Research on the Application of Marine Aggregate Concrete in Floating City

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Abstract. As population growth leads to a corresponding increase in the number of buildings, many high-rise buildings produce pressure, resulting in the extrusion and subsidence of underground rocks in the city. To create a sustainable life, building floating cities on the sea has become one of the important directions to solving ecological and environmental problems. At the same time, using traditional building materials in the construction process means a large amount of transportation costs, etc. By studying the application of marine aggregate concrete in floating cities and confirming its feasibility, it can reduce construction costs and save local resources. This paper mainly studies the coral aggregate concrete and sea sand concrete which have been put into production. This paper mainly gives the corresponding solution to the problem of the easily corrosive reinforcement existing in the concrete application of seawater sand concrete. This paper suggests using a new corrosion-resistant, high-performance material FRP reinforcement to show the feasibility of seawater Marine aggregate concrete in the construction of floating cities. The research in this paper can provide the theoretical basis for the application of Marine aggregate concrete in subsequent floating city construction projects.

Keywords: Seawater marine aggregate concrete, Floating City, new materials.

1. Introduction

As the global population drives urban development and expansion, high-rise buildings become a way to meet the challenges of urbanization. These building forms enable more efficient use of limited land resources and provide sufficient space to meet the growing population's needs. However, many high-rise buildings produce pressure resulting in the extrusion of the underground rock in the city. At the same time, large-scale industrial production has exacerbated the problem of climate warming, melting icebergs, and rising sea levels. Therefore, to create a sustainable life, floating city construction provides a unique solution. Floating city construction, capable of accommodating tens of thousands of people with features of emerging cities, is a current research hotspot globally. Building a city must be inseparable from the use of building materials, due to the special location of the floating city, using traditional building materials in the construction process will face huge transportation costs. However, sea Marine aggregate concrete using Marine resources, such as seawater, sand, coral, shells, local materials, can, to a certain extent, solve the floating city construction dependence on inland resources, to reduce the construction cost. Compared with fresh water and ordinary aggregate, seawater ocean aggregate contains a large number of salt and other substances that will have a certain impact on the physical and mechanical properties of concrete. In recent years, scholars at home and abroad have studied seawater and ocean aggregate concrete. Li Shicai [1] et al. found that the high content of chloride in Marine aggregate will accelerate the hydration and condensation of cement, leading to early coagulation and early strength improvement. But the growth becomes slow in the later stage, and the final strength is similar to that of freshwater river sand concrete. A small amount of shells in sea sand has little influence on the working properties and mechanical properties of concrete. In addition, the transmission and binding mode of chloride ions in seawater sand concrete is more complex, which is different from the mixed chloride ion, which leads to the corrosion mechanism of steel bars in seawater sand concrete.

This paper summarizes the performance of coral aggregate concrete and seawater marine sand concrete and discusses the solution of seawater marine aggregate concrete. This paper aims to study

the feasibility of the application of Marine aggregate concrete in floating city construction, to provide a theoretical reference for the application of Marine aggregate concrete in floating city construction.

2. Overview of Seawater and Marine Aggregate Concrete

2.1. Concept of Seawater and Marine Aggregate Concrete

Seawater Marine aggregate concrete refers to the use of seawater, Marine aggregate instead of the sand and water in traditional concrete, to save freshwater resources and reduce transportation costs. The Marine aggregate is mainly sea sand and coral aggregate. Sea sand aggregate selects sand from the estuary and the surrounding area. Coral aggregate is the calcium aggregate formed after the death of Marine coral. Its main component is calcium carbonate, which can reduce the impact of building materials on the environment. Because of the differences between the use environment of Marine aggregate and traditional aggregate, some special properties of Marine aggregate may affect the performance of concrete. Therefore, it is particularly important to make the correct configuration after reasonable treatment of Marine aggregate.

In the configuration of seawater Marine aggregate concrete, it must be purified first. And marine aggregates cannot be used alone and need to be used together with artificial or natural sand. In addition, ocean aggregate can not be directly prepared into prestressed concrete. Because the aqueous solution of sea sand contains too high a concentration of chloride ions, and in the concrete, the chloride ion concentration of aggregate should be less than 0.03%, otherwise, it will affect the durability of the concrete structure, so that the corrosion of the steel bar is more serious.

2.2. Working Performance of Seawater and Marine Aggregate Concrete

2.2.1 Working performance of seawater and sea sand aggregate concrete

Table 1. Basic properties of river sand and sea sand

type	modulus of fineness	The apparent density of kg / m^2	stacking density kg/m^2	Chloride content and mass fraction %
river sand	2.66	2610	1510	<0.001
sea sand	2.24	2660	1470	0.57

As can be seen from Table 1, there are large differences in chloride content mass fraction between sea sand and river sand. In the preparation of seawater marine sand aggregate concrete, a lot of chloride NaCl in seawater will work with the cement hydration product Ca (OH) 2 reactions, and generate CaCl2, thus accelerating the cement hydration, accelerating the condensation speed, leading to early coagulation, affect the working performance of concrete. On the other hand, the high content of shells in sea sand will increase the friction of the slurry and reduce the slump of concrete. In general, the influence of seawater sea sand on concrete working performance is mainly reflected in the setting time, fluidity, water retention, and slump.

(1) Time of setting:

The water content in the mixture has a great influence on the hydration process of concrete, thus affecting the initial setting time. Because the Marine aggregate has more water absorption and the water content in the mixture is higher, the seawater mixing can reduce the initial setting time of the concrete by about 30% [2,3]. In the overall setting time, there is little difference between freshwater concrete and seawater marine aggregate concrete. Yang et al. [4] showed that sea sand has little influence on the setting time of concrete.

(2) Fluidity and water retention

Mobility refers to the performance of fresh concrete under the action of dead weight or mechanical vibration, which can produce flow, and evenly fill the template, water retention refers to the performance of fresh concrete has a certain water retention ability, in the construction process, do not occur water phenomenon. Seawater ocean aggregate will reduce the fluidity and water retention of

concrete. Limeira[5] and other research showed that concrete fluidity and water retention decrease with the increase of shell content. Safi et al [6] study showed that the fluidity of mortar decreases with the increase of shell substitution rate. Ningbo et al [7] study found that the fluidity of sea sand mortar is lower than that of river sand and standard sand mortar, mainly because the unique physical properties of sea sand absorbs more water, increases the friction between particles and reduces the fluidity.

(3) Slumps

Slump is a special measurement of concrete and workability method and indicators to measure its degree, to judge whether the construction can be carried out normally. Although the slump of seawater marine aggregate concrete is slightly smaller than that of freshwater concrete, overall, Xing Li [8] and Chen [9] show that the slump of seawater sand concrete increases and decreases respectively with the increase of chlorine salt and shell content. When Younis et al [10] study found that the water glue ratio was the same, Compared with freshwater concrete, the slump of seawater concrete is reduced by 20%. Liu Wei et al. [11] concluded that different sand does not influence the concrete slump with the same water-cement ratio.Yang Ming-Ao [12] research shows that the slump of sea sand concrete is slightly smaller than that of river sand concrete, But its work still meets the engineering needs.

As for the early compressive strength, the research of scholars at home and abroad generally believes that both the incorporation of seawater and sea sand will accelerate the hydration of cement, to improve the early compressive strength of concrete. As for the impact of long-term compressive strength, the research results of domestic and foreign scholars are different.

2.2.2 The working performance of coral aggregate concrete

In addition to the effects of the same high chloride content as sea sand aggregate, the development environment, chemical composition, and mineral composition of coral aggregate cause its porous and brittle properties. Large porosity, light mass, is a natural light aggregate. Furthermore, due to the basic characteristics of coral aggregate, whose concrete density is usually less than ordinary concrete, the following are several studies using coral sand replacing river sand for concrete configuration. Chen Fei et al. [13] used coral sand instead of ordinary river sand to prepare coral sand concrete and compared it with ordinary river sand concrete. According to the experimental results, the compressive strength of coral sand concrete with the same mix ratio is less than that of ordinary river sand concrete, while the folding strength and splitting tensile strength of the two are not much different. The use of different cement varieties has a great influence on the mechanical properties of coral aggregate concrete. Gao Qi [14] designed coral aggregate concrete and test the mechanical properties of the shaft, split tensile strength, elastic modulus, and cubic compressive strength are obtained by fitting the experimental data. The compressive strength of each test block is above 50 MPa. The change law of the mechanical properties of coral aggregate concrete with age is also different from that of ordinary concrete. As shown in Fig.1, Zhao Yanlin [15] used coral stone as coarse aggregate, and ordinary river sand for fine aggregate preparation coral aggregate concrete, through the experimental study of the coral aggregate concrete compressive strength with age, the conclusion: different molding batch early compressive strength of coral concrete are increasing rapidly, including 7d concrete strength is about 80% of 28d strength, and in the later stage, the compressive strength growth is slow.

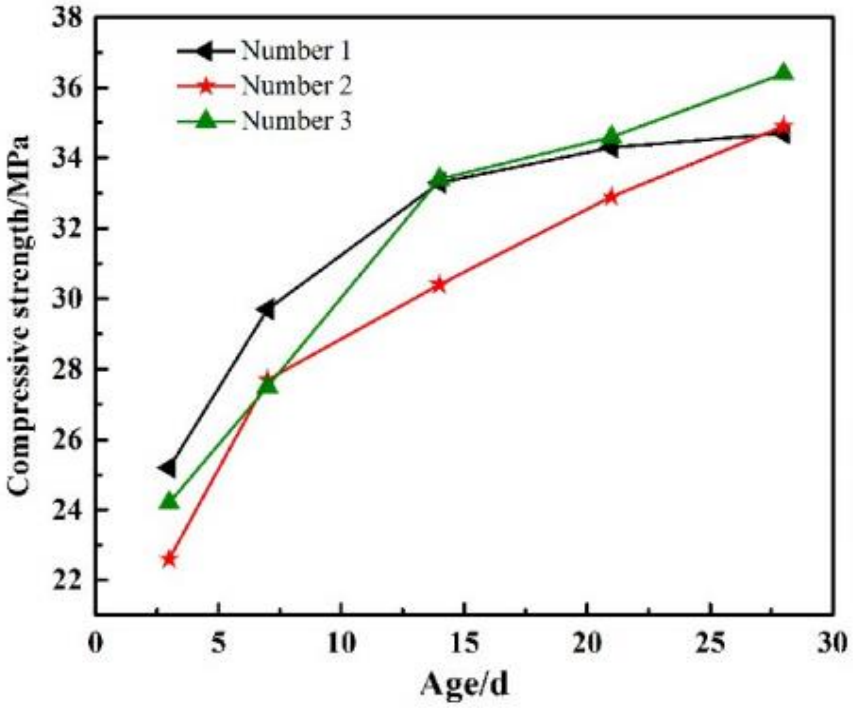


Fig. 1 Change law of compressive strength of coral aggregate concrete with age[15].

3. The way to improve the workability of seawater marine aggregate concrete

To ensure that the working performance of seawater Marine aggregate concrete meets the needs of the project and avoids the corrosion problem of traditional reinforced concrete, fiber-reinforced composite material (fiber-reinforced polymer, FRP) can be used to improve the working performance of seawater Marine aggregate concrete.

In research, Marine Feng Peng [16] put forward the new FRP sea sand concrete composite structure, designed to solve the challenges of concrete engineering in the Marine environment, the column design for external FRP tube + internal FRP extrusion profile + middle sea sand concrete filling form, beam system by squeezing FRP beam and porous FRP plate assembly, the structure of the flexible design, when built on local materials, has the advantages of reusable, seawater corrosion resistance. Zou Tong et al. [17] applied GFRP bars with a tensile strength of 900MPa to the comprehensive pipe gallery structure of the Yangshan Phase IV project to realize the requirements of heavy load and anti-magnetic design. In the project, the GFRP reinforcement accelerated aging test was carried out, and the tensile performance of the reinforcement under harsh conditions was studied. It was found that the strength guarantee rate of GFRP reinforcement under normal use conditions was 0.7. This value is approximately the guarantee rate considering the strength reduction coefficient in the specification, which verified the rationality of the coefficient set. It is found that the section shape of FRP reinforcement changes and the strength decreases greatly. Therefore, the weakening effect of the hook design should be considered when used for the stirrup, and the bending area should be avoided in a large force position. The reinforcement follows the principle of "small diameter, dense covering". Some scholars have studied the long-term performance of BFRP tendon under alkali solutions and 20,40 and 60℃ and estimated that the tensile strength retention rate of BFRP tendon after 100 years is about 70%, which meets the engineering requirements

Although the combination of sea sand and FRP tendon has achieved good application results, the durability of this combination needs to be studied more deeply, and the prediction model of anti-corruption duration of FRP tendon can be developed, to be put into use better. Under practical conditions, the FRP cement seawater Marine aggregate concrete is determined by a variety of factors, including temperature and humidity, freezing and thawing, salinity, etc. The joint mechanism and durability influence the relationship of multifactorial conditions and need further experiments.

4. Conclusion

By analyzing and summarizing the research of marine aggregate concrete, this paper discusses the concrete and its working properties which can be combined with it to solve the corrosion problem of FRP.

Marine aggregate is taken from the calcareous aggregate of Marine organisms, such as corals and shells, or the estuary and the surrounding areas of the ocean, such as sea sand. Because the materials are geographically close to the ocean, there are many differences in the ion content of seawater and ocean aggregate and the raw materials of freshwater concrete. As described in this paper, the marine aggregate needs to be treated first to meet the engineering requirements. In terms of working performance, marine aggregate mainly affects the working performance of concrete in three aspects initial setting time, fluidity, water retention, and slump. With the increase in the amount of ocean aggregate, the initial setting time of concrete is shortened accordingly, and the fluidity, water retention, and slump will be reduced. In particular, the coral aggregate has a loose, porous, and brittle texture. This paper discusses the influence of this property on compressive strength, folding strength, and cracking tensile strength. It concludes that concrete the new concrete made of coral aggregate is slightly less than traditional concrete, while the other two aspects are no different. After 28d of maintenance, the compressive strength tends to be consistent with traditional concrete. In general, seawater ocean aggregate concrete represented by seawater sea sand concrete and coral aggregate concrete has good working performance and can replace traditional concrete. The main problem of rust can be solved not only by pretreatment or desalination of Marine aggregate but also by combination with new composite FRP tendons. In the future, the further improvement of the technical level can make the seawater and Marine aggregate concrete more widely used in floating cities and other coastal projects, to save freshwater resources and achieve sustainable life.

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