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Research Article

Effect of Fine Food Mineral Dosage on the Properties of Cemented Backfill Material

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Abstract: Properties of Cemented Backfill Material (CBM) are highly affected by the gradation of food mineral the main components of the material. This study is concluded that with the increase of fine food mineral rate, the slump and divergence of fresh mixture increase firstly and then decrease and the maximum values were got at 50%, the bleeding rate approximate linear decrease. Cube compression strength for different ages decrease firstly and then increase with the increase of fine food mineral dosage, however, shrink ratio shows opposite trend, the maximum for the former and the latter are obtained at 40% and the variation of porosity explain those trend. Based on tests, the slump, slump extension, bleeding rate, cube compression strength and shrinkage of different ages were determined to evaluate the workability, mechanical property and deformation properties and the porosity was measured by mercury intrusion porosimeter to explore the relationship between the dosage of fine food mineral and the properties of binder backfill material.

Keywords: Fine food mineral, mechanical property, shrinkage property, working performance

INTRODUCTION

Cemented Backfill Mining (CBM) is a mining technology which is mix cementitious materials, solid waste produced in mining and water in a proportion, then fill into the gob to alleviate the collapse and subsidence of rock and provide a working place or act as an artificial roof. Presently, for food mining, cement and fly ash are used as cementitious materials and food mineral is used as aggregate. Because food mineral account for 70% of bulk volume, its physical characteristics, such as strength, particle size, shape and gradation have a great influence on the properties of backfill material (Shuguang *et al*., 2006). The related research about CBM mostly focus on mix design related to cementitious materials (Zhang *et al*., 2012) rather than food mineral which only be treated as waste.

Research method about the influence of aggregate on concrete can be used to study the influence of food mineral on properties of CBM, due to the component of cemented filling material is similar to concrete. In concrete industry, sand that diameter less than 5 mm is known as fine aggregate, crush stone that diameter greater than 5 mm as coarse aggregate (Jianzhuang *et al*., 2014) and the mass ratio of sand of sand to sand and crush stone is called sand ratio which is one of the three basic parameter of design (Wang and Ai, 2002). There is an optimal sand ratio for different proportion because the change of sand ratio will significantly improve material porosity and total specific surface area of aggregate, then affects the performances of concrete, especially for the fresh concrete. Obviously, the dosage of fine aggregate has an effect on the properties of CBM and there is an optimum dosage of fine aggregate for food mineral aggregate based CBM. The suitable content of fine food mineral can optimize the aggregate gradation and structure, refine pore size, decrease porosity, consequently, enhance the strength and decrease shrinkage value. Centroplasm hypothesis perfectly explain how the content of fine aggregate effect shrinkage value of CBM.

MATERIALS AND METHODS

Ordinary Silicate cement with flexural strength of 6.5MPa and 28d and compressive strength of 48.0MPa was used in this study.

Fly ash: Second grade fly ash produced by power plant of Fenxi mining Group Corporation was used in this study, which with fineness of 45μm, square hole sieve residue of 28.6%, loss on ignition of 3.7% and water content 0.58%.

Food mineral: food mineral used in this study was obtained from Xinyang food mine, Fenxi mining group, which was reprocessed to create two grain size grades corresponding to fine aggregate with particle size of 0-5 mm and coarse aggregate with particle size of 5-15 mm, respectively.

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Table 1: Experimental results

	Workability			Mechanical property				Deformation properties						
				Cube compressive strength/MPa				Shrinkage value/µm						
Serial number	Slump /mm	Slump extension /mm	Bleeding rate /%	3d	7d	14d	28d	1d	3d	7d	14d	28d	60d	90d
G1	210	370	9.21	0.30	1.77	3.53	5.37	97	183	251	297	390	514	659
G2	220	420	8.58	0.47	1.87	3.57	5.57	65	170	217	270	364	497	634
G3	240	425	7.76	0.90	2.10	3.80	5.93	47	123	193	243	331	449	607
G4	260	440	7.13	0.53	1.90	3.57	5.30	63	165	203	264	359	485	630
G5	235	420	6.17	0.33	1.60	3.43	5.37	81	187	228	283	378	503	649

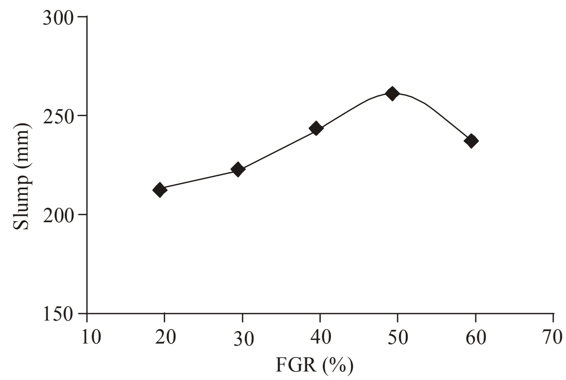

Fig. 1: Slump-FGR

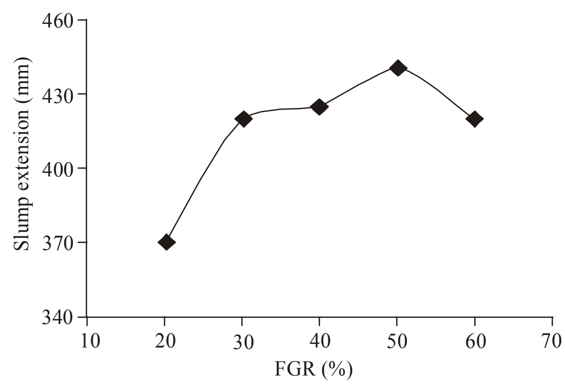

Fig. 2: Slump extension-FRG

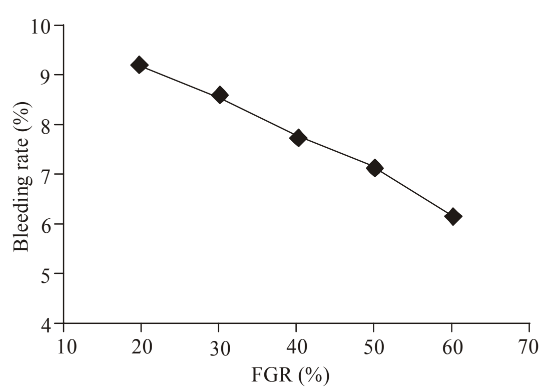

Fig. 3: Bleeding rate-FGR

Water: Tap water was used.

According to the preliminary test, the mass ratio of water: cement: fly ash: mineral is 2:1:2:6.3, fine mineral rate were 20, 30, 40, 50 and 60%, respectively and the corresponding number followed by G1, G2, G3, G4 and G5.

Test content and method:

- Slump, slump extension and bleeding rate were tested in accordance with the Standard Test Method for the Performance of Ordinary Concrete (GB/T 50080-2002).
- The compressive strength was tested in accordance with the Standard of Mechanical Properties of Ordinary Concrete (GB/T 50081-2002) and the cube specimen of 100mm×100mm×100mm was adopted.
- The performance of the dry shrinkage was tested in accordance with Standard for the Long-term Performance and Durability of Ordinary Concrete (GBJ 82-85). Prism specimens of 100mm×100mm×40mm were made with steel modules and cured for 2d in a standard cure room, then, demoulded and transferred to a room with constant temperature and humidity. Specimens were fixed on shrinkage frame made by ourselves, adjusting the dial mineral to a suitable position and set to zero, record deformation values, at 1, 3, 7, 14, 28, 60 and 90 days, respectively. The results are shown in Table 1 the effect of fine mineral ratio on the working performance.

Figure 1 to 3 shows the trend of slump, slump extension and bleeding rate for different aggregate gradation of paste.

RESULTS AND DISCUSSION

It can be found that with the increase of fine food mineral rate, the slump and slump extension of fresh mixture increase firstly and then decrease when the total weight of cementitious materials, water and aggregate are constant.

In that case, fine food mineral content is too small to sufficiently fill the porosity between larger size food mineral to form effective lubrication layer and the friction resistance of coarse particles is so large that the mixture has a poor fluidity, lower slump and divergence. With the increase of fine mineral ratio in certain range, gradation relationship between aggregate is improved (Maoxue, 2011) and lubrication of slurry become more and more obvious which reduced friction between the coarse aggregate, therefore, the slump and slump extension of fresh mixture increases. With the dosage increase of fine mineral, total surface area of aggregate increases. However, dosage of water and cementitious materials are constant. When the content of fine mineral is more than a specific value, water used to wet fine aggregate surface and slurry to encapsulate fine aggregate surface are insufficient, the mixture become dry and sticky which decrease the workability.

In Fig. 3, the bleeding rate of paste shows a downward trend with the increase of FGR. The reason is that there are some pores connect to surface in food mineral, water can not only stay the surface of the aggregate particles forming the water film but also enter the inside of aggregate particle that means food mineral is of water-retaining property (Fall *et al*., 2010). The more the content of fine aggregate is, the larger the tall surface area of aggregate is, therefore, more water was absorbed inside and kept on surface of food mineral resulting in a reduction in the rate of bleeding.

The effect of fine mineral ratio on mechanical properties.

Figure 4 shows the compressive strength change trend of CBM in different ages with FGR changes. It can be found that with the change of FGR, the cube compressive strength in different ages increase firstly and then decrease. That is because that the total content of food mineral is constant, if the FGR is less, the coarse aggregate content is more, in this case, fine aggregate is not sufficient to fill up the pore between coarse mineral, resulting in poor compactness and low strength of CBM. With the increase of FGR, the compactness is improved and the strength increased. When the rate of fine mineral continually increase, the overall specific surface area of paste increase, leading a serious shortage of slurry and weakening of chemical coagulation generated by hydration reaction of the cement particles and physics condensation effect, so the strength decreased. It can also be seen that both early and later strength are obviously higher in the FGR of 40%.

CBM, as concrete, is also a kind of porous media material and the content of pore, pore size distribution and porosity have a direct influence on the performance of its Porosity and pore size distribution of samples with different fine mineral rate were measured by mercury intrusion method after care of 28 days to explore the relationship between its pore changes and the compressive strength for different fine mineral rate (Fig. 5). It can be detected that with the increase of fine

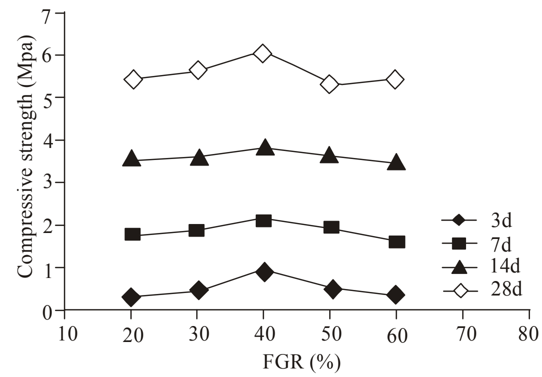

Fig. 4: Compression strength- FRG

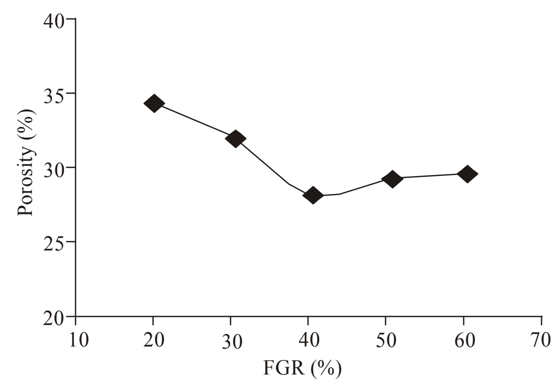

Fig. 5: Porosity-FRG

mineral rate, porosity reduced drastically and when fine mineral rate increase to 40% the porosity reach the lowest point and after that there is a slight increasement. This trend fit in with the change trend of compressive strength with FGR, which means that the increase of FGR resulting in the porosity change in the internal CBM and then cause the change of strength, that is, the greater porosity is, the lower strength is (Fig. 6). Moreover, in Fig. 7, the distribution of pore size changes with the change of FGR. When fine mineral rate is low, average pore diameter is larger for the high content of larger aperture resulting in a lower strength. Therefore, the compressive strength of CBM can be improved by changing the pore structure and reducing the porosity.

The effect of fine mineral rate on deformation performance.

The effect of FGR on the deformation properties of CBM can be attributing to the variation of porosity and "effective zone" caused by the change of FGR. Figure 8 shows the trend of shrinkage value.

It can be found that with the increase of FGR, the shrink value of CBM decrease firstly and then increase and when FGR increase to 40% the minimum of shrink value was got. The reason is as follows: The increase of FGR improves the aggregate gradation then aggregate with good gradation bear a part of shrinkage stress and constrain shrinkage of cement paste. In addition,

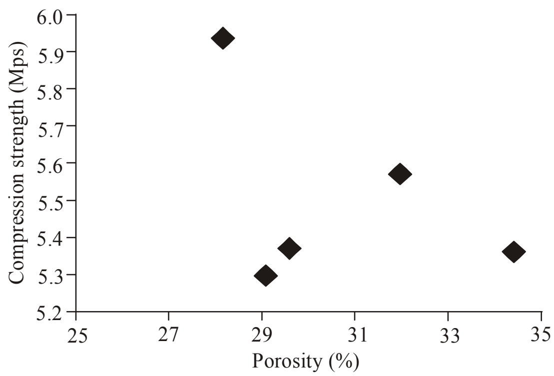

Fig. 6: Compression strength-porosity

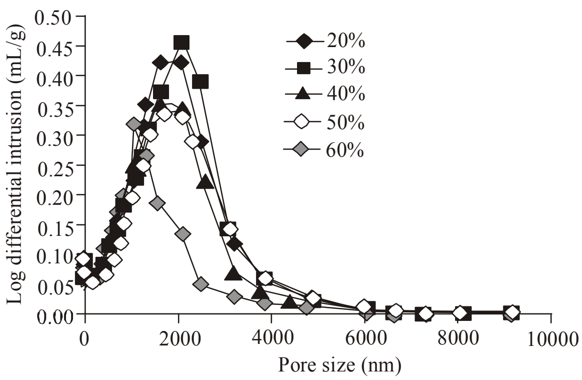

Fig. 7: Compression strength-pore size

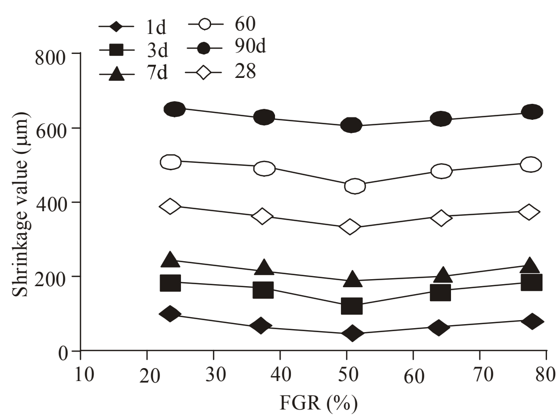

Fig. 8: Shrinkage value- FGR

aggregate with good gradation can form a more compact spatial structure and reduce the shrinkage of the paste by reducing porosity. But as the rate over 40%, the shrink ratio of CBM increase as the increase of FGR, the reason is that interface between slurry and aggregate is not a "face", but a "transition layer" structure with the thickness of 0~10 μm. This "transition layer" is come from the water-binder ratio gradient which forms in the process when the water of slurry transfers to the surface of the aggregate. The water-binder ratio on the aggregate surface is the largest and then decreases gradually from the surface to the system of cementitious materials slurry until reach the value of the cement paste. In the same conditions, the thickness of “transition layer” between single aggregate and the interface of the paste varies with the change of aggregate surface area and the aggregate with smaller size is of smaller transition layer. According to the centroplasm hypothesis, there is a transition layer between the centroplasm and the medium at any levels, the structure, composition and performance outside of the centroplasm are all belong to the transitional layer. In CBM, aggregate is large centroplasm, it will have physical and chemical effect on surrounding medium(slurry), such as adsorption, combination, bonding, strengthening, that is so called “large core effect” and its influence scope is “effect circle”. Transition layer is a part of the “effect circle”, favorable “large core effect” can not only improve the size and structure of transition layer, but also make the large particles inside the transition layer have some performance the large centroplasm owned , which is beneficial to improve improve the macroscopic behavior of CBM. In the case of a smaller FGR, coarse aggregate content is larger, so the transition layer is thicker and the “large core effect” is stronger. Although there are much weak links in the thicker transition layer, they are in the range of “effect circle” of “large core effect”. So the damage effect is weakened due to the favorable effect of the large centroplasm and shrinkage ratio of CBM is relatively small. With the increase of fine mineral rate, the content of coarse aggregate decrease, the “large core effect” and the skeleton function of food mineral are weakened, so shrinkage value increases (Fig. 8).

CONCLUSION

The dosage of fine food mineral have greater influences on working performance, mechanical properties and deformation properties of CBM and there is a optimal fine food mineral ratio that make all of the performance of CBM is good. In this study, the ratio is 40%, which is consistent with that of concrete. Refer to the research method for concrete, the percentage of fine food mineral that diameter less than 5mm in the total mass of food mineral is named Fine Mineral Ratio (FGR), the work performance, mechanical properties and deformation properties of CBM with different FGR were studied by test and the porosity was measured by mercury intrusion porosimeter. Based on these, effect of fine food mineral dosage on the performance of CBM was explored and the optimum fine mineral was suggested which is contribute to the effective utilization of food mineral in cemented backfill mining.

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