The Characteristics and Applications of Sustainable Green Concrete

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Abstract. Green concrete is an advanced civil engineering material to optimize people's living environment. The study introduces the basic concept of green concrete, analyzes the characteristics and advantages of green concrete, including vegetation greening concrete, waste recycling concrete, and self-compacting concrete, and discusses the application of these green concrete in practical engineering. Results show that vegetation green concrete is a new type of concrete that combines plants and concrete, which can be used in urban greening and highway vegetation concrete slope protection. Waste recycling and environmental protection concrete is a kind of green concrete that can reduce environmental pollution without affecting the performance of concrete by using existing waste materials as raw materials. It can be used to produce autoclaved aerated concrete blocks and modified rubber or recycled aggregate concrete through special processing. Self-compacting concrete becomes dense from its gravity, which reduces the energy required for mechanical vibration. Because of its high strength, steel can be used to produce high-strength self-compacting concrete-filled steel tubular columns or anchor bolts.

Keywords*:* Green Concrete; Sustainable Development; Waste Recycle; Practical Application.

1. Introduction

Infrastructure construction plays a very important role in people's life, work and production. Developing countries need to carry out various engineering construction, while developed countries still have a large number of infrastructures to be rebuilt. However, concrete cement is an important component in the production process, but it is not an environment-friendly material. The total emission of CO2 from the world's cement industry is about 1.6 billion tons, accounting for about 7% of the global greenhouse gas emissions. In addition, a large number of raw materials, such as limestone and clay, fuel coal, could be mined, resulting in large-scale deforestation and soil loss. The annual consumption of sand and gravel for the production of concrete in the world is 10-11 billion tons, which negatively impacts forest areas and river bed ecology. About 1 trillion liters of water is used to mix concrete every year, and a large amount of water is also needed to clean sand, stone and maintain concrete. In addition, a large amount of solid waste is formed from the engineering construction process and brings great pressure on nature. The release and diffusion of construction noise and toxic substances may also cause some problems. Therefore, the concrete industry is facing challenges to the environment.

As the concept of sustainable development has gradually taken root in the hearts of the people, the development of green concrete materials has gradually attracted people's attention. These building materials based on environmental performance, in addition to traditional landscape design, also include reducing CO2 emissions, saving natural resources, reducing energy consumption, reducing waste, and environmental safety. These limits corresponding to the environmental performance requirements should be formulated. As an important part of energy consumption and environmental impact, the concrete industry produces concrete by using recycled auxiliary cementitious materials and chemical admixtures to achieve the development of green concrete and green buildings.

At present, the research on green concrete mostly focuses on improving the composition of a single material or restricting the service conditions of a certain concrete through experiments in different environments, so as to relatively reduce the loss of materials other than normal use. Based on the concept of green concrete, this study summarizes and analyzes the characteristics and advantages of various green concrete materials, and compares the suitable use conditions of different green concrete materials. In addition, this study also investigates the current application of some kinds of green concrete and proves the feasibility of these kinds of green concrete in practical engineering.

2. Concept of Green Concrete

Different experts have different ways to define green concrete. Since the World Conference on environment and development held in Rio de Janeiro in 1992, the green cause has been paid more attention worldwide, and the concept of green concrete has been refined with the improvement of understanding. Wu proposed that the main meaning of green concrete includes: (1) saving resources and energy; (2) being more conducive to the environment; (3) being sustainable. However, Burgass and Gibbings argued that due to the limitations of existing data and experiments, the limited expected number of available indicators, and the lack of consensus on the boundaries of sustainable concrete in the industry, the comprehensiveness of the concept of green concrete is still difficult to establish. Furthermore, Margo believes that green concrete has become a new type of concrete using environmental protection materials or concrete products using the environmental protection design concept.

It indicates that there is no unified definition of the concept of green concrete up till now. However, in general, the strength and durability of green concrete is better than those of traditional concrete. Green concrete can also recycle non-renewable resources and reduce the emission of harmful substances, reducing environmental hazards and achieving the sustainable development of natural ecosystems.

3. Characteristics and advantages of green concrete

3.1 Vegetation Greening Concrete

Vegetation greening concrete is a kind of concrete with a special mix proportion to form a space where plant roots can grow and uses chemical and plant growth technology to create conditions for plant growth. It can protect the environment, improve ecological conditions, and maintain the performance of raw structural materials.

Porous continuous greening concrete is a kind of vegetation greening concrete, which takes concrete as the skeleton structure and has a certain number of connecting pores inside, providing space for green plants on the concrete surface to grow and absorb nutrients. Porous concrete is used as the matrix for plant growth, and the pores can be filled with substances required for plant growth. During the preparation of vegetation greening concrete, the construction personnel can select Portland cement and pozzolan cement, and prepare them according to the relevant proportion to form a 1:8 cement slurry. Larger stones are usually selected when selecting aggregates to improve the water permeability of concrete further.

At the same time, the demand for vegetation greening concrete for its strength is relatively low, so it usually meets the demand for water permeability when it is prepared. Because the water-cement ratio is one of the important factors that affect the permeability and strength of concrete, and when its value is 0.3, the effect is the best.

Vegetation greening concrete is mainly used in greening projects in cities and plays a role in soil consolidation. For example, the green separation belt and the surface of pedestrian crossings in various cities. At the same time, during the construction of various construction projects, vegetation greening concrete can be used to improve the greening degree and improve the ecological environment on the premise of meeting the construction requirements.

There has been a lot of research on greening concrete vegetation technology in China and abroad. The most common greening concrete comprises two layers: porous concrete layer and surface spraying layer. Porous concrete is composed of aggregate and cement slurry, which can be applied to relatively stable concrete slope, but not to the unstable slope. The defect of this application condition can be solved by increasing the strength of the covering layer and improving the ability of water conservation and drought resistance. Therefore, it is necessary to study a vegetation concrete slope protection greening technology suitable for highway slopes. Taking Suizheng Expressway in Guizhou Province as an example, due to the soil, climate and vegetation conditions of its slope, the vegetation concrete slope protection greening technology is adopted to evenly mix and spray cement, green soil, concrete greening additives, with planting seeds onto the engineering slope surface. The plants can grow normally on this substrate, which is especially suitable for the greening engineering of low-quality soil and rock slopes. According to the geological characteristics of Guizhou, 85% of the slope after mountain excavation is rock slope, and most of the rock is limestone and mudstone. The unstable slope after excavation is generally treated with an anchor cable frame, but it cannot prevent the slope from continuing to be weathered, and the ecological greening landscape effect is poor; Net shotcrete can effectively prevent the slope from falling, but it has no ecological greening landscape effect, and the cost is high. Therefore, the application of vegetation concrete greening technology in this project can solve the core problems.

3.2 Waste Recycling And Environmental Friendly Concrete

Waste recycling and environmentally friendly concrete (WREFC) is a kind of green concrete with high utilization rate of solid waste, which is formed by using certain technical measures to mix it with other materials after the artificial stone with certain mechanical properties and particle grading is obtained from solid waste through the processes of sorting, crushing and screening. The most significant difference between the composition of this concrete and traditional concrete is that certain technical measures have been taken, using industrial waste liquid as raw material and adding a large amount of solid waste and additives. This practice not only realizes the recycling of various wastes, but also plays a dual role in waste utilization and reducing the environmental pollution.

The technical ways to prepare WREFC mainly include fully digesting industrial waste, treating municipal solid waste, and recycling aggregate concrete.

3.2.1. Fully Digest Industrial Waste

Fully digesting industrial waste refers to a method of using a high ratio of treated industrial waste residue as cement admixture within the allowable range to achieve the purpose of reducing the amount of cement.

Reducing the amount of cement is one of the essential methods of making green concrete from industrial waste. Under the original process conditions, by adding a lot of crushed industrial waste residue treated by certain measures, the performance of concrete can be improved and the reuse of industrial waste residue can be achieved simultaneously. Currently, the proportion of industrial waste slag mixed depends on the design and use requirements of concrete. Generally, the performance of concrete with the amount of 15% - 30% of the weight of cement can be guaranteed. In addition, using industrial wastes such as waste boiler cinder, coal gangue from coal mines, and fly ash from thermal power plants as lightweight aggregate to prepare lightweight concrete not only has the advantages of low density, high relative strength, good heat preservation and frost resistance, but also reduces the production cost of concrete, alters waste for use, reduces pollution in cities or factory areas, reduces the land occupied by accumulated waste, and is also beneficial to environmental protection . For a long time, all kinds of industrial waste liquid, especially black pulp waste liquid, have caused serious pollution to surface runoff and groundwater quality in China. The use of pulp waste liquid to produce concrete water reducer is used to help paper mills treat and recycle the waste liquid and reduce its great harm to the environment, industrial and agricultural production and human health.

Industrial solid waste can be used as raw materials to produce autoclaved aerated concrete blocks after processing. Autoclaved aerated concrete is an excellent new wall material. Autoclaved aerated concrete block is made of siliceous materials, sand and calcareous materials, added with an appropriate amount of regulator and foaming agent, mixed and stirred, poured and foamed, green body static stop, cutting, high temperature and high-pressure steam curing and other processes. Because the product has countless tiny closed, independent and evenly distributed pore structures, it has many functions, such as lightweight, high-strength, durable heat insulation, sound absorption, sound insulation, waterproof, fire prevention, earthquake resistance, fast construction, strong processability and so on. Taking fly ash from coal-fired power plants as an example, its total amount of silicon dioxide and aluminum oxide is high. After high-temperature calcination, they form part of glassy silicon and aluminate substances. Their high activity can bring high compressive strength to autoclaved aerated concrete products. Fly ash autoclaved aerated concrete can be used in industrial and civil buildings and multi-story and high-rise buildings to improve the seismic capacity of buildings. Autoclaved aerated concrete blocks made from industrial solid waste in construction projects are one of the best choices.

3.2.2. Treatment Of Municipal Solid Waste

Municipal solid waste generally refers to solid waste produced in urban life or production. Municipal waste is the most important kind of municipal solid waste. It refers to domestic, commercial, industrial, and urban maintenance and management waste produced in urban life. It is a major topic for the development of green concrete to carry out resource management of municipal solid waste and apply it to concrete manufacturing after processing through certain technical methods.

Its action principle is that the biocatalyst added to solid domestic waste concrete (SWC) accelerates the decay, degradation and dehydration, and finally forms dry matter. The additive is added to the dry matter, which is sterilized and solidified to make a solid material with a certain strength, no toxicity and high density. Due to the presence of plastics, slag and stones in the garbage, it plays a role in mutual traction and reinforcement in the SWC, and is also conducive to the improvement of the compressive and flexural strength of the material. SWC production technology is developed for mixed waste without classification. The process is relatively simple. There is no residual or recycled waste after treatment, so domestic waste can be treated entirely and used as building materials. Wherever solid objects are needed, SWC is the potential application direction, such as wall tiles, roads, ports, dams, and rockeries. Currently, subgrade materials and colored pavement bricks (blocks) have been studied and matured.

Construction waste accounts for about one-third of the total urban waste, and its resource utilization rate is less than 10%. The existing treatment method is landfill after long-distance transportation, which not only requires a lot of freight, but also brings a lot of land pollution. From the existing research at home and abroad, it is an advanced green recycling technology to replace some raw materials with waste rubber in the construction waste to prepare recycled concrete. It uses the recycled aggregate of construction waste and waste rubber to develop a high-performance environmental protection building material suitable for civil engineering - Rubber recycled concrete (RRAC), which not only saves building materials, but also increases the utilization of construction waste and reduces direct waste landfilling, protect the environment. At the same time, the rubber particles or powder formed by recycling waste rubber products can be mixed into the existing concrete in a certain proportion to make rubber concrete, which can improve the fatigue resistance, impact resistance, vibration resistance and noise reduction of concrete. In developing the recycling of construction waste and waste rubber, the expected results are significant in scientific research and high value in engineering applications.

3.2.3. Recycled Aggregate Concrete

Concrete removed from old buildings or structures is broken and graded into coarse and fine aggregates. Recycled aggregate concrete is produced by replacing some sand and gravel in the concrete with the prepared concrete in the production process. Using recycled aggregate to prepare recycled concrete has been regarded as one of the main measures to develop green concrete. Compared with natural aggregate, recycled aggregate's porous structure gives it better water absorption capacity, but this structure also reduces its strength. These characteristics lead to great changes of the recycled aggregate concrete compared with natural aggregate concrete. For example, the loose and porous structure of recycled aggregate causes the reduction of elastic modulus, strength and stiffness of concrete; Strong water absorption increases the shrinkage of concrete after a water loss. However, if the natural aggregate in the concrete is replaced by less than 30% recycled aggregate, at present, recycled aggregate concrete is mainly used for bridge substructures, blocks, road auxiliary foundations, gravity piers, coastal breakwater, foundation cushions, non-structural concrete, simple house concrete foundation.

Recycled aggregate concrete has created a comprehensive use of construction waste. Production and recycling equipment is used to treat old concrete rather than natural materials, reduce damage caused by extracting gravel, reasonably solve problems, and use construction waste to create new concrete blocks. A significant reason for the difference in the production cost of recycled concrete is whether concrete waste is used in equipment and processing technology. As in Europe and Japan, the most economical treatment method is to use mobile equipment for thorough cleaning. After the first treatment, impurities can be removed. After the second grinding treatment, recycled aggregate concrete is used to replace some ordinary concrete, reducing the production cost and improving the all-around performance of concrete products after further processing. Industrial materials and additives, such as fly ash, can be used. Australia, the Netherlands, Germany and the United States have conducted many experiments on this technology and preliminarily obtained a more effective method of applying this kind of concrete to subgrade and pavement.

Applying recycled aggregate in highway construction can reduce waste concrete's harm to the environment and achieve good economic benefits. For example, at present, 10% of concrete aggregate in Hong Kong comes from recycled aggregate obtained from waste concrete processing. According to the data of the Belgian Highway Research Center, the repair or demolition and reconstruction of highway projects can reduce the material cost by about 20%, the waste treatment cost by 10%, and the transportation cost of waste transportation and new materials transportation by 70%, if the waste is treated and utilized on-site. The economic and environmental benefits are considerable. Since the 1980s, cities such as Melbourne and Sydney in Australia have begun to use recycled aggregate concrete. It is estimated that about 400000 tons of old concrete are recycled in Sydney and 350000 tons in Melbourne annually. In 1998, a 6-story office building with a parking lot was built in Darmstadt, Germany. The office building was all built with recycled aggregate concrete. This is the first project in Germany that was built entirely with recycled aggregate concrete and has become a demonstration project.

3.3 Self-Compacting Concrete

Due to its own characteristics, self-compacting concrete can be compacted by its own gravity, eliminating the additional consumption of human and mechanical energy. Because this kind of concrete should have enough cohesion to ensure that it will not be separated during pouring, the amount of powder required is large. If all cement is used, it is easy to cause cracking, so the amount of fly ash, slag or limestone powder is usually high. For example, 150kg of light limestone powder is mixed in the concrete of the anchorage pier of Akashi bridge in Japan.

The advantage of self-compacting concrete is that there is no need for vibrating tools at the construction site; The construction time limit is small; Little impact on workers; The concrete quality is uniform; It is also easy to pour when the reinforcement arrangement is dense, or the component shape is irregular; The construction progress is fast, and less workers are needed on site. Generally speaking, self-compacting concrete has high fluidity. Its application in construction projects can effectively save energy and noise, reduce dust, shorten the construction cycle, and achieve good environmental benefits.

The self-compacting concrete used in the project mainly includes the following four types: (1) In the manufacture requiring high strength, the proportion of self-compacting concrete used in many engineering projects should comply with the requirements. The quality ratio of acid superplasticizer includes 465:65. The measured slump expansion takes 5 minutes to 1 hour, 730-600mm, and the 28-day compressive strength is 95mpa, the dry shrinkage at 60 days is 380, and the dynamic elastic modulus at 28 days is 45 N/mm2. For example, Seattle's double square in the United States belongs to the use of self-compacting concrete, and its performance strength is the highest square. In this project, a 62-story double square concrete-filled steel tubular column is built. The application of ultra-high strength self-compacting concrete can reduce the structural cost by 30%. This project is an outstanding example of the essential structural engineering of self-compacting concrete. (2) Mass self-compacting concrete. A bridge is erected in the Mingshi Strait, with a total length of 3910m and a central offset of 1990m. 240000 cubic meters of self-compacting concrete with a strength of 25MPa have been used for the two anchors of the bridge. Since the application of self-compacting concrete construction technology, the construction period of two anchors has been shortened from 2.5A to 2a, and the construction period has been shortened by 20%. Compared with China, the early hydration rate of self-compacting concrete prepared with CEMIII/A32.5R (300 kg / m3), polyacrylic acid-based superplasticizer, ultra-fine amorphous silica gel of fly ash of 1%-2%, and coarse aggregate with the maximum particle size of no more than 20mm in Europe is small, which can form bulk concrete. (3) For self-compacting steel fiber concrete, adding steel fiber in the construction of self-compacting concrete can reduce the degree of plastic shrinkage. By studying the influence of different types, forms and sizes of steel fiber on the performance of self-compacting concrete and hardened concrete, The technician detected the influence of steel fiber on the performance of hardened concrete by J-ring bending test (better reflect the gap trafficability of self-compacting steel fiber concrete than L-shaped instrument and select appropriate superplasticizer to effectively reduce the influence of steel fiber on the working performance of self-compacting concrete). However, during the experiment, steel fibers do not significantly affect concrete compressive strength and density.

Thus, according to the actual engineering construction conditions, formulate reasonable self-compacting concrete construction measures to optimize the performance of the concrete structure in all aspects, which is conducive to the overall stability of the construction project and the guarantee of construction quality in terms of materials.

4. Conclusion

Concrete is an essential building material widely used in civil engineering. This paper summarizes the definitions, characteristics, and applications of three kinds of green concrete. The advantage of vegetation greening concrete is the combination of engineering and greening, but this kind of concrete has high requirements for soil environment and is not widely used in the engineering field.

By using waste materials as concrete raw materials or additives, waste-friendly concrete greatly reduces the cost of concrete production, meets the requirements of the concept of sustainable development, and gives play to the value of waste materials. However, in actual production, the waste after crushing often needs to be further processed before mixing, which will bring additional energy consumption. Compared with general concrete production, the environmental protection effect is not significant, so the promotion and application of this concrete need to be developed.

The material characteristics of self-compacting concrete make it possible to omit the step of mechanical vibration and rely on its own gravity to compact, so as to reduce the loss of manpower and energy. This kind of concrete improves the surface quality of concrete and increases the freedom of structural design. However, in the relatively cold environment, the durability of hardened self-compacting concrete is low. At the same time, bubbles may exist in self-compacting concrete, which is easy to cause uneven stress and potential dangers.

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