Research on Sand for Ultra-High Performance Concrete

Yuanzi Zhang*

KZJ New Materials Group Guizhou Co., Ltd., Longli, Guizhou, 551206, China

*2421882708@qq.com

Abstract. Currently, there is a significant demand for ultra-high performance concrete, yet the technology for preparing ultra-high performance concrete with good performance and ease of construction is not yet mature. This article aims to study the impact of different sands on its performance, thereby preparing ultra-high performance concrete with excellent performance. Experiments show that under the same mix ratio, concrete with quartz sand and basalt sand has a relatively small slump/expansion degree and a slower inverted flow rate, with a maximum 28-day compressive strength of up to 138MPa, which can only be used as ordinary concrete. Concrete with iron sand has a slightly larger slump/expansion degree and a faster inverted flow rate, with a maximum 28-day compressive strength of over 150MPa, which can be applied in super high-rise buildings. Concrete with emery sand has the largest slump/expansion degree and the fastest inverted flow rate, with a maximum 28-day compressive strength of over 200MPa, which can be applied in large-scale projects with high strength requirements.

Keywords: ultra-high performance concrete; quartz sand; basalt sand; iron sand; emery sand

1 Introduction

With the rapid development of current social construction, a large number of complex buildings such as super high-rise buildings, long-span or ultra-long-span bridges, subsea tunnels, offshore oil platforms, and nuclear reactors are being constructed. Engineering structures require materials with high strength, good durability, and excellent volume stability [1-2]. Ordinary concrete can no longer meet the requirements of these projects. Therefore, designing ultra-high-performance concrete is the development trend of concrete in the future.

Ultra-high performance concrete (UHPC) can meet the strength requirements of special engineering projects, and it exhibits better toughness and corrosion resistance compared to ordinary concrete. The lower limit of compressive strength for UHPC is 150MPa [3-4]. However, it is challenging to prepare concrete with a strength level of C120 or higher using traditional raw materials and methods [5]. Preparing UHPC poses significant challenges to current preparation technologies. As early as 1986, Xia Fang [6] proposed that ultra-high strength concrete mixed with silica fume exhibits a higher

Y. Zhang et al. (eds.), *Proceedings of the 2024 10th International Conference on Architectural, Civil and Hydraulic Engineering (ICACHE 2024)*, Advances in Engineering Research 259,
https://doi.org/10.2991/978-94-6463-658-1_26

elastic modulus. In 1988, Zhu Mengliang [7] studied the use of silica fume to prepare C100 ultra-high strength concrete, which also confirmed its feasibility.

During the concrete preparation process, methods such as adding silica fume, increasing cement content, and reducing the water-binder ratio are employed to enhance concrete strength. However, these methods have reached their limits in terms of increasing concrete strength. Moreover, using these methods to prepare ultra-high-performance concrete results in a higher viscosity, poor workability, rapid loss, and failure to meet construction requirements. Therefore, special aggregates must be used to increase concrete strength and achieve the goal of preparing ultra-high-performance concrete. As early as 2000, Jiang Jingping [8] and others prepared ultra-high-strength concrete with a compressive strength exceeding 100MPa using conventional machine-made sand and other materials. Pu Xincheng [9] and others were the first to prepare ultra-high-strength concrete using ultra-fine sand, achieving a compressive strength exceeding 120MPa. Liu Yongdao [10] and others proposed using a closely packed technology to determine the proportion of cementitious materials and machine-made sand, which can prepare ultra-high-strength concrete with a compressive strength exceeding 140MPa.

2 Experiment

2.1 Experimental Raw Materials and Instrumentation

Detailed information on the raw materials used in this experiment is shown in Table 1:

Table 1. Experimental raw materials

	Experimental raw materials	Specifications	manufactor
	cement	P.O52.5	Conch Cement Plant in Qingzhen
	Quartz sand	0mm-5mm	Shanghai Haiyi Technology and Trade Co., Ltd
	Xuanwu sand	0mm-5mm	Qingzhen Wanlongda Mineral Development Co., Ltd
measure try	iron sand	0mm-5mm	Shanghai Haiyi Technology and Trade Co., Ltd
material material	Diamond sand	0mm-5mm	Shanghai Haiyi Technology and Trade Co., Ltd
	Steel fiber	0.22mm×13mm	Sweco Engineering Fibers
	Silica fume	4000 mesh	Jinyuan Mining Processing Plant
	Water (W)	tap water	self-control
	Water reducing agent	High-performance water reducer	Kezhi Jie New Material Group (Guizhou) Co., Ltd

Detailed information regarding the main instruments used in this experiment is presented in Table 2:

Table 2. Main instruments

Experimental instruments	model	Main technical parameters
Fully automatic constant stress testing machine	JYE-3000 model	Maximum load: 3000KN
Forced-type single-horizontal-shaft concrete mixer	JSD type	Maximum mixing capacity: 60L
Standard constant temperature and humidity curing chamber	YH-40B model	Constant temperature value: 20°C
Electronic scale	TCS-150 model	Maximum weighing capacity: 150kg

2.2 Mix Proportion Design

Based on the theory of maximum packing density, the theoretical mix proportion of ultra-high performance concrete is designed, with a water-binder ratio of 0.18. The sand used is one of quartz sand, basalt sand, iron sand, or emery sand, with a sand ratio of 70%. The admixture content is 18kg. The determined mix proportion is shown in Table 3 below:

Table 3. Mix Design (Unit: Kg/m3)

number	cement	Silica fume	Xuanwu Stone	sand	Steel fiber	water	admixture
1	660	160	463	1080	45	147	18

Cement: Conch P.O 52.5 from Qingzhen, Guizhou; silica fume: Jinyuan Mining Processing Factory in Lingshou County; basalt sand and basalt stone: Wanlongda Mineral Development Co., Ltd. in Qingzhen City; quartz sand, iron sand, and emery: Shanghai Haiyi Technology and Trade Co., Ltd.; steel fiber: Shiweike Engineering Fiber, which is straight, with a diameter of 0.22mm, a length of 13mm, and a length-to-diameter ratio of 60; admixture: Kezhijie New Material Group (Guizhou) Co., Ltd. high-performance water reducer, with a solid content of 30% and a water reduction rate of >30%.

3 Results and Analysis

3.1 Analysis of the Working Performance of Concrete Mixed with Different Sands

After mixing concrete with different sands according to the theoretical mix ratio, the workability of the concrete is shown in Table 4.

From Table 4, it can be observed that after adding quartz sand, the initial slump/expansion of concrete is 240mm/600mm, and the slump/expansion after 2 hours is 230mm/580mm. Compared to adding quartz sand, adding basalt sand increases the initial slump/expansion of concrete by 5mm/20mm, and the slump/expansion after 2 hours is still 240mm/600mm. After adding iron sand, the initial slump/expansion of concrete continues to increase to 260mm/650mm, and the slump/expansion after 2 hours increases to 255mm/640mm. The concrete exhibits good workability. After adding emery sand, the initial slump/expansion of concrete reaches its maximum, which is 260mm/690mm, and the slump/expansion after 2 hours is 255mm/685mm. The inverted flow rate of concrete indicates that after adding quartz sand, the initial inverted flow rate of concrete is 7.2s, and the inverted flow rate after 2 hours is 9.3s, indicating a slower flow rate. After adding basalt sand, the inverted flow rate of concrete increases slightly, with an initial inverted flow rate of 6.8s and an inverted flow rate after 2 hours of 8.8s. After adding iron sand, the initial inverted flow rate of concrete is 5.2s, and the inverted flow rate after 2 hours is 7.5s, indicating a faster flow rate. After adding emery sand, the inverted flow rate of concrete is the fastest, with an initial inverted flow rate of only 4.1s and an inverted flow rate after 2 hours of 6.3s, indicating the fastest flow rate. Therefore, it can be concluded that adding emery sand results in the best workability of concrete.

Table 4. Concrete Workability

sand	T_{0h} slump/expansion (mm/mm)	T_{2h} slump/expansion (mm/mm)	Initial inverted flow (s)	2h inverted flow (s)
Quartz sand	240/600	230/580	7.2	9.3
Xuanwu sand	245/620	240/600	6.8	8.8
iron sand	260/650	255/640	5.2	7.5
Diamond sand	260/690	255/685	4.1	6.3

3.2 Compressive Strength at Various Ages after Mixing Concrete with Different Sands

Concrete samples mixed with different sands were molded, and their compressive strengths were tested at 3d, 7d, and 28d. The test results are shown in Figure 1.

As shown in Figure 1, the 3-day compressive strength of concrete with quartz sand added is 92MPa, the 7-day compressive strength is 105MPa, and the 28-day compressive strength is 132MPa. The addition of basalt sand does not significantly increase the strength of concrete at all ages, with the 3-day compressive strength increasing by 6MPa, the 7-day compressive strength by 3MPa, and the 28-day compressive strength by 6MPa. The addition of iron sand significantly increases the 3-day compressive strength of concrete to 110MPa, the 7-day compressive strength to 122MPa, and the 28-day compressive strength to 158MPa. When adding emery sand, the 3-day compressive strength of concrete reaches 125MPa, the 7-day compressive strength is 145MPa, and the 28-day compressive strength reaches 210MPa, which is extremely high and can be used as the preferred concrete for large-scale projects.

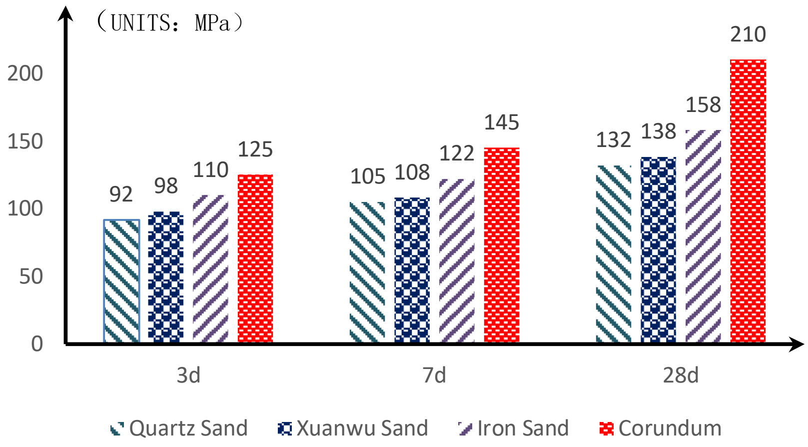

Fig. 1. Concrete Compressive Strength Test

The concrete after mixing with different sand was formed, and the 3d, 7d and 28d bending strength of concrete were tested respectively. The test results are shown in Figure 2:

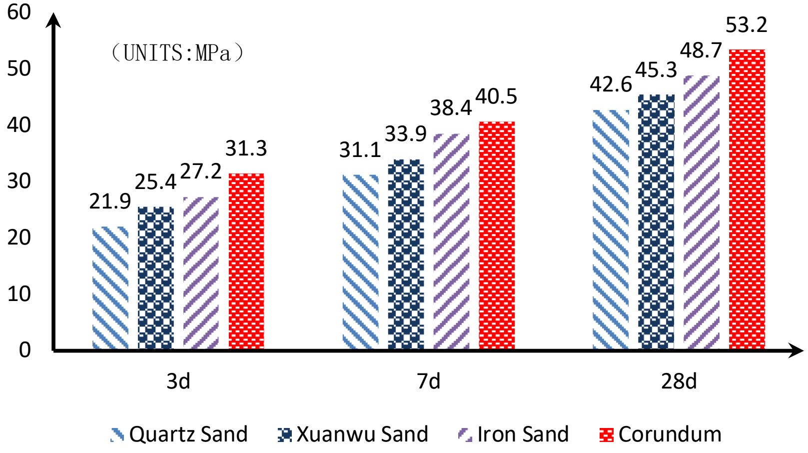

Fig. 2. Flexural Strength Concrete Test

As shown in Figure 2, from quartz sand to emery, the 28d flexural strength of concrete increases by 25%.

4 Conclusions

(1) This article compares the applications of quartz sand, basalt sand, iron sand, and emery in ultra-high-strength concrete;

(2) Under the same mix ratio, the slump/expansion of concrete with quartz sand and basalt sand is relatively small, while the slump/expansion of concrete with iron sand increases, and the slump/expansion of concrete with emery sand is the largest;

(3) Under the same mix ratio, the inverted flow of concrete with quartz sand and basalt sand is slower, while that with iron sand is faster, and that with emery sand is the fastest;

(4) Under the same mix ratio, the compressive strength of concrete with quartz sand and basalt sand at various ages is relatively low. The 28-day compressive strength of concrete with iron sand can reach 158MPa, while that of concrete with emery sand can reach 210MPa;

(5)Under the same mix ratio, the 28d flexural strength of concrete with emery is the highest, reaching 53.2MPa.

(6) Concrete mixed with emery has good workability and high compressive strength, making it suitable for large-scale projects with high strength requirements.

References

1. Shao Xudong, Fan Wei, Huang Zhengyu. Application of ultra-high-performance concrete in structures [J]. China Civil Engineering Journal, 2021, 54(1): 1-13
2. CHEN Y, LIU P, SHA F, et al. Study on the mechanical and rheological properties of ultra-high performance concrete [J]. Journal of Materials Research and Technology, 2022 (17): 111-124
3. Shao Xudong, Qiu Minghong, Yan Banfu, et al. Progress in Research and Application of Ultra-High Performance Concrete in Bridge Engineering at Home and Abroad [J]. Materials Review, 2017, 31(12): 33-43
4. Wang Hui. Review of Ultra-High Performance Concrete (UHPC) Research [J]. Concrete and Cement Products, 2022(4): 25-29
5. Pu Zhihai, Chen Xingsheng, Yao Ruishan, et al. Research on the Mix Proportion and Durability of Coarse Aggregate C120 Ultra-High Strength High-Performance Concrete [J]. Low-temperature Building Technology, 2022(3), 163-166
6. Xia Fang. Cast-in-situ Ultra-high-strength Concrete with Silica Fume [J]. Industrial Construction, 1986, (05): 60
7. Zhu Mengliang. Preliminary Experimental Study on Preparing 100MPa Ultra-high Strength Concrete with Silica Fume [J]. Journal of Changsha Jiaotong University, 1988, (Z1): 41-51
8. Jiang Jingping, Gao Zhixiang, Fan Wanxiang. Development of ultra-high-strength and high-performance concrete using machine-made sand [J]. Concrete, 2000, (04): 18-22
9. Pu Xincheng, Yan Wunan, Wang Chong, et al. Preparation technology of ultra-fine sand ultra-high strength high performance concrete [J]. Journal of Chongqing Jianzhu University, 1999, (01): 3-6+33
10. Liu Yongdao, Chen Jing, Lin Xihua, et al. Preparation of ultra-high-strength high-performance concrete with machine-made sand based on the principle of dense packing [J]. Concrete and Cement Products, 2014, (09): 25-29. DOI: 10.19761/j.1000-4637.2014.09.006