The Effect of Testing Temperature on the Mechanical Properties of polymerized Self-Compacting Concrete (PSCC)Mixes

Najah M. Lateef Al Maimuri[1], Adnan M. Shihab[2], Kareem F. Abood[3] Arkan R. Abid[4], Muhammad Kareem Abid[5]
Babil Technical Institute, Babylon, Iraq, E-mail: Najahml@yahoo.com

Abstract- A laboratorial study has been conducted to evaluate the effect of the polypropylene (PP) fibers on the mechanical performance of polymerized self-compacting concrete (PSCC) mixes under the effect of different testing temperatures. Briefly the prepared specimens have been heated after accruing to the required testing temperature. PSCC mixes loss part of their mechanical performance for all cement percentage content by weight of PP fibers as heating temperature increases. Five percentages of PP; (0, 0.05, 0.1, 0.15, and 0.2)% of cement are used to polymerize the self-compacting concrete mixes (PSCC). Laboratorial results shows that the maximum compressive strength and splitting tensile strength has been occurred at PP=0.1% by weight of concrete. Whereas the maximum modulus of elasticity values are always higher with pp=0.1% by weight of cement than other percentages of PP before 67Cº but it reduces slightly after that as testing temperature rises to 80Cº. The maximum flexural strength is not occurred with PP= 0.1% by weight of cement at low testing temperature (20Cº) but it becomes approximately maximum to be equal to (5.48Mpa) at high testing temperature of (80Cº).

Keywords- PP: Polypropylene, PSCC: Polymerized Self-Compacting Concrete, Testing Temperature

1. introduction

The mechanical properties of concrete may be improved by randomly oriented short discrete fibers which prevent or control the formation propagation of coalescence of cracks Hannant (1987). In addition Luo et al. (2000) emphasizes that fiber tissues additions can improve some physical properties of concrete such as flexural strength, tensile strength, creep behavior, impact resistance and toughness. Kakemi and Hannat (1996), Qian and Stroeven (2000), Martinez et al (2005), Wang et al (2006), Brostow et al (2006), and Hsie et al (2008) indicate that many types of fibers tissues have been used in concrete engineering; metallic, polymeric, coated, uncoated and/or modified by radiation for their specific advantage but steel fibers have high elastic modulus and stiffness. Accordingly the characteristics of tensile strength and toughness of special concern in self-compaction concrete mixes SCC is investigated. Song (2005) presents that the use of steel fibers at the exposed concrete surfaces accompanied with some unfavorable properties such as rusting, electrical conductivity and magnetic fields occurrence. Iraqi specifications (1984) outlines that (PP) fibers have a good ductility to be capable to restrain a plastic cracks and efficient to resist moisture or alkali media of concrete which resulting in long term durability concrete. Accordingly (PP) fibers may be considered to be a potential replacement for steel fibers if they are used in normal and high testing temperatures.

In this research, the use of (PP) as coarse synthetic monofilament fibers in PSCC mixes under the effect of different testing temperature is evaluated

2. Research Significance

The current laboratorial study focused on testing the negative effects on the mechanical properties of hard PSCC mixes with addition of (PP) as coarse synthetic monofilament fibers under high testing temperature.

3. Material & Methodology

1- **Cement:** Ordinary Portland cement subjected to No.5-84 [4] and ASTM-C150-97a [11] is tested. Table (1) shows the laboratorial physiochemical properties.

2- **Limestone:** It is of a dust filler passing Sieve No.200. Table (2) is included with its chemical properties.

3- **Fine Aggregate:** Iraqi Sand of 4.75mm Max size, G.s of 2.6, and sulfate content of 0.24% is used. The gradation is compatible to zone (2) according to Iraqi specification No.45-84 [12]. Table (3) shows its gradation.

4- **Coarse Aggregate:** a rounded aggregate with max size of 14mm, G.s of 2.8, and sulfate content 0.06%. Its gradation is included in Table (4).

5- **Super plasticizer (SP):** Gleniume 51 with a dose of 2% by weight of cement to ensure the required flowability and porosity is used. The properties as outlined by the manufacturer are in Table (5).

6- **Fiber:** Monofilament (PP) fibers with wavy shapes as shown in Fig.(1). It is manufactured by (Propex Inc. Southampton, UK. Table (6) shows its mechanical properties.

Fig. (1) Wavy Shape Polypropylene Fibers

4. PSCC Mix Design

Five contributions of fiber; (0, 0.05, 0.1, 0.15, and 0.2) % by weight of cement corresponding to five SCC mixes. The mixes design is conformed to the international limitations. Accordingly, the fine and coarse aggregates are fixed to (40 and 50)% of (mortar volume and solid volume) respectively. The water/binder ratio is 0.33 as recommended by Ouchi (2003) and Okamura and Ozawa (2005). Table (7) presents mix proportions of PSCC mixes.

5. Fresh Concrete Test Results

Four tests for fresh concrete mixes have been executed for the selected type of cement under interest; they are Slump Flow, T_{50}, L-Box, and V-Funnel corresponding to Efnarc (2002). Anyway the results of fresh concrete tests of PSCC mixes are represented graphically in Figs. (2 to 5).

6. Hard Concrete Test Results

- A compressive strength of 150mm cubes of concrete are prepared and tested at age of 28 days. according to B. S. 1881: Part 116-83, 1881
- Splitting Tensile Strength based on ASTM| C494-86 is carried out for (150*300) mm concrete cylinder at age of 28 days.
- Flexural Strength Test has been conducted for a prismatic concrete specimens of standard dimensions of (100*100*400)mm after 28days corresponding to B.S :1881: part 118-89 to evaluate the modulus of rupture.
- Static Young Modulus is measured according to ASTM C469-87 for cylinders of (150*300)mm at age of 28days.
- Ultra-sonic Pulse Velocity is also determined according to ASTM C597-94.

Figs. (6 to 10) present the hard concrete tests.

7. Results Analysis & Discussion

7.1 Compressive strength: Fig.(6) shows that PSCC mixes loss a part of their compressive strength for all percentage content of PP fibers as testing temperature increases as outlined by Alcock et al (2007). Fig.(10) reveals that the maximum compressive strength (40.08Mpa) have been occurred at pp=0.1% by weight of concrete at 80Cº of testing temperature.

7.2 Splitting Tensile Strength: Fig. (11) Indicates that the splitting tensile strength (3.8Mpa) have been occurred at pp=0.1% by weight of concrete at 80Cº of testing temperature.

7.3 Modulus of Elasticity: Fig.(8) shows that elastic Modulus values of PSCC Mixes are always higher at PP=0.1% by weight of cement before 67Cº but it reduces slightly thereafter as shown in Fig.(12).

7.4 Flexural Strength: Fig.(9) shows that maximum flexural strength is not occurred with PP= 0.1% by weight of cement at low testing temperature (20Cº) but it reaches approximately its maximum value of (5.48Mpa) at high testing temperature of (80Cº) as shown in Fig.(13).

8. Conclusions

1- PSCC mixes loss part of their Mechanical Performance for all cement percentage content by weight of PP fibers as the temperature increases as approved by Ward and Sweeney J. (2013).

2- The maximum compressive strength and splitting tensile strength has been occurred at pp=0.1% by weight of concrete.

3- The maximum modulus of elasticity values are always higher with pp < 0.1% by weight of cement than other percentages of PP before 67Cº but it reduces slightly after that as testing temperature rises to 80Cº.

4- The maximum flexural strength is not occurred with PP= 0.1% by weight of cement at low testing temperature (20Cº) but it reaches approximately its maximum values of (5.48Mpa) at high testing temperature of (80Cº).

9. Recommendation

It is recommended to use a polypropylene (PP) percentage of 0.1% to polymerize the self-compacting concrete mixes under the effect of different temperatures; 20 to 80Cºsince it offers a higher mechanical performance characteristics.

10. References

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Table (4) Physiochemical Properties of Portland Cement

Physical Properties			
Test	Results	ASTM No.5-84	Allowable Limits According to IQS No.5/1984
Setting Time, Min, Initial	135	≥ 45 min	≥ 45 min
Final	360	≤ 375 min	≤ 600 min
Fineness (Blaine), m^2/kg	3280		≥ 2300
Compressive Strength, MN/m^2 at 3days	18.6	≥ 12	≥ 15
7days	26.3	≥ 19	≥ 23
Soundness (Auto Clave), %	0.3		≤ 0.8
Chemical Properties			
Oxide Composition	Content		Allowable Limits According to IQS No.5/1984
Alumina (Al_2O_3)%	4.56		≤6
Silica (sio_2)%	22.07		≥21
Ferric Oxide (Fe_2O_3)%	3.64		≤6
Free Lime (CaO)%	62.06		-
Sulphate (SO_3)%	2.05	≤3	≤2.8
Magnesia (MgO)%	2.7	≤6	≤5
Free Lime	0.76		-
Loss on Ignition	1.9	≤3	≤4
Insoluble Residue (I.R)%	0.7	≤0.75	≤1.5
Lime-saturation Factor (L.S.F)	0.86		0.66-1.02
C_3S	31.49		≥5
C_2S	37.7		-
C_3A	12.07		-
C_4AF	8.01		-

Table (2) Chemical Composition of Limestone Dust

Oxide	Content %
Lime (Cao)	53.1
Silica (Sio_2)	1.4
Alumina (Al_2O_3)	0.7
Ferric Oxide (Fe_2O_3)	0.2
Magnesia (So_3)	0.1
Sulphate (SO_3)	3.2
Lose on Ignition (L.O.I)	40.6

Table (3) Gradation of Fine Aggregate

Sieve Size, mm	% Passing By Weight	Iraqi Specifications Limits No 45-1984
4.75	100	90-100
2.36	80	75-100
1.18	64	55-90
0.6	39	35-59
0.3	32	8-30
0.15	1	0-10

Table (4) Gradation of Coarse Aggregate

Sieve Size, mm	% Passing By Weight	Iraqi Specifications Limits No 45-1984
14	98	95-100
10	32	30-60
4.75	10	0-10
2.36	0	0-5

Table (5) Typical Properties of (SP)

Main Action	Concrete Super-plasticizer
Subsidiary Effect	Harding Retard
Form	Viscous Liquid
Color	Light Brown
Relative Density	1.1 at 20cº
Viscosity	128±30 cps at 20cº
Ph	6.6
Recommended cement percentage	2-5
Transport	Not Classified as Dangerous

Table (6)Physical &Mechanical Properties of PP Fibers

Length,mm	Dia, mm	Density, g/cm^3	Elastic Modulud, Gpa	Tensile Strength, Mpa	Melting Point Cº	Rupture Extension, %
45	1	0.91	5.88	320	165	14

Table (7) Mix Proportion of PP SCC Mixes

Material	Content	Allowable Limits According to DIN 1045
Cement, kg/m^3	450	450-500
Lime, kg/m^3	150	5--150
Fine Aggregate, kg/m^3	450	325-525
Coarse Aggregate, kg/cm^3	750	750-920
Sp % by weight of Cement	2	-
Water/Binder (Cement+lime)	0.33	-
Water, kg/m^3	200	-
PP Fiber% by Weight of Cement	0-2	-

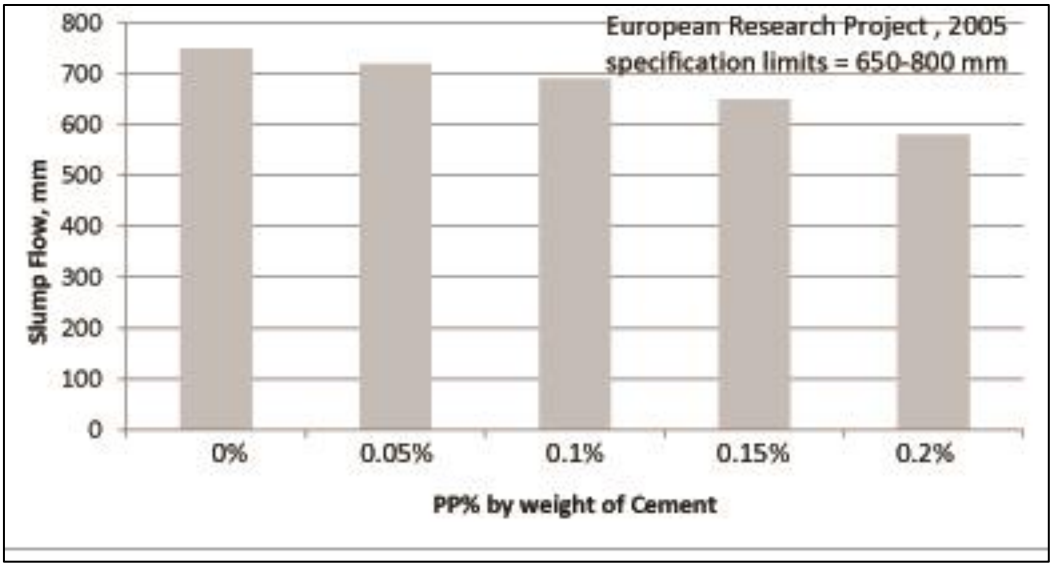

Fig.(2) Slump Flow Test Results of PSCC Mix

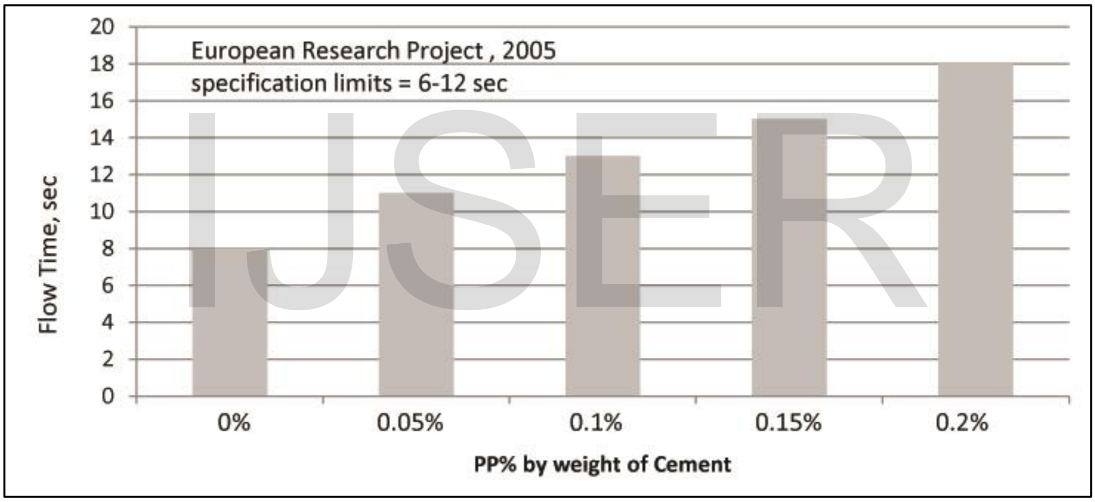

Fig.(3) V-Funnel Test Results of PSCC Mix

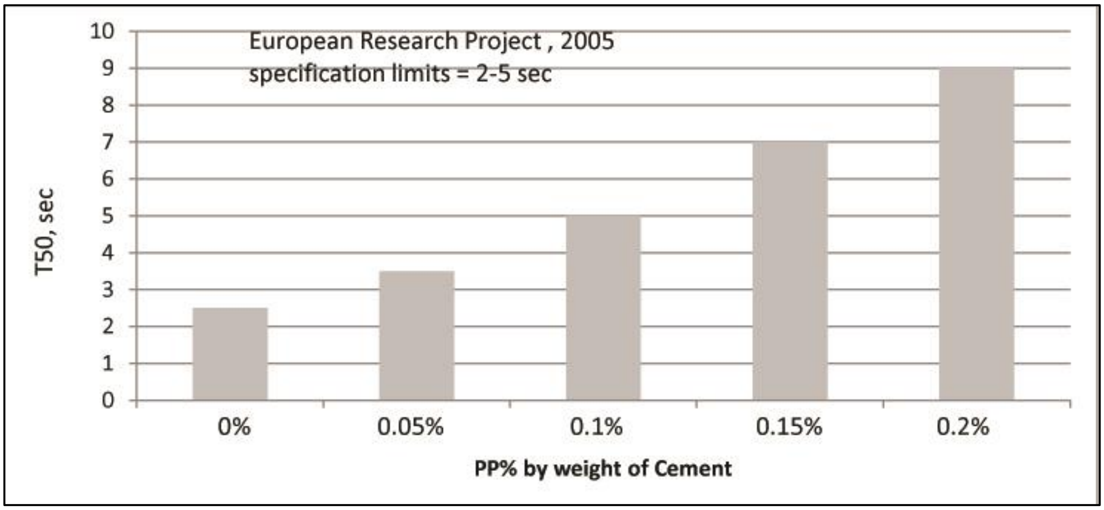

Fig.(4) T_{50} Results of PSCC Mix

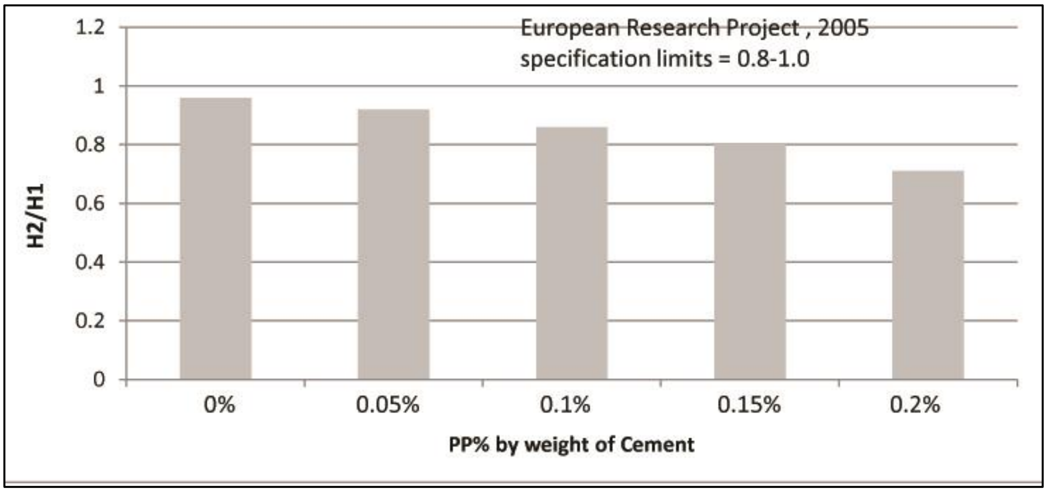

Fig.(5) L-Box Test Results of PSCC Mix

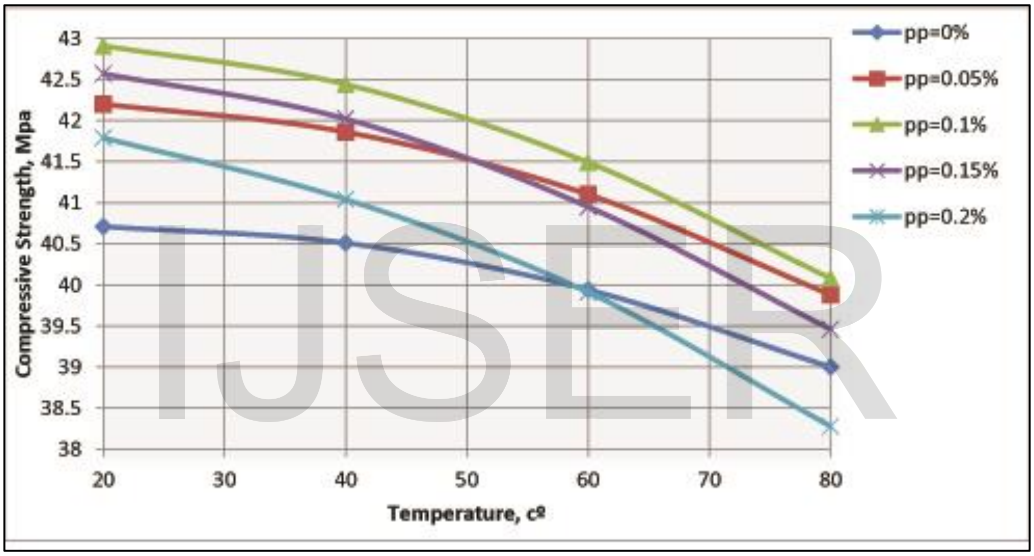

Fig.(6) Compressive Strength of PSCC Mixes Results

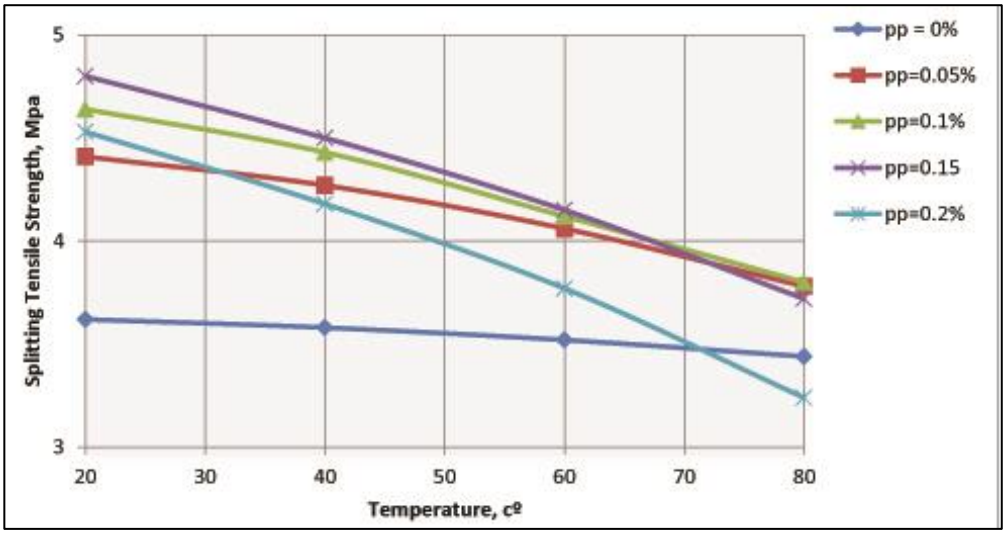

Fig.(7) Splitting Tensile Strength of PSCC Mixes Results

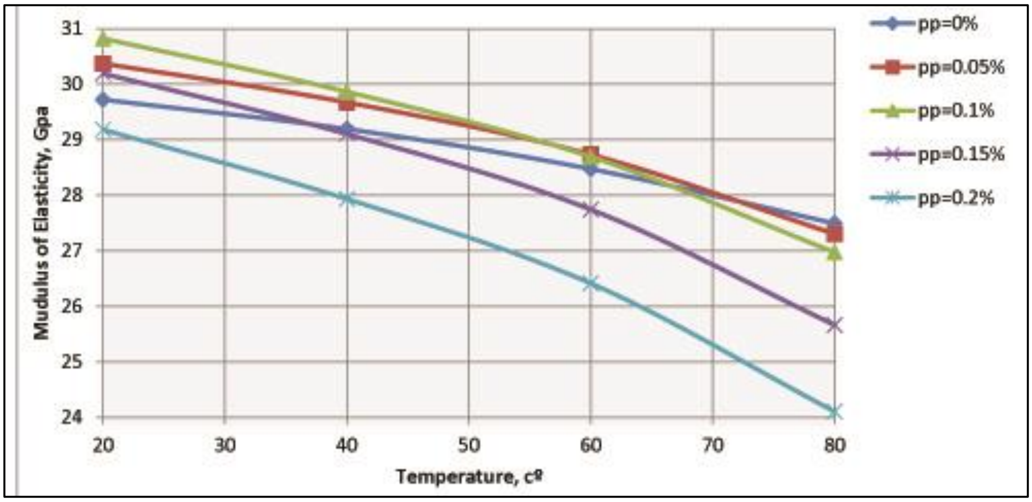

Fig.(8) Modulus of Elasticity of PSCC Mixes Results

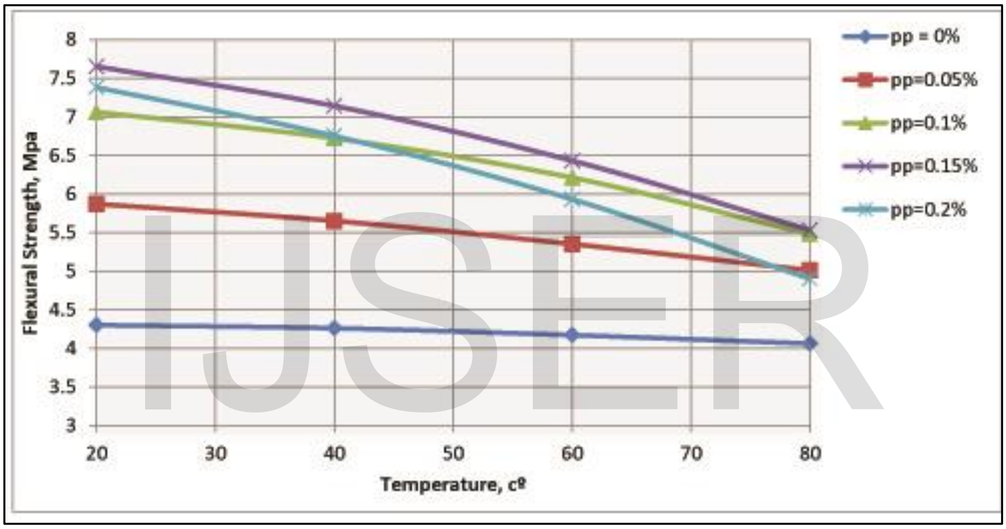

Fig.(9) Flexural Strength of PSCC Mixes

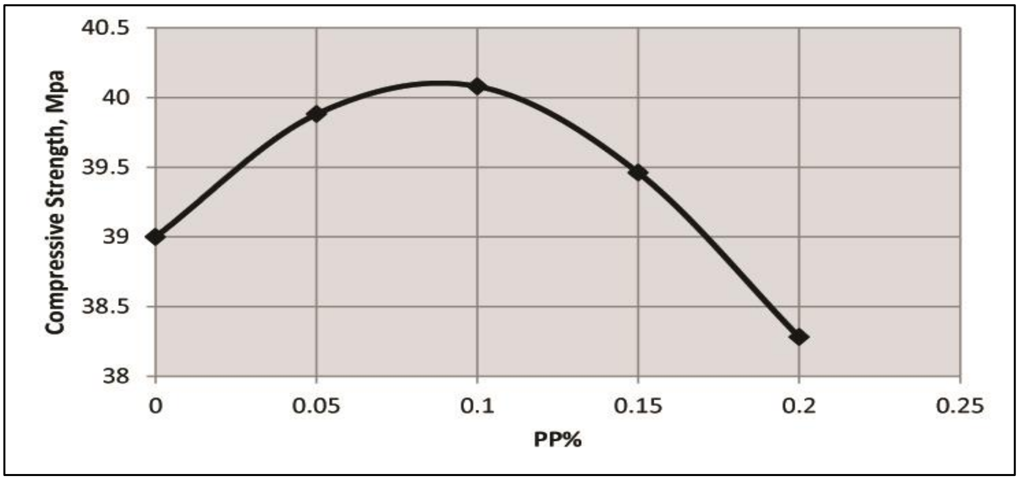

Fig.(10) Compressive Strength of PSCC Mixes Showing that Max. Comp. Strength Occurred at PP= 0.1% at 80C^o

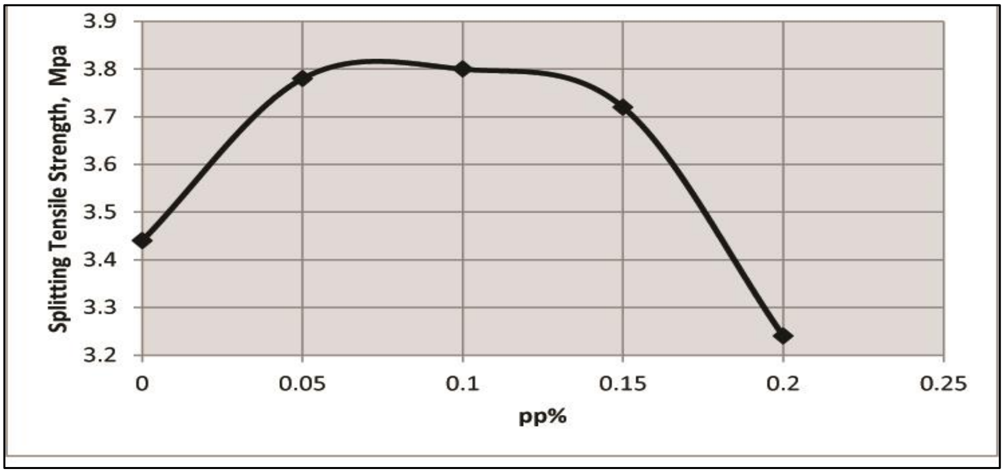

Fig.(11) Splitting Tensile Strength of PSCC Mixes Showing that
Max. Comp. Strength Occurred at PP= 0.1% at 80C^{o}

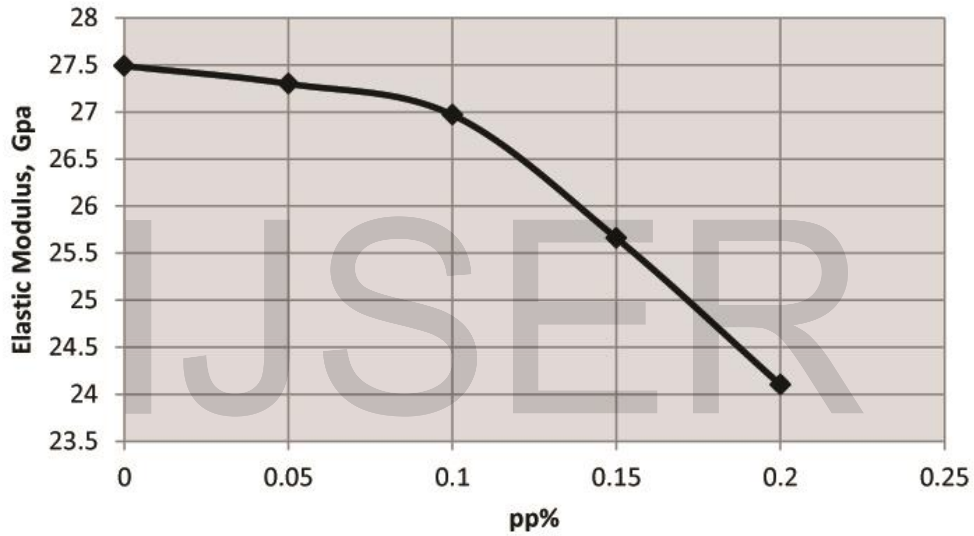

Fig.(12) Modulus of Elasticity of PSCC Mixes at 80C^{o}

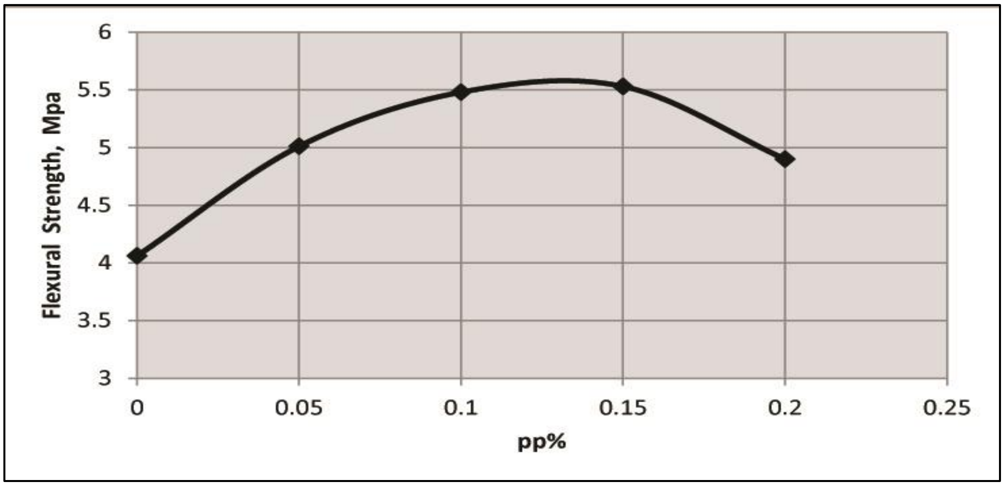

Fig.(13) Flexural Strength of PP SCC Mixes Showing that
Max. Flexural Strength approximately Occurred at PP= 0.1% at 80C^{o}