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Survey on the Performance of Underwater Non-dispersive Concrete

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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Review Article

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ABSTRACT

Ordinary concrete in the water is poured by the erosion of water flow when the dispersion resistance is insufficient, easy to make cement and aggregate separation, resulting in concrete compressive strength and work performance greatly reduced, and often must be complemented by cofferdam and other construction methods, high cost. And underwater non-dispersible steel fiber concrete can be poured directly in water, greatly simplifying the construction process, simple and economic. Because of the effect of flocculant, the concrete still has good working and mechanical properties when it is washed by water flow, This paper will discuss the influence of flocculants, water-cement ratio and water-reducing agent, mineral admixtures and nano-materials on the performance of underwater non-dispersible concrete in order to help the research of underwater non-dispersible concrete.

Keywords: Underwater non-dispersion; flocculant; mineral admixtures; nanometer material.

1. INTRODUCTION

Underwater non-dispersive concrete has good scouring resistance, can be directly poured underwater, and is not prone to dispersion and segregation. And it will not pollute the environment. It has low requirements for construction equipment. The quality and strength

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of the concrete poured are guaranteed. It overcomes the shortcoming that ordinary concrete cannot be poured directly underwater. It is known as "new, ideal and epoch-making concrete". The core difference between underwater non-dispersive concrete and ordinary concrete is the addition of flocculant on the basis of ordinary concrete, The so-called flocculant is a kind of water-soluble polymer material, which is a kind of water-soluble polymer compound with long chain structure and strong adsorption capacity. It can adsorb cement particles, aggregates, etc. together, improve the cohesion between the particles of the concrete mixture, thus greatly improving the anti-washability of the concrete mixture, so that it can be directly poured in the water, improve the strength of underwater concrete and ensure the engineering quality of underwater concrete, It fundamentally solves the problem of separation of fresh concrete from water, and realizes the "land-based" underwater construction, so it has great potential advantages in underwater engineering construction.

2. EFFECT OF FLOCCULANT

The underwater non-dispersible concrete flocculant technology was first invented in 1974 by SiBo enterprise group in the former Federal Republic of Germany, named UWB (Under Wsasser Beton), and was successfully used in concrete; Subsequently, Japan introduced the patent and established a set of technical system suitable for Japan from design, materials to construction based on its own construction technology. The research on underwater non-dispersive concrete in China began in 1983. In 1987, the China National Petroleum Corporation Engineering Technology Research Institute cooperated with SiBo Group in Germany to develop the advanced underwater concrete special admixture - UWB series flocculant. In 1990, the newly developed SCR series flocculant was launched and applied to the project, and certain results were achieved [1].

The key of underwater non-dispersible concrete is the research of flocculant, which is the core factor different from ordinary concrete. On the basis of UWB I flocculant, Lin Xian et al. [2] developed UWB II flocculant with a new polymer compound and other concrete additives. Through test and comparison, it is found that the fluidity of concrete mixed with UWB α flocculant can be maintained for more than 1h without loss, and the initial setting and final setting time of underwater non-dispersive concrete can be adjusted by using chlorine-free coagulant, and the water-land strength ratio of 7d and 28d concrete can also be significantly improved.

Zhang Ming et al. [3] compared the effect of flocculants with molecular weight of 4 million, 6 million, 8 million and 10 million on cement paste, and used a small amount of auxiliary agents to replace some flocculants to achieve a significant improvement in the performance of flocculants. It was found that flocculants with molecular weight of 6 million to 10 million have the most significant impact on the rheological properties of cement paste, and the shear stress and viscosity of cement paste continue to rise with the increase of flocculant content.

Muhammad Ali Sikandar [4] studied the effectiveness of using different modifier admixtures (VMAs), including gum arabic (GA), xanthan gum (XG), superabsorbent polymer (SAP), modified starch (MS) and Veegum (VG) as anti-erosion admixtures (AWAs) to prepare UWC mixture. The research shows that the compressive strength of concrete can be improved by adding biopolymers GA and XG into concrete. UWC with different AWAs can reduce the bleeding and shrinkage of concrete. GAC, XGC and SAPC have the lowest bleeding rate and drying shrinkage, and the largest erosion loss reduction.

Zhao Tongfeng et al. [5] analyzed the effects of anti-dispersant, thixotropic agent, early strength component and micro-silicon powder on the performance of concrete in order to obtain the underwater non-dispersant concrete mix ratio with high adhesive force for strengthening the structure.The results show that the setting time of concrete is gradually prolonged with the increase of the dosage of flocculant. When the dosage exceeds 2%, the setting time increases rapidly; With the increase of the amount of thixotropic agent, it first decreases and then increases, but the overall change is not significant. The addition of early strength components greatly reduces the initial and final setting time of concrete, and also reduces the initial and final setting time difference. The expansion degree of concrete decreases with the increase of the amount of flocculant, and the increase of the amount of micro-silica powder also makes the expansion degree increase at first and then decrease significantly. However, the early strength component and thixotropic agent have little effect on the expansion. The loss of cement decreases with the increase of the dosage of flocculant, and decreases first and then increases with the increase of early strength components; The addition of micro-silica powder improves the compactness of the cementitious material and improves the cohesion, thus reducing the cement loss; The thixotropic agent also improves the cohesion of the cementitious material and reduces the cement loss when it is still.When the dosage of flocculant is from 2% to 2.5%, the strength ratio of water and land increases significantly, and the increase decreases after reaching 3%. The thixotropic agent, early strength component and micro-silica powder also reduce the underwater loss of concrete strength, and increase the strength ratio between water and land.

Sonebi M [6] showed that the addition of AWA decreased the fluidity of the mixture and increased the erosion resistance. When AWA was increased from 0.55% to 0.60%, the slump and slump spread decreased by 6% and 5% respectively. The amount of AWA was reduced from 0.55% to 0.30%, and the erosion loss increased by 90% and 112%. The addition of SP increases the fluidity of the mixture and reduces the erosion resistance. The two complement each other.

3. INFLUENCE OF WATER-CEMENT RATIO AND WATER-REDUCING AGENT

Zhang Ming et al. [7] found that with the increasing of water-cement ratio, the slump and slump expansion of concrete mixture increased continuously, and the flow performance became better and better; The content of suspended matter, PH value and turbidity value are also increasing, and the anti-dispersion performance is gradually reduced. The compressive strength of formed concrete on land at 7d and 28d gradually decreased, but the compressive strength of formed concrete in water at 7d and 28d increased first and then decreased; When the water-binder ratio is 0.37, the strength of concrete formed in water reaches the peak value in 7 days, and when the water-binder ratio is 0.35, the strength of concrete formed in water reaches the peak value in 28 days.

The parameters considered in Khayat KH [8] study are cementitious material content (CM), water cement ratio (w/cm), sand ratio (s/a), anti-erosion admixture and high range water-reducing agent concentration. The order of influence of each parameter on the model response is revealed. The use of these models to optimize the concrete mixture is discussed to achieve a good balance between slump consistency, scouring resistance, compressive strength and cost. The water-cement ratio is 0.43, the CM dosage is 550 kg/m3, and the HRWR is 1.35%. When the AWA dosage increases from 0.09% to 0.135%, the erosion mass loss of concrete mixture decreases from 33% to 15%. At the given concentration of s/a, w/cm and AWA, the increase of cm content will significantly increase the fluidity and erosion mass loss. When the water-cement ratio and HRWR are fixed, the fluidity can be improved by increasing the amount of cementitious materials. When w/cm is 0.40, HRWR is 0.70%, and the amount of cm is 450 and 550 kg/m3, the slump of concrete is 400 and 550 mm respectively. Increasing the AWA dose from 0.07 to 0.13% will further reduce the erosion mass loss, while the demand for HRWR will increase significantly, and the HRWR dose required to reach the 500 mm slump will increase from 0.55 to 1.4%. For 420 kg/m3 CM concrete, reducing the sand rate can slightly improve the fluidity, but has little impact on scouring. For 540kg/m3 CM concrete, reducing the sand rate can significantly reduce the fluidity and erosion loss.

4. INFLUENCE OF MINERAL ADMIXTURES

The mineral admixtures commonly used in concrete include fly ash, slag ash, zeolite powder and silica fume, which generally produce pozzolanic effect, morphology effect, micro-aggregate effect and interface effect in concrete. Mineral admixtures can replace part of cement with low cost and improved economic benefits. In addition, SiO_2, Al_2O_3 and other potential active substances in the admixture will react with gypsum to form hydraulic substances.

The content of sharp angular particles in mineral admixtures is high, which is easy to cause concrete bleeding, while the content of spherical particles in fly ash is high, which can increase the fluidity of concrete. The fine particles in the admixture can be evenly distributed in the cement slurry to fill the pores, improve the pore structure of the concrete, make the particle grading more reasonable, increase the compactness, and improve the impermeability and corrosion resistance of the concrete.

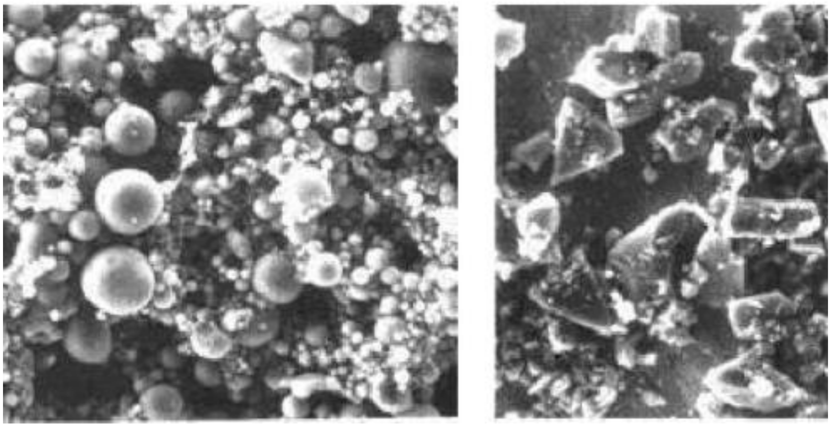

Fig. 1. Morphological effect of mineral admixtures

Niu Jishou and other studies [9] show that the fluidity of underwater non-dispersible concrete without fly ash is very low and the flow loss is large, while the slump and slump expansion increase with the increase of fly ash content. When the content reaches 30%, the slump reaches the peak, and when the content reaches 40%, the slump reaches the peak. With the further increase of the mixing amount, the fluidity of the concrete mixture gradually decreases, and the flow loss also increases. When the content of fly ash is less than 30%, the change of the content has little effect on the PH value and turbidity, but when the content exceeds 40%, the turbidity value increases by 30%, indicating that the addition of fly ash does not improve the anti-dispersion performance. The increase of fly ash content reduces the early strength of concrete and the grip strength with reinforcement, but makes the later strength of concrete gradually increase, and the grip strength gradually increases with the extension of age. With the increase of fly ash content, the water seepage height of concrete specimen decreases gradually, and the shrinkage deformation of concrete is also reduced.

Lv Ziyi et al. [10] studied the influence of fly ash and ground slag powder on the slump expansion of underwater non-dispersive concrete mixture by changing their content, fineness of fine aggregate and mixing time. The results show that the slump expansion of concrete increases with the increase of fly ash content, and reaches the peak at 30%, and then decreases with the increase of fly ash content; The slump loss is decreasing. When slag powder is added alone, the concrete slump increases with the increase of slag powder content; The slump loss decreases gradually, reaches the minimum when the dosage is 30%, and then increases with the increase of the dosage. The slump expansion of concrete increases first and then decreases with the extension of mixing time. When the mixing time is 3min, the slump expansion reaches the peak, indicating that the combined function of flocculant and water reducer can be fully played at this time. The slump expansion of concrete first increases and then decreases with the increase of the fineness modulus of fine aggregate, and reaches the peak when the fineness modulus is 2.7, indicating that the sand with medium sand and coarse sand is more suitable for underwater non-dispersive concrete.

Fei Sha et al. [11] prepared portland cement-based grout with 30% (GBFS) blast furnace slag (GBFS) and 40% grade C fly ash (FA). It is found that the addition of SP can offset the negative impact of AWA on the flow performance, and AWA can improve the stability and effective W/S. At a high initial W/S (0.8~1.2), the addition of 1.0% SP and 0.13% AWA reduced the bending strength at 28 and 91 days. When the initial W/S is 0.8~1.2, the bending strength increases significantly from 28 days to 91 days.

Zhang Ming et al. [12] explored their influence on some properties of underwater non-dispersive concrete by adding different amounts of fly ash and slag powder into underwater non-dispersive concrete. The results show that when fly ash or slag powder is added, the slump, slump, suspended matter content and PH value are large, and the fluidity is good, but the anti-dispersion is insufficient. When the content of fly ash and slag powder is 1:3, the slump and slump reach the minimum at the same time, and the content of suspended matter and PH value of the water sample reach the minimum at the same time when the proportion of fly ash and slag powder is equal, which indicates that the anti-dispersion performance of concrete can be significantly improved when the fly ash and slag powder are mixed together.

El ż Bieta Horszczaruk [13] studied the effect of black coal circulating fluidized bed fly ash (CFBC) on the performance of underwater non-dispersible concrete by changing its content of 0%, 20%, 30%, 40%, 50%, fixed water-binder ratio of 0.48, and AWA content of 1%. The results show that with the increase of CFBC content, the viscosity of UWC mixture will increase significantly, resulting in the slow decrease of slump flow and the gradual increase of flow time through V-shaped funnel; The erosion mass loss of the mixture containing CFBC will increase significantly at the beginning and decrease significantly after 60 minutes. The addition of CFBC reduces the early strength of concrete, and the 56d compressive strength is close to the benchmark concrete at 30%.

The water-cement ratio of concrete prepared by Moon HY [14] is 0.5, and fly ash (FA) and slag powder (SG) partially replace ordinary portland cement (OPC) in the range of 10-30% and 40-60%, respectively. With the increase of replacement rate, the content of suspended solids has an increasing trend, which is 102-127 and 73-94 mg/L, respectively, while the content of suspended solids in OPC is 65 mg/L, and the fluidity is significantly improved. The early compressive strength of AWC with FA and SG was lower than that of OPC, and the later strength increased.

5. INFLUENCE OF NANOMATERIALS

Yaoyu Wang et al. [15] show that nano-materials exhibit nuclear effect, filling effect or pozzolanic effect in the hydration process, which improves the microstructure, reduces the porosity, increases the density of the interface transition zone, and thus improves the bonding strength of the interface of the underwater non-dispersive concrete, and the improvement effect at the age of 3 days is more obvious than that at the age of 28 days. Nano SiO_2 is the most effective to improve the bond strength. At the age of 28 days, 0.01% and 0.03% can improve the bond strength by 38.87% and 108.54%, respectively; Nanometer metakaolin can also significantly improve the bond strength, but when the content of metakaolin is more than 3%, agglomeration will occur, which has a negative impact on the strength; Nano Al_2O_3 . The bond strength of concrete is slightly improved.

Jeon In Kyu et al. [16] studied the effect of nano-silica NS and MgO as mineral admixtures on the performance of UWC. The addition of MgO particles and NS enhances the adhesion of cement paste, reduces its fluidity, and the particle size of NS is much smaller than that of MgO, so NS has a greater role in increasing viscosity. The initial setting time of concrete decreased by 60.1%, 79%, 38.46% and 70.63% respectively compared with the blank group, and the final setting time decreased by 42.42%, 58.1%, 12.1% and 33.84% respectively, when the NS content was from 1% to 2% and the MgO content was from 5% to 10%. The addition of NS and the replacement of MgO both enhance the anti-dispersion performance of the mixture, and the higher the proportion, the more obvious the strengthening effect. The addition of NS slightly increased the compressive strength of concrete, and the replacement ratio of 5% and 10% MgO reduced the compressive strength by 7.13% and 10.48%, respectively, compared with the control group.

GRZESZCZYK [17] has studied the impact of silica nanoparticles on the erosion of underwater concrete and hardened concrete. The research shows that:The anti-dispersion ability of underwater non-dispersible concrete with nano-particles is enhanced, and the flow performance is weakened. Adding 0.5% sio2 nanoparticles can reduce the elution rate by more than 40%; Nano-particles can accelerate hydration in cement paste, and at the same time, they can be used as reinforcing materials and filling materials to densify the microstructure of cement paste, thus reducing porosity; And adding a small amount of sio2 nanoparticles has little effect on the compressive strength of concrete.

6. CONCLUSION

Since the research and development of underwater non-dispersive concrete, it has made certain progress through extensive engineering practice and theoretical research. However, at present, underwater non-dispersive concrete is mostly used in shallow water and low or still water environment. The actual construction environment is complex and the requirements for underwater concrete durability are increasingly high in the future. Therefore, higher requirements must be put forward for the development and improvement of flocculants.

After the existing flocculant is added into the concrete, the collapse is too fast, which brings a lot of inconvenience to the concrete construction. It is very important to study the compatibility between the water reducer and the flocculant; Adding appropriate mineral admixtures, especially the emerging nano-materials, can optimize the preparation of anti-dispersion concrete.

At present, the flocculant added to the underwater concrete often causes the concrete to set slowly, and the underwater construction requires the poured concrete to set relatively quickly. Therefore, it is necessary to add the admixture to adjust the setting speed of the rubber material into the concrete. At this time, there is interaction between the flocculant and the accelerator. If the two are not suitable, it will also affect the construction and anti-dispersion effect of the concrete.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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