Research on Carbon Emission of Renewable Concrete in the Context of Green Building

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Abstract. With the increasing carbon emission of buildings, concrete, as an important building material, needs to adopt reasonable strategies to reduce carbon emission. Based on the research background of green building, this paper mainly studies the production of new renewable concrete by recycling industrial waste. In this paper, the different material ratios of recycled concrete and their different properties are studies firstly. Then, the appropriate material ratios are selected to ensure the stability of the structure and effectively reduce carbon emissions. The results show that the carbon emission and strength of recycled concrete decrease with the increase of the amount of recycled material. When the dosage is 50%, the strength of the renewable concrete is improved. Through the study of renewable concrete, the carbon emission calculation of renewable concrete and the change of structural properties under different material ratio are realized, which provides ideas for the production of new concrete materials.

Keywords: Renewable concrete; structural performance; carbon emission.

1. Introduction

In recent years, global carbon emissions have been increasing. Carbon emissions from buildings account for the majority of man-made carbon emissions, about 41% [1]. In this context, the concept of green building needs to be reflected in contemporary architecture. Green building includes some building design methods and building technology, and the application of new materials to reduce the carbon emission content of the building itself is one of the important ways of green building technology. In addition, it also includes green buildings through passive energy saving and equipment energy saving, which are aimed at reducing energy consumption and carbon emissions. Different countries have corresponding carbon emission evaluation systems, so all buildings need to be able to control carbon emissions within each national evaluation system, and to reduce building carbon emissions as much as possible.

In the building to do as much as possible to save energy and reduce emissions, especially to reduce carbon emissions. However, concrete is still one of the most important materials in building structures, whether it is frame structure or shear wall structure will use concrete. According to statistics, the annual global carbon emissions are about one billion tons [2]. Because concrete carbon emissions account for an important proportion of overall building carbon emissions, reducing concrete carbon emissions can make an important contribution to the reduction of overall carbon emissions. Since much of the waste from the demolition of buildings is concrete, this figure is about 40%-67% [3]. Because the production of concrete will produce a lot of waste, to make reasonable use of these wastes, it is necessary to take some methods to deal with these wastes, and choose the right mix ratio to produce new concrete. Therefore, this material should be recycled, not only to achieve waste utilization, but also to reduce carbon emissions. Renewable concrete is a new type of concrete based on the industrial waste and waste concrete generated by disassembly. This new type of renewable concrete can reduce the waste of resources and make full use of industrial waste. In addition, with the secondary use of industrial waste, renewable concrete can also protect the environment to a certain extent and reduce the pollution of garbage.

Recycled concrete can reduce greenhouse gas emissions and energy consumption to the greatest extent by disassembling discarded concrete in buildings. In addition, the mechanical properties, fire and sound insulation capabilities, seismic and waterproof properties of recycled concrete are

comparable to those of ordinary concrete [4]. In this paper, the renewable concrete of industrial waste will be introduced and its different proportioning methods and its carbon emission results will be also discussed. Furthermore, the carbon emission of renewable concrete in the process of transportation and production is compared with that of traditional concrete. And the carbon emission advantage and calculation analysis of renewable concrete are carried out.

2. Suitable Ratio and Basic Performance Analysis of Renewable Concrete

There are a variety of mixing methods for renewable concrete, and based on different mixing methods for concrete itself, it also includes the addition of recyclable materials for industrial waste. As for the renewable concrete itself, there are many different properties from ordinary concrete. The difference in the content of industrial waste will lead to the difference in the structure and performance of the final renewable concrete. Firstly, taking C20 concrete as an example, the concrete is prepared according to the standard raw material ratio, and on this basis, the renewable material is added, and the slump of its apparent density is compared with that of different renewable content [5].

Table 1. The relationship between concrete mix ratio and its apparent density and slump [5].

Recycled material content/%	slumps/mm	Apparent density/(kg/m^3)
0	180	2436
50	100	2368
100	50	2268

In addition to density and slump, the compressive strength of concrete is also an important property. Through the study of concrete with specific water-cement ratio, it is found that the change trend of compressive strength of concrete with different age days is calculated under the condition of different content of renewable materials.

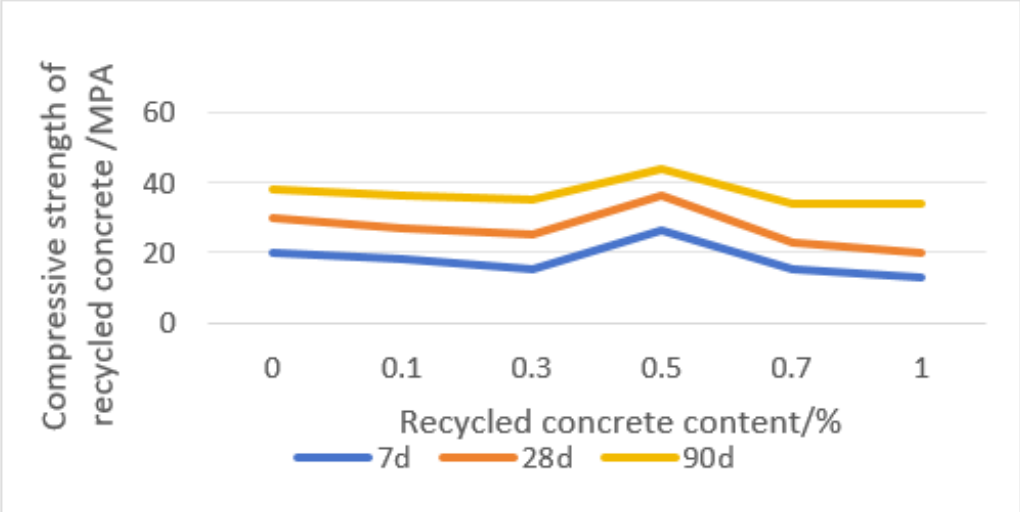


Fig 1. Relationship between compressive strength and renewable material content of concrete at different ages when water-cement ratio is 0.43 [6].

According to Table 1, under the condition of the same kind of concrete, the more renewable materials are added, the lower the apparent density will be. In addition, when the water-cement ratio is 0.43, it can be seen from Fig. 1 that the overall compressive strength will decrease with the increase of renewable material content. However, when the proportion of renewable materials was 50%, the compressive strength increased significantly. The reason for this phenomenon may be that the gradation of natural coarse aggregate and regeneration is better at this time [6]. The reason for the decrease in compressive strength on the overall trend is that the strength of the renewable material itself is low, and due to the service life is too long, its ability to combine with other materials will also decline. This is also the reason why the density of renewable materials decreases as the more

renewable materials are mixed in, the rough surface of the renewable materials may be generated by the machine crushing treatment, resulting in some cracks in the interior of some concrete. These are also the reasons for the low strength and low density of renewable concrete, and such characteristics will also bring the problem of high water absorption. High water absorption will inevitably lead to increased dry shrinkage of concrete after water loss, which will lead to deformation of concrete after pouring, especially when the replacement rate of recycled aggregate exceeds 40%, the water absorption of renewable concrete will increase with the increase of renewable aggregate [7]. Such problems need to be addressed.

To sum up, when the proportion of renewable materials is 50%, renewable concrete has the best compressive strength, but the water absorption and shear resistance of renewable concrete are compared with ordinary concrete, which needs to add some other materials on the basis of the addition of renewable materials to achieve the performance of renewable concrete. For example, adding coal ash and high efficiency water reducing agents to regulate the excessive water absorption of renewable concrete [5]. The utilization of renewable concrete can reduce the waste of resources to a considerable extent and improve economic benefits. And it can also effectively protect the environment, because the waste materials are used again, garbage and pollutants can be reduced a lot. After a basic understanding of the impact of the ratio of renewable concrete on its basic performance, the appropriate ratio can be selected and applied to the actual construction, so as to reduce the consumption of concrete raw materials, avoid a large waste of resources, and appropriate amount of special materials should be added to improve the strength and other properties of concrete, so as to avoid safety problems during use.

3. Research on Carbon Emission of Renewable Concrete

3.1. Carbon Emission Advantages of Renewable Concrete

3.1.1. Introduction to carbon emission of traditional concrete

The carbon emission calculation of concrete is carried out according to certain calculation standards and data boundaries. For concrete, the sources of carbon emissions are mainly divided into four parts, namely, the production stage, the transportation stage, the operation stage and the demolition stage. Each stage will have a different carbon footprint. In Table 2, the main sources of carbon emission and the carbon emission mode of each stage of concrete transportation and pouring are introduced. Almost all steps in the full life cycle led to carbon emissions from concrete, and how to reduce carbon emissions requires different approaches at different stages. For building materials such as concrete, a large amount of carbon emissions are usually generated in the production stage of the material, so this stage is also the stage with the greatest potential to reduce carbon emissions.

Table 2. Analysis of main sources of carbon emission in concrete production [8].

Concrete production stage	Major source of carbon emissions
Raw materials contain carbon emissions	Cementing materials, sand, admixtures and other concrete components contain carbon emissions
Carbon emissions from transportation of raw materials	Carbon emissions from cementing materials, sand, admixtures and other materials transported to mixing stations
Carbon emissions from concrete production	Carbon emissions from energy consumption in concrete production systems
Carbon emission from concrete transportation and pouring	Carbon emission caused by fuel combustion during concrete transportation and pouring

3.1.2. Carbon emission advantages of renewable concrete

For renewable concrete, it uses waste concrete and other materials generated from industrial waste, and realizes recycling of the material itself, saving resources and reducing the overall carbon emission. In addition, renewable concrete also has different advantages in different stages of carbon emission.

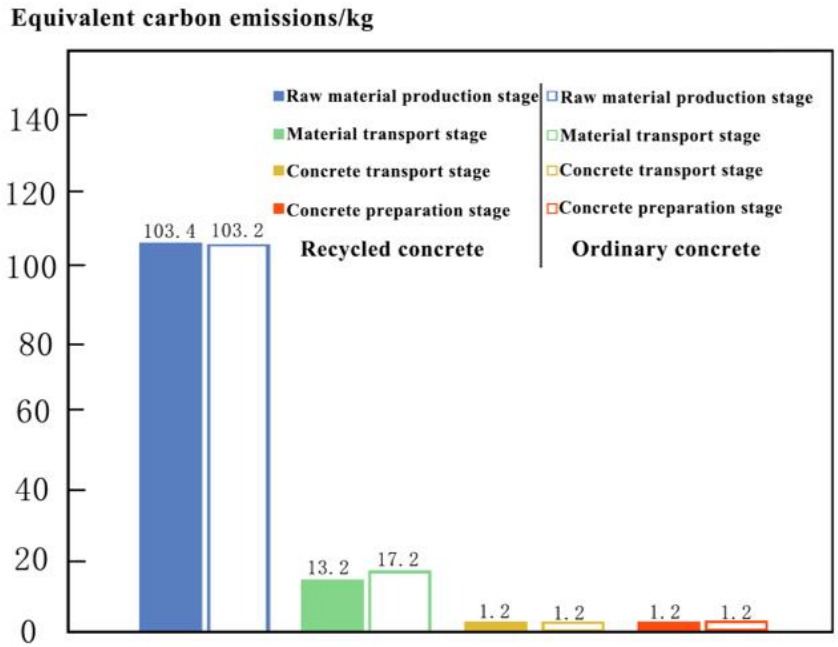


Fig 2. Carbon emissions of 40% renewable concrete compared with ordinary concrete [9].

As can be seen from Fig. 2, the carbon emission of renewable concrete as a whole is lower than that of ordinary concrete, and there is an obvious gap in the transportation stage. The main reason for this phenomenon is that waste concrete and other renewable materials are mainly from existing demolished buildings, and most urban areas have demolished buildings. The result is that wherever there is a demand for concrete, there is enough renewable material available locally, without the need to generate excessive carbon emissions during the transportation of concrete aggregates. However, more carbon emissions are generated in the concrete production process, which is limited by the strength problem in the actual situation. As mentioned above, the strength of renewable concrete is generally lower than that of ordinary concrete, it is generally chosen to add some other materials to the renewable material to achieve the strength standard. According to Table 3, if only renewable materials are used and the content of other materials is controlled, the carbon emission of renewable concrete will be more significantly reduced.

Table 3. Carbon emission content of concrete with different renewable material content [10].

Recycled material content /%	Production stage carbon emissions /kg	total carbon emission /kg
30	263.7	323.1
50	261.2	320.5
70	258.5	317.9
100	253.4	312.8
0	270.5	330

In addition to reducing the corresponding carbon emissions during the production stage, according to research, renewable materials are also better at carbon sequestration and carbon dioxide absorption than traditional concrete. This is because the surface of the renewable material will become rough after being crushed and reconstituted, and a gap will be formed in the middle of the concrete after reconstituting the concrete, which helps the renewable concrete to absorb carbon dioxide. A certain amount of carbon emissions can be reduced, and the proportion of absorbed carbon emissions is about 2.8% to 3.6% of the total carbon emissions [10].

3.2. Influence and Calculation of Performance of Renewable Concrete

3.2.1. Influencing factors of performance and carbon emission of renewable concrete

For renewable concrete, there are many factors that affect its carbon emission content and its performance. Among them, the most important thing is the selection and proportion of renewable

materials. For the performance of renewable concrete, especially the compressive strength, 50% of renewable materials is the most appropriate choice, but the carbon emission of concrete at this time is not the lowest value. With the addition of renewable materials, the carbon emission of concrete will gradually decrease. However, due to the reduction of strength, some materials such as cement will be added to achieve structural stability and strengthen the compressive ability. Although the use of cement will lead to an increase in carbon emissions in the production process to a certain extent, it's recycling of waste materials and energy saving in the transportation process can effectively reduce carbon emissions. In addition, the choice of suitable renewable materials is also the way to improve the performance of concrete, in addition to conventional waste concrete and sand and stone water, there are still quite a few renewable materials to choose from. According to the alternative renewable materials chart, it can be seen that there are many renewable materials to choose from. Taking renewable glass as an example, some renewable glass can be added in the process of making concrete to improve its performance and strength. Other materials can also provide different performance optimization for concrete, and it is possible to compound different waste materials to form new renewable walls, so as to improve performance and reduce carbon emission [11].

Another important factor affecting the carbon emissions of renewable concrete is the transportation process, different concrete materials have different carbon emission factors, which means that even if the same distance will produce different carbon emissions. Although recycled aggregate can be sourced locally, its utilization still needs processing, and renewable material processing plants should be established as close as possible. And for materials with high carbon emission factor, recyclable materials should also be used as far as possible to reduce carbon emissions during transportation.

3.2.2. Summary of calculation methods

There are many ways to calculate the carbon emissions of renewable concrete, but basically they can be summarized in the sum of the production process, transportation process and use process and then remove the carbon emissions absorbed by concrete. According to the calculation boundary definition of CO_2 emission in the whole life cycle of recycled concrete, the calculation formula of CO2 emission in the whole life cycle of recycled concrete is determined, as shown in equation (1).

$$C=C1a+C1b+C2+C3+C4+C5-C6 \quad (1)$$

In this formula, C is the overall carbon emission in the whole life cycle, and C1 is the carbon emission in the production process of raw materials, but the carbon emission in this process is divided into two stages, namely, the production process and the transportation process of raw materials. For C2, it is mainly aimed at the carbon emissions generated during the production of renewable concrete. C3 is the carbon emission during the construction phase. C4 is the mixing and preliminary treatment stage. C5 is the carbon emissions consumed during the final demolition phase, which is usually similar to the carbon emissions consumed during the construction phase, while C6 is the carbon dioxide absorbed by the concrete. Through the above formula, effective and targeted treatment of carbon emissions in different processes can be achieved [12].

4. Conclusion

This paper mainly studies the concrete made of industrial waste concrete and draws the following conclusions:

(1) The performance of renewable concrete under different material content and ratio is discussed. The compressive strength of renewable concrete decreases with the increase of renewable material content, but increases with the content of 50%. The overall water absorption also increased with the increase of the content.

(2) In the process of changing the content of renewable materials, the carbon emission of renewable concrete as a whole decreases with the increase of the content of renewable materials. In the production stage, some concrete will be affected by the strength and the addition of cement will lead to the increase of carbon emissions. However, in the transportation process, because the

demolition site is often close to the demand site, the carbon emissions of transportation will be reduced compared with traditional concrete.

(3) This study is not fully aware of the reasons for the increase in compressive strength of 50% renewable concrete. In the future, it is hoped that a deeper study will be conducted on the concrete with this content ratio and the most appropriate ratio will be found to manufacture low-carbon concrete with excellent performance.

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