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Analysis of Environmental Protection Measures for Concrete Blocks

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Abstract. Concrete blocks have a huge application market in China, but the traditional concrete blocks have big environmental problems. In this paper, the problem is solved from two perspectives: raw material replacement and improvement of construction process. Firstly, from the perspective of raw material replacement, plastic fiber, recycled aggregate, ceramic polishing waste and wheat straw are used to replace the raw materials for concrete block production. All four materials are recycled, thus reducing the need for new raw material extraction. The use of these replacement materials saves energy and reduces emissions while maintaining material performance. Then from the perspective of improving the construction process, this paper provides construction environmental measures in the construction of aerated concrete blocks, concrete hollow core blocks, and expanded polystyrene (EPS) blocks, which ultimately allows these final construction results to meet the performance of thermal insulation while reducing carbon emissions. The results of the study show that the environmental impact of concrete blocks can be significantly reduced from these two perspectives. Research on the environmental dimension of concrete blocks is beneficial to the sustainable development of the construction industry.

Keywords: Concrete block; Production; Construction; Energy saving; Environmental protection.

1. Introduction

With the goal of "carbon peak and carbon neutral", energy saving and emission reduction have been emphasized by more and more industries. According to a survey, the carbon emissions from the whole process of construction in China account for about 50% of the national carbon emissions. Therefore, the reduction of carbon emissions in the construction industry plays a key role in the realization of the "double carbon" goal. The promotion and utilization of new wall materials is one of the most important methods for energy saving and carbon reduction in construction [1]. In the production process, the massive construction of houses consumes a huge amount of natural resources and emits a large amount of construction pollution, which leads to serious environmental problems [2]. During the construction process, house construction is highly prone to produce waste and noise exhaust, which has a great adverse effect on the surrounding environment and violates the goal of sustainability [3]. Studies have shown that the construction waste generated from building construction sites in China amounts to more than 100 million tons per year, The demolition of old buildings generates more than 500 million tons of construction waste per year, and construction waste has accounted for 30% to 40% of the total amount of urban waste. The vast majority of these construction wastes are directly transported to the suburbs and villages by construction units without any treatment, and are disposed of in open piles or landfills. In addition, some problems such as scattering, dust and dust and sand flying generated during the transportation and stacking of construction wastes can cause serious environmental pollution and put increasing pressure on the environment. In such a scenario, the treatment of civil engineering construction waste is particularly important [4]. In order to realize the goal of sustainable development and to reduce the impact of construction materials on the environment, the use and continuous research and development of energy-saving and environmentally friendly construction materials are particularly important [5].

This paper summarizes environmental protection measures in the replacement of raw materials, the improvement of the construction process and the disposal of production waste, with the aim of minimizing the impact of construction materials on the environment in order to achieve the goal of sustainable development.

2. Replacement of Raw Materials

The environmental performance of concrete blocks can be improved by replacing the raw materials used in the production of concrete blocks during the production process.

2.1. Use of Plastic Fibers

The emergence of plastics has brought great convenience to people's lives and serious environmental pollution at the same time. The global production of plastics has been increasing with the development of society, and a large amount of plastics exist in the environment in an untreated state, posing a serious threat to the lives of wild land animals and marine life. Polyethylene terephthalate (PET) is a common, traditional plastic that is not easily biodegradable, and takes about 450 years to decompose naturally in a landfill. It takes about 450 years to decompose naturally in a landfill. PET along with highdensity polyethylene (HDPE), low-density polyethylene (LDPE), polypropylene (PP), polyvinyl chloride (PVC), can be used in a variety of applications. Polystyrene (PS) / EPS are the main types of plastic pollution. Plastics can enter various ecosystems in a variety of ways, both directly and indirectly, and therefore anthropogenic activities are the most significant cause of this type of pollution. When they enter the marine environment, these plastic pollutants can accumulate on the seabed and eventually cause great harm to marine life. Therefore people need to consider recycling of plastics. Today the market for recycled plastics applications is also growing. However, due to technical and market considerations, recycled plastics are not more commonly used than virgin plastics. Moreover, not all plastics are recyclable. The four plastics that are commonly recycled are HDPE, LDPE, PP, PS/EPS and PVC.

Nonautoclaved plastic fber-reinforced aerated concrete (NAPFRAC) using plastic fibers performs better in vertical and horizontal loads compared to conventional blocks and hence can be used in high-rise buildings. Moreover, the plastic fibers are beneficial in enhancing the crack resistance of the wall panels. From the analysis of energy demand for production and inherent carbon emission, the carbon emission of NAPFRAC is significantly lower than that of conventional blocks. From the whole process of production to use, NAPFRAC emits less carbon dioxide, with 28.1% lower energy consumption and 18.95% lower implied carbon emissions. Therefore, NAPFRAC with plastic fibers has great potential to become a sustainable building material. It reduces both plastic pollution and carbon emissions, which is more conducive to sustainable development [6].

2.2. Use of Recycled Aggregates

Sintered clay bricks are the most used traditional masonry material. The use of this material causes a lot of pollution and damage to agricultural land and resources, leading to many environmental problems [7]. The progress of urbanization has brought about a large amount of consumption of natural resources, energy, etc., resulting in the emission of many construction wastes, which cause serious damage to the environment. However, some of the construction waste itself can be re-invested into building houses as a recyclable resource. For example, construction waste can be used as recycled aggregate, which can partially replace natural aggregate in the production of concrete. In this way, it can not only reduce the exploitation of natural sand and gravel resources, but also solve the problem of utilization of waste concrete, which is of great benefit to both resources and environmental improvement. Moreover, recycled concrete is in line with the ideas and concepts of developing a circular economy and building a resource-saving and environmentally friendly society, and is one of the important measures to develop green concrete and realize the sustainable development of construction, resources and the environment.

In the selected ratio, the recycled coarse aggregate replacement rate of recycled concrete hollow core blocks was 75%. Recycled concrete hollow core blocks are made from local waste concrete, and the compressive strength is reduced from 9.3 MPa to 8.6 MPa compared to ordinary concrete hollow core blocks, and the environmental impacts of the four types of recycled concrete hollow core blocks are less than that of ordinary concrete hollow core blocks as can be seen from Table 1. The Global Warming Potential (GWP) value of recycled concrete hollow block is 5.54% lower than that of ordinary concrete hollow block, and the environmental impacts of recycled concrete hollow block are less than that of ordinary concrete hollow block in the three types of environmental impacts, including Eutrophication Potential (EP) and Photochemical Fog in the Atmosphere Potential (POCP). EP and POCP were reduced by 19.2%~65.1% compared with the normal concrete hollow block respectively. A large part of the reason is that the recycled coarse aggregate is made from local waste concrete, which does not need to be transported over long distances compared with natural coarse aggregate, thus reducing the carbon emission in the transportation process. In Table 1, the GWP value from transportation of recycled coarse aggregates is 147.4% lower than that of natural coarse aggregates, and the GWP value from production of recycled coarse aggregates is 79.2% higher than that of natural coarse aggregates. This is partly due to the current crude manufacturing process of recycled coarse aggregates, in which the crushing and grading of waste concrete consumes a lot of energy (electricity) and generates a lot of dust, which in turn increases environmental emissions. In addition, the manufacturing of cement is the main cause of greenhouse effect GWP, accounting for 92.5% and 87.7% of the GWP emissions of greenhouse gases from recycled and ordinary concrete hollow core blocks, respectively. As can be seen from Table 2, the GWP and POCP of recycled concrete hollow block contribute the most to the overall environmental emissions, accounting for 47.0% and 22.7%, respectively. In addition, the normalized results of the types of environmental impacts of recycled concrete blocks are smaller than those of ordinary concrete blocks, indicating that the use of recycled aggregates to make concrete blocks can effectively reduce the environmental emissions of small blocks and improve the environmental benefits [2].

Table 1. The Results of Raw Material Acquisition and Production Stage Normalization of Concrete Hollow Block [2]

Item	GWP (kgCO_2-eq)		EP (kgPO_4^{3-}-eq)		POCP (kg ethylene-eq)	
	Recycled	Ordinary	Recycled	Ordinary	Recycled	Ordinary
Cement production	2.84×10^{2}	2.84×10^{2}	7.80×10^{-2}	7.80×10^{-2}	9.86×10^{-2}	9.86×10^{-2}
Natural coarse aggregate production	7.60×10^{-1}	3.27	7.01×10^{-4}	3.01×10^{-3}	4.94×10^{-4}	2.12×10^{-3}
Regenerated coarse aggregate production	5.10	0	2.78×10^{-3}	0	2.16×10^{-3}	0
Natural sand production	1.79	1.79	1.47×10^{-3}	1.47×10^{-3}	8.13×10^{-4}	8.13×10^{-4}
Transportation of various raw materials	1.35x10	3.34x10	2.90×10^{-2}	6.94×10^{-2}	5.55×10^{-2}	1.70×10^{-1}
Block production	2.13	2.13	7.30×10^{-3}	7.30×10^{-3}	1.72×10^{-2}	1.72×10^{-2}
Total value	3.07×10^{2}	3.24×10^{2}	1.19×10^{-1}	1.59×10^{-1}	1.75×10^{-1}	2.89×10^{-1}

Table 2. The results of raw material acquisition and production stage normalization of concrete hollow block [2]

Item	GWP100		EP		POCP	
	Recycled	Ordinary	Recycled	Ordinary	Recycled	Ordinary
Cement production	7.35x10^{-12}	7.35x10^{-12}	6.05x10^{-13}	6.05x10^{-13}	2.17x10^{-12}	2.17x10^{-12}
Natural coarse aggregate production	1.97x10^{-14}	8.46x10^{-14}	5.43x10^{-15}	2.33x10^{-14}	1.09x10^{-14}	4.67x10^{-14}
Regenerated coarse aggregate production	1.32x10^{-13}	0	2.16x10^{-14}	0	4.75x10^{-14}	0
Natural sand production	4.65x10^{-14}	4.65x10^{-14}	1.14x10^{-14}	1.14x10^{-14}	1.79x10^{-14}	1.79x10^{-14}
Transportation of various raw materials	3.49x10^{-13}	8.65x10^{-13}	2.25x10-13	5.38x10^{-13}	1.22x10^{-12}	3.74x10^{-12}
Block production	5.52x10^{-14}	5.53x10^{-14}	5.66x10^{-14}	5.66x10^{-14}	3.78x10^{-13}	3.78x10^{-13}
Total value	7.96x10^{-12}	8.41x10^{-12}	9.25x10^{-13}	1.23x10^{-12}	3.84x10^{-12}	6.35x10^{-12}

2.3. Use of Ceramic Polishing Waste

Ceramic factory in the production of polished tiles will produce ceramic polishing waste as a by-product. According to statistics, each production of 1m² polished tiles need to be polished grinding head thrown off the ceramic surface layer of 0.8 ~ 1.2 mm thick, about 2.0 kg of polishing waste, but these wastes but for a long time has not been effectively utilized. These piles of ceramic polishing waste constraints on the ceramic factory industry optimization and upgrading, but also not conducive to environmental protection.

In recent years as the scale of engineering construction continues to rise, natural sand resources are becoming more and more scarce. The current price of commercial sand increases year by year, while the quality of sand appears to fluctuate, and the product often fails to meet the standard of construction sand. In addition, due to the excessive mud content, affecting the stable production of aerated concrete enterprises. Ceramic polishing waste in the SiO_2 content of 65% or more, with good volcanic ash activity, and ceramic polishing waste activity is higher than the fly ash Ba, fine particles, used to replace the sand is very suitable. With the increase of the proportion of ceramic polishing waste in the compound, the compressive strength and dry density of the aerated concrete blocks become larger, and the more stable performance of the B07 grade blocks can be obtained [8].

2.4. Straw Concrete Blocks

Wheat straw concrete block refers to the addition of wheat straw material in the concrete, so that the concrete and this lightweight, heat preservation, low-carbon materials fully integrated to achieve lightweight, heat preservation, environmental protection and other aspects of the requirements of the crop by-products at the same time make full use of it, in line with the standards of green building materials, sustainable development.

Straw concrete with the addition of straw content continues to increase its compressive strength continues to decrease, in the straw to add less than 0.2%, the compressive strength of its straw concrete test block is in line with national requirements of the compressive standard, and according to meet the compressive standard test block of straw accounted for the percentage of thermal insulation made of the test block to measure its thermal conductivity, with the straw content continues to increase the coefficient of thermal conductivity decreases, indicating that its thermal insulation is also the better, so in the project made of straw concrete block not only meets the standard of compressive strength, but also has good thermal insulation properties. With the increasing content of straw, the thermal conductivity gradually decreases, indicating that its thermal insulation is also the better, so in the project made of straw concrete blocks not only comply with the compressive strength standards, but also has good thermal insulation properties. This study also makes full use of wheat straw as a crop by-product, which achieves the purpose of low carbon and environmental protection [9].

3. Improving the Construction Process

3.1. Use of Aerated Concrete Blocks

Aerated concrete block (or steam pressurized concrete) is a kind of concrete block with environmental protection performance, the raw materials are ash, water, silica sand, and cement, gypsum and other materials, not only the air permeability, heat storage performance is better, but also the adaptability, electrical conductivity, crack resistance is good, and the emission of dust and exhaust gas is less. After gas generation, the density of the blocks is only 1/5 of that of ordinary building bricks, so they have excellent properties such as light weight, earthquake resistance, thermal insulation, sound insulation, shrinkage resistance and fire prevention, and are green building materials worth promoting [8].

In the construction of external wall and bathroom, you can choose large aperture, high density, lightweight aggregate aerated concrete blocks, together with the side length of 500mm gypsum blocks of the internal partition wall, to achieve good acoustic insulation effect. Before the construction of the blocks, the position of belt placement and structural columns should be reserved in advance to avoid the secondary structure leakage of slurry and mold expansion. Subsequent walls do not need to be plastered, you can directly use brushed gypsum priming after scraping two putties, the ground part is wrapped with both thermal insulation and fire resistance performance of rock wool, underground are divided into wrapped 50mm extrusion board and paste special polymer mortar [3]. Secondly, the use of insulated composite wall materials in the building will greatly reduce energy waste. The main method is to add appropriate amount of aerated concrete in autoclaved fly ash as the building material of the outer wall of the house. After technical treatment, the wall materials can effectively improve the thermal insulation effect of the structure and achieve the purpose of environmental protection [10].

3.2. Use of Concrete Hollow Blocks

Using concrete small hollow block bricks and PS board outer insulation composite wall, the thickness of outer wall is reduced from 370 mm to 260 mm by the traditional brick structure, 240 mm to 190mm by the inner wall day, the wall is thinned, and the effective use area is increased by 6% to 8%, which is equivalent to the increase of the use area of a room by 6-8 m^2 according to the calculation of 100m building area of each household [5]. As a new type of wall material, the hollow block of porous concrete brick is made of waste porcelain sand, fly ash and cement, which is prepared according to a certain proportion, stirred, injected mold, formed and maintained, and becomes a hollow block, which has the advantages that other wall materials can not be compared.The average volume weight does not exceed 1080 kg/m^3, which is 2/3 of the ordinary shell sand brick. Using it as the wall filling material for the earthquake-proof frame structure can greatly reduce the building's own weight, improve the earthquake resistance, greatly reduce the civil construction investment, greatly improve the labor efficiency of construction workers and reduce the labor intensity. The thermal conductivity of the hollow block of porous concrete brick is 1.81 $W/m^2 \cdot K$, which has good thermal insulation and thermal insulation performance. Due to the above good thermal performance and the diversification of products, there are blocks of different specifications, which not only save labor and materials in construction use, but also have a stable and safe structure. Moreove, the production has the advantages of land saving, energy saving and waste benefit [11].

According to the current requirements for construction operations in China, hollow aerated concrete blocks have replaced the solid bricks that were commonly used before. The main reason why the hollow aerated block has been widely popularized is that it can not only realize the requirements of environmental protection and energy saving, but also it is a renewable building material. Hollow aerated concrete blocks are mainly composed of raw materials for waste concrete, and a little fly ash, slag, cement, etc. These raw materials constitute a solution to the recycling of waste products, but also a reasonable and scientific recycling of resources. Hollow aerated concrete blocks are more lightweight and sturdy, not only convenient for transport operations, more importantly, can be liberated from the labor force at the same time does not affect the speed and quality of construction, but also to facilitate the future renovation of the design of the exterior wall and beautify the color. In addition, hollow aerated concrete blocks are not only lighter and more environmentally friendly and durable than the previous solid bricks, but also further enhance the efficacy of moisture, moth and sound insulation, which is worthy of popularization and application [11].

In response to the different requirements of internal and external masonry walls in terms of thermal and acoustic insulation, the building design should use high-precision hollow core blocks of different sizes and types. The matching ratio and construction dimensions of the hollow block materials used for the exterior and interior walls will also differ. In order to meet the different functional characteristics of the interior and exterior walls, combined with the characteristics of the hollow core block, it is made in a customized hollow core block factory. The factory produces hollow core blocks according to the requirements of the drawings for the interior and exterior walls, allowing the blocks to be formed once and avoiding the need for secondary cutting during construction site operations. This customized approach helps to improve the efficiency and quality of building wall construction, and also meets the thermal and acoustic insulation requirements of different walls. By using] hollow blocks, the stability and strength of the wall can be effectively improved, and noise pollution and waste of resources during the construction process can be reduced [12].

3.3. Use of EPS Blocks

Traditional building materials have gradually failed to meet the requirements of sustainable development with the development of the construction industry in China. By analyzing the technical and economic indicators of waste EPS foam, slag, and waste concrete blocks in full compliance with national requirements, and the cost-benefit analysis of the life cycle of the developed block commuting wall, it was concluded that the developed self-insulation system wall building materials have obvious comprehensive economic benefits [13]. With the increase in the doping of EPS particles, the thermal conductivity gradually decreased from 0.168W/(m-K) to 0.1395W/(m-K) with a relative decrease of 16.96%. The compressive strength changed from 1.22MPa to 1.56MPa.The EPS lightweight wall material prepared by using industrial solid waste in large dosage showed significant improvement in mechanics and durability. This material has the same improvement in thermal insulation, weight and strength. Therefore, this material has good application prospects [14].

One is to use EPS block masonry vertical joint processing technology. The left and right faces of the blocks are designed with concave and convex mortise and tenon, and the left and right connections between blocks and blocks are connected by mortise and tenon bearing insertion, canceling the vertical mortar joints, which can effectively improve the shear bearing capacity of vertical joints of the blocks, and it is more reasonable compared to the conventional mortar joints. At the same time, it can save the bonding material of vertical mortar joints, simplify the construction process, and greatly improve the efficiency of block masonry.

The other is to use EPS block masonry horizontal mortar joints processing technology. The top and bottom surfaces of EPS boards are exposed, and the top surface of EPS boards protrudes upward by 10mm, which makes the horizontal mortar joints of this block can not be treated according to the conventional technology. During the construction of horizontal mortar joints, the masonry mortar was spread only on the concrete skeleton of the blocks, and no mortar was spread on the EPS boards. The top and bottom skin blocks were bonded only to the concrete skeleton by masonry mortar, while the EPS panels were aligned directly to the top and bottom. This makes the horizontal and vertical mortar joints in the wall not a cold bridge in the wall, and the heat preservation and insulation performance of the wall is more excellent [15].

The carbon emissions of the wall using EPS insulation materials are obviously less than those using PU (rigid polyurethane foam board), rock wool two kinds of thermal insulation materials, and the difference between the carbon emissions of PU and rock wool is not significant, when the same thermal insulation materials are used, the construction mode is lower carbon emissions of the research program of the internal insulation of the external wall. the carbon emissions of the EPS insulation materials building materials production stage are less, and the wall with thick thermal insulation materials, the Low heat transfer coefficient, more favorable to carbon emission reduction [16].

4. Conclusion

This paper focuses on the emission reduction measures of concrete blocks in the production process and construction process, and the following conclusions were obtained:

(1) The use of plastic fibers, recycled aggregates, ceramic polishing materials and straw as raw materials for the production of concrete blocks reduces the carbon footprint of the environment, and the fact that these materials are derived from a variety of waste materials from production and use improves the efficiency of resource utilization. In addition, the use of such recycled materials can also reduce the pollution brought by these materials to the environment, reduce the carbon emissions of other processes, and significantly improve the sustainability of the production process.

(2) In the construction process, the use of aerated concrete blocks, concrete hollow core blocks, EPS blocks can also effectively reduce the carbon emissions of concrete. From the point of view of the blocks themselves, the use of these new types of blocks is quite environmentally friendly compared to traditional blocks. And these materials have significant advantages in terms of weight, thermal insulation, heat preservation and other properties. The use of composite walls can improve resource utilization and reduce energy waste.

(3) Currently, the use of environmentally friendly materials to replace the original materials used in the production of concrete blocks is still not on a sufficient scale and is not yet mature enough at the technical level. For example, the production process of recycled coarse aggregate is too rough, resulting in many problems that need to be optimized, such as excessive consumption of electricity and dust pollution. Wheat straw as a very environmentally friendly material its own performance is not superior, although its environmental performance is very conducive to the realization of the goal of sustainable development, but also need some other technology to improve the mechanical properties of wheat straw concrete blocks. In the process of using EPS blocks, the research on the sound insulation performance of EPS blocks is still relatively lacking, and future research in this area will play a certain role in the promotion of EPS blocks.

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