The 3rd International Conference on Materials Chemistry and Environmental Engineering
DOI: 10.54254/2755-2721/3/20230349

Analysis of the Dominance of Steel and Concrete in Architecture

Chengjun Fu

School of Engineering, Main Campus, University of Glasgow, University Avenue, Glasgow, Scotland, UK, G12 8QQ

2512211F@student.gla.ac.uk

Abstract. The issue of carbon emissions from building materials is an important issue in today's society and concrete buildings are one of the main contributors to carbon emissions. As a result, steel construction is very popular in modern society. However, with improvements in concrete technology, it is gradually starting to gain acceptance again. The focus of this review article is to discuss the dominant role of steel and concrete in construction. This paper adopts the method of literature analysis and reading. At the same time, the data of this study come from SteelConstruction.info (The free encyclopedia for UK steel construction information), British Constructional Steelwork Association (BCSA) and Steel Construction Institute (SCI) and The British Standard Institute. The following conclusions can be drawn: Steel structures are getting more and more attention. Steel structure and cement play an important role in construction.

Keywords: Steel, Concrete, Architecture, Low carbon, Green concrete.

1. Introduction

With the development of science and technology, building materials are also gradually evolving. From earth, wood, later concrete and steel and even the fibre reinforced polymer (FRP), building materials have continued to advance [1].

However, among the materials mentioned above, concrete and steel seem to have a significant and dominant role in the stage of construction, as seen by most of the existing architectural observations in the world [2]. Therefore, this paper will focus on the dominance of steel and concrete in architecture.

It also discussed which of the two building materials, concrete or steel, is dominant and to give a reference opinion on the use of building materials. In addition, this paper will provide some views on the development of these two materials and a review of the possible dominance of new materials. This research reveals the dominance of steel and concrete materials in construction and provides a reference for future research.

DOI: 10.54254/2755-2721/3/20230349

2. Analysis of historical changes in building materials

Figure 1. The concrete building and the steel building, University of Glasgow.

When walking through the streets of the world, a wide variety of buildings and the use of various materials in these buildings can be clearly observed. In China, for example, tall buildings are more common in the streets of large cities such as Shanghai and Beijing, and most of these buildings are made of steel, whether it is the China National Stadium (The Bird's Nest), and Water Cube built for the Beijing Olympics or the Shanghai World Financial Centre standing in the centre of downtown. Both are very famous modern steel buildings in the world. But if looking a little further down, it is easy to see that most of the older Chinese buildings are made of concrete. If then narrowing the perspective even further, from urban architecture to a specific area building, for instance, the buildings of Glasgow University in Glasgow, England, far away from China, as shown in Figure 1, the higher grey building on the left can be clearly observed that it is the main concrete structure, which was built in 1972. And the lower light-coloured building on the right is a main steel structure built in 2021. it seems that the trend of modern building materials is from concrete structure to steel structure. This is a change that is visible to the naked eye.

In addition to the visible change in building materials, sustainable development is the development paradigm of this world nowadays, and this concept is introduced in 1987 and defined as the production, living and creation of human beings in a way that does not impact the future survival needs [3]. As this development model is recognised worldwide, the protection of the planet is also a significant factor in the evolution of construction materials. Under the Kyoto Protocol, adopted on 11 December 1997, binding carbon reduction targets were set for 37 industrialised countries and economies in transition, as well as the European Union [4]. Carbon dioxide, the main greenhouse gas driving climate change, is released from many aspects of cement production, and concrete-built buildings constitute a major source of carbon emissions that need to be adequately controlled [5].

According to the mentioned two factors, the use of dominant materials in buildings is indeed in flux, both in terms of observation in daily life and the impact of proposed policies on the use of building materials. The causes and implications of changes in the dominant materials in buildings are therefore worthy of further study.

3. The significance of building materials

Architecture is the primary space for human life’s survival. It is a necessary condition for social operation and has an essential impact on the whole earth [6]. Especially in today's population explosion, architecture is a necessary dependency for urban residents. Without architecture, there is no place for further human activities. Thus, building is significant for human society and the development of the earth to create habitable space on the limited land resources. Furthermore, on the basic concept that architecture cannot be separated from human society, it is necessary to study architecture. Among them,

DOI: 10.54254/2755-2721/3/20230349

the discussion of building materials could be a meaningful topic. Therefore, it is particularly essential to analyse their position at a time when steel and concrete are still used as the main building materials.

4. Analysis of Steel's Dominance in Building Materials

According to the free encyclopedia for UK steel construction information created and maintained by Tata Steel, the British Constructional Steelwork Association (BCSA) and the Steel Construction Institute (SCI). Steel is an alloy of iron and some other elements, mainly carbon, with high tensile strength and a relatively low cost. In the UK construction materials market, for example, steel prices have been falling since 1980 [7] and its high market share in multi-storey construction is around 65%. Independent studies (SteelConstruction.info) consistently show that steel is the most cost-effective framing solution in the UK market [8]. Early forms of steel have been around since 1800 BC and have since been used by the Greeks, Romans, Indians and Chinese. The material properties of steel make it the ultimate sustainable building material, both in terms of its material properties and its qualification for steel frame construction [9]. Steel as a building material offers short construction times, good building results and low costs. This is the basis for steel being an important building material.

In the UK, for example, reducing the operating carbon emissions of buildings is the primary driver of sustainable construction. Through the Climate Change Act, the UK government has set an ambitious and legally binding target to reduce the UK's national greenhouse gas emissions by at least 100% by 2050, with an intermediate target of 68% by 2030. In addition, the Energy Performance of Buildings Directive (EPBD) requires all new buildings to be "near-zero energy consumption" by December 2020 [10]. Furthermore, according to SteelConstruction.info, steel is a material that can be recycled and reused. This unique property makes steel highly valuable at all stages of its life cycle. The recycling infrastructure for steel recycling is highly developed and efficient and has existed for decades. In addition, according to data provided by WRAP, the current recycling rate of steel structures on demolition sites in the UK is about 99%, and the recycling rate of all structural steel products is about 96%, which is much higher than that of any other building material [11]. This means that recycled steel is "true recycling", and the used steel is completely reusable [11]. Globally, recycled steel accounts for 50% of new steel production [7]. Its infinitely recyclable properties make it an environmentally friendly building material that meets the requirements of various countries for low carbon emission.

All the above data could deeply explain that, in the face of the demand for sustainable development, the dominant role of steel structures in architecture has its own environmental reasons. Steel structure building is necessary and straightforward in the pursuit of ultimate low carbon emissions. Therefore, in recent years, it is an indelible fact that steel structure buildings have become more and more dominant in construction.

5. Analysis of Concrete's Dominance in Building Materials

Concrete is also a material that meets the requirements of sustainable development [12]. According to Eurocode, it has many advantages over other building materials, such as high fire and corrosion resistance; room temperature pouring and hardening ability; ability to work cooperatively with toughened materials (steel bars, steel tubes, steel fibres, etc.); the absorption capacity of industrial by-products; appreciable load capacity; permeability resistance; long service life and so on [13]. All of these characteristics combine to make concrete the most widely used building material in the world today [14]. In the face of such a high dominance of steel structures as a building material nowadays, while recognising the advantages of concrete, it is crucial to realise the potential for further optimisation of the material, especially the ability to promote environmental and eco-friendliness, in order to obtain concrete with ever-increasing performance, while identifying the advantages of concrete. Therefore, the concept of green concrete is gradually gaining ground.

Green concrete is a raw material by improving concrete. It is a high-performance, high-durability concrete made of mineral composites, recycled aggregates, and other components. The concept of green concrete was first proposed by Denmark in 1998 [15]. In the field of civil engineering, the term green concrete usually has two meanings. It refers to the concrete that has finally been set but has not yet

DOI: 10.54254/2755-2721/3/20230349

acquired appreciable load capacity and the capacity of resource and energy conservation, environmental and ecological protection in the process of preparation and use [16]. However, green concrete can be divided into many categories.

5.1. Air-purifying concrete

Air-purifying concrete is a new type of product that uses an additive containing titanium dioxide to combine nitrogen oxide with sunlight and turn it into harmless nitrate. It absorbs harmful gases and removes pollution-free substances. The University of Twente in the Netherlands has developed an air-purifying concrete that converts nitrous oxide into harmless nitrates when exposed to sunlight by combining titanium compounds with nitrogen gases from car exhausts. The nitrates produced are washed away by heavy rains, which reduces, or even eliminates, pollution. It can reduce the nitrogen oxide concentration by 25%-45%, purify the local air, and make a significant contribution to the realisation of sustainable human development [17]. The benefits of low carbon and energy efficiency make this material in line with social trends.

5.2. Recycled aggregate concrete

The waste cement concrete can be recycled in situ by the blocks, and then crushed, washed, and graded as the natural aggregate mixture of the recycled aggregate concrete in full or in part to replace the recycled aggregate concrete. This can not only fundamentally solve the problem of disposal of waste concrete, but also save natural comprehensive resources, with significant social, economic and environmental benefits. In the UK, the most aggregate of origin will be composed of a mixture of crushed brick and concrete [18]. Using recycled aggregate made from building waste solid materials instead of natural aggregate can save resources, protect the environment, and significantly reduce the cost of engineering materials and the project cost. It has been applied to many projects.

5.3. Summary for green concrete

All kinds of green concrete mentioned in this part are making efforts to reduce the carbon emissions of concrete. As a result, many practical examples demonstrate that concrete has an irreplaceable role in the building, whether it is the mechanical structure's corrosion and fire resistance or service life. These functions cannot be found in steel, and the development of new low carbon concrete also contributes to the world's sustainable development. Therefore, in the subsequent development, the dominanting position of concrete in the building is not to be underestimated.

6. Conclusion

To sum up, the introduction of building materials, from the perspective of the overall history. There is indeed a tendency to transition from concrete to steel as the main building material. Steel structure advantages are prominent because they have low carbon, energy-saving, green environmental protection. The advantage of reusable, reconstruction, renovation, and demolition means that almost no construction waste will be produced. Steel can be recycled, and even create the miracle of close to zero emissions. Compared with other building, steel structure is one of the most popular kinds of architecture. However, the continuous development of concrete buildings, especially the concept of green concrete, has completely disrupted the transition process of the dominant position of building materials. Concrete has its own very big advantages, whether air-purifying concrete or recycled aggregate concrete, which are good examples of solving the problem of concrete carbon emissions, so concrete has gradually been paid attention to again, returning to the dominant stage of building materials. The importance of steel and concrete structures in architecture could be realised by combining new and old buildings and building materials. However, there is a certain lack of understanding of the latest developments in concrete in this paper, while steel materials are also in a developmental phase and the dominance of FRP is increasing. Whether concrete is still the dominant material in construction, therefore, requires further data and research.

DOI: 10.54254/2755-2721/3/20230349

References

[1] T. Mottram, "UK project to challenge concrete's construction dominance," Reinforced Plastics, vol. 41, no. 6, p. 14, Jun. 1997, doi: 10.1016/s0034-3617(97)91477-6.

[2] PERI Group, "Concrete vs. steel," Designingbuildings.co.uk, 2014. https://www.designingbuildings.co.uk/wiki/Concrete_vs._steel.

[3] J. Butlin, "Our common future. By World commission on environment and development. (London, Oxford University Press, 1987, pp.383 £5.95.)," Journal of International Development, vol. 1, no. 2, pp. 284–287, Apr. 1989, doi: 10.1002/jid.3380010208.

[4] United Nations Climate Change, "What is the Kyoto Protocol? | UNFCCC," Unfccc.int, 2019. https://unfccc.int/kyoto_protocol.

[5] P. S. Fennell, "Decarbonizing cement production," Joule, vol. 5, no. 6, pp. 1305–1311, Jun. 2021, doi: 10.1016/j.joule.2021.04.011.

[6] D. Costanzo, What Architecture Means. Routledge, 2015.

[7] SteelConstruction.info, "The case for steel," steelconstruction.info, 2022. https://www.steelconstruction.info/The_case_for_steel#Economics

[8] SteelConstruction.info, "Cost of structural steelwork," www.steelconstruction.info, 2011. https://www.steelconstruction.info/Cost_of_structural_steelwork

[9] British Constructional Steelwork Association (BCSA) and Steel Construction Institute (SCI), "Sustainability," www.steelconstruction.info, 2021. https://www.steelconstruction.info/Sustainability#Steel_manufacture.

[10] "The Climate Change Act 2008 (2050 Target Amendment) Order 2019," Legislation.gov.uk, 2019. https://www.legislation.gov.uk/uksi/2019/1056/contents/made.

[11] "WRAP - Circular Economy & Resource Efficiency Experts," wrap.org.uk. https://wrap.org.uk/

[12] A. A. A. Samad et al., "Development of Green Concrete from Agricultural and Construction Waste," Transition Towards 100% Renewable Energy, vol. 36, pp. 399–410, 2018, doi: 10.1007/978-3-319-69844-1_36.

[13] British Standard Institute, Structural eurocodes : PP1990, 2010 : extracts from the structural eurocodes for students of structural design. London: Bsi, 2010.

[14] V. Vishwakarma and D. Ramachandran, "Green Concrete mix using solid waste and nanoparticles as alternatives – A review," Construction and Building Materials, vol. 162, pp. 96–103, Feb. 2018, doi: 10.1016/j.conbuildmat.2017.11.174.

[15] A. A. Gedi, "Research on Green Concrete: A Review," IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), vol. 16, no. 15, pp. 28–33, Oct. 2019.

[16] Aci Committee 116, Cement and concrete terminology. Farmington Hills, Mich.: American Concrete Institute, 2000.

[17] J.-X. Lu and C. S. Poon, "Recycling of waste glass in construction materials," New Trends in Eco-efficient and Recycled Concrete, vol. 6, pp. 153–167, 2019, doi: 10.1016/b978-0-08-102480-5.00006-3.

[18] C. Fabiani, A. L. Pisello, and H. Paksoy, "2.30 Novel Building Materials," Comprehensive Energy Systems, pp. 980–1017, 2018, doi: 10.1016/b978-0-12-809597-3.00257-1.