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Durability Properties of High Performance Foamed Concrete

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Abstract

Foamed concrete (FC) is promising material in modern building industry because of simple technology and wide range of properties may be achieved. Basic problems of FC are shrinkage and decreased strength, comparing to aerated autoclaved concrete. In the case of wet and cold climate, durability also plays in an important role. The paper discussed the possibilities for creating durable high performance FC by applying intensive mixing technology and using modifying micro admixtures. Characteristics of FC, such as strength, density, water absorption, carbonization and frost resistance, are discussed as the basic components of durability. Properties of different compositions of FC were tested and compared. Technological methods for obtaining high performance concrete are summarized. It is pointed out, that creating of more durable FC makes possible to increase life cycle of material and promote rational use of natural resources.

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Keywords: Foamed concrete; cavitation; carbonization; water absorption; frost resistance.

1. Introduction

Light weight concretes still are an important material in modern building industry. It combines positive properties of constructive and insulation materials and is characterized by moderate strength, low density and ripping thermal properties. Cellular concrete composed on mortar matrix and specially created system of air cells, which occupies up to 85 % of material volume. High porosity limits potential of mechanical strength, but high volume of open pores is the main reason of increased water absorption and drying shrinkage. These properties are to be taken into account, especially in the case of wet and cold climate.

Two types of cellular concrete are traditionally used in nowadays. The first type is autoclaved cellular concrete which is chemically aerated using special gas producing admixture. The most popular one is autoclaved gas silicate concrete, which is obtained from lime and silicate component.

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Technology of this concrete requires special steam pressure chamber, therefore, only small-sized prefabricated elements can be produced, such as wall blocks and plates. FC is other kind of cellular concrete, it is produced by aeration of cement mortar using foaming agents [1]. FC is more universal material and it may be applied both for monolithic and prefabricated constructive elements. Controlling the ratios of cement, sand, water and foaming agent, a wide range of densities achieved, depending on its application. In previous studies researchers developed dry density values between 240 to 1800 kg/m^3 and compressive strength for 28-day from 0.2 to 91.3 MPa [2]. FC is produced from cement mortar, foaming agent and don't requires additional thermal treatment. Simple technology and good water resistance also are the advantages of FC. Table 1 present basic classification of aerated concrete and their basic physical, mechanical and thermal properties.

Table 1.Classification of lightweight concrete.

Concrete type	Density, kg/m^3	Thermal conductivity λ, W/mK	Compressive strength, MPa
Constructive FC	600-2000	0.2-1	6-60
Constructive FC for insulating	350-600	0.15-0.2	1-6
Ultra lightweight foam concrete	<350	0.04-0.15	0.1-2

At the same time, FC has lower strength, comparing to autoclaved gas silicate concrete with the same density. Developing technology of high performance FC should be focused on achieving higher compressive strength in lower density or to reach lower density in sufficient compressive strength. Aerated concretes, especially materials of low density and autoclaved gas silicates, are characterized by high open porosity and increased water absorption capacity.

Shrinkage is a serious problem of FC. Reasons of shrinkage are autogenesis shrinkage which is associated with chemical process of cement hydration, but drying shrinkage deals with loss of water. Low density FC and autoclaved gas silicate concrete especially could be very sensitive against water action and requires long-term drying. This fact causes reduction of strength, increasing heat conductivity and increases the risk of damages during freezing and thawing cycles. Although FC when normal exploitation has not subjected to direct freeze-thaw cycles in water saturated condition, it may be moistened with water during construction process or in result of incorrect exploitation. Therefore, high water resistance is necessary condition for increasing durability. Another type of shrinkage is caused by carbonation of portlandite mineral $Ca(OH)_2$ which is long-term process and depends on permeability [3].

Properties of FC depend on mix composition and the method of mix preparation, therefore two directions for achieving high performance properties should be mentioned. One direction implies the use of technology of intensive mixing, including the effects of turbulence and cavitation. The second implies development of composition of FC mix, using special chemical and mineral admixtures and fibers.

Mixing technology takes effect on concrete's density, strength and geometry of air cells. The method of pre-foaming includes generation of basic matrix by substantive aquatic foams. Technique of foam preparation affects the quality of FC by bubble size. The other method – mixed foaming – provides producing of foam in cellular structure in FC by mixing base ingredients with active agents [4]. Use of pre-foaming method can provide two types of foam – wet and dry. Dry foams are more stable than wet foams and produce two to five times smaller size of bubbles (< 1 mm). First type of foam spray over a fine mesh while other type of foam are produced by compressed air into mixing chamber [5]. One of the FC components is the foaming agent (surface active admixture), which is responsible for creating air bubbles in cement paste [6].

Method of intensive mixing has many advantages, for example, provides homogenous mix, promotes accelerated hydration and effective use of cement, and keeps together fine aggregate and agglomerated cement. Intensity of mixing depends on speed of mixing elements. Traditional low speed mixers is characterized by speed about 2 m/s, turbulence 2-10 m/s and effect of cavitation may be achieved in speed >15 m/s. FC compositions prepared in turbulence mixer with effect of cavitation, has been evaluated in this study.