A STUDY OF COMPRESSIVE STRENGTH AND DENSITY OF AERATED CONCRETE

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ABSTRACT

The research deals with the experimental study of aerated concrete. The proposed method of producing the aerated concrete is to add the stable foam into the mortar slurry during mixing. The stable foam is obtained by the process of compressing the air into the mixture by volume between 4 percent of Sodium Lauryl Ether Sulphate and water. Consideration is focused on the relationships between density and its compressive strength in order to determine the possibility of using the aerated concrete as a construction material for non-structural element. The results reveal that the compressive strength of the aerated concrete is proportional to its density and inversely proportional to the amount of the stable foam. It is also found that the density of the aerated concrete depends on ratio of cement to fine sand and the amount of added stable foam. In addition, the water-cement ratio of 0.6 is the most suitable for all ratios of cement to fine sand and for all stable foam contents. The aerated concrete with the compressive strength of 3.5 MPa (35 kg/sq.cm) and the density of 1,000 kg/cu.m can be achieved by using the cement-fine sand ratio of 1.0 by volume and the stable foam content of not more than 0.15 cu.m/100 kg of cement.

INTRODUCTION

Concrete is one of the main materials used in construction industry. It has the advantages in that it can easily be cast in any desirable shapes and sizes; moreover, it gives a good fire protection as well as a good heat insulation. However, the concrete has the disadvantage in that it has a high unit weight which directly affects the foundation of structures.

Many researches have been carried out in order to achieve the concrete with lighter weight and having adequate compressive strength. Such concrete is called the lightweight concrete. It is more applicable to the non-structural elements such as partitions, walls, roofs, etc. There are three types of lightweight concrete, namely, lightweight aggregate concrete, no-fine aggregate concrete, and aerated concrete.

The aerated concrete is of interest; it consists of the mixture between mortar and the stable uniform air bubble or foam. The foam should be stable during the process of mixing, placing and the final set of concrete. Two methods can be used to produce the aerated concrete, i.e., the chemical and mechanical methods. The mechanical method seems to be easier and cheaper than the chemical method, therefore, it has widely been used. There are three approaches in the mechanical method, namely, excess water method, air-entrained method and preformed foam method. Hoff¹ proposed the determination of compressive strength of cellular concrete in terms of water-cement ratio and density.

The present work deals with an experimental study of the aerated concrete produced by the method of preformed foam. The study is intended to investigate the various factors which influence the properties of aerated concrete, especially its density and compressive strength. The preformed foam agent used in this study is Sodium Lauryl Ether Sulphate and its properties are indicated in Table 1. The mortar has the ratios of cement to fine sand of 1:1, 1:1.5, 1:2 and 1:2.5 by weight while the water-cement ratio and the amount of foam are kept as parameters.

TABLE 1
DESCRIPTION OF SODIUM LAURYL ETHER SULPHATE

Chemical formula	: NaC ₁₂ H ₂₅ SO ₄
State	: liquid
Specific gravity	: 1.05
Chloride content	: less than 1.50%
Sulphate content	: less than 1.50%
pH of 10% solution	: approximately 6.50
Viscosity at 20°C	: 10,000–12,000 CPS
Type of ion	: negative

The equipment used in this experiment consists of a concrete mixer and a foam producing tank. The concrete mixer has the capacity of 0.035 cu.m and the rotating speed of approximately 60 rpm. It is noted that the speed of the mixer is higher than the ordinary concrete mixer. The foam producing tank is of the cylindrical column type as shown in Figure 1. The tank was designed in order that the compressed air can flow into the tank at the bottom and pass through the solvent which had already filled into the tank from the top. The solvent was the mixture between Sodium Lauryl Ether Sulphate and water at the ratio of 1:25 by volume (4%). As a result, the foam was formed and flowed out along the pipe at the top of the tank.

Fig. 1 Foam producing tank

Fig. 2 Mixing of foam and mortar

Foam was added into the mixer to mix with the mortar as shown in Figure 2. In this manner, the aerated concrete was obtained and then placed into the standard cylindrical molds in accordance with the ASTM C 192-81. Ten specimens were cast for each mixing ratio of mortar having difference in water-cement ratios and the foam content. The specimens were then cured by covering with a plastic sheet. Totally 1,120 specimens were cast and brought to test at the age of 14 days. This is due to the fact that the cement used in this study is of type III (rapid-hardening) which gives the early strength. It should be noted that the fine sand is passing through sieve no. 8 and retained on sieve no. 200.

EXPERIMENTAL RESULTS

The aerated concrete produced from this study has porous texture. This is the result of the stable foam maintained in the mixture of concrete as shown in Figure 3. Figures 4(a) and 4 (b) show the floating of a panel and a cylinder of concrete which indicate the light - weight property of the aerated concrete.

The test results are tabulated in Table 2. The results indicated in the table are the average values of the compressive strength and density among the 10 specimens tested. The water-cement ratio and the amount of foam used in producing the aerated concrete are plotted against the compressive strength as shown in Figures 5(a) - 12(a) and against the density as shown in Figures 5(b) - 12(b) respectively. In addition, Figure 13 shows the relationships between the compressive strength and density of the aerated concrete.

Fig. 3 Porous texture of aerated concrete

Fig. 4(a) Floating of an aerated concrete panel

Fig. 4(b) Floating of an aerated concrete cylinder

TABLE 2
DETAILS AND RESULTS OF THE AERATED CONCRETE

W/C Ratio		0.4		0.5		0.6		0.7	
Mixing Ratio	Foam [†] in $\times 10^{-3} \text{ m}^3$	Density kg/m^3	$\sigma_c^{\dagger\dagger}$ MPa	Density kg/m^3	σ_c MPa	Density kg/m^3	σ_c MPa	Density kg/m^3	σ_c MPa
1 : 1	25	1790	22.27	1830	18.25	1770	15.34	1740	10.38
	50	1670	18.37	1540	11.51	1620	12.87	1430	5.97
	75	1270	4.47	1310	6.56	1360	7.09	1240	3.94
	100	1240	3.44	1240	4.87	1320	6.17	1090	2.64
	150	900	0.63	970	2.92	1060	3.19	960	2.00
	200	790	0.15	780	0.55	820	1.25	800	0.81
	300	520	0.13	610	0.15	760	0.84	650	0.68
1 : 1.5	25	1690	13.96	1840	21.69	1880	19.10	1840	14.20
	50	1570	5.59	1520	10.69	1590	12.16	1650	11.92
	75	1340	2.39	1310	4.89	1430	7.11	1480	8.52
	100	1250	3.02	1220	4.38	1250	4.31	1210	3.00
	150	1070	0.62	1160	1.66	1090	1.28	1180	3.57
	200	770	0.11	850	0.49	890	1.31	880	1.23
	300	620	0.03	670	0.07	650	0.16	890	0.51
1 : 2	25	1790	14.05	1880	19.47	1890	20.40	1870	15.45
	50	1580	10.94	1660	13.75	1650	12.22	1580	9.40
	75	1410	5.07	1390	5.10	1350	5.01	1420	6.50
	100	1280	1.46	1340	5.59	1300	4.55	1390	5.52
	150	1130	1.63	1180	2.27	1120	2.29	1100	1.98
	200	860	0.09	1010	0.44	1000	1.85	920	1.40
	300	690	0.08	750	0.28	810	0.53	780	0.55
1 : 2.5	25	1720	15.19	1840	20.19	1860	17.18	1860	13.98
	50	1580	10.40	1580	9.62	1670	11.64	1660	10.05
	75	1470	6.10	1430	3.66	1530	8.45	1510	8.35
	100	1310	1.42	1320	3.66	1340	3.55	1410	5.94
	150	1170	0.69	1120	0.68	1130	2.20	1270	4.14
	200	920	0.13	950	1.11	950	1.00	1040	2.07
	300	*	*	860	0.32	890	0.27	980	0.52

† Amount of foam in 100 kg of cement

†† σ_c = Compressive strength

* Failure due to the excessive amount of foam

Fig. 5(a) Relationship between compressive strength and water-cement ratio (mixing ratio 1:1)

Fig. 5(b) Relationship between density and water-cement ratio (mixing ratio 1:1)

Fig. 6(a) Relationship between compressive strength and water-cement ratio (mixing ratio 1:1.5)

Fig. 6(b) Relationship between density and water-cement ratio (mixing ratio 1:1.5)

Fig. 7(a) Relationship between compressive strength and water-cement ratio (mixing ratio 1:2)

Fig. 7(b) Relationship between density and water-cement ratio (mixing ratio 1:2)

Fig. 8(a) Relationship between compressive strength and water-cement ratio (mixing ratio 1:2.5)

Fig. 8(b) Relationship between density and water-cement ratio (mixing ratio 1:2.5)

Fig. 9(a) Relationship between compressive strength and the amount of foam (mixing ratio 1:1)

Fig. 9(b) Relationship between density and the amount of foam (mixing ratio 1:1)

Fig. 10(a) Relationship between compressive strength and the amount of foam (mixing ratio 1:1.5)

Fig. 10(b) Relationship between density and the amount of foam (mixing ratio 1:1.5)

Fig. 11(a) Relationship between compressive strength and the amount of foam (mixing ratio 1:2)

Fig. 11(b) Relationship between density and the amount of foam (mixing ratio 1:2)

Fig. 12(a) Relationship between compressive strength and the amount of foam (mixing ratio 1:2.5)

Fig. 12(b) Relationship between density and the amount of foam (mixing ratio 1:2.5)

DISCUSSION

From the analysis of results, it is observed that the compressive strength and the density of aerated concrete depend on the water-cement ratio, the amount of foam and the cement-fine sand ratio.

Figures 5(a)–8(a) show that the aerated concrete tends to give higher compressive strength when the water-cement ratio is equal to 0.6. However, the water-cement ratio has little or practically no effect on the density as shown in Figures 5(b)–8(b). This is due to the fact that the aerated concrete samples were tested after the final setting of concrete in dry condition. Therefore, the suitable water-cement ratio can be taken as 0.6 for the strength consideration.

The amount of foam has the significant effect on both compressive strength and density of the aerated concrete as shown in Figures 9(a,b)–12(a,b). It is seen that the increment of foam up to 0.15 cu.m/100 kg of cement will drastically reduce both strength and density and the reduction becomes insignificant when the amount of foam exceeds 0.15 cu.m/100 kg of cement. It should be noted that the compressive strength of concrete-block for use as non-structural element is specified at least 2.5 MPa. Therefore, in order to achieve this specified strength, the amount of foam used should not be more than 0.15 cu.m/100 kg of cement.

It should also be observed, from Figures 5(a,b)–12(a,b), that the cement-fine sand ratio of 1.0 gives comparatively higher compressive strength as well as lower density than the rest of other ratios.

Figure 13 shows the relationship between the compressive strength and the density for all mix proportions. The curve indicates rather good correlation between the compressive strength and the density.

From the studies, the aerated concrete with the compressive strength of 3.5 MPa and the density of approximately 1,000 kg/cu.m can be produced by using the cement-fine sand ratio of 1.0, water-cement ratio of 0.6 and the amount of foam of 0.15 cu.m/100 kg of cement.

Finally, the consideration of the sulphate content concerning the durability of concrete is also of interest. For example, the maximum sulphate content for this study occurs at the lowest water-cement ratio of 0.4 and the sulphate content in water resulting from the solvent is only 0.03 percent which is considered to be negligible for concrete attack.⁶

Fig. 13 Relationship between compressive strength and density (drawn from 1,120 specimens)

CONCLUSION

The experimental results presented in this paper can be concluded as follows:

1. The compressive strength of aerated concrete is proportional to the density and inversely proportional to the amount of foam used.
2. The density of aerated concrete is inversely proportional to the amount of foam and cement–fine sand ratio.
3. The effect of the water–cement ratio on the density of aerated concrete is not significant.
4. Higher strength and lower density of aerated concrete can be achieved by using the cement–fine sand ratio of 1.0.
5. The suitable water–cement ratio for aerated concrete is equal to 0.60.
6. The workable aerated concrete should have the amount of foam not exceeding 0.15 cu.m/100 kg of cement.

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