Heat of hydration in Mass pours using Supplementary Cement Replacements for High performance Concrete
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Learning objectives

- Heat of hydration for Mass pours
- Thermal cracking and Delayed Ettringite formation DEF
- Various uses and applications of Mass pours
- Factors that effect temperature raise in mass pours
- Sand witch method of concrete placement with case studies
Chemical reaction between cement and water is exothermic liberating heat.

Mass Pour: ACI 116 defines Mass Pours as “any volume of concrete with dimensions large enough to require that measures be taken to cope with generation of heat from hydration of cement and attendant volume changes to minimize cracking”.

Raft foundations, Pile caps, Dams, Transfer slabs, large columns, core walls, tunnel lining etc having large thickness exhibit higher heat of hydration.

Supplementary cementicious materials like GGBS, Fly ash help reduce heat of hydration for mass pours.
Large Mass Pours

Project: Sky Spiral Tower - Dubai
Raft Foundation 22,000+ m³

Project: Landmark Tower - AUH
Raft Foundation 16,000+ m³
Guinness World Record Pour

Project: Geepas Tower - Dubai
Raft Foundation 19,793+ m³
2000+ trips 3 batching plants
High-rise Towers

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Industrial Projects

Emal - Abu Dhabi

Khalifa Port - Abu Dhabi

Borouge - Abu Dhabi

NPP - Doha
What happens if heat of hydration is high?

- Cracking due to thermal behavior,
- Loss of structural integrity
- Loss of monolithic action,
- Shortening of service life,
- Seepage through cracks
- In dams, tunnel linings etc cracks are objectionable and unacceptable
- Delayed Ettringite Formation
Increasing Portland Cement Content
Increasing placing temperature
Increasing pour thickness
Increasing restraint

How to reduce crack widths:

By increasing % of horizontal reinforcement and by using smaller diameter with minimum permissible cover
Main causes for Thermal contraction cracking are:

- Temperature differential across concrete sections
- Rapid cooling of surface
- Localized restraint against contraction

Thermal contraction cracking typically forms 1-2 weeks after casting well after plastic shrinkage cracking and well before drying shrinkage cracking.
Thermal Contracting Cracking

- No edge restraint
  - Free to shrink?
  - Less “Self-insulation” from lower section thickness
- Thermal contraction of concrete after hardening
- Base restraint from mature concrete
- Sections > 0.5m thick considered “Self-Insulating”
- Internal restraint
If concrete is subject to high temperature during curing ettringite formation may be delayed and its gradual formation in cooled surface may lead to expansion and cracking

- It may take 8 - 20 years for the cracking to be apparent
- $T_p < 60^\circ C$ - No risk
- $T_p < 70^\circ C$ - Very low risk
- $T_p < 80^\circ C$ - Low risk
Measures to control differential temperature

Sand witch method - Mass pour split into sections with variable temperatures

- Lower fresh concrete temperature in the central portion to reduce core temperature
- Higher fresh concrete temperature in the surface portion to control differential temperature between the core and the surface.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Temperature</th>
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</thead>
<tbody>
<tr>
<td>Top 1/3 layer</td>
<td>32°C</td>
</tr>
<tr>
<td>Middle 1/3 layer</td>
<td>25°C</td>
</tr>
<tr>
<td>Bottom 1/3 layer</td>
<td>32°C</td>
</tr>
</tbody>
</table>
Case studies of mass pours

Grade: C 65/20 (OPC + 60%GGBS + MS), Transfer beam, temp ≤ 30°C
Case studies of mass pours

Grade: SCC 65/20 (OPC + 60%GGBS + MS), Transfer beam 2.5X4.0X37.0m, sandwich temp ≤ 30/22/30°C
Case studies of mass pours

Grade: C 70/85 (OPC + 50%GGBS + 8%MS) – 510 Kg, Raft depth of 2.0 m, Sandwich method 32/25/32°C
Case studies of mass pours

Grade: C 75/90 (OPC + 16%Fly ash + 9%MS) – 530 kg, Core wall 1m X 3.6m, temp ≤ 25°C
Grade: C 55/70 (OPC + 50%GGBS + 5%MS) – 460kg, Raft depth – 3.0m, temp ≤ 25°C
Grade: C 60 (OPC + 50%GGBS + 8%MS) - Raft varying depth of 0.9 - 2.0 m
Challenges faced in middle east for mass pours

- Grades for raft foundations & transfer beam increased from 40-45 to 60-85 MPa
- High grade, higher cementitious and higher heat of hydration
- Max core temperature - 70°C
- Max differential temperature - 20°C, difficult to achieve in winter months without insulation
- Fresh concrete temperature - 25°C, difficult to achieve in summer
- Strength at 28 days even for SCM rich mixes
- Large depth pours with huge volume placed in one time
Insulation of mass pours
Insulation of mass pours
Section thickness on heat of hydration
How Ready mix supplier can help reduce fresh concrete temperature

- Store Cement in silos for at least 2 days before any large pour
- Ensure sufficient shaded area for aggregates
- Ensure chilled water temperature is always below 3-4 deg
- Having sufficient chiller plants and chilled water storage including sub-cooling
- Ensure sufficient capacity ice plants and large ice storage
Recommendation

Project specifications for mass pours shall recommend

- Lower Concrete grades,
- Thinner sections or Construction joints to restrict thickness
- Higher replacement with GGBS or Fly ash
- For high strength concrete, 56/90 days acceptance for strength
- Lower fresh concrete temperature or sand witch method of placing
- Insulation of concrete surface, delay in removal of formwork
- Higher limits for core & differential temperatures
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“Green Concrete”

Thank You