UHPFRCC: Development & Applications

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Layout

- Concrete as construction material
- Development of new concretes
- Recent advancements
- Applications
- Future
- Conclusions
The use of cementing materials is more than 2000 years old.

Pozzolana + Limestone + Clay = mortar!

In 1824 Joseph Aspdin developed and patented “Portland Cement”.

Extensive research led to the development of better cements.

Today concrete is the most widely used construction material in the world.

The yearly production of concrete is of the order of 13 billion tones.
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Concrete Developments

• In early 1970s experts predicted that $f_{cu}$ will not exceed 43 MPa.
• Few years later the threshold of 43 MPa broke.
• In early 1990s 131 MPa concrete used in practice.
• ACI defines HSC as the concrete with $f_{cu}$ more than 41 MPa.
• Today the characterization of HSC has been altered significantly.
Concrete Developments

- Further research led to improved microstructure and hence increased compressive strength.
- Concretes with $f_{cu}$ larger than 130 MPa made possible (HPC).
- Compressive strength increased, but how about ductility and durability?
- FRC – HPFRC
- The fundamental concept: the enhanced microstructure
Concrete Developments – Role of Microsilica

Cementitious Materials

- A number of pozzolanic materials available (silica fume, fly ash).
- The particles of such material are extremely fine and hence improve packing.
- Production of secondary hydrates by pozzolanic reaction.

Concrete Developments - Superplasticisers

Role of Superplasticisers:

- Defloculation of cement and microsilica particles.
- Reduction in water demand without reducing workability.
- Creating a better packing in the matrix.
Concrete Developments

Fiber Reinforcement:

- Fiber type used in concrete still under debate.
- Volume fraction is of major importance.
- Mixing of fibers is a major issue.
- Mechanical properties of fibered matrices.
- Fit for purpose.

Recent Advancements

- A new class of materials – UHPFRCC
- Unique production techniques.
- Special curing methods.
- Significantly improved mechanical properties.
- High durability.
- High energy absorption capacity.
- Very brittle microstructure.

- Macro Defect Free cement (MDF)
- Slurry Infiltrated Fibre Concrete (SIFCON)
- Engineered Cementitious Composites (ECC)
- Reactive Powder Concrete (RPC)
- Ductal®
- CARDIFRC®
## Recent Advancements

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### Young’s Modulus (GPa) – Compressive Strength (MPa) – Indirect Tensile Strength (MPa)

<table>
<thead>
<tr>
<th>Material</th>
<th>Compressive Strength (MPa)</th>
<th>Indirect Tensile Strength (MPa)</th>
<th>Young’s Modulus (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPC</td>
<td>200</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>Ductal®</td>
<td>180</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>CARDIFRC®</td>
<td>180 - 210</td>
<td>20 - 30</td>
<td>47 - 50</td>
</tr>
</tbody>
</table>
Recent Advancements

CARDIFRC®

- Two different mixes (designated CARDIFRC®, Mix I and Mix II).
- Two different lengths of fibre used at high volume fractions.
- Optimisation of grading of quartz sands used led to considerable reduction in the water demand.
- It is characterised by very high compressive strength, high tensile/flexural strength and high energy-absorption capacity.
Recent Advancements

CARDIFRC® Mix I and Mix II (per m³)

<table>
<thead>
<tr>
<th>Constituents (kg)</th>
<th>Mix I</th>
<th>Mix II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>855</td>
<td>744</td>
</tr>
<tr>
<td>Microsilica</td>
<td>214</td>
<td>178</td>
</tr>
<tr>
<td>Quartz sand:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-300μm</td>
<td>470</td>
<td>166</td>
</tr>
<tr>
<td>250-600μm</td>
<td>470</td>
<td>-</td>
</tr>
<tr>
<td>212-1000μm</td>
<td>-</td>
<td>335</td>
</tr>
<tr>
<td>1-2mm</td>
<td>-</td>
<td>672</td>
</tr>
<tr>
<td>Water</td>
<td>188</td>
<td>149</td>
</tr>
<tr>
<td>Superplasticiser</td>
<td>28</td>
<td>55</td>
</tr>
<tr>
<td>Fibres: - 6mm</td>
<td>390</td>
<td>351</td>
</tr>
<tr>
<td>- 13mm</td>
<td>78</td>
<td>117</td>
</tr>
<tr>
<td>Water/cement</td>
<td>0.22</td>
<td>0.20</td>
</tr>
<tr>
<td>Water/binder</td>
<td>0.18</td>
<td>0.16</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Mix I</th>
<th>Mix II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indirect tensile strength (MPa)</td>
<td>28.6</td>
</tr>
<tr>
<td>S-I Specific Fracture Energy (J/m²)</td>
<td>30000</td>
</tr>
<tr>
<td>Compressive Strength (MPa)</td>
<td>207.0</td>
</tr>
</tbody>
</table>

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Contour plots showing the X-ray absorption (left) and fibre distribution (right) for a cylinder (100 mm diameter) cross-section for (a) slice 3 and (b) slice 10.

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Recent Advancements

Applications

- High rise buildings
- Off-shore structures
- Underwater structures
- Long span, heavy duty bridges
- Shotcrete
- Repair and strengthening of existing structures
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Future

• The target is not the strength but durability.
• Mix optimization.
• Exploitation of waste materials.
• Nanomaterials and future developments.
• Retrofitting of existing concrete structures.
• Composite applications.
• Protection against blast and impact.
• Nuclear waste disposal units.

Conclusions

Advantages
• More durable concretes.
• Utilization of waste materials.
• Extended life circle.
• Can give a wide range of applications regarding repairs.
• Can solve the problem of nuclear waste disposal.

Disadvantages
• Cost
• Specialized production techniques.