PROPERTIES OF SHALE ASH (TAKEN FROM THE BOILING FURNACE) PORTLAND CEMENT

Han Zhongpu (韩忠普)*
(Engineering Construction Technology Institute of Petroleum Industry Ministry, Tianjin, China)

Xiao Qihai(肖其海)
(Maoming Petroleum Industrial Corporation, SINOPEC, Maoming, China)

ABSTRACT

The properties of shale ash taken from the boiler furnaces in Maoming and the characteristics of shale ash portland cement containing the Maoming shale ash, as an admixture, are investigated systematically in this paper.

Through the physical and chemical test, we have obtained the high quality shale ash admixture thaken from boiling furnace at burning temperature of 850℃ to 950℃. The cement with 30% shale ash content possesses the following features. The compressive strength ratio may reach to 75%, it increases about 10% as compared with the reburning shale ash commonly used by Maoming. The coefficient of antichemical attack increases 50% as compared with the controlled specimen; the drying-shrinkage value increases slightly; the water retentivity is excellent; non-corrosiveness to steel reinforcement;more fast strength development in later stage.

INTRODUCTION

It is most effective that low calorie fuels, such as Maoming shale ash, are burnt and activated hotly in boiling burning furnace for the effective use of shale ash in producing shale ash portland cement because the boiling burning furnace (or boiling furnace) may

---

* The research workers of the project are: Qan Juzhen, Cui Lianmin, Lin Xian, Yu Jie, Xu Zhihua.

accelerate the burning process of fuels, the internal temperature and burning period in the furnace can be controlled.(1)

MATERIAL AND EXPERIMENT

The boiling furnace shale ashes burnt at 760℃, 860℃, 920℃, fly ash and coal spoil used for contrasting, are adopted here. The material and its specific properties are shown in table.

The pozzolanic activity of shale ash are tested in accordance with ISO method. The compressive strength test of shale ash mortar is carried out according to ratio of 1: 2.5 mortar specimen. The water quantity requirement of normal consistency is controlled by keeping the fluidity within 125-135 mm. Cement strength test is done with 1: 2.5 mortar specimen. The water quantity requirement of normal consistency is controlled by keeping the fluidity no less than 116 mm. The coefficient measurement of antichemical attack test is according to ratio of 1: 2.5 mortar (w/c=0.5), the 10×10×60 mm specimen is immersed in 3% Na_2SO_4 solution.

RESULT AND DISCUSSION

Maoming oil shale containing 85-88% clay minerals is mainly kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$). Kaolinite has disappeared at 760℃-920℃, and does not appear corresponding new crystal phase, therefore, it is known that it has changed as a non-definite form meta-kaolinite ($Al_2O_3 \cdot 2SiO_2$), this is source of pozzolanic activity. The main chemical composition of shale ash is SiO_2 and Al_2O_3, the sum of the both minerals is over 80%, but some kinds of shale ash abroad contain calcium oxide over 30%(2) Passing through the standard ball mill for 10 minutes, its specific surface area reaches 12000 cm^2/g, it is of fine grindability. The specific density and bulk volume density of shale ash increases as the burning temperature increases, but on the contrary the water quantity requirement of normal consistency is decreased along with the increase of burning temperature. The pH value increases towards alkalinity as CaO content increases. The plasticity of shale ash is as good as clay.

Specific properties of material studied Table 1

Item	760℃ shale ash	860℃ shale ash	920℃ shale ash	Maoming clinker	LiTang clinker
SiO2 (%)	59.45	60.64	61.31	20.21	21.07
Al2O3 (%)	22.46	20.09	20.16	6.71	6.79
Fe2O3 (%)	10.69	11.89	9.63	4.02	4.41
CaO (%)	0.73	1.29	2.94	63.44	63.60
MgO (%)	1.25	0.83	1.09	3.55	1.82
SO3 (%)	0.38	0.61	1.36	0.43	0.71
L O I (%)	1.57	0.55	1.05	0.62	0.52
Crystal phase compositions	quartz feldspar mica hematite	the same as left	the same as left	C3S 49.15% C2S 20.86% C3A 10.97% C4AF 12.22% f CaO 1.09%	36.83% 32.60% 10.52% 13.41% 2.11%
Specific gravity (g/cm³)	2.62	2.63	2.67	3.13	3.13
Specific surface area (cm²/g)	12200	12100	11200	2990	3070
Water quantity requirement of normal consistency(%)	55	53	53		
Plasticity index (%)	10.9	-	10.4		

Crystal phase composition of Maoming oil shale:
quartz 3%
pyrite 3-5%
mica 1-3%
carbonate 1%
clay mineral 85-88%

Fig 1 represents that the boiling furnace shale ashes burnt at different temperature are of the pozzolanic activity when they are maintained 7 days at 40℃.

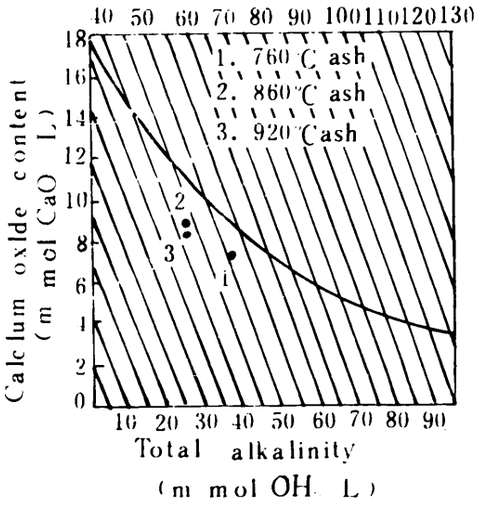

Fig 1. Pozzolanicity test for shale ash cement (P/C=30/70) BY ISO

The compressive strength ratio test of shale ash cement mortar for 28 days represents: the compressive strength ratioes of the pure cement containing 30% Maoming boiling furnace shale ash content which they are burnt at 760℃, 860℃, and 920℃, are respectively 71% 72% and 75%, the compression strength ratio of Maoming shale ash burnt generaly in stacking form is 63%, and that of coal spoil and fly ash is 68%. Therefore, the boiling furnace shale ash cement strength increases 10% as compared with ordinary shale ash cement. The best burning temperature of boiling furnace shale ash is at 900℃, thus, we can get a high-quality shale ash admixture(3).

Fig 2 shows the basic properties of boiling furnace shale ash cement. The cement specimen consists of Maoming pure cement and 860℃ shale ash. The specific density, bulk volume density, mortar compressive strength of this cement decreases as the content of the shale ash increases. The setting time has a little change as the shale ash content increases. The water quantity requirement of normal consistency and water-cement ratio increases as shale ash content increases. The shale ash cement contains 30% shale ash content, for exemple, the water quantity requirement of normal consistency is 32%, the water-cement ratio is 0.49, the 28 days strength is 89% times as large as pure cement. The heat of hydration of the cement decreases as shale ash content increases. These have the same heat of hydration as ordinary pozzolanic ash cement. The coefficient of antichemical attack of shale ash cement reaches the biggest value as shale ash content increases (the coefficient of antichemical

attack is 166% as shale ash content is 40%), it decreases slightly in later. The boiling furnace shale ash cement has good sulphate resistance.

The results of the bleeding test of the shale ash cement are shown in Fig 3. The bleeding ratio is very small (about 1%) as the cement contains shale ash content over 30%, it is much less than fly-ash cement and coal spoil cement. It can be considered that shale ash cement will suit construction technology process of all cement and concrete needed the better water retentivity.

The dry-shrinkage test of shale ash cement are shown in Fig 4. The specimen tested consists of Litang pure cement and 760℃ shale ash which its water quantity requirement of normal consistency is a little more. The dry-shrinkage value of 6 months old hydrated cement mortar with 20% shale ash

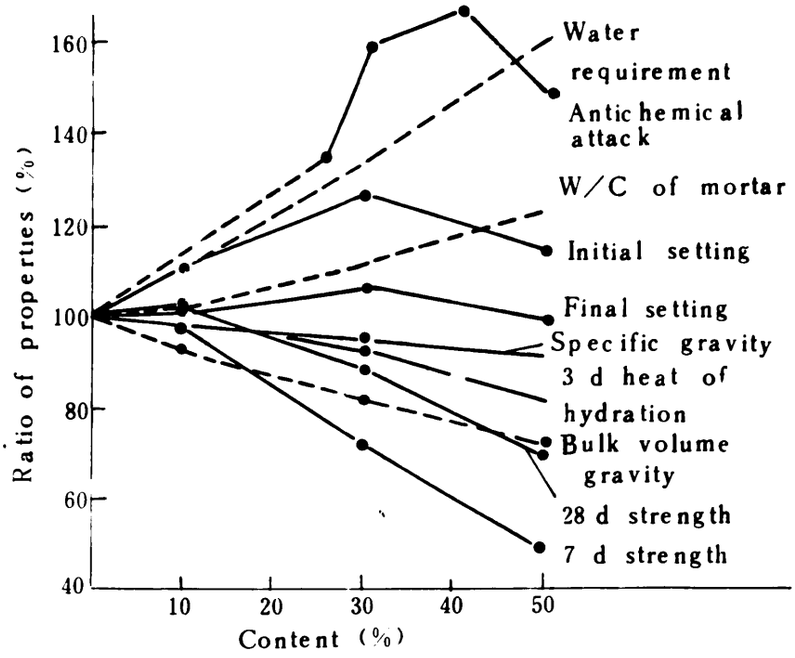

Fig 2. Curves of 860℃ shale ashes for the properties of shale ash cements

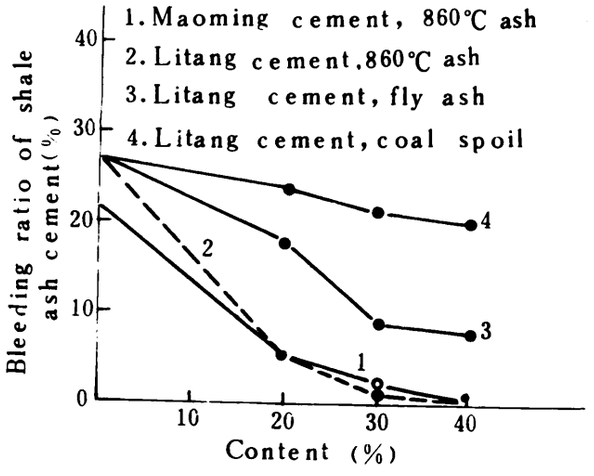

Fig 3. Relations of shale ash contents for the bleeding ratioes of cements

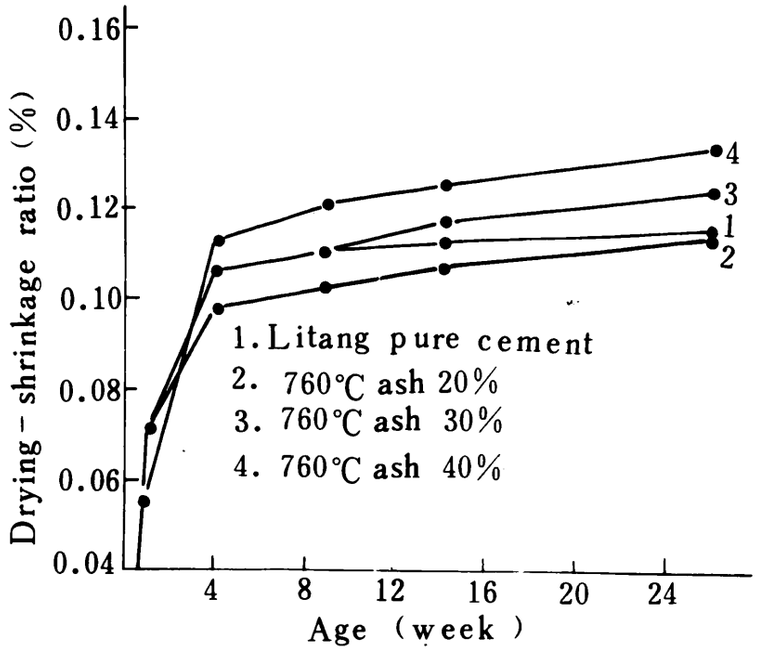

Fig 4. Relations of the drying-shrinkage ratios of shale ash cement mortar for time

content is the same as pure cement. The dry-shrinkage value of 6 months old hydrated cement with 30% shale ash content is -0.124%, but pure cement is -0.116% at the same condition, the cement with 30% shale ash content is a little more.

The carbonation and corrosive test of shale ash cement mortar proves that passing through one year old dry-humid cycle, the shale ash cement containing 760℃ shale ash and Maoming pure cement, and the coal spoil cement (it is a high-quality pozzolanic cement tested for long time) are both the cements of non-corrosive to steel reinforcement. The carbonization depth for one year old hydrated shale ash cement with 30% shale ash content and the coal spoil cement with 30% coal spoil content are within 2.5-3.0 mm, the both are similar.

The concrete tests of the shale ash (boiling furnace ash) cement prove that shale ash cement containing 30% 860℃ shale ash content and 70% Maoming pure cement content may be designed for 30 MPa strength concrete, its impermeability is more than 1.2 MPa. Therefore it has higher impermeability and denseness, and can be applicated in hydraulic structure construction.

CONCLUSION

1. A series data are provided in this paper, it provid for reference for the produce and application of oil shale ash (from boiling furnace) and shale ash portland cement.

2. The best controlled temperature of Maoming boiling furnace oil shale ash is 850℃-950℃. Thus, we can get a high-quality pozzolanic admixture.

The specification quota of boiling furnace oil shale ash is defined: loss on ignition is less than 2%, the compressive strength ratio is no less than 70%, pozzolanic activity test and SO3 content percent is in keeping with GB2847-81.

3. It is benefit for reducing costs, ensuring quality, increasing production and extending the market in producing oil shale ash.

REFERENCES

(1) Xue Junxuan etc, translated from "7th Int Cem. Chem. congr. --Selected Thesis" first edition, (in chinese), Construction Industry Publishing House, P307, 1986, Beijing.

(2) W. H. Kikas etc, "Cement" No 11, P 16, 1983, USSR.

(3) Cement Research Institute of Building Material Scientific Academy, "The physical properties and test of cement", (in chinese), 1982, Beijing.

Acknowledgement

Thanks for the senior engineers Huan Langgu. Wu Zhonghu amd Li Xianqin who gave us help for this thesis.