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STRENGTH CHARACTERSTICS OF SELF COMPACTING CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT BY MINERAL ADMIXTURES USING POLYPROPYLENE FIBERS

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Abstract - *This paper focuses on the experimental investigation of strength parameters such as Compressive strength, Split tensile strength and Flexural strength of M40 grade concrete for 7 and 28 days curing period using mineral admixtures and Polypropylene Fibres. Moreover, Utilization of mineral admixtures in SCC not only reduces cost but also reduces the heat of hydration. Optimum dosage of super plasticizer is added to ensure workability of SCC. Various workability tests (Slump Flow, V-Funnel, U-box and L-box) were performed as specified in EFNARC Guidelines. The mix design was carried out according to Nan Su method. In this study Cement was partially replaced by Ground Granulated Blast furnace slag (GGBS) 10% and 15%, Fly ash 10%, 15% and 20% and Alccofine 10% in one mix at a time in different proportions along with Polypropylene.*

***Key Words*: Self Compacting Concrete, Strength Properties, Mineral Admixtures, Polypropylene, Microstructure of concrete.**

1. INTRODUCTION

Self-compacting concrete is the one which can flow on its own weight without any vibration. Self-compacting concrete was initially introduced by japan in 1990's due to lack of skilled workmen. It doesn't need any vibration at the time of placing of concrete. Due to its workability properties, SCC can be used even in the dense reinforcements. In modern scenario, the use of high strength concrete is rapidly increasing because of its higher strength and better workability properties than conventional concrete for the same grade of concrete. Many research and development programs are undertaken to improve its strength and durability properties by replacing constituents of concrete by many other alternative materials like Industrial waste, Agro industrial waste and various types of mineral admixtures.One of main difference between conventional concrete and SCC is use of superplasticizers and in SCC cement and fine aggregate quantity will be more when compared to normal concrete. Polypropylene fibres were added to concrete in order to increase the strength characteristics like compressive strength, split tensile strength and flexural strength slightly. Mineral admixtures like Ground granulated blast furnace slag (GGBS), Fly Ash and Alccofine are added so that concrete can be economical.

2. OBJECTIVE

The main objective of this research work is to find the strength characteristics such as Compressive strength, split tensile strength and flexural strength of self compacting concrete with and without polypropylene fibers separately for different mixes where cement is partially replaced by various mineral admixtures and to study microstructure using Scanning Electron Microscope of those mixes.

3. MATERIALS

All the materials used for the project like cement, fine aggregate, coarse aggregate, water, GGBS, fly ash, alccofine, superplasticizer are tested for basic material test.
Cement: OPC 53 Grade
Fine Aggregates: River sand
Coarse Aggregates: 12.5 mm size
Mineral Admixtures: Ground Granulated Blast Furnace Slag (GGBS), Class F Fly Ash and Alccofine 1203
Superplasticizer: MasterGlenium SKY 8630
Polypropylene Fibres of effective diameter 25 – 40 microns

3.1 Workability Properties of concrete

Self Compacting Concrete should satisfy certain fresh concrete properties like Filling ability, Passing ability and segregation resistance. there are various test to test those properties namely slump flow test, V funnel test, U box test, J ring test, Orimet, L box and fill box test. Superplasticizer dosage is kept as 1% in concrete without polypropylene where as in concrete with polypropylene superplasticizers dosage is increased to 1.5% to meet the requirements of EFNARC guidelines.

Table -1: Workability property of concrete without polypropylene fibres

Property	Mix 1	Mix 2	Mix 3	Mix 4	EFNARC
Slump Flow [mm]	722	685	693	709	650-800
V Funnel test [sec]	8	11	10	9	6-12
U Box Test [mm]	15	11	12	13	0-30
L Box Test	0.82	0.94	0.91	0.84	0.8-1

Table -2: Workability property of concrete with polypropylene fibres

Property	Mix 1	Mix 2	Mix 3	Mix 4	EFNARC
Slump Flow [mm]	683	665	654	671	650-800
V Funnel test [sec]	10	13	12	11	6-12
U Box Test [mm]	19	14	16	17	0-30
L Box Test	0.90	0.97	0.94	0.91	0.8-1

4. Experimental Program

In this research work mix design was carried according to Nan Su method. M40 grade of concrete was opted for this study. Here cement is partially replaced by mineral admixtures such as GGBS, Fly Ash and Alccofine. 48 cubes, 48 cylinders and 48 prisms were casted to determine compressive strength, split tensile strength and flexural strength respectively curing period is taken as 7 days and 28 days. Usage of mineral admixtures reduces environmental pollution. Class F fly ash has only pozzolonic properties. GGBS reduces heat of hydration and decrease the water content required. Along with improving strength chaecterstics it also reduces tendency of cracking and shrinkage is also reduced. Samples of each mix were taken for SEM analysis.

4.1 Mixes

Mixes without polypropylene fibres
Mix 1: 100% Cement
Mix 2: 70% Cement + 15% GGBS + 15% Fly Ash
Mix 3: 70% Cement + 20% Fly Ash + 10% Alccofine
Mix 4: 70% Cement + 10% GGBS + 10% Fly Ash + 10% Alccofine
Mixes with polypropylene fibres
Mix 1: 100% Cement + polypropylene
Mix 2: 70% Cement + 15% GGBS + 15% Fly Ash + polypropylene
Mix 3: 70% Cement + 20% Fly Ash + 10% Alccofine + polypropylene
Mix 4: 70% Cement + 10% GGBS + 10% Fly Ash + 10% Alccofine + polypropylene

4.2 Mix Design

Design Requirements

- Packing factor (PF) (coarse aggregates) = 1.1
- Packing factor (PF) (fine aggregates) =1.1
- Water cement Ratio =0.40
- Specific gravity of cement =3.15
- Specific gravity of Coarse Aggregates =2.65
- Specific gravity of Fine Aggregates =2.63
- Bulk Density of Coarse Aggregates (W_{fal}) =1347 kg/m^3
- Bulk Density of Fine Aggregates (W_{cal}) =1456 kg/m^3
- Ratio of fine aggregate to total mass aggregate (s/a) = 0.54

Step 1: Calculation of Fine aggregate & Coarse aggregate

$W_{fa} = PF \times W_{fal} \times (s/a)$
$W_{fa} = 1.10 \times 1456 \times 0.54$
$W_{fa} = 865.327$ kg/m^3
$W_{ca} = PF \times W_{cal} \times (1-s/a)$
$W_{ca} = 1.1 \times 1347 \times (1-0.54)$
$W_{ca} = 681.379$ kg/m^3

Step 2: Calculation of Cement content

$C = c \times (f'c/20)$
$C = 1.38\ (40/0.14)$
$C = 394.28$ kg/m^3
c – Correction factor (1.38 for M40 grade concrete)

Step 3: Calculation of Mixing Water

$W_{wc} = (w/c) \times C$
$W_{wc} = 0.40 \times 394.28$
$W_{wc} = 157.71$ kg/m^3

Step 4: Calculation of filler materials

$$V_{pf} = 1 - \left(\frac{C}{1000 \times Gc}\right) - \left(\frac{Wfa}{1000 \times Gfa}\right) - \left(\frac{Wca}{1000 \times Gca}\right) - \left(\frac{Wwc}{1000 \times Gwc}\right) - V_a$$

$$V_{pf} = 1 - \left(\frac{394.28}{1000 \times 3.15}\right) - \left(\frac{865.327}{1000 \times 2.63}\right) - \left(\frac{681.379}{1000 \times 2.65}\right) - \left(\frac{157.71}{1000 \times 1}\right) - (1/100)$$

$V_{pf} = 1 - 0.125 - 0.329 - 0.257 - 0.155 - 0.01$
$V_{pf} = 0.1209$

Amount of filler required

$$W_f = \frac{Vpf \times 1000 \times Gf}{1 + (\frac{W}{p}) \times Gf}$$

$$W_f = \frac{0.1209 \times 1000 \times 3.15}{1 + 0.4 \times 3.15}$$

$W_f = 168.607$ kg/m^3

Total cement content = $W_{f+}C$
= 168.607 + 394.28
= 562.893 kg/m³

Step 5: Calculation of water needed for SCC

$$W_w = \left(1+\frac{wf}{p}\right)\left(\frac{w}{c}\right)C + \left(\frac{w}{f}\right)Wf$$

$$W_w = \left(1+\frac{168.607}{562.893}\right)(0.40)394.28 + (0.40)168.607$$

W_w= 67.962 kg/m³
Total water content W = $W_{wc} + W_w$
= 157.71 + 67.962
= 225.677 kg/m³

Mix Proportion

Cement – 562.893 kg/m³
Fine Aggregates – 865.327 kg/m³
Coarse Aggregates – 681.379 kg/m³
Water – 225.677 kg/m³
Superplasticizer (1%) – 5.62lit/m³
Superplasticizer (1.5%)– 8.44lit/m³
Polypropylene (0.25%) – 1.40 kg/m³

5. RESULTS

5.1 Compressive Strength

Compressive strength of the specimen is found out by testing cubes of size 150mm×150mm×150mm.

Table 3: Compressive Strength

Mixes	Without Polypropylene		With Polypropylene	
Age	7 days [MPa]	28 days [MPa]	7 days [MPa]	28 days [MPa]
Mix 1	42.48	51.72	46.70	55.53
Mix 2	30.30	42.11	32.31	46.82
Mix 3	36.45	46.70	38.22	50.55
Mix 4	29.66	40.03	35.45	47.74

Graph 2: 28 days compressive strength

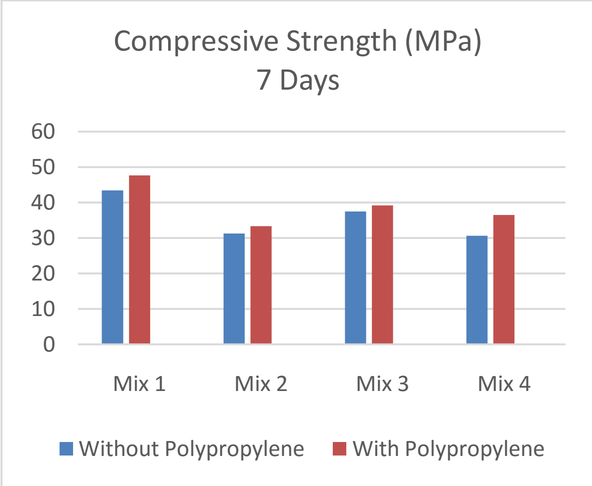

Chart -1: 7 days compressive strength

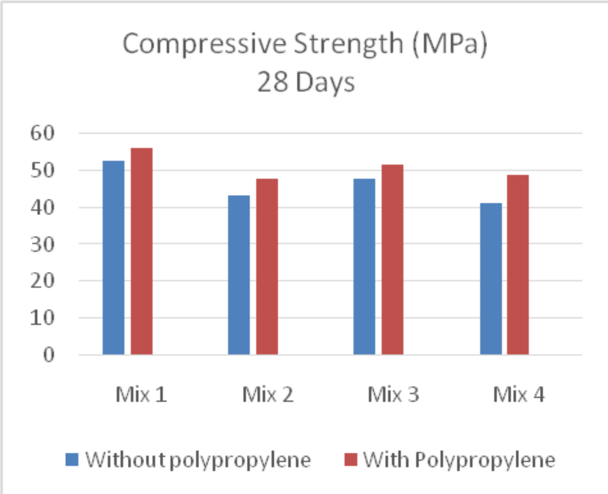

Chart -2: 28 days compressive strength

5.2 Split Tensile Strength

Tensile strength of the specimen is found out by testing cylinder of diameter 150mm and length 300mm.

Table 4: Split tensile Strength

Mixes	Without Polypropylene		With Polypropylene	
Age	7 days [MPa]	28 days [MPa]	7 days [MPa]	28 days [MPa]
Mix 1	2.67	3.18	2.92	3.40
Mix 2	2.46	2.94	2.54	3.02
Mix 3	2.17	3.58	3.29	3.62
Mix 4	2.11	2.93	2.83	3.01

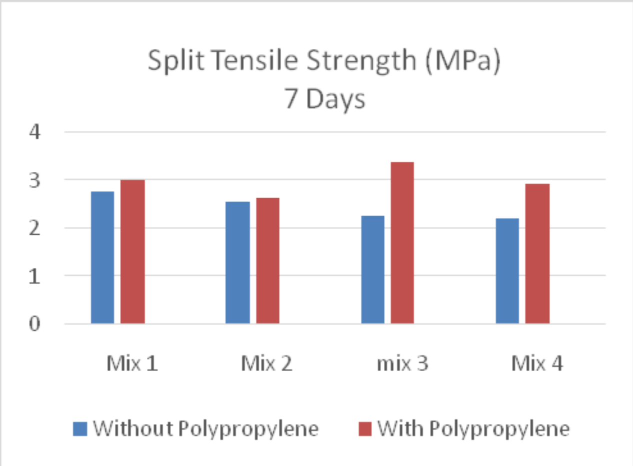

Chart -3: 7 days Tensile strength

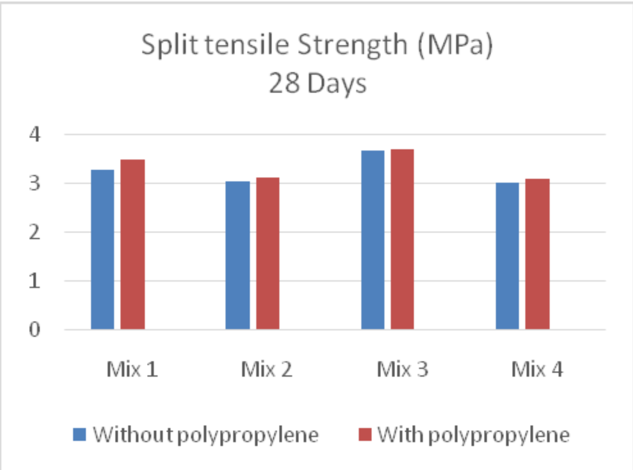

Chart -4: 28 days Tensile strength

5.3 Flexural Strength

Flexural strength of the specimen is found out by testing prism of size 100mm × 500mm × 500mm.

Table 5: Flexural Strength

Mixes	Without Polypropylene		With Polypropylene	
Age	7 days [MPa]	28 days [MPa]	7 days [MPa]	28 days [MPa]
Mix 1	8	10.5	8.5	11.25
Mix 2	5	7.5	6	8.25
Mix 3	6	9.25	7.25	10.5
Mix 4	5.5	7.25	6.5	8.5

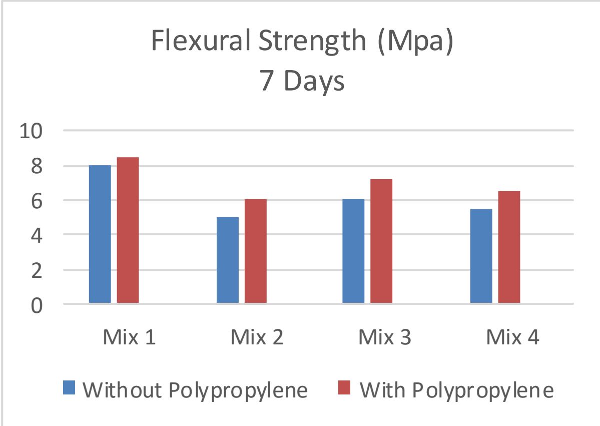

Chart -5: 7 days Flexural strength

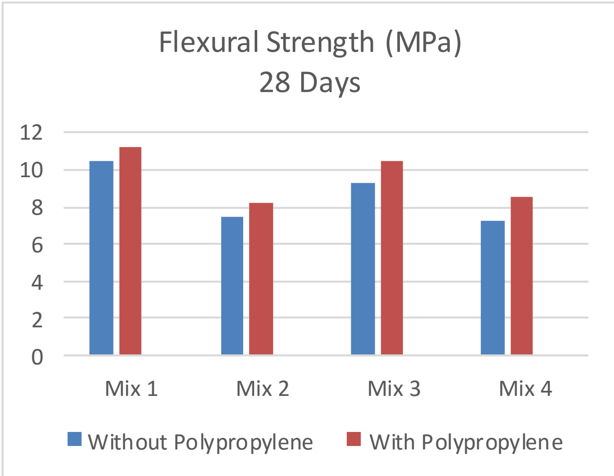

Chart -6: 28 days Flexural strength

5.4 Microstructure (SEM)

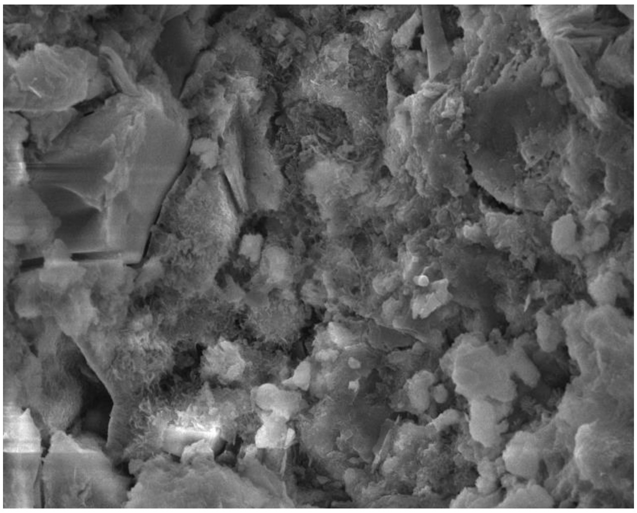

Fig -1: Mix 3 (28 Days without Polypropylene)

In SEM of mix 3 (28 days without polypropylene) we can see the formation of CSH gel and we can come across round shape bubble which indicates Fly Ashand micro cracks is also present in it.

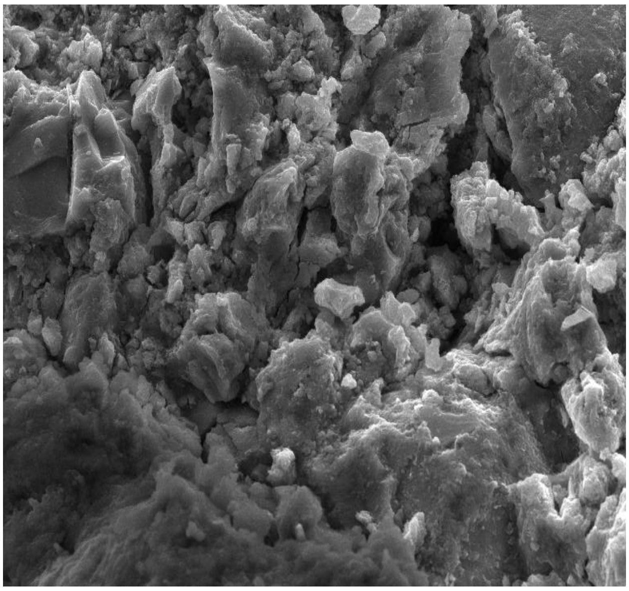

Fig -2: Mix 4 (28 Days without Polypropylene)

In SEM of mix 4 (28 days) a bar like structure is identified as calcium hydroxide along with bubble like structure is identified as fly ash. CSH gel is also formed in this mix.

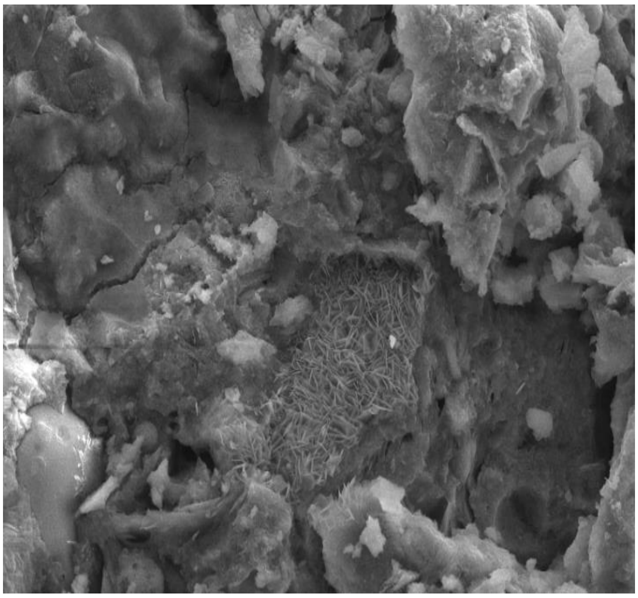

Fig -3: Mix 3 (28 Days with Polypropylene)

In SEM of mix 3 (28 days with polypropylene) some ettringite particles are seen and bar like structure is seen which is calcium hydroxide and we can identify micro cracks and fly ash in this mix

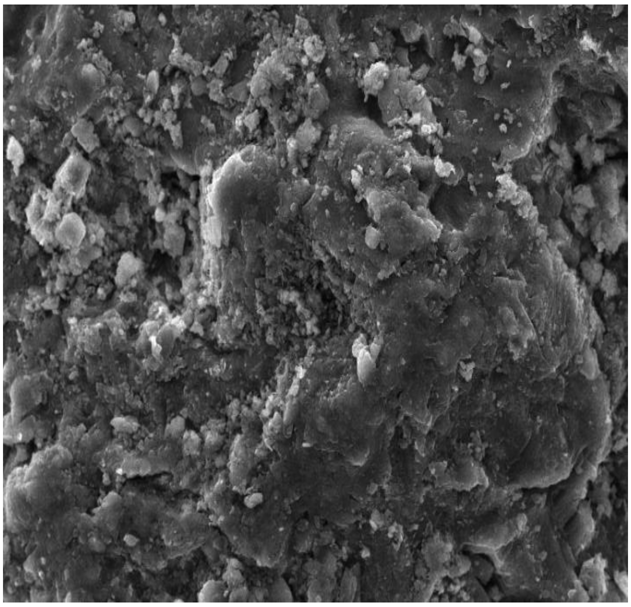

Fig -4: Mix 4 (28 Days with Polypropylene)

In SEM of mix 4 (28 days with polypropylene) bubble like structure is seen which is fly ash and we can see some bright spots which indicates unhydrated cement paste. At some places flower like structure is present which is CSH gel.

6. CONCLUSIONS

- All the Mixes in this paper satisfy the requirements quoted by EFNARC guidelines.
- Nan Su method can be used for designing Self compacting concrete
- Usually Self compacting concrete costs more than conventional concrete but by using mineral admixtures cost can be reduced considerably.
- As we see mix 4 gives almost same strength as mix 1 in all strength aspects like compressive strength, split tensile strength and flexural strength.
- In present study mix 1 gives better strength when compared to other mix in all strength aspects.
- Workability of concrete can be altered by varying the dosage of Superplasticizer.
- By adding polypropylene the concrete workability is decreased but with proper dosage of superplasticizers the strength of concrete with polypropylene fibres can be increased.
- Extent of cracking is relatively less when polypropylene is added to concrete.
- Incorporation of mineral admixtures in concrete is acceptable as it is providing considerably good strength.
- By using mineral admixtures environmental pollution can be reduced and cost of construction is reduced.

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