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Influence of manufactured sand's characteristics on its concrete performance

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HIGHLIGHTS

- The stone power of MS is most significant factor on the performance of MS concretes.
- The gradation of the MS does not have a negative character on concrete.
- The MS concrete has narrower and denser ITZ than that of RS.
- There is no obvious element enrichment at the micro scale of the MS concrete paste.

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ABSTRACT

Manufactured sand (MS) is widely considered as an alternative of the river sand (RS) recently, and to clarify the influence significance and influence mechanism of MS characteristic parameters on its concrete performance is essential to its scientific application. This paper presented series of experimental studies on the influence of MS characteristics on MS concrete performance. Results indicated that the particle shape of MS had little influence on the performance of its concretes, while the stone powder of MS had more remarkable influence on its concrete performance. When the gradations of manufactured sand B (MSB) and RS was adjusted according to Fuller's curve, the strength of MSB concrete was only lower than that of RS concrete, thus the gradation of MS was not a negative characteristic to concrete strength. The stone powder of MS is most significant factor on its concrete strength and the strength can reach a peak value when the content of stone powder is 7.5%. The MSB concrete has narrower ITZ than that of RS, and only a small amount of AFt crystals is found in the ITZ of MSB, while the stick AFt, AFm and portlandite crystal are enriched at the ITZ of RS concrete, the microstructure of MSB concrete is denser than that of RS.

1. Introduction

Whereas the high-grade natural river sand (RS) gradually decreased in more and more areas in China, the market share of manufactured sand (MS) keeps sharp increasing for the boom of infrastructure construction [1,2]. Transported long distance by water or wind, RS is rounded and has characteristic abrasion patterns on its grain surface, while the MS is prepared by mechanical crushing of parental rock, therefore it is very different from RS in shape, gradation, composition and the content of stone powder (micro fines) [3–5]. Consequently, the characteristic of MS particle has various influences on the properties of the fresh concrete and the hardened concrete as well [6–8]. Generally speaking, the particle characteristic of MS influences the flow resistance of mortar in fresh concrete, thus this will affect the workability of its concretes, and change the structure of interfacial transition zone (ITZ) and the bond force between sands and cement pastes, so it has a significant impact on the mechanical properties and durability of concretes [9–11]. The characteristics of MS and MS concrete have been extensively studied. Shen et al. [1] reported that, mostly, in the micro scale, MSs had lower surface roughness than RS because the surface of MS was mainly made of very smooth new broken crystal surface, MS had higher angularity also. Li et al. [3] reported the strength of concretes was significantly related surface

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morphology of fine aggregate particles. Wang et al. [12] reported that RS particles shape was closed to a sphere and more rounded, and when the concrete prepared with the same amount of cement, the MS concrete had higher water demand, less air content and had higher strength than RS concrete. Donza et al. [13] found that angular-shape granite MS required more water reducer dosage than rounded particle shape RS to achieve the same slump, and the mechanical properties of MS were better than RS during the concrete life cycle. Dilek [14] reported that particle angularity of MS and fineness of the sand gradation influenced the water demand of mortars. Coo and Pheeraphan [15] reported that, with the increase in sand content, the mechanical strength of preplaced aggregate concrete also increased, while coarse aggregate gradation had no significant effect in preplaced aggregate concrete mechanical strength. Celik [16] reported that the specific surface area of aggregate will increase as the increase of stone powder content under the condition of not changing the proportion of coarse and fine aggregate, and the water demand of concrete will increase. Hudson et al. [17] thought the stone powder of MS filled the gap between the large particles, which acted as a lubricant in the aggregate system. Malhotra [18] reported that the compressive strength of concrete mixed with MS with 7% stone powder was superior to that of RS in the same water-cement ratio. Bonavetti [19] reported that the increase of stone powder content will increase impermeability of pastes for any specific water-cement ratio. Most research works [1,3,6,7,11,20–26] indicated that the

Table 1
The physical properties of cement.

Cement type	P.O 42.5
Normal consistency%	27.2
Initial setting time min	130
Final setting time min	195
3 d strength (flexural/compressive) MPa	6.9/27.4
28 d strength (flexural/compressive) MPa	9.4/52.6

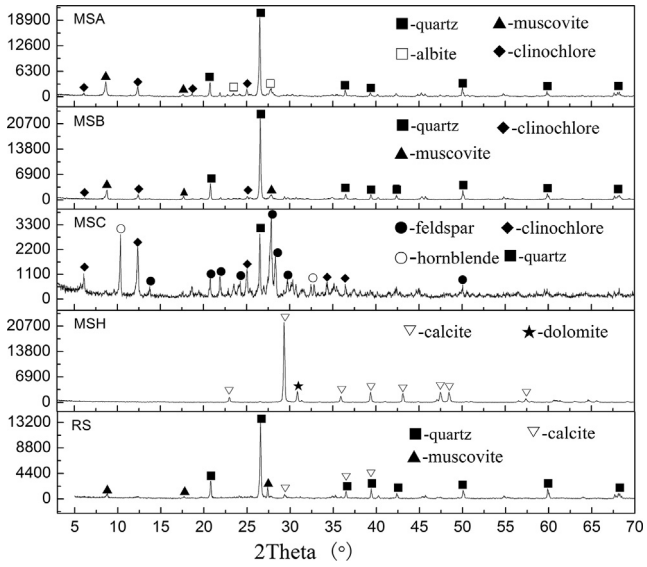

Fig. 1. The XRD patterns of various sands.

Table 2
The grain shape of various manufactured sand.

NO	Roundness			Length-width ratio			Surface roughness (μm)
	Max	Min	Mean	Max	Min	Mean	
MSA	1.762	1.153	1.354	2.743	1.069	1.463	16.41
MSB	1.958	1.140	1.387	2.844	1.012	1.582	10.97
MSC	2.580	1.135	1.377	2.318	1.012	1.452	15.38
MSH	1.838	1.151	1.323	2.316	1.038	1.409	15.83
RS	1.853	1.058	1.181	1.793	1.023	1.277	19.97

Table 3
The physical properties of various manufactured sand.

NO	MSA	MSB	MSC	MSH	RS
Bulk density (kg/m^3)	1583.5	1513	1622.7	1636	1473.3
Apparent density (kg/m^3)	2746.0	2741.5	2913	2700	2626.6
Crushing value index (%)	28.63	14.40	17.10	23.30	9.42
Powder content (%)	15.3	16.4	16.9	2.3	0.6
Clay lump content (%)	3.7	0.8	4.8	0.4	—
MB Value	0.50	0.50	1.25	0.25	—

Note: the crushing value index is parameter crushing mount of the aggregate under a certain compressive load with a standard testing method; the Powder content is the content of particle under the 0.075 mm sieve; the Clay lump content of a sand is the content of soft particle with normal size above 1.25 mm but can be smashed into powder smaller than 630 μm. MB Value is an index of absorption ability on methylene blue of the powder in the sand to represent the clay content in its powder.

Table 4
The size distribution of various manufactured sand.

NO	Sieve size mm/ accumulated screening rate%							Fineness modulus
	4.75	2.36	1.18	0.6	0.3	0.15	0.075	
MSA	0.6	24.7	43.1	58.8	68.3	77.2	84.1	2.71
MSB	0.2	19.9	42.8	62.9	72.5	79.5	83.6	2.77
MSC	1.1	9.2	30.3	52.3	64.6	72.4	83.1	2.26
MSH	3.7	42.5	65.9	83.1	87.1	95.3	97.7	3.69
RS	3.9	16.9	34.1	59.8	83.1	97.9	99.4	2.83