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Preparation of Low-Cost Foam Concrete Using Detergent

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Abstract- This study consisted of foam concrete preparation by using local detergent and comparing its properties with commercially used foam concrete and plain cement mortar. Nine mixes of foam concrete with seven samples each were prepared, according to ASTM C-192/C 192M-02, standard 150 mm cube by varying percentages of cement (55-65%), sand (35-45%) and local detergent (0.35-0.45% by weight of cement); with water to cement ratio as 0.6. Similarly, three mixes of plain cement mortar and one mix of foam concrete using commercial FA (Foaming Agent) with seven samples each were prepared. Different parameters were compared in this study, like compressive strength, density, water absorption and acid resistance. In this study, it was concluded that foam concrete prepared by mixing of cement 60, sand 40% with detergent of 0.4% by weight of cement to be the best possible mix out of the selected mix ratios without compromising the engineering properties of concrete.

Keywords- Local Foam Concrete, Detergent, Porous Concrete, Compressive Strength, Foaming Agent.

I. INTRODUCTION

Foam concrete is a type of porous concrete with properties like free-flow and self-levelling, hence requires no compaction. It is ecologically clean, breathes, noninflammable and even easy to produce on a construction site [1]. It is produced from components available in any region and its prime cost is low. Its main advantage over more traditional fill or sub-base material is its ability to flow around pipes and cables in situations where congestion in excavations would make it difficult to adequately compact other materials. It is also a useful material to use where side stability of trenches is poor or where there is undercutting of the adjacent carriageway. Foam concrete is a viable solution for reducing loading on burden soil and, in its hardened state, is less susceptible to differential settlement due to its lighter weight. Generally, the density of lightweight foam concrete ranges from 400-1850 kg/m^3 [1]. Heavier density (1000 kg/m^3) foam concrete is mainly used for applications where water ingress would be an issue in filling cellars, or in the construction of roof slabs.

Uniform distribution of air bubbles through the mass of cement makes foam concrete. Foam concrete is created by the mechanical blending of foam prepared ahead of time with concrete mixture, and not with the assistance of chemical reactions. The manufacturing procedure of foam concrete is illustrated in Fig. 1. Around the globe research have been carried to study the behavior of foam concrete in its fresh and hardened state. Foam concrete being porous influences the strength and durability related properties. Size, volume and void-spacing are the regulating parameters but there is no influence of air-void shape on properties of foam concrete [2]. The ultra-lightweight foaming concrete [3] might need materials like fly ash and chemical admixtures, making the whole concrete matrix uneconomical at the same time enhancing its applicability in the huge span covering dome and shell structures. Use of expensive and sophisticated foaming agents are more common in the production of foam concrete [4] with research of characterizing air-void shape and size and influence of such parameters on the strength of concrete[5].

Furthermore, ordinary concrete needs inputs of natural resources like sand and stone. As the demand is increasing which increase the damage to natural resources Hwang and Tran [6] investigated the use of lightweight aggregates in addition to the foaming agent. Various properties and applications of foam concrete were investigated [7, 8] with and without supplementary cementitious materials. Nambiar and Ramamurthy [9, 10] have investigated the sorption-related properties of foam concrete as affected by its composition and pore structure and reported that sorption values of foam concrete are less than the corresponding plain mix.

Foam concrete with fly ash shows lesser dependency on pore parameters than cement-sand mixes as reported

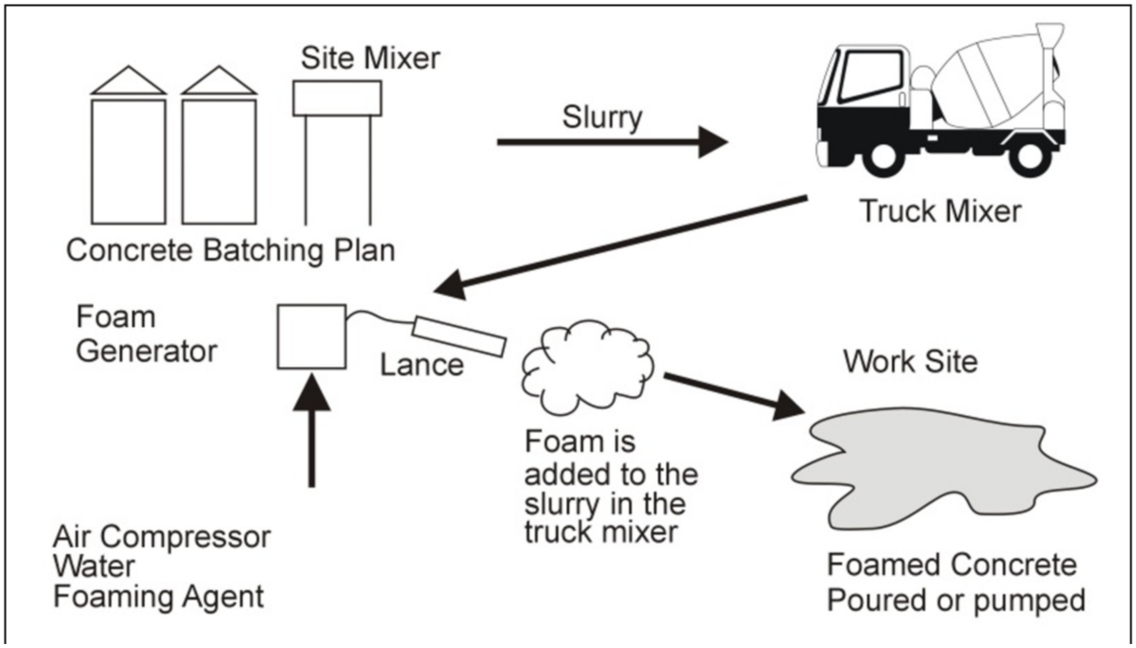

Fig. 1. Life Cycle of Commercial Manufacturing Foam Concrete [7]

by [11]. Ramamurthy et. al., [12] have classified the literature on foam concrete in terms of constituent materials (foaming agent, cement and other fillers used.

Kuzielová et. al., [13] have examined the effect of the foaming agent concentration and its microwave and ultrasonic treatment in relation to the foam stability, bulk density, microstructure and resulting compressive strength. Ma and Chen[14] have reported that the water repellents improve the compressive strength to a certain extent without compromising the thermal insulation property of the foamed concrete. Tian et. al., [15] have used original PG (Phosphogypsum), which is a waste of phosphoric acid manufacturing by dehydrating process, as raw material for the manufacture of foam concrete and worked out its optimum content for compressive strength of concrete. Krämer et. al., [16] have used nanotubes to improve performance of foam concretes due to nan-reinforcement and their nucleation abilities. Lim et. al., [17] have reported that the use of high-volume quarry dust could reduce the fluidity and increase the compressive strength and the thermal conductivity of lightweight foam concrete[18, 19].

Based on the literature survey, it was observed that most of the investigations were to assess the foam concrete properties, and with a little focus on its economical production using cheap foaming agent

TABLE 1
NOMENCLATURE AND MIX DESIGNS RATIO OF SPECIMENS

Type	Sample	Cement (%)	Sand (%)	Detergent (% wt. of cement)	W/C Ratio
PM	M1	65	35	0.00	0.60
	M2	60	40	0.00	0.60
	M3	55	45	0.00	0.60
CFA	*FA-1	60	40	*	0.60
LD	D1-A	65	35	0.35	0.60
	D1-B	60	40	0.35	0.60
	D1-C	55	45	0.35	0.60
	D2-A	65	35	0.40	0.60
	D2-B	60	40	0.40	0.60
	D2-C	55	45	0.40	0.60
	D3-A	65	35	0.45	0.60
	D3-B	60	40	0.45	0.60
	D3-C	55	45	0.45	0.60

* Foaming Agent (FA-1), used on basis of 0.45 kg/m^3, density-600kg/m^3

without compromising the strength and other engineering properties of foamed concrete matrix. Two of the commonly used foaming agents in Pakistan are Noraite PA-1 (Protein) and Noraite SA-1 (Synthetic). The aim of this study was to prepare foam concrete using low-cost indigenous materials. The material used for the preparation of this concrete and its dosage was varied to obtain different samples and were tested for its different properties. Appropriate dosage of indigenous materials was used during this study to obtain the optimum results.

II. MATERIALS

The cement used in the study for the manufacture of different types of concrete mixes was commercially available OPC (Ordinary Portland Cement) (Type-I), with local brand name Maple Leaf. The fine aggregate used was from one of the best quarries (Lawrencepur) in Pakistan and was bought commercially. The sand used met the requirements of ASTM C-33. Clean and drinkable tap water was used and a commercially available and renowned foaming agent (FA-1, Beijing trinity construction material trade co. ltd) was used to cast air-entrained concrete. The amount of foaming agent was kept constant as specified by the manufacturer as shown in footnote of Table 1.

III. MIX DESIGN SPECIFICATIONS

Three types of specimens were prepared. The specimens prepared using PM (Plain Mortar), using CFA (Commercial Foaming Agents), and LD (Local Detergents). Specimens (i) using PM, were divided into three subcategories named as M1, M2, M3 based on variation of quantities of cement and sand (ii) using CFA are designated as FA-1 and (iii) using local detergents are specified as D1, D2, D3 etc. based on variation of cement and sand, furthermore the samples were divided into three sub-groups (suffice alphabetically) based on variation in percentage of detergents The test matrix is given in Table 1.

A. Commercial Methods for Producing Foam Concrete

Foam concrete is generally made by adding water-based, gas-filled foam into a paste that commonly constitutes water and OPC alone or Portland concrete with a fine, lightweight aggregate. The foam paste solidifies to give a low-density concrete that is utilized as a part of either ground surfacing or roofing applications where either thermal protection or acoustical damping is required. Beforehand, OPC was the preferred material used to deliver foam concrete. The foam structure is developed by adding the gas-generating chemical to the OPC paste or by mixing a preformed, water-based foam into the cement paste. Portland cement-based, foamed concretes are typically slow to cure and have relatively low strength.

B. Foam Concrete Preparation

The production of foam concrete using detergents was divided into two steps shown in Fig. 2 and Fig. 3. First, the required quantities were calculated. The said amount of detergent was added to water in the concrete mixer until a uniform froth (20 cycles in 3 minutes) was prepared.

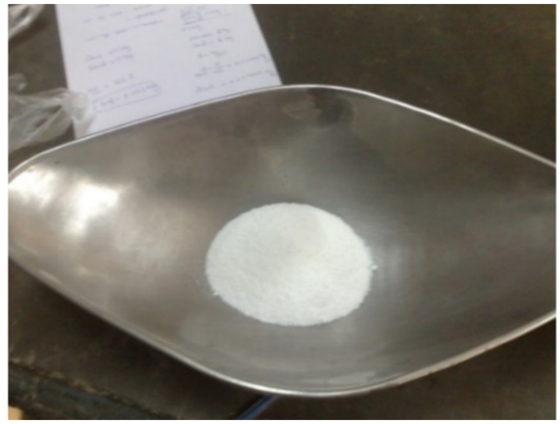

Fig. 2. Commercially available detergent

Then the calculated amount of cement and sand which was already graded was mixed in the foam slurry. The mixer was allowed to run for 4-5 minutes till the uniform air-entrained concrete mix was prepared. Each mix design was used to prepare seven samples which were thereafter used in the series of testing carried out. The w/c ratio was kept constant at 0.6 throughout the manufacture of different mix designs.

Fig. 3. Foam formation in mixer machine

IV. EXPERIMENTAL WORK AND LABORATORY TESTS

Table 2 described the different water-related test performed on the water sample. Tests presented in Table 3, were carried out to determine and analyse the physical and chemical (durability) properties of different mixes. The preparation of mix and the specimens are illustrated in Fig. 4 and Fig. 5, respectively.

TABLE 2
REPORT OF WATER TESTS

Test	01	02	Unit
Turbidity	0.915	0.672	NTU
Total Dissolved Solids	450	410	mg/lit
Total Hardness $CaCO_3$	30	50	mg/lit
Sulphate Content SO_4	2	1.7	mg/lit
P.H	7.90	7.95	No.

Fig. 4. Preparation of samples

Fig. 5. Casting of samples

A. Compressive Strength Test Results

The 28 days compressive strength of specimens prepared using local detergent varied from 4.07-4.82 MPa. It is to be noticed that all the detergent mix designs produced in this research work yielded a compressive strength well over the base prerequisite of 1.38MPa put forward by ASTM Specifications C 796-04 and C 869-91. Generally, the compressive strength of foam concrete was observed to be 8-12% of the compressive strength of corresponding non-air-entrained mortar mixes **at 28-days, shown in Fig. 6. The** 28-days compressive strength of mix FA-1 with 60% cement and 40% sand is approaching to 6.14 MPa. Fig. 7 and Fig. 8 show the results of compressive strengths of different mixes at different ages.

B. Density Test Results

As placed density of specimens prepared using local detergent varied from 865-960 kg/m^3. However, as-placed density increased with the increase in cement content. The as-placed density of specimens prepared using detergent was almost half of samples prepared using plain mortar. The oven-dry density of samples prepared using local detergent varied in the range of 785-880 kg/m^3. Dry density observed to be less than as placed density in the range of 80-130 kg/m^3. It decreased with increase in dosage of detergent. By examination, the oven-dry density of foam concrete is around 50-60 % less as that of plain mortar mixes. Fig. 9 and Fig. 10 and Table 4 show the results of as-place and oven-dry densities, while for mix FA-1 showed densities as 940 kg/m^3 and 858 kg/m^3 at cement 60% and sand 40% mix composition, respectively.

C. Water Absorption Test Results

The water absorption capacity of plain mortar samples was observed to be 50-60% of foam concrete samples. Increase in quantity of foaming agent (detergent) results in increase of water absorption capacity. By comparison, detergent mixes demonstrated higher water absorption than that of control mix as shown in Fig. 11. Different detergent mixes demonstrated a standard deviation in the scope of 1.07-1.31.

D. Acid Resistance Test Results

Samples prepared using local detergent showed almost 15-25% weight loss as compared to PM samples. Foam concrete showed much better resistance when immersed in hydrochloric acid solutions, as compared to non-air-entrained mortar mixes. By comparison, weight loss was slightly higher in the case of detergent mix designs as compared to the control mix designs. Specimens gave light yellow appearance after removal from hydrochloric acid tank. There were no indications of any scaling or decay. Weight loss for concrete specimens prepared with CFA was not determined. Results are presented in Fig. 12, for the % wt. loss of material in 5%-HCL solution.

V. DISCUSSION

The suitability parameters/properties of foam concrete chosen for this study were density, water absorption, compressive strength and acid resistance. These parameters are interlinked with one another. The volume of cube remains constant but in foam concrete volume of void is variable depending upon the percentage of foaming material added to the mix. The variable percentage of foaming material will produce variable voids in mix causing variable level of porosity

TABLE 3
MATERIAL TESTING AS PER THE CURRENT CODE OF PRACTICE

Test	Specification	Specimen	Remarks
Compressive Strength	BS 1881-116 (1983) ASTM C109/C 109M-02 and C 796	Standard Cube (150 mm)	In understanding the arrangements of ASTM C 109/C 109M - 02, samples were wet cured till the date of testing. Testing was completed at 7 days and 28-days
As-Placed Density	ASTM C-138/C 138M - 01a	Standard Cube (150 mm)	Standard cube moulds were filled with fresh foam concrete, and the as-placed density was calculated from the weights of filled moulds and their volume
Oven-Dry Density	ASTM C 642-97	Standard Cube (150 mm)	After 28-days curing, these cubes were oven-dried for 24-hours at a temperature of 100ºC. The oven-dry density of each mix was calculated from the oven-dry mass.
Water Absorption	ASTM C 642-97	Standard Cube (150 mm)	Oven dry samples were used in the first place, by immersing them into the water for 48 hrs. Their weight was recorded before and after the immersion.
Acid Resistance	N/A	Standard Cube (150 mm)	Oven dry samples were immersed in a 5% hydrochloric acid solution for 28 days. It was then again oven-dried for 24-hours and weighed again. The difference of weights at initial and final stages was recorded.

TABLE 4
COMPARISON OF AS-PLACE AND OVER DRY DENSITY

Sample	Cement (%)	Sand (%)	Detergent (% wt of cement)	w/c Ratio	As-place Density (kg/ m^3)	Oven dry Density (kg/m^3)
D1-A	65	35	0.35	0.6	869	797
D1-B	60	40		0.6	419	825
D1-C	55	45		0.6	948	877
D2-A	65	35	0.4	0.6	884	790
D2-B	60	40		0.6	934	810
D2-C	55	45		0.6	981	865
D3-A	65	35	0.45	0.6	820	758
D3-B	60	40		0.6	879	799
D3-C	55	45		0.6	951	822
M1	65	35	0.54	0.6	2112	2071
M2	60	40	0.66	0.6	2050	2021
M3	55	45	0.82	0.6	2014	1982

and thus variable density. The density of casted cubes thus has direct effect on its water absorption, compressive strength and partially on acid resistance properties. The detergent (surf excel) has been used for the first time for making foam concrete. The density of foam /lightweight concrete is dependent upon life of bubbles created by foaming agent in a mix. The commercial foaming agent is prepared to keep in view this aspect while detergent is prepared basing on their coagulant properties.

The mixing percentages of additives selected in the study were cement (55-65%), sand (45-35%), detergent (0.35-0.45% by weight of cement). The average percentage of each additive cement (60%), sand (40%) and detergent (0.40% by weight of cement). The results against each parameter followed a similar trend, that's why mix design D2-B has been selected as optimized mix. The dry density for D2-B was (810 kg/m^3) as compared to FA-1 (858 kg/m^3). The water absorption of this mix was 22.97% as compared to FA-1 (26.43%). The 28 days compressive strength of D2-B was (4.81 MPa) as compared to FA-1 (6.14 MPa). Weight loss against acid resistance for D2-B was (1.24%) as compared to FA-1 (1.12%). Basing on above comparison, detergent has satisfactorily qualified the requisite parameters set for a foam concrete. The detergent mixed foam concrete showed 19% lesser cost for 1 cubic-foot mix as compared to commercial foaming agent.

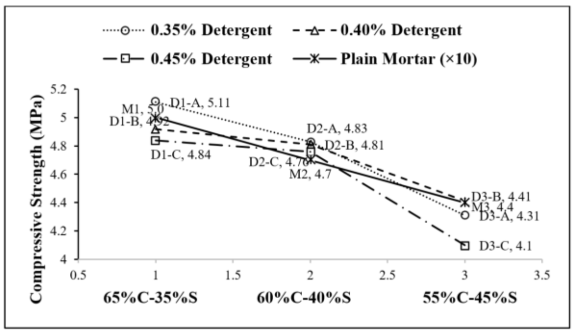

Fig. 6. Compressive strengths of different mixes

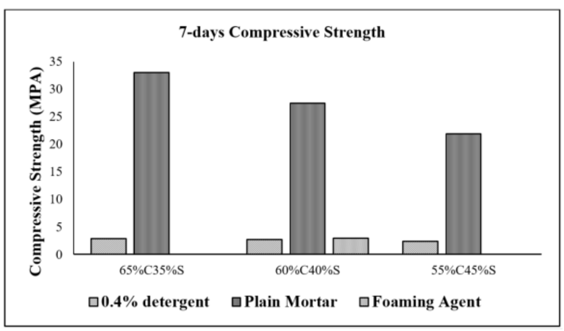

Fig. 7. 7-Days compressive strength of mix designs

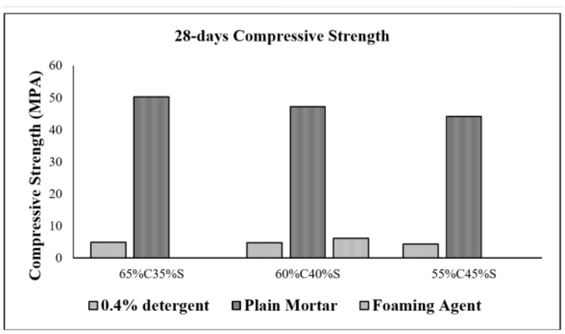

Fig. 8. 28-Days compressive strength of mix designs

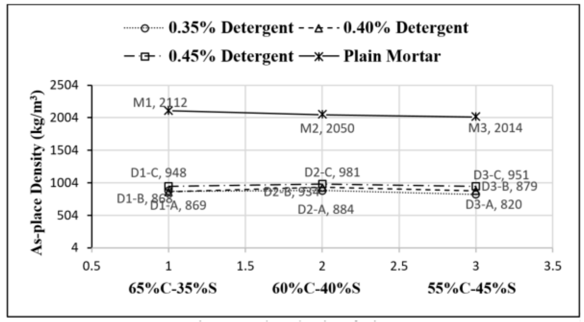

Fig. 9. As-place density of mixes

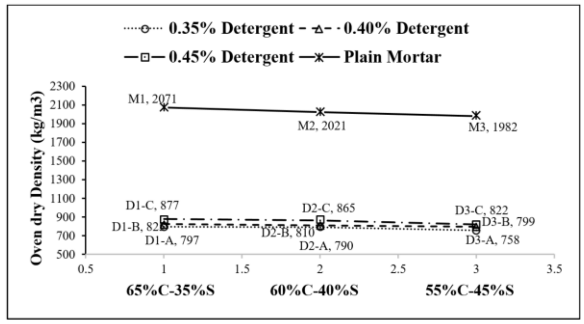

Fig. 10. Oven dry density of mixes

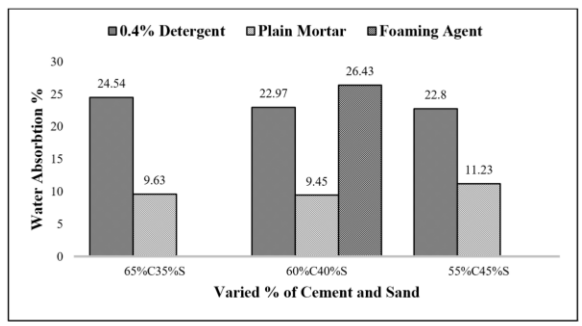

Fig. 11. Water absorption of mix designs

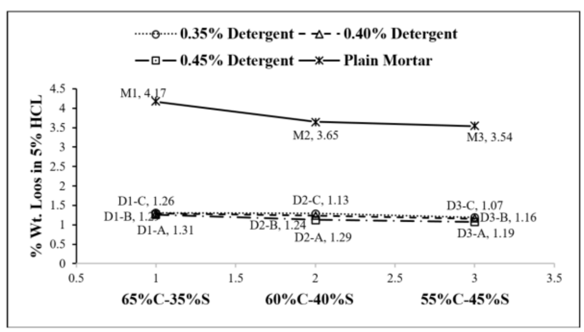

Fig. 12. Percentage weight loss in 5% HCL solution of mix designs

VI. CONCLUSIONS

The experiments and results conducted to produce low-cost foam concrete using ordinary/local detergent available in the market. Following conclusions have been drawn to determine the crux of the project with best possible solution to prepare foam concrete by this method followed specifications/standards of foam concrete laid by different codes and standards.

- The production of low-cost foam concrete using detergents was very successful as per set objectives for the study.
- Foam concrete prepared by mixing cement 60%, sand 40% with detergent of 0.4% by weight of cement was found to be the best mix.
- With this study, it may be safely commented that now a foam concrete of 4.8-5.17 MPa can be prepared by using local detergent; which was comparable foam concrete prepared by using foaming agent FA-1.
- The foam concrete prepared in this study was cost-effective along with satisfying requisite properties for foam concrete. The detergent mixed foam concrete showed 19% lesser cost for 1 cubic-foot mix as compared to commercial foaming agent (FA-1).
- The foam concrete prepared in this study may have good durability in an acidic environment.

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