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EXTENDED ABSTRACT

Service Life Prediction and Life Cycle Assessment of Pozzolanic Concretes

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1. Introduction

Due to the increase in urbanization and the rapid growth of the construction industry around the world, cement has become one of the most widely used construction materials. It has been widely reported that the production and consumption of Portland cement is one of the main factors of global warming and greenhouse gas emissions. Recent studies have shown that cement production is responsible for 12-15% of total energy consumption in industry and approximately 5% of carbon dioxide emissions from human activity. The Portland Cement Association showed that the production of one ton of cement produces 0.9 tons of carbon dioxide gas. Reducing the harmful effects of rapid consumption of cement, which has an adverse effect on global warming, is an alarming concern.

In a study conducted by Pakmezgi et al (2004), the effects of pozzolan on the properties of concrete with different types and volumes of pozzolan were investigated. In this study, the effect of a natural pozzolan on concrete properties was investigated. For this purpose, concrete mix was produced in three series with control mixes with cement content of 300, 350 and 400kg. These control mixes were modified to have a combination of 250, 300 and 350 kg of cement and 40, 50, 75 and 100kg of pozzolan for 1 cubic meter of concrete. Pozzolan efficiency was obtained by using Bloomy and Fert resistance equations on 28-day concretes. The maximum amount of pozzolan with optimal efficiency was determined. This study shows that the efficiency obtained from each resistance equation is similar and these values decrease with increasing pozzolan-cement ratio.

2. Methodology

2.1. Experimental study

In this research, three types of pozzolans, including slag, fly ash, and silica fume, have been investigated as a partial replacement of cement. In terms of different weight percentages of these materials, four separate designs of concrete mix and a basic design without the use of concrete additives have been defined. Then, the service life and the life cycle of the produced concrete slab and wall have been evaluated using the life-365 model. In this section, the pozzolanic materials used are explained first, then the different designs of the

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concrete mix are introduced. In the end, the technical and environmental basics related to the life cycle assessment model are examined.

In this research, to achieve the optimal mixing plan, four concrete mixtures have been tested. The first mixing plan is related to the weights of fly ash and slag 20 and silica fume 10kg/m^3. This mixing scheme has the lowest weight percentage for using pozzolanic materials (i.e. 12.5%). The second mixing plan is related to the weights of fly ash and slag equal to 40kg/m^3 and silica fume 20kg/m^3. In this design, pozzolanic materials account for a total of 25% of the weight of cement. Mixing plan number 3 is related to the weights of fly ash 20, slag 80 and silica fume 60kg/m^3, which in total, pozzolanic materials in this plan account for 40% of the weight of cement. In the fourth mixing plan, fly ash is not used. The weight of slag is 100 and silica fume is 60kg/m^3, and in total, pozzolanic materials account for 40% of the weight of cement used in this project. In all these plans, 900kg/m^3 of sand and 1000kg/m^3 of coarse stone materials with a diameter of 5-10mm have been used. The water used is drinking water and its amount is 160kg/m^3.

3. Results and discussion

The results show that when these amounts are used as additives in concrete, in the first mixing plan, it shows a very low percentage of materials for environmentally friendly conditions (8.5%). When these values are used as additives in concrete, according to Table 2, it shows a better ratio than the first mixing of materials for environmentally friendly conditions (17%). With changes in the amount of fly ash and on the one hand the decrease of this amount and the increase of other compounds it was observed that the environmental parameters are up to 2 times higher than when more cement is used and on the other hand with the decrease of the amount of fly ash this percentage It has improved and advanced to 34%. The fourth mixing plan has resulted in an excellent improvement of 35.9% in environmental conditions.

Fig. 2 summarizes the concrete life prediction results for the four designs compared to the base design. This figure shows that the useful life of the concrete slab of the basic plan, which does not add any additives to the concrete, is equal to 11.9 years. Also, in the first design, the useful life of concrete is about 16 years, which is almost 1.34 times the useful life of the base. Also, these data showed that the life of the concrete made in the second design is about 23.5 years, which shows an almost 2-fold increase in useful life, which is a better growth compared to the initial mixing design.

Using the results, the balance of useful life for mixing plans 1 to 4 will be equal to 1.34, 2.0, 8.91 and 8.45, respectively. Therefore, plans 3 and 4 have higher efficiency in terms of increasing the useful life of concrete. On the other hand, considering the figures obtained from the calculation of the potential of reducing harmful environmental effects, the fourth mixing plan is introduced as the optimal plan of this research. In this plan, the amount of slag is about 100 kg per cubic meter and silica fume is about 60kg. Due to the limitation in the percentage of additives, ash was not used instead of cement (about 40%).

4. Conclusions

The results of this research show that by replacing slag additives, fly ash, and silica fume as a part of the cement used in reinforced concrete structures, not only will there be a significant increase in the useful life of concrete, but also by reducing the amount of cement. Carbon footprint is also reduced and the compatibility of concrete with the environment increases. The results of the first and second mixing plans showed that by doubling the materials compared to the initial mixing, the life and environmental compatibility of concrete is almost doubled. The results of the third and fourth mixings showed that this diagram is not linear with the increase in the number of additives, and with the increase in the amount of fly ash, although the life of the concrete increases, on the other hand, the environmental percentage of the concrete does not increase much, and it advances to almost 34%. slow the experiments of the third mixing showed that with the increase in the amount of silica ash in the concrete sample and the decrease in slag, the life of the concrete increases, but on the other hand, it reduces the compatibility with the environment. For example, when fly ash accounts for 5% of the weight of cement, silica fume is 15%, and slag is 20% of the weight of cement, although the life of concrete increases to 106 years, on the other hand, its compatibility with the environment increases to 2.33. The percentage reaches or when the amount of fly ash reaches 10%, silica fume 10%, and slag reaches 20% of the weight of cement, the life of concrete will reach 65 years, and on the other hand, its compatibility with the environment will decrease to 30%. This data shows that the increase in fly ash is not always the reason for the high life of concrete, but silica fumes in its highest amount, i.e. 15%, has the best answer for increasing the life and compatibility with the environment. which was clear in the fourth mixing. The fourth mixing showed that by removing fly ash and increasing the amount of soot and slag by 40% of cement weight, it has provided the best performance in terms of compatibility with the environment and resistance. The table shows that by mixing plan 4, it is possible to achieve 35.9% productivity in environmental systems. Therefore, it can be definitively concluded that if the amount of carbon black is 15% and slag is 25%, the permeability can be reduced and the life of concrete can be increased in chlorine corrosive environments, and as a result, chlorine ions can be prevented from reaching the rebar surface in a large amount.