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Properties of Sand Grout with Iron Ore Tailings as Fine Aggregate

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Key words: iron ore tailings; size distribution of granules; compressive strength

Abstract: Innovative researches on properties of sand grout with iron ore tailings (IOT) as fine aggregate were conducted. The results show that exclusive ferrous mineral in the IOT is merrihueite beside quartz in both IOT and nature sand (NS). IOT have similar thermal stability with NS. Sand grout with IOT has higher compressive strengths resulted from existence of ferrous minerals and more complex morphology of particles. However, size shrinkage of the sand grout slightly increases to 0.09% of initial testing specimen. It is feasible that IOT as fine aggregate can be used to produce sand grout.

It is always difficult for utilization of iron ore tailings (IOT) on all industrial waste up to now and has resulted in serious environmental problems [1]. According to the incomplete statistics, all kinds of tailings have amounted to 6,000,000,000 tons, with the increasing speed of more than 500,000,000 tons per year. For recycling utilization of IOT, many researchers have been focusing on the program and made great progress [2]~[8]. However, due to great amount of IOT and lack of activity, the efficiency of utilization is too low and not enough to fundamentally eliminate harm caused. Nature sand (NS), as a kind of natural resources, is an important raw material fabricating concrete and sand grout in the construction. Usually, its regeneration needs to experience a long period and long-term mining makes its reserves depleted near urban in China. There is an urgent need to seek artificial sand for replacement of NS. Since the solidness and size of IOT are similar to NS, IOT replacing of NS as fine aggregate may provide special source for concrete or sand grout with great consumption of IOT. However, IOT may be different from NS (especially the river sand) in some aspects including chemical composition, mineral composition, and physical morphology. It is questionable for the replacement of IOT to NS, especially river sand. At present, many scholars have focused on utilization of various wastes crushed and graded as fine aggregate, such as trash of building demolished, coal gangue, and slow cooling slag. However, few researches [9~11] are conducted focusing on the stability and feasibility of IOT using fabrication of cement-based materials so far.

In this study, the properties of sand grout with IOT are explored by comparing the composition, thermal stability, size distribution of particles, compressive strength and shrinkage between IOT and NS. The suitability of replacement of artificial sand of IOT to river sand is appraised.

Experiment

Material

IOT from a discharging point in Zhashui county, Shaanxi province, in China, were determined to be safe according to “limit of radionuclide in building materials” GB 6566-2010 [12]。NS used for the study are from Weihe River in Xi 'an city, Shaanxi province and ISO standard from Pingtan in Fujian province respectively, in China. P.O32.5 cement was produced by Shaanxi Jidong cement manufacture. Setting time and cubage stability of the cement conforms to the standard requirement and the measuring results of the cement strength provide a proof on reliability of its mechanical properties according to "construction sand" GB/T 14684-2011 method [13].At the same time, level of the class Ⅰ sand was determined by testing harmful substance content and sturdiness of IOT .

Experiment method

Chemical composition of artificial sand for IOT after grinded and dried were detected by fluorescent element analyzer of S4 PIONEER type (BRUKER Company in Germany). XRD spectrums were obtained to identify mineral composition by using X-ray powder diffraction of D/MAX - 2400 type (Rigaka Company in Japan). The instrument was operated on the run parameters fixed including Cu Ka target, voltage of 40 kV for X-ray acceleration tube with electric current of 40 mA, scanning speed of 4 ^{o} /min and scanning range（2θ）of 3 ^{o} ~90 ^{o}.

The thermo-gravimetric differential thermal coupled analyzer, SDTQ 600 type (TA Company in America), is employed to analyze the thermal stability of raw material. Heat rate was set at 10 ^{o}C/min with nitrogen gas for protective atmosphere and temperature range of 0 ~ 1200 ^{o}C

Shrinkages value of sand grouts sample with size of 25×25×280mm are measured. The mass ratio of the cement and fine aggregate is 1:2.25 and the mass ratio of water and cement is 0.47 in those samples. The experiment aim to observe difference of size stability which is derived from change of fine aggregate shape among IOT, NS, and mixed sand containing IOT of percent 50 and NS of percent 50.

Size distributions of IOT used in the experiment are adjusted to the same size range with NS and are shown in table 1:

Table1 Size distribution of fine aggregate for the shrinkage test

mesh size	2.36~4.75mm	1.18~2.36mm	0.6~1.18mm	0.3~0.6mm	0.15~0.3mm
Mass percent %	10	25	25	25	15

Size of two specimens are measured at the periods of 1 day, 3 days, 7 days, 14 days, 28 days, 42 days, 56 days, 90 days, 120 days and 180 days respectively. Size variety of sand grout specimens of IOT or NS with prolongation of time can be obtained under the condition of the same size distribution and different shape of granules.

To analyze the effect of IOT on the mechanical behavior of cement sand grout, we totally designed the M5, M10, M15, M20, M25 five class of sand grout in accordance to codes for design of masonry sand grout mix proportion JGJ/T 98-2010 [14]. Fine aggregate are pure NS, mixed sand made by 50 percent pure NS adding 50 percent artificial sand of IOT and pure artificial sand of IOT. The compressive strengths of sand grouts are acquired at 3rd days, 7th days and 28th days, respectively. Here, fine aggregates sieved off size range of IOT from 0 to 0.3 mm are called as artificial sand of IOT. Mix proportions are shown in table 2.

Table 2 Mix proportion of sand grout

Sample		Cement/kg	Nature sand/kg	IOT/kg	Water/kg
S_1	S_{11}	180	820	0	150
	S_{12}	180	410	410	150
	S_{13}	180	0	820	150
S_2	S_{21}	240	760	0	180
	S_{22}	240	380	380	180
	S_{23}	240	0	760	180
S_3	S_{31}	290	710	0	192
	S_{32}	290	355	355	192
	S_{33}	290	0	710	192
S_4	S_{41}	340	660	0	196
	S_{42}	340	330	330	196
	S_{43}	340	0	660	196
S_5	S_{51}	380	620	0	192
	S_{52}	380	310	310	192
	S_{53}	380	0	620	192

Results and discussions

Raw material composition analysis

Chemical compositions of IOT and NS are shown in table 3:

Table 3 Main chemical composition of raw materials %

Samples	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	**Fe_2O_3**
IOT	0.14	1.52	17.18	51.51	4.89	0.65	**16.20**
NS	3.83	0.79	13.45	70.00	3.53	1.67	**1.79**

XRD spectrums of IOT and NS have been shown in Fig.1 and Fig.2 respectively.

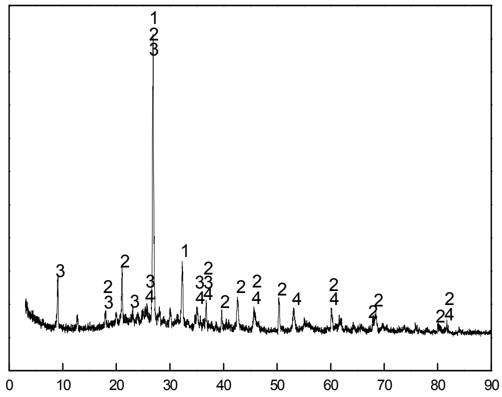

Fig.1XRD spectrum of IOT

1—Merrihueite **（K,Na）$_2$（Fe,Mg）$_5$**
2—Quartz **SiO_2**
3—illite **$(K,H_3O)Al_2Si_3AlO$**
4—Wollastonite **$CaSiO_3$**

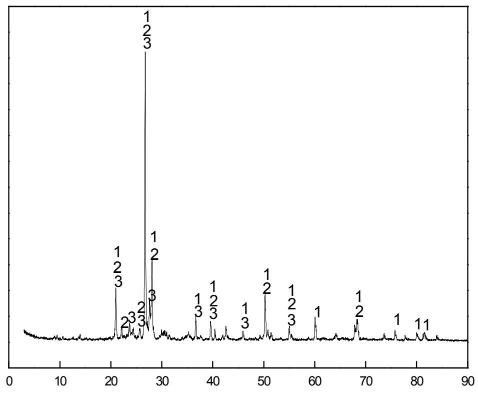

Fig.2 XRD spectrum of NS

1—Quartz,syn **SiO_2**
2—Albite,calcian,ordered **（Na,Ca）Al_2（Si,Al）$_3O_8$**
3—Microcline, intermediate **$KAlSi_3O_8$**

Main chemical composition and content of IOT are comparable to those of NS. Amounts of silicon and alumina elements are predominant in two kinds of raw materials. A significant difference is ferrous element, accounting for about 17 percent in IOT, and yet only 1.79 percent of NS. Mineral composition analysis shows that both of NS and IOT contain large amounts of quartz (74 percent of NS and 67 percent of IOT).There are about 7 percent of Merrihueite in IOT different from NS, while 30 percent of feldspar minerals are detected in NS. In general, it is possible for replacement of IOT to NS duo to no activity of mineral compositions in IOT.

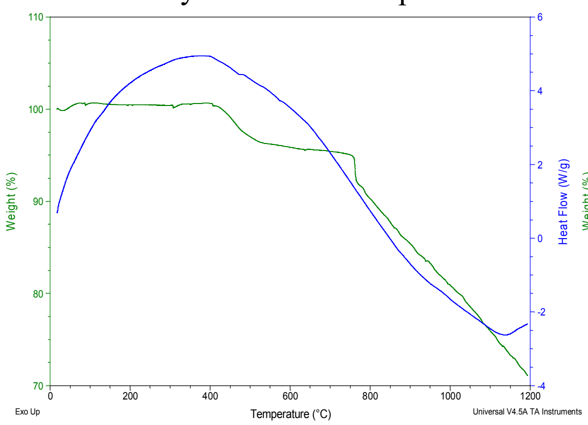

Fig.3Thermal analysis curves of IOT

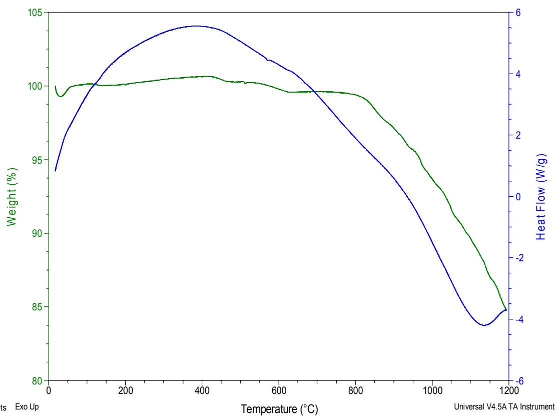

Fig.4 Thermal analysis curves of NS

Fig.3 and Fig.4 show that the heat change process between IOT and NS is similar from room temperature to 1100°C.Phenomena of obvious mineral phase transition have not been observed. Mass of IOT keep constant before 400°C,slightly reducing about 5 percent of the mass after 400 °C. Great mass loss occurs beyond 800°C. Mass stability of NS is similar to IOT below 400°C. Mass loss with 2 percent of NS is comparable to IOT at about 400°C-800°Cand then increase steeply after 800°C.From the above thermal analysis curves, it can be known that heat stability of IOT fall slightly compared with NS, yet almost omitted. Heat stability of IOT can meet the needs of sand grout and concrete.

Particle size distribution of IOT

With references of “the construction sand "GB/T14684-2011, we determine of the iron tailings and fineness modulus, comparing with NS, ISO standard sand.

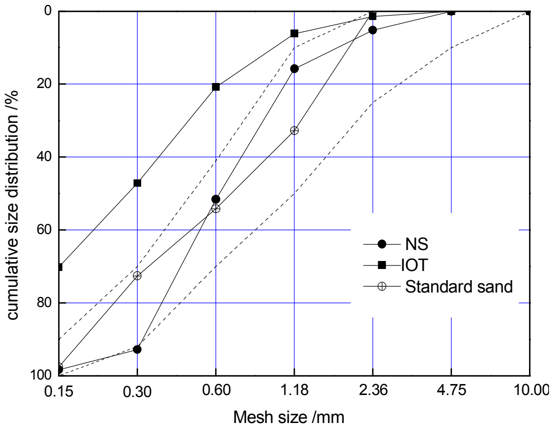

Fig.5.1 IOT, NS and standard sand

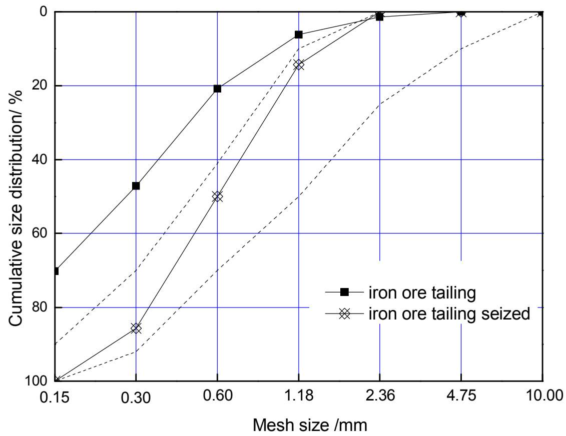

Fig.5.2 raw IOT and artificial sand from raw IOT partially seized off finer powders

Fig.5 Size distribution curve

Figure 5.1 shows that compared with standard sand and NS in Ⅱ size distribution region, the particles size of IOT are divided to five ranges of size distribution: 0~0.3 mm, 0.3~0.6 mm, 0.6~1.18 mm, 1.18~2.36mm and 2.36~2.36 mm. Mass percent of particles are 52.8%,26%,14.6%,4.8% and1.4% in the five ranges respectively. The results indicate that IOT are characteristic feature of I size distribution region and fineness modulus is only 1.46 due to higher particle content at range of 0~0.3mm in IOT than NS. Smaller particles in fine aggregate usually may lead to many disadvantages such as higher water demand, worse mechanical properties, and lower resistance to environmental medium corrosion and so on. It is necessary that size distribution of IOT as aggregate should be adjusted by sieving out partial grain of 0~0.3mm. New size distribution curve relocated at II region shown from figure 5.2 reveal that IOT handled, called as artificial sand of IOT, acquire similar size effect with NS and fineness modulus is increased to 2.49.

Mechanics and shrinkage analysis of IOT sand grout

Suitable strength and size stability are required for sand grout with artificial sand of IOT due to their engineering application. In this study, strength development and size shrinkage change of sand grout with different fine aggregates were investigated.

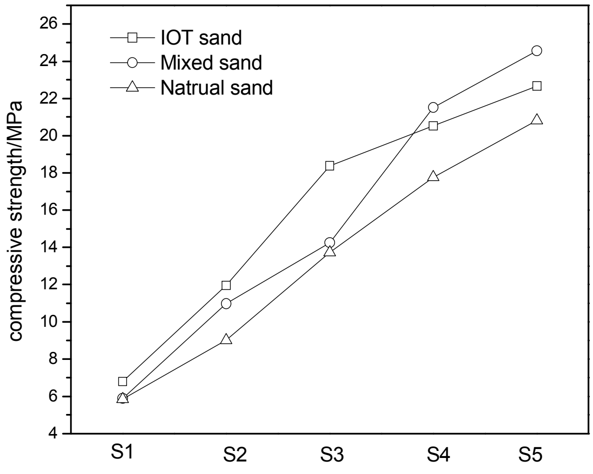

Fig.6 Variation of compressive strength

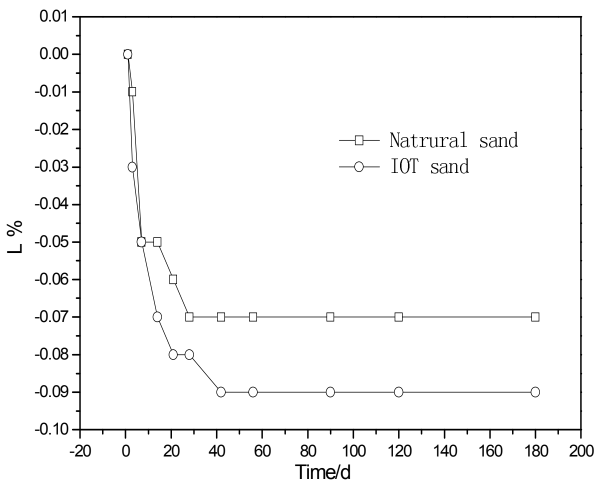

Fig.7 Variation of size shrinkage

Fig.6 shows the strength development of sand grouts. From the histograms in the figure, it can be seen that with the increase of cement, compressive strength of sand grouts with three kinds of fine aggregates increase. Under the condition of the same amount of cement, sand grout with NS always show lower compressive strength. Replacement of Artificial sand of IOT and mixed sand to NS lead to obvious growth of strength at the 28th day.

The results of compressive strength indicate that shape and particle size of IOT should be responsible for the change of mechanics properties. The growth of compressive strength can be attributed to the fact of more complex shape observed on the surface of IOT than NS. In this cementitous system, more cohesive region between cement hydration and IOT are formed due to special shape of IOT and finally make the cement paste compacted. Another reason resulted in growth of strength is some ferrous minerals in the IOT. It can enhance solidness of IOT and improve mechanical properties of sand grout. From Fig.6, sand grout with IOT as fine aggregate regarding lower strength, may be show higher strength and sand grout of mixed sand can be subjected to more load for requirement of higher strength.

Fig.7 is a representative curve showing the effect of IOT on size stability of sand grout. It can be seen that size of sand grout with the two kinds of fine aggregates embody different stability under nature environment of laboratory as size distribution of IOT is adjusted to particle range of NS. With the prolongation of time, the shrinkage value of sand grout with NS increase quickly to 0.07 percent of initial sample at 28th day and then tend to slow development.

Size reduction of sand grout specimen with IOT develops rapidly until 40th day with shrinkage of 0.09% a bit higher than NS. Due to similar size distribution between IOT and NS for the test, it is an important factor for influence of particle morphology on size stability. Morphological feature of IOT may be associated with the increase of shrinkage. More edges and corners on the surface of IOT than NS increase water requirement of sand grout for suitable workability. Therefore, size of sand grout with IOT show more negative variation. However, the change with time can be endured for application of sand grout.

Conclusions

Based on the above investigations, the following conclusions can be drawn.

1) Both of IOT and NS have similar chemical composition, including silicon and aluminum element, except more iron element in IOT. Quartz minerals play a predominating role in two kinds of materials. Two kinds of fine aggregate have similar thermal stability before 400℃.

2) IOT contains more fine powder and complex surface than NS. IOT should be sieved out partial fine granules and make size of IOT close to NS for application.

3) Compared with NS, sand grout with replacement of IOT to NS can significantly improve compressive strength and slightly increase size shrinkage of sand grout.

References

[1] Wanzhong Yin, Lixia Li. Comprehensive utilization of tailings and management of tailings pond [M]. Beijing：Metallurgical Industry Press, 2009:1-2. In Chinese.

[2] Liqing Zhang, Linyan Zhao, Huafeng Zhou. The extraction from rare earth tailings for calcium and the preparation of GDF. Zhongnan University (Natural Science), 2003，(44):32-37.In Chinese.

[3]Jinqiu Xu, Fangji Li, Xinglan. Bastnaesite and monazite flotation tailings recycling[J].Rare earths, 2006, 27(5): 67 −72. In Chinese.

[4] Shiwei Huang, Yanyan Li, Cheng Lin. Unburned brick from steaming preparation from meishan iron tailings［J］.Metal Mine, 2007(4):41-44. In Chinese.

[5] Qiang Yang, Yun Tang, Anrong Liu. A study of pyrite Tailings experimental study[J].Metal Mine，2010(02)：163-170. In Chinese.

[6]Yingcan Wang, Qiong Na. Iron tailings preparation of lightweight insulation building materials[J].Metal Mine,2007(05)： 75-77. In Chinese.

[7]Zhi Li, Qichun Zhang, Qiaominge Ye. Pyrite tailings preparation of glass [J]. Multipurpose Utilization of Mineral Resources. 2007(01) :42-45. In Chinese.

[8]S. M. Adedayo , M. A. Onitiri. Journal of Minerals and Materials Characterization and Engineering, 2012, 11 (07):671-678.

[9]Chunli Bi, Xiao Qi, li Zhang. Industrial residues in concrete[J].Concrete,2005(12):71. In Chinese.

[10]Mingtang Tang, Wenhao Pan. Strength characteristics of ceramic wastes instead of sand in preparation of concrete.Concrete,2007(12):1-3. In Chinese.

[11] Liang Hu, Zhiyong Xu, Wenwu Zhang. The application of steel slag composite powder in the composite concrete products [J]. Commercial Concrete, 2011(08):42-43. In Chinese.

[12] GB 6566-2010, Building materials radionuclide limits[S]. Beijing：Standards Press of China, 2010. In Chinese.

[13] GB/T14684-2011, Building sand[S]. Beijing：Standards Press of China, 2011. In Chinese.

[14] JGJ/T 98-2010, Masonry sand grout mix design procedures [S]. Beijing：Standards Press of China, 2010. In Chinese.