UTILISATION OF 'BALCRETE' FOAMING AGENT

Part I.—Production of Cellular Concrete (with Neat Cement)

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This paper deals with the preparation and physical properties of moist cured cellular concrete based on neat cement. Methods of production based on high speed stirrers and ordinary non-tilting drum concrete mixer using 'Balcrete' foaming agent have been successfully developed. The ratio of rate of production to mixer capacity is 2.6-2.8 which is very satisfactory since the highest reported ratio using assembly line techniques is 3.0. Compressive and flexural strengths as well as thermal conductivity values have been determined for cellular concrete of varying densities. The ratio of flexural to compressive strength varies from 0.12 to 0.20, the ratio increasing with increase in density. This is in contrast to the results given in the literature for autoclaved cellular concrete in which case the ratio decreases with increase in density.

The cellular concrete has adequate strength for structural use at densities above 60 lbs. per cu. ft., for partition walls at densities between 40-60 lbs. per cu. ft., and for thermal insulation at densities below 30 lbs. per cu. ft.

Introduction

Concrete weighing from 20 to 100 pounds per cubic foot and having a homogenous cell structure is usually known as cellular concrete although descriptions like 'aerated', 'porous' and 'foamed' concrete have been used, irrespective of the method of producing the cell structure. These definitions do not ordinarily encompass light-weight aggregate concretes.

Various methods in use for the production of cellular concrete may be classified as follows:—

(i) Processes in which a gas is produced by a chemical reaction within the mix before it sets.

(ii) Processes involving use of excess water which on drying out leaves air-filled pores. This method of making cellular concrete was first patented in 1930,[1] but has found only limited use and that also in conjunction with the aeration by chemical means.

(iii) Foaming processes, which may be described as air-entraining in character, the additives used for the purpose being known as 'foaming' or 'air-entraining agents'. This type of process was first patented by Bayer[2] in 1923. The following types of foaming agents have been used:

(a) Detergents (sodium lauryl sulphate, alkyl aryl sulphonate etc.).

(b) Resins, oils and their soaps.

(c) Hydrolysed protiens containing suitable additives to provide stable foam volume.

Agents in category (c) have come to be used extensively for cellular concrete in recent years. A composition for foaming agent belonging to this class and developed at these laboratories[3] has been used in the investigations reported in this paper.

The paper is confined to cellular concrete subject to moist curing since the alternative method of curing in autoclaves at about 350 °F. was not considered practical or economical for this country at this stage. The present study may be divided into three steps, namely (a) preparation of cellular concrete, (b) control of density of cellular concrete and (c) examination of physical properties of cellular concrete.

Preparation of Cellular Concrete

Two types of methods are commonly used for production of cellualr concrete: (a) 'Mix-foam' method in whch foaming agent is added to the mixture after all the other ingredients have been mixed to a fairly thin slurry. High speed stirrers (1400-2800 r.p.m.) or concrete mixers with motor attachments to permit continuous variation in paddle speed from 30 to 90 r.p.m. are recommended for this method. (b) 'Pre-foam' method which involves the generation of foam by aerating a protein base compound through a nozzle and adding it to the concrete in place of the usual aggregates. Several variations of these methods have been investigated in the present study.

(a) High speed stirring mixer (Fig. 1): For laboratory work high speed turbo stirrer (A Gallenkamp & Co. Cat. No. 35-705) using stirring rotor turbo reactor has been used for investigations but for regular production a similar stirrer of diameter 14" with a speed of 1425 r.p.m. using 7.5 H.P. motor was fabricated and used for the purpose. This particular stirrer has been used for producing 40,000 cu. ft. of cellular concrete from neat cement (density 30-35 lbs./cu. ft.) at Chichoki Hydel Station. The method of using this stirrer is as follows:

Three and a half gallons of water is taken in 45-gallon barrel and 56 lbs. of cement added gradually with continuous agitation. When the cement and water slurry are thoroughly mixed, one litre of foaming agent is added and the mixing continued for 7-10 minutes. Finally, the material is drawn off from the drum and poured into moulds for making bricks. Part of the production at Chichoki was cast in situ on a flat roof. For this purpose the roof area was divided into 2′ × 4′ panels using wooden forms into which foam concrete was poured to a depth of 3″. Alternate panels were poured together so that as every other section sets, the forms could be removed and the intervening area filled.

Control of density of cellular concrete prepared by this method is comparatively easy, but this stirrer is useful only for neat cement and failed to give satisfactory results when sand had to be incorporated in the mix.

(b) Cement mixer, tilting drum type capacity 2 cu. ft. (Fig. 2). This mixer has been modified to revolve at a speed of 40-50 r.p.m. The details of producing cellular concrete by this method are similar to those described for the high speed stirrer. Attempts to generate foam in the mix before adding cement did not give satisfactory products, but it is believed possible to get better results, if the mixer is run at a low speed in the initial stages. This method has one advantage over the high speed stirrer method, namely that cellular concrete of all types can be produced, whether containing neat cement or mixtures of cement and aggregate.

(c) Ordinary non-tilting drum concrete mixer-capacity 6 cu. ft. Speed of revolution 10-12 r.p.m. (Fig .3) This type of mixer is easily available in the country, and it was therefore considered desirable

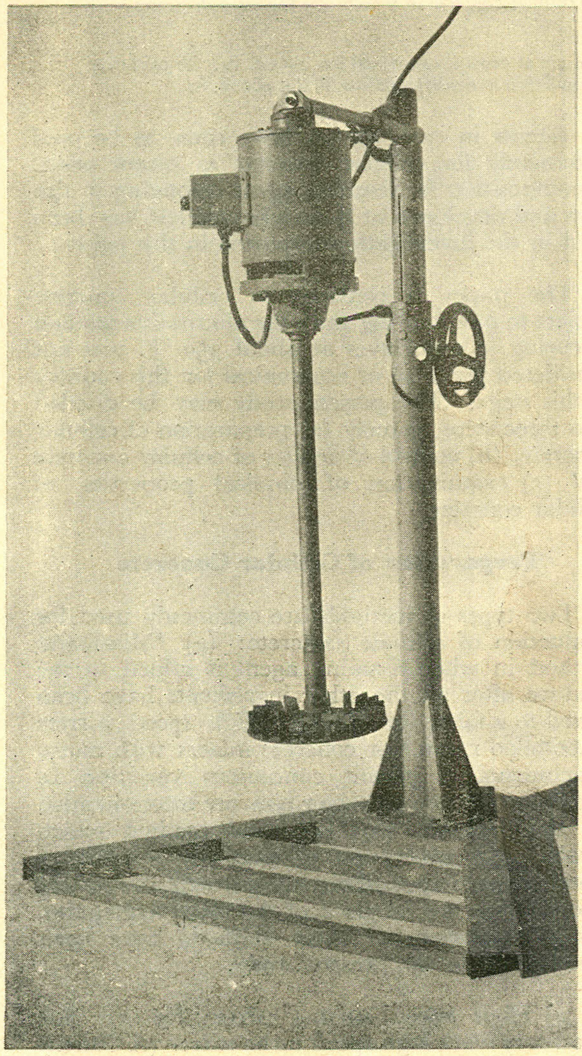


Fig. 1

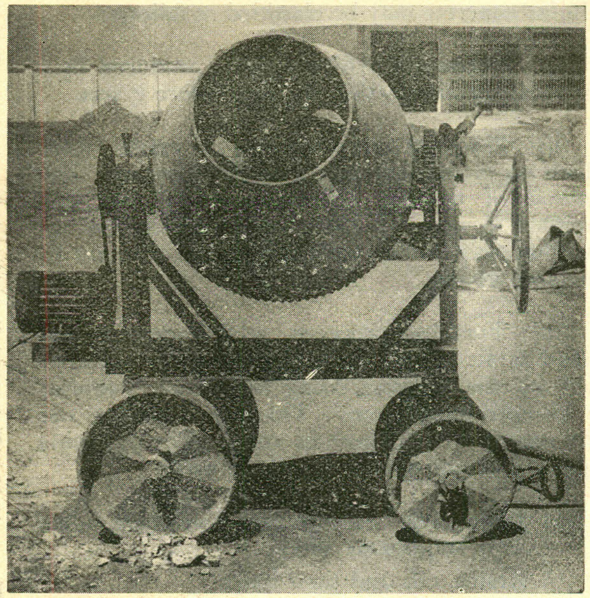


Fig. 2

to work out a method for production of cellular concrete without any modifications of the normal mixer. The method which has been found to work most satisfactorily with this mixer is described below.

Fifteen gallons of water and 4.5 lbs. foaming agent (2.0% by weight of cement) are poured in the mixer, which is then run for 2-3 minutes so as to generate foam. 224 lbs. of cement is gradually added to the foam. The mixer is run for about fifteen minutes altogether, when a uniform slurry is obtained, which is drawn off from the mixer and poured into wooden moulds. The moulds are opened after 18-24 hours to avoid breakages.

This mixer gives satisfactory results even when aggregate is used as one of the ingredients, and has been used by the Pakistan P. W. D., Lahore, for P. & T. 'Repeater huts' for production of cellular concrete containing cement and sand in the proportions of 1:1 and 1:3.

The quantity of foaming agent required for producing 100 cu. ft. of cellular concrete of density 30-35 lbs./cu. ft. based on neat cement is given in Table 1 for the three methods (a), (b) and (c), while Table 2 gives the corresponding rates of production.

TABLE 1.—EFFECT OF METHOD OF PRODUCTION ON FOAMING AGENT REQUIREMENT.

Method of production	Amount of foamig agent	
	by weight of cement %	per 100 cu. ft. of concrete
(a)	3.5	140 lbs.
(b)	3.0	120 lbs.
(c)	2.5	100 lbs.

TABLE 2

Method of production	Mixer capacity	Rate of production cu. ft./hr.	Rate of production to mixer capacity
(a)		6- 7	
(b)	2 cu. ft.	4- 5	2-2.25
(c)	6 cu. ft.	16-17	2.6-2.8

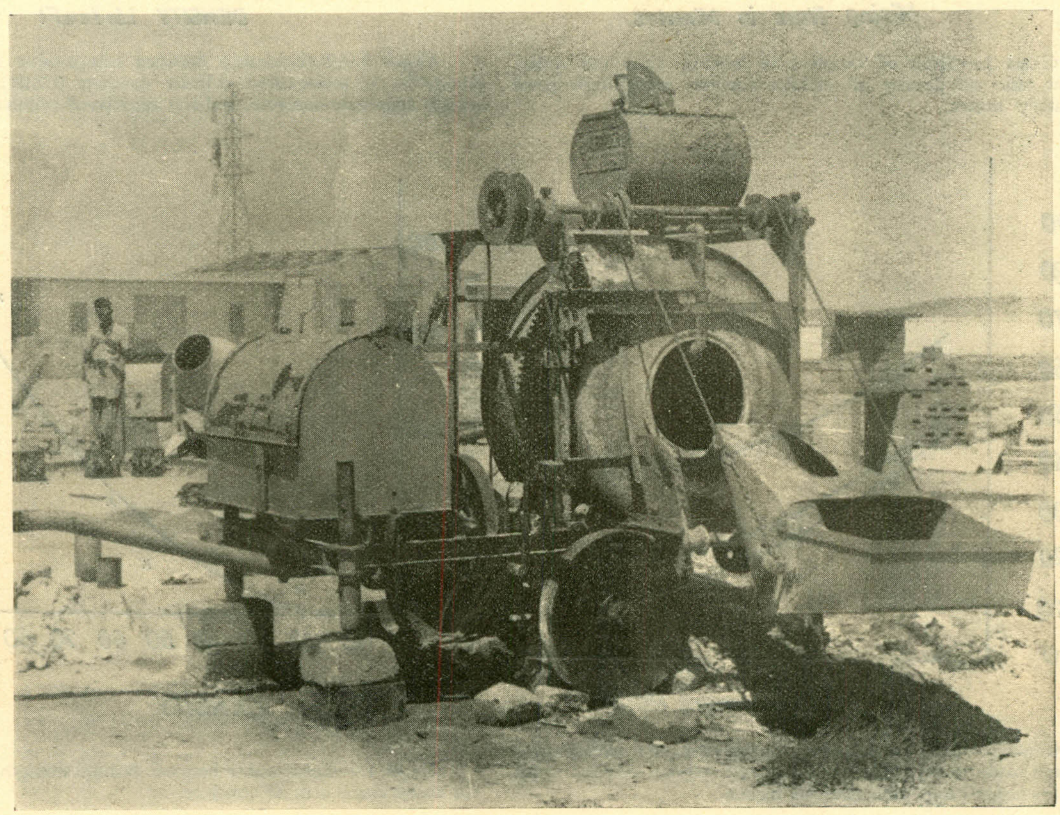
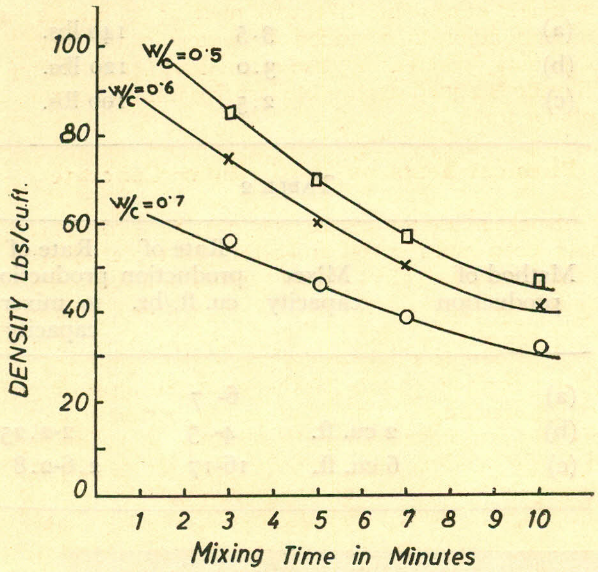


Fig. 3

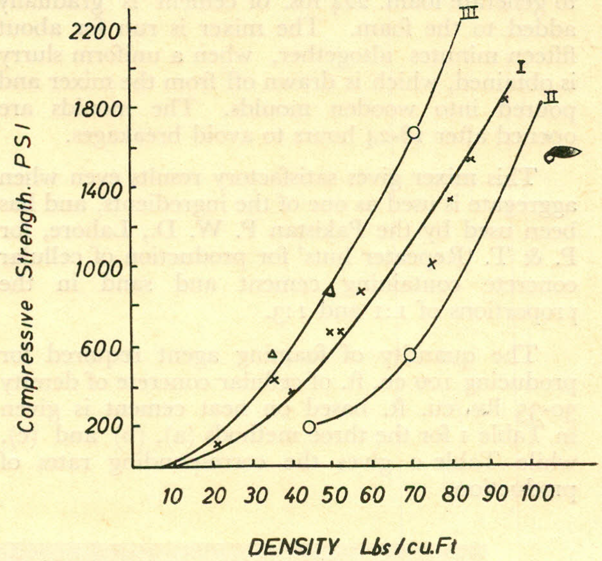
According to National Foam System Inc., Pa., U.S.A ,[4] their preformed foam method can use 'assembly line techniques' in making installation, mixing and pouring 15 cu. yd. of concrete an hour using a 5 cu. yd. end loaded transit mixer. The ratio of hourly production rate to the mixer capacity in this case works out to 3.0 whereas for the method (c) described above without the use of any assembly line techniques, the ratio of production rate to mixer capacity is 2.6-2.8 which is very satisfactory indeed.

Control of Density of Cellular Concrete

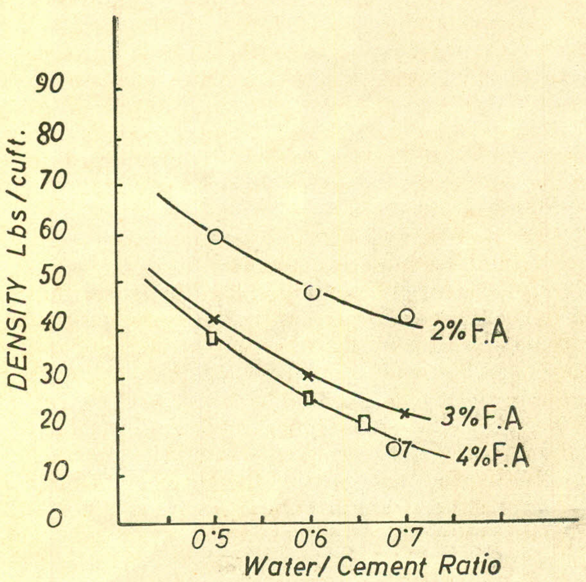
Since most of the physical properties of light-weight concretes depend quite sensitively upon



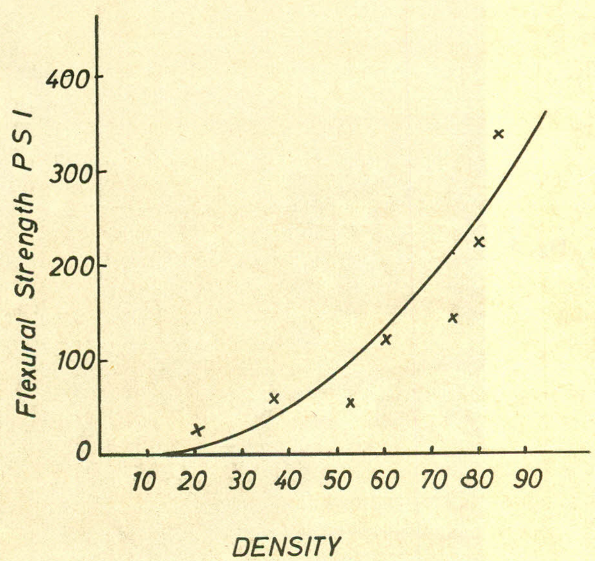
Graph 1.—Effect of variation in mixing time and water/cement ratio on density of cellular concrete using high speed laboratory mixer.



Graph 3.—Relationship between compressive strength and density for: (i) moist cured cellular concrete (CSIR), (ii) light-weight aggregate concrete, and (iii) autoclaved cellular concrete.

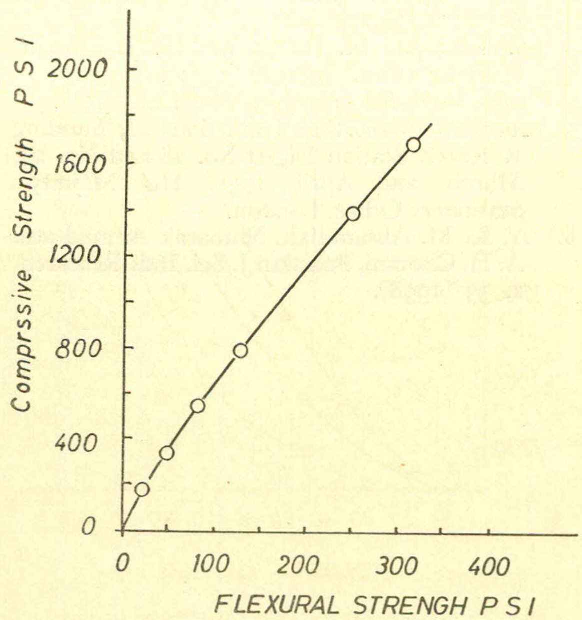


Graph 2.—Effect of variation in proportion of foaming agent used and water/cement ratio on density of cellular concrete using ordinary non-tilting drum concrete mixer.

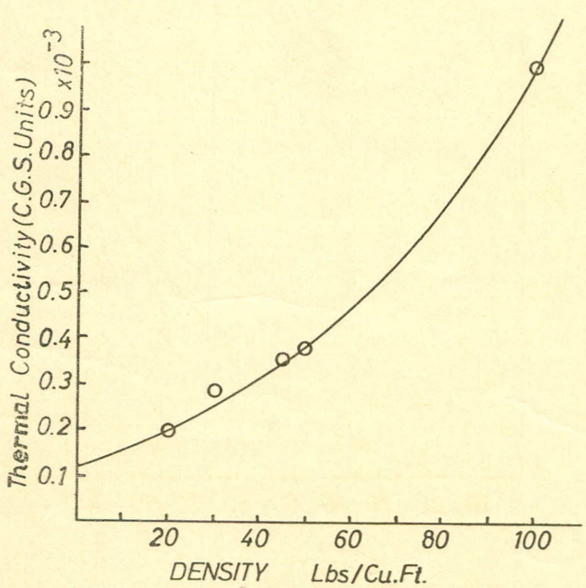


Graph 4.—Relationship between flexural strength and density for moist cured cellular concrete.

density, it is important to have a fairly rigid control on density of the product, which depends on several factors, viz., quantity of foaming agent, type of mixer used, length of the mixing cycle and the water cement ratio. The effect of mixing time and water cement (W/C) ratio on the density of the cellular concrete using 3% foaming agent by weight of cement and high speed laboratory stirrer is shown in Graph 1. Control of density using an ordinary cement mixer is possible by adjustment of the quantity of foaming agent and the water/cement ratio, since minimum mixing time had to be maintained at 15 minutes to get a uniform slurry. The results are shown in Graph 2. Cellular concrete of densities below 30 gave depression in precast blocks on curing and it was therefore found necessary to use calcium chloride 1-2% by weight of cement. In case of method (1) and (2) calcium chloride is added to water in the very beginning, whereas in case of method (3) calcium chloride is added during the last five minutes of the mixing time.



Graph 5.—Relationship between compressive and flexural strength of moist cured cellular concrete.



Graph 6.—Relationship between thermal conductivity and density of moist cured cellular concrete.

Physical Tests on the Cellular Concrete

Bricks made for testing the physical properties have been moist cured and strengths reported are for specimens 28 days old and tested in a room dry condition.

The compressive strength was determined on 4″ cubes in a 40-ton hand operated compression testing machine. The relationship between density and compressive strength is shown in Graph 3 and for comparison, curves for light weight aggregate (pumice) concrete and autoclaved cellular concrete as reported in the literature[5] have been included in the graph. For the flexural strength, 18″ × 4″ × 4″ bricks were tested at a span of 15″, and the results were calculated according to ASTM specification C 293-54 T (1955). The relationship between density and flexural strength is shown in Graph 4 and that of compressive with flexural strength in Graph 5. The ratio of flexural to compressive strength varies from 0.12 to 0.20, the ratio increasing with increase in density. This is in contrast to the results given in literature for autoclaved cellular concrete in which case this ratio decreases with increase in density, the ratio varying from 0.35-0.20.

The thermal conductivity values for moist cured cellular concrete made of neat cement are given in Graph 6. The method used for determining the coefficient of thermal conductivity was that described previously by Ahsanullah, Ahmad and Chotani.[6] K value for local cement brick as determined by the method is 0.68 ± 0.03 cal. cm. sec.$^{-1}$/°C., whereas values reported for cement in the literature vary from 0.8-1.2. This together with the earlier anomaly in the ratio of flexural to compressive strength suggests the need for a fuller investigation of the cement as such.

The properties of moist cured cellular concrete containing portland cement with sand and other aggregates and the economics of production of various types of cellular concrete will form the subject matter of Part II of the present paper.

Conclusions

Whereas cellular concrete has been produced commercially in Europe for over 30 years and its use in the U.K. and the U.S.A. has been comparatively recent, in Pakistan, the C. S. I. R. has been the first to introduce cellular concrete in the country and develop an economical and easily controlled method of its production. On the basis of the foregoing results in this paper, it may be recommended that cellular concrete of lower densities in the 30 pounds per cubic foot range may be used where insulation value rather than structural strength is the determining factor. For structural applications the density range that may be recommended is from 60 pounds per cubic foot up. The lower densities (45-60) are useful for partition walls. Cellular concrete may als be used as roof or floor fills and for fire protection.

References

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