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Effects of Dimensions and Amount of Polymer Fibers on the Strength and Durability of Roller-Compacted Concrete under Freeze-Thaw cycling

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ABSTRACT: In recent years, the use of Roller–Compacted Concrete Pavement (RCCP) has developed in road pavement due to its great advantages. Adding fibers to RCC can improve some properties of the concrete, including flexural strength, fatigue resistance, crack growth rate, and shear transfer along cracks and joints. Many experiments have shown the advantages of using fiber-reinforced concrete in RCC, but more information is needed about their behavior in cold regions, and especially the exposure to Freeze-Thaw cycling. Investigation and comparing the effect of polymer fibers on the strength and durability of Roller-Compacted Concrete under Freeze-Thaw cycling are the main goal of the present article. Therefore, specimens with weight percentage of fiber equal to 1, 2.5, and 4% (by weight of cement) and fibers of to 5, 20 and 40 mm lengths are made. Durability test against a Freeze-Thaw cycling and compressive strength are measured on samples after 7, 28 and 90 days. Analysis of the results shows that the additive fiber increases the compressive strength of the RCC, but decreases its durability against the melting and freezing cycles. Therefore, the use of fibers on RCC in cold regions should be done due accuracy and attention.

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1. INTRODUCTION

RCCP can be reinforced by short fibers randomly distributed in its content and improve some of its properties including compressive strength, flexural strength, tensile strength and durability [1]. It is very important that while using fiber-reinforced RCCP, especially in cold regions, its durability in Freeze-Thaw cycling should be taken into consideration. A few studies have been conducted on durability of available fiber-reinforced concrete. In this research, in addition to measuring the compressive strength of fiber-reinforced RCCP using destructive testing of compressive strength and ultrasonic nondestructive testing after 7, 28 and 90 days, we measured the durability of RCCP against Freeze-Thaw cycling.

2. METHODOLOGY (LABORATORY PROGRAM)

This research has been carried out in a laboratory. In order to achieve the purpose of this study, the compressive strength of the RCC specimens containing varying amounts of macro-synthetic fiber in different lengths were measured using hydraulic jacks and dynamic modulus using ultrasonic device meeting ASTM C597 standards, and durability of the specimens were measured in Freeze-Thaw cycling up to 300 cycles in accordance with the ASTM C666 standard.

Materials used in RCC include aggregates, cement, water and fibers. The grading used to make the specimens was selected based on the most common grading used in RCCP according to publication no. 354 and available standards (ACI 325.10R, SCDOT, 2001) [2,3]. The cement used in this research is Type 2 Firuzkoh cement. Besides, the amount of cement used according to the mix design is 305 kg/m3, and the water to cement ratio is based on Vebe test according to ASTM C1176 standard for all the specimens. In this study, single strand polyolefin polymer fibers with high strength and macrofiber (Mex.200) with high molecular weight and strength were used. 1%, 2.5% and 4% fiber content by weight of cement fraction were used.

Concrete mix design for testing of concrete consistency was conducted based on ASTM C1170 standard. The specimens with different percentage and dimensions of the fibers were labeled as shown in Table-1. This table also summarizes the results of the mix designs, including the amount of cement, water and Vebe time. 150×150×150 mm cubic specimens for testing ultrasonic properties and compressive strength after 7, 28 and 90 days, and prismatic specimens of 300×100×75 mm which are cut out of 300 ×150 mm cylinder samples were used to test the Freeze-Thaw cycling. Two specimens were made for each mix design.

3. RESULTS AND DISCUSSION

3.1.Compressive strength

Compressive strength of the cubic specimens using a hydraulic jack, the weight of the specimens before and after

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Table 1. label of different mix designs intended for various weight amount and dimensions of fibers

Specimen labels	mix design types	amount of cement (kg/m3)	amount of water (kg/m3)	Vebe time (seconds)
A	Roller concrete without additives	305	122	30
B-1	RCC with 1% fiber content by weight of cement (5 mm long fiber)	305	138	35
B-2	RCC with 2.5% fiber by weight of cement (5mm long fibers)	305	138	35
B-3	RCC with 4% fiber content by weight of cement (5mm long fiber)	305	138	30
C-1	RCC with 1% fiber content by weight of cement (20mm long fiber)	305	138	36
C-2	RCC with 2.5% fiber content by weight of cement (20mm long fiber)	305	138	36
C-3	RCC with 4% fiber content by weight of cement (20mm long fiber)	305	138	37
D-1	RCC with 1% fiber content by weight of cement (40mm long fiber)	305	138	33
D-2	RCC with 2.5% fiber content by weight of cement (40mm long fiber)	305	138	32
D-3	RCC with 4% fiber content by weight of cement (40mm long fiber)	305	138	34

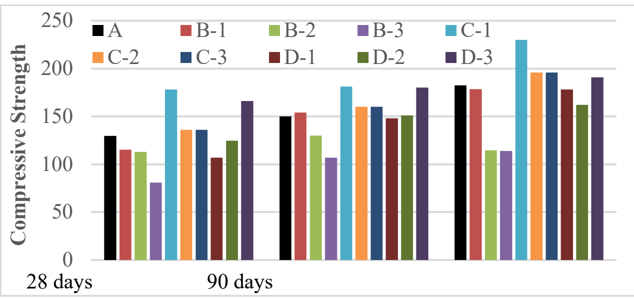

Fig. 1. Compressive strength of the specimens made in 7, 28 and 90 days

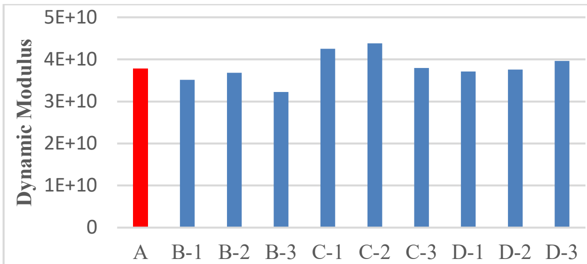

Fig. 2. Dynamic modulus of 90-day specimens

the test, stress and Poisson's ratio were calculated. The amount of compressive strength for the specimens with various mix designs after 7, 28 and 90 days are shown in Fig. 1.

3.2. Ultrasonic Test Results

Dynamic modulus for the 90-day specimens and the percent of their change compared to the reference specimen A are shown in Fig. 2. According to the results that are in line with the results of the compressive strength, the specimens containing 2.5% fiber 20 mm long have demonstrated the best performance.

Ultrasonic wave velocity in the specimens can be examined which is shown in Fig. 3 for fibers with different lengths. Similar to previous results, according to ultrasonic wave velocity we may conclude that the addition of 2.5% macrosynthetic 20 mm long fibers produces the biggest improvement in RCC.

3.3. Test results for Freeze-Thaw cycling

To investigate the effect of the fiber on the strength of the specimens under Freeze-Thaw cycling, durability indexes of the specimens were compared. Fig. 4 shows the durability index of the specimens with different percentages and lengths

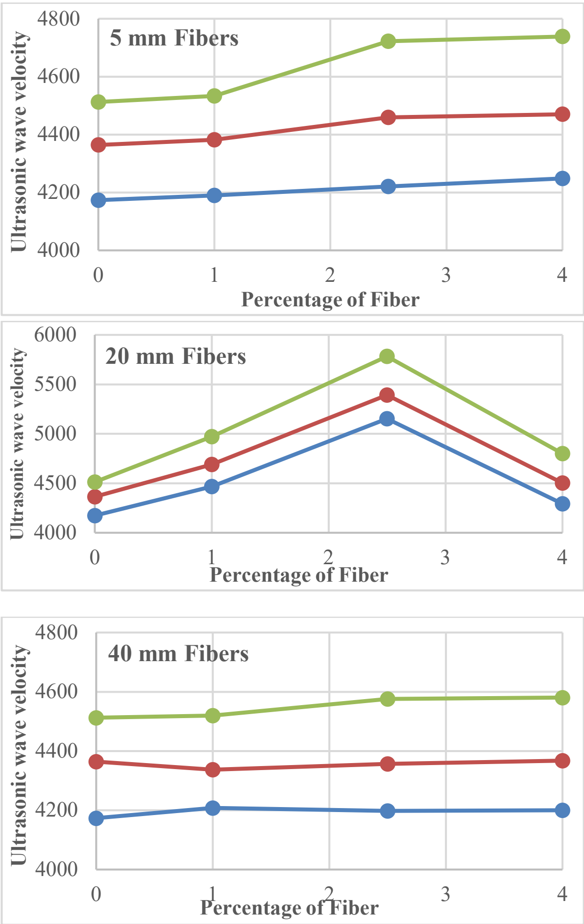

Fig. 3. Ultrasonic wave velocity for 7(Blue Line), 28(Red Line) and 90 day (Green Line) specimens containing 5 , 20 and 40 mm long fibers

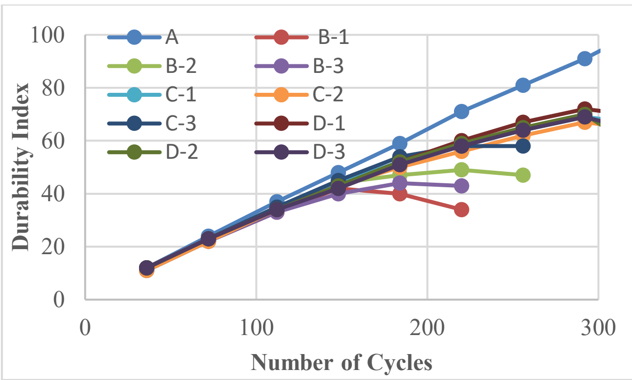

Fig. 4. Durability Index of RCC specimens in terms of the number of freezing-thawing cycles

of fiber in terms of numbers of cycles. As you can see, in general, the durability index values for the specimen without fiber (mixed design A) are higher than that of other specimens. In fact, it can be concluded that the addition of fiber reduces resistance against Freeze-Thaw cycling of RCC However, higher percentages of macrosynthetic fibers, compared to its lower percentages result in relative improved durability of the specimens (in all three sizes used, fibers with higher percentage resulted in higher durability compared to lower percentages). On average, the addition of macrosynthetic fibers reduced the durability of RCC specimens by 30%. This can be due to non-uniform dispersion of fibers in concrete content, and its accumulation in some areas. For further investigation, you should evaluate how the fibers are dispersed within the RCC specimen.

4. CONCLUSIONS

In this study, we examined the effects of adding macrosynthetic fibers in various length and weights on the compressive strength and durability of RCC against freezing and thawing cycles. For this purpose, 10 different mix designs were provided in which 1, 2.5 and 4% fiber by weight of cement were used which were 5, 20, and 40 mm long. To measure the compressive strength of the specimens, ultrasonic devices and hydraulic jacks were used. The specimens were also exposed to 300 freezing-thawing cycles. Some of the research findings are as follows:

•While conducting the compressive strength test using a hydraulic jack, we found that addition of 5 mm long fibers results in lower compressive strength; however, 20 mm and 40 mm long fibers result in higher compressive strength.

•Specimens containing 2.5% macrosynthetic fibers 20 mm long, according to the results of the compressive strength test, which resulted in a 33% increase in compressive strength, are introduced as the efficient mix design.

•Evaluation of the results of the dynamic modulus obtained from ultrasonic and ultrasonic wave velocity tests of the specimen have also produced results similar to the compressive strength test.

•Based on ultrasonic test, specimens also containing 2.5% macrosynthetic fibers 20 mm long are introduced as the efficient mix design.

• Reduced compressive strength of the specimens containing fibers 5 mm long can be caused by the accumulation of fibers and their non-uniform distribution in the specimens.

•The results of freezing-thawing cycles imply that addition of macrosynthetic fibers generally reduces the durability of the specimens against freezing-thawing cycles.

•When using fibers, increasing the percentage of 40 mm long fibers in the specimens has no effect on the durability of the specimens, addition of 20 mm long fibers reduced the durability of the specimens, and the addition of 5 mm long fibers had decreasing-increasing effects.

•The shorter the fibers used in the RCC specimens, the more is the decline of the durability index in freezing-thawing cycles.

•Decreased durability of the RCC specimens containing macrosynthetic fibers can be associated with heterogeneous distribution of fiber he specimens.

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