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 effect of using natural and polypropylene fibers on Properties of fresh and hardened concrete. The first goal is using natural fibers such 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 proportion of 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 proportion of 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.

Date of Submission: 21-06-2020
Date of Acceptance: 10-07-2020

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 fibers with polymers is to enhance the mechanical properties of the materials [10-11]. Oussama Benaimech, 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. Mehedden 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 Dawod 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 Table 1.
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.
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Fig. 1: Sieve Analysis of Fine Aggregate.  Fig. 2: Sieve Analysis of Coarse Aggregate.

Table 1: Properties of Used Aggregate.

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Aggregate Size [mm]</td>
<td>16</td>
</tr>
<tr>
<td>Fineness Modulus of Sand</td>
<td>2.24</td>
</tr>
<tr>
<td>Specific Gravity of Coarse Aggregate</td>
<td>2.73</td>
</tr>
<tr>
<td>Specific Gravity of Fine Aggregate</td>
<td>2.50</td>
</tr>
<tr>
<td>Unit Weight of Coarse Aggregate [kg/m³]</td>
<td>1.58</td>
</tr>
<tr>
<td>Unit Weight of Fine Aggregate [kg/m³]</td>
<td>1.77</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Property</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Density [kg/m³]</td>
<td>512.2-1088.8</td>
</tr>
<tr>
<td>Absorbate Density [kg/m³]</td>
<td>1300.0-1450.0</td>
</tr>
<tr>
<td>Natural Moisture Content (%)</td>
<td>9.5-10.5</td>
</tr>
<tr>
<td>Water Absorption after 5 min under water (%)</td>
<td>60.1-80.1</td>
</tr>
<tr>
<td>Water Absorption to saturation (%)</td>
<td>95.8-203.5</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>0.91 gm nominal</td>
</tr>
<tr>
<td>Length</td>
<td>18mm</td>
</tr>
<tr>
<td>Tensile Strength [N/mm²]</td>
<td>300 – 400</td>
</tr>
<tr>
<td>Elongation</td>
<td>&gt; 80%</td>
</tr>
<tr>
<td>Absorption</td>
<td>Nil</td>
</tr>
<tr>
<td>Specific Surface Area</td>
<td>250 sq meter per KG</td>
</tr>
<tr>
<td>Melt Point</td>
<td>160 °C</td>
</tr>
<tr>
<td>Ignition Point</td>
<td>365 °C</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>Low</td>
</tr>
<tr>
<td>Electrical Conductivity</td>
<td>Low</td>
</tr>
<tr>
<td>Acid Resistance</td>
<td>High</td>
</tr>
<tr>
<td>Alkali Resistance</td>
<td>100%</td>
</tr>
</tbody>
</table>
Table 4: Physical and Mechanical Properties of Flax Fibers (FF) [22].

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Average Value</th>
<th>Standard Deviation</th>
<th>Coefficient of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Density (g.cm⁻³)</td>
<td>1.521</td>
<td>±0.002</td>
<td>0.001</td>
</tr>
<tr>
<td>Diameter (µm)</td>
<td>14.66</td>
<td>±2.95</td>
<td>0.20</td>
</tr>
<tr>
<td>Tensile Strength (MPa)</td>
<td>1254</td>
<td>±456</td>
<td>0.36</td>
</tr>
<tr>
<td>Ultimate Strain (%)</td>
<td>1.86</td>
<td>±0.60</td>
<td>0.32</td>
</tr>
<tr>
<td>Young’s Modulus(GPa)</td>
<td>65.5</td>
<td>±14.8</td>
<td>0.23</td>
</tr>
<tr>
<td>Water Content (%)</td>
<td>7.63</td>
<td>±0.10</td>
<td>0.01</td>
</tr>
<tr>
<td>WA₂₅ (%)</td>
<td>132.4</td>
<td>±4.2</td>
<td>0.03</td>
</tr>
</tbody>
</table>

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 solution for 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 m³ 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%) and 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/m³).
Table 5A: Mix Proportions for Control Mixture.

<table>
<thead>
<tr>
<th>Class</th>
<th>Mix Details</th>
<th>Cement (kg/m³)</th>
<th>Sand (kg/m³)</th>
<th>Basalt (kg/m³)</th>
<th>Water (kg/m³)</th>
<th>PF (kg/m³)</th>
<th>Proportions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class (1)</td>
<td>C1 (Control mix)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>0</td>
<td>1:1.79:2.45</td>
</tr>
<tr>
<td>Class (2)</td>
<td>C2 (Plain Concrete+PF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>0.90</td>
<td></td>
</tr>
</tbody>
</table>

Table 5B: Mix Proportions for DPF Mixes.

<table>
<thead>
<tr>
<th>Class</th>
<th>Mix Details</th>
<th>Cement (kg/m³)</th>
<th>Sand (kg/m³)</th>
<th>Basalt (kg/m³)</th>
<th>Water (kg/m³)</th>
<th>DPF (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class (3)</td>
<td>DPF0.25 (0.25 Vf % DPF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>3.50</td>
</tr>
<tr>
<td>Class (4)</td>
<td>DPF0.5 (0.5 Vf % DPF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>7.00</td>
</tr>
<tr>
<td>Class (5)</td>
<td>DPF0.75 (0.75 Vf % DPF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>10.50</td>
</tr>
</tbody>
</table>

Density of DPF used was 1.40 gm/cm³.

Table 5C: Mix Proportions for DPFP Mixes.

<table>
<thead>
<tr>
<th>Class</th>
<th>Mix Details</th>
<th>Cement (kg/m³)</th>
<th>Sand (kg/m³)</th>
<th>Basalt (kg/m³)</th>
<th>Water (kg/m³)</th>
<th>DPF (kg/m³)</th>
<th>PF (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class (6)</td>
<td>DPFP0.25 (0.25 Vf % DPF+PF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>3.50</td>
<td>0.90</td>
</tr>
<tr>
<td>Class (7)</td>
<td>DPFP0.5 (0.5 Vf % DPF+PF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>7.00</td>
<td>0.90</td>
</tr>
<tr>
<td>Class (8)</td>
<td>DPFP0.75 (0.75 Vf % DPF+PF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>10.50</td>
<td>0.90</td>
</tr>
</tbody>
</table>

Table 5D: Mix Proportions for FF Mixes.

<table>
<thead>
<tr>
<th>Class</th>
<th>Mix Details</th>
<th>Cement (kg/m³)</th>
<th>Sand (kg/m³)</th>
<th>Basalt (kg/m³)</th>
<th>Water (kg/m³)</th>
<th>FF (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class (9)</td>
<td>FF0.15 (0.15 Vf % FF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>2.28</td>
</tr>
<tr>
<td>Class (10)</td>
<td>FF0.3 (0.3 Vf % FF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>4.56</td>
</tr>
<tr>
<td>Class (11)</td>
<td>FF0.45 (0.45 Vf % FF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>6.84</td>
</tr>
</tbody>
</table>

Table 5E: Mix Proportions for FFP Mixes.

<table>
<thead>
<tr>
<th>Class</th>
<th>Mix Details</th>
<th>Cement (kg/m³)</th>
<th>Sand (kg/m³)</th>
<th>Basalt (kg/m³)</th>
<th>Water (kg/m³)</th>
<th>FF (kg/m³)</th>
<th>PF (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class (12)</td>
<td>FFP0.15 (0.15 Vf % FF+PF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>2.28</td>
<td>0.90</td>
</tr>
<tr>
<td>Class (13)</td>
<td>FFP0.3 (0.3 Vf % FF+PF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>4.56</td>
<td>0.90</td>
</tr>
<tr>
<td>Class (14)</td>
<td>FFP0.45 (0.45 Vf % FF+PF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>6.84</td>
<td>0.90</td>
</tr>
</tbody>
</table>

Density of FF used was 1.521 gm/cm³.

DOI: 10.9790/1684-1703052536 www.iosrjournals.org 29 | Page
Table 5F: Mix Proportions for DPSF Mixes.

<table>
<thead>
<tr>
<th>Class</th>
<th>Mix Details</th>
<th>Cement (kg/m³)</th>
<th>Sand (kg/m³)</th>
<th>Basalt (kg/m³)</th>
<th>Water (kg/m³)</th>
<th>DPSF (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class (15)</td>
<td>DPSF0.5 (0.5 Vf % DPSF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>7.5</td>
</tr>
<tr>
<td>Class (16)</td>
<td>DPSF1.0 (1.0 Vf % DPSF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>15</td>
</tr>
<tr>
<td>Class (17)</td>
<td>DPSF1.5 (1.5 Vf % DPSF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>22.5</td>
</tr>
</tbody>
</table>

Table 5G: Mix Proportions for DPSFP Mixes.

<table>
<thead>
<tr>
<th>Class</th>
<th>Mix Details</th>
<th>Cement (kg/m³)</th>
<th>Sand (kg/m³)</th>
<th>Basalt (kg/m³)</th>
<th>Water (kg/m³)</th>
<th>DPSF (kg/m³)</th>
<th>PF (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class (18)</td>
<td>DPSFP0.5 (0.5 Vf % DPSF+PF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>7.5</td>
<td>0.90</td>
</tr>
<tr>
<td>Class (19)</td>
<td>DPSFP1.0 (1.0 Vf % DPSF+PF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>15</td>
<td>0.90</td>
</tr>
<tr>
<td>Class (20)</td>
<td>DPSFP1.5 (1.5 Vf % DPSF +PF)</td>
<td>411.11</td>
<td>733.85</td>
<td>1005.87</td>
<td>185</td>
<td>22.5</td>
<td>0.90</td>
</tr>
</tbody>
</table>

Density of DPSF used was 1.5 gm/cm³.

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) during Casting.

Fig. 10b: Beams (100 mm *100 mm*500mm) 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.

3.4.2.1 Flexural Strength Test

For flexural strength test, 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/cm²).

\[ f_c = \frac{P_{\text{max}} L}{b d^2} \]

\[ L = 30 \text{ cm} \]
\[ b = d = 10 \text{ cm} \]

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 illustrates that the slump reduced with increasing the proportion of natural fibers (DPF, FF and DPSF mixes). Also, the slump values are decreased with adding PF to mixes of DPFP, FFP and DPSFP (hybrid fibers).

<table>
<thead>
<tr>
<th>Reference</th>
<th>%DPF</th>
<th>%DPF + PF</th>
<th>%FF</th>
<th>%FF + PF</th>
<th>%DPDF</th>
<th>%DPDF + PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td>0.25</td>
<td>0.5</td>
<td>0.75</td>
<td>0.25</td>
<td>0.5</td>
<td>0.75</td>
</tr>
<tr>
<td>PC+FP</td>
<td>4.0</td>
<td>3.5</td>
<td>3.0</td>
<td>3.0</td>
<td>2.5</td>
<td>2.0</td>
</tr>
</tbody>
</table>

4.1.2 Compacting Factor Test Results

From Table 7, it is 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>
<thead>
<tr>
<th>Reference</th>
<th>%DPF</th>
<th>%DPF + PF</th>
<th>%FF</th>
<th>%FF + PF</th>
<th>%DPDF</th>
<th>%DPDF + PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td>95</td>
<td>90</td>
<td>88</td>
<td>85</td>
<td>85</td>
<td>78</td>
</tr>
<tr>
<td>PC+FP</td>
<td>90</td>
<td>88</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>78</td>
</tr>
</tbody>
</table>

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.20 illustrates that with increasing DPSF, flexural strength decreases. The optimum proportion of DPSF is 0.5 Vf %. Also, with 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.
**Effect of Using Natural and Polypropylene Fibers on Fresh and Hardened Concrete Properties**

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

6. The compacting factor also decreased with adding PF to mixtures 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. The optimum proportion of FFP is also 0.3%.
13. 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.

References