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Assessment of the Effect of Air-Entraining Agent Content in Reducing the Severity of Plastic Shrinkage Cracking in Air-entrained Concrete Pavements

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ABSTRACT: Plastic shrinkage cracking is one of the most common distress in concrete pavements, which reduces the durability and level of service. Using different admixtures in the optimal amount can reduce these cracks. This study investigates the effect of air-entraining agent content in creating intentional air in air-entrained concrete pavements, in controlling or reducing the severity of plastic shrinkage cracking. For this purpose, the effect of adding air-entraining agent in the amount of 0.04, 0.07, and 0.10% by weight of cement on the severity of plastic shrinkage cracking in concrete pavement mixture with water to cement ratios of 0.40, 0.45, and 0.49 was investigated by using ASTM C1579 method. The results showed that the addition of air-entraining agent reduced the severity of plastic shrinkage cracking in air-entrained concrete compared to the conventional one. It was seen that with more addition of air-entraining agent than a certain amount, the severity of cracking has increased, which is a specific and optimal amount of 0.07% in this study. The results showed that increasing the water to cement ratio at lower change intervals has a greater effect on the severity of cracking. Also, the percentage of entrained air due to the addition of the optimal amount of air-entraining agent is less than the maximum percentage of allowed entrained air in concrete pavements. Therefore, with the use of this admixture in the optimal amount, the severity of plastic shrinkage cracking in concrete pavements can be reduced.

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1- Introduction

One factor that reduces the durability of concrete pavements is the cracking of the pavement slab due to various factors. Plastic shrinkage is one of the causes of cracks in concrete pavements at an early age. This type of shrinkage occurs due to the formation of negative capillary pressures after the equilibrium of evaporation and bleeding rate at the pavement surface. If the concrete slab is prevented from moving due to this shrinkage, tensile stresses will occur on the slab surface. Local cracking will occur if the tensile stresses exceed the tensile strength of fresh concrete [1].

Various additives are used in concrete pavements to improve their properties in the short and long term. Air-entraining agents are one of the additives used in concrete pavement, which creates entrained air in concrete, and as a result, increases the durability of pavement against freeze and thaw cycles and chemical substances. Concrete pavements are usually exposed to various freeze and thaw cycles or chemical substances, so using air entrainment in concrete pavement is required to increase the durability of concrete against freeze and thaw cycles and the effect of various chemical substances [2].

The study of the effect of various admixtures, including air-entraining agents, on the plastic shrinkage of concrete, has attracted the attention of some researcher [3-5]. Air-entraining agents are essential in concrete pavements that are exposed to freeze and thaw cycles or chemical substances. Moreover, because air-entrained concrete mixtures have lower permeability and, as a result, are more resistant to sulfate attacks and alkali-silica reaction, the use of air-entraining agents in concrete pavements is essential. The research background reveals that the addition of air-entraining agents in concrete may control and reduce plastic shrinkage cracking in concrete. However, evaluating the effects of the air-entraining agent contents on mitigation and reducing plastic shrinkage cracking in concrete pavement has received less attention.

The present study investigates the effect of different contents of air-entraining agents on the severity of plastic shrinkage cracking in the air-entrained concrete pavement mixtures with different water-to-cement ratios and tries to determine the effect of the amount of this admixture in controlling and reducing the plastic shrinkage cracking in concrete pavements.

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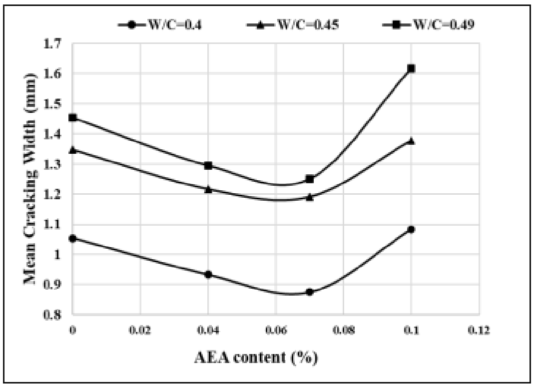

Fig. 1. Change of mean cracking width of air-entrained concrete pavement mixtures relative to air-entraining agent content

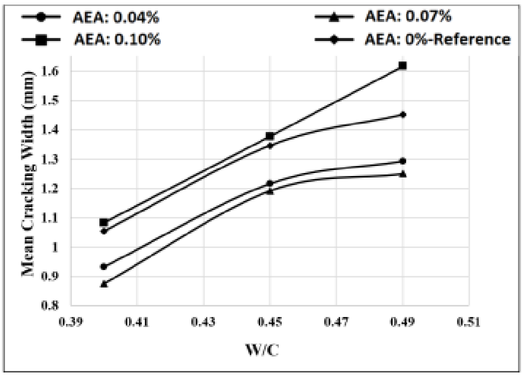

Fig. 2. Change of mean cracking width of air-entrained concrete pavement mixtures relative to W/C

2- Materials and Methodology

The air-entraining agent used in this study is the chloride-free super air-entraining agent. The recommended consumption of this material is 0.5 per 1000 of cement weight, which in this study, this amount was used as a criterion to determine the different consumption contents in the concrete pavement mixtures. Portland Cement type II with a unit weight of 3150 kg/m^3 was used. Limestone aggregates with a maximum size of 5 mm for fine aggregates and 25 mm for coarse aggregates were used in concrete mixtures. Based on the test method according to ASTM C128 and ASTM C136, the relative density, water absorption, and fineness modulus of fine aggregates 2.50, 3.2, and 2.4%, respectively. Relative density and water absorption of coarse aggregates according to ASTM C127 standard were 2.60% and 1.2%, respectively. Coarse aggregates were used in two gradation types, including coarse aggregates with a size of 5-12 mm and 12-25 mm. Tap water was used in concrete mixtures fabrication.

The mixture proportions of air-entrained concrete pavement used in this research were determined based on the requirements and criteria mentioned in the instructions for designing, implementing, and maintaining concrete pavement for roads, manual No. 731. Three values of the water-to-cement ratio (W/C), including 0.4, 0.45, and 0.49 in air-entrained concrete mixtures with different water-to-cement values, were selected. According to the maximum allowable air in concrete pavement mixture (8%), the maximum amount of air-entraining agents to entrain air in concrete lower than this level was determined by adding different content of this admixture and trial and error method and then measuring the amount of entrained-air by the compression method according to ASTM C231 standard method. According to the experiment, by adding air-entraining agents material at the content of 0.1% of cement weight in the concrete mixture with a W/C of 0.49, the air content of concrete was 7.9%, which is less than the maximum allowable amount (8%). According to the obtained content, the suggested content by the manufacturer, and the available laboratory facilities, three air-entraining agent contents (AEA) of 0.04%, 0.07%, and 0.10% of the cement pavement were considered in this study. Therefore, the mixture proportions of 1 m^3 air-entrained concrete in saturated surface dry condition of materials are as follows: Fine aggregates (0-5 mm): 849 kg, Coarse aggregates (5-12 mm): 537 kg, Coarse aggregates (12-19 mm): 359 kg, water: 168 kg (W/C:0.4), 180 kg(W/C:0.45) and 196 kg (W/C:0.49), AEA: 0 kg (AEA:0-Reference mixture) 0.160 kg (AEA:0.04%), 0.280 kg (AEA: 0.07%) and 0.400 kg (AEA:0.10 %).

The standard test method ASTM C1579 was used to evaluate the plastic shrinkage cracking of the concrete slabs. Concrete slabs were placed and tested in an environmental simulator chamber. The environmental conditions in this study included a temperature of 35 ° C, relative humidity of 25%, and wind speed of 18 km/h. The variable studied in this experiment to determine the severity of plastic shrinkage cracking was the mean cracking width of the samples. At the end of the experiment, the mean cracking width of each sample was measured using a digital caliper with an accuracy of 0.001 mm.

3- Results and Discussion

Figure 1 shows the change in mean cracking width of air-entrained concrete pavement mixtures relative to air-entraining agent content. It can be seen that the addition of an air-entraining agent up to 0.07% causes a relative decrease in the mean cracking width. It may be due to the reduction of surface stress in the surface between water and air in the concrete mixture, thus reducing the surface tension in the concrete. By increasing the content from 0.07 to 0.1%, the cracking severity increased dramatically. The addition of more air-entraining agents, which further increases the amount of entrained air in the concrete, reduces the tensile strength of the concrete. Therefore, by adding more air-entraining agents than a certain percentage amount, the negative effect of entrained air in reducing the strength of concrete exceeds its positive effect on reducing capillary and surface stresses in plastic shrinkage, thus increases the cracking severity. AEA content of 0.07% causes less air in concrete than the allowable amount in all mixtures (8%). Therefore, this amount may be the optimal amount of AEA content to reduce the maximum cracking due to plastic shrinkage in concrete.

Figure 2 shows the change in mean cracking width of air-entrained concrete pavement mixtures relative to W/C. It can be seen that increasing the W/C in all mixtures has increased the severity of cracking. The reason may be the fact that the increase in capillary pressures and the decrease in tensile strength by increasing the W/C. It is also observed that the effect of increasing the W/C on the severity of cracking in the W/C interval of 0.40 to 0.45 is more significant than the interval of 0.45 to 0.49. The greater the W/C, the greater the amount of water in the concrete, and as a result, there is more water on the surface to compensate for water evaporation. Therefore, the equilibrium of bleeding and evaporation occurs later, leading to a reduction in the severity of plastic shrinkage cracking.

4- Conclusion

The present study investigates the effect of different contents of air-entraining agents on the severity of plastic shrinkage cracking in the air-entrained concrete pavement mixtures with different W/C. The most important findings of this study are as follows:

• The addition of AEA up to the content of 0.07% reduced the severity of cracking.

• Adding more AEA from 0.07% to 0.10% resulted in a significant increase in cracking severity.

• Consumption content of 0.07% causes less air in the concrete than allowable amount. Hence, the severity of plastic shrinkage cracking in concrete pavements could be reduced by using the AEA in the optimal amount (0.07%).

• The effect of increasing the W/C on the severity of cracking in the lower change interval of W/C was more significant than, the higher one.

References

[1] M. Kayondo, R. Combrinck, W. Boshoff, State-of-the-art review on plastic cracking of concrete, Construction and Building Materials, 225 (2019) 886-899.

[2] H. Ziari, P. Hayati, J. Sobhani, Air-entrained air field self-consolidating concrete pavements: strength and durability, International Journal of Civil Engineering, 15(1) (2017) 21-33.

[3] M. Sirajuddin, R. Gettu, Plastic shrinkage cracking of concrete incorporating mineral admixtures and its mitigation, Materials and Structures, 51(2) (2018) 48.

[4] R. Combrinck, M. Kayondo, B. le Roux, W. de Villiers, W. Boshoff, Effect of various liquid admixtures on cracking of plastic concrete, Construction and Building Materials, 202 (2019) 139-153.

[5] I. Yakoubi, S. Aggoun, H. Ait Aider, H. Houari, The influence of bleeding, extra water and superplasticizer on the SCC plastic shrinkage cracking: case of hot weather, Journal of adhesion science and Technology, 30(23) (2016) 2596-2618.

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