Sustainable and Economic Concrete

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Sustainable and Economic Concrete

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Sustainable development

- Qatar National Vision 2030
  - Human, Social, Economic and Environmental development
  - Economic growth is balanced with protection of the environment
- Qatar National Development Strategy
  - Waste management hierarchy
  - Target to recycle 38%
Research into practice

- Partnership between government and industry
- Applying new technology suitable for Qatar and the region
- Evidence-based research
- Implementation in practice
- Updating construction specifications and practice
- Support government strategy
Achievements

- Recycling in construction
  - First recycling specification in Qatar and the GCC
- National and Regional recognitions
  - Qatar Contractors Forum 2013.
  - Green Mind Award 2014.
  - Qatar Green Building Award 2016.
- Gulf Standards
  - Qatar Recycling Standard was adopted as GCC standard in 2015.
Sustainable and economic concrete

- Sustainable development
- Aggregate replacement
  - Wadi gravel
  - Steel slag
- Cement replacement
  - Used cooking oil
- Economic & environment benefits
Wadi gravel in concrete

- Private Engineering Office
- TRL + MME (Qatar Standards)
- Mekaines site
  - Vast quantities
  - Sand rejects (coarse + sulphate)
  - Agriculture soil
- Convert rejects into high-value aggregate
- Sustainable and economic development
Aggregate constituents

<table>
<thead>
<tr>
<th>Limestone (36%)</th>
<th>Gypsum Matrix (20%)</th>
<th>Quartz (17%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhyolite (9%)</td>
<td>Granite (7%)</td>
<td>Quartzite (5%)</td>
</tr>
</tbody>
</table>
# Aggregate properties – As received

<table>
<thead>
<tr>
<th>Property</th>
<th>QCS limit</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fines content</td>
<td>2% Max</td>
<td>8.5</td>
<td>5.5</td>
<td>9.5</td>
<td>7.5</td>
<td>4.3</td>
</tr>
<tr>
<td>Clay lumps and friable particles</td>
<td>2% Max</td>
<td>0.22</td>
<td>0.46</td>
<td>0.09</td>
<td>0.66</td>
<td>0.16</td>
</tr>
<tr>
<td>Lightweight pieces</td>
<td>0.5% Max</td>
<td>0.9</td>
<td>0.6</td>
<td>1.1</td>
<td>0.7</td>
<td>0.4</td>
</tr>
<tr>
<td>Los Angeles abrasion</td>
<td>30% Max</td>
<td>27</td>
<td>31</td>
<td>34</td>
<td>34</td>
<td>26</td>
</tr>
<tr>
<td>Particle density</td>
<td>2.0 Min</td>
<td>2.71</td>
<td>2.74</td>
<td>2.69</td>
<td>2.70</td>
<td>2.72</td>
</tr>
<tr>
<td>Water absorption</td>
<td>2% Max</td>
<td>1.96</td>
<td>1.64</td>
<td>1.84</td>
<td>1.90</td>
<td>1.84</td>
</tr>
<tr>
<td>Soundness</td>
<td>15% Max</td>
<td>20</td>
<td>9</td>
<td>17</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>Acid-soluble chlorides</td>
<td>0.04% Max</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Acid-soluble sulphate</td>
<td>0.3% Max</td>
<td>1.15</td>
<td>2.63</td>
<td>4.08</td>
<td>2.70</td>
<td>1.20</td>
</tr>
</tbody>
</table>
Full-scale building trials – Mekaines
Steel slag in concrete

- Qatar Steel
- TRL + MME + Ashghal
- 1.6 Mt stockpiled
- 350k tonnes / year
- Potential use in:
  - Asphalt
  - Concrete
  - Subbase
- Radiation study
Routine testing – SG & absorption

Water Absorption to ASTM C127

- Water Absorption (%)
- Date

Expansion by ASTM D4792 test

- Expansion (%)
- Date

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Slag weathering trials

- Lack of rain in Qatar
- Crushing after weathering
- Slag sample of 20t – 5 sizes
- Water spray – 1 year
- Stable slag products

**pH - Slag 2014**

- 10.75
- 11.00
- 11.25
- 11.50
- 11.75
- 12.00

Number of Weeks

- Fines (2014)
- 5 – 10 (2014)
- 10 – 20 (2014)
- >20 (2014)
Development of concrete products

- Precast concrete applications
- Currently 20% permitted by MME
## Concrete mixtures

<table>
<thead>
<tr>
<th>No.</th>
<th>Mix</th>
<th>PC</th>
<th>Water</th>
<th>Fine</th>
<th>Coarse aggregate</th>
<th>$S_P^{l/m^3}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sand</td>
<td>Slag</td>
</tr>
<tr>
<td>1</td>
<td>Control</td>
<td>370</td>
<td>163</td>
<td>758</td>
<td>-</td>
<td>1209</td>
</tr>
<tr>
<td>2</td>
<td>20% Slag (fine)</td>
<td>370</td>
<td>163</td>
<td>606</td>
<td>215</td>
<td>1209</td>
</tr>
<tr>
<td>3</td>
<td>50% Slag (fine)</td>
<td>370</td>
<td>163</td>
<td>379</td>
<td>537</td>
<td>1209</td>
</tr>
<tr>
<td>4</td>
<td>20% Slag (coarse)</td>
<td>370</td>
<td>163</td>
<td>758</td>
<td>-</td>
<td>967</td>
</tr>
<tr>
<td>5</td>
<td>50% Slag (coarse)</td>
<td>370</td>
<td>163</td>
<td>758</td>
<td>-</td>
<td>605</td>
</tr>
<tr>
<td>6</td>
<td>100% Slag (coarse)</td>
<td>370</td>
<td>163</td>
<td>758</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Fresh concrete – Slump

20% Slag (fine) ✔️

50% Slag (fine) ✗

100% Slag (coarse) ✔️
Concrete strength – C40

The graph shows the compressive strength (MPa) of concrete at different ages (3 days, 7 days, 28 days) for various slag additions:

- Control
- 20% Slag (Fine)
- 50% Slag (Fine)
- 20% Slag (Coarse)
- 50% Slag (Coarse)
- 100% Slag (Coarse)

The graph indicates that the addition of slag increases the compressive strength of concrete, with 100% Slag (Coarse) showing the highest strength at all ages.
Durability – Absorption & RCP

- **Water penetration (QCS 5-30mm)**
  - Control
  - 20% Slag (Fine)
  - 50% Slag (Fine)
  - 20% Slag (Coarse)
  - 50% Slag (Coarse)
  - 100% Slag (Coarse)

- **RCP (500-4000 Coulombs)**
  - Control
  - 20% Slag (Fine)
  - 50% Slag (Fine)
  - 20% Slag (Coarse)
  - 50% Slag (Coarse)
  - 100% Slag (Coarse)
VegeBlocks – Cement-less blocks

- Qatar National Research Fund
- TRL, MME, Doha Municipality
- 100% recycled materials
- No cement – used cooking oil as a binder
- Any aggregate (fines, salts, contamination)
- Thermal treatment – oil polymerisation
Optimisation and durability

- Optimised mixtures
  - Aggregate/oil type
  - Curing temperature & duration
  - Compaction

- Durability
  - Water
  - Salts (sulfate, chloride)
  - Fuel resistance
  - Fire resistance
Curing and product improvement
Constructed VegeBlock wall
Economic, Sustainability & Environment Benefits

- **Economic**
  - Cost savings - materials
  - New business opportunities
  - Similar performance to conventional materials.

- **Sustainability**
  - Reliance on local resources
  - Sustainable supply of materials
  - Support government strategy

- **Environment**
  - Reduce landfill
  - Reduce carbon emissions
  - Protect the environment
Conclusions

- Government support to sustainable development
- Working in partnership with industry
- Support government strategy
- Minimise waste to landfill
- Develop high-value products
- Similar performance to conventional materials
- Economic & environment benefits
- More case studies!!!
Thank you