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Short communication

Study on polyurethane foamed concrete for use in structural applications

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ABSTRACT

Recently, foamed concrete is being widely used in civil construction and building, because of its high fluidity and settlement, low self-weight and low thermal conductivity. However, it has some major setbacks such as low strength and increased shrinkage at later ages. The strength gain of concrete depends upon several variables; one of these is the curing conditions. This work aims to study the potential production of foamed concrete as a sustainable structural material by varying the curing methods. For this purpose, sample cubes, cylinders and prisms were prepared to find the compressive strength, modulus of elasticity and drying shrinkage at different ages. Samples of the polyurethane foamed concrete cured under four different curing regimes (water, moisture, sealing by membrane-forming curing compound and air curing). At the end of the study, polyurethane foamed concrete used for this study has shown the potential for use in structural applications. Also, the results show that the samples cured by moisture have the highest compressive strength at all ages.

1. Introduction

Structural lightweight concrete has an in-place density (unit weight) of the order of (1440–1840) kg/m^3 compared to normal weight concrete with a density in the range of (2240–2400) kg/m^3. For structural applications, the concrete strength should be greater than (17 MPa) according to ACI 213R [23]. Foamed concrete is a type of lightweight aerated concrete which consists principally of a cement paste or mortar with at least 20% of its volume as air. Foamed concrete is produced by two methods: the first is the pre-foaming method and the second is the mixed foaming method. The pre-foaming method involves the isolated production of the base mix cement slurry (cement paste or mortar) and production of a stable foam (foam agent with water) and then mixing this foam into the base mix. In the mixed foaming method, the foaming agent is added to the pre-prepared base mixture and during the mixing foam is produced resulting in a cellular structure in the concrete [17,14].

Foamed concrete can have a wide range of dry densities (400–1600) kg/m^3 and compressive strengths (1–25) MPa. The increase in compressive strength of foamed concrete formed of fly ash, micro silica, and SiO_2 powder is in the range of (20–25) MPa, this increment in strength shows that this foamed concrete is satisfactory to be used for structural applications or load bearing purposes [11]. The strength of foamed concrete is little affected by the percent cement replaced by fly ash and even when replacing a high amount of cement with fly ash it does not much affect the later compressive strength of properly cured foamed concrete [13]. The best-pulverized fly ash content for greatest strength of foamed concrete is around 20% to 30% [18].

The properties of foamed concrete differ with the difference in curing type and duration. Correct curing will enhance the durability and increase strength, volume stability, abrasion resistance, impermeability and resistance to freezing and thawing [16]. Falade et al. [9] found that air cured specimens developed a higher strength than water curing for foamed concrete with 10%

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replacement of cement with ground bone and noticed that no difference in strength occurred progressive at later ages of 60 days and 90 days for samples cured in water and air. This study agreed with a study performed by Arif et al. [1] and Kearsley [12]. Whilst the results of the study by Zhao et el [19] showed otherwise; the water cured specimens led to better strength development of foamed mortar. However, the natural weathering regime (air curing) produced the lowest compressive strength for foamed mortar and led to an average reduction in compressive strength of 28.2% as compared with the water curing condition. This was also found acceptable with a study performed by Laing and Chang [15].

1.1. Benefit of research

The goals of this work are to:

- Find applicability to produce foamed concrete using polyurethane as a foaming agent and its applicability as a construction building material.
- Test the effect of different curing conditions on some mechanical properties of polyurethane foamed concrete.
- Find some mechanical properties of polyurethane foamed concrete with and without fly ash.

2. Experimental work

2.1. Materials

Combinations of the following constituent materials were used to produce foamed concrete in this study:

- Ordinary Portland Cement type (I): The chemical and physical properties of this cement conformed to BSEN 196-1; 2005 [8].
- Class F fly ash supplied by a local supplier and conformed to ASTM C618 [3].
- Natural sand supplied locally and conformed to the requirements of BS 812-103.1:1985 [7] for verifying distribution and particle size. The specific gravity of the sand was 2.6.
- High range water reducing agent (HRWRA) Glenium 51; the normal dosage for Glenium 51 is (0.5–0.8) l/100 kg of cement.
- Tap water was used for both mixing and curing.
- Liquid membrane-forming curing compounds: Setseal 22 is a water based curing compound formulated from selected emulsified paraffin to form a low viscosity wax emulsion. The color is a white liquid, which creates a white film when applied to concrete surfaces and reflects (60–80)% of the sunlight.
- Foam: The foaming agent of density 45 kg/m^3 used in this study was polyurethane (PU) foam. As shown in the pictures below:

Pictures: Elucidation the polyurethane.

Tables 1–3 illustrate the details of the ingredients of the materials used in this work.

2.2. Mix proportions

The mix proportion guideline of ASTM C796 [4] was followed in the laboratory mixing. The mix proportions of foamed concrete for this study are given in Table 4. The final mix proportions were established by laboratory trials to achieve a target density of 1600 kg/m^3.

2.3. Specimens preparation

For this investigation, a pre-foaming method was adopted to provide polyurethane foamed concrete. The mixing procedure started with the cleaning of the laboratory mixer and emptying the excess water, one-third of the calculated mixing water was added, then the fine aggregate followed by the cement. The materials were allowed to mix for three minutes, then the fly ash and the remaining water was added. This was allowed to blend together till an appreciable slurry was achieved. The ready-made foam was added to the base mix through the nozzle of the foam can according to the calculated amount by trial and error. The density of the foamed concrete produced was then checked against the target density, 1600 kg/m^3.