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Research on Green Concrete: A Review

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Abstract: *Green concrete is a new, environmentally friendly material compatible with "sustainable development." It has high strength, durability, plant similarity, and environmental friendliness. It is a concrete manifestation of development policy aimed at creating a conservation-minded society and an environmentally friendly society. With the addition of minerals, recycled aggregates, permeability, and green concrete, it can achieve the sustainable and environmentally friendly use of concrete, with the goal of improving resource use, protecting the environment to achieve sustainable development of resources.*

Keywords*: green concrete; saving resources; improving the environment; environmental protection; sustainable development.*

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I. Introduction

In October 1990, at the international seminar on "Material for Human Life and Behavior and Environmental Relations," the concept of "eco-environmental materials" was put forward by Yamamoto, Japan, and was rapidly popularized all over the world. The concept of green building materials is closely linked with sustainable development strategy [1]. Green building materials with sustainable development characteristics have rapidly become the focus of its research and development. Meyer et al. [2]. Among them, concrete as the most essential building material in the world, its research and development focus has begun to shift from high strength and high performance to energy saving and environmental protection. The concept of green concrete was first proposed by Denmark in 1998 to assist it in fulfilling its commitments under the Kyoto Protocol signed in 1997 (reducing Denmark's carbon emissions to 1.5% in 2012) Pandey et al., [3]. In the same year, academician Zhongwei et al, [4] put forward the concept of "green high-performance concrete," and suggested that attention should be paid to resource and energy conservation and ecological, environmental protection in the process of concrete preparation, which laid a foundation for the development of green concrete in China. Later, Jin et al., [5] and others defined green concrete as concrete produced from alternative or renewable waste to reduce energy consumption, environmental impact, and natural resource consumption. Generally speaking, green concrete is a concept that combines environmental considerations with raw material procurement, mixed design, structural design, and maintenance of concrete structures, and it is an inevitable trend of concrete development in the future.

II. Development and Application of Green Concrete

1.1 Mineral admixture concrete

In the field of concrete, the application of mineral admixtures has been trendy. The main way is to replace part of cement with potentially active admixtures (such as fly ash, ground slag, pozzolanic, etc.) Khan et al[6]. It not only saves some cement, but also reduces the hydration heat of coagulation, improves pore structure and workability, and is beneficial to volume stability and durability. [7]. With the deepening of research, its application field is expanding, and the blending ratio is getting higher and higher.

It is reported that Professor Davis of the University of California has systematically studied the blending of fly ash and successfully applied it to the Obama Project in the United States [8]. The Canadian Department of Energy and Mineral Resources has developed a large amount of fly ash, which is used in cement. The substitution rate is more than 50%, and its durability and mechanical properties can meet the application requirements [9].

[10]Mukherjee et al. used about 40% to 70% of fly ash replacements of ordinary Portland cement (OPC) and superplasticizer 1% to obtain concrete with excellent working performance, 3 D strength higher than 20 MPa and 28 d strength higher than 50 MPa. Therefore, the addition of mineral admixtures not only saves cement resources but also reduces environmental pollution, which is a very significant achievement in the green process of concrete.

1.2 Recycled Aggregate Concrete

Recycled aggregate concrete is made of waste, after crushing, screening, and cleaning. It is one of the essential ways of recycling waste concrete and one of its essential development directions. It has been applied in many projects. Compared with natural aggregate, recycled aggregate has many problems:

More edges and corners, a more significant proportion of needles, cement wrapping on its surface, and high-water absorption, large void ratio, broad crushing index, and low apparent density, which lead to low strength, poor durability and limited application scope of concrete.

At present, Most of the recycled aggregate concrete is only used for non-structural concrete such as subgrade and backfill [11]. In recent years, in order to make up for the shortcomings of low strength and poor durability, the scholars have broken through the bottleneck of its application and introduced steel fiber to prepare steel fiber recycled concrete. The high tensile strength of steel fibers is used to compensate for the defects of low strength and multiple cracks, so as to improve the tensile strength and flexural strength of steel fibers [12], to prevent the propagation of cracks and reduce the width of cracks, thereby improving their toughness [13], and at the same time improving their durability [14].

1.3 Pervious Concrete

Pervious concrete is a kind of concrete with honeycomb structure formed by cement slurry coated coarse aggregate and bonded with each other. It is an environment-friendly building material. Because of its porous, light, and permeable characteristics, it has made significant contributions to the construction of "sponge city," sound absorption and noise reduction, and the mitigation of "heat island effect"[15].

However, its strength is due to bone. The porous structure of the frame is lower than that of ordinary concrete. The results [16] show that: the main limiting factors for the application of pervious concrete are the choice of gravel and pebble, the choice of particle size, gradation, porosity, and water-cement ratio, etc. Researchers usually study their performance from these perspectives. Ghafoori et al., [17] studied its mechanical properties, water permeability, and paving methods; Lo et al., and others [18] used X-ray system to study the effect of light aggregate on its performance improvement, and observed its Micro-changes by SEM; but in order to meet the requirements of water permeability (permeability coefficient is more than 0.5 mm/s), the internal void age is significant, and its mechanical properties are difficult to improve. Compressive strength is generally lower than 30 MPa, which severely restricts its application range [19, 20].

1.4 Green Concrete

Green concrete refers to concrete using waste as at least one component, or its production process will not lead to environmental damage. It should also have high performance and life cycle sustainability. Green concrete is environmentally friendly concrete. Green concrete improves three pillars of sustainability: environmental, economic, and social impacts. The critical factors in determining whether concrete is green are the quantity, manufacturing process, method, performance, and life cycle sustainability of Portland cement substitutes. Green concrete is cheap because it is made of waste materials, which reduces energy consumption and improves the strength and durability of concrete. Green concrete was first developed by Dr. W. G. in 1998, Tiwari et al., [21]. The preparation of green concrete includes mechanical properties, fire resistance, durability, strength, thermodynamic properties, environmental properties, and other aspects. Green concrete should follow any two processes of reduction, reuse, and recycling technology or concrete technology. The three main objectives behind the green concept of concrete are to reduce greenhouse gas emissions (carbon dioxide emissions from the cement industry); to reduce the use of natural resources such as limestone, shale, clay, natural river sand, and natural rocks for humus development. A human being who does not feedback to the earth; and the use of waste in concrete causes air, land, and water pollution. This goal behind green concrete will achieve sustainable development without destroying natural resources [22].

III. Performance of Green concrete

2.1 Mechanical Properties

Strength is the main index of mechanical properties of green concrete and is greatly affected by the type and strength of cementitious materials. Vilane et el [23], studies show that aggregate gradation, strength, and particle size have a more significant impact on its strength, and it was concluded that workability (slump) of concrete is proportional to aggregate size. The average compressive strength of concrete increases with the increase of aggregate size. Ismeik et el. [24]studies show that mineral admixtures can adjust the performance of green concrete. And improve its mechanical properties, and the effect of silica fume, slag or slag combined with fly ash is better; Aliabdo et el, and other [25] studies show that lime can improve the compressive strength of fly ash concrete; [26]Wang et el, review shows that adding limestone powder to green concrete can achieve micro-aggregate effect, improve and ease of setting. The strength and impermeability can be improved under a specific time.

Aoki et al., [27]studies show that the porosity and strength of concrete are more affected by the number of cementitious materials used, and the amount of cementitious materials used is proportional to its compressive strength and inversely proportional to its porosity. [28]Mahalingam et al. studied two kinds of aggregate gradations with different aggregate to cement ratios. The permeability coefficient and porosity are proportional to the size of aggregate. The strength is inversely proportional to the particle size of aggregate. Liu et al. [29] studied the porosity, compressive strength, and the aggregate size of green concrete by orthogonal test. The results showed that (a) compressive strength reduces approximately 24% when the aggregate size is the same as designed porosity from 15% to 25%; (b) when the preferred porosity is the same, compressive strength reduces approximately 15% when the aggregate size changes from 4.75 mm to 16 mm. [19] Also drew a similar conclusion through experiments: there was an inversely linear relationship between the porosity and compressive strength. Sumanasooriyaet el. [30]studied the effect of aggregate size on its properties based on porosity and performance requirements. The results show that both porosity and pore size are proportional to aggregate size.

In addition, besides the influence of material itself, mixing method and curing conditions also have an impact on the mechanical properties of [31] Research from Elhakamet al, shows a two-stage mixing method, i.e., mix total water, cement, additives, and recycled aggregate firstly, then add natural sand and natural coarse aggregates, they found out that the two-stage mixing method can enhance the performance of recycled aggregate concrete by strengthening recycled aggregate particles and their reflective bonding on concrete. The improvement is more pronounced of compressive and tensile strength. Curing conditions, by immersing recycled aggregate in water for 30 days, the mechanical properties of recycled aggregate concrete are improved, especially in the case of low cement content.

2.2 Durability

The durability of concrete refers to the ability to ensure its performance, appearance integrity, and structural safety in the course of application. Its leading indicators are anti-freezing, anti-seepage, and anti-erosion performance. Ndahirwa et al., [32] Considered that the main factors affecting the durability of concrete were internal factors (such as chloride ion internal erosion) and external factors (such as concrete external carbonization). They also pointed out that macro-test, durability analysis, and multi-scale durability should be carried out simultaneously if the durability damage and evolution law of concrete were to be fully understood.

Moriconi et al., [33] Uses recycled aggregates about 15 mm in size, containing up to 30% of masonry and debris, to make structural concrete as a complete substitute for fine and coarse natural aggregates. This study concludes that the compressive strength of concrete can be improved by adding fly ash as a substitute for fine aggregate to the mixture. The durability-related aspects of recycled aggregate concrete indicate that fly ash is added to improve pore structure and reduce large pore volume. There is no difference in the resistance of concrete to freeze-thaw cycles. Also, due to the filling effect and the pozzolanic activity of fly ash, the addition of fly ash reduces the depth of carbonation and chloride ion penetration in concrete because the pore size of the cement matrix is excellent. Yang et al. [34] studies show that the frost resistance of green concrete is inversely proportional to the number of freeze-thaw cycles.

Qiuyi et al., [35] Studied the strength and anti-sulfate corrosion performance of macroporous eco-concrete. The results showed that the use amount of cementitious materials, porosity and water-binder ratio would affect the performance, and the performance was proportional to the use amount of cementitious materials; when the porosity was fixed, it was inversely proportional to the water-binder ratio; and when the use amount of cementitious materials was fixed, it was inversely proportional to the porosity.[36] Studied The strength degradation of concrete under the dry-wet cycle action of sulfate solution. The results show that the strength of concrete shows a significant rise and fall area after sulfate corrosion. The concrete strength reached its peak on the 60th day of corrosion and increased by ~6.4% based on the initial strength. However, as the degradation period increases, the strength of the concrete continues to decrease. After 90, 120, and 150 days of corrosion, the compressive strength decreased by about 4.4%, 18%, and 43.1%, respectively.

2.3 Plant Performance

Porosity, average pore size, and pH value of the water environment in the pore play a decisive role in the growth performance of green concrete, and the pore structure characteristics of green concrete are greatly affected by the coarse aggregate size and water-cement ratio. Malhotra et al. [37] studied the effect of plant growth on green concrete. The results showed that grassroots expanded from soil to surrounding after penetrating its pore, and did not cause expansion damage, and had excellent penetration stability. Many studies have shown that there is a specific relationship between the strength and porosity of concrete. When the porosity decreases, the compressive and flexural strength of concrete increases. Linear curvature is suitable for describing this relationship. Considering that porous eco-concrete needs enough porosity to plant plants and qualified structural application strength, it is proved that aggregate size from 20 mm to 30 mm can meet these two requirements [38]. [39]XIE et al., Found A non-linear curvature to describe the relationship between strength and porosity. He thinks the logarithmic function is better than a linear function (Fig. 1).

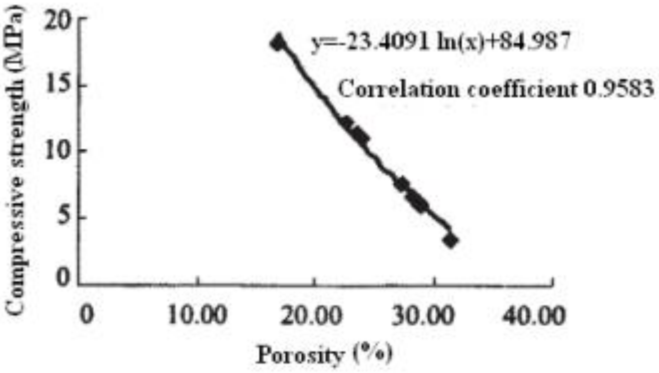

Fig1: Relationship between compressive strength and porosity

The strength and porosity of concrete are always promoted in the opposite direction. In many types of research, people use advanced cement or special admixtures to achieve high strength and high porosity. All of these increase the cost of porous concrete and are not conducive to its comprehensive application. Low cost and effective methods are needed in its engineering application.

IV. Environmental Protection Concrete

Concrete materials have brought about different degrees of negative impact on the environment, such as a large number of heat and harmful gases produced in the preparation of cement, which have a prominent impact on climate and weather, including the impact of climate warming and acid rain on the environment, including the increasingly severe noise pollution, and environmental protection departments. Most of the complaints about noise coming from construction noise. Consequently, the definition of environmentally friendly concrete comes into being. Its purpose is to reduce the pollution of the earth's environment and promote the harmonious coexistence with the natural ecosystem, to construct a more comfortable living environment for human beings. Therefore, as a building material with enormous demand, the "green" and "environmental protection" of concrete should not only ensure its functional requirements but also consider environmental factors to achieve the ecological balance of resources and energy. [40].

V. Conclusion

With the rapid development of the World's construction industry, World's infrastructure construction projects still rely on the use of a large number of concretes. Green concrete is of great significance. At the same time, it is more necessary to develop and use concrete with scientific engineering theory to improve the general performance and service life of concrete, and then promote the rapid and sustainable development of green concrete and green buildings. After recent years ‘development, green concrete has been widely applied in practical projects with various purposes.

1) Therefore, the addition of mineral admixtures not only saves cement resources but also reduces the Environmental pollution and hydration heat of coagulation, improves pore structure and workability, and is beneficial to volume stability and durability, which is a very significant achievement in the green process of concrete.
2) Pervious concrete is an environment-friendly building material. Because of its porous, light and permeable characteristics, it has made great contributions to the construction of "sponge city," sound absorption and noise reduction, and the mitigation of "heat island effect".
3) Strength is the main index of mechanical properties of green concrete and is greatly affected by the type and strength of cementitious materials. In addition, besides the influence of material itself, mixing method and curing conditions also have an impact on the mechanical properties of green concrete.
4) The durability of concrete refers to the ability to ensure its performance, appearance integrity, and structural safety in the course of application. Its leading indicators are anti-freezing, anti-seepage, and anti-erosion performance.
5) Porosity, average pore size and pH value of water environment in the pore play a decisive role in the growth performance of green concrete, and the pore structure characteristics of green concrete are greatly affected by the coarse aggregate size and water-cement ratio.

6) In a word, as one of the most important directions for the future development of building material concrete, the development of green concrete is the only way for the whole industry to achieve clean production and circular development, and also the only way to achieve energy, resource conservation and environmental protection.

Only by saving energy and resources, reducing building pollution and recycling production waste in the whole cycle of concrete, can concrete develop in the right direction and be the only way to a new green and environmental society in the future.

However, there are still many problems in its performance improvement, supporting technology development and application promotion, which need the joint efforts of workers. At the same time, the immaturity of new technology will inevitably increase the price of concrete, and the higher research and development cost will make many enterprises hesitate to green concrete. So how to improve the economy of green concrete while paying attention to "green" will become another new problem in the development of green concrete.

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