UTILIZATION OF BALCRETE FOAMING AGENT

Part III.—Production of Air-entrained Concrete

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This paper describes the use of 'Balcrete' foaming agent as air-entraining agent for entraining air in cement concrete. The addition of Balcrete, in small quantities, increases the compressive strength of concrete made with less graded aggregates. The increased water-repelling property suggests the use of air-entrained concrete where chemical resistance is required. The other uses of Balcrete as retarder and wetting agent are also briefly discussed.

Introduction

Air-entrained concrete, which has become increasingly popular in the U.S.A. since about 1938, is distinguished from aerated or cellular concrete by the amount of air entrapped in the mixture. The proportion of air in the air-entrained concrete is generally limited to 5 per cent, whereas it is normally much higher in cellular concrete. This type of concrete was discovered[1] as a result of an investigation into the causes of the high frost resistance of the concrete made with certain cements in the north-eastern states of America. The high durability was associated with lower densities and numerous minute bubbles distributed throughout the mass. The cause was traced to the use of resinous or fatty materials as grinding aids during the manufacture of Portland cement. The entrainment of air has since been accomplished by adding an air-entraining agent to the mix which results in the dispersion of non-coalesicing spheroids of air having diameters from 0.003 to 0.05 inch. The amount of air entrained depends on the quantity of agent added which is either intermixed with the cement during grinding or added as a separate ingredient in the mixer. The latter method is preferred because it permits a greater degree of control. Organic impurities in aggregates and pozzolanas in portland cements influence the amount of air entrained for a given amount of agent. The laboratory work and field trials have proved that this purposeful entrainment increases the resistance of concrete to the disintegrating action of freezing and thawing. The bubbles provide spaces where forces causing deterioration can be dissipated. The entrainment of air reduces the strength of rich mixes more than that of leaner mixes and very lean mixes are slightly increased in strength. The use of 'Balcrete' foaming agent for cellular concrete with neat cement[2] and with cement-sand mixtures[3] has been reported earlier. Its use for the air-entrained concrete and the physical porperties of the products are presented in this paper.

Aggregates and Compressive Strength

Entrained air increases workability of the mix and permits the use of less well graded aggregates. Table 1 shows the sieve analysis of Malir river coarse aggregate extensively used in Karach

Table 1.—Grading of Malir Double Chhan 'Bajri' (Double Screened Aggregate).

Sieve	Percentage by weight retained sieve								Percentage retained (Average)
	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5	Sample No. 6	Sample No. 7	Sample No. 8	
1/2″	—	8.5	—	—	13.6	6.0	6.0	—	4.2
1″	5.3	3.0	1.6	9.6	3.6	2.8	11.6	12.3	6.2
3/4″	2.8	1.8	4.0	3.8	4.6	4.0	6.8	3.3	3.8
1/2″	8.0	6.0	6.0	3.5	3.1	7.6	6.5	—	4.9
3/8″	6.3	5.3	6.5	7.0	3.8	4.9	6.6	4.8	5.6
3/16″	16.6	13.0	10.3	9.6	8.6	11.1	14.8	9.0	11.6
8	21.5	18.5	17.6	16.8	16.3	17.3	16.3	17.8	17.7
16	17.6	17.6	21.3	20.8	19.3	20.6	16.3	23.3	19.6
30	12.0	13.3	17.0	15.8	14.0	15.6	9.3	17.1	14.2
50	5.6	7.0	8.6	7.8	7.3	6.5	3.0	7.5	6.6
100	1.8	1.8	1.6	2.1	2.3	0.3	0.1	0.5	1.3
200	1.1	2.0	4.9	2.0	2.0	3.1	1.6	4.1	2.6

and locally termed as double screened 'bajri'. This aggregate is deficient in fines and very poor in grading. The average of eight samples analysed has been taken as the grading of coarse aggregate for the purpose of determining the effect of the addition of Balcrete on various properties of cement concrete. For fine aggregate used in this investigation, the coarser particles retained on sieve No. 8 were removed from Malir sand. The grading of this sand has been reported in an earlier communication.[4] The concrete mix was prepared in the proportion of 1:2:4 of Zeal Pak portland cement, fine and coarse aggregates by volume. The water-cement ratio in cement concrete was varied to find out the most effective percentage of Balcrete for the best workability in the mix. The different ingredients of concrete were mixed in a non-tilting concrete mixer for 5 minutes in each case. Uniform tamping was given to all 4-inch cubes as is generally done in the field. The cubes were stored in stacks under shade and were cured by sprinkling water twice a day. The crushing strength was measured at 7 and 28 days and recorded in Table 2 for water-cement ratios (inclusive of the water absorbed by dry aggregates) 0.60, 0.65 and 0.70. For dry strength the samples were kept in the oven at about 110°C. for 24 hours. The compressive strength of the concrete increased at 7 and 28 days when 0.1 per cent of Balcrete foaming agent (by weight of portland cement) was added to the mixing water of concrete. The increase of strength was more prominent in the concrete when 0.60 water cement ratio was used.

TABLE 2.—EFFECT OF BALCRETE FOAMING AGENT ON THE COMPRESSIVE STRENGTH OF 1:2:4 (by volume) CONCRETE.

S. No.	Water/cement ratio (by weight)	Foaming agent by weight of cement	Wet crushing strength in lbs./sq. inch at		Dry crushing strength in lbs./sq. inch at 28 days
			7 days	28 days	
1.	0.70	Nil	1210	1621	2216
2.	,,	0.1	1574	1936	2341
3.	,,	0.2	1072	1332	1534
4.	,,	0.3	854	1149	1195
5.	0.65	Nil	1376	2152	2712
6.	,,	0.1	1825	2409	2805
7.	,,	0.2	1295	1820	2263
8.	,,	0.3	940	1556	1948
9.	0.60	Nil	1217	1445	2006
10.	,,	0.1	1591	2992	3185
11.	,,	0.2	1604	2101	2794
12.	,,	0.3	1087	1540	2076

The mechanism of this action is not fully understood but it is most probably connected with the modified pore system. The minute bubbles are not interconnected and are of approximately uniform size. The purposeful entrainment reduces bleeding and segregation and facilitates the placing and handling of concrete. The segregation of coarse aggregate frequently indicates a deficiency of fines and it is generally accompanied by bleeding which is mainly due to the excessive use of water in the mix. Reduced bleeding permits finishing of concrete surfaces earlier and usually with less work. Each per cent of air allows a reduction in mixing water from 2 to 4 per cent with no loss in slump.

Setting Time

The effect of Balcrete on setting properties of portland cement and clinker is shown in Table 3. The addition of 0.25 per cent foaming agent by weight of cement increased the initial setting of Daud Khel portland cement from 1 hr. 48 mins. to 1 hr. 59 mins. and final setting time from 3 hrs. 10 mins. to 3 hrs. 20 mins. The results of 0.5—1.0 per cent foaming agent show that Balcrete can also be used as retarder in special circumstances to delay the setting of portland cements.

Air Content

The air contents of fresh manually mixed concretes with portland cement, aggregates, water and Balcrete foaming agent in varying proportions have been measured with Techkote White Air Meter designed to ASTM Designation: C231-54, and are recorded in Table 4. The percentages of entrained air, when different ingredients of concrete are mixed in a non-tilting concrete mixer,

are shown in Table 5. The aggregate correction factor has also been determined with the same meter, as the voids in aggregates used are appreciable. Desirable air contents, at the mixer, for the concrete subjected, to severe freezing is about 5 per cent of the aggregate used. The air proportion may be reduced as much as one fourth if the concrete is not freezed. In a country like Pakistan, where frost is no serious problem, the entrainment of $1\frac{1}{2}$—$2\frac{1}{2}$% air is desirable to

TABLE 3.—EFFECT OF BALCRETE FOAMING AGENT ON SETTING OF PORTLAND CEMENT AND CLINKER.

Portland cement/clinker	Foaming agent by weight of cement/clinker %	Setting times		Mixing water by weight of cement/clinker
		Initial hrs-mns.	Final hrs-mns.	
Daud Khel cement ..	Nil	1—48	3—10	33 % Distilled
,, ..	0.25	1—59	3—20	,,
,, ..	0.50	2—52	4—0	,,
,, ..	1.00	3—22	4—32	,,
Daud Khel clinker ..	Nil	0—12	0—22	,,
,, ..	0.25	0—21	0—50	,,
,, ..	0.50	0—27	0—52	,,
,, ..	1.00	0—35	1—17	,,

TABLE 4.—THE EFFECT OF BALCRETE FOAMING AGENT ON THE ENTRAINMENT OF AIR IN 1:2:4 CONCRETE (BY VOLUME) MIXED MANUALLY.

Water/cement ratio	Foaming agent by weight of cement %	Air-meter reading (average) %	Aggregate correction factor (average) %	Air-entrained %
0.70	0.1	7.76	5.76	2.00
,,	0.2	7.78	,,	2.02
,,	0.3	7.86	,,	2.10
0.65	0.1	7.25	,,	1.49
,,	0.2	7.41	,,	1.65
,,	0.3	7.86	,,	2.10
0.60	0.1	7.17	,,	1.41
,,	0.2	7.36	,,	1.60
,,	0.3	7.55	,,	1.79

TABLE 5.—THE EFFECT OF BALCRETE FOAMING AGENT ON THE ENTRAINMENT OF AIR IN 1:2:4 CONCRETE (BY VOLUME) MIXED IN NON-TILTING CONCRETE MIXER.

Water/cement ratio	Foaming agent by weight of cement %	Air-meter reading (average) %	Aggregate correction factor (average) %	Air-entrained %
0.70	0.1	8.48	5.76	2.72
,,	0.2	8.55	,,	2.79
,,	0.3	8.58	,,	2.82
0.65	0.1	7.91	,,	2.15
,,	0.2	8.00	,,	2.24
,,	0.3	8.06	,,	2.30
0.60	0.1	7.55	,,	1.79
,,	0.2	7.68	,,	1.92

increase the workability without affecting the compressive strength of the concrete. This percentage of air can easily be obtained by adding 0.1 per cent Balcrete foaming agent to the concrete during mixing. Air contents after placing and compaction are decreased by about one-fifth from the values at the mixer.

Water-Repellent Properties

The purposeful entrainment increase water tightness of cement concrete. The water-repelling properties of ordinary and air-entrained concretes were evaluated by the determination of moisture penetration through 4-inch cubes by the device reported earlier.[3] The time for the fall of water level is recorded for each division and the results are presented in Fig. 1. The addition of 0.2% Balcrete by weight of Portland cement in 1:2:4 concrete made with 0.65 water-cement ratio reduces the rate of fall of water from 24 divisions in 1 hr. 38 mins. to 4 divisions in 2 weeks. The increase of foaming agent from 0.2 to 0.3 per cent did not result in any further improvement. The results indicate that the employment of more than 0.3 per cent of foaming agent may reduce water proofing properties of the air-entrained concretes.

Conclusion

On the basis of the foregoing results, Balcrete foaming agent can be used as air-entraining agent for the concrete which is to be added as separate ingredient at the mixer. In less graded aggregates, the addition of Balcrete increases workability of the mix with the consequent increase in the compressive strength of the cement concrete. Balcrete, when used as wetting agent in the concrete allows reduction of portland cement which may be required especially in dams or thick concrete constructions where low strengths and low heat evolutions are desirable. The addition of this foaming agent from 0.1 to 0.2 per cent adds water-repelling property to the cement concrete and makes portland cement more resistant to the chemical attack of soluble salts. Balcrete can be useful in reducing water-cement ratios in hand mixed concretes which is the common practice in Pakistan due to the shortage of concrete mixers.

The limiting of air content for precast concrete pipes at less than 3 per cent, as generally recommended, can be obtained with the addition of 0.1 per cent of Balcrete by weight of cement. The use of Balcrete as a retarder in very hot weather, in cements of short setting times, in

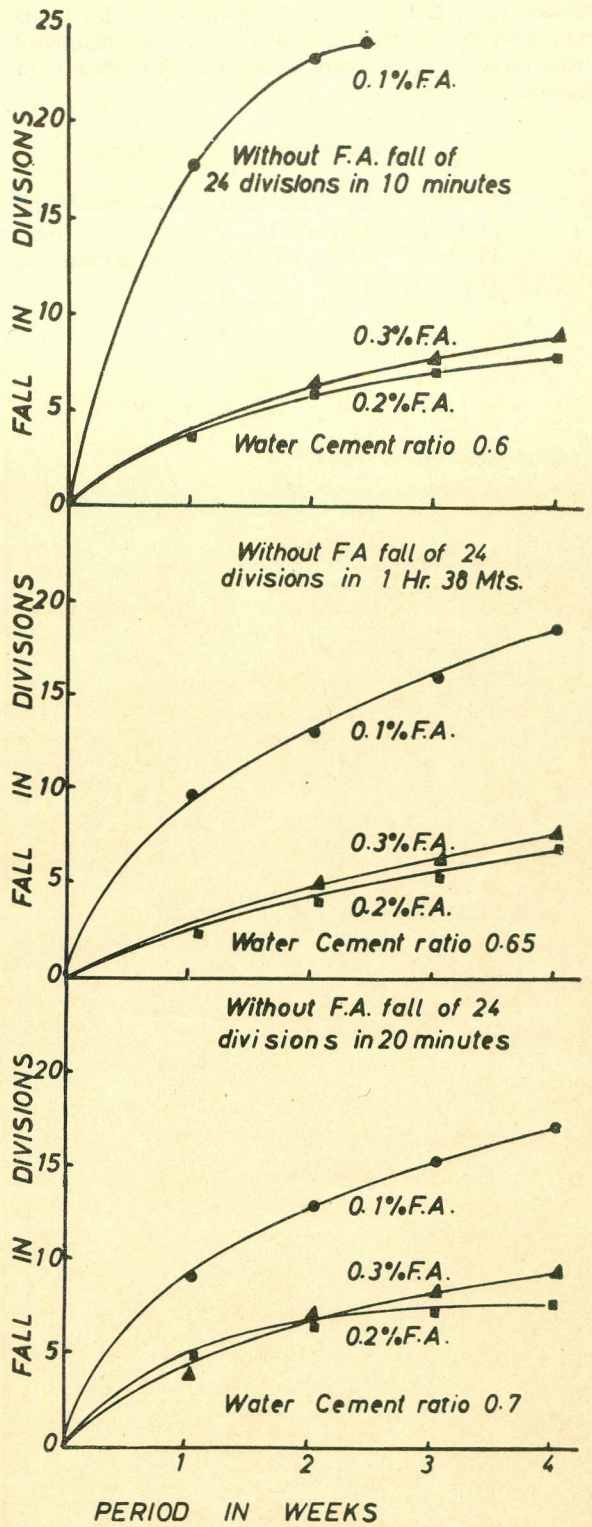

Fig. 1—The effeet of Balcrete foaming agent addition to portland cement on moisture penetration through cement concretes.

tunnel lining, where placing of the concrete needs considerable time, and for several other purposes may also prove useful. Further work regarding the suitability of Balcrete as mortar plasticisor is in progress.

References

1. *The use of air entrained concrete in pavements and bridges*, Current Road Problems No. 13-R, Highway Research Board, Washington, D.C., 1950.

2. M. Aslam, S. Tehzibul Hasan, Mubarak Ahmad and M. Jehangir, Pakistan J. Sci. Ind. Research, **4**, 9 (1961).

3. M. Aslam, S. Tehzibul Hasan and M. Jehangir, Pakistan J. Sci. Ind. Research, **5**, 112 (1962).

4. Riaz Ali Shah, S. Tehzibul Hasan and Mubarak Ahmad, Pakistan J. Sci. Ind. Research, **6**, 32 (1963).