Evaluation of the comparative effect of macro polypropylene fibers and steel reinforcement bars in controlling and reducing plastic shrinkage cracking in concrete pavements

Mohammad Reza Hajizadeh[a], Abolfazl Hassani[b*]

[a] Department of Civil and Environmental Engineering, Amirkabir University of Technology (Tehran Polytechnic)

[b*] Department of Roads and Transportation, Faculty of Civil and Environmental Engineering, Tarbiat Modares University

ABSTRACT

Reducing the severity of plastic shrinkage cracking in concrete pavements by using new materials and comparing with traditional methods by using new analysis methods can increase the durability and improve the performance of concrete pavements. The current research examines the comparative effect of macro polypropylene fibers and reinforcement bars in controlling and reducing plastic shrinkage cracking in concrete pavements. The severity of cracking in the reference concrete mixture, steel bars mesh at intervals of 100 x 100 mm and macro polypropylene fibers in the amount of 1.8 Kg/m^3 was evaluated according to the ASTM C1579 standard method. The results indicated that both reinforcement bars and fibers significantly reduce the cracking area up to 40% in concrete containing reinforcement and 68% in fiber-reinforced concrete. The length of the crack changes more than the average width of the crack. The cracking behavior of concrete containing steel bars mesh is similar to the cracking behavior of fiber concrete, as a result, macro polypropylene fibers may be considered as a suitable substitute for steel bars mesh. It was also seen that the effect of fibers in reducing cracking is greater than the effect of steel bar mesh.

KEYWORDS

Concrete pavement, Plastic shrinkage cracking, Steel bar mesh, Macro polypropylene fibers, Comparative effect.

* hassani@modares.ac.ir

1. Introduction

Cracking in concrete pavement provides the basis for the growth and expansion of more cracks in concrete and causes local or general destruction in the pavement[1].One of the causes of cracking in concrete pavements is plastic shrinkage in the concrete slab. After the construction of the concrete slab, the concrete constituent materials settle down due to the difference in the available mass and gravity[2]. After the evaporation rate is equal to the water bleeding rate on the surface of the concrete slab, the water layer is removed from inside the concrete and the negative water pressures (capillarity) is formed on the concrete surface. These negative pressures cause shrinkage in the concrete, which, if the concrete structure is restraint, tensile stresses begin to form on the surface of the concrete. Due to the low tensile strength of concrete in the early hours after construction, the amount of tensile stress exceeds the tensile strength of concrete and causes cracking due to shrinkage of concrete[3].

One of the resistant forces against the driving forces (tensile stresses) caused by various factors such as plastic shrinkage is reinforcing elements include steel bars. This reinforcement can increase the tensile strength of plain concrete and prevent the expansion and growth of various cracks in the concrete structure. In concrete structures, in order to prevent corrosion and preserving of steel bars, concrete coating is used[4]. This concrete cover is unreinforced, so it is always subject to cracking. After creating a crack in the concrete cover, the ground for water and other harmful substances to enter the concrete is provided and it leads to the corrosion of the rebars.

According to the raised issue, researchers and professionals of the concrete industry conducted several studies on the use of other approaches and methods to control and reduce cracking in concrete. One of these approaches is the use of different fibers in concrete. Fibers in concrete mixtures reinforce it in different points and directions, thereby increasing the tensile strength of concrete. Also, fibers increase flexural strength, impact resistance and improve energy absorption properties in concrete. Among the different fibers, synthetic fibers based on polypropylene have received more attention and use more than other fibers in the industry[5]. In terms of resistance and geometric properties, these fibers are produced and used in two groups, including micro and macro polypropylene fibers. Macro polypropylene fibers have received more attention due to their higher resistance properties, more suitable performance and greater simplicity in their production than micro polypropylene fibers[6].

The investigation of the background of the research shows that plastic shrinkage cracking is one of the common causes of cracking in concrete pavements, which can reduce the durability and level of service in these structures. It was seen that the use of new materials can be effective in controlling and reducing the severity of these cracks. Fibers used in concrete mixtures is one of the new approaches in this field. Despite conducting some research in the field of using macro polypropylene fibers to control and reduce cracking in concrete, less research has been done to evaluate the effect of these fibers in controlling and reducing plastic shrinkage cracking in concrete pavements. Also, less research has been done to evaluate the effect of reinforcing bars on plastic shrinkage cracking in concrete pavement. The comparison of these fibers in the same conditions, with reinforcing bars, is one of the other important cases that needs further investigation. Examining these cases can greatly help to increase the durability and improve the performance of concrete pavements, for this reason, the present research investigates the mentioned cases.

2. Materials & Methodology

The cement used in this research included Portland cement type 1-425 with a specific weight of 3150 kg/m^3. The aggregates used in this research included limestone stone materials with a maximum size of 12.5 mm. The fibers used in this research included macro synthetic fibers based on polypropylene with a twisted shape under the brand name Permanent Polytar and conforming to ASTM C1116 and ASTM D7508 standards. The steel bars used in this research was made of steel with an ultimate strength of 300 MPa and a diameter of 4 mm. this. The bars are made in grids with dimensions of 100x100 mm, which will be used in the reference concrete mixtures. The concrete mixtures for concrete pavement were designed using the criteria mentioned in Rule 731. The weight of the materials that make up the reference concrete mixtures is: cement: 4001.8 kg/m^3, aggregates (0-5 mm): 10281.8 kg/m^3, aggregates materials (5-12 mm): 6921.8 kg/m^3, water: 2001.8 $kg/m^{3.}$ The consumption of macro polypropylene fibers was chosen as 1.8 kg/m^3.

Plastic shrinkage cracking in concrete mixtures was evaluated using ASTM C1579 standard test method. A climate simulator chamber was used to create the desired environmental conditions in the experiment. After the experiment, microscopic images of the cracked were taken using an optical microscope connected to a computer. The geometric characteristics of cracking including the length, average width and area

of cracking in each concrete slab were calculated using the image analysis tool included in the software.

3. Results & Discussions

Figures 1, 2 and 3 show the results of the average cracking width, cracking length and cracking area of the reference, steel and fiber concrete mixtures, respectively. According to the obtained results, it can be seen that the intensity of plastic shrinkage cracking in concrete is reduced by adding steel bars or macro polypropylene fibers. By adding steel bars to the reference concrete mixture, the tensile strength of concrete affected by the addition of steel increases. As a result, the strength of the concrete structure increases under the tensile stresses plastic shrinkage. In fiber concrete mixtures, the addition of fibers increases the tensile strength and improves the energy absorption capacity of concrete mixtures. Also, the fibers prevent the growth and spread of micro-cracks created on the surface of the concrete by being placed in the place of cracking. From this point of view, the intensity of plastic shrinkage cracking in Concrete mixtures containing macro polypropylene fibers are reduced.

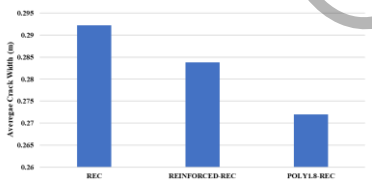

Figure 1. Average crack width in Reference, steel-reinforced and fiber reinforced concrete mixtures

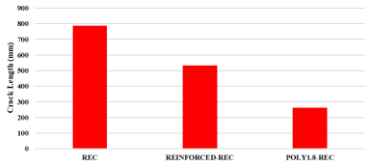

Figure 2. Crack length in Reference, steel-reinforced and fiber reinforced concrete mixtures

According to the obtained results, it can be seen that the reduction of average cracking width in concrete mixtures containing steel bars and macro polypropylene fibers has the lowest reduction among the geometric characteristics of cracking. Also, the reduction of cracking area is more than the reduction of cracking length in these two concrete mixtures. By further examining the results, it can be seen that the effect of macro polypropylene fibers in controlling and reducing of plastic shrinkage cracking in concrete mixtures is greater than the effect of steel bars. This issue can be investigated by comparing the severity of plastic shrinkage cracking in concrete mixtures containing macro polypropylene fibers and steel bars.

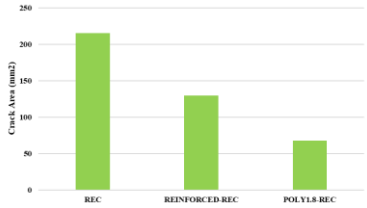

Figure 3. Crack area in Reference, steel-reinforced and fiber reinforced concrete mixtures

4. Conclusions

- It has been observed that the steel bars and macro polypropylene fibers cause a significant change in the behavior of plastic shrinkage cracking in concrete mixtures.
- It was seen that the effect of fibers in controlling and reducing the severity of plastic shrinkage cracking is greater than the effect of steel bars in reducing this type of cracking.
- The appearance, technical specifications and amount of consumption of macro fibers can have a significant impact on its performance in cracking control.

5. References

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