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The Effect of Polypropylene Fibers on Slump Flow of Fresh Self-Compacting Lightweight Concrete

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Abstract: **This paper investigates the effect of polypropylene fibers on slump flow of self-compacting lightweight concrete. The water/binder ratio that was used in concrete mixes was set to 0.4. four mixes with different proportions of Polypropylene fibers were prepared and adjusted by inserting micro-silica and fly ash as supplementary cementitious materials. The percentages of micro-silica and fly ash were fixed to have the values of 5% and 20%, respectively. The replacement ratios of Polypropylene Fibers were from 0% up to 0.4%. The graduation, specific gravity, water absorption, and fineness modulus have been testified for two types of local fine aggregates, in addition to, the graduation, specific gravity, water absorption, particle shape, and surface texture of lightweight scoria coarse aggregate. the relationships between the proportions of fibers and slump flow of fresh concrete have been identified as well.**

Keywords: **Lightweight Concrete (LWC), Self-compacted Concrete (SCC), Self-Compacted Lightweight Concrete (SCLC), Micro Silica (MS), Fly ASH (FA), Polypropylene Fibers (PF), Scoria Coarse Aggregate.**

I. INTRODUCTION

Fibered Self-Compacting Lightweight Concrete is becoming more and more popular due to its Construction advantages and ease of use. Developing fibered- self compacting lightweight concrete requires studying the mechanical properties of fresh and hardened concrete. Mazaheripour et al. [1] studied the propertied of fresh SCLC and reported in their research the adverse relationship between inserting FB and slump flow or flowability of concrete. Mazaheripour et all Applied 0.3% volume fractions of polypropylene fiber to the SCLC and resulted in 40% reduction in the slump flow (from 720 mm to 430 mm). Ozel et al. [2] mentioned that Polypropylene fibers did not influence the compressive strength and elastic modulus of SCLC, however applying these fibers at their maximum percentage volume increased the tensile strength and the flexural strength. Dalvand and . Mastali. [3] have studied Fresh and Hardened Properties of SCC Reinforced with Hybrid Recycled Steel and Polypropylene Fiber and resulted

increasing the content of PP fiber reduces the effect of recycled steel fiber in improvement of flexural strength. Akhazhanov et al. [4] have investigated the effect of low-modulus of FB on physical and mechanical properties of SCC and mentioned that shrinkage deformations reduced to 75% compared to the concrete without fiber and stated that the disperse reinforcement with low-modulus FB increases the characteristics of SCC in production. Gokulnath et al. [5] have proofed in their research the enhancement of flexural strength of SCC which contained PF with a fiber length of 6–12 mm breadth of 14 µm and an angle proportion of 0.3, 0.6, 0.9, and 1.2.

Cifuentes et al. [6] concluded that addition of fibers to the concrete (SSC) will affect positively on both compressive and tensile strengths at different proportions and At 0.75% addition of FB the maximum compressive strength of 40.8 N/mm2 were attained. The main objective of this study is to identify The Effect of Polypropylene Fibers on Slump Flow of Fresh Self-Compacting Lightweight Concrete and studying the relationship between FB and flowability of SCLC.

II. USED MATERIALS

The materials used in experimental investigation include:

2.1. Cement

The cement that has been used in this study was Type I normal Portland cement from Yanbu cement company and had a specific gravity of 3.17 g/cm^3. The specific surface of Yanbu cement was 3450 cm^2/g and its initial and final setting times were 2.35 h and 3.01h, respectively. The cement properties conform to ASTM C 150 for type 1 cement and its chemical compositions are given in table 1.

Table I: Chemical Composition of Cement, Fly Ash and Micro Silica (%)

Oxide composition	Cement (C)	Fly ash (FA)	Micro silica (MS)
SiO_2	20.20	60.420	89.2
LOI	1.80	0.43	3.260
CaO	63.42	0.181	0.057
Fe_2O_3	3.58	5.710	3.09
SO_3	2.91	0.364	0.461
MgO	2.45	0.798	0.663
K_2O	-	1.457	1.12
Na_2O	-	0.832	0.464
Al_2O_3	4.67	25.086	0.610

2.2. Fly Ash

The fly ash that has been used was type F and its source from India. The specific gravity of fly ash was 2.25 and its surface area was 3100 cm^2/g. SiO2 and SO3 content of the current fly ash are 60.42% and 0.364%, respectively. ASTM C-618 [5] requires that minimum SiO2 and maximum SO3 content of fly ash to be 40% and 3%, respectively. The chemical analysis that of fly ash is shown in table 1 and complies with the chemical requirements of ASTM C618 for fly ash.

2.3. Micro Silica

The utilized micro silica was from India as well. The specific gravity of micro silica was 2.43 and its surface area was 16*10^4 cm^2/g. the chemical composition of micro silica is illustrated in table 1 which complies with the chemical requirements of ASTM C1240 for silica fume.

2.4. Polypropylene Fibers

High performance micro–polypropylene fibers has been used in this study and their source was from Forsroc company. The main goals for inserting micro polypropylene fibers into mix were not only controlling the cracks resulted from plastic and autogenous shrinkage or increasing the tensile strength of the mix, however, the most important goal was to increase the cohesiveness and homogeneity of the mix. Banthia ,and Gupta [6] have proved in their research that the effectiveness of polypropylene fibers depends upon their lengths and diameters. The relation between the length and effectiveness is directly proportional where the relation of fibers diameter and their effectiveness is inversely proportional. The length of the fiber was chosen to be 12 mm to be suitable with the nominal maximum aggregate size. The properties of PF such as: specific gravity, alkali content, sulphate content, air entrainment, and many other properties are provided in table 2.

Table II: Properties of Polypropylene Fibers

Specific Gravity	0.91 g/cm^3
Alkali Content	Nil
Sulphate Content	Nil
Air Entrainment	Air Content of Concrete Will Not Be Significantly Increased
Chloride Content	Nil
Constituents	Virgin Polypropylene C3H6
Fiber Thickness	18 Micron
Min. Specific Surface Area	220 M^2/kg
Storage Life	Minimum 12 months from date of manufacture
Youngs Modulus	5500-7000 Mpa
Tensile Strength	350 Mpa
Melting Point	160 °C
Fiber Length	12 mm
Aggregate Size, Max	32 mm
Dosage	0.6/0.91 kg/m^3

2.5. Retarding Admixture

Since SCLC need to be mixed, transported, handled, and finished before the initial set, a great demand for using retarding admixtures to delay its initial set of and provide adequate time for dealing with it. Viscocrete RM-115 from Sika company was utilized in the mix. Sika defines its product as a polycarboxylate based superplasticizer developed particularly for use in ready mixed concrete to give extended slump retention and high strength development of high specification grade concrete mixes. It is suitable for use in concrete mixes incorporating pozzolanic materials such as GGBS, PFA, MS, and appropriate for the use in hot climatic conditions. The composition of RM-115, density, chloride ion content, and recommended dose from sika company are shown in table 3.

Table III: Properties of Retarding Admixture

Composition	Aqueous Solution of Modified Polycarboxylates, Co-Polymers
Density	~1.09 Kg/ L (+25 °C)
Chloride Ion Content	Nil
Recommended Dosage	0.7-1.5 % By Weight of Binder

2.6. Water-Reducing Agent

Superplasticizers help us increasing the powder content at a given water quantity without compromising the workability of the mix. Minimizing the water content in mixes will result by improving the mechanical properties of concrete such as its compressive, and tensile strength. Plastiment RP-150 from SIKA company has been used in mixes as a water reducer. According to SIKA PR-150 is a highly effective water reducing agent with controlled retardation over a wide dosage range and suitable for use in tropical and hot climatic conditions. The composition of RP-150, density, chloride ion content, and recommended dose from sika company are shown in table 4.

Table IV: Properties of Water-Reducing Agent

Composition	Modified Lignosulphonate
Density	~1.135 kg/L (+25 °C)
Chloride Ion Content	Nil
Recommended Dosage	0.3-0.8 % By Weight of Binder

2.7. Fine Aggregate

Two types of fine aggregate have been proportioned and used in the mixes. The first one is called dune sand and its source from Al-bowatt which is a village on the outskirts of Al-Medina in the Kingdom of Saudi Arabia and located 40 km northwest of Medina. The second one is called Crash sand. The utilized fine aggregates in the mixes have been proportioned as 45% of dune sand and 55% of crash sand. The main parameters that were controlling the proportioning processes were slum-flow and cohesiveness. ASTM C128 have been conducted on dune sand the results are shown in table 5 and the results of sieve analysis ASTM C136 of 45% of dune sand and 55% of crash sand are shown in table 6 as well.

Table V: Specific Gravity of Dune Sand:

	Natural Washed Sand	Dune Sand (Al-Bader Sand)
Weight of S.S.D. Sample in Air (g)	500.7	500.2
Weight of Oven Dry Sample in Air (g)	490.1	496.4
Weight of Pycnometer Filled with Water (g)	1173.8	1174.6
Weight of Pycnometer Filled with Water + Sample (g)	1481.2	1484.2
Absorption (%)	2.16%	0.77%
Sp. Gr. (Oven Dry)	2.535	2.604
Bulk Sp. Gr. S.S.D.	2.590	2.624
Apparent	2.683	2.657

Table V1: The Gradation of 45% of Crash Sand (05mm) and 55% of Dune Sand (Al-Bader Sand).

Sieve size	Wet, Retain	Retain %	Passing %	Limits
No. 4	34.0	5.2	94.8	95~100
No. 8	110	16.9	83.1	80~100
No. 16	221.0	34.0	66.0	50~85
No. 30	322.0	49.5	50.5	25~60
No. 50	534.0	82.2	17.8	10~30
No. 100	633.0	97.4	2.6	2~10
No. 200	648.9	99.8	0.2	0~5

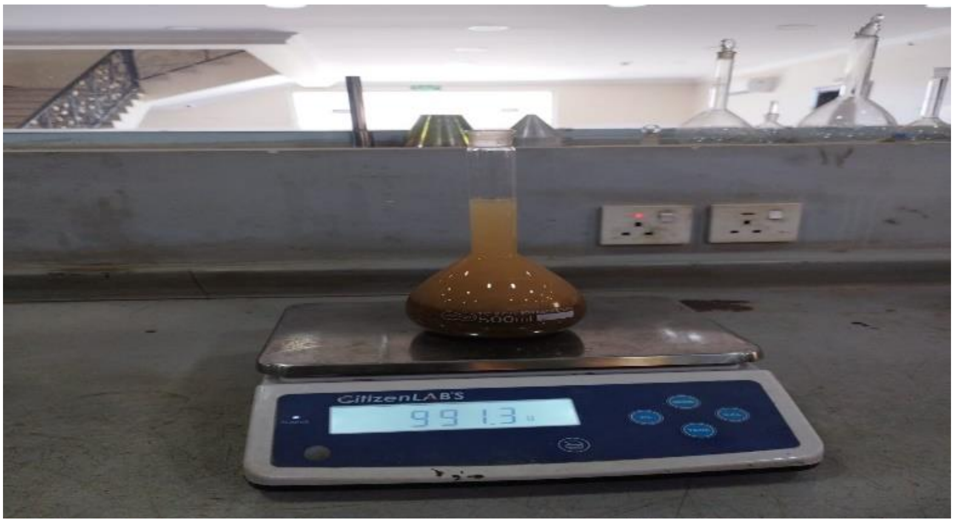

Fig. 1: Specific Gravity of Dune Sand.

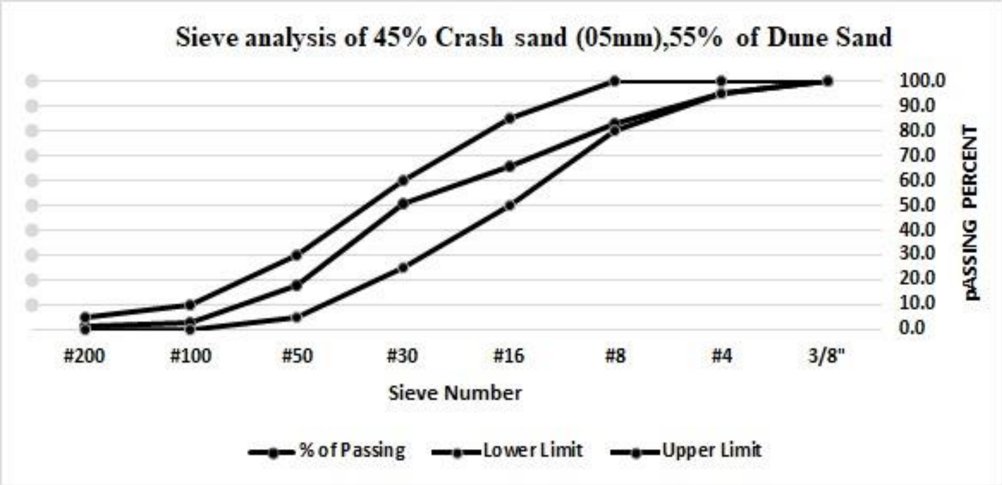

Fig. 2: Sieve Analysis of 45%Crash sand (05mm) and 55% of dune sand.

2.8. Scoria Coarse Aggregate

Crushed basaltic pumice (scoria) has been used as lightweight aggregates due to its high porosity and low density for producing self-compacted lightweight concrete. The source of scoria was locally from Al- Medina Al- Munawara and two sizes of aggregate have been used 1/2 and 3/8 inch, respectively. Teymen et al. [7] showed in their research that the size (nominal maximum aggregate size) of scoria coarse aggregate has an important impact on the mechanical properties of lightweight concrete. scoria has angular shape, and its surface texture is rough and that will produce a strong relation between the mortar phase and aggregate, hence, improving the mechanical properties of the mix. the density of 3/8-inch scoria was 1730 kg/m^3 where the density of 1/2 inch scoria was 1690 kg/m^3 because of its higher void ratio as a nominal aggregate size have increased. the gradation of both sizes of scoria aggregate have been tested and is shown in fig.4, and 5

Table VII: ASTM C127 For All Types of Coarse Aggregate.

	Bulk Dry Sp. Gr (g)	Bulk SSD Sp. Gr (g)	Apparent Sp. Gr (g)	Absorption (%)
Scoria 3/8 Inches	1.61	1.84	2.09	12.50
Scoria 1/2 Inches	1.59	1.85	2.14	14.05

Fig. 3: Specific Gravity of Scoria Coarse aggregate.

Table VIII: The Gradation of Scoria Coarse Aggregate

Sieve size	Wet, Retain	Retain %	Passing %
3/4 in	0	0	100
1/2 in	0	0	100
3/8 in	39.42	5.77	92.22
No. 4	682.14	100	0

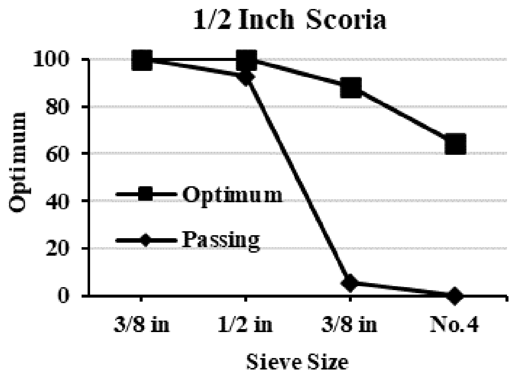

Fig. 4: Sieve Analysis of 1/2 Inch Scoria

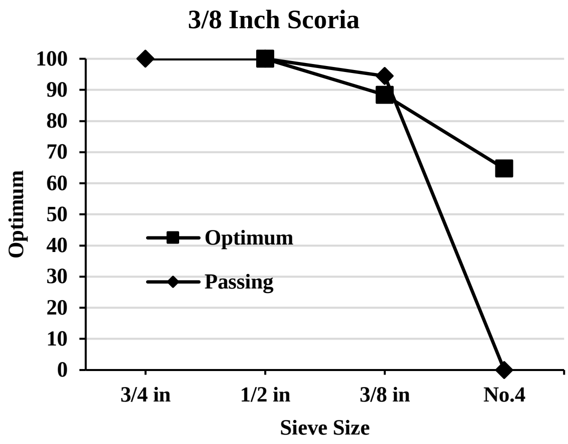

Fig. 5: Sieve Analysis of 3/8 Inch Scoria

2.9 Mixing Water

Fresh portable water which is free from concentration of acid and organic substances was used for mixing the concrete and curing. And TDS test has been conducted on mixing water and its result is illustrated if fig6.

Fig.6: the result of TDS test of mixing water.

III. MIXTURE PROPORTIONS AND SPECIMEN PREPARATION

Four mixes have been prepared and mixed labeled as M1, M2, M3, M4. with fixed proportion of all mixing materials except polypropylene fibers. A gradual replacement of fibers through four stages have been modified as the following: firstly, M1 had no replacement of FB and the main reason for that is to identify the value of slump flow of fresh SCLC before adding FB. Secondly, the replacement of FB in M2, M3, M4 were (0.2%,0.3%,0.4% respectively) from the cement content to be compatible with the weight of FB (0.8 kg/m^3,1.2kg/m^3,1.6kg/m^3). lastly, table 9 shows the properties and mix proportions of all mixes which have been used in the experiment.

Table IX: The Proportions of Mixes

Mix ID	M1	M2	M3	M4
w/b	0.4	0.4	0.4	0.4
Water(kg/m^3)	160	160	160	160
Binder(kg/m^3)	400	400	400	400
PC (kg/m^3)	291.74	290.94	290.54	290.14
FA (kg/m^3)	80	80	80	90

MS (kg/m^3)	20	20	20	22.5
Total sand(kg/m^3)	865	865	865	865
Dune sand(kg/m^3)	389.25	389.25	389.25	389.25
Crash sand (kg/m^3)	475.75	475.75	475.75	475.75
Total coarse aggregate	513	513	513	513
3/8 in Scoria	205.2	205.2	205.2	205.2
NO.4 Scoria	307.8	307.8	307.8	307.8
Rb-150(kg/m^3)	5.866	5.866	5.866	5.866
RM-115(kg-m^3)	2.4	2.4	2.4	2.4
Polypropylene %	0	0.2	0.3	0.4
Density of Designed fresh concrete (kg/m^3)	1938	1938	1938	1938
Density of air-dry concrete	1867.91	1866.82	1865.23	1868.4

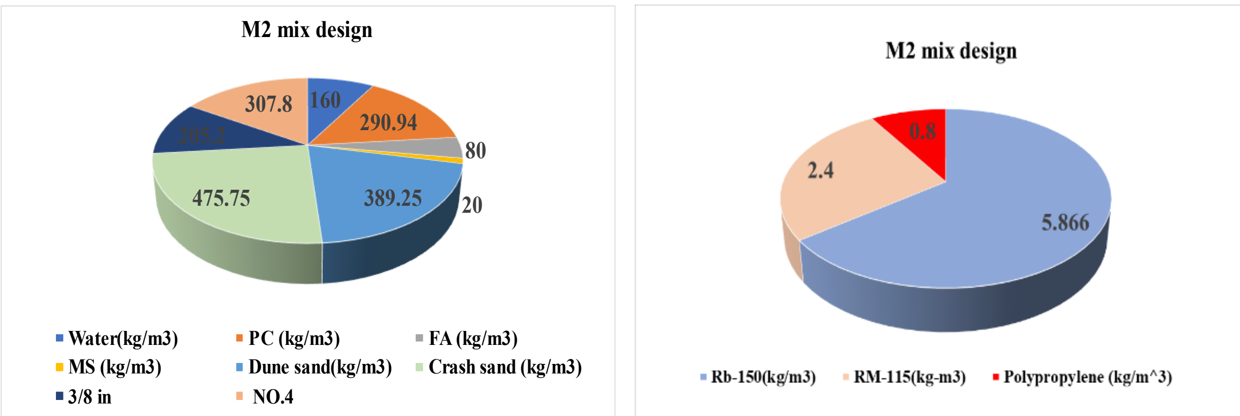

Fig.7: the mix proportions of M2 expressed in kg/m^3

IV. RESULT

There is an adverse relationship between the flowability and inserting the FB in the mixes of SCLC. It can be easily noted that the use of FB should be limited and there is a specific weight of replacement can not pass because it will result in losing the workability of concrete and not achieving self- compaction. Fig 8. Illustrates the relation between the values of slum flow test and the percentages of polypropylene fibers as a replacement of cement content in all mixes.

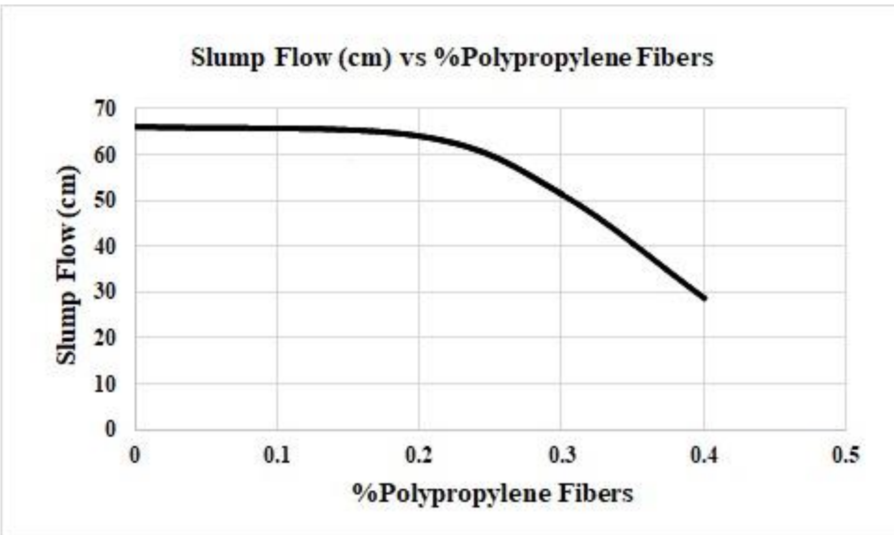

Fig.8: % of polypropylene fibers VS Slump flow

Fig.9: loss of flowability in M4 After 0.4% replacement of FB

V. CONCLUSION

This study investigated the influence of polypropylene fibers on slump flow of fresh Self-Compacting Lightweight Concrete. The following conclusion can be drawn based on these experimental results:

- Experimental observations showed that the minimum value of fineness modulus for achieving self-compaction of concrete (slump flow greater than 650 mm) is 2.95.
- Polypropylene fibers control plastic and autogenous shrinkage and increase the cohesiveness and homogeneity of the mix.
- The slum flow of M1 have the greatest value which is 662.4mm at 0% of polypropylene fibers of replacement, hence, the workability of M2 decrease till reach 641.7mm at 0.2% of PF replacement.
- Slump flow continue decreasing to achieve 515mm in M3 at 0.3% of PF replacement and 22.25% reduction of workability compared with M1.
- The largest loss of workability was observed experimentally in M4 at 0.4% of PF replacement to be recorded as 288 mm and 65.57% of reduction from M1.
- There is an inverse relationship between PF and slum flow of SCLC and at certain percentage of PF replacement if we go beyond it, we will not be able to achieve self-compaction of SCLC.

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