Progress in the influence of mechanical sand properties on concrete properties

Abstract: Machine-made sand is less than 4.75mm particle size, made of limestone, granite, basalt, gneiss, sandstone and other stones by crushing, grinding and screening process, because it does not contain soft, wind erosion of rock particles, it belongs to the natural product under the destruction of mechanical external force. The characteristic properties of machine-made sand, such as parent rock lithology, particle shape, particle gradation and stone powder content, make machine-made sand different from natural sand, and machine-made sand affects concrete performance to a certain extent. In this paper, the effects of the sand on concrete performance are discussed from these three perspectives.

Key words: machine-made sand, parent rock lithology, particle gradation, particle shape, stone powder content, concrete performance.

0 Introduction

With the depletion of natural resources and the enhancement of human awareness of environmental protection, the use of artificial sand instead of natural river sand for cement concrete and engineering construction has become the inevitable development of The Times. Machine-made sand is less than 4.75mm in particle size and is made of limestone, granite, basalt, gneiss, sandstone and other stone blocks by crushing, grinding and screening processes. With its advantages of sufficient raw materials and green environmental protection, it is gradually becoming the main variety of construction sand in China. In the current market environment where demand exceeds supply, sand enterprises are uneven, the source of mechanical sand

changes frequently, and the technical nature is unstable. As a key raw material constituting the concrete skeleton, the performance of concrete will be affected by the fluctuation of the technical nature of the mechanical sand, resulting in the decline of the performance of concrete, in the process of producing concrete, often appear water, segregation, workability and other phenomena is the most important performance, the former will affect the performance of concrete mix, Even the strength index of concrete does not reach the design value, resulting in serious engineering accidents. In this paper, the concrete performance will be analyzed from the three aspects of sand particle shape, fineness modulus and stone powder content to provide a basis for engineering sand.

1 Characteristics of machine-made sand

The emergence of machine-made sand, to a certain extent, can replace river sand as a fine aggregate of concrete, the reasons are: first of all, in order to meet a variety of engineering requirements, specific projects need to use customized machine-made sand, through mechanical grinding machine-made sand grading is convenient and reliable; Secondly, in terms of surface roughness, natural sand is smoother than machine-made sand, the former is eroded by rain, while the latter is made by mechanical crushing, so machine-made sand can better play the role of fine aggregate filling than natural river sand, thereby improving the workability of concrete; Secondly, in terms of mechanical properties, the compressive, tensile and flexural strength of machine-made sand concrete are higher than that of river sand concrete, and the dry shrinkage rate is lower; Finally, the production of machine-made sand is more green, economic and environmental protection, and can be produced by concrete waste or crushed stone to realize waste utilization. However, it also has some shortcomings, such as the boundary of 0.075mm, below this grade of machine-made sand made of concrete is less strong. The

characteristics of machine-made sand are described in detail below. Production characteristics:

（1）Particle grading: The particle distribution of machine-made sand can be roughly summarized as the characteristics of large two ends and less in the middle, with 2.36mm and 0.15mm as the boundary. There are more particles than the former and less than the latter, and there is still a grain grade without sand. In general, the gradation of machine-made sand can meet the technical specification requirements of river sand.

（2）Particle shape: The production of machine-made sand is made by mechanical crushing of rock, ore or building waste material, so its shape is mostly irregular, which is mostly flaky particles. It is because of the rough surface of the particles and the irregular shape, which can help the cement mix mix better. But at the same time will have some adverse effects, in the production of concrete in the process of bleeding, segregation, workability is poor and other phenomena.

（3）Stone powder content: The presence of stone powder distinguishes machine-made sand from natural river sand. The addition of stone powder can improve the workability, pumping performance and aggregate grading of concrete. The performance of all aspects of concrete has been significantly improved. However, too much stone powder has a significant impact on its working performance, so the content of stone powder needs a limit.

2 Mechanism the effect of sand mother rock lithology on concrete performance

In essence, machine-made sand is a small particle size product that meets the standard after the natural rock, engineering waste or mine tailings of large particle size raw materials are smashed. Therefore, the properties of machine-made sand are closely related to the properties of its raw material

parent rock. In different areas, due to the different natural environment and geographical factors, the properties of limestone, granite and other rocks as the mother rock of machine-made sand are different, so the impact on the nature of machine-made sand is also different. Therefore, many researchers have carried out a lot of research through experiments, and found that the properties of machine-made sand with different lithology are quite different, which affects the properties of machine-made sand concrete.

Wang Jili[1]ang studied the influence of six representative lithology stone powders such as quartzite, gneiss, granite, basalt, limestone and marble on the effect of chemical admixtures and on the performance of concrete. The results show that the change of lithology of stone powder has a slight effect on the workability, strength and volume stability of concrete, but the difference is not significant, and the change of lithology of stone powder has no effect on concrete durability.

Zhong Guocai[2] used pyroxene, granite, basalt and limestone as the mother rocks to make sand respectively under the same production process. The grading, fineness modulus, particle morphology, angularity and specific surface area of the four kinds of sand were systematically tested. The test results show that the more the fineness modulus of the sand prepared by the mother rock deviates from the design value, the larger the fineness modulus is and the smaller the specific surface area is. The more angular the sand is.

Song Shaom[3]in et al., under the condition of the same gradation and grain shape of machine-made sand, carried out concrete performance tests on 6 kinds of common machine-made sand with different lithology, and studied the influence of machine-made sandstone properties on the properties of colloidal sand and concrete. The results show that the lithology of machine-made sand has a great influence on the workability of concrete, and the calcareous machine-made sand is superior to the siliceous machine-made sand on the whole. Granite, tuff and gneiss sand have great influence on the workability of concrete. The surface texture, stone powder adsorption and chemical

composition of sand with different lithology mechanism have no significant influence on the strength of concrete.

Taking limestone, pebble and basalt sand as fine aggregate and concrete strength grade as variable parameter, Xie Kaizhong[4] et al. found that the failure forms of these three lithologic sand concrete were roughly the same during uniaxial compressive test. The mechanical properties of machine-made sand concrete are related to the physical characteristics of fine aggregates of different lithology. With the increase of fineness modulus or the increase of stone powder content, the peak stress and peak strain of machine-made sand concrete specimens increase first and then decrease. The elastic modulus of pebble-made sand concrete is higher than that of limestone and basalt made sand concrete.

3 Effect of sand particle shape on concrete performance

The difference between machine-made sand and natural sand in particle shape morphology mainly lies in the difference between particle shape and surface roughness. Under the long-term action of water erosion and wind erosion, natural sand has a more rounded surface and is more like a spherical particle as a whole compared with the formation conditions of mechanical crushing of machine-made sand. The surface of the machine sand is rough, and the shape is varied, there are more needle-like and flaky particles, relatively speaking, angular. Therefore, in some more demanding projects, such as road and railway beams, pile foundation and other road projects, natural sand concrete can often show better working performance than machine-made sand concrete.

In general, the spherical particles are more, the compactness is better, that

is, the voidage is smaller. Due to the "congenital deficiency" of machine-made sand, the machine-made sand particles must be fully wrapped with slurry materials in the concrete mixing process and shaped into a particle shape similar to natural sand in order to play a better working performance. Therefore, the same volume of machine-made sand concrete requires more water and colloidal materials such as cement to fill more voids of machine-made sand than natural sand. This is easy to produce concrete in the process of mixing the water segregation phenomenon, so that the performance of concrete is reduced.

However, the increase of voidage makes the slurry material more perfect, which can improve the durability and flexural strength of concrete, that is, the mechanical properties of concrete are more significant.

Chen Can[24] et al. explored the relationship between the mechanical sand type and the fluidity, rheology parameters and strength of mortar by studying the influence of different mechanism sand types on the workability, rheology and mechanical properties of mortar. It is found that machine-made sand with better grain type can effectively improve the workability and rheology of mortar, and the strength of machine-made sand mortar is basically greater than that of natural sand, and the overall correlation between mortar workability and rheology is good.

Zhou Xinwen[25] et al. used digital image processing technology (DIP) to quantitatively characterize the shape of sand particles, and found that the rod-like and flaky degree of machine-made sand was higher than that of natural river sand. The rheological curve of mortar shows that the irregular shape of sand particles will lead to the increase of mortar flow resistance. The yield stress of machine-made sand is 1.5 times that of natural river sand. The apparent viscosity of machine-made sand mortar is greater than that of natural river sand, especially at low shear rate. The surface roughness of machine-made sand particles will also affect the working performance of concrete, but the impact is not as great as the shape of the particles, so there

are few research results on this.

Ahn[26] believes that in the case of the relatively rough surface of the machine-made sand, although the bonding performance of the slurry material has been improved, relative to the whole, these improvements are a drop in the bucket, because the change of roughness will also lead to changes in voidage, etc., which will also have an adverse impact on the shear and tensile strength of concrete. On the contrary, the strength and performance of concrete are declining.

4 Effect of sand and gravel powder content on concrete performance

One of the differences between machine-made sand and natural sand is that in the production of machine-made sand, a certain amount of stone powder will be produced, which is the same material as the mother rock of machine-made sand. According to the content of stone powder, the grading of machine-made sand will have different effects. Even the same content of stone powder will have different consequences on the working performance and mechanical properties of concrete. Therefore, at present, scholars at home and abroad have carried out a lot of research on the influence of stone powder content on concrete performance, but there are still huge controversies.

However, for the influence of stone powder on the performance of concrete, there is a consensus that the appropriate amount of stone powder can improve the performance of concrete, but if the limit is exceeded, it will have an adverse impact on the performance of concrete. Therefore, for the content of stone powder in machine-made sand, there is a limit value in all countries, the maximum limit value is 10% in our country, 7% in the United States, Japan, and up to 15% in Britain, France and other countries. However, due to the actual situation of different parts of the country, local standards are different on the

basis of national standards, such as in Shanxi, the content of stone powder below C25 is up to 20%, C30~C55 is up to 15%, and C60 is 6%.

Liu Shuhua[15] studied the hydration properties and hydration products of limestone powder in composite cementing materials and found that the incorporation of limestone powder will reduce the strength of composite cementing materials, but the influence on the later strength will gradually decrease; In the early stage, the hydration degree of limestone powder and ordinary silicate cement is low, and in the later stage, it will hydrate with aluminate to produce hydrated calcium carboaluminate; Under the excitation of calcium aluminate cement, limestone powder can participate in the hydration to produce calcium aluminate hydrate in the early stage. Therefore, the stone powder can improve the early strength of the concrete material, but it is not good for the later strength.

Sherong Zhang[16] et al. found that concrete with 10% SF and 5~ 20% WMP has the best mechanical properties; SF and WMP have significant effects on the water absorption of concrete; The optimum concrete mix has obvious sulfate acid resistance; The addition of SF and WMP improves the microstructure of concrete.

Through experimental study, Yu Zewen[17] et al discussed the influence of stone powder content on the working performance, mechanical properties, homogeneity and drying shrinkage of C40 mechanism sand concrete. It is found that stone powder can improve the cohesiveness and water retention, avoid bleeding segregation, and improve the bending, splitting and compressive strength of concrete. When the content of stone powder is in the range of 10% ~ 15%, it has the best effect on the working performance and strength of concrete. With the increase of stone powder content, the homogeneity of concrete is improved, and when the stone powder content exceeds 10%, the homogeneity improvement tends to be stable; The early dry shrinkage of machine-made sand concrete increases with the increase of stone powder content, and the dry shrinkage after 7 days is the largest when the

stone powder content is 10%.

CAI Jiwei[18] studied the influence of stone powder on the properties of cement and concrete. For the poorly graded machine-made sand, stone powder can improve the workability of machine-made sand concrete. The content of stone powder has an effect on the compressive strength, flexural strength and dry shrinkage of concrete. The content of stone powder can also affect the axial compressive strength and splitting tensile strength of machine-made sand concrete, and the enhancement amplitude increases with the increase of stone powder content. The elastic modulus depends on the influence of stone powder on the strength and the amount of slurry. Stone powder can enhance the impermeability of concrete. High strength machine-made sand concrete has high frost resistance, and the influence of stone powder content on it is not obvious. The frost resistance of medium and low strength machine-made sand concrete is lower than that of natural sand concrete, and stone powder can slightly improve the frost resistance. Stone powder can make the transition zone of concrete dense and improve the pore structure, so as to enhance the performance of machine-made sand concrete.

Hong Jinxiang[19], Yue[20]Haijun, Li Beixing[21] and others have carried out a lot of research on the stone powder content of machine-made sand and the influence on the performance of concrete, including the influence on different strength grades of concrete and the experience of high strength concrete preparation. By analyzing the content of machine-made sand and gravel powder of granite lithology, Yu Honda[22] et al. obtained that concrete with 8% stone powder content has good mechanical properties and durability.

LAN Con[23]g et al. 's study on the mechanical sand powder content of limestone lithology shows that different sources of limestone mechanical sand powder mainly affect the unit water consumption, water reducing agent content and mechanical properties of concrete. High-quality limestone sand powder can obviously improve the interfacial transition zone of concrete and increase the compressive strength of concrete.

5 Effect of mechanical sand particle grade on concrete performance

The difference between machine-made sand and natural sand in grain shape is mainly due to the difference in particle shape and surface roughness. Under the long-term action of water erosion and wind erosion, the surface of natural sand is more rounded and the whole is more like a spherical particle compared with the formation conditions of machine-made sand mechanical breakage. The surface of the machine sand is rough, the shape is varied, needle and flake particles are more, relatively speaking, angular. Therefore, in some more demanding projects, such as road and railway beams, pile foundation and other road projects, natural sand concrete can often show better working performance than machine-made sand concrete. In general, the spherical particles are more, the compactness is better, that is, the voidage is smaller. Due to the "congenital deficiency" of machine-made sand, the machine-made sand particles must be fully wrapped with slurry materials in the concrete mixing process to form a particle shape similar to natural sand in order to play a better working performance. Therefore, the same volume of machine-made sand concrete needs more water and colloidal materials such as cement to fill more voids of machine-made sand than natural sand. This is easy to cause the concrete mixing process in the seperation phenomenon, so that the performance of concrete is reduced.

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6 conclusion

This paper discusses the influence of machine-made sand characteristics on concrete performance from four aspects: lithology, particle gradation, stone powder content and particle shape.

（1）Parent rock lithology: the different parent rock lithology has a certain

effect on the work and strength of concrete, but has little effect on the durability, and calcareous sand is better than siliceous sand on the whole.

（2）Particle shape: the grain shape of the made sand is irregular and the surface is rough, which is helpful to improve the compactness and mechanical properties of the concrete, but it may also lead to problems such as bleeding, segregation and poor workability. The machine-made sand with better grain shape can significantly improve the workability and rheology of the mortar, and the strength is usually higher than that of natural sand mortar.

（3）Particle grading: The particle distribution of machine-made sand presents the characteristics of "big at both ends and less in the middle", which can generally meet the technical specification requirements of river sand. The poor grading of machine-made sand will lead to an increase in voidage and require more cement slurry material to fill, thus affecting the working performance and cost of concrete.

（4）Stone powder content: The right amount of stone powder (usually between 5%-10%) can improve the workability and pumping performance of concrete, enhance the strength and durability of concrete, too much stone powder will reduce the working performance of concrete, and may have an adverse effect on the later strength.

References

[1]Chen Xiaohe, Zhao Wei. Development of Machine-made sand and production process plan of Qualified Machine-made sand [C]. Proceedings of the 8th National Science and Technology Conference on Sand and Aggregate Industry.2021:22-32.

[2]Che Gongyi, Zhao Minghua, Chen Xugui. Quality control of artificial sand in the Three Gorges Project [J]. China Three Gorges Construction,2000(09):51-53.

[3]Li Pengping, Xiong Jianbo, Wang Shengnian. Preparation technology of machine-made sand and its application in a bridge project [J]. Concrete,2012(03):127-130.

[4]Chen Jialong, Fang Yuanxing. Status and problems of concrete aggregate in China [J]. Building Technology,2005(01):23-25.

[5]Xia Longxing, WU Rong. Study on properties of machine-made sand and natural sand [J]. Concrete,2008(07):60-61.

[6]Yue Haijun, Li Beixing, Zhou Mingkai, et al. Discussion and experiment on gradation of machine-made sand for cement concrete [J]. Concrete,2012(03): 91-94.

[7]Qin Lian, Zhang Xiong, Wu Genhuo, et al. Mother rock inspection and evaluation method of machine-made sand before production line putting into operation [J]. New Building Materials, 2,012,39(01):24-26.

[8]He Shengdong, Liu Lixin, Wang Hua, et al. Experimental study on compressive strength of machine-made sand concrete with different substitution rates [J]. Concrete,2010(10):109-111.

[9]Pang Bin, DA Jun. Application of mechanized sand in pumped concrete of low strength grade [J]. Commercial Concrete,2011(7):56-63.

[10]Wang Jiliang. Effect of Mechanical sand Characteristics on Concrete Performance and mechanism Research [D]. Wuhan University of Technology,2008.

[11]Zhong Guocai. Study on properties of machine-made sand and its influence on rheological properties of cement slurry based on parent rock properties [D]. Huaqiao University,2017.

[12]Song Shaomin, Cheng Cheng, Yang Nan. Study on effect of mechanical sandstone properties on properties of mortar and concrete [J]. Concrete,2019(09):67-70.

[13]Xie Kaizhong, Liu Zhenwei, Gai Bingzhou, et al. Constitutive relationship and mechanical properties of machine-made sand concrete with different lithology [J]. Journal of Building Science and

Engineering,2021,38(01):99-106.

[14]Chen Zhi-wen. Experimental Study on Mechanical Properties and Microstructure characteristics of stone powder Concrete [D]. Xi 'an University of Science and Technology,2021.

[15]Liu Suhua, Yan Peiyu. Hydration properties of limestone powder in composite cementing materials [J]. Journal of the Silicate, 2008(10):401-405.

[16]Sherong Zhang et al.Effect of silica fume and waste marble powder on the mechanic al and durability properties of cellular concrete[J].Construction and Building Mat erials,20,241(C):117980-117980.

[17]Yu Zewen, Yuan Fei-Fei, Zhou Xiao-Jun, et al. Study on effect of mechanical sand and gravel powder content on concrete performance [J]. Sichuan Architecture,2021,41(0 4):214-216.

[18]CAI Jiwei. Study on Effect of stone powder on properties of Machine-made sand Concrete and its mechanism [D]. Wuhan University of Technology,2006.

[19]Hong Jinxiang, Jiang Linhua, Huang Wei, et al. Study on Effect of stone powder in artificial sand on Concrete Properties and its Mechanism [J]. Highway Traffic Science and Technology,2005(11):88-92.

[20]Yue Haijun, Li Beixing, Zhou Mingkai, et al. Discussion and experiment on gradation of machine-made sand for cement concrete [J]. Concrete,2012(03):91 94.

[21]Li Bexing, Zhou Mingkai, CAI Jiwei, et al. Study on the influence of stone powder in machine-made sand on the properties of concrete with different strength grades [J]. Concrete, 2008(07):51-54+57.

[22]Yumoto Tian, Liu Tong, Wang Huan, et al. Study on Effect of granite-porphyry rock powder Content on properties and Microstructure of concrete [J] Journal of Jilin University (Engineering and Technology Edition):1-13.

[23]LAN Cong, Chen Jing, Liu Xia, et al. Study on the influence of stone powder in limestone sand on the performance of concrete [J]. New Building

Materials,2018,4, 5(07):46-48+130.

[24]Chen Can, Liu Hujun, Fan Zhihong, et al. Study on effect of mechanical sand grain type on workability and mechanical properties of mortar [J]. Building Structures,2021, 51(S2):1020-1025.

[25]Zhou Xinwen, Liu Jianzhong, Liu Guangyan, et al. Study on effect of grain shape of machine-made sand on rheological properties of mortar [J]. Concrete and Cement Products,2020(05):1-5.

[26]Ahn,N.An Experimental Study on the Guidelines for Using Higher Contents of Aggreg ate Microfinesin Portland Cement Concrete [D].Austin,University of Texas,2000.