials had the first impact on the environment. It is suggested that the negative surface of the bridge beam is mainly in the production stage of raw materials, the construction stage and the waste stage.

Wang and Pang [8] used two index systems to establish two analysis models for Bridges. One is to consider the impact of ecology and take resources and energy, ecological balance and human health as indicators. The other is to take environmental discharge as the index, which is divided into global warming potential value, acid potential value, solid waste and so on. By using the terminal damage model and the midpoint damage model to analyze the Ginkgodu Jialing River Bridge, it is concluded that the material production stage has the greatest ecological impact, accounting for 70% of the total impact. 90% of the environmental impact is in the production stage of the material. Through the analysis of the two types of molds, the absolute impact of the raw material production process on the biological environment is strongly adjusted.

Pan and Wang [9] used the basic method and theoretical framework of life cycle to summarize and sort out the energy consumption and carbon emission inventory of highway pavement materials and other related products. It can be used to quantify and analyze the energy consumption and carbon emission of different high-speed roads with different pavement materials in each stage of life cycle and obtain the environmental emission Angle of greenhouse gases. The carbon emission effect is the most significant in the material stage, the paper does not consider the recycling of materials.

Keoleian et al. [10] conducted the comparison of the various stages of the life cycle of the water-mud composite material connecting bridge surface system and the steel extension joint bridge surface plate, and the results are shown in the table. More materials, energy sources and wastes are consumed by steel extension joint deck system. However, the operation of water-mud composite material is not beneficial to the maintenance of the bridge, increasing the number of maintenance and reducing the flow rate of the bridge.

3. Specific in Material Production-Steel

According to the China Metallurgical News, this paper summarized the following major steel suppliers and supply of Hongkong-Zhuhai-Macao Bridge (HZMB), as shown in Table 1 [11]. Obviously, during the construction of HZMB, the use of steel is very large which will lead to a large emission of carbon.

Table 1. Suppliers and supply of steel

No.	Supplier	Supply (t)
1	Bao	340,000
2	Shao	300,000
3	Tai	8200
4	Ma	4600
5	An	17000
6	He	240000

3.1. Methods of Calculating Carbon Emissions

Firstly, this steel is a recyclable material. Each time it is recycled, it is reduced for various reasons, such as it may be corroded, or a part of the steel needs to remove an impurity. It's going to be less than it used to be. For example, there are 1 kg of steel at the beginning, after the first use, the material can be used again, and then it is rebuilt, and only 0.8 kg is left. Then the 0.8 kg are rebuilt again and find that 0.64 kg are left. When it's recycled for the N^{th} time, it's going to zero infinitely, as shown in Fig. 2.

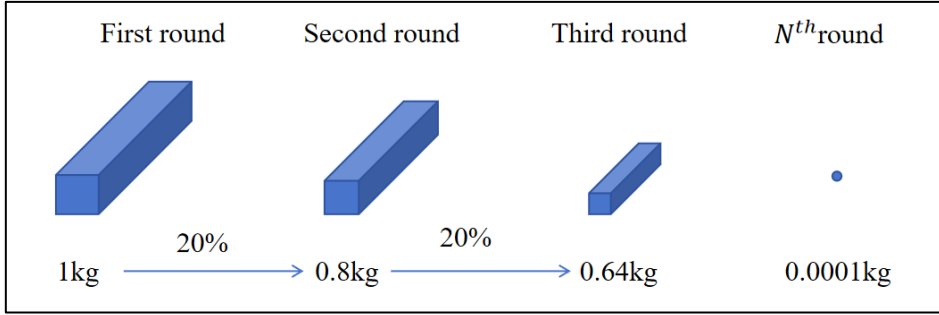


Figure 2. The process of steel production

$$\text{Total impact for n loops} = X_{prim} + RR \times X_{rec} + [RR]^2 \times X_{rec} \dots + [RR]^{n-1} \times X_{rec} \quad (1)$$

$$\text{Total mass of steel produced} = 1 + RR + [RR]^2 + \dots + [RR]^{n-1} \quad (2)$$

$$\frac{\text{impact}}{\text{mass}} = \frac{(1)}{(2)} \quad (3)$$

$$1 + RR + [RR]^2 + \dots + [RR]^{n-1} = \frac{[RR]^{n-1}}{RR - 1} \quad (4)$$

$$X_{total} = \frac{(X_{prim} - X_{rec})(1 - RR)}{(1 - [RR]^n) + X_{rec}} \quad (5)$$

$$X = X_{prim} + RR (X_{rec} - X_{prim}) \quad (6)$$

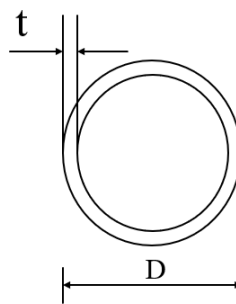
where X_{prim} is the impact for primary steel production, X_{rec} the impact for secondary steel production (Specific value seeing Table 2), and $[RR]^n$ is the mass for a round.

Table 2. Steel-latest values [12]

Type	GWP primary	PEC primary	Recovery Rate	GWP secondary	PEC secondary
Sections (beams, columns)	1.157	14.8	95	0.409	6.35

3.2. Specific Calculation on Steel Column

For the steel columns, circular shaped are considered, namely circular hollow section CHS50810 and the other one named CHS355,6×10, as shown in Fig. 3. The steel yield strength equals 355MPa and the Young's modulus is 210GPa. The design was made for a steel column of 5m length, the dimensions of the profiles are taken from ArcelorMittal catalogue.

**Figure 3.** The steel columns

The final calculation data are shown in Table 3. The radius of S690 is 355.6, which is smaller than that of S355. The reason is that S690 is more intense. The stronger the steel, the less steel is used. The less carbon emission they will have.

Table 3. Results of some calculation on different types of steel

Type	Unit	CHS508×10	CHS355.6×10
Outside diameter	mm	508.0	355.6
Wall thickness	mm	10.0	10.0
Area of structural steel	m ²	0.0156	0.0108
Mass of structural steel per m	kg/m	122.5	84.8
Sections (beams, columns)	Kg CO ₂ e / kg	0.42396	0.42396
Total impact	Kg CO ₂ e	259.6	179.7

4. Conclusion

In this paper, based on the production process of steel, the environmental impact of different types of steel is studied, especially the carbon emission part. This paper also explores the relationship between different types of steel in the production process and their associated carbon emissions. The main conclusions are as follows:

(1) In order to address climate change, most major international steel companies and multinational corporations, while setting long-term carbon neutral goals, are achieving these goals through advances in technological research and development, application of process technology and

promotion of demonstration projects. This gradual process highlights the determination of steel companies to fulfill their social responsibility of carbon reduction.

(2) This paper only considers the carbon emissions generated by different steel sections, and does not comprehensively consider the different section sizes and different amounts of steel used in I-beam and box beam to consider the price issue. It is hope to contribute to the international goal of reducing carbon emissions through further research in the future.

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