Investigate of engineering properties of biological lightweight concrete and evaluating air-entrained protective effect on bacteria performance improvement

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ABSTRACT

Regarding the particular position of lightweight concrete in the world's construction industry, producing the high-quality lightweight concrete which is based on the creative materials, has become one of the fundamental aspects of this ever-developing industry. Microbial calcite precipitation induction is known as a new environmental friendly strategy. Although the main goal of developing the biological concrete has been crack healing, achieving to this goal not only must be without negative effects on the mechanical properties and durability of concrete, but also through knowing and testing the key effective parameters, a biological concrete with the ideal engineering properties can be obtained that is distinguished among the other typical kinds of concrete. In this study, to produce the lightweight concrete with desirable durability and resistance, the technique of using bacteria in concrete has been enjoyed. Small concrete pores, alkaline environment, inaccessibility to nutrients and enough oxygen are the basic challenges of the using biological minerals in concrete. Therefore, the air-entrained has been used as a protective approach to enhance bacteria durability and preserve colonies. The results of the tests conducted show that Calcium carbonate precipitation resulted from metabolic activity of microorganisms has resulted in the increase of mechanical properties and improvement durability of lightweight concrete. Also, air-entrained as an effective factor has had a fundamental role in preserving durability and improving the bacteria performance. The use of bacteria in concrete has led to an increase of 19.8% in compressive strength and 63.9% in electrical resistance. Also, the maximum reduction of water absorption and reduction of chloride ion penetration in the biological sample was 62.7% and 40.7%, respectively.

KEYWORDS

Biological lightweight concrete, air-entrained concrete, bacteria, durability, curing environment.

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1. Introduction

The application of lightweight concrete is increasingly growing in construction industries today. These advantages include the low density, thermal insulation, reducing the dead load, and consequently reducing the seismic force to the structure [1]. However, the permeability and the mechanical properties of the lightweight concrete due to their light and porous aggregates within the concrete are relatively weaker compared to the ordinary concrete [2]. Various influential processes including temperature changes, external load, support-settlement and shrinkage leads to cracks in the concrete structure [3]. Moisture and other aggressive agents are able to permeate into the concrete through the cracks, causing negative effects on its durability by damaging the concrete[4]. Therefore, it is required to reinforce the concrete using a technique which not only prepares the conditions for the self-healing of the concrete, but also improves its durability, and mechanical properties. The biological approach is a procedure compatible with the environmental concerns, making it a suitable choice to construct high quality concrete [5]. In the meanwhile, a review of the experimental data gained from the previous studies reveals the optimal concentration of the bacteria to enhance properties and improve durability and concrete to be ranging from 10^3 cells/ml to 10^7 cells/ml [6, 7]. In addition to the concentration of the bacteria, a number of other effective factors are to be taken into consideration while making the biological concrete. The bacteria durability during the mixing process [8], the lack of access of the bacteria to nutrients and oxygen [9], small pores, the dry environment, and the high pH value of the concrete matrix [10], are among the major challenges in using bacteria to make concrete. In the present study, in order to increase the viability of the bacteria in the concrete matrix, the air-entrained admixtures (AEA) have been used as an economical technique. In order to achieve the intended purpose, concentration have been utilized 3.5×10^6 cells/ml. This article focuses on the following purposes:

- The investigation of the impact of the Sporosarcina pasteurii bacteria on the engineering performance of the lightweight biological concrete containing the silica fume.
- The investigation of the effects of the AEA on the bacteria performance and the formation of precipitation in the lightweight concrete.
- The comparison of the curing environment of the water containing calcium chloride and urea, and water.

2. Methodology

To achieve the intended aims, the Sporosarcina pasteurii 1645 (DSM33) bacteria were taken from the Persian Type Culture Collection. To create one liter of an exclusive culture medium, 8 gr nutrient broth powder must be used. First of all, the prepared culture medium was sterilized at the temperature of 121 C^o in the autoclave. Then, 20 gr urea was added to the culture medium through a sterile filter. Finally, following the processing, the culture medium containing bacteria was placed in an incubator with the run of 200 rpm for 48 hours. The serial dilutions technique was used to identify the bacteria concentration. Additionally, through setting the wavelength of spectrometer at 600 nm, the optical density was determined. Finally, founded on the relevant literature, the bacteria concentration was set to be in an average range of the optimal concentrations (i.e. 3.5×10^6 cells/ml). The grown bacteria were directly added to the concrete mixing water. Also, in making half of the specimens, AEA were used to make the durable air voids for the sake of protecting the bacteria under the harsh conditions of the concrete matrix. The specimens were cured in two different mediums; one medium was water and the other was water containing calcium chloride and urea. The aim of doing so was to investigate the possible effects of calcium sources on the improved performance of the bacteria.

In the present study, making concrete from specific aggregates like crashed granite, crystal stone, and lightweight expanded clay aggregate (leca) has been carried out. The criteria to evaluate the concrete performance included certain experiments, such as the compressive strength, scanning electron microscope, water absorption, electrical resistivity and rapid chloride permeability test (RCPT).

3. Discussion and Results

The key parameter to improve the engineering properties of the biological concrete is the formation of mineral precipitation. In fact, the minerals precipitation pattern on the surface of the concrete and in its internal matrix varies for different conditions. It is clear high amounts of precipitations function as a protection on the surface of the concrete. Blocking the flow water path in the concrete, particularly in the early stages, has disrupted the cement hydration. Furthermore, limiting the access of the bacteria to nutrients, reduces carbonate calcium precipitation in the concrete. These factors lead to the reduction in the compressive strength in the sample BCA.

One of the major findings of the present study is the increase of compressive strength and the reduction of chloride ion permeability in those specimens in which the AEA method has been used as a protective approach to bacteria. The air voids in the concrete improved the bacteria performance through providing the bacteria with sufficient oxygen and space to be deployed bacteria in the alkaline matrix of the concrete. Therefore, under such conditions, there exists an AEA concrete which contains calcium carbonate precipitations as well.

The AEA used in the concrete had a different behavior. It is likely to attribute such improvements to simultaneous application of the AEA and silica fume. The positive impact of pozzolans on the improvement of the lightweight concrete properties is mainly manifested in two mechanisms. Pozzolanic reactions convert calcium hydroxide crystals into C-S-H gels, improving the compressive strength. On the other hand, the tiny particles in pozzolans fill in the empty voids in the concrete. AEA created a roller state in the concrete, allowing the materials to move more smoothly and making the concrete mixture more homogenized. Therefore, the simultaneous use of AEA, and silica fume has improved the properties of the lightweight concrete.

4. Conclusions

1- The highest increase in electrical resistivity was observed in the biological specimen contained AEA which cured in the water, in a way that the electrical resistivity this specimen is 63.9% higher than the control concrete.

2- The maximum reduction in chloride ion penetration were obtained in the biological specimen contained AEA which cured in the water, showing a 40.7% decrease compared to the control concrete. The precipitation of calcite caused by metabolic activities of bacteria has decreased the specimens' porosity via filling the pores.

3- The maximum water absorption reduction in the bacterial specimens cured in the calcium environment obtained, showing a 62.7% decrease compared to the control concrete.

4- The compressive strength of the bacterial specimens has increased due to filling of the pores in the concrete matrix with the formed precipitations. The maximum increase compressive strength were obtained in the specimens cured in the calcium-rich environment, which increased 19.8% compared to the control concrete.

5- The curing environment is an influencing parameter of the carbonate calcium precipitation. It is worth noting that although the existence of an external calcium source leads to the formation of more precipitation, the bacterial metabolic activity can be done without the presence of such source, as well. It seems that the bacteria are able to use the free calcium oxide which exists in cement ingredients as the nutrient.

5. References

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