A comparison study on the mechanical and durability performances on High Volume Fly Ash Concrete (HVFAC) with polypropylene fiber

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Abstract
This paper presents a comparative study on two categories of fly ash namely treated fly ash (Dirk fly ash) obtained from Nasik Thermal Plant (NTP) and non-treated fly ash obtained from Mettur thermal Plant (MTP). In this study on investigation has been carried out on the mechanical strength performances and durability performances of High Volume Fly Ash Concrete with partial replacement of fly ash with cement with fly ash 0 %, 30 %, 40%, 50%, 55%, and 60% by weight. The mechanical strength performances were determined at 7th, 28th and 56th days, whereas the durability performances were found at 28th and 56th days. Rapid Chloride Permeability Index Test (RCPT) and water absorption tests were carried out to determine durability performances. In order improve the mechanical strength performances and durability performances in High Volume Fly Ash Concrete (HVFAC) polypropylene fibers were added. Results show that the replacement of cement with 50% Dirk fly ash significantly improved the mechanical strength performances of HVFAC and the durability performances of HVFAC. The properties of HVFAC containing 50% treated fly ash exhibited superior mechanical strength performances and durability performances than the non-treated High Volume Fly Ash Concrete (HVFAC)

Keywords: High Volume Fly Ash Concrete (HVFAC), mechanical strength performances, durability performances, polypropylene fiber.

1. Introduction
Concrete is the most comprehensively used material in construction. The development of sustainability in the construction industry is an important factor for the modern construction industries. The main ingredient of concrete is Portland cement. The Portland cement production is a modes sources of Carbon dioxide (CO2) into environment in order to minimize the CO2emission, it is necessary to minimize the consumption of cement. Replacement of cement with fly ash which is a waste material in thermal power plant is one of the methods to reduce the usage of cement. Dale P. Bentz et al [1] made on investigation in various parameters like workability, mix proportioning, and analysis for incompatibilities, curing options, strength development and durability of HVFA concrete. Balakrishnan and Abdul Anwar [2] conclude that High Volume Fly Ash
Concrete was positively influenced in the workability and increased the setting time of concrete. Development of strength has been relatively slower but gained higher strength at later ages. Srinivas T and Raman Rao N V [3] observed that the compressive and flexural strengths of concrete decreased with 70% replacement of cement with fly ash.

They observed that the serviceability limits were as per IS 456-2000 with a 70% replacement of cement. Rafat Siddique [4] revealed that durability improved at 28th day at a replacement level of 50%. He also reported that the HVFA Concrete is applicable for precast elements and R.C. Concrete construction. Fibres are usually used in concrete to control the cracking which is caused due to plastic shrinkage and drying shrinkage. In this Report that the permeability of concrete and also the bleeding of water in concrete reduced. Adanagouda et al [5] reported that the composite fiber content of 1.25% (steel and polypropylene) by volume with 10% fly ash resulted in an increase in compressive strength, split tensile strength and flexural strength. OkanKarajan and Cengiz Duran Atis [6] made an exhaustive report on the durability properties of concrete containing polypropylene fiber and fly ash.

It was reported that addition of fly ash and polypropylene fibers resulted in reducing drying shrinkage and improved the freeze-thaw resistance. Narendra B K and Mahadeviyah T M [7] reported an experimental investigation on High Volume Fly Ash Concrete. They reported that workability, impermeability, resistance to chemical attack improved durability than the ordinary Portland cement concrete. Kolli. Ramujee [8] made that the compressive strength and split tensile strength was increased with the addition of Polypropylene fibres. O. Kayali et al [9] reported that addition of fiber enhanced the performance due to the micro structural modification and densification in the transition zone between the matrix and the fibers. He reported that High Volume Fly Ash concrete gains of strength at later ages at 56 and 120 days. He reported that HVFA Concrete resistance to brittleness and excellent durability resistance to chloride ions penetration. Mullica K [10] that the durability characteristics of HVFA concrete improved significantly compared with the control concrete. The resistance to de-icing salt scaling decreases significant Bouzoubaa N et al [11].

In this research work two types of fly ash (FA) namely the treated fly ash and untreated fly ash were used as a partial replacement material for cement at various levels of 30, 40, 50, 55 and 60% with polypropylene fiber were also added to HVFA Concrete enhance the durability of concrete. Optimum proportions of FA and polypropylene are given based on the mechanical strength and durability performances.

2. Experimental Investigation
2.1 Materials

In this investigation on HVFA Concrete mixtures were developed using Ordinary Portland cement (OPC) of 53 grade confirming to 12269-1987. Table 1 shows the properties of OPC and FA. The coarse aggregate (CA) was crushed granites stones to maximum size of 12.5 mm and fine aggregate (FA) was natural sand. The Specific gravity was of CA and FA aggregate was 2.56 and 2.79 respectively. To achieve the workability with a low Water-Power ratio, Polycarboxylate Based Super plasticizer with specific gravity 1.09 ± 0.01 at 25 °C was used, HVFA concrete were curing with potable water. The polypropylene fiber KEM –Fibre with the modulus of elasticity 5.5-7 GPa, have a filament diameter 13.69 micron sand a specific gravity of 0.91 were used. The length of fiber was 15 mm and the aspect ratio was 1096.
Table 1. Chemical and physical properties of OPC and FA.

<table>
<thead>
<tr>
<th>Chemical Compositions</th>
<th>OPC</th>
<th>FA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MTPP</td>
</tr>
<tr>
<td>Calcium oxide (CaO)</td>
<td>60.81</td>
<td>2.98</td>
</tr>
<tr>
<td>Silica (SiO$_2$)</td>
<td>19.50</td>
<td>53.68</td>
</tr>
<tr>
<td>Alumina (Al$_2$O$_3$)</td>
<td>4.12</td>
<td>23.07</td>
</tr>
<tr>
<td>Iron oxide (Fe$_2$O$_3$)</td>
<td>6.06</td>
<td>10.03</td>
</tr>
<tr>
<td>Magnesia (MgO)</td>
<td>1.52</td>
<td>2.16</td>
</tr>
<tr>
<td>Total loss on ignition</td>
<td>3.41</td>
<td>2.47</td>
</tr>
<tr>
<td>Available alkali (Na$_2$O)</td>
<td>0.05</td>
<td>0.52</td>
</tr>
<tr>
<td>K$_2$O</td>
<td>0.28</td>
<td>0.94</td>
</tr>
<tr>
<td>Physical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific gravity</td>
<td>3.16</td>
<td>3.16</td>
</tr>
</tbody>
</table>

Table 2 Mix composition of HVFAC.

<table>
<thead>
<tr>
<th>Mix designation</th>
<th>W:P</th>
<th>Fly Ash (FA) %</th>
<th>Cement kg</th>
<th>Sand kg</th>
<th>CA kg</th>
<th>Water litres</th>
<th>SP litres</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>0.33</td>
<td>0</td>
<td>448</td>
<td>732</td>
<td>1125</td>
<td>148</td>
<td>2.240</td>
</tr>
<tr>
<td>M2</td>
<td>0.33</td>
<td>30</td>
<td>313</td>
<td>732</td>
<td>1125</td>
<td>148</td>
<td>2.240</td>
</tr>
<tr>
<td>M3</td>
<td>0.33</td>
<td>40</td>
<td>268</td>
<td>732</td>
<td>1125</td>
<td>148</td>
<td>2.240</td>
</tr>
<tr>
<td>M4</td>
<td>0.33</td>
<td>50</td>
<td>224</td>
<td>732</td>
<td>1125</td>
<td>148</td>
<td>2.240</td>
</tr>
<tr>
<td>M5</td>
<td>0.33</td>
<td>55</td>
<td>201</td>
<td>732</td>
<td>1125</td>
<td>148</td>
<td>2.240</td>
</tr>
<tr>
<td>M6</td>
<td>0.33</td>
<td>60</td>
<td>180</td>
<td>732</td>
<td>1125</td>
<td>148</td>
<td>2.240</td>
</tr>
</tbody>
</table>

2.2 Mix proportion
The mix proportion for the HVFAC are summarized in Table 2, the range of mix components proportions recommended to typical ranges of HVFA Concrete Malhotra et.al [12]. HVFA concrete of the fresh and hardened properties attained in order to the guidelines procedure in Dale P. Bentz [1].

2.3 Mechanical strength Properties
The mechanical properties represented namely as strength performances titled as compressive and split tensile strengths were determined as per IS: 516-1959 and IS: 5816-1999 respectively. To evaluate the strength, 150 mm standard cube and cylinder diameter height 300 were used. The three sets of specimens were cast and tested after a curing of period 7, 28 and 56 days.

2.4 Durability Performances
The durability performances evaluated on HVFA Concrete were weight loss, Water absorption and RCP Test Values.

2.5 Resistance to Sulphate Attack
In order to determine the resistance to sulphate attack, concrete cubes of size 100mm were cast and cured for 28 days. After curing, the specimen were cleaned and immersed in an acid-resisting tank containing Sulfuric acid (N2SO4) with a concertation of 10 % solution by volume. The initial weight (W1) were noted.
During twelve weeks of immersion specimens were removed from sulphate solution every week, rinsed and dried the weight (W 2) was noted as per ASTM [13]. The solution was renewed every week to maintain constant concentration. The parameters investigated from the acid attack test were time and weight loss of fully-immersed HVFA concrete specimens in the solution. The cumulative weight loss at each week was calculated by

\[
\text{Weight loss (\%)} = \left( \frac{W_1 - W_2}{W_2} \right)
\]

2.6 Water Absorption Test

Test was carried out to determine water absorption, the concrete cubes specimens of size 100 mm were cast and cured for 28 days. The HVFAC specimens were cured and placed in oven for 72 ± 2 hour at a temperature of 105 ± 5 °C. The HVFA Concrete specimens were cooled in a airtight container for 24 ± 0.5 h and the weight (Wd) was noted. The specimen were immersed in water for period of 30 ± 5min. The specimens were taken out and wiped with a dry cloth to remove the free water. The water absorption was determined as follows.

\[
\text{Weight loss (\%)} = \left( \frac{W_s - W_d}{W_d} \right)
\]

2.7 Rapid Chloride Permeability Test (RCPT)

The RCPT was carried out on specimen in 100 mm Diameter and 200 mm height as per ASTM C 1202 (2009). The cured cylinder specimen was cut into 50 mm thick pieces and then coated epoxy. The air dried epoxy coated specimen was kept in the vacuum chamber for 3 hour duration for the removal of excess water. The dried specimen was kept in between cell of 0.3 sodium hydroxide and 3.0 percentage of sodium chloride. The Rate of permeability measured by total charges passed in specimen in six hours. Table 3 shows the rating of chloride ion penetration according ASTM C 1202 [14].

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Mix</th>
<th>Rate of Charge passed HFVA Concrete with ordinary Fly Ash (MTP) in (Coulombs)</th>
<th>Rate of Charge passed HFVA Concrete with treated Fly Ash (NTP) in (Coulombs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. M1</td>
<td>1024</td>
<td>1024</td>
<td>1024</td>
</tr>
<tr>
<td>2. M2</td>
<td>885</td>
<td>450</td>
<td></td>
</tr>
<tr>
<td>3. M3</td>
<td>774</td>
<td>115</td>
<td></td>
</tr>
<tr>
<td>4. M4</td>
<td>554</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td>5. M5</td>
<td>524</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>6. M6</td>
<td>435</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
3. Experimental Investigation

3.1 Mechanical strength performances for HVFAC mixes.

3.1.1 Compressive strength

The compressive strengths of concrete made with treated and untreated fly ash are given in Table 4.

### Table 4 Compressive Strength of HVFA Concrete

<table>
<thead>
<tr>
<th>SI no</th>
<th>Mix</th>
<th>Compressive Strength of HFVA Concrete with ordinary Fly Ash (MTP) in MPa</th>
<th>Compressive Strength of HFVA Concrete with treated Fly Ash (NTP) in MPa</th>
<th>Comparison Percentage increase in compressive strength (NTP) in MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>7th</td>
<td>28th</td>
<td>56th</td>
</tr>
<tr>
<td>1</td>
<td>M1</td>
<td>35.56</td>
<td>47.54</td>
<td>49.87</td>
</tr>
<tr>
<td>2</td>
<td>M2</td>
<td>25.85</td>
<td>38.85</td>
<td>41.85</td>
</tr>
<tr>
<td>3</td>
<td>M3</td>
<td>23.75</td>
<td>37.56</td>
<td>39.84</td>
</tr>
<tr>
<td>4</td>
<td>M4</td>
<td>21.44</td>
<td>35.24</td>
<td>38.35</td>
</tr>
<tr>
<td>5</td>
<td>M5</td>
<td>18.31</td>
<td>33.12</td>
<td>36.75</td>
</tr>
<tr>
<td>6</td>
<td>M6</td>
<td>16.89</td>
<td>31.25</td>
<td>34.33</td>
</tr>
</tbody>
</table>

From the Table 4, it can be seen that the compressive strength of HVFAC with treated fly ash is more than that of HVFAC with untreated fly ash. The compressive strength of M4 mix in which cement was replaced with 50% fly ash was found to be maximum in case of HVFAC in the treated flyash. However in case HVFAC with untreated fly ash, the strength decreases with addition of fly ash. The maximum increases in strength was found to be 26.32, 27.35, and 35.55% at 7th days, 28th days, and 56 days respectively. The results shows increases of compressive strength due to accelerated pozzolanic plugs the micro pores reported by the Faiz et al. [15]. Durán-Herrera et al. [16] similar results shows in the untreated fly ash decreased in the compressive strength by increases of fly ash. Comparison of Similar results reduction is confirmed by an additional increase of FA level to 55wt% reduced in the compressive strength shown in Fig 1a. The based on the comparison of results, solution was derived for the Probable Compressive Strength $f_{ckNTP}$ and $f_{ckMTP}$ in MPa

$$F_{ck}\text{'}_\text{NTP}=T (22-3\times T) +3/T+7\times T$$

$$F_{ck}\text{'}_\text{MTP}=T (22-3\times T) +3/T$$

Where

$F_{ck}\text{'}_\text{NTP}$ is Probable compressive strength of treated fly ash at 7, 28, 56 days
Fck′MTP is Probable compressive strength of untreated fly ash at 7, 28, 56 days T value is 1, 2, 3 respectively for 7, 28, 56 days.

![Fig 1a) Compressive Strength of HVFA Concrete](image1.png)

![Fig 1b) Compressive Strength of HVFA Concrete with fiber](image2.png)

The compressive strength results show increased with increasing fiber up to 0.25 wt % of cement 22.84 to 37.56 MPa in 7th days, 38.12 to 50.42 MPa at 28th days and 41.53.35 to 58.80 in 56th days. The results show that the higher rate of attainment in compressive strength in all mixes as shown in Fig 1b. The similar results revealed in investigations J.J.Raju et al [17-18]

### 3.1.2 Split Tensile strength

The Split strengths of concrete made with treated and untreated fly ash are given in Table 5
From the Table 5, it can be seen that the Split tensile strength of HVFAC with treated fly ash is more than that of HVFAC with untreated fly ash. The Split tensile strength of M4 mix in which cement was replaced with 50% fly ash was found to be maximum in case of HVFAC in the treated fly ash. In results trends in split tensile strength similar to compressive strength. The maximum increases in strength were found to be 40.59, 28.99, and 28.90 at 7th days, 28th days, and 56 days respectively. The Split tensile strength increased trends shown in in Fig 2a. The addition of polypropylene fiber in HVFA concrete further gained on split tensile strength at 28 days as compared to 56 days. The increases in split tensile strength with increase in PPE fiber contents up to 0.25 wt% of cement similar findings has been investigated [17-20] as shown in Fig 2b. Comparison of Similar results reduction are confirmed by [16,20].

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3.1.3 Resistance to Sulphate Attack

From the Fig 3, it can be measure the rate of concrete deterioration due to sulphate assault was estimated in terms of loss in weight and loss in strength in HVFAC with treated fly ash is less than that of HVFAC with untreated fly ash. The result shows of strength loss % it is found in mixes with M4 mix in which cement was replaced with 50 % fly ash was found to be minimum in case of HVFAC in the treated fly ash is maximum. However in case HVFAC with untreated fly ash, the result shows of strength loss % it is found that mixes with increases with addition of fly ash. The maximum strength loss % it is found that 50 % treated fly ash replacement exhibit better performances in M4 mixes, strength loss 23 % lower than the untreated fly ash replacement mixes. [21] Reported that the better improvement have been reported in sulphate resistance in the reduction of CH decreases of porosity by tobermorite gel formation and results related to the present investigation.

3.1.4 Water Absorption test

From the Fig 4a, it indicated that the water absorption results in HVFAC with treated fly ash are lower than that of HVFAC with untreated fly ash. The result shows of water absorption it is found exhibit better performances that mixes with M4 mix in which cement was replaced with 50 % fly ash was found to be minimum in case of HVFAC in the treated fly ash is maximum; also water absorption results 59.26 % lower than the untreated fly ash replacement mixes.

Faiz U.A [15] has been reported on the mechanism of reduction in water sorptivity, it is improved by ultra-fine fly ash reaction of CH. The improved bonding effect cement and aggregate reduces the pore volume, reaction related to the ultra-fine Fly ash.
3.1.5 Rapid Chloride Permeability Test

From the Fig 4b, it shown the RCPT results in HVFAC with treated fly ash is lower than untreated fly ash. The result shows that it was found in all mixes with M4 mix in which cement was replaced with 50 % fly ash was found to be lower permeability in HVFAC treated fly ash, RCPT results was found 43% lower permeability than the untreated fly ash, which enhance the low permeability in treated fly ash due to the formation of improved CSH formation, reduction of size pores. Kavitha O R [22]reported that the addition of fly ash in HVFAC increased the chloride bind capacity system. Also fly ash content increased up to 50 %, shows that the decreases in permeability at all ages of curing due to the dilution effect. The lower value of RCPT is attributed to change of concrete microstructures and refinement in the pore system, the similar influences of results have been by Faiz U.A [15]. The ultra-fine fly ash RCPT results similar reflected in treated fly ash.

4 b. Rapid Chloride Permeability Test

4. Conclusions

In this paper following comparison results on HVFAC with treated fly ash (NTP) and untreated fly ash (MTP) have been drawn for Mechanical properties & Durability studies.

The above comparison results found that the mechanical properties on treated fly ash M4 mixes more performances than the untreated fly ash. The compressive strength in treated fly ash was gained significant increased at 7 days strength compared but compared to the M1 lower strength treated fly ash. However in case HVFAC with treated fly ash mixes in M4 has significant development in compressive strength at 28th, 56th days compared to untreated fly ash and M1 mixes. Based on the above results the
optimum level replacement M4 contained 0.25 wt % of polypropylene fiber achieved higher compressive strength at 7 days, 28 days and 56 days. Further comparison studies reflect a similar trend in treated fly ash on split tensile strength. It comparison showed that treated fly ash M4 mixes with0.25 wt % of polypropylene fiber leads to significant enhancement in the split strength.

The Durability comparison studies result on treated fly ash shows that conclude based on the pozzolanic reactions CH consumes more numbers in hydration processes. In fly ash fineness alters the pore structure of concrete it causes the resistance to permeability of water. Degradation of the matrix due to the higher amount of modification in chloride ions. HVFA Concrete containing treated fly ash 50 % exhibited significant enhancement of durability performance to sulphate assault, chloride penetration, and water permeability.

5.  REFERENCE


