The Effect of Reinforcement, Expanded Polystyrene (EPS) and Fly Ash On The Strength of Foam Concrete

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Abstract - Foam concrete is a type of lightweight concrete. The main characteristics of foam concrete are its low density and thermal conductivity. Its advantages are that there is a reduction of dead load, faster building rates in construction and lower haulage and handling costs. This research was conducted to investigate the compressive strength and flexural strength of reinforced foam concrete. The use of fly ash and Expanded Polystyrene (EPS) as cement and sand replacement were also included in the production of reinforced foam concrete. There were two types of reinforcements used to reinforce the foam concrete namely plastic and wire mesh. Physical failure mode, compressive strength and flexural strength of samples were compared and analyzed. The replacement percentages for both fly ash and EPS were varied between 0-50% and 0-40% respectively. The study showed that it is feasible to reinforce the foam concrete and the best result was obtained from wire mesh reinforcement. The study also showed that the optimum replacement level for both fly ash and EPS was 30% based on compressive and flexural strength results.

***Keywords*:** Foam Concrete, Wire Mesh, Fly Ash, Expanded Polystyrene (EPS), Strength

I. INTRODUCTION

Foam concrete is one of type lightweight concrete. It is composed of Portland cement, sand, water and air pores [1]. The air pores are produced by agitating air with a foaming agent diluted with water, creating mechanically manufactured foam [2]. This foam is then carefully blended with the cement slurry or base mix. Depending on the amount of foam introduced, foam concrete has low densities typically ranging from 400 – 1600 kg/m^3 which ensures economical use for walls of the lower floors and foundations [3][4][5]. Besides that, it possesses high flowability, minimal consumption of aggregate, controlled low strength and excellent thermal insulation properties [3]. Foam concrete is suitable for a number of applications like cladding panels, curtain walls, composite flooring systems, and load bearing concrete blocks [3].

However, the use of foam concrete in structural applications is quite limited due to its low compressive strength [6]. Therefore, this study is an attempt to attain reasonably high strength foam concrete by reinforcing the foam concrete with wire mesh. Another aspect of the study is to investigate the effect of fly ash and EPS as cement and sand replacement respectively in foam concrete[7][8][9][10].

II. MATERIALS AND MIX CONSTITUENT OF FOAM CONCRETE

Materials

Cement which is Ordinary Portland Cement and Class F fly ash are used as cementitious materials in the concrete mixes. River sand from Kuching area with specific gravity of 2.5 is used. In this work, the range sizes of EPS beads that are used are 600 micrometer to 3.35 millimeter. The reinforcements used are the plastic and wire mesh as shown in Figure 1.

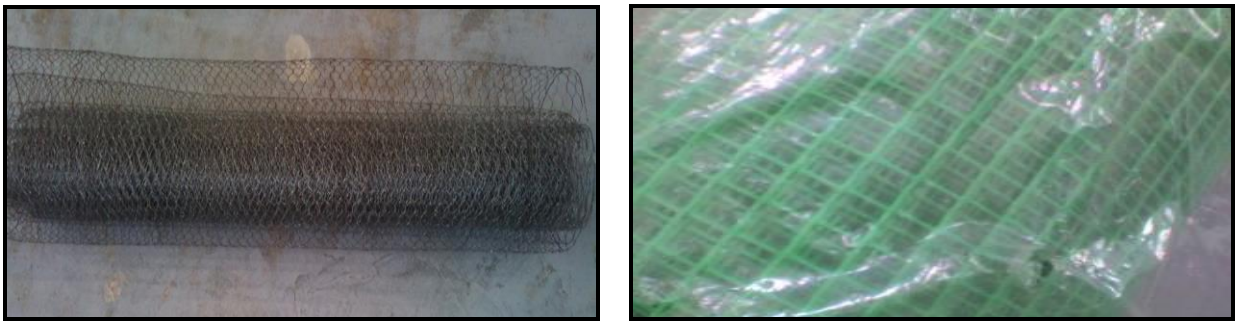

Figure 1: Photos showing wire and plastic mesh

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Mix Proportions

Seven mix proportions were prepared in this study. For each mix, the value of water/cement (w/c) ratio was 0.4. The volumes of foam used were varied as the desired densities were ranged between 1000 to 1200 kg/m^3. All of the samples were labeled with Exx Fxx. For example, E20 F30 represents 20% EPS 30% fly ash used as sand and cement replacement respectively. Table 1 presents the mix proportions that are used in this study.

Table 1: Mix proportions of showing various percentages of replacement of fly ash and EPS

Mix	Cement:Sand ratio	w/c	Percentage of fly ash as cement replacement by weight (%)	Percentage of EPS as sand replacement by volume (%)
*E0 F30	1:1	0.4	30	0
E20 F30			30	20
E30 F30			30	30
E40 F30			30	40
*E30 F0			0	30
E30 F40			40	30
E30 F50			50	30

III. EXPERIMENTAL PROCEDURES

Initially, the wire mesh was formed into the cubic shape (140x140x140 mm) and prism shape (140x140x 740 mm). The moulds were prepared and the wire mesh was placed in them. Then, the constituent materials like cement, sand, fly ash and EPS were weighed and were mixed in concrete mixer. After that, water was added and mixed for one minute. The mixing was carried out for one minute duration. Finally, foam was added to the wet slurry until the desired wet density ranging from 1000 to 1200 kg/m^3 was achieved. The density was measured each time after adding foam into the mixture. Next, mixing was continued for 30 seconds only to avoid the foam to disintegrate [4]. Then, they were poured into the cube moulds of size 150x150x150 mm and beam moulds of size 150x150x750 mm. After 24 hours, the samples were taken out from the moulds and immersed in water for curing process until they were ready for testing.

IV. RESULTS AND DISCUSSIONS

Physical Failure

The failure pattern of reinforced foam concrete upon compressive strength and flexural strength test are investigated by comparing the results to the unreinforced foam concrete. For the ordinary unreinforced foam concrete, initially the cracks occurred at the top part of the sample. Then the shear stress along the diagonal of the samples was clearly formed at ultimate stage. Figure 2 (a-b) and (c-d) shows the failure pattern of one sample before and after undergo compressive and flexural test.

In the case of foam concrete reinforced with wire mesh, the failure pattern is the same where initially, the cracks just occurred at the top part of the sample. However the reinforcement has reduced and slowed down the crack propagation and prevents the samples from brittle collapse for temporary period. Figure 3 (a-b) and (c-d) showed the failure pattern of one sample before and after undergoing the compressive and flexural test.

However, in the case of foam concrete reinforced with plastic mesh, the maximum shear stress was at lower bottom quarter of the sample and the crack lines being formed at the bottom half of the samples. This is because the plastic mesh itself is a soft material. It will bends and breaks the sample from inside when the sample was being tested under axial compression as shown in Figure 4(a-b). Figure 4(c-d) showed one of sample before and after undergo flexural strength test.

Figure 2a: Unreinforced Cube samples before failure

Figure 2b: Unreinforced Cube samples after failure

Figure 2c: Unreinforced Prism samples before failure

Figure 2d: Unreinforced Prism samples t after failure after failure

Figure 3a: Wire mesh reinforced cube samples before failure

Figure 3b: Wire mesh reinforced cube samples after failure

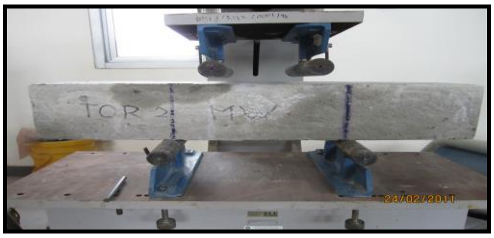

Figure 3c: Wire mesh reinforced prism samples before failure

Figure 3d: Wire mesh reinforced prism samples after failure

Figure 4a: Plastic mesh reinforced cube samples before failure

Figure 4b: Plastic mesh reinforced cube samples after failure

Figure 4c: Plastic mesh reinforced prism samples before failure

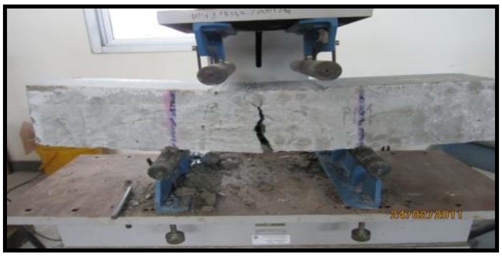

Figure 4d: Plastic mesh reinforced prism samples after failure

The Effect of Types of Reinforcement

Table 2 summarizes the strength properties of foam concrete samples obtained from wire mesh, plastic mesh reinforced samples and those without any reinforcement. Figure 4a and 4b shows the compressive strength and flexural strength of mix E30 F30 respectively.

Table 2: The compressive strength result for E30 F30 sample

Mix	Density (kg/m^3)	Types of Reinforcement	Cube Test at 28 days (N/mm^2)	Flexural Test at 28 days (N/mm^2)
E30 F30	1000	No Reinforcement	0.77	0.66
		Plastic Mesh	0.93	0.78
		Mesh Wire	1.38	1.32

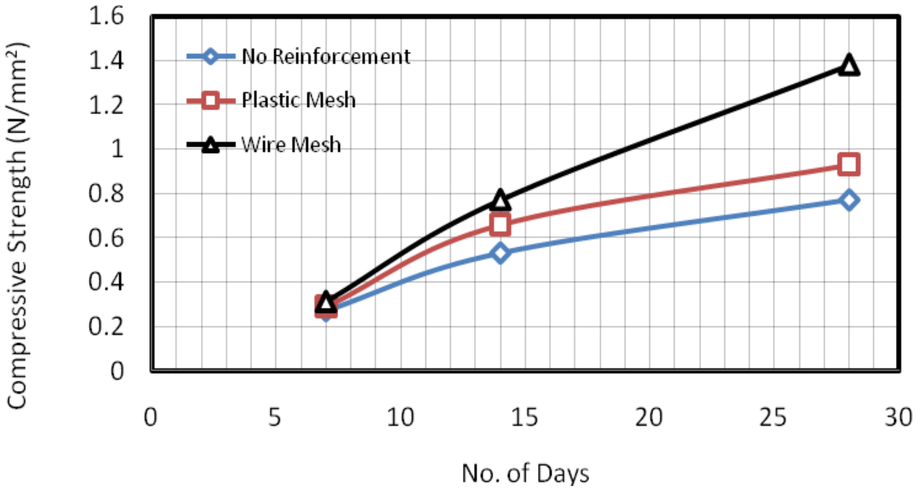

Figure 4a: Compressive strength of samples with different reinforcement

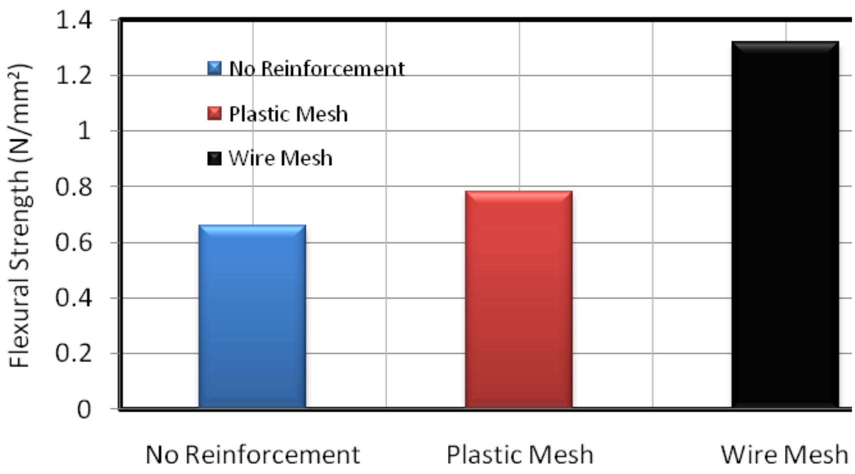

Figure 4b: Flexural strength of samples with different reinforcement

Figures 4a and 4b indicates the strength developments of the two different types of reinforced sample. The rate of strength growth was similar in the case of plastic mesh and unreinforced samples while the rate was higher for wire mesh reinforced foam concrete. As expected, the compressive and flexural strength of foam concrete that are reinforced was greater than the one without reinforcement. The wire mesh reinforced sample had the highest compressive strength and flexural strength of the three samples. It is clear that wire mesh reinforcement strengthened the foam concrete by 44% from o.77 to 1.38 N/mm^2 for compressive strength and 48% from 0.66 to 1.32 N/mm^2 for flexural strength.

In the case of plastic mesh reinforced foam concrete, the compressive strength and flexural strength of the sample was slightly greater than the unreinforced sample. The plastic mesh reinforcement strengthened the foam concrete by 17% for compressive strength and 14% for flexural strength. This is because plastic mesh is very soft and flexible. Plastic mesh will bend and breaks the foam concrete from inside due to the force acted on it. It is to be noted that the ratio of flexural to compressive strength is 1.0 compared to 0.25 for the same ratio of normal unreinforced foam concrete. This is because of the use of reinforcement, fly ash and EPS enhanced the flexural strength of foam concrete.

The Effect of Fly Ash

Table 3 summarizes the compressive strength and flexural strength of reinforced and unreinforced foam concrete with fly ash and EPS. Figure 5a and 5b indicates the effect of fly ash to the compressive strength of unreinforced and reinforced foam concrete with 30% EPS respectively. The flexural strength of the similar samples is shown in Figure 5c.

As expected, the compressive and flexural strength of foam concrete of reinforced foam concrete was greater than the unreinforced foam concrete. Both Figures 5a and 5b shows the similar growth pattern except for 30% fly ash replacement. The concave down pattern for graph E30 F30 in Figure 5a indicates that the concrete with fly ash take longer time to develop strength as compared to ordinary foam concrete. In the case of reinforced foam concrete, graph E30 F30 shows concave up pattern. It shows that when foam concrete reinforced by wire mesh, the optimum replacement for concrete containing fly ash without affecting the strength development of the samples is 30%.

Table 3: Influence of fly ash addition on compressive and flexural strength of foam concrete with EPS

Mix	Density (kg/m^3)	Cube Test at 28 days(N/mm^2)		Flexural Strength at 28 days (N/mm^2)	
		Without Reinforcement	With Reinforcement	Without Reinforcement	With Reinforcement
E30 F0	1000	1.04	1.13	0.82	1.95
E30 F30	1050	0.94	1.01	0.75	1.62
E30 F40	1050	0.78	0.83	0.43	1.02
E30 F50	1100	0.65	0.74	0.37	0.96

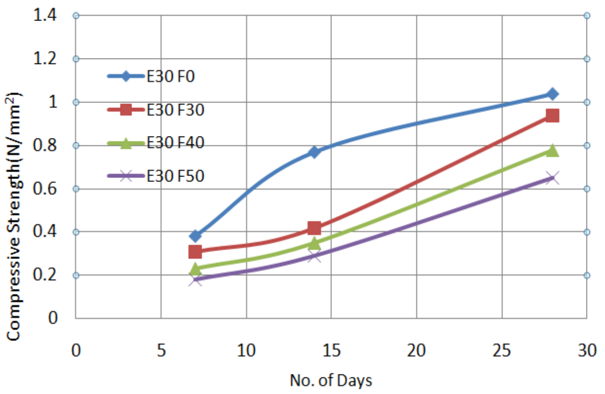

Figure 5a: The effect of fly ash on the compressive strength of foam concrete containing EPS without reinforcement

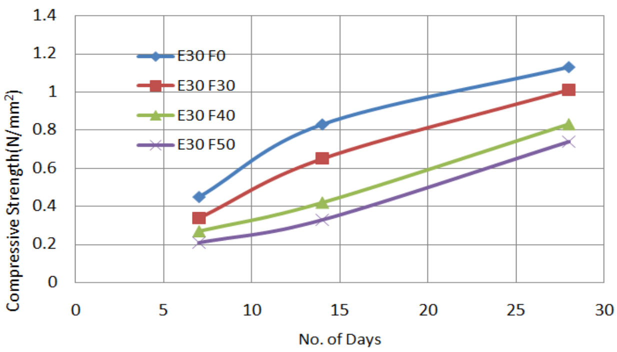

Figure 5b: The effect of fly ash on the compressive strength of foam concrete containing EPS with mesh wire as reinforcement

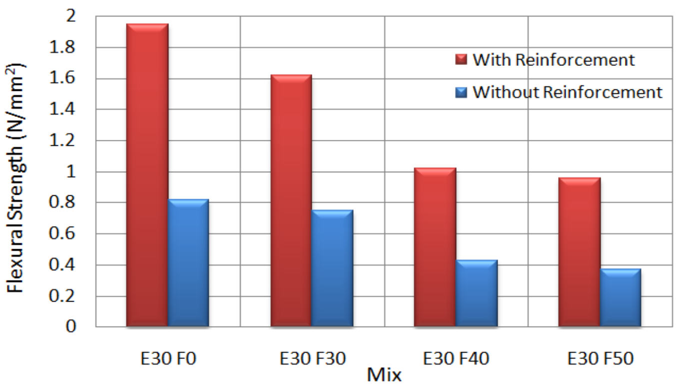

Figure 5c: The effect of fly ash on the flexural strength of foam concrete with EPS

The effect of EPS

The compressive and flexural strength of foam concrete containing 30% fly ash with different percentage of EPS as sand replacement are summarized in Table 4. Figures 6a, 6b and 6c show the strength development of unreinforced and reinforced foam concrete respectively. The use of 30% EPS as sand replacement showed the highest compressive and flexural strength results. This is the optimum percentage of replacement for foam concrete with EPS.

Table 4: Influence of EPS addition on compressive and flexural strength of foam concrete with fly ash

Mix	Density (kg/m^3)	Cube Test at 28 days(N/mm^2)		Flexural Strength at 28 days (N/mm^2)	
		Without Reinforcement	With Reinforcement	Without Reinforcement	With Reinforcement
E0 F30	1000	1.02	1.14	0.62	1.37
E20 F30	1000	0.92	1.21	0.55	1.35
E30 F30	1100	1.09	1.85	0.75	1.62
E40 F30	1100	0.81	1.01	0.5	1.21

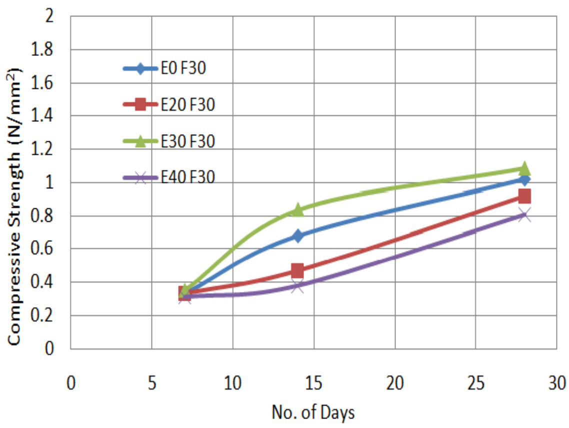

Figure 6a: The effect of EPS on the compressive strength of foam concrete with fly ash without mesh wire

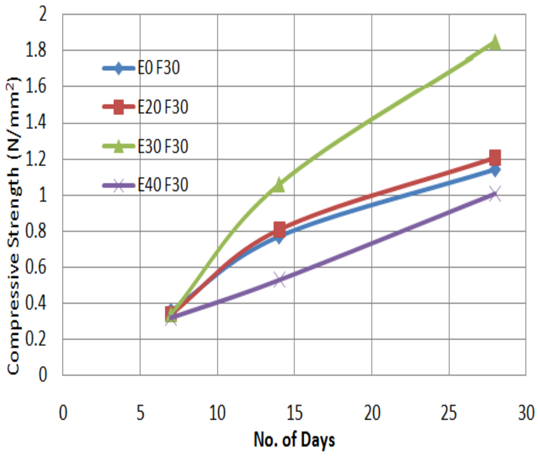

Figure 6b: The effect of EPS on the compressive strength of foam concrete with fly ash and reinforced with mesh wire

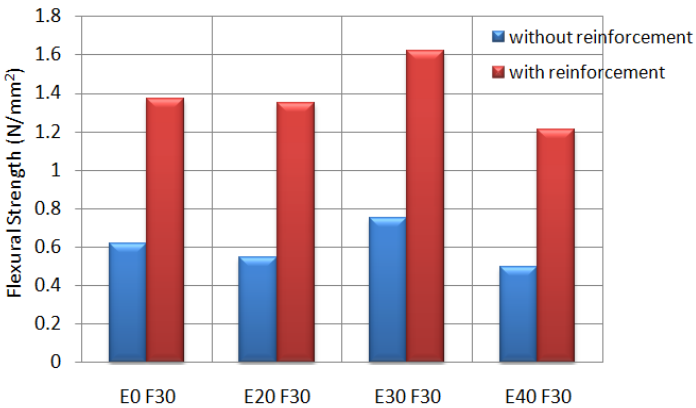

Figure 6c: The effect of EPS on the flexural strength of foam concrete with fly ash

V. CONCLUSIONS AND RECOMMENDATIONS

It was found that reinforced foam concrete results in greater compressive strength and flexural strength compared to unreinforced foam concrete. From the two choices experimented in this study, the wire mesh reinforced foam concrete showed more promising results than the foam concrete reinforced by plastic mesh. With respect to fly ash and EPS replacement, an optimum replacement level of 30% produces best results. As a conclusion, the application of reinforcing foam concrete is feasible and contributed to better compressive and flexural strength.

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