STUDIES ON STRENGTH AND WORKABILITY OF HIGH-STRENGTH AND FLOWING CONCRETE UTILIZING LOW CALCIUM OIL SHALE ASH

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ABSTRACT

The low calcium oil shale ash is nonreactive alone itself, but when it is mixed with cement, the pozzolanic reaction will occur.

Blending the shale ash with cement to make up high-strength and flowing concrete have been studied. The results showed that: for the concrete with same W/C ratio, 20 - 25 % of cement could be replaced by shale ash, while the compressive strength of the concrete could be up to 75 Mpa and increased about 20 % more than that of unblended concrete. For the fresh concrete, workability was improved also, the slump was 170 mm over, and bleeding and segregation were eliminated.

It has been showed that the effect of blended-ash was more markable for the latter period strength of the concrete with lowetr W/C ratio.

Introduction

For the full utilization of oil shale and environmental protection, it is an important aspect to use the ash as building material. Many successful experiences in utilization of high calcium content shale ash, which usually has higher pozzolanic reactivity, have been achieved in some countries.[1-3] While the calcium content of the oil shale ash from Maoming, China, is quite low, only about 0.4-2 % . When the ash is mixed alone with water, the mixture is not cementitious, if it is mixed with portland cement or lime, the pozzolanic reaction will occur.

The object of the present work was to make up high-strength and flowing concrete with the shale ash as blending material of portland cement. The concrete, which should have compressive strength above 60 MPa and slump above 150 mm , could be used in high-story or large span buildings and marine structures extensively. It is made of quality cement with larger unit content, and bleeding and segregation would be often induced when superplasticizer was used to obtain high fluidity. It was expected that the unit cement content could be reduced and the properties of the concrete could be improved by blending the shale ash. The optimum blended amount of the shale ash and the effects of superplasticizer and water-cement ratio on strength and workability of the concrete have been in consideration as well.

Experimentation

To satisfy the requirments of the concrete on strength, fluidity and durability, some design parameters of mix proportion of concrete were selected as follow:

1. Same unit water content was used in any mix proportions of the concrete.
2. Four lower levels of W/C ratio, 0.36, 0.39, 0.42 and 0.45 were determined.
3. For each W/C ratio level, cement was replaced by shale ash in proprotions of 0, 10, 20, 25 and 30 % respectively, while the total amount of binder could be kept unchanged.
4. Superplasticizer was used to obtain larger fluidity, the dosage was about 1.5% by weight of total binder.

In order to measure the fluidity of the concrete, slump test and flow test have both been done. The fluidities of cement motar that blended with shale ash in various blended rates were tested also by jump table method.

The shape of the specimen for compressive strength was cubic, in size of 100 x 100 x 100 mm.

After test in laboratory, the test in situ was carried out in the southern city of China, Maoming. Except the climatic environment, the objects and conditions of the test were substantially similar to the test in laboratory.

Materials

The oil shale ash used in this investigation was obtained from a fluid-bed combustion, its specific gravity was 2.60 g/cm , and the fineness was similar to that of the cement used. X-ray diffraction analysis of the ash showed that the principal present minerals were quartz and feldspar.

The quality of the portland cement used was accordant with the Chinese national standard of 525# Portland cement.

Chemical compositions of the portland cement and the shale ash were showed in Table 1.

Table 1 Chemical compositions of the cement and the shale ash

material	content (%)						
	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	K_2O	Na_2O
cement	57.32	22.70	7.01	4.90	1.61	0.50	1.42
ash	0.45	59.81	20.53	9.89	2.77	2.47	2.50

Results and Discussions

Compressive Strength

Relations between compressive strength of the concrete, which tested after curing ages of 7 and 28 days, and ash-blended rates were showed in Fig.1. In both figures, four relational curves were given according to various W/C ratios. The data were the average strengths resulted from tests in laboratory and tests in situ.

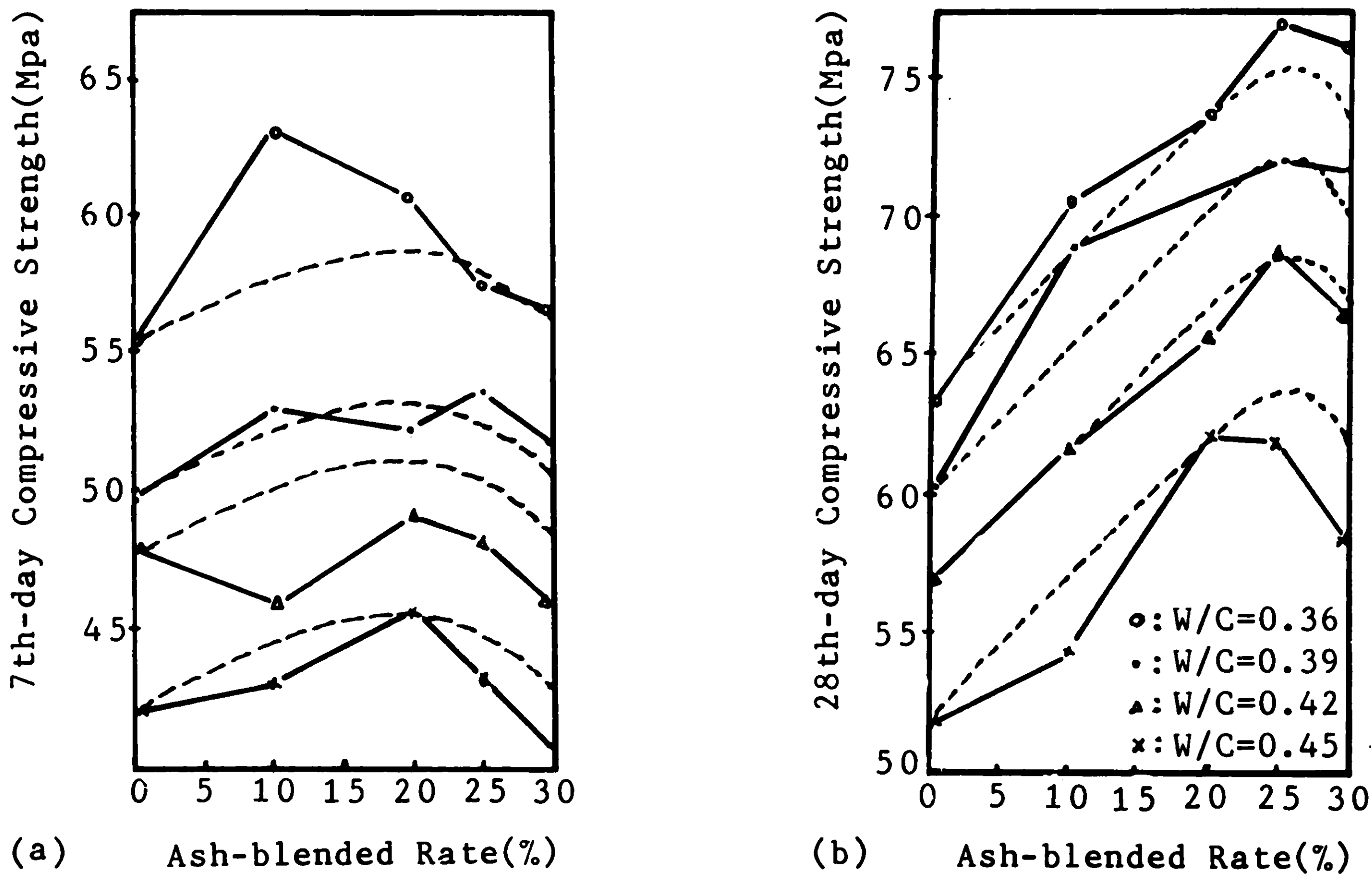

Fig.1 Relations between compressive strength of concrete and ash-blended rate with various W/C ratios

1. As showed in Fig.(1-b), the effect of blended ash was considerable for the 28th-day strength of concrete. The strength was increased with ash-blended rate until it reached a peak almost in any curve when ash-blended rate was about 25 % . In the test range, all of strengths of ash-blended concrete were higher than that of unblended concrete, and the maximum strength in various curves were 20.3, 22.5, 22.4 and 19.2 % more than the strength of unblended concrete respectively.

2. Contrasting above-mentioned situation, the effect of blending ash on the development of 7th-day strength of the concrete was not so similar, as showed in Fig.(1-a). In general, the strength was increased with ash-blended rate as well, but the increase was not as much as that of 28th-day, and there was not a identical ash-blended rate against which the peak occured in every curve. Sometimes, when W/C ratio was higher especially, the strength of ash-blended concrete was lower slightly than that of unblended concrete.

3. In order to sum up the effects of ash-blended rate on the concrete with various W/C ratios, the average strength curves of both ages were showed in Fig.2. The developing trends of the curves were more smooth and explicit than that showed in Fig.1 . The maximum of 28th-day strength was still against ash-blended rate at about 25 % and were 21.1 % more than that of unblended concrete. For the 7th-day strength, a peak occured on the curve as well when ash-blended rate was about 20 % .

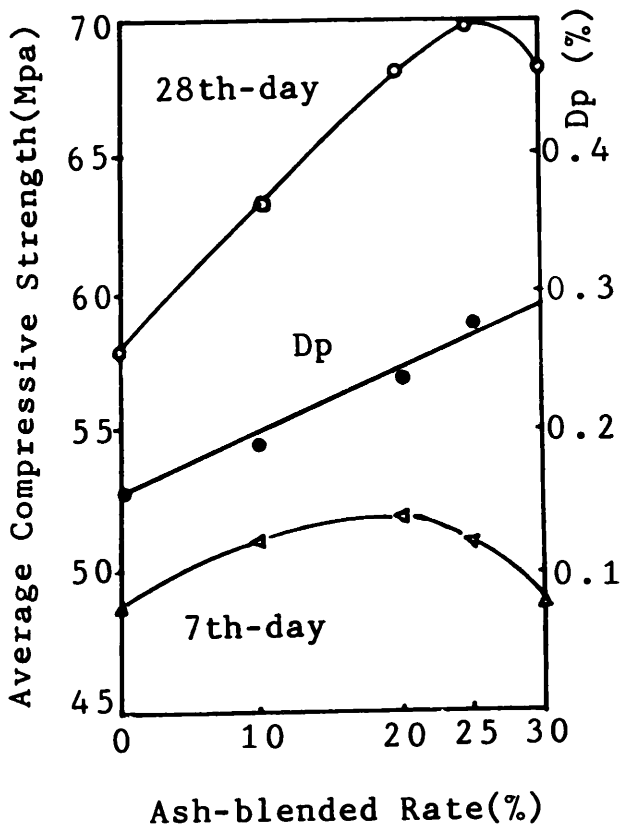

Fig.2 Relation between compressive strength of various W/C ratios of concrete &. ash-blended rate

4. The developing trends of average strengths of the concrete with ash-blended rate, that showed in Fig.2 , were compared with those of the test strength curves in form of dotted line, as showed in Fig.1 . The results showed that the curves which in higher W/C ratios were usually located at the average curve below, especially for young concrete. This might mean that the effect of blended ash was better in low W/C ratio concrete.

5. From results showed in Fig.2 , the relation between strengths of 7th and 28th days might be expressed as formula:

$$Dp = (1 - R_7 / R_{28}) \times 100 \% \qquad (1-1)$$

where Dp was the difference of the average strength percentage of both ages. And the relation between Dp and ash-blended rate was showed as the straight line in Fig.2 . Since the difference was increased in direct ratio with ash-blended rate and the average strength of ash-blended concrete were all higher than that of unblended concrete, it could be said that blend of ash would increase the 28th-day strength of the concrete, and it might explain why the ash-blended rate against which the maximum average strengths occured were different for the concrete tested at different curing ages.

Fluidity and Slump

1. The relations between fluidity of the motar that with various dosage of superplasticizer and ash-blended rate was showed in Fig.3 , the results were as follows:

1) When the ash-blended rate was determined, the fluidity of the motar was increased with the dosage of superplasticizer;

2) When the dosage of superplasticizer was determined, the fluidity of motar was decreased with the increase of ash-blended rate;

3) When the dosage of superplasticizer was less than 0.5 % , the higher the dosage was, the more quickly the fluidity of the motar decreased with increase of ash-blended rate. And when the dosage was more than 0.5 % , the situation was inverse.

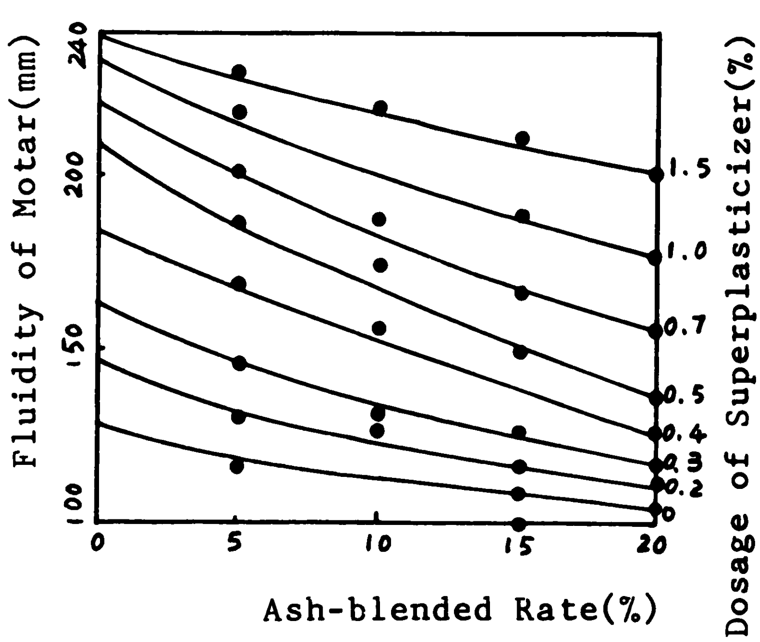

Fig.3 Relation between ash-blended rate, dosage of superplasticizer and fluidity of motar

2. The fluidity test for the concrete with dosage of superplasticizer in 0.5 , 0.7 , 1.0 and 1.2 % by weight of total binder have been done. The results showed that: The fluidity of the concrete with

dosage of superplasticizer less than 1.0 % could not be enough to satisfy the requirement; and although the slump of fresh concrete with 1.0 % dosage of superplasticizer could be over 150 mm generately, but slump would be lost much more quickly than of the concrete with 1.5 % dosage when the same way of addition was used.

3. Relations between slump of fresh concrete and ash-blended rate are showed in Fig.4 . When the blended-ash percentage was less than 20 % , the slump of the fresh concrete could be above 170 mm and had less change with various ash-blended rates, but it could be decreased somewhat with the increase of W/C ratio. If the ash-blended rate was over 20 % , the slump was decreased quickly, and the lower the W/C ratio of concrete was, the more quickly the slump could be decreased. The similar phenomena also occured in flow test, as showed in Fig.5 .

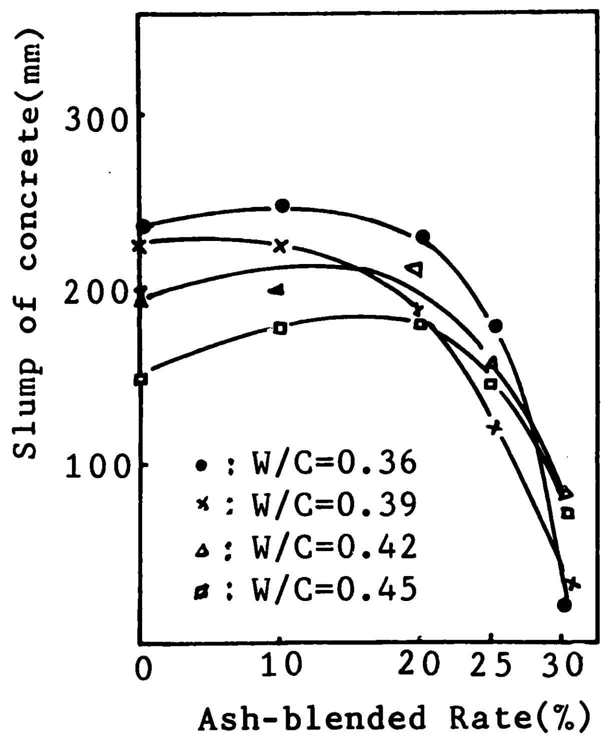

Fig.4 Relation between slump and ash-blended rate of concrete

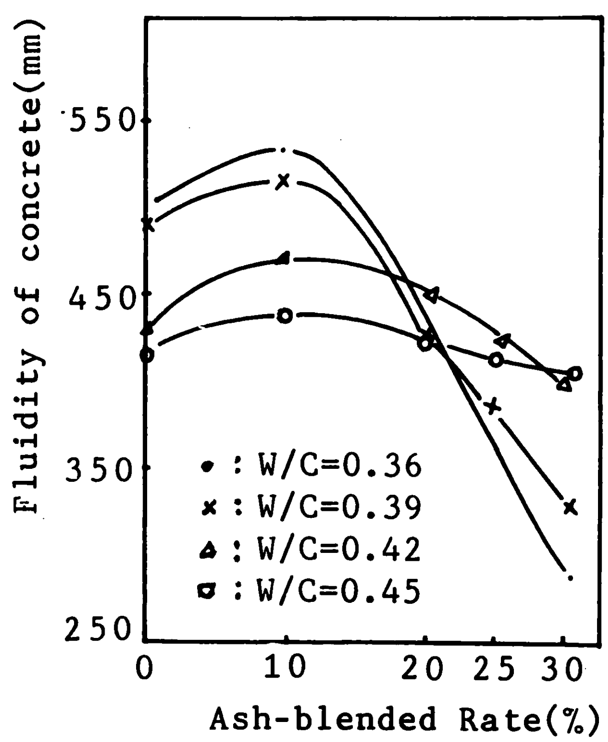

Fig.5 Relation between fluidity and ash-blended rate of concrete

4. Result of slump loss test shows that slump loss was affected greatly by the way of addition of superplasticizer. The effect of multiple addition was better than that of once-through addition, that slump could keep higher value after the concrete have been made for certain time.

Conclusions

1. Low calcium oil shale ash could be used to make up high-strength and flowing concrete. Cement might be replaced by the shale ash less than 30 % , and the strength of concrete, with unchanged W/C ratio, could be raised with larger proportion. The optimum blended amount of oil shale ash was 20 - 25 % by weight of total binder, and in this case the strength of the concrete was about 20 % more than that of unblended concrete.
2. The effect of blended ash was more markable in latter period strength of the concrete with lower W/C ratio. The strength of the concrete could be up to 75 Mpa in present experiment.
3. The bleeding and segregation that usually occured in unblended concrete could be reduced or eliminated by blending ash.
4. By adding superplasticizer, the slump of the fresh concrete with ash-blended rate less than 20 % could be up to 170 mm or more.

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