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Material and Structural Behaviour of a Novel Material

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ABSTRACT

The growing need for a better and effective way of reducing structural weight and high cost in productivity of concrete products has lead to great innovation in the use of lightweight concrete such as foam concrete which is known to be in use for about thirty to forty years, but its low quality characteristics has in no small measure hinder its wide industrial application.
This paper presents a novel material the Aer-Tech product which early results from laboratory compressing testing of samples suggests that it has formidable characteristics and the potential to result in lightweight elements and huge savings in the construction of structures.

INTRODUCTION

The environmental challenges in reducing the self weight of a structure and its overwhelming high cost demand in the construction industry has undoubtedly considered the light weight cementitious material as an advantage against the bulkeous use of concrete. In addition to reducing stresses through the life time of structure, by using smaller elements, the total weight of material to be handled during construction is drastically reduced, which consequently increases productivity and reduction on environmental hazards caused by concrete. For this reason was the Aer-Tech material developed.

Aer-Tech has evolved out of concrete but where stone aggregates were replaced with air cells. The Aer-Tech machine equipment uses a patented screw, mixing system and atomised liquid dosing system which produces a regular, consistent homogeneous mix. The atomiser injects air cells as small as 20 micron into the mix replacing the stone aggregate and the mixing screw mixes sand, cement and water with consistency and even distribution, creating a geodesic structure (see Fig.1). The consistent structure created provides the strengths achieved without using any stone aggregates. Importantly, all constituents including air cells are intended to be evenly distributed throughout the mix. This remarkable consistent distribution of air cells creates a geodesic structure, which in effect makes the material unique. However, it is evident that Aer-Tech distinctively posses the characteristics, different from other lightweight materials because, its billions of air cells do not collapse, but coalesce on axial loading, giving the material a high compressive strength. More so, the high strength and low density display of Aer-Tech materials gives it, greater potential for use in thermal and acoustic insulation, floating pontoons, making of floor tiles, roof tiles, building walls, slabs and an encasement for toxic waste etc.

Fig.1 Aer-Tech material being poured in the moulds

Similar studies have shown that base mixes of uniform distribution of air-cells in a plastic mortar give a higher strength (Nambiar and Ramamurthy, 2006). It is also said that bigger pores in a base mix influence the strength. This is correct as the pore system in cement-base material is conventionally, classified as gel-pores, capillary pores, macro- pores due to deliberately entrained air. However, the gel pores do not influence the strength of Aer-Tech materials through it's porosity. But the capillary pores and other large pores are responsible for reduction in strength and elasticity (Neville and Brooks, 2004).

Several investigations had been carried out on foam concrete, which is defined as self flowing and self compacting concrete, without a coarse aggregate. Over the years, empirical models have been developed to relate the porosity and strength, which focus on extended models of aerated concrete carried out by (Narayaman and Rammamurthy, 2000) and for foam concrete by (Hoff, 1972) and (Kearsely and Wainwright, 2001). These models reflect the effect of porosity on strength and may not adequately represent the pore structure.

According to Cebcci (1981) air entraining agents introduce large air voids and do not alter the characteristics of the fine pore structure of hardened cement paste appreciably (Kearsely and Visagie, 1999) reported that the air- void size distribution is one of the most important micro properties influencing the strength of foam concrete.

The Aer-Tech material is defined as a cementiteouse material with more than 10% of mechanically entrained air-voids. The paper focuses on highlighting the importance of the machine tuning and adjustments and preliminary tests of compressive strength performance of the Aer-tech materials.

According to (Nambiar and Ramamurthy, 2006), fresh state characteristics of foam concrete consistency is an important determining factor in a lightweight mix as it is observed that consistency values either lower (mixture is too stiff causing the bubbles to break) or higher (slurry becomes too thin to hold the bubbles resulting in segregation) than this value lead to an increase in density .This further defined the stability of foam concrete “as the state of mix at which density ratio is closer to unity”. This depends on the consistency of foam concrete is reduced, which is inherent on the foam volume added and for a given density. Following, this occurrence, super-plasticizers are employed to maintain a suitable workability, even though it may reduce the stability of foam concrete (Saucier et. al., 1991, and Cox and Van Dijk, 2002).

EXPERIMENTAL PROGRAMME

Material and mixture composition

The constituent material used to produce Aer-tech materials were comprised of: Pro-chem cement conforming to BS8110, pulverized river sand finer than 300µ (specific gravity 2.5), and foam produced by aerating a foaming agent (Aer-Sol) (dilution ratio 1:5 by weight) using an indigenously Aer-Tech machine calibrated to a density of 1810kg/m^3. For this experiment three different types of mixes were used: (1) several specimens were composed of Pro-chem cement, pulverized river sand, distil water and foam (2) a good number of specimens were composed of Pro-chem cement, pulverized river sand, distilled water, foam and a plasticizer and (3) the third types of specimens are composed of Pro-chem cement, water, foam and fibre mesh. Different mixes of the Aer- Tech materials were made varying the filler- cement ratio of 4.78:1 and 5.83:1 design mixes.

The mixing sequence consisted of a well calibrated Aer-Tech machine, which passes the constituent material from its internally built in conveyor to a mixing chamber, which is designed like a mini batch plant. This process continues until a uniform homogeneous base mix was achieved.

The high air content eliminates any tendency to bleed and with good insulation properties, as the mix temperature increases during setting the air expands slightly which ensures good filling and contact in confined voids.

Test Procedure

With a clear objective of assessing the compressive strength performance of Aer-Tech, the author had considered the use of cubes and mini beams as specimens for testing. The base mix from the Aer-Tech machine is poured into cube moulds and mini beam moulds. The samples are then levelled to achieve good finished surface, left for 24 hours, after which the moulds are uncoupled and carefully placed for air curing in accordance to BS8110 testing procedures. The air-curing period are 7 days, 14 days, 28 days, 56 days and 6 months period as the case maybe. On completion of air-curing period in compliance with test requirements, a compressive strength test is carried out to ascertain the Aer- Tech resistance capability.

In order to study the behaviour of Aer-Tech materials, normal concrete testing was done to determine the material and structural properties of each type of Aer-Tech and how these properties differ according to different types of mix design.
Once the concrete has hardened, it is subjected to a wide range of tests to prove its ability to perform as planned and to determine its characteristics. In the next section are given the results of compressive strength tests carried out on Aer-Tech specimens.

RESULTS AND ANALYSIS

Tables 1 to 4 show the results of compressive strength for a number of specimens with different densities and different water content ratios, with or without plasticizer.

As may be seen, the compressive strength is seen to increase with increased density of the material. For a given mix, overall the density of the material is seen to reduce with time (age). This is due to water evaporation with time. Also, the introduction of 1% plasticizer is seen to reduce the compressive strength by more than 50% for the lower density specimens.

Table 1. 5.83:1mix

Specimens	**Density**	**Compressive Strength**	**Age (days)**
CU320	1993	13.14	7
CU325	1964	16.93	14
CU322	1945	20.24	28
CU321	1925	21.65	56

Table 2. 5.83:1 with 1% plasticizers

Specimens	**Density**	**Compressive Strength**	**Age (days)**
CU420	1993	6.7	7
CU426	2010	13.9	14
CU429	1943	15.14	28
CU428	2003	14.55	56

Table 3. 4.78:1 mix with 20% water reduction

Specimens	**Density**	**Compressive Strength**	**Age (days)**
CU331	1816	16.43	7
CU337	1830	26.56	14
CU330	1805	27.30	28
CU336	1858	28.30	56

Table 4. 4.78:1 20% water reduction and 1% plasticizer

Specimens	**Density**	**Compressive Strength**	**Age (days)**
CU455	1729	13.6	7
CU457	1722	15.19	14
CU456	1692	13.4	28
CU453	1747	18.83	56

Duration of Curing	7	14	28	56
Compressive strength (No Additives)	16.43	26.56	27.30	28.30
1% Plasticiser Compressive strength	5.88	17.4	6.97	20.86

Table 5.

20% water reduction Compressive strength	16.43	26.56	27.3	28.30
12% water reduction Compressive strength	14.33	21.93	23.29	25.62
8% water reduction compressive strength with 1.8g/mould fibermesh	11.54	14.24	17.55	18.39
5% w/r compressive strength	16.38	20.45	23.4	25.78
5% w/r with 1.8g/mould fibermesh Compressive strength	17.01	18.48	24.31	25.01

There seem to be some signs of inconsistency of the results using the plasticiser additive. This is probably due to a chemical reaction with the foaming agent. This an example of this research being so important, as it is part of the research programme to investigate material behaviour with various additives, but also to effectively calibrate the Aer-Tech machine more finely and to produce consistent materials and results in the future.

The reduction of mixing water by 20% with no additives added, have produced the highest compressive strengths of Aer-Tech materials.

The use of fibermesh added to the mix shows that more mixing water is required to achieve higher compressive strengths.

The compressive strength of Aer-Tech material is determined by carrying out 7, 14, 28 and 56 days testing for specimen taken after a complete air-curing. These specimens are then placed under an axial max load of 2000 kN. Essentially, this research had produced extensive number of samples, for a proper analysis. The results of density and strength values were taken based on average results given. On the whole, fewer variables had been set for different ultimate mixtures as mentioned earlier, these variables will change while others, were fixed to forecast their effects on the mixture. Thus, the varying percentage of foam agent, water, fibermesh, plasticisers, cement and sand ratio were variables made during mixing process. For example Table 5 shows that a particular mix of 4.78:1 can be displayed in variable content of water, plasticisers and fibermesh. It shows an extraordinary performance of Aer-Tech, as it confirms that at lower water-cement ratio and presence of high % of fibermesh, a clear indication of high strength is observed. This is achieved due to the even distribution of fibermesh, which is fed into the mixing screw to overcome any clogging up problems in Aer-Tech machine.

On a broad view, it may be observed that a percentage reduction in water volume gives a corresponding increase in compressive strength, appreciably 20% water reduction shows higher strength value as against 12%, 8% and 5% reduction of water in a 4.78:1 mix for the same duration. Interestingly, it is clear that higher % reduction of water content for this mix ratio, led to a higher compressive strength due to the cement paste forming a stronger bond and setting quickly.

The results as presented in Table 1 show that the compressive strengths for Aer-Tech material, are lower. This is because the ratio of the mix used was 5.83 parts sand to one part cement. The density is higher due to the increase in the sand proportion in the mix. As a result, compressive strength decreases with the increase in the voids ratio.

CONCLUSIONS

Considering the important factor influencing strength and density of Aer-Tech materials, it is clear that the percentage of foam in Aer-Tech base mix is a determining factor. The test results have also shown that the adjustment of the Aer-Tech machine is an important parameter of the research programme and can have a big influence of the results and their consistency. All of these will be part of the further research programme to be carried out in the future.

The research has also shown that reasonable amount of strength is gained using admixtures like fibermesh by using more mixing water. A higher reduction of water content in Aer-Tech mixes with no additives leads to higher strength gains.

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RECOMMNENDATIONS AND FUTURE WORK

Future research work will consist of the following tasks:

- Continue with the process of adjusting the Aer-Tech machine. Such adjustment is vital for obtaining consistent results.
- Investigate the Aer-Tech material with different mixes, such as fly ash and fibre (steel and glass).
- Investigate structural behaviour of Aer-Tech materials by undertaking flexural tests of beams.

REFERENCES

British Standards BS8110 (2000). Testing Hardened Concrete: Part 14.

Cebeci, O.Z. (1981). “Pore structure of air-entrained hardened cement paste”. *Cement and Concrete Research* **11**, pp. 257–265.

Cox, L. and Van Dijk, S. (2002). “Foam concrete: a different kind of mix”. CONCRETE, Vol.36, No.2, pp.54-55.

Hoff, G.C. (1972). “Porosity–strength considerations for cellular concrete”. *Cement and Concrete Research* **2**, pp. 91–100.

Kearsley, E. P. and Visagie, M. (1999). “Micro-properties of foamed concrete”. *R.K. Dhir, N.A. Handerson (Eds.), Proceedings of congress on creating with concrete (conference on specialist technology and materials for concrete construction).* Dundee, Thomas Telford, pp. 173–184.

Nambiar, E. K. K. and Ramamurthy, K. (2006). “Air-void characterization of foam concrete”. *Elsevier*, 37 221-230.

Narayanan, N. and Ramamurthy, K. (2000). “Structure and properties of aerated concrete: a review”. *Elsevier Science Ltd*.

Neville, A.M. and J.J. Brooks, J.J. (2004). “*Concrete Technology”*, Pearson Education Pvt. Ltd., Singapore.

Saucier, F., Pigeon, M. and Cameron, G. (1991). “Air-Void Stability, Part V: Temperature, General Analysis and Performance Index,” *ACI Materials Journal*, V. 88, No. 1, pp.25-36.