

A study of the relevance of seismic steel structures to urban carbon neutrality

Kim jungeun*

Industrial Design Institute, Carnegie Mellon University, USA;

*85755086@qq.com

Abstract. Global warming has triggered dramatic climate change and natural disasters. Since the 21st century, the frequency of all kinds of extreme weather has increased significantly. This study, in accordance with the carbon peak targets and stage requirements, improve the building low carbon building standards system, accelerate the formulation, revision and collation of energy-saving design standards for public buildings energy-saving and carbon reduction standards. The application of earthquake-resistant steel structure of the building, the promotion of green low carbon building materials and green construction methods. Actively promote such buildings, the past sixty years each country's carbon emissions intensity have shown a general downward trend, especially South Korea, South Africa and Brazil and other countries due to economic development began to focus attention on environmental issues. In this study, we take Busan, Korea as an example, and use carbon neutral calculations to realize carbon neutrality by designing superstructures with a reduced degree of intensity, so that the reduction of carbon emissions mainly includes emission reductions brought about by a reduction in the amount of steel and cement used. It is hoped that this study will be taken into account, and that the early realization of peak carbon emissions in South Korea will be the current situation to be realized, and will be a challenge not only for developing countries, but also an important issue to be considered by all countries.

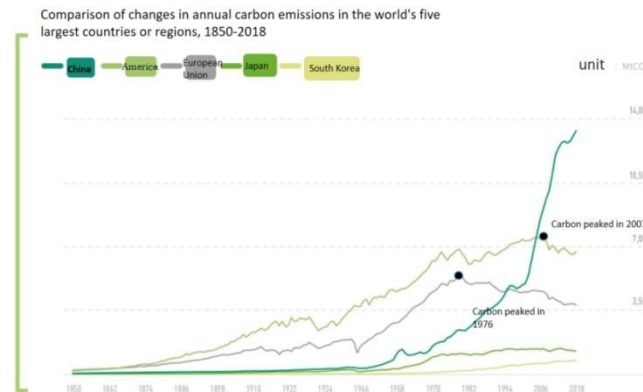
Keywords: Seismic Steel Structure , Energy Saving and Carbon Reduction in Buildings, Circular Economy, Low Carbon Buildings, Carbon Neutral

1. Introduction

Revised sentence: In order to combat the global greenhouse effect, the Paris Agreement was signed by countries during the Paris Climate Conference in 2015, with the objective of limiting the rise in global average temperature to 2 degrees Celsius compared to pre-industrial levels. Efforts are underway to further restrict this increase to 1.5 degrees Celsius. Currently, "net-zero" emission targets have been set by 45 economies (58 countries), accounting for 53.3 percent of global greenhouse gas emissions. To mitigate climate change impacts and risks while ensuring a high quality of life for urban residents, there is a strong impetus towards green and low-carbon transitions within the construction sector. South Korean President Moon Jae-in has committed to achieving carbon neutrality by 2050. This study underscores the significance of integrating nature into urban design, planning, and management solutions as a means of attaining optimal socio-ecological outcomes.

As can be observed in Figure 1, the European Union, as a developed country, had already achieved peak carbon emissions in 1976, while the United States reached its peak in 2007. It is important to promote green and low-carbon building materials as well as green construction methods. Furthermore, the development of assembly-type buildings should be prioritized so that by 2025, they will account for 55% of new construction areas in China. [3] Additionally, there should be active promotion of ultra-low-energy buildings. Over the past six decades, every country has shown a general downward trend in carbon emission intensity. Notably, South Korea, South Africa and Brazil have started paying attention to environmental issues after their economic development; however, South Korea still needs to achieve its peak carbon emissions and this should be a priority for them. The reduction of total carbon emissions along with decreasing emission intensity and per capita emissions while fostering economic growth is not only a challenge faced by developing countries but also an important issue for all nations.[1]

Table 1. Comparison of changes in annual carbon emissions in the world's five largest countries or regions, 1850-2018



As can be observed in Table 1, as a developed country, the European Union has already achieved peak carbon in 1976, while the United States achieved peak carbon by 2007. Promote green and low-carbon building materials and green construction methods, and further develop assembly-type buildings, so that by 2025, China will realize that assembly-type buildings will account for 55% of new construction area. Actively promote ultra-low-energy buildings. Over the past six decades, the carbon emission intensity of each country has shown a general downward trend, especially in South Korea, South Africa and Brazil, which have begun to pay attention to environmental issues after economic development, and South Korea has not yet achieved peak carbon is the current situation to strive to achieve. Korea's carbon emission reduction process should play an important role in the world. Reducing the total amount of carbon emissions, the intensity of carbon emissions, and per capita carbon emissions while developing the economy is not just a challenge for developing countries, but also an important issue for all countries to consider.[2]

2. Building maintenance

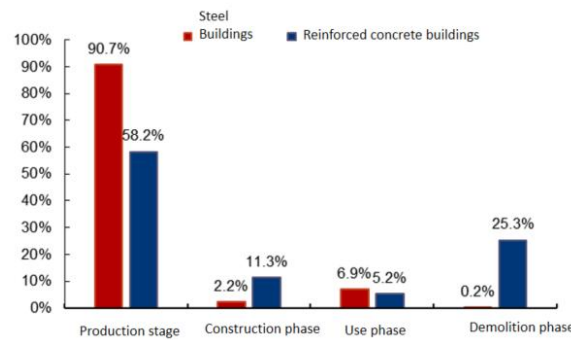
In accordance with the carbon peak target and stage-by-stage requirements, improve the low-carbon building standard system, accelerate the formulation and revision of energy saving and carbon-reducing standards such as energy saving design standards for public buildings and seismic energy saving standards for agricultural buildings.[5]

Green buildings are mainly constructed in an assembly mode. Compared with traditional concrete buildings, assembled buildings are a form of low-energy and low-emission construction, which is fully consistent with the green building concept and is a model for green buildings.[3]

A comparison of the energy-saving and carbon reduction of assembled PC buildings and its effect on steel structure buildings reveals that steel structure buildings reduce carbon emissions by about 40% over the life cycle compared with reinforced concrete buildings, which is better than the 5.6% carbon reduction effect of assembled PC buildings.

As shown in Table 2, assembled buildings will become an important carrier for the construction industry to achieve energy saving and emission reduction, steel structure assembled building prospects in the medium and long term will continue to be good at the same time, to the perspective of the whole life cycle, steel structure building demolition of the construction waste generated can be recycled and reuse, reuse process can reduce carbon emissions (scrap steel as raw material, the use of the electric furnace process of ironmaking and steelmaking), in comparison with the concrete building does not have the above advantages. [6]

Table 2. Comparison of Whole Life Cycle Carbon Emissions of Different Structural Types of Buildings



Low-carbon design based on the whole-life carbon footprint of a building, where a whole-life environmental impact analysis of the project is conducted and the results of the whole-life evaluation are used to optimize the building design. This includes the use of environmentally friendly building materials and energy solutions for the building, and a whole-life carbon emissions analysis.

3. Discussion

According to the summary of Journal of Cleaner Production, among various building materials, steel and cement have the highest proportion of carbon emission, accounting for 40.8% and 36.6% respectively, which is more than 77%, while other building materials such as bricks and tiles, timber, aluminum and glass only account for less than 23%. [10]

Morphological Reference ASCE 7-16 states that the probability of collapse of Class I and Class I Risk Structures under the Maximum Considered Earthquake (MCE) shaking hazard shall be less than 10 percent.[12]After adopting the seismic isolation technology, the superstructure can be designed with a reduced degree of seismic intensity, which has a great impact on the structural strength, and after the reduced degree of design, the amount of steel and cement can be significantly reduced, which is in line with the development trend of the international "carbon-neutral" target.[1][11]

Taking China as an example, the emission reduction under the application of vibration isolation is estimated, and it is found that every 10% penetration on average is expected to contribute 10.47 million tons of carbon emission reduction, which will help China's national building materials industry to reduce emissions by nearly 1%. Under the background of "carbon neutrality", the green building design technology of "vibration isolation" that can significantly reduce carbon is expected to gain rapid application, and the switch from "passive" to "active" will be accelerated. The switch from "passive" to "active" will accelerate the penetration and expand the scope of application, the development prospects of the industry will be more optimistic, positive, neutral, negative measurements of the industry space is expected to see 1100/710/515 billion per year, much higher than our previous forecast of 30-40 billion.[14]

4. Measurement method:

Carbon reduction contributed by seismic isolation technology application = Reduced use per unit of steel * Steel unit carbon emissions + Reduced use per unit of concrete * Concrete unit carbon emissions + Others[8]

Hypothesis:

According to formula

$$C_{sc} = \sum_{i=1}^n M_i F_i \quad (1)$$

after adopting the seismic isolation technology of building, the carbon emission of steel per square and concrete per square is 41kg and 37.5-50kg respectively. We assume that the carbon emission that can be reduced by adopting the vibration isolation technology = carbon emission corresponding to the reduction of the use of building materials - carbon emission increased by production of vibration isolation bearing, and after synthesizing the relevant cases, we can see that the consumption of steel can be reduced by 25%-40% or so, the average per square foot can reduce carbon emissions of about 50kg.[4]

5. Application of the LCA analysis

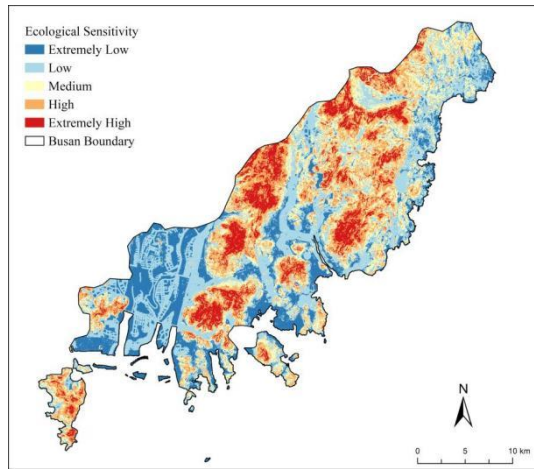


Fig. 1 Elevation Sensitivity

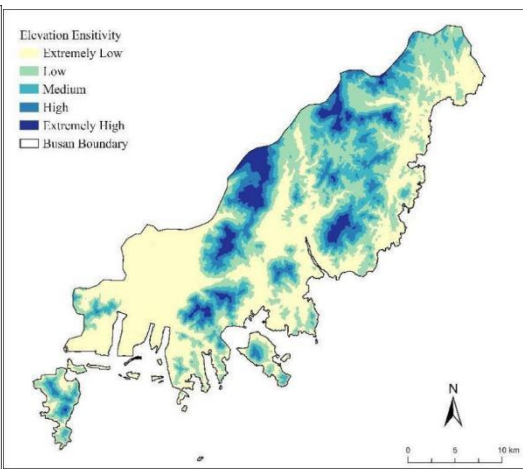


Fig. 2 Ecological Sensitivity

As shown in Fig. 1 and Fig. 2, the ecological sensitivity of Busan area is distributed according to the levels of very low, medium-high, and very high, and green building construction is improved in the very low part of the urban construction. As shown in the figure, in the area that needs to be improved the most, low carbon construction is used as much as possible in the construction of municipal buildings.[7]

According to the Code for Seismic Design of Buildings, after adopting the seismic reduction and isolation technology, the superstructure can realize the design of degree reduction, and the seismic intensity has a great influence on the structural strength. [13]

The seismic intensity has a significant impact on the strength of the structure, and the use of steel and cement can be significantly reduced after downgraded design.

The project is located in Busan, Korea. The height of the structure is 58.9m, the width is 31.2m, and the seismic design of the project is 9 degrees. The project adopts seismic isolation design, using 18 sets of LRB900 seismic isolation bearings and 16 sets of LRB1100 seismic isolation bearings, while the superstructure is preliminaries designed in accordance with the goal of one degree of reduction, the size of the superstructure members and reinforcement is reduced accordingly, while the non-structural components and decoration anchorage connection structure can be simplified. After adding seismic isolation bearings, the structural cycle was considerably extended.

The carbon emission formula for the production phase of building materials is

$$C_{sc} = \sum_{i=1}^n M_i F_i$$

where M_i is the consumption of building material type i , F_i is the carbon emission factor for building material type i (kg CO₂e/unit quantity of building material), According to the carbon

emission factor F steel is approximately 2050kg CO₂e/t, FConcrete is approximately 300-400kg CO₂e/m³.

Due to the superstructure buckling design, the project adopts seismic isolation after the amount of steel reinforcement is 797t, 513t lower than conventional consumable volume of 1310t (40%), According to the carbon emission formula, the carbon emission saving is about 513t (M) * 2050 (F) = 1051650kg = 1051.65t;

Concrete using C30-C55 multi-type products, saving 661m³ (13%) compared to traditional consumables, It is calculated that the corresponding saving of carbon emissions is about 661*350 = 231350kg = 231.35t, Total reduction of steel and cement carbon emissions 1283t CO₂.

6. Summary and interpretation of the results

After adopting seismic isolation, the carbon emission of the project mainly includes the carbon emission from the production of seismic isolation bearings and other unusual structures of seismic isolation, etc. The LRB900 corresponds to 1000kg, and the LRB1100 corresponds to 1500kg. The seismic isolation bearing LRB900 used in the project is commensurate with 1000kg, and LRB1100 corresponds to 1500kg, which corresponds to about 86t of carbon emission according to the same method. In a comprehensive view, the adoption of seismic isolation can reduce carbon dioxide emission by 1283-86=1197t, which is an average reduction of 50kg of carbon dioxide per square meter. The reduction of carbon emissions mainly includes the reduction of steel and cement consumption due to the downsizing design of the superstructure.

7. Conclusion

In the overall process of carbon neutrality, reaching carbon peak and carbon neutrality in the building sector is one of the keys for the whole country's industry-wide goal of carbon neutrality, due to the characteristics of the building itself, which is characterized by large emissions and a long lock-in cycle. This study provides ideas for carbon emission accounting and emission reduction paths for urban development of green buildings. The next step will be to track and monitor the carbon emission level data and establish a rationalized emission factor database, which is an important direction to improve the accuracy of green building carbon emission accounting.

With the advancement of building technology, new building construction modes will be produced in the future, and the concept of green building or low carbon building, which aims to further reduce carbon emissions, has been put forward, as well as the use of natural elements, and the application of plant carbon sequestration in buildings, which can further achieve the optimal solution in terms of environmental protection and economy. Green building is currently further developed to the stage of ultra-low carbon building, but the construction path to fully realize the true meaning of the building carbon neutral is still in the process of exploration and development.

8. Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

- [1] AISC (2016b) Seismic provisions for structural steel buildings. ANSI/AISC 341-16, 12 July. Chicago, IL: American Institute of Steel Construction.
- [2] Biswas WK. Carbon footprint and embodied energy consumption assessment of building construction works in Western Australia. *Int J Sustain Built Environ* 2014;3:179 – 86.

- [3] Building Energy Efficiency Research Center, Tsinghua University(2020)China Building Industry Press, China Building Energy Efficiency Annual Development Research Report 2020. China.
- [4] Chau C, Leung T, Ng W. A review on life cycle assessment, life cycle energy assessment and life cycle carbon emissions assessment on buildings. *Appl Energy* 2015;143:395 – 413.
- [5] Chen Jianghong , Li Qiming , Deng Xiaopeng (2008) Energy Consumption Analysis of the Whole Life Cycle of Residential Buildings, *Building Economics*, Vol. 7, pp. 117-120.
- [6] China's Ministry of Ecology and Environment: Implementation Plan for Setting and Allocating Total National Carbon Emission Trading Allowances for 2019-2020 (Power Generation Sector)
- [7] Computers Structures Inc. (CSI) (2019) ETABS V18 2.0, software. Available at: <https://www.csiamerica.com/> (accessed 6 July 2020).
- [8] Fenner, A. E. et al. The carbon footprint of buildings: A review of methodologies and applications. *Renew. Sustain. Energy Rev.* 2018;94:1142 – 1152.
- [9] Guo and Cache , Cui Yannan , Wang Ying , Cao Chen , (2017) A study on the whole life cycle carbon emissions of green residential buildings, *China Building Materials Science and Technology*, Vol. 5, pp. 9-12.
- [10] IEA (2020) World Energy Statistics and Balances (database), www.iea.org/statistics, and IEA (2020b) Energy Technology Outlook, Building Model, www.iea.org/buildings.
- [11] Lee K, Foutch DA (2002) Performance evaluation of new steel frame buildings for seismic loads. *Earthquake Engineering & Structural Dynamics* 31(3): 653–670.
- [12] Liu Mei Yang Jie(2021) China National Institute of Standardization (CNIS), "Carbon Peak Carbon Neutrality and Standards Series Interpretation No. 2 - The Long Way to the Launch of the International Standard for Carbon Neutrality (ISO14068)".
- [13] Pomponi F, Lenzen M. Hybrid life cycle assessment (LCA) will likely yield more accurate results than process-based LCA. *J Clean Prod* 2018;176:210 – 5.
- [14] Rafael A. Salgado, Defne Apul, Serhan Guner (2020) Life cycle assessment of seismic retrofit alternatives for reinforced concrete frame buildings , *Journal of Building Engineering*, Volume 28, 101064. <https://doi.org/10.1016/j.jobe.2019.101064>
- [15] Taoo Kim, M.EERI, and Sang Whan Han, M.EERI , View all authors and affiliations,(2020) Seismic collapse performance of steel special moment frames designed using different analysis methods ,*Earthquake Spectra* , Volume 37, Issue 2