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Investigation of Comparative Effect of Macro and Micro Polypropylene Fibers on Controlling or Mitigation of Plastic Shrinkage Cracking in Concrete Pavements in High-Temperature Conditions

S. J. Vaziri Kang Olyaei[1], H. Fazaeli[2*]

[1] School of civil engineering, Iran University of Science and Technology, Tehran, Iran.
[2] School of civil engineering, Islamic Azad University (Tehran North Branch), Tehran, Iran.

ABSTRACT: Plastic shrinkage cracking in concrete pavement is a place for ingression of water and corrosive substances to the pavement, which reduces its durability and ultimately leads to failure of the pavement slab. The use of fibers is one way to control these cracks. This study investigates the effect of the addition of macro polymer fibers in comparison with micro polymer fibers on plastic shrinkage cracking in concrete pavements. For this purpose, one type of micro polypropylene fibers and two types of macro polypropylene fibers in a volume of 0.1% was used to make the samples. Mechanical tests including compressive, tensile, and flexural strengths and evaluation of plastic shrinkage cracking according to ASTM C 1579 in climate conditions including relative humidity of 20%, wind speed of 30 km/h, and temperatures of 35 and 40 Celsius degrees, were performed. The results showed that concrete samples containing both macro and microfibers had better performance in controlling cracks than control samples. Meanwhile, microfibers performed better in controlling crack width at both temperature conditions. In contrast, macro fibers showed a better effect in reducing the length of cracking, especially at higher temperatures. The use of macro fibers can significantly reduce the length and area of plastic shrinkage cracking in concrete pavements.

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1. INTRODUCTION

One of the reasons that reduce the durability of concrete pavements is the cracking of pavement. The presence of cracks in concrete pavements provides a place for water and corrosive substances such as acid to enter the concrete slab and causes corrosion of rebars, local destruction of concrete, and ultimately failure of the pavement [1]. The formation of negative capillary pressures causes this shrinkage due to the drying of the pavement surface, and if the structure is constrained, it causes the formation of tensile stresses on the concrete surface. If the tensile stresses exceed the tensile strength of fresh concrete, cracks will occur [2].

The use of fibers is a common and useful approach in controlling and reducing plastic shrinkage cracking in concrete pavements. Among the various fibers used, polymer fibers, due to their excellent performance in controlling cracks caused by plastic shrinkage, low cost, and a wide range of fiber properties, absorbed so much researchers' attention. These fibers are made in two groups in terms of dimensional, mechanical, and appearance characteristics: micro and macro. Microfibers are often used in low consumption amounts to control and reduce early-age cracking in concrete pavements[3]. Macro fibers, often in higher amounts (<0.5%), are used in fiber-reinforced concrete pavements to improve mechanical properties, energy absorption, ductility, and control of long-term cracks in the pavement.

*Corresponding author's email: fazaeli@iau-tnb.ac.ir

Much research has been done on the effect of micro-polypropylene fibers in controlling and reducing plastic shrinkage cracking. Islam and Gapta reported the optimal amount of micro polypropylene fibers in concrete with 0.1% by volume, taking into account the least reduction in compressive strength, the highest increase in tensile strength, and the best performance in controlling and reducing crack cracking[4]. However, some researchers have studied the effect of adding macro-fibers on this cracking and reported this fiber's good performance in reducing and mitigating plastic shrinkage cracking[5].

Macro fibers can improve the adhesion between the fibers and the cement matrix and positively affect the mechanical properties, energy absorption, and ductility of concrete pavements. To the authors' best knowledge, less attention was paid to the effect of macro polypropylene fibers compared to micro polypropylene fibers, at a low volume percentage of 0.1% (optimal percentage of macro polypropylene fibers in the control of plastic shrinkage cracking) on the geometric properties of concrete plastic shrinkage in different temperature conditions. For this reason, the present study

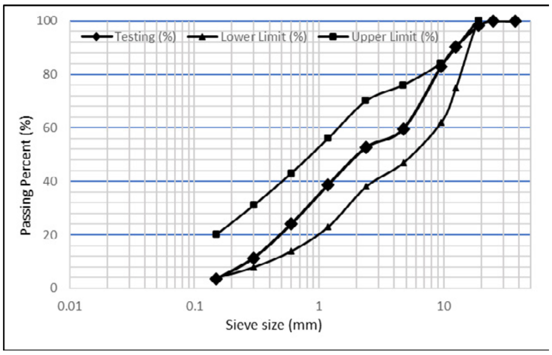

Fig. 1. Gradation of used aggregates.

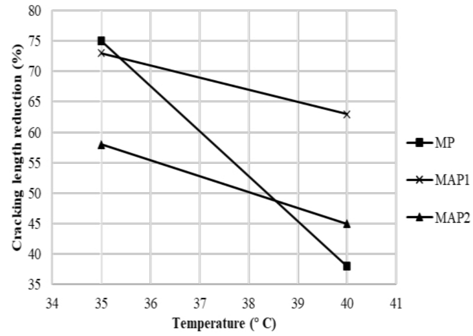

Fig. 2. Reduction of cracking length.

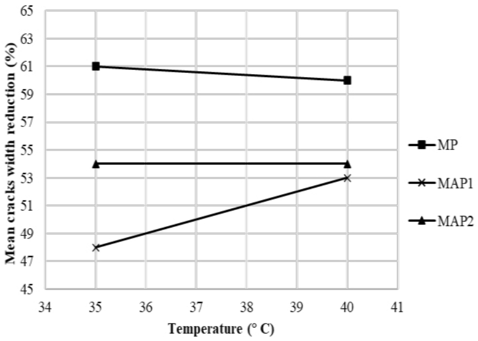

Fig. 3. Reduction of mean crack width.

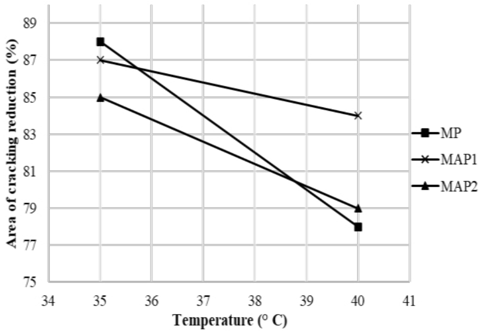

Fig. 4. Reduction of area of cracking.

investigates this issue.

2. MATERIALS AND METHODOLOGY

The materials used in this research include type 425-1 cement with a relative density of 3150 kg/m^3, fine aggregate with a maximum size of 5 mm, the relative density of 2.54 and a fineness modulus of 2.88, coarse-aggregates with a maximum size of 19 mm and the relative density of 2.68, and tap water. Aggregates gradation and mix design specifications follow the concrete pavement design, construction, and maintenance manual criteria, No. 731[6]. Fig. 1 shows the allowed and selected gradation of aggregates. W/C of 0.5 and the cement content of 460 kg/m^3 were chosen to increase the cracking potential. 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). One type of microfiber and two macro fibers, including twisted and continuously embossed fiber, were used in the amount of 0.1% by volume of concrete. Thus, one reference mixture and three fiber mixtures were considered. Mechanical tests to determine the compressive and flexural strength of different mixtures were also performed.

The ASTM C1579 method for the evaluation of plastic shrinkage cracking was used. The experiment's environmental conditions included relative humidity of 20%, wind speed of 30 km/h, and two high temperatures of 35 and 40 ° C. The environmental simulator chamber created different climate conditions for 22 hours. Two samples in each condition were examined, and the average results were considered. Digital images were taken from the samples' cracking path at 4 cm intervals by a digital microscope 2 hours after the experiment's termination. These images were analyzed in image analysis software Digimizer to measure cracking length, mean crack width, and area of cracking of each sample.

3. RESULTS AND DISCUSSION

Figs. 2, 3, and 4 show the reduction in length, mean width, and area of cracking of fiber-reinforced specimens compared to reference specimens at different temperatures after 22 hours from the start of the experiment.

The addition of micro and macro fibers in both temperature conditions reduced the crack's geometric properties. According to Figs. 2 and 3, the cracking length decreases faster than the width of the mean crack. Since the cracking area depends on the crack area's length and width, this issue has affected the changes in the crack area (Fig. 4) and has caused the changes in the reduction of this variable to occur at a faster rate.

Based on the above results, it is observed that the effect of the addition of micro polypropylene fibers at 0.1% of concrete volume at 35 ° C has the best performance in reducing geometric variables compared to macro fibers. However, by increasing the temperature by 40 ° C, micro fibers' effect in controlling the cracking length decreases. MAP1 and MAP2 fibers have better performance in reducing crack length, especially at high temperatures, and this also affects the reduction of cracking area.

It can be interpreted from the results that at a temperature of 35 °C, micro polypropylene fibers have a good performance in reducing cracking geometric variables. However, with increasing temperature to 40 ° C, this type of fiber maintains its good performance in the relative reduction of crack width. However, in the relative reduction of crack length, it has a more unsatisfactory performance than 35 ° C. Macro fibers at 35 ° C have lower performance in reducing geometric variables than micro-polypropylene fibers. However, with increasing temperature, this type of fiber has a better effect on the relative reduction of cracking length than microfibers. It is seen that the performance of both macro fibers is close.

4. CONCLUSIONS

In this study, macro polypropylene fibers' effect in reducing plastic shrinkage cracking in concrete pavement compared with micro polypropylene fibers in different temperature conditions was investigated. According to the results obtained, the following results can be seen:

- The addition of micro and macro fibers in both temperature conditions reduced the geometric properties of the crack.
- At 35 ° C, microfibers had the best performance in reducing the geometric properties of cracks. However, at 40 ° C, these fibers' performance in controlling and reducing the crack's length was reduced.
- The macro fibers' performance in reducing the cracking length in both temperature conditions was better than its performance in controlling the crack's width. This caused the proper performance of these fibers in reducing the cracking area.
- At higher temperatures (40°C), macro fibers' performance in controlling the cracking length was better than the performance of microfibers. Also, the performance of both macro fibers was close.

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