QUID 2017, pp. 475-483, Special Issue N°1- ISSN: 1692-343X, Medellín-Colombia

INVESTIGATING THE STRENGTH INDICES OF ROLLER COMPACTED CONCRETE CONTAINING PROPYLENE FIBERS FOR THE PAVEMENT OF ROADS

(Recibido el 15-06-2017. Aprobado el 04-09-2017)

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Resumen: El hormigón compactado con rodillos (RRC) es un hormigón sin contracción que es compactado por rodillos y por sus ventajas, es ampliamente utilizado en la construcción de pavimentos de carreteras de hormigón. RCC refuerzo por armadura, debido a ciertas circunstancias no es posible implementar. Por esta razón, los investigadores han estado buscando maneras de mejorar su ductilidad y propiedades de resistencia a la flexión. El uso de fibras de acero aumenta la resistencia como parte de la mezcla, pero el módulo de ruptura no se vería afectado. En este sentido, el uso de una capa delgada de hormigón armado de grano fino en el lado del RCC con redes tejidas de fibras de pavimento de hormigón aumenta en gran medida su resistencia y se puede utilizar para rutas con tráfico ligero y también con rodillos (RCCP) Con tráfico pesado y el procedimiento RRC utilizado en este tipo de pavimento tiene propiedades tales como alta resistencia, bajos costos de construcción y mantenimiento a niveles bajos. En este artículo, se examinaron las propiedades del hormigón y se evaluó su uso en pavimentos viales. En este trabajo, para mejorar el desempeño de RCC utilizando fibras de polipropileno tres global, incluyendo RCC, RCC que contiene fibras de polipropileno y RCC que contiene fibras de polipropileno y materiales puzolánicos (micro sílice, cenizas volantes y caliza) y se analizaron los resultados. Para evaluar el rendimiento de la mezcla anterior, se han estudiado propiedades tales como resistencia a la flexión y compresión, cantidad de expansión y contracción y absorción de agua. Sobre la base de los resultados de las pruebas, las fibras de polipropileno causan las mejoras de las propiedades mecánicas de RCC tales como resistencia a la compresión, resistencia a la flexión y durabilidad frente a los ambientes corrosivos. En diseños que contenían fibras de polipropileno y material pozolánico se observó que las muestras mencionadas tienen mejores propiedades que las muestras de fibra de propileno solamente. Entre estos el diseño que contiene fibras de polipropileno y micro sílice junto con la durabilidad del concreto, tiene los mejores resultados de resistencia en comparación con otras muestras.

Palabras clave: RCC, fibras de polipropileno, resistencia, construcción de carreteras

Abstract: Roller compacted concrete (RRC) is a concrete without slump which is compacted by rollers and due to its advantages, it is widely used in pavement construction of concrete roads. RCC reinforcement by armature, due to certain circumstances is not possible to implement. For this reason, researchers have been seeking ways to improve its ductility and flexural strength properties. The use of steel fibers increases the resistance as part of the mix, but the modulus of rupture would be unaffected. In this regard, the use of a thin layer of fine-grained reinforced concrete in side of RCC with woven networks from pavement fibers made of concrete increases its resistance greatly and it can be used for routes with light traffic and also roller (RCCP) routes with heavy traffic and RRC procedure used in this type of pavement has properties such as high strength, low construction costs and maintenance at low levels. In this article, we examined the properties of the concrete and evaluated its use in road pavement. In this paper, to improve the performance of RCC using polypropylene fibers three overall, including RCC, RCC containing polypropylene fibers and RCC containing polypropylene fibers and pozzolanic materials (micro silica, fly ash and limestone) was made and the findings were analyzed. To evaluate the performance of the above mixture, properties such as flexural and compressive strength, amount of expansion and contraction and water absorption have been studies. Based on the results of the tests, Polypropylene fibers cause the improvements of the mechanical properties of RCC such as compressive strength, flexural strength and durability against the corrosive environments. In Designs containing polypropylene fibers and pozzolanic material it was observed that mentioned samples have better properties than a fiber propylene only samples. Among these the design containing polypropylene fibers and micro silica along with concrete durability, has the best results of resistance compared to other samples.

Keywords: RCC, polypropylene fibers, resistance, road construction

1. INTRODUCTION

As all types of concrete, RCC is a mixture of inert aggregate, cement and water. RCC is a new material and method for economical building large structure including gravity dam. In this type of concrete, a combination of soil and concrete properties are used and it is transported, and compressed by machines. So concreting becomes faster and running costs reduces greatly. RCC pavement is in fact a kind of concrete pavement. It is a stiff and relatively dry mixture of aggregates, cement, water and additives which is diffused by conventional devices of asphalt pavement (paver) and then it is crushed by Quaker steel rollers and rubber wheel and finally after hardening as a result of cement hydration reaction it is converted to concrete. In fact RCC is a concrete with lower cement and higher aggregates (75-85 % wt) with zero slump. The main advantage of RCC pavements than conventional concrete pavement is higher speed of construction and lesser cost of construction. Usually it has about 30% economic saving. Roller compacted concrete pavement (RCCP) is appropriate as pavement under heavy loads and in such applications, its performance is as good as conventional concrete pavement.

In the meantime, it should be noted that achieving surface flatness for high speeds with RCC is difficult. So the use of this type of pavement is suitable for low speeds. With improvements in methods and implementation facilities, it is possible to make RCC pavement with tolerances accessible with conventional concrete and development of this type of pavement on the road at high speed is also raised.

RCC has never been a new method in pavement. That is before and after the First World War in many countries, concrete pavement was compacted with using roller. The construction phases of pavement concrete roller include concrete mixing, transportation to the site by truck mixers, concrete spread by graders on the wet layer with maximum thickness 25 cm and performing the density by heavy vibratory roller with rubber wheel roller. It is worth mentioning that this type of pavements are more applicable on roads with low traffic volumes and low speed (heavy vehicles in industrial areas) which most of them are implemented without asphalt coating layer (plated).

A new type of RRC is concrete containing the fibers. In RCC fibers, regarding the amount of optimal proportion of used polymer fibers in mixture as well as the specific mechanical properties of these fibers, we see an increase in strength parameters of reinforced RCC mixture. On the other hand, calculations and results of quasi-experimental design (M-E) conducted in the composite pavements with medium and heavy passing traffic, represents a 20% reduction in thickness of fiber reinforced RCC to conventional RCC in these type of pavements.

It should be noted that based on different experiences of workshops from the implemented projects, in order to achieve the best results in the workshop and have laboratory-confirmed values we should use a proper method of materials mixed design and their combination with this type of fiber network. Otherwise, due to the none-homogeneous distribution of the fibers and pellets, the expected performance is not achieved. Since composite pavements include a combination of two types of asphalt pavement as flexible surface layer and concrete pavement as rigid substrate, therefore in the case of using fiber reinforced RCC as rigid substrate, then by using an asphalt pavement we can improve its quality. In developed countries, many researches have been done on reinforcing RCC with fiber. Experts and researchers in our country in recent years have conducted extensive laboratory researches which ultimately leads to patents, presenting articles at famous international conferences and implementing on a large scale. For the implementation of RCC with fibers, there is a need to use special equipment to do mixing process and adding fibers. Because the most important issue in this method is homogeneous distribution of fibers to have a good performance. Also today in order to achieve greater resistance and durability in addition to the main constituent of concrete that is cement, water and aggregate, other materials are used in concrete which is called pozzolanic materials. In fact, this material can be used as a fourth factor mentioned in concrete production. Furthermore, pozzolanic materials due to the high density of materials and lack of penetration of chloride ions into concrete, provide durability and quality of concrete in different conditions, including corrosive environments of Persian Gulf coast. The above use of these materials mostly depend on the richness of technical knowledge in connection with their use during the implementation and post-implementation maintenance (2). At an early age of concrete (from the concreting up to 24 hours later) the obtained resistance by concrete is limited and a very small tension can lead to cracks. Cracks arises through bind and desire of concrete for shrinkage, changes in temperature (cooling concrete after the concrete temperature has gone up due to hydration) or evaporation of water from the concrete surface. High tensile strength of polypropylene fibers at this period of time prevents concrete cracking. Polypropylene fibers prevents concrete bleeding of water and also prevent water transportation to concrete surface resulting in homogenization of concrete and assimilation of water-cement ratio in concrete and maintaining hydration process. These fibers can reduce the permeability of concrete surface and increases concrete lifetime and abrasion resistance of concrete. So the concrete surface will not be crunched and laminated. This process means avoid creating weak spots in the concrete and after the hardening of concrete, stops its shrinkage and prevents the creation of thermal cracks in large amounts. So in this sense it is a good alternative for thermal reinforcement. Use of polypropylene fibers increases the tensile strength and flexural and shear concrete and after the failure of concrete, (even under flexural moment) it remains integrated. Increased resistance to melting and solidification cycles which results from concrete permeability reduction and increased fatigue resistance, abrasion and cavitation are among other advantages of using polypropylene fibers. Since a large number of research findings of researchers throughout the world show that use of fiber as a replacement for Portland cement in concrete construction has multiplied the performance and strength of these concrete roller. So in the present study, the properties and durability of concrete roller including propylene fibers, micro silica, fly ash with polypropylene fibers and RCC containing limestone powder silica nanoparticles with control concrete RCC have been investigated.

2. THE ENVIRONMENTAL CONDITIONS AND MATERIAL PROPERTIES

In this study, to evaluate the resistance indices of RCC, 4 concrete mixtures were built where two of them are RCC containing propylene fibers and three micro silica pozzolan and fly ash. Also an RCC contains fibers of polypropylene and limestone powder and a control RCC. Super plasticizer with the brand name VandSuperplast PCE with PH equal to 7 and aggregates are Gravel - rounded pebbles type usually of river or sea origin where the biggest size of aggregate is 12.5 mm. Also durability and mechanical features of samples after construction and processing in normal and salt water environments were evaluated.

2.1. Properties of Materials

Polypropylene fibers

Fibers used in this study is polypropylene synthetic fibers (PP). These fibers is made of pellets that is pellets of petrochemical derivatives and 19, 12 and 6 mm sizes are available. The size used in this study is 6 mm and the color of the fibers as can be seen in Figure 1 is white.

Figure 1. Polypropylene fibers

Table 1. propylene fiber properties

propylene	Type of fiber
0.91	**Density g/cm3**
0.65	**Tensile strength(MPa)**
8	**Modulus of elasticity(GPa)**
8	**Elongation percent**
0.29-0.46	**Poisson's ratio**

2.2. aggregates:

The materials used in this project are produced materials of Tabriz mine including natural sand 0-6, Pea gravel with maximum size 12.5 mm and almond sand with maximum size 19 mm. Gradation curve and mixture of aggregate are presented in figures 1 to 4. The curve of figure a is drawn the ratio of aggregate 60 percent sand, 10 percent pea gravel and 30 percent almond sand. The important point in selecting sand is the gradation continuity and being in the suitable proposed range in national method of mix design.

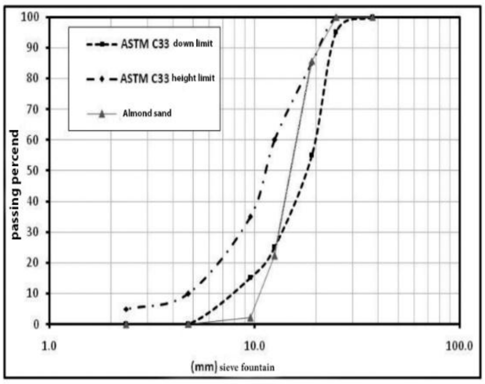


Figure 1-1-almond-shaped sand laced grain

Figure 1. grading curve of almond sand mixture

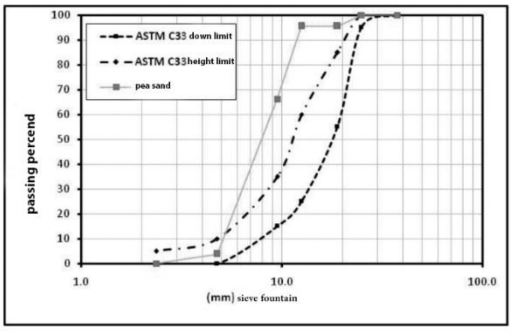


Figure 1-2-pea-shaped sand laced grain

Figure 2. grading curve of pea sand mixture

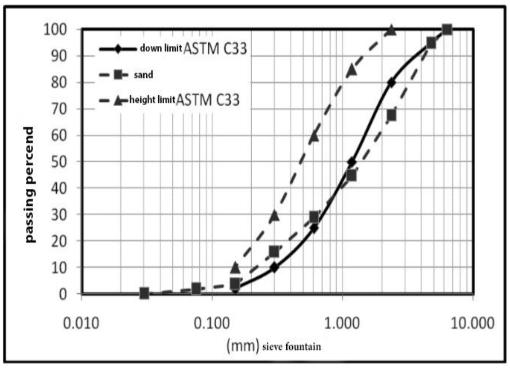


Figure 1-3- sand laced grain

Figure 3. grading curve of consumed sand mixture

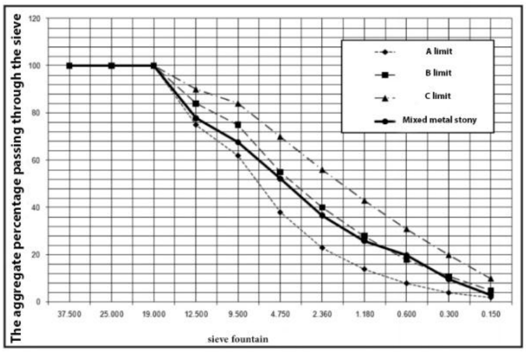


Figure 1-4-mixed metal stony laced grain

Figure 4. grading curve of consumed aggregate

2.4. Cement:

In concrete cement has the role of grip. The consumed cement is Portland cement type 2 of factory Cain in Khorasan Razavi Province with density 3.15 T/m^3 according to standard ASTM-C150 that its chemical properties are shown in Table 3.

Table 3. Chemical properties of Cement Type II

Ingredients	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	K_2O	NaO_2	So_3	OL	C_4Af	C_3A	C_3S	C_2S
standard value (ASTM)	---	Min 20	Max 6	Max 6	Max 5	0.6	0.5	Max 3	---	9	Max 6.5	55	17.5
The amount in	64	22.5	5.48	5.52	3	0.6	0.4	1.4	---	8.5	5.18	37.2	15

sample/gram													

2.5. Other consumable materials

The fly ash used in this study was taken from Pasilou Company.

Limestone powder consumption was produced in Qazvin Company and all of its particles are passed through sieve 50.

Water used in this project is drinking water of Tehran city.

2.6. Superplasticizer

In this study, concrete superplasticizer of Chemical polycarboxylate which is superplasticizer addition of superplasticizers new generation by having repulsive properties of cement particles causes proper spread and uniformity in concrete. Also it prevents the reconnection of particles to each other. This property creates maximum psychological effect, drastic reduction of water-cement ratio and thus increase the initial and final resistance and impermeability of the concrete. (Table 4)

Table 4. Technical Specifications of superplasticizer

Weight	7± 1.2gr/cm3
Chloride	Zero
PH	About 5.5
Color / physical appearance	light brown
physical state	Fluid
Solubility	in the water

3. LABORATORY RESEARCHES AND EVALUATING THE RESULTS

It was done to study the properties of fresh concrete, including the filling, passing ability and resistance to segregation, funnel V and Box L. another test that was performed on fresh air was determining the air content of fresh concrete. Compressive strength and flexural tests were done all the samples, ages 7 to 180 days in both aqueous and corrosive environments. In order to verify the results of various tests, ultrasonic non-destructive testing was performed on all cases. Also, in order to determine the permeability and contractile behavior of samples, tests of water absorption at 28 days, contraction and expansion was done on samples at different ages and the results were compared with control samples.

3.1. Mix method of samples

In this study the mix method used for making samples was based on proposed method of standard ASTM C305 (8).

3.1.1. Amount of polypropylene fibers in mortar containing fly ash

In this study by making mortars with different percentages of fibers from 1% to 7% and 30%, fly ash was considered as a substitute for cement. The results of compressive strength were carried out at ages 3, 7, 28, 60 and 90 days that are mentioned in the figure below. As is evident from the figure, the mortar by 4% propylene fiber has the highest compressive strength compared to similar samples and will be used as optimal percentage.

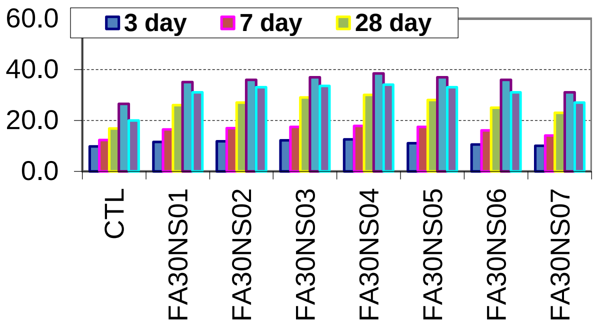


Figure 5. The compressive strength of mortars with fly ash with different percentages of propylene fibers at different ages

3.1.2. The compressive strength of mortar

The examination of this the mechanical behavior of mortars was done according to standard ASTMC109-99 (7). Casting of samples was done at maximum of 3 minutes and eventually 30 seconds after making cement. A layer of mortar with a thickness of about 25 mm (half-height of mortar) in casts in the shape of cube and sides of 5 cm was poured based on the mentioned standard. Slamming pressure was enough to fill the mortar in the cast. 4 levels of slamming was done in each cube and them other cube was slammed. When slamming of first layer was completed, we fill all the parts with remainder of mortar and like layer one, layer two was also slammed. Finally the surface became smooth by a trowel. Samples made was out of cast after 24 hours and until compressive strength testing they were kept in water tank with temperature of 2 ± 23 ° C. Before the start of loading, the sample should be clean and dry and loose aggregate must be resolved. Load was applied on flat aspects of sample in contact with body cast. The samples were carefully placed in the middle of the car Grips and no interface material as the substrate or padding were loaded between sample and Grips. The speed of loading based on the aforementioned standard should be in the range of 900 to 1800 Newton per second. In the conducted tests the loading speed was 1350 Newton per Second. Loading was done by hydraulic jacks Controls model 50-C5800. The final compressive strength was calculated based on the average strength of the three samples. According to the aforementioned standard, samples that their resistance were made with medium strength of samples similar to that of the mortar and were tested in one age, have more than 7.8% difference must be eliminated.

3.1.3. Optimization of the amount of polypropylene fibers in mortar containing limestone powder

This matter was done by making mortars with different percentages of polypropylene fibers from 1% to 7% as a substitute for cement and 40% limestone powder and the results of compressive strength was carried out at ages 3, 7, 28, 60 and 90 days which is mentioned in the following figure. As is evident from Figure, mortar with 5% polypropylene fiber has the highest strength compared to the similar samples and as optimum percent of polypropylene fibers will replace cement in RCC mix design.

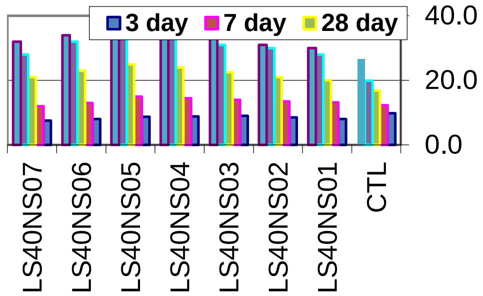


Figure 6. The compressive strength of limestone mortars with different percentages of nano silica at different ages

3.2. Making samples of concrete mix designs

The mixing process used in concrete construction is based on the proposed instruction method ASTM C305 (7) and with some modifications inspired by articles it in accordance with the following instructions. Based on standard of concrete construction, all samples of concrete must be kept in cast for 24 hours and then take them out of cast and until testing in water tank, keep them at a temperature of 2 ± 23 ° C. In table 5 mix design of samples can be seen.

Table 5. weight properties of mix designs

Project Name	Cement	SF	FA	LS	Gravel		Nano	Sand	Water	W/(C+b)	**SP (%)**
					-30	-63					
RCC (Ctrl)	500	-	-	-	712	115	-	810	205	0.5	1/6
RCC Nano	500	-	-	-	712	115	5%	810	205	0.5	1/6
SF10-Nano3	500	45	-	-	712	115	3%	810	205	0.5	1/6
FA30-Nano4	500	-	135	-	712	115	4%	810	205	0.5	1/6
LS40-Nano5	500	-	-	180	712	115	5%	810	205	0.5	1/3

3.3. Tests

3.3.1. Compressive strength

The compressive strength test was done in accordance with ASTMC109 (7) on samples of cube with the sides of 10 cm. Concrete construction was carried out in accordance with the instructions outlined in construction section. According to the mentioned standard loading must be in the range of 900 to 1800 newton per second where in conducted tests, this parameter was considered 1350 newton per second. In the cases where cross section has more than 5.1% difference with nominal speed the actual cross-sectional area was used to determine the compressive stress. The final compressive strength was calculated based on the mean of three samples resistance.

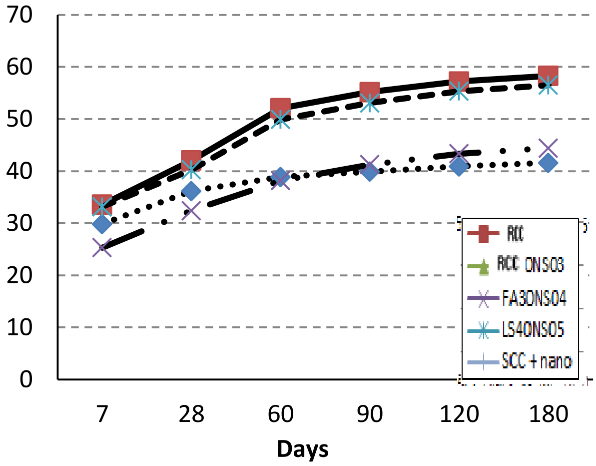


Figure 7. Compressive strength test results

3.2.2. Flexural strength

Flexural strength test was done on prismatic sample 7 × 7 × 28 cm and with speed (0.8-1.2 Mpa /min). In the flexural strength testing we tried to follow the standard requirements of ASTM C348 (8) as much as possible.

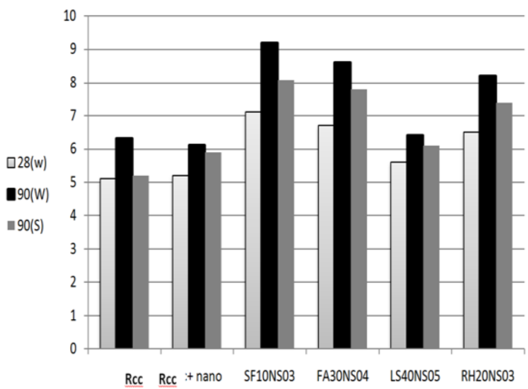


Figure 8. Flexural strength samples results

3.3.3. V funnel and L-box

The results of V funnel and L-box are indicated in tables 6 and 7

Table 6. V funnel test results according to S

V funnel according to S		Row
6/1	RCC (Control)	**1**
6/7	Rcc+nano	**2**
7/7	SF10NS03	**3**
6/5	FA30NS04	**4**
6/9	LS40NS05	**5**

Table 7. L-box test results

L-box	Row	
69.8	RCC (Control)	**1**
82.8	Rcc+nano	**2**
50.8	SF10NS03	**3**
0/88	FA30NS04	**4**
0/89	LS40NS05	**5**

3.3.5. Expansion and contraction test

Expansion and contraction tests were done on prismatic samples 4 × 4 × 30 cm. Samples construction and their casting was carried out according to the instructions described in the flexural strength section. After removing the samples from the cast, samples surface which was in contact with cast wall, was completely cleared from oil and other impurities by clean cloth. Expansion and contraction sample were put at laboratory condition. First reading was done after 3 days of installing scales and the rest of the readings were done at ages 7, 14, 28, 35, 60, 90, 120, 150 and 180 days by special gage with accuracy of 2 micrometer.

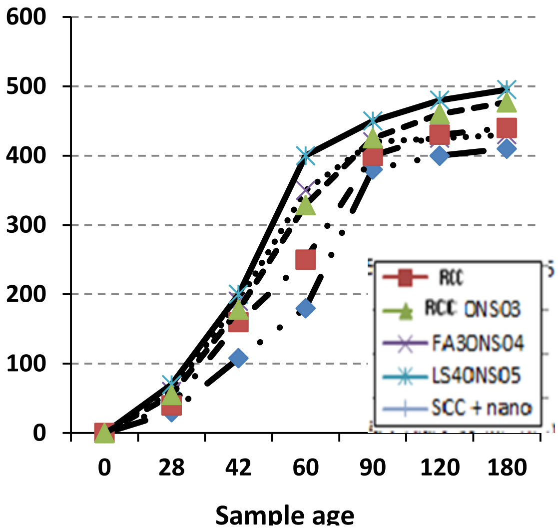


Figure 11. Graph of different mixtures for contraction

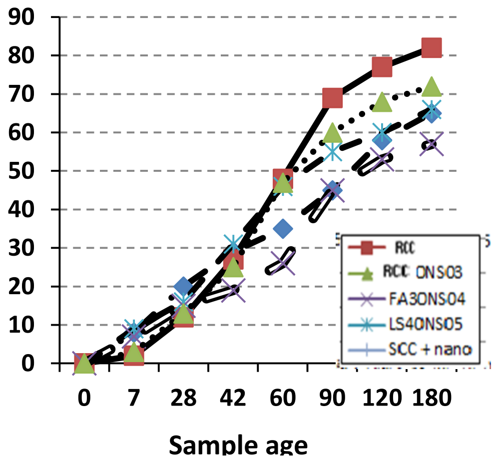
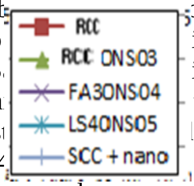


Figure 12. Graph of different mixtures for expansion

4. CONCLUSION

According to the results of research polypropylene fibers is associated with an increase in the compressive strength of RCC. Compressive strength of RCC, containing polypropylene fibers will be more with the addition of pozzolanic materials and the amount of increase in RCC containing polypropylene fibers is the most. For example, 28-day compressive strength of control RCC was 19/36 Mpa, concrete containing polypropylene fibers and micro silica was 06/42 Mpa. Which shows growth of 16%. This increase for fly ash is 11% and 180-day compressive strength were for RCC with polypropylene fibers 95 percent, concrete containing micro silica 1.98 %, concrete containing fly ash 4/95% and concrete containing limestone powder 106%. Results indicate that polypropylene fiber has a significant impact on the strength and durability of concrete.

Like compressive strength, flexural strength test results indicate that adding polypropylene fiber causes improvement in flexural strength samples and more enhancement can be achieved in combination with pozzolanic materials. Samples containing polypropylene fil one powder has similar results to ing only propylene fiber. S ing polypropylene fibers and m the greatest increase in flexural s to the control sample and it has 4 90 days. Corrosive environment, reduces tensile strength is all samples.



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