Investigation of the effect of different climate conditions on the temporal characteristic of plastic shrinkage cracking in concrete pavements

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ABSTRACT

plastic shrinkage cracking in concrete pavement occurs in the early hours after construction due to the rapid drying of the pavement surface. These cracks in concrete pavements affect the beauty of the structure, reduces the durability of the pavement in the long term, and decrease pavement serviceability. Due to the different climate conditions at the pavement site, plastic shrinkage cracking are subject to change. This study examined the temporal characteristics of plastic shrinkage cracking in concrete, including the balance time of bleeding and evaporation and the time of cracking onset, by utilizing the ASTM C 1579 standard method, in 27 different climate conditions with the use of the continuous photo-taking system. Results showed that changing climate conditions have a more significant impact on balance time than the time of the start of cracking. Also, the relative humidity of the air has the most pronounced effect on the temporal characteristics of cracking, and the impact of ambient temperature and wind speed are close to each other. The results also showed that time of balance of beeling and evaporation could be a good criterion for predicting the risk of plastic shrinkage cracking in concrete pavements in different climate conditions. It is necessary to use appropriate curing methods to prevent the excessive reduction of balance time and increase the rate of plastic shrinkage cracking in concrete pavements.

KEYWORDS

Plastic shrinkage, concrete pavement, different climate conditions, balance time, cracking start time.

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Introduction

The use of concrete in the pavement is a cost-effective and high-performance choice for the construction of roads and highways[1]. Properly designed and built with durable materials, these pavements can serve without maintenance or with little maintenance. One of the factors reducing the durability in concrete pavements is cracking. Cracks are a place for the ingression of corrosive substances into the pavement, which leads to corrosion of concrete and reinforcing rebars[2]. Plastic shrinkage is a common reason for cracking in the concrete pavement that reduces its durability. Plastic shrinkage occurs due to the formation of capillary pressures when the evaporation rate exceeds the bleeding rate in concrete. Due to restraint in concrete, tensile stresses are formed in the concrete. If these stresses exceed the tensile strength of fresh concrete, cracks will occur[3].

In the case of constant concrete mixture and structure properties, the amount of bleeding in concrete is constant, and the evaporation rate can be variable. The rate of evaporation in concrete depends on climate factors, including ambient temperature, relative humidity, and wind speed. Changing the evaporation rate of concrete would change the time of balance of bleeding and evaporation, which affects the time of onset of negative capillary pressures. As a result, plastic shrinkage cracking is affected by the influence of these climate factors[4].

The study of effects of climate factors on plastic shrinkage cracking has been considered by some researchers[5]. Kwak and Ha[6] studied numerical models to estimate the time of occurrence of paste cracking in different environmental conditions and concluded that using these models are appropriate to predict cracking. Yakoubi et al.[7] concluded that harsh environmental conditions increased the rate of crack growth and crack width, which is due to the faster equilibrium of the rate of dewatering and evaporation.

Due to the changes in climate conditions in concrete pavement, it is essential to investigate the effects of climate factors on plastic shrinkage cracking. To authors' best knowledge, less attention was given to temporal characteristics of plastic shrinkage cracking in different climate conditions in concrete for use in the pavement. For this reason, the present study investigates the effect of climate factors on the temporal characteristics of plastic shrinkage cracking of concrete pavement, includes the time of balance of bleeding and evaporation and time of the start of cracking in 27 different climate conditions using digital image analysis.

Materials and Methodology

Type 42.5-1 cement, drinking water, coarse aggregates with a maximum size of 19 mm and a specific gravity of 2.68, fine aggregates with a maximum size of 5 mm with a specific gravity of 2.54 and a fineness modulus of 2.88 were used. Concrete mix design is determined based on the criteria of concrete pavement mixture in accordance with manual No. 731. Figure 1 shows the allowed and selected gradation of aggregates. The w/c of 0.5 and cement content of 460 kg/m^3 were chosen to increase the cracking potential of the specimen. However, these values do not exceed the allowed limits. Thus, materials constituents of mix design for 1 m^3 of concrete are as following: 460 kg of cement, 230 kg of water, 928 kg of fine aggregates (0-5 mm), 403 kg of coarse aggregates type I (5-12 mm) and 245 kg of coarse aggregates type II (12-19 mm).

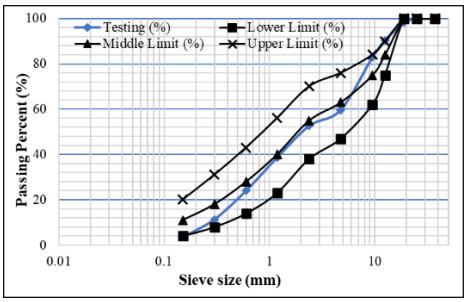

Figure 1. Gradation of used aggregates

The ASTM C1579 method for the evaluation of plastic shrinkage cracking in 27 different climate conditions, which are a combination of three values of ambient temperature (T:30, 35 and 40 ° C), three values of relative humidity (R:20, 45, and 70%) and three values of wind speeds (W:18, 24 and 30 km/h) were used. The environmental simulator chamber created different climate conditions for 22 hours. Two samples in each condition were examined, and the average results were considered. Also, digital images of the specimen surface during the experiment were taken by the continuous photo-taking system to evaluate the temporal characteristics of specimens. The bleeding and evaporation balance is a state in which the evaporation rate is equal to the bleeding, and no water is observed on the specimen surface. Digital images were analyzed in image analysis software Digimizer at intervals of 10 minutes and 2 minutes to determine this variable, and the time of not observing water at the specimen surface was recorded as the time of balance (T_b). The time of the start of cracking (T_{sc}) was the onset time of the first visible cracks at the specimen surface and was obtained by analyzing digital images of the central region of the sample (above the stress riser) at 40-second intervals.

Results and Discussion

Figures 2, 3, and 4 show the time of balance (T_b) and the time of the start of cracking (T_{sc}) in the 26 climate conditions[2]. The average and the maximum relative decrease of temporal parameters in different environmental conditions due to the change in wind speed from 18 km/h to 30 km/h are 37% and 50% for T_b, and 15% and 22% for T_{sc}, respectively. Changes in wind speed have a more significant impact on T_b than T_{sc}. The average and maximum relative decrease due to relative humidity reduction from 70% to 20%, are 64% and 72% for T_b, and 24% and 49% for T_{sc}, respectively. The results show that reducing relative humidity has a more significant impact on T_b, which is due to changes in the severity of evaporation at the concrete surface.

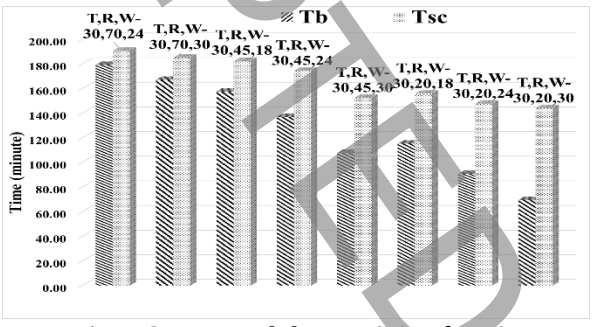

Figure 2. Temporal characteristics of specimens

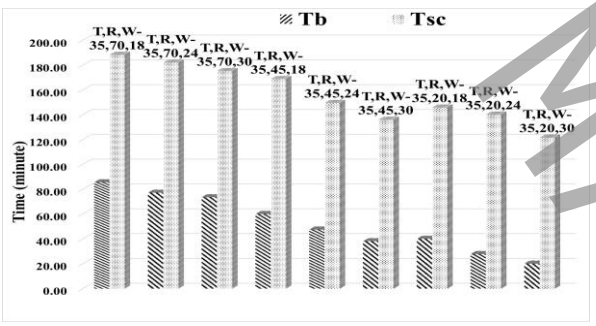

Figure 3. Temporal characteristics of specimens

The average and the maximum relative increase in temporal variables due to ambient temperature change from 30 °C to 40 °C are 39% and 54% for T_b, and 15% and 22% for T_{sc}, respectively. These results suggest that by changing the temperature from 30 °C to 40 °C, the T_b is more affected. T_b is more affected by the change in climate factors. The reason is that the effects of climate factors during the bleeding period are more than its effect on the drying period. Thus, T_b may be a good factor for the prediction of plastic shrinkage cracking in concrete pavements in different climate conditions.

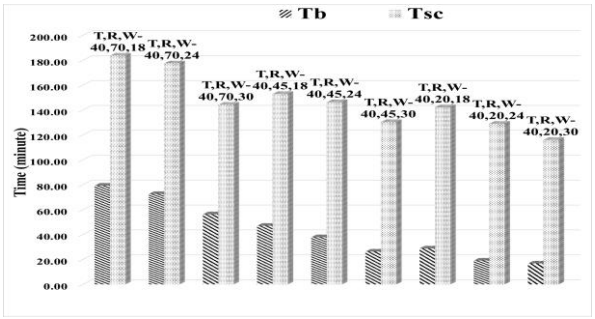

Figure 4. Temporal characteristics of specimens

Conclusions

The important conclusions obtained from this study are as blew:

- Changing climate conditions have a more significant impact on the time of balance.
- Changes in relative humidity have the greatest impact on temporal characteristics.
- The effects of ambient temperature and wind speed on temporal characteristics were almost the same.
- Time of balance may be a good factor for predicting the plastic shrinkage cracking in concrete pavements in different climate conditions.

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[2] Each condition is shown as following: T,R,W-(values of each climate factor). The condition T,R,W-30,70,18 is a no-cracking condition and is not considered in results.