

Effect of Paste-to-Voids Volume Ratio on the Performance of Concrete Mixtures

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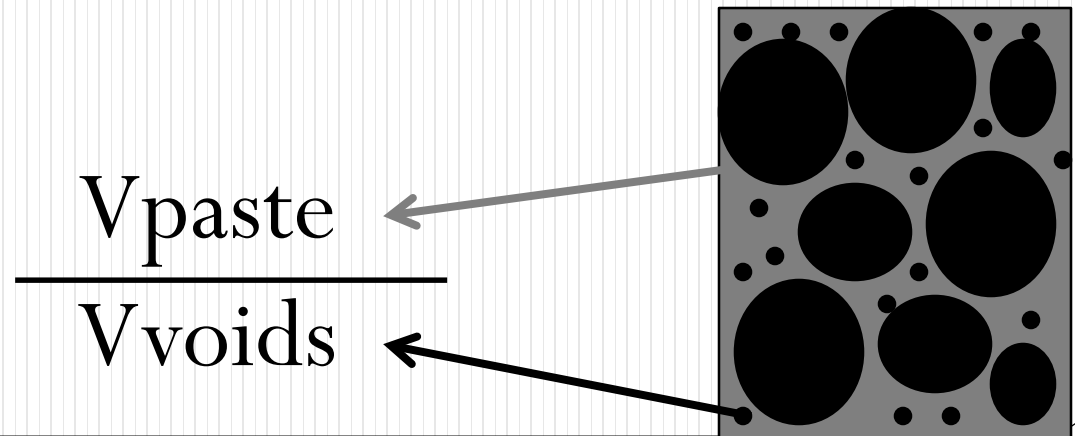
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Background

- In concrete mixes, enough cement paste should be provided that:
 - not only fills the voids between aggregates
 - but also covers the aggregates and separates them



Background

- Overall performance is affected by the mix design variables such as:
 - Quantity and type of the cementitious materials
 - Quality of the paste
 - Shape, texture, gradation and size of aggregates
- &
- The interactions between these variables

Background

What is mix proportioning?



Background

- Concrete is a complex material...

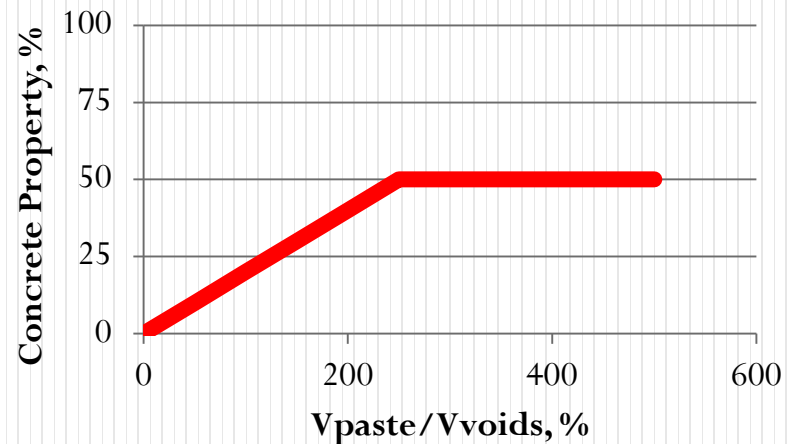


Motivation

- Current mix proportioning methods are predominantly prescriptive-based
 - material quantity ↑
 - cost ↑
 - sustainability ↓
- The construction industry has been moving from prescriptive towards performance-based (P2P) specifications

Purpose

- To investigate the critical minimum paste requirement for a mixture by analyzing the effect of paste-to-voids volume ratio on concrete properties



Materials

- ASTM C150 Type I ordinary portland cement
- ASTM C618 Class F fly ash
- ASTM C618 Class C fly ash
- ASTM C989 slag cement
- 1” nominal maximum size crushed limestone
- No 4 nominal maximum size concrete sand
- ASTM C494 Type F high range water reducer

Variables

- Binder content: 400, 500, 600 and 700 pcy
- w/b: 0.35, 0.40, 0.45 and 0.50
- Binder systems:
 - 100% ordinary portland cement (OPC)
 - 80% OPC+20% Class F fly ash
 - 80% OPC+20% Class C fly ash
 - 60% OPC+40% Slag cement
- Fixed aggregate system
 - Fine-to-total aggregate ratio: 0.42



Total matrix
64 mixtures

Tested Properties

- Workability
- Air content
- Setting time
- Compressive strength
- Rapid chloride penetration
- Air permeability

Results

- If there is insufficient paste to fill all of the voids between the aggregate particles, then performance is likely to be compromised
- Once adequate paste is obtained, then the quality of paste (not the quantity) dominates the trends

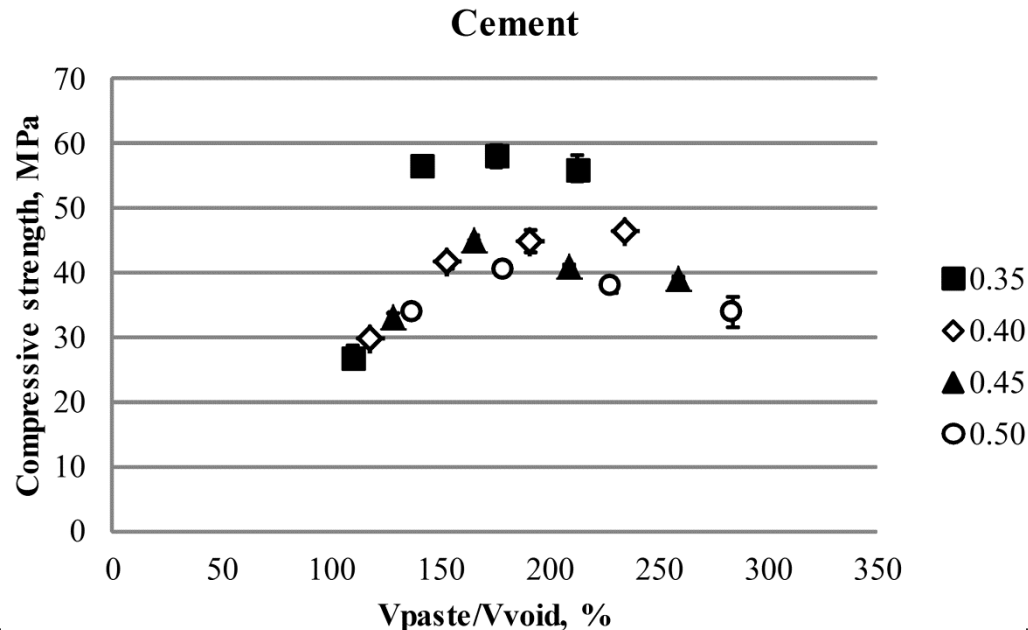
Workability

- A minimum of 1.5 times more paste is required than the voids between the aggregate particles to achieve a workable mix
- Below this number, even a high dosage of HRWR did not contribute to improved workability



Compressive Strength

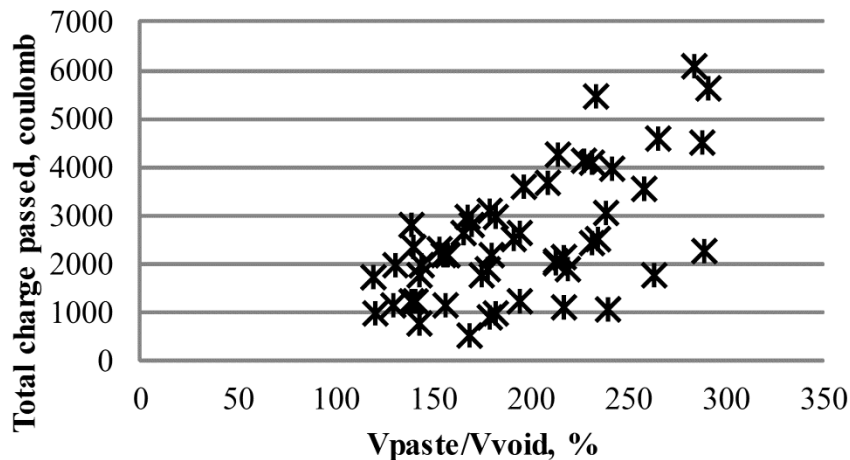
- Strength increased with increasing paste content, up to a limit
- Once a certain paste content was reached; strength became independent of paste content



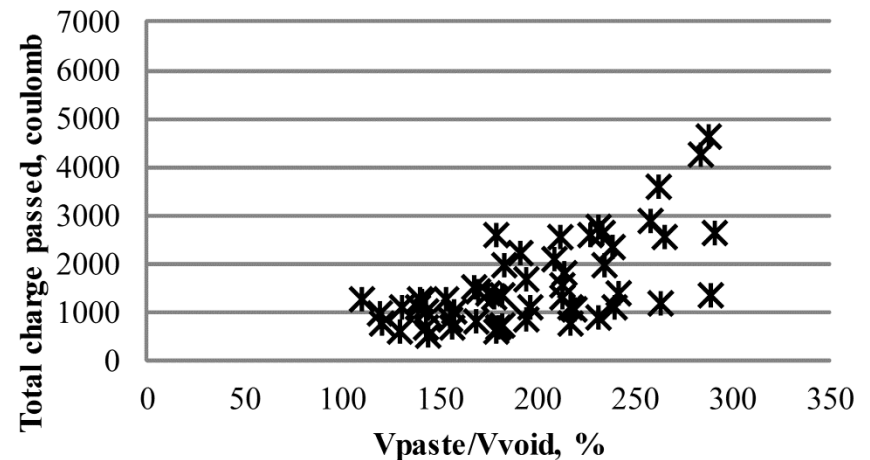
Chloride Penetration

- Increasing the paste volume increased the chloride penetrability
- Hydration at later ages helped to fill some of the capillary voids and reduced penetrability

28-day

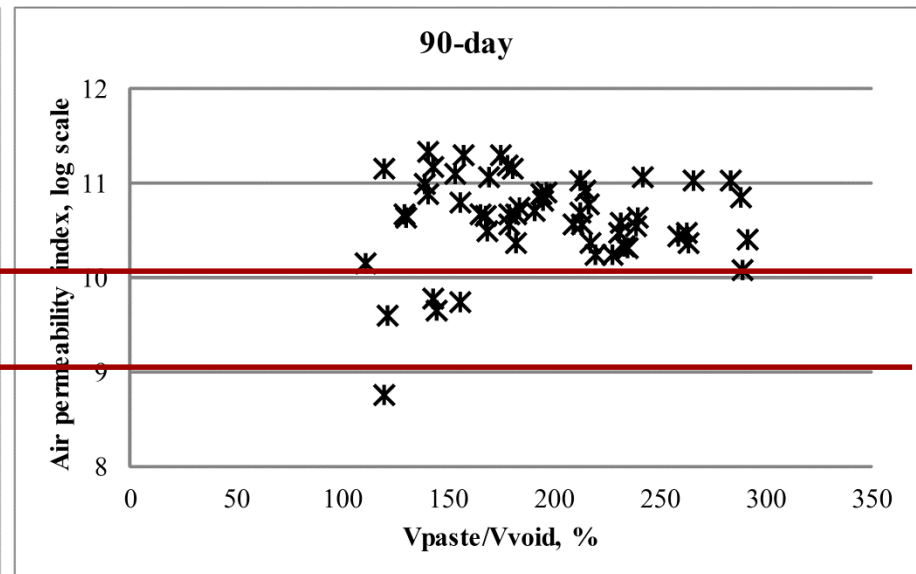
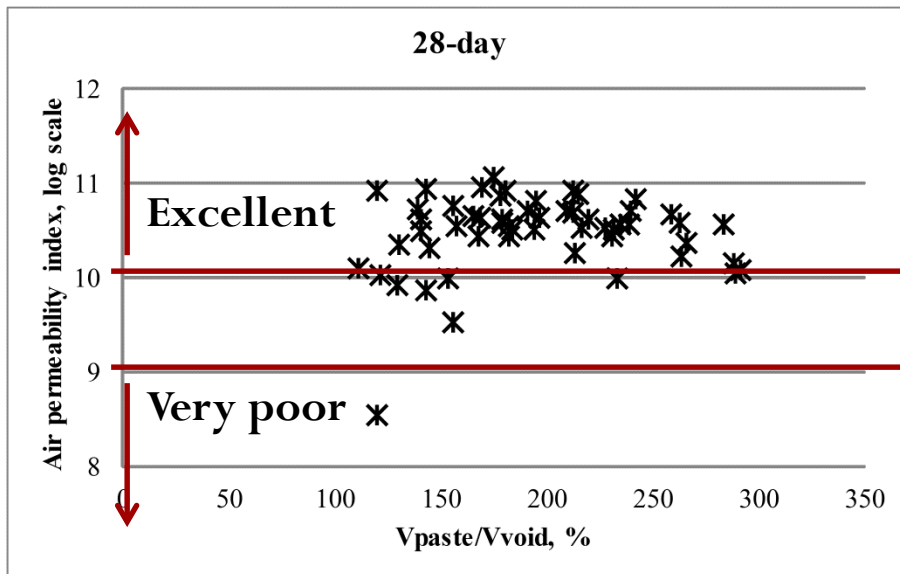


90-day



Air Permeability

- Higher air permeability index indicates lower permeability
- Increasing V_p/V_v above certain value decreased permeability
- When V_p/V_v was increased from 100 to 150%, permeability decreased likely because mixtures with low binder content had macro porosity



Conclusions

Critical minimum paste requirement
 $V_{paste} / V_{voids}, \%$

Property	OPC	F ash	C ash	Slag
Workability	150	150	125	125
Compressive strength	150	175	150	175
Air permeability	175	175	125	200

Concluding Remarks

- ~1.5 times more paste by volume is required than voids between the aggregates for minimum workability
- For a given w/cm , increasing cementitious content:
 - does not significantly improve compressive strength
 - increases chloride penetrability
 - Increases air permeability

Questions & Comments

