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Effect of Using Natural and Polypropylene Fibers on Fresh and Hardened Concrete Properties

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Abstract:
*Concrete plays an important role as a construction material in most of infrastructure projects because of its low cost and ease of manufacture. Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. This study investigated effectof using natural and polypropylene fibers on Properties of fresh and hardened concrete. The first goal is using natural fiberssuch as date palm fibers (**DPF**), flax fibers (**FF**) and date palm spikelet fibers (**DPSF**).This study was conducted to investigate the use of different percentages of **DPF (0.25, 0.5 & 0.75%)**, percentages of **FF (0.15, 0.3 & 0.45%)** and percentages of **DPSF (0.5, 1.0 & 1.5%)** as a volume fraction. The second goal is using hybrid fibers by adding constant amount of polypropylene fibers (**PF**) to **DPF**, **FF** and **DPSF** mixes (**DPFP, FFP and DPSFP**). Proportions of mixes determined using **ACI 318-2019** recommendations. Beams have a dimension of 100*100*500 mm were chosen to study flexural strength of concrete. The tested samples were curing in pure water.The concrete beams were tested at the curing ages of 28 days. Slump and compacting factor tests were carried out to check the effect of using natural fibers and polypropylene fibers on consistency and workability of concrete. From results, it was observed that the slump and compacting factor decreased with increasing proportion of **DPF**, **FF** and **DPSF**.With increasing proportionof **DPF**, flexural strength increases. Optimum proportion of **DPF** is **0.75%**. With adding **DPF** with **PF** to concrete, flexural strength decreases than using **PF** only in concrete. Optimum proportion of **FF** and **FFP** is **0.3%**. With increasing proportionof **DPSF**, flexural strength decreases. Optimum proportion of **DPSF** and **DPSFP** is **0.5%**. With adding **PF** to **FF** and **DPSF** mixes, flexural strength increases than using **FF** and **DPSF** only in mixes.*

***Key Word:** Concrete,Date Palm Fibers (**DPF**), Flax Fibers (**FF**), Date Palm Spikelet Fibers (**DPSF**), polypropylene fibers (**PF**), Slump, Compacting Factor, Flexural Strength.*

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I. Introduction

Concrete and mortars made with Portland cement are known to be easy to form and relatively strong in compression but weak in tension, tend to be brittle and have poor impact strength and toughness .The weakness in tension could be overcome by the use of conventional rod reinforcement and to some extent by the inclusion of a sufficient volume of certain fibers **[1-2]**.Natural fibers were used in some applications in the construction field early in the 19th century. Later, interest goes toward synthetic fibers because of their superior properties. However, due to scarcity in raw material and energy consumption, the attention is drawn again towards natural and renewable resources like vegetable fibers. Nowadays, Natural Fiber Reinforced Concrete **(NFRC)** is one of the main research topics in structural engineering applications **[3]**. The primary advantage of using fibers in the concrete mix is represented by the significant improvement in concrete properties and its relative low cost **[4-5]**. Out of the commonly used and easily available low cost natural fibers are renewable source materials. Applications of natural fibers are growing in many sectors such as automobiles, furniture, packing and construction. This is mainly due to their advantages compared to synthetic fibers, i.e. low cost, low weight, less damage to processing equipment, improved surface finish of moulded parts composite, good relative mechanical properties, abundant and renewable resources **[6]**.

Natural fibers are used in various applications such as building materials, particle boards, insulation boards, human food and animal feed, cosmetics, medicine and for other biopolymers and fine chemicals **[7]**. The current concern over the environment and greenhouse gas emissions, natural fibers are increasingly being considered as an environmentally friendly substitute for synthetic fibers in the reinforcement of polymer based composites **[8–9]**. Nowadays, plant fibers are the most commonly used natural fibers for polymer composites and the reinforcing these fibers with polymers is to enhance the mechanical properties of the materials **[10-11]**.Oussama Benaimeche, et al**[12]** discussed the influence of date palm mesh fiber reinforcement on flexural and fracture behavior of a cement based mortar.The **DPM** fibers are added in the cement-based mortar matrix, with a fiber content equal to 2%, 4%, 6%, 8% and 10% by volume.Interesting fracture properties are obtained for low content of **DPM** fibers (that is, 2% by volume).The addition of **DPM** fibers in mortar specimens generally improves both the post peak behavior and the ductility in comparison to plain specimens and delays the failure of the composite material.Jonathan Page, et al**[13]** published a paper proposing multi physical properties of a structural concrete incorporating short flax fibers (**FF**). The study was conducted from two points of views: improving the workability of the concrete in a fresh state and improving the flexural strength in the hardened state.Salim Abdelaziz**,**et al**[14]** investigated Date palm spikelet fibers (**DPSF**) in mortar to reveal the mechanical performance. Date palm residues capabilities in civil engineering are evaluated by combining numerical and experimental approaches.The use of chemical treatment or the decrease of the size of spikelet improves the mechanical performance of modified mortars. The chemical treatment allows interfacial stiffness nearly seven times better than formulation involving untreated spikelet.Meheddene M. Machaka, et al**[15]**studied the effect of using fan palm natural fibers on the mechanical properties and durability of concrete.The parameters are the percentage of fiber volume fraction (0, 0.5, 1.0 and 1.5%), fiber aspect ratio L/D (60 and 100), and concrete strength (30, 40 and 60MPa).The resistance to plastic shrinkage cracking increased significantly with increasing the percentage of fiber volume in concrete, and tends to eliminate this defect in concrete at 1.5% fiber. Bekir Çomak, et al **[16]** discussed effects of hemp fibers (**HF**) on characteristics of cement based mortar. In this study, hemp fiber reinforced cement mortars with different ratios (0%, 1%, 2% and 3%) and different lengths (6 mm, 12 mm and 18 mm) were manufactured. It was determined that cement mortars reinforced with 2–3% amount and 12 mm length of natural hemp fiber give the optimum results. Mohammad S. Islam and Syed Ju Ahmed **[17]**studied influence of jute fiber (**JF**) on concrete properties. Locally produced jute fibers having two different lengths of 10 mm and 20 mm and four different volumes of 0.0%, 0.25%, 0.5%, and 1.0% were added to prepare concrete cylinders and beams.The influence of jute fiber on the flexural strength mainly depended on fiber volume. The maximum and minimum increase in flexural strength obtained for 0.5% and 0.25% jute fiber, respectively, whereas a reduction in flexural strength was noted for the maximum amount (1.0%) of jute fiber.Eethar Thanon Dawood and Mahyuddin Ramli **[18]**investigated contribution of **hybrid fibers** on the properties of high strength concrete having high workability. This study was conducted to investigate the use of different percentages of **steel fiber** (0, 1.0, 1.25, 1.5, 1.75 and 2%) as vol. %. Consequently, the hybridization of the steel fiber and palm fiber (**PF**) as 2% volumetric fractions on the high strength concrete was applied and determine the density, compressive strength, flexural strength and toughness indices for all the mixes. The flexural strength of concrete mixes containing steel fibers increases with the increasing volume fraction. The highest values for these properties obtained as the 1.5% of steel fiber included in the mix. The use of palm fibers as 0.25 vol. % in hybrid fiber mixes gives the higher increment in flexural strength.

II. Research Significance

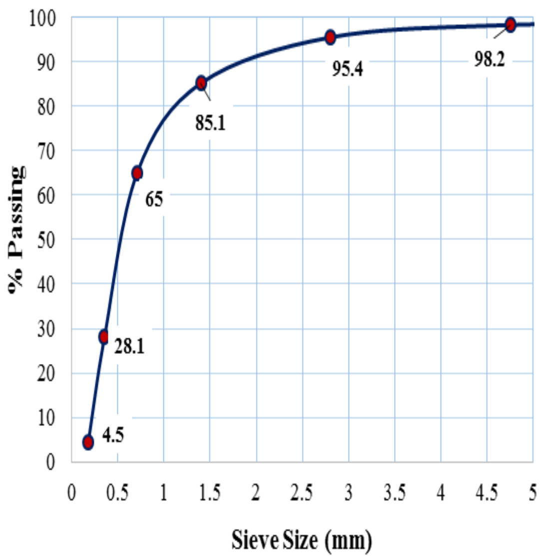
The first goal is using agricultural waste as fibers such as date palm fibers (**DPF**), flax fibers (**FF**) and date palm spikelet fibers (**DPSF**). **The second goal** is using hybrid fibers by adding polypropylene fibers(**PF**) to **DPF**, **FF** and **DPSF** mixes. Mix design according to **ACI 318 -2019[19]** recommendations, introduced to achieve the flexural strength of concrete. In order to achieve this objective, a total of 60 beams (100 mm *100 mm *500 mm) were casted and tested.

III. Experimental Work

3.1 Material properties

Materials used in concrete mixtures were ordinary Portland cement grade 42.5, specific gravity of cement used was 3.15, fine aggregate, coarse aggregate (basalt), natural fibers (date palm fibers (**DPF**), flax fibers (**FF**) and date palm spikelet fibers (**DPSF**)), polypropylene fibers (**PF**) and pure water. Fine and coarse aggregate were tested according to Egyptian standard specifications **[20]** and ASTM. List of tests presented following:

1. Sieve analysis as shown in **Fig. 1** and **Fig. 2**.
2. Maximum aggregate size of coarse aggregate and fineness modulus of sand as shown in **Table 1**.
3. Specific gravity of coarse and fine aggregate as shown in **Table 1**.
4. Unit weight of coarse and fine aggregate as shown in **Table1**.
5. Physical Properties of **DPF** as shown in **Table 2**.
6. Properties of **PF** from Sika company as shown in **Table 3 and Fig. 3**.
7. Physical and Mechanical Properties of **FF** as shown in **Table 4**.



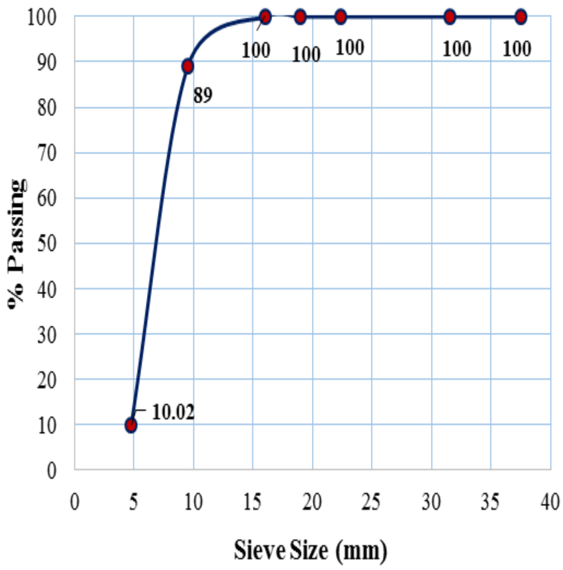


Fig. 1: Sieve Analysis of Fine Aggregate. **Fig. 2**: Sieve Analysis of Coarse Aggregate.

Table 1: Properties of Used Aggregate.

Type of Test	Value
Maximum Aggregate Size [mm]	16
Fineness Modulus of Sand	2.24
Specific Gravity of Coarse Aggregate	2.73
Specific Gravity of Fine Aggregate	2.50
Unit Weight of Coarse Aggregate [t\m^3]	1.58
Unit Weight of Fine Aggregate [t\m^3]	1.77

Table 2: Physical Properties of (**DPF**)**[21]**.

Property	Range
Bulk Density [kg/m^3]	512.2–1088.8
Absolute Density [kg/m^3]	1300.0–1450.0
Natural Moisture Content [%]	9.5–10.5
Water Absorption after 5 min under water [%]	60.1–84.1
Water Absorption to saturation [%]	96.8–202.6

Table 3: Typical Properties of Polypropylene Fibers (**PF**) from Sika Company.

Density	0.91 gm nominal
Length	18mm
Tensile Strength [N/mm^2]	300 – 400
Elongation	> 80%
Absorption	Nil
Specific Surface Area	250 sq meter per KG
Melt Point	160 ºC
Ignition Point	365 ºC
Thermal Conductivity	Low
Electrical Conductivity	Low
Acid Resistance	High
Alkali Resistance	100%

Table .4: Physical and Mechanical Properties of Flax Fibers (**FF**) **[22]**.

Characteristics	**Average Value**	**Standard Deviation**	**Coefficient of Variation**
Real Density ($g.cm^{-3}$)	1.521	±0.002	0.001
Diameter (μm)	14.66	±2.95	0.20
Tensile Strength (MPa)	1254	±456	0.36
Ultimate Strain (%)	1.86	±0.60	0.32
Young's Modulus(GPa)	65.5	±14.8	0.23
Water Content (%)	7.63	±0.10	0.01
WA_{24} (%)	132.4	±4.2	0.03

DPF and **FF** were treated by immersing in 5% of NaOH solution. They were immersed in the solution for 12 hours in the normal room temperature. After treatment, they were washed several times and dried in the open air, then cut **DPF** to 10 mm length and cut **FF** to 15 mm length (**Figs**. 3 and 4).

DPSF were treated also by immersing in 5% of NaOH solutionfor 24 hours in the normal room temperature. After treatment, they were washed several times and dried in the open air, then cut to 18 mm length (**Fig**. 5).

Fig.3: Polypropylene Fibers (**PF**).**Fig.4**: Date Palm Fibers (**DPF**) after Treatment.

Fig.5:Flax Fibers (**FF**) after Treatment.**Fig. 6**: Date Palm Spikelet Fibers (**DPSF**)

3.2 Mix Design

Table 5A, **Table 5B,Table 5C, Table 5D, Table 5E, Table 5F and Table 5G** show contents of 1 m^3 concrete for control mix, **DPF, FF, DPSF, DPFP, FFP and DPSFP** mixes, respectively.Twenty classes of concrete were produced to cast series of test specimens. Mixtures are designed using the American code (**ACI 318-2019**) **[19]** recommendations.Different percentages of **DPF** (**0.25, 0.5 and 0.75%**), percentages of **FF** (**0.15, 0.3 and 0.45%**) and percentages of **DPSF** (**0.5, 1.0 and 1.5%**) as a volume fraction are used.One percent of Polypropylene Fibers (**PF**) is added as recommended by the producer (0.9 kg /m^3).

Table 5A: Mix Proportions for Control Mixture.

Class	Mix Details	Cement (kg/m^3)	Sand (kg/m^3)	Basalt (kg/m^3)	Water (kg/m^3)	PF (kg/m^3)	Proportions
Class (1)	**C1 (Control mix)**	411.11	733.85	1005.87	185	0	1:1.79:2.45 – W/C = 0.45
Class (2)	**C2 (Plain Concrete+PF)**	411.11	733.85	1005.87	185	0.90	

Table 5B: Mix Proportions for**DPF** Mixes.

Class	Mix Details	Cement (kg/m^3)	Sand (kg/m^3)	Basalt (kg/m^3)	Water (kg/m^3)	DPF (kg/m^3)
Class (3)	**DPF0.25(0.25 Vf % DPF)**	411.11	733.85	1005.87	185	3.50
Class (4)	**DPF0.5(0.5 Vf % DPF)**	411.11	733.85	1005.87	185	7.00
Class (5)	**DPF0.75(0.75 Vf % DPF)**	411.11	733.85	1005.87	185	10.50

Table 5C: Mix Proportions for**DPFP**Mixes.

Class	Mix Details	Cement (kg/m^3)	Sand (kg/m^3)	Basalt (kg/m^3)	Water (kg/m^3)	DPF (kg/m^3)	PF (kg/m^3)
Class (6)	**DPFP0.25(0.25 Vf % DPF+PF)**	411.11	733.85	1005.87	185	3.50	0.90
Class (7)	**DPFP0.5(0.5 Vf % DPF+PF)**	411.11	733.85	1005.87	185	7.00	0.90
Class (8)	**DPFP0.75(0.75 Vf % DPF+PF)**	411.11	733.85	1005.87	185	10.50	0.90

Density of **DPF** used was 1.40 gm/cm^3.

Table 5D: Mix Proportions for**FF**Mixes.

Class	Mix Details	Cement (kg/m^3)	Sand (kg/m^3)	Basalt (kg/m^3)	Water (kg/m^3)	FF (kg/m^3)
Class (9)	**FF0.15(0.15 Vf % FF)**	411.11	733.85	1005.87	185	2.28
Class (10)	**FF0.3(0.3 Vf % FF)**	411.11	733.85	1005.87	185	4.56
Class (11)	**FF0.45(0.45 Vf % FF)**	411.11	733.85	1005.87	185	6.84

Table 5E: Mix Proportions for**FFP**Mixes.

Class	Mix Details	Cement (kg/m^3)	Sand (kg/m^3)	Basalt (kg/m^3)	Water (kg/m^3)	FF (kg/m^3)	PF (kg/m^3)
Class (12)	**FFP0.15(0.15 Vf % FF+PF)**	411.11	733.85	1005.87	185	2.28	0.90
Class (13)	**FFP0.3(0.3 Vf % FF+PF)**	411.11	733.85	1005.87	185	4.56	0.90
Class (14)	**FFP0.45(0.45 Vf % FF+PF)**	411.11	733.85	1005.87	185	6.84	0.90

Density of **FF** used was 1.521 gm/cm^3.

Table 5F: Mix Proportions for**DPSF**Mixes.

Class	Mix Details	Cement (kg/m^3)	Sand (kg/m^3)	Basalt (kg/m^3)	Water (kg/m^3)	DPSF (kg/m^3)
Class (15)	**DPSF0.5(0.5 Vf % DPSF)**	411.11	733.85	1005.87	185	7.5
Class (16)	**DPSF1.0(1.0 Vf % DPSF)**	411.11	733.85	1005.87	185	15
Class (17)	**DPSF1.5(1.5 Vf % DPSF)**	411.11	733.85	1005.87	185	22.5

Table 5G: Mix Proportions for **DPSFP**Mixes.

Class	Mix Details	Cement (kg/m^3)	Sand (kg/m^3)	Basalt (kg/m^3)	Water (kg/m^3)	DPSF (kg/m^3)	PF (kg/m^3)
Class (18)	**DPSFP0.5(0.5 Vf % DPSF+PF)**	411.11	733.85	1005.87	185	7.5	0.90
Class (19)	**DPSFP1.0(1.0 Vf % DPSF+PF)**	411.11	733.85	1005.87	185	15	0.90
Class (20)	**DPSFP1.5(1.5 Vf % DPSF +PF)**	411.11	733.85	1005.87	185	22.5	0.90

Density of **DPSF** used was 1.5 gm/cm^3.

3.3 Test Specimens

For each mixture three beams specimens were cast to test concrete flexural strength at 28 days. The experimental program of this study involved testing of 60 beams (100 mm*100 mm*500 mm) as shown in **Fig. 10a** and **Fig. 10b**. After casting, placing, compacting and finishing operation, all specimens were covered with a plastic sheet till demoulding. Thereafter, specimens were cured by submerging them into fresh water tank. Once the desired curing period is completed, specimens were taken out from the curing tank to perform test program.


Fig. 10a: Beams (100 mm *100 mm*500mm)**Fig.10b**: Beams (100 mm *100 mm*500mm)
during Casting.after Curing.

3.4 TESTS

3.4.1 Fresh Concrete Tests

3.4.1.1 Slump Test

For measure the consistency of each fresh mix and compare between conventional mixes and others include natural fibers, slump test has performed. Tools for slump test essentially consist of a metallic mould on the form of a cone having internal dimensions of 20 cm diameter bottom, 10 cm diameter top and 30 cm in height. The mould is placed on a smooth, horizontal and non-absorbent surface. The fresh test sample of concrete is taken from the pan mixer immediately after mixing and is placed into the cone mould at three layers. Each layer is compacted 25 times by a standard tamping rod. Slump is measured immediately by determining the vertical distance between the height of the mould and that of highest point of the specimen being tested as shown in **Fig. 11**.

3.4.1.2 Compaction Factor Test

Value of workability is estimated by the compaction factor apparatus as shown in **Fig.12**. The compaction factor can be determined by filling the upper cone with fresh concrete and allow concrete sample to fall in the lower cone by opening the upper cone's door. At last, the sample is allowed to fall again in the cylinder and is weighted with the sample (partially compacted). After that, the cylinder is filled with fully compacted sample and is weighted (fully). Finally, compacted factor (C.F) is determined (partially weighted / fully weighted).

3.4.2 Hardened Concrete Tests

Tests of hardened concrete play an important role in controlling and confirming its quality. Tests help to achieve higher efficiency of the material used and greater assurance of the performance of the concrete with regard to both strength and durability.

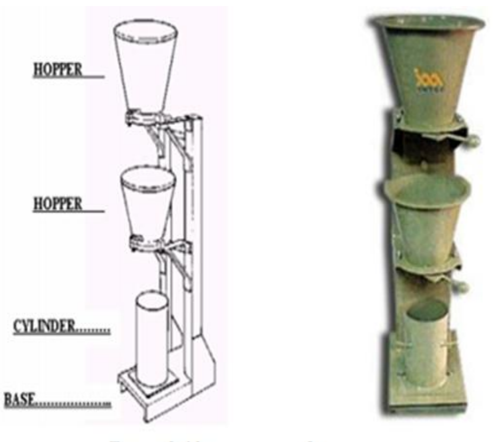


Fig. 11: Slump Test.**Fig. 12**: Compacting Factor Apparatus.

3.4.2.1 Flexural Strength Test

For flexural strengthtest, prepared nine beams specimens for each mix of dimensions 100 mm * 100 mm * 500 mm were caste. Samples were demoulded, after 24 hours from casting kept in a pure water tank for 28 days to cure. Specimens were tested in machine as shown in**Fig. 13** and tested for flexural strength.In each category, for each mix three beams, their average value is reported by using following form:Flexural Strength (Kg/cm^2).

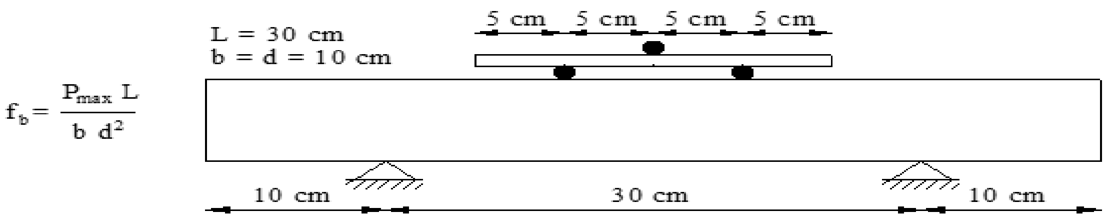


Fig. 13a: Beam dimensions

Fig. 13b: Beam (100 mm *100 mm*500mm) during Flexural Strength Test.

IV.Experimental Results and Discussion

4.1 Fresh Concrete Properties

4.1.1 Slump Test Results

Table 6 illustrate that the slump reduced with increasing the proportion ofnatural fibers**(DPF**, **FF** and **DPSF mixes)**.Also, the slumpvalues is decreased with adding **PF** to mixes of **DPFP**, **FFP** and **DPSFP (**hybrid fibers).

Table 6: Slump Results for different mixes (cm)

Reference		%DPF			%DPF + PF			%FF			%FF + PF			%DPDF			%DPDF + PF		
PC	PC+FP	0.25	0.5	0.75	0.25	0.5	0.75	0.15	0.3	0.45	0.15	0.3	0.45	0.5	1.0	1.5	0.5	1.0	1.5
5.0	4.0	4.0	3.5	3.0	3.0	2.5	2.0	4.0	3.0	2.5	3.5	2.5	2.0	4.0	3.5	3.0	3.5	3.0	2.5

4.1.2 Compaction Factor Test Results

FromTable 7 its observed that the Compacting Factor reduced with increasing the proportion of **DPF**, **FF** and **DPSF** (Natural Fibers).Also, the Compacting Factor is decreased with adding **PF** to mixes of **DPF**, **FF** and **DPSF**(Hybrid Fibers).

Table 7: Compacting Factor for different mixes (%)

Reference		%DPF			%DPF + PF			%FF			%FF + PF			%DPDF			%DPDF + PF		
PC	PC+FP	0.25	0.5	0.75	0.25	0.5	0.75	0.15	0.3	0.45	0.15	0.3	0.45	0.5	1.0	1.5	0.5	1.0	1.5
95	90	90	88	85	85	83	78	90	85	80	87	83	78	90	87	85	87	85	80

4.2 Hardened Concrete Properties

4.2.1 Flexural Strength Test Results

From**Fig.14**, flexural strength test results for**DPF** show that with increasing proportion of **DPF**, Flexural strength increases. The optimum proportion of **DPF** is 0.75 Vf %. From **Fig.15**, flexural strength test results for **DPFP** show that with adding **PF** with **DPF**, flexural strength decreases. From **Fig.16**, using **DPF** in concrete only is better than using him in concrete with **PF**.

From **Fig.17**and **Fig.18**,it was observed that the optimum proportion of **FF** is 0.3 Vf %.**Fig.19**shows that with adding **PF**, flexural strength increases.

Fig.20illustrates thatwith increasing **DPSF**, flexural strength decreases. The optimum proportion of **DPSF** is 0.5 Vf %.Alsowith adding **PF** to **DPSF** (**DPSFP**), flexural strength increases as shown in **Fig.21** and**Fig.22.**

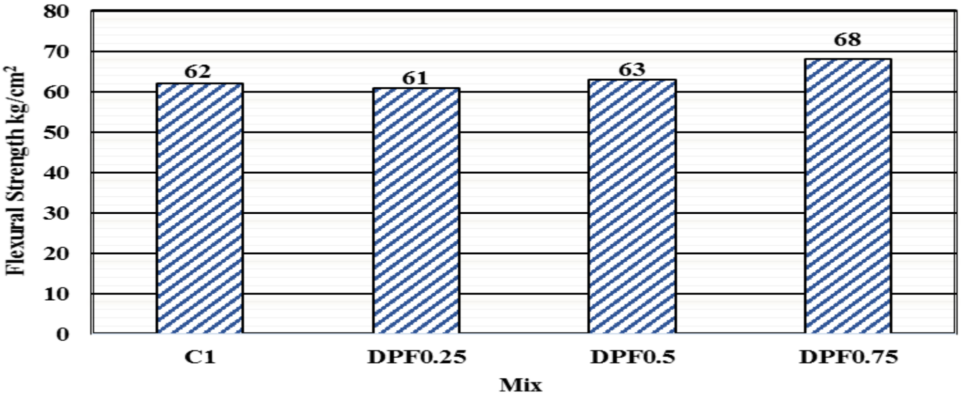


Fig.14: Average Flexural Strength for **DPF** at 28 Days.

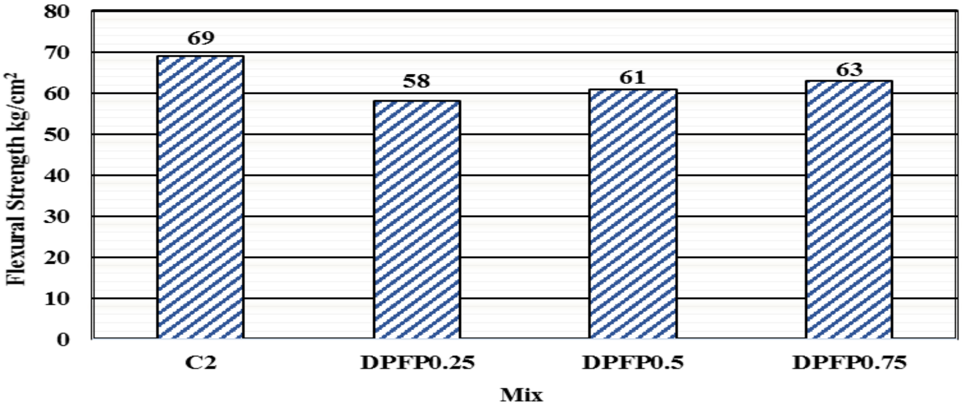


Fig.15: Average Flexural Strength for **DPFP** at 28 Days.

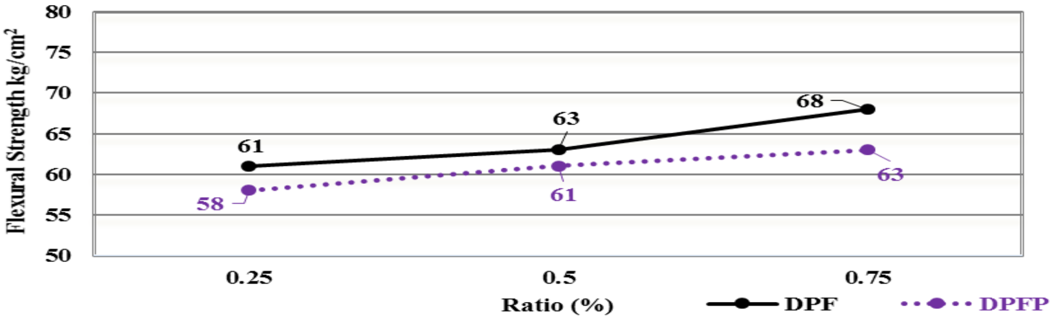


Fig.16: Comparison between Average Flexural Strength for **DPF** and **DPFP** at Different Ratios.

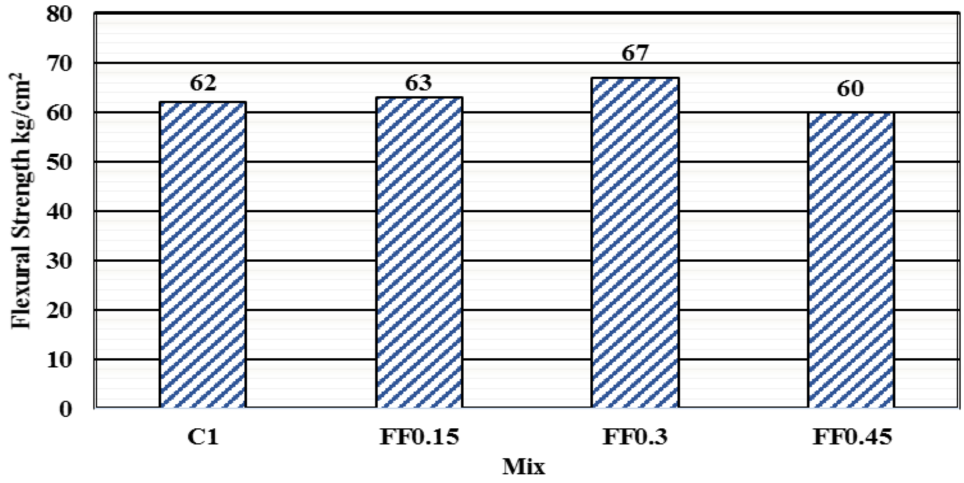


Fig.17: Average Flexural Strength for **FF** at 28 Days.

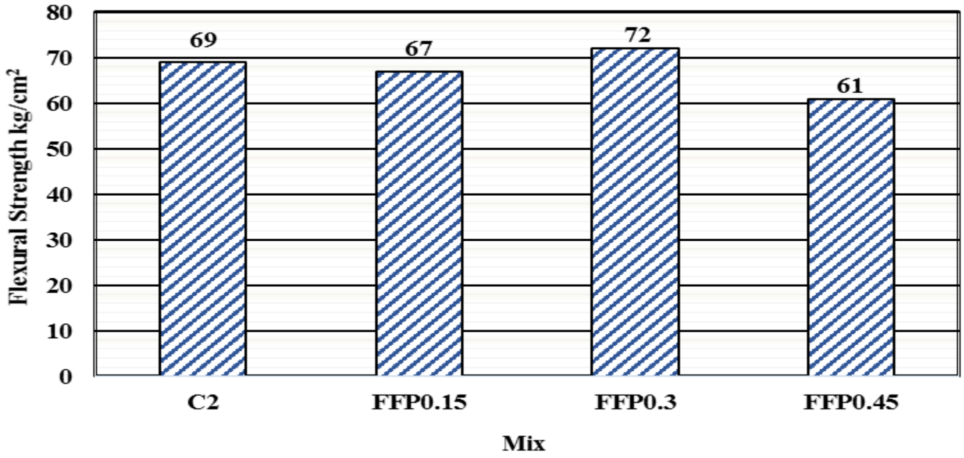


Fig.18: Average Flexural Strength for **FFP** at 28 Days.

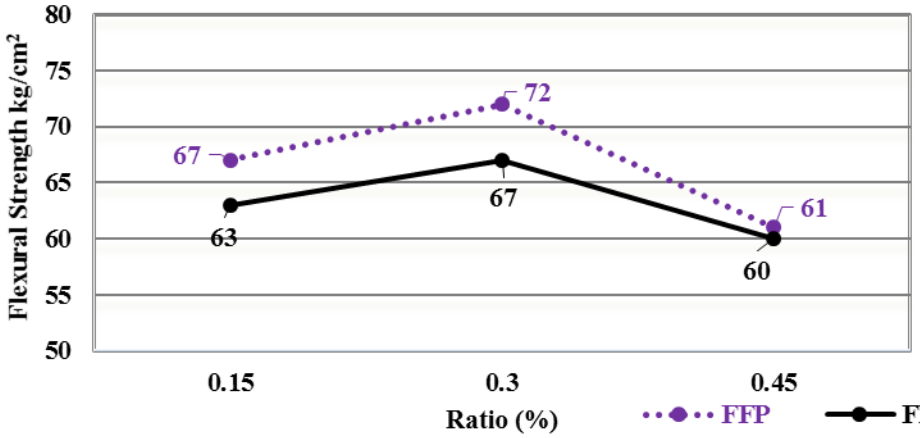


Fig.19: Comparison between Average Flexural Strength for **FF** and **FFP** at Different Ratios.

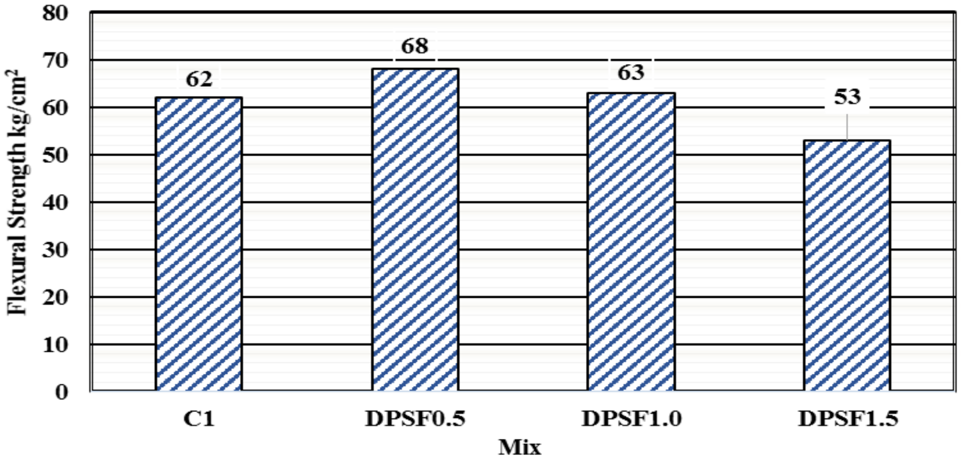


Fig.20: Average Flexural Strength for **DPSF** at 28 Days.

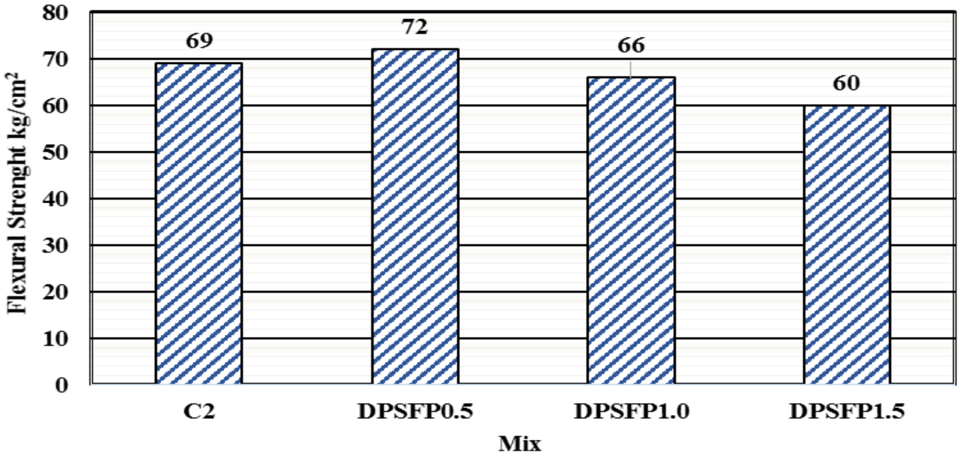


Fig.21: Average Flexural Strength for **DPSFP** at 28 Days.

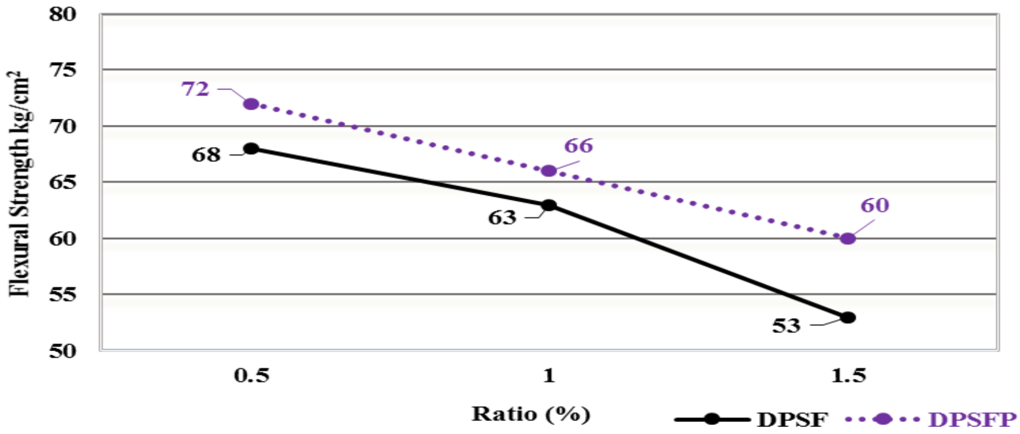


Fig.22: Comparison between Average Flexural Strength for **DPSF** and **DPSFP** at Different Ratios.

V.Conclusions

The following conclusions could be drawn from the experimental data presented in the reported study:

1. The slump of test samples ranged between 2 cm to 5 cm.
2. The slump decreased with increasing proportion of **DPF, FF** and **DPSF**.
3. The slump also decreased with adding **PF** to mixes of **DPFP, FFP** and **DPSFP**.
4. The Compaction factor of test samples ranged from **78%** to **95%.**
5. The compacting factor decreased with increasing content of **DPF, FF** and **DPSF**.

6. The compacting factor also decreased with adding **PF** to mixes of **DPFP, FFP** and **DPSFP**.
7. Flexural strength test results for adding **DPF** to concrete show that with increasing proportion of **DPF**, Flexural strength increases. The optimum proportion of **DPF** is **0.75%**.
8. Flexural strength of **0.75% DPF** samples at 28 days increased by **9.68%** of that control mix (plain concrete),while it decreased by **1.45%** of that of control mix (plain concrete+**PF**).
9. Results of addition **DPF** to concrete only is better than that of addition **PF** with **DPF** to concrete.
10. The optimum proportion of **FF** is **0.3%**.
11. Flexural strength of **0.3 % FF** samples at 28 days increased by **8.06%** of that control mix(plain concrete).
12. 13. The optimum proportion of **FFP** is also 0.3%.
13. 14. Flexural strength of **0.3% FFP** samples at 28 days increased by **16.13%** of that control mix (plain concrete) and also increased by **4.35%** of that control mix (plain concrete+**PF**).
14. With adding **PF** to **FF** mixtures, flexural strength increases than that using **FF** only in concrete.
15. With increasing proportion of **DPSF**, flexural strength decreases. The optimum proportion is **0.5%**.
16. Flexural strength of 0**.5% DPSF** samples at 28 days increased by **9.68%** of that control mix (plain concrete) and also decreased by **1.45%** of that control mix (plain concrete+**PF**).
17. With adding **PF** to **DPSF** samples, flexural strength increases. The optimum proportion of **DPSFP** is **0.5%**.
18. Flexural strength of **0.5% DPSFP** samples at 28 days increased by **16.13%** of that control mix (plain concrete) and also increased by **4.35%** of that control mix (plain concrete+**PF**).
19. Using natural fibers in construction reduces pollution if they were burned. So, we recommend using them to improve properties of fresh and hardened concrete.

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