Appendix 1

Table 4 presents the preliminary tests carried out to develop ECC mixture. After mixing the material as explained in Section 3.2.1, the quality of distribution of PVA fibre in ECC was checked manually. If the distribution of ECC fibre in the mixture was uniform and any bundle of fibre was not observed in the ECC the mixture selected for next step. A 2% PVA fibre was used for all mixtures. Different fly ash, silica sand were tested to find the appropriate material. Aim to develop the ECC mixture a series of parameters including water to binder (cement and fly ash) ratio (W/B), Fly ash to cement ratio (FA/C) and silica sand to cement ratio (S/C) and superplasticizer (HRWR) ratio are adjusted during the tests. Chemical properties of cement, fly ash and silica sand finally selected to produce the ECC are presented in Table 1, 2 & 3 respectively.

Table 1. Properties of Cement (CEM I 52,5N)

<table>
<thead>
<tr>
<th>Oxide Analysis (%)</th>
<th>Properties</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₃</td>
<td>2.5–3.5</td>
<td></td>
</tr>
<tr>
<td>Cl</td>
<td>Less than 0.10</td>
<td></td>
</tr>
<tr>
<td>Na₂O</td>
<td>&lt;1.0</td>
<td></td>
</tr>
<tr>
<td>C₃S</td>
<td>40–60</td>
<td></td>
</tr>
<tr>
<td>C₂S</td>
<td>12–30</td>
<td></td>
</tr>
<tr>
<td>C₃A</td>
<td>7 to 12</td>
<td></td>
</tr>
<tr>
<td>C₄AF</td>
<td>6–10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface area</td>
<td>300–450 (m²/kg)</td>
</tr>
<tr>
<td></td>
<td>fc 2 day</td>
<td>25–35 (N/mm²)</td>
</tr>
<tr>
<td></td>
<td>fc 7 day</td>
<td>40–50 (N/mm²)</td>
</tr>
<tr>
<td></td>
<td>fc 28 day</td>
<td>52–65 (N/mm²)</td>
</tr>
</tbody>
</table>

Table 2. Oxide Analysis and Size of the Fly-ash used in this research (% by weight)

<table>
<thead>
<tr>
<th>Chemical material</th>
<th>EN 450 (%)</th>
<th>Superpozz V80 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>53.34</td>
<td>53.5</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>28.93</td>
<td>34.3</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>6.31</td>
<td>3.6</td>
</tr>
<tr>
<td>CaO</td>
<td>2.81</td>
<td>4.4</td>
</tr>
<tr>
<td>Na₂O</td>
<td>1.40</td>
<td>-</td>
</tr>
<tr>
<td>MgO</td>
<td>1.48</td>
<td>-</td>
</tr>
<tr>
<td>Size</td>
<td>More than 85% finer than 45µm</td>
<td>More than 80% finer than 25 µm</td>
</tr>
</tbody>
</table>
Table 3. Chemical and Physical Properties of RH110

<table>
<thead>
<tr>
<th>Oxide Analysis (% by weight)</th>
<th>Sieve NO</th>
<th>Passing (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO\textsubscript{2}</td>
<td>98.8</td>
<td>250</td>
</tr>
<tr>
<td>FeO\textsubscript{3}</td>
<td>0.09</td>
<td>180</td>
</tr>
<tr>
<td>AlO\textsubscript{3}</td>
<td>0.21</td>
<td>125</td>
</tr>
<tr>
<td>K\textsubscript{2}O</td>
<td>0.03</td>
<td>90</td>
</tr>
<tr>
<td>LOI</td>
<td>0.14</td>
<td>63</td>
</tr>
</tbody>
</table>
### Table 4. Preliminary tests carried out to develop ECC mixture

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Fly-ash</th>
<th>Silica sand</th>
<th>HRWR %</th>
<th>W/B</th>
<th>FA/C</th>
<th>S/C</th>
<th>Observation and conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cem I 52.5</td>
<td>EN450</td>
<td>AFA100</td>
<td>0.5, 1,1.5,2</td>
<td>0.22, 0.25, 0.28, 0.32</td>
<td>1.6-1.8-2</td>
<td>0.6,0.8</td>
<td>Several fibre bundles were observed in the ECC mixtures</td>
</tr>
<tr>
<td>2</td>
<td>Cem I 52.5</td>
<td>EN450</td>
<td>AF 100</td>
<td>0.5, 1,1.5,2</td>
<td>0.22, 0.25, 0.28, 0.32</td>
<td>1.6-1.8-2</td>
<td>0.6,0.8</td>
<td>Several fibre bundles were observed in the ECC mixtures</td>
</tr>
<tr>
<td>3</td>
<td>Cem I 52.5</td>
<td>EN450</td>
<td>RH110</td>
<td>0.5, 1,1.5,2</td>
<td>0.22, 0.25, 0.28, 0.32</td>
<td>1.6-1.8-2</td>
<td>0.6,0.8</td>
<td>Several fibre bundles were observed in the ECC mixtures</td>
</tr>
<tr>
<td>4</td>
<td>Cem I 52.5</td>
<td>Superpozz SV80</td>
<td>DA 110</td>
<td>0.5, 1,1.5,2</td>
<td>0.22, 0.25, 0.28, 0.32</td>
<td>1.6-1.8-2</td>
<td>0.6,0.8</td>
<td>The fibre distributed uniformly but sedimentation was observed in the mixture</td>
</tr>
<tr>
<td>5</td>
<td>Cem I 52.5</td>
<td>Superpozz SV80</td>
<td>DA 80F</td>
<td>0.5, 1,1.5,2</td>
<td>0.22, 0.25, 0.28, 0.32</td>
<td>1.6-1.8-2</td>
<td>0.6,0.8</td>
<td>The fibre distributed uniformly but bleeding was observed in the mixture</td>
</tr>
<tr>
<td></td>
<td>Cem I 52.5</td>
<td>Superpozz SV80</td>
<td>AF 100</td>
<td>0.5, 1, 1.5, 2</td>
<td>0.22, 0.25, 0.28, 0.32</td>
<td>1.6-1.8-2</td>
<td>0.6, 0.8</td>
<td>The fibre distributed uniformly but sedimentation was observed in the mixture</td>
</tr>
<tr>
<td>---</td>
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<td>---------------------------------------------------------------------</td>
</tr>
<tr>
<td>6</td>
<td>Cem I 52.5</td>
<td>Superpozz SV80</td>
<td>M6</td>
<td>0.5, 1, 1.5, 2</td>
<td>0.22, 0.25, 0.28, 0.32</td>
<td>1.6-1.8-2</td>
<td>0.6, 0.8</td>
<td>The fibre distributed uniformly but bleeding was observed in the mixture</td>
</tr>
<tr>
<td>7</td>
<td>Cem I 52.5</td>
<td>Superpozz SV80</td>
<td>M300</td>
<td>0.5, 1, 1.5, 2</td>
<td>0.22, 0.25, 0.28, 0.32</td>
<td>1.6-1.8-2</td>
<td>0.6, 0.8</td>
<td>The fibre distributed uniformly but bleeding was observed in the mixture</td>
</tr>
<tr>
<td>8</td>
<td>Cem I 52.5</td>
<td>Superpozz SV80</td>
<td>AFA100</td>
<td>0.5, 1, 1.5, 2</td>
<td>0.22, 0.25, 0.28, 0.32</td>
<td>1.6-1.8-2</td>
<td>0.6, 0.8</td>
<td>The workability of mixture was low and sedimentation was observed</td>
</tr>
<tr>
<td>9</td>
<td>Cem I 52.5</td>
<td>Superpozz SV80</td>
<td>RH110</td>
<td>0.5, 1, 1.5, 2</td>
<td>0.22, 0.25, 0.28, 0.32</td>
<td>1.6-1.8-2</td>
<td>0.6, 0.8</td>
<td>The fibre distribution was uniform without bleeding and sedimentation</td>
</tr>
<tr>
<td>10</td>
<td>Cem I 52.5</td>
<td>Superpozz SV80</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cem I 52.5</td>
<td>Superpozz SV80</td>
<td>TRUCA RB UF</td>
<td>0.22, 0.25, 0.28, 0.32</td>
<td>1.6-1.8-2</td>
<td>0.6-0.8</td>
<td></td>
<td></td>
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<tr>
<td>---</td>
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<td>11</td>
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</tr>
</tbody>
</table>

Mixture was too viscose and adding superplasticiser more than 1.5% caused to bleeding and sedimentation

Mixture was too viscose and adding superplasticiser more than 1.5% caused to bleeding and sedimentation

Mixture was too viscose and adding superplasticiser more than 1.5% caused to bleeding and sedimentation

The workability of mixtures was low and sedimentation was observed
Appendix 2

a) First impact

Time = 1ms

Time = 2ms

Time = 3ms

Time = 4ms

b) Second impact

Time = 1ms

Time = 2ms

Time = 3ms

Time = 4ms

c) Third impact

Time = 1ms
Time history of crack pattern and failure during impact tests for HFO4

a) First impact

b) Second impact
Time history of crack pattern and failure during impact tests for HFO2

Time history of crack pattern and failure during impact tests for HFO7
Time history of crack pattern and failure during impact tests for HFO1

Time history of crack pattern and failure during impact tests for LFO8
Time history of crack pattern and failure during impact tests for LFO11.
Time history of crack pattern and failure during impact tests for HPO5

C) Third impact

Time = 1ms
Time = 2ms
Time = 3ms
Time = 4ms

a) First impact

Time = 1ms
Time = 2ms
Time history of crack pattern and failure during impact tests for HPO6

Time history of crack pattern and failure during impact tests for HPO3

a) First impact
d) Fourth impact

Time = 1ms

Time = 2ms

Time = 3ms

Time = 4ms

Time history of crack pattern and failure during impact tests for LPO9

a) First impact

Time = 1ms

Time = 2ms

Time = 3ms

Time = 4ms
b) Second impact

Time = 1ms

Time = 2ms

Time = 3ms

Time = 4ms

Time history of crack pattern and failure during impact tests for LPO10

a) First impact

Time = 1ms

Time = 2ms

Time = 3ms

Time = 4ms
b) Second impact

Time = 1ms

Time = 2ms

Time = 3ms

Time = 4ms

C) Third impact

Time = 1ms

Time = 2ms

Time = 3ms

Time = 4ms
Time history of crack pattern and failure during impact tests for HFT14

a) First impact

Time = 1ms

Time = 2ms

Time = 3ms

b) Fourth impact

Time = 1ms

Time = 2ms

Time = 3ms

Time = 4ms
Time history of crack pattern and failure during impact tests for HFT12

a) First impact

1. Time = 1ms
2. Time = 2ms
3. Time = 3ms

b) Second impact

1. Time = 1ms
2. Time = 2ms
3. Time = 3ms
4. Time = 4ms
b) Second impact

Time = 1ms

Time = 2ms

Time = 3ms

Time = 4ms

C) Third impact

Time = 1ms

Time = 2ms

Time = 3ms
Time history of crack pattern and failure during impact tests for LFT16

a) First impact

Time = 1ms

Time = 2ms

Time = 3ms

Time = 4ms

b) Second impact

Time = 1ms

Time = 2ms

Time = 3ms
Time history of crack pattern and failure during impact tests for LFT21
Time history of crack pattern and failure during impact tests for LFT19
b) Second impact

Time history of crack pattern and failure during impact tests for HPT13
a) First impact
- Time = 1ms
- Time = 2ms
- Time = 3ms
- Time = 4ms

b) Second impact
- Time = 1ms
- Time = 2ms
- Time = 3ms
- Time = 4ms
Time history of crack pattern and failure during impact tests for HPT15

a) First impact

Time = 1ms

Time = 2ms

Time = 3ms

Time = 4ms

b) Second impact

Time = 1ms

Time = 2ms

Time = 3ms
Time history of crack pattern and failure during impact tests for LPT18

Time = 2ms

Time = 3ms

Time = 4ms

a) First impact

Time = 1ms

Time = 2ms

Time = 3ms
C) Third impact

Time history of crack pattern and failure during impact tests for LPT17
a) First impact

Time = 1ms

Time = 2ms

Time = 3ms

Time = 4ms

b) Second impact

Time = 1ms

Time = 2ms

Time = 3ms
Time history of crack pattern and failure during impact tests for LPT20