Pergamon

Cement and Concrete Research, Vol. 26, No. 4, pp. 585-592, 1996

0008-8846/96 $15.00 + .00

PII S0008-8846(96)00030-0

IMPROVING COMPRESSIVE STRENGTH OF CONCRETE BY A TWO-STEP MIXING METHOD

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(Refereed)
(Received June 1, 1995; in final form January 25, 1996)

ABSTRACT

The effects of a two–step mixing method upon the properties of concrete mixtures containing superplasticizing admixtures have been investigated. The processes of this method are described, as are the materials and machines employed. The properties of the two–step mixed concrete and conventional concrete are compared. At 28–day age, concrete mixed by the two–step mixing method showed about 8 to 17% higher compressive strength than the concrete mixed by the normal method, depending upon the water – cement ratio, the mixing process and the type of mixer. But concrete mixed by the premixing of grout process gave higher strengths than the concrete mixed by the premixed cement paste process.

Introduction

The basic advantages derived by the use of superplasticizing admixtures such as Betoplast 1 are: the production of concrete having high workability for easy placement without a reduction in cement content and strength; the production of high strength concrete with normal workability but a lower water content; the possibility of making a mix having a combination of better than normal workability and a lower than normal amount of water; and designing a concrete mix with less cement but having the normal strength and workability (1,2). In this investigation, the superplasticizer (Betoplast 1) was employed for the purpose of producing high-strength concrete with normal workability but a lower water content.

The object of mixing is to coat the surface of all aggregate particles with cement paste, and to blend all the ingredients of concrete into a uniform mass. Therefore, many methods are used to mix concrete. In this investigation, a two-step mixing method was used. This method involves the advance preparation of a cement paste or grout which is then blended with aggregate to produce concrete (3-8).

Two–step ming methods are used to improve the properties of concrete. This benefit is presumably attributable to more efficient hydration of the cement resulting from the more intimate contact between cement particles and water achieved in the vigorous blending of the cement paste. The main purpose of this experimental program was to evaluate the relative effectiveness of the two-step mixing method on the properties of concrete.

Mix Proportions

Concrete mixtures of three water–cement ratios (0.40, 0.45 and 0.50) were included in the experimental program. The quantity of cement was kept constant (350 kg/m^3) for all concrete mixtures. The mix proportions, by weight, are presented in Table 1.

Cement paste and grout mixtures were also made in which the mix proportions, by weight, were the same as in the concrete mixtures (Table 1).

Materials

The same commercially available Type C35, Portland cement with fly ash (Polish production) was used in all of the experiments. It was homogenized and stored in the laboratory room to maintain the same quality throughout the testing period. Physical properties and chemical composition of the cement were determined in accordance with the Polish standard, PN–91/B–04300. The results are reported in Tables 2 and 3 respectively.

The superplasticizing admixtures used was a Betoplast 1 (Polish production). For all mixtures the percentage of superplasticizer was 2% by weight of cement.

The coarse and fine aggregates used in this research were commercially available materials, from natural sources. The fine aggregate-coarse aggregate ratio was kept constant (0.562) for all concrete mixes.

The fine aggregate was a natural sand, dry, graded to a maximum size of 2 mm, having 100% pass the 2 mm sieve, 85.81% pass the 1 mm sieve, 51.42% pass the 0.5 mm sieve, 14.60% pass the 0.25 mm sieve, 1.36% pass the 0.125 mm sieve and 0.14% pass the 0.065 mm sieve. The coarse aggregate was a natural gravel, dry, graded to a maximum size of 32 mm, having 100% pass the 32 mm sieve, 65.00% pass the 16 mm sieve, 37.11% pass the 8 mm sieve and 10.98 pass the 4 mm sieve.

Mixing Method

Cement Paste and Grout. All cement paste and grout mixtures were mixed using either a normal mixer (100 litres capacity, with a speed of 27 revolutions per minute) for 3 minutes or a high–speed mixer (Ultramixer UM6, 500 litres capacity, with a speed of 3000 – 3500 revolutions per minute, Figure 1,(9)) for 2 minutes or a ball mixer (150 litres capacity, with a speed of 27 revolutions per minute) for 2 minutes.

TABLE 1
Mix Proportions of Concrete

Mix No.	Cement (kg/m^3)	Water–Cement ratio	Betoplast 1 (kg/m^3)	Cement : sand : coarse aggregate ratio
1	350	0.40	7	1 : 2.01 : 3.59
2	350	0.45	7	1 : 1.97 : 3.50
3	350	0.50	7	1 : 1.92 : 3.42

TABLE 2
Physical Properties of Cement

Test		Result
Specific gravity		3.107
Blaine fineness, (cm^2/g)		3155
Setting time: Initial (h. – m.)		3 : 20
Final (h. – m.)		5 : 55
Compressive strength:	3 day (MPa)	24.52
	7 day (MPa)	31.98
	28 day (MPa)	41.34

Normal Concrete. All mixtures were prepared using a normal mixer. The coarse aggregate, sand and cement were mixed for 0.5 minute, then the water and superplasticizer were added and thoroughly mixed with the other ingredients for 3 minutes.

Two–Step Mixed Concrete (Pre–mixing of Cement Paste). Water, superplasticizer and cement were mixed using a high–speed mixer (Ultramixer) or a ball mixer, for 2 minutes. The resulting cement paste was then mixed with aggregate for 2 minutes, using a normal mixer.

Two–Step Mixed Concrete (Pre–mixing of Grout). Water, superplasticizer, cement and sand were mixed using a high–speed mixer (Ultramixer) or a ball mixer for 2 minutes. The resulting grout was then mixed with coarse aggregate for 2 minutes, using a normal mixer.

Casting, Curing and Testing

Twelve concrete samples (151515 cm) were made from each mixture. After the casting process, the concrete moulds were placed on the vibratory table (380 V, 50Hz and 295 revolution per minute) until the cement paste appeared on the surface of the samples, Polish standard PN 88/B–06250. Also, six samples (4416 cm) were made from each cement paste or grout mixture without vibration. After casting, the specimens were left in the laboratory for 24 hours, after which they were removed from the moulds and covered with wet burlap for 7 days. Then the specimens were stored in the open air (in the laboratory) until tested. The testing time for all samples was 28 days. Samples were tested according to the Polish standard, PN 88/B–06250.

TABLE 3
Chemical Composition of Cement

Component	SiO_2	CaO	Fe_2O_3	Al_2O_3	MgO	SO_3	Loss on ignition	Insoluble residue
%	18.57	55.24	2.89	5.16	1.16	3.05	1.97	10.25

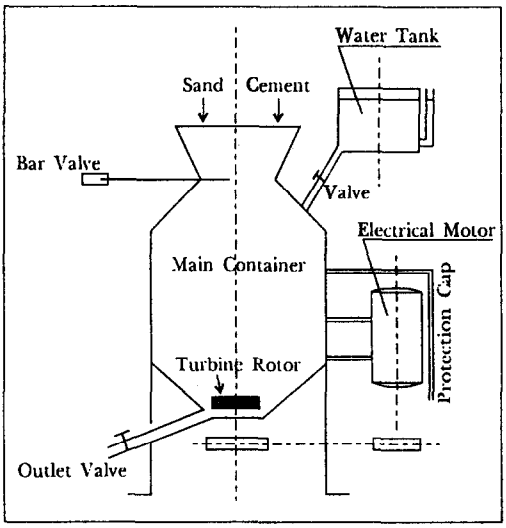

FIG. 1.
Ultramixer UM6.

Experimental Results and Discussion

The test results for all cement paste, grout and concrete samples are presented in Tables 4 to 8. Each compressive strength value represents the average of 12 samples. It can be seen that three water–cement ratios were used and the quantity of cement for all concrete mixtures was 350 kg/m^3. All mixture proportins are presented in Table 1.

Table 4 gives the properties of concrete mixed by the normal mixing method and includes compressive strength, consistency, standard deviation and variation coefficient.

The properties of the two–step mixed concrete, using an Ultramixer and a normal mixer, are presented in Table 5. The test data show that in all the mixtures, the average compressive strength of two–step mixed concrete is greater than compressive strength of normal concrete.

TABLE 4
Properties of Normal Concrete

Water–Cement* ratio	Slump (cm)	Compressive strength (MPa)	Standard deviation (MPa)	Variation coefficient (%)
0.40	3.5	45.20	1.68	3.71
0.45	17.5	40.38	1.68	4.16
0.50	24.0	36.76	1.59	4.32

* Mix proportions are in Table 1.

TABLE 5
Properties of Concrete Mixed by Two–Step Mixing Method
(Using an Ultramixer and a Normal mixer)

Mixing method	Water–Cement ratio	Slump (cm)	Compressive strength (MPa)	Standard deviation	Variation coefficient (%)
Pre–mixing of cement paste	0.40	4.5	50.97	2.52	4.94
	0.45	18.5	46.22	1.55	3.35
	0.50	24.5	42.17	1.94	4.60
Pre-mixing of grout	0.40	3.5	51.73	1.84	3.55
	0.45	18.0	47.15	1.43	3.03
	0.50	24.0	43.04	2.06	4.78

For mixtures having water–cement ratios of 0.4, 0.45 and 0.50 the compressive strength of concrete mixed by pre–mixing of the cement paste method are 12.74% , 14.46% and 14.71%higher than concrete mixed by the normal method at 28 day age, respectively. But, for the water–cement ratios, concrete mixed by the pre–mixing of grout method have 14.44%, 16.76 and 17.08% higher strengths than that of normal concrete, respectively.

The compressive strength results (Table 5) show that the concrete mixed by the pre–mixing of grout method showed higher strengths than concrete mixed by pre–mixing the cement paste method.

Table 6 gives the properties of two-step mixed concrete (using a ball mixer and a normal mixer). The difference between the strength of normally mixed concrete and that of concrete from two-step mixing by the ball mixer and the normal mixer lies in the range 8.47 to 11.80, depending upon the water–cement ratio and mixing method.

In all cases, the test data shows that the effect of two–step mixing on the consistency (slump) of concrete was very slight.

TABLE 6
Properties of Concrete Mixed by Two-Step Mixing Method
(Using a Ball Mixer and a Noermal Mixer)

Mixing method	Water–cement ratio	Slump (cm)	Compressive strength (MPa)	Standard deviation	Variation coefficient (%)
Pre–mixing of cement paste	0.40	4.5	49.03	1.31	2.67
	0.45	18.5	44.09	1.36	3.08
	0.50	25.0	39.88	1.49	3.73
Pre-mixing of grout	0.40	4.0	50.10	1.21	2.41
	0.45	18.0	44.94	1.64	3.64
	0.50	24.0	41.10	1.41	3.43

TABLE 7
Properties of Cement Paste

Type of mixer	Water–Cement ratio	Sedimentation* (%)	Compressive strength (MPa)	Standard deviation (MPa)	Variation coefficient (%)
Normal mixer	0.40	4.04	48.16	1.47	3.05
	0.45	6.23	43.18	1.37	3.17
	0.50	7.46	39.32	1.70	4.32
Ultramixer	0.40	3.07	57.61	1.59	2.75
	0.45	4.29	53.15	1.23	2.31
	0.50	5.16	48.37	1.42	2.93
Ball mixer	0.40	3.60	54.62	1.00	1.83
	0.45	5.07	48.86	1.52	3.11
	0.50	6.10	44.32	1.27	2.86

(*)Testing time of sedimentation was 3 hours.

The properties of cement pastes of same mix proportions produced by using a normal mixer, a ball mixer and by a high–speed mixer (Ultramixer UM6) are compared in Table 7. In all cases, cement pastes mixed by the Ultramixer or the ball mixer showed a lower sedimentation percentage and a higher compressive strength than the cement pastes mixed by the normal mixer. But cement pastes mixed by the Ultramixer have lower sedimentations and higher strengths than the same cement pastes mixed by the ball mixer. The difference between the strength of normally mixed cement paste and that of high-speed mixing cement paste (Ultramixer) lies in the range 19.62 to 23.08, depending upon the water-cement ratio. The

TABLE 8
Properties of Grout

Type of mixer	Water–Cement ratio	Cement : Sand ratio	Sedimentation* (%)	Compressive strength (MPa)	Standard deviation	Variation coefficient (%)
Normal mixer	0.40	1 : 2.01	1.65	43.43	1.00	2.30
	0.45	1 : 1.97	2.85	38.41	1.41	3.67
	0.50	1:1.92	3.64	35.71	0.91	2.54
Ultramixer	0.40	1 : 2.01	0.50	51.19	1.11	2.16
	0.45	1 : 1.97	1.66	46.86	1.08	2.30
	0.50	1:1.92	2.44	43.63	1.52	3.48
Ball mixer	0.40	1 : 2.01	1.06	47.69	1.74	3.64
	0.45	1 : 1.97	2.29	42.84	1.50	3.50
	0.50	1:1.92	2.98	39.27	1.28	3.25

(*)Testing time of sedimentation was 3 hours.

difference between the strength of normally mixed cement paste and that of cement paste mixed by the ball mixer lies in the range 12.71 to 13.41, depending upon the water-cement ratio.

Similarly grouts of the same mix proportions mixed by Ultramixer or by ball mixer have lower sedimentations and higher compressive strengths than those mixed by a normal mixer (Table 8). The data showed that the effect of Ultramixer on the properties of grouts higher than the effect of ball mixer. The difference between the strength of normally mixed grout and that of high-speed mixed grout (by Ultramixer) lies in the range 17.86 to 22.17, depending upon the water-cement ratio. But the difference between the strength of normally mixed grout and that of grout mixed by the ball mixer lies in the range 9.80 to 11.53%, depending upon the water-cement ratio.

From experimental test results, the difference between the sedimentation of normally mixed cement paste and that of high-speed mixing cement paste (Ultramixer) lies in the range 24.00 to 30.83, depending upon the water-cement ratio. But the difference between the sedimentation of normally mixed cement paste and that of cement paste mixed by the ball mixer lies in the range 10.89 to 18.23, depending upon the water-cement ratio.

Also, from experimental test results, the difference between the sedimentation of normally mixed grout and that of high-speed mixed grout (by Ultramixer) lies in the range 32.29 to 69.69, depending upon the water-cement ratio. But the difference between the sedimentation of normally mixed grout and that of grout mixed by the ball mixer lies in the range 18.13 to 35.75, depending upon the water-cement ratio.

Conclusion

The main purpose of this experimental program was to evaluate the relative effectiveness of the two-step mixing method on the properties of concrete. The two-step mixing method is used to improve the properties of concrete. This technique involves the advances preparation of a cement paste or grout which is then blended with aggregate to produce concrete.

The two-step mixing method produced significant increases in compressive strength for all water-cement ratios investigated in this research. In all cases, this technique was found to produce higher strengths than the standards. Based on the results obtained, it can be seen that the difference between the strength of normally mixed concrete and that from two-step mixed concrete lies in the range 8.47 to 17.08, depending upon the mixing method, water-cement ratio and type of mixer. Higher compressive strengths thus obtained are presumably attributable to more efficient hydration of the cement resulting from the more intimate contact between cement particles and water achieved in the vigorous blending of cement paste and grout. Also premixing of grout forms a coating of cement paste on the surfaces of sand particles and effectively increases the cohesivenness between sand particles.

In all cases, the two-step mixing method, using an Ultramixer and a normal mixer, was found to produce higher strength than the concrete mixed by two-step mixing, using a ball mixer and a normal mixer. On the other hand, the pre-mixing of grout method was found to produce higher strengths than the pre-mixing of cement paste method.

The experimental test results shows that the cement pastes or grouts mixed by a high-speed mixer (Ultramixer) showed higher strengths and lower sedimentation than the same mixtures mixed by the ball or the normal mixer. It is considered that the high-speed mixing increases the reactions between water and cement.

The two-step mixing methods may be used to produce concrete with low cement content, aggregates of low natural strengths, poor cements and also my be used for producing lightweight concrete.

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