American Concrete Institute®
Advancing concrete knowledge

Durability and Long-Term Performance of SCC Part 2 of 2

ACI Spring 2010 Xtreme Concrete Convention
March 21 - 25, Chicago, IL

ACI Web Sessions

The audio for this web session will begin momentarily and will play in its entirety along with the slides.

However, if you wish to skip to the next speaker, use the scroll bar at left to locate the speaker's first slide (indicated by the icon in the bottom right corner of slides 9 and 37). Click on the thumbnail for the slide to begin the audio for that portion of the presentation.

Note: If the slides begin to lag behind the audio, back up one slide to re-sync.

ACI Web Sessions

ACI is bringing you this Web Session in keeping with its motto of "Advancing Concrete Knowledge." The ideas expressed, however, are those of the speakers and do not necessarily reflect the views of ACI or its committees.

Please adjust your audio to an appropriate level at this time.

ACI Web Sessions

ACI Web Sessions are recorded at ACI Conventions and other concrete industry events. At regular intervals, a new set of presentations can be viewed on ACI's website free of charge.

After one week, the presentations will be temporarily archived on the ACI website or made part of ACI's Online CEU Program, depending on their content.

ACI Online CEU Program

ACI offers an easy-to-use Online CEU Program for anyone who needs to earn Continuing Education credits.

Once registered, you can download and study reference material. After passing a 10-question exam on the material, you will receive a certificate of completion that you can present to local licensing agencies.

Topics recently added to the program:

- RAP Bulletin 10: Leveling and Reprofiling of Vertical and Overhead Surfaces
- RAP Bulletin 11: Slabjacking
- RILEM Report on Self-Compacting Concrete (Parts 1 and 2)

Visit www.concrete.org/education/edu_online_CEU.htm for more information.

ACI Web Sessions

This ACI Web Session includes two speakers presenting at the ACI Xtreme Concrete convention held in Chicago, IL, March 21st through 25th, 2010.

Additional presentations will be made available in future ACI Web Sessions.

Please enjoy the presentations.

ACI WEB SESSIONS

American Concrete Institute®
Advancing concrete knowledge

Durability and Long-Term Performance of SCC Part 2 of 2

ACI Spring 2010 Xtreme Concrete Convention
March 21 - 25, Chicago, IL

ACI WEB SESSIONS

Patrick Bamonte, is an Assistant Professor in the Civil Engineering School of Politecnico di Milano, Italy, where he earned his MS in civil engineering (majoring in structures) in 2001 and his PhD in structural engineering in 2006. In recent years he has been involved in several national and international research projects. His main research interests are the behavior of reinforced and precast concrete structures subjected to fire, reinforced concrete slabs, high temperature characterization of high-performance and ultra-high-performance concretes, and bond between reinforced bars and normal-strength and high performance concrete. Mr. Bamonte is author and coauthor of over 30 publications in international journals and conference proceedings. He is a member of FIB Task Group 4.3, "Fire Design of Concrete Structures."

ACI WEB SESSIONS

ACI Spring 2010 Convention
March 21-25, 2010 – Chicago (USA)

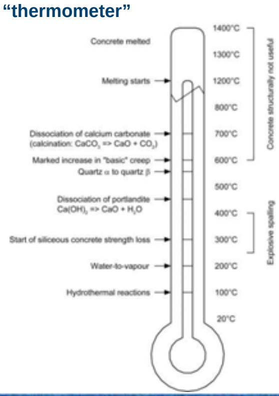
POLITECNICO DI MILANO

High-Temperature Resistance of Self-Consolidating Concrete

Patrick Bamonte and Pietro G. Gambarova
Politecnico di Milano – Milan (Italy)

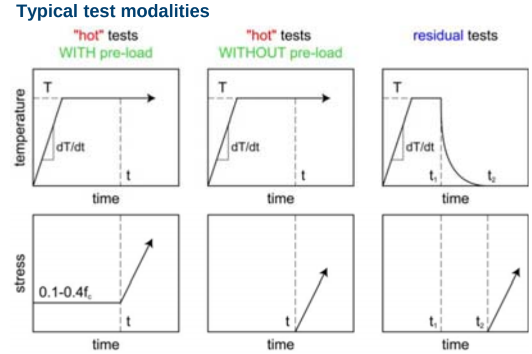
ACI WEB SESSIONS

The concrete "thermometer"



ACI WEB SESSIONS

Typical test modalities



The heating rate (dT/dt) is usually very low (0.5-2.0°C/min).

ACI WEB SESSIONS

First phase of the project (2005-2007)

- Three SCCs (NSC, HPC and HSC, f_c = 50, 80 and 90 MPa) to be investigated with reference to:
  1. stress-strain curves in compression;
  2. tensile and compressive strength;
  3. elastic modulus;
  4. fracture energy;
  5. thermal diffusivity;
  6. comparison with available test results
- test conditions: high temperature (hot properties) and after cooling (residual properties)
- heating technique (hot tests): pre-heating of insulated cylinders
- reference temperatures: T = 20, 200, 400 and 600°C

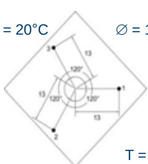
Mix Design

Concrete No. and type	1 - NSC	2 - HPC	3 - HSC
Cement type	II/A-LL 42.5	I 52.5	I 52.5
Cement content (c) [kg/m³]	350	480	520
Calcareous filler [kg/m³] (cf/c)	130 (0.37)	100 (0.21)	100 (0.19)
Acrylic superplasticizer/cement	1.2%	2.0%	2.0%
Water [kg/m³] (w/c)	175 (0.50)	168 (0.35)	172 (0.33)
Aggregate - d_a [mm]/mass [kg/m³] Type	16/1700 mixed nat.	16/1600 mixed nat.	16/1600 mixed nat.
Mass per unit volume [kg/m³]	2359	2358	2402
f_c [MPa]	51	82	90

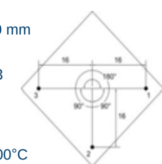
Hot tests in compression
Pre-heating technique

T = 20°C

∅ = 100 mm, h = 200 mm

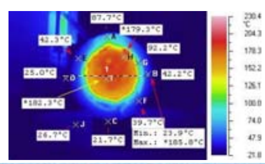


LVDT: No 1, 2, 3

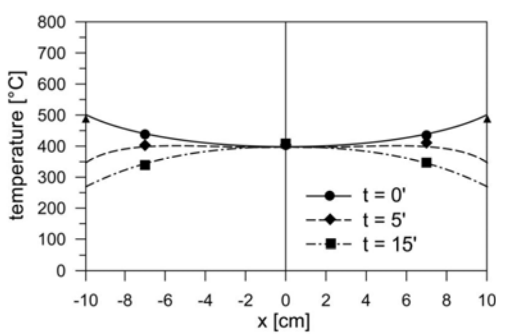


T = 200, 400 and 600°C

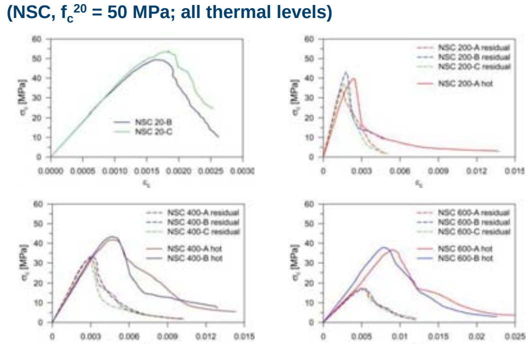
Measurements of the temperature decrease



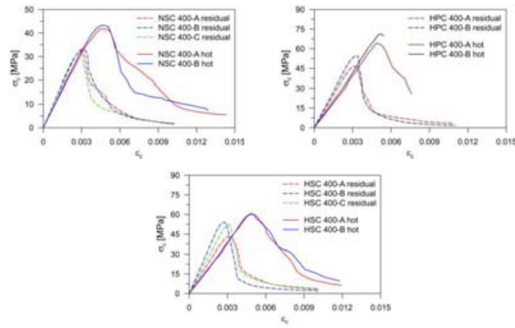
Temperature profiles along the specimen axis



Hot and residual stress-strain curves
(NSC, f_c^{20} = 50 MPa; all thermal levels)

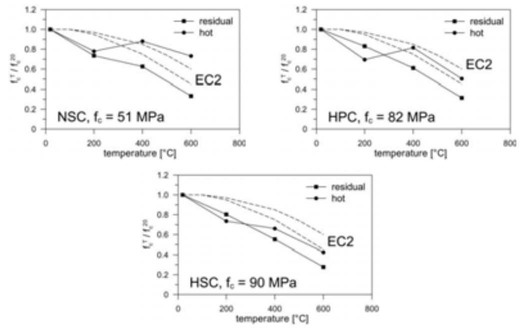


Hot and residual stress-strain curves (T = 400°C, all concretes)



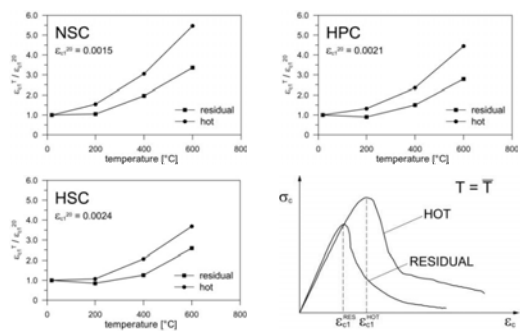
ACI WEB SESSIONS

Relative decay of the compressive strength



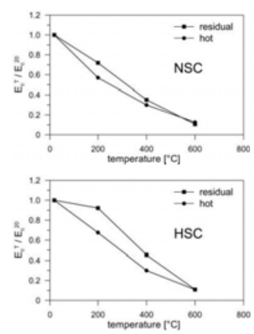
ACI WEB SESSIONS

Generalized increase in deformability



ACI WEB SESSIONS

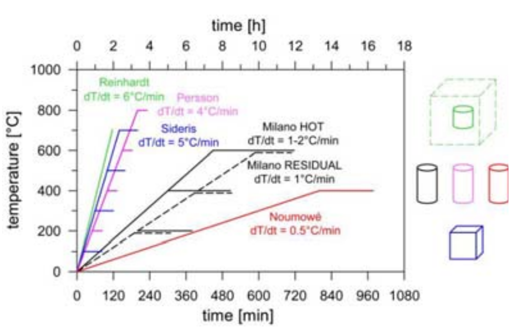
Relative decay of the elastic modulus



E_c^{HOT}/E_c^{RES} at 400°C	NSC	HPC	HSC
	0.83	0.75	0.70
Viscosità termica!			

ACI WEB SESSIONS

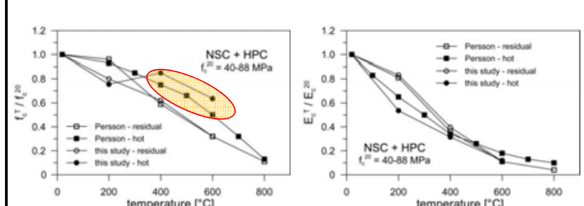
Comparison with available literature Heating rates



ACI WEB SESSIONS

Comparison with the literature (1)

Persson (2004)



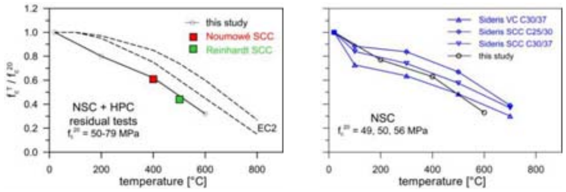
ACI WEB SESSIONS

Comparison with the literature (2)

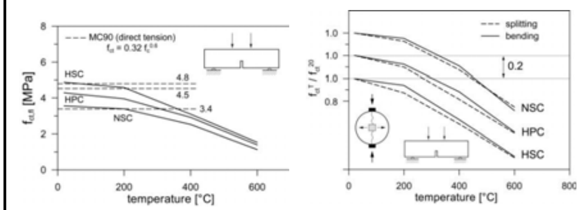
Noumowé et al. (2006)

Reinhardt and Stegmaier (2006)

Sideris (2007)

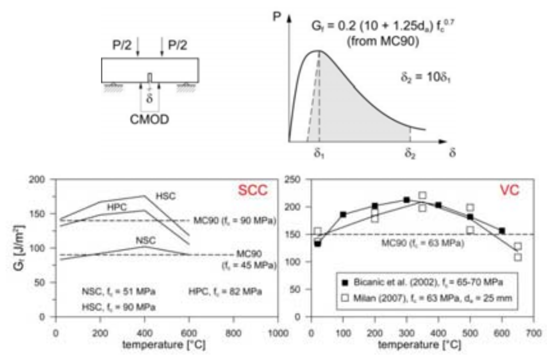


Residual tensile strength in bending and by splitting

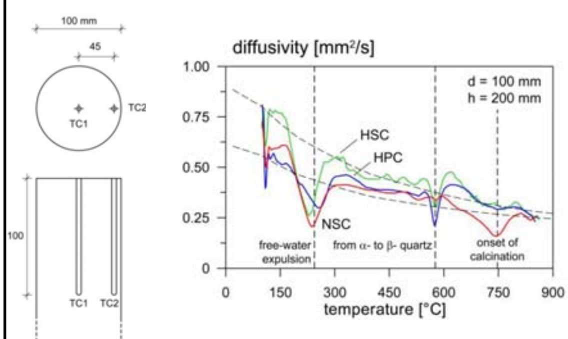


$f_{ct,fl} \approx f_{ct,sp}$ = 3.5-4.0 MPa NSC
= 4.3-5.5 MPa HPC
= 4.9-6.0 MPa HSC

Residual fracture energy



Thermal diffusivity



Second phase of the project (2009-2010) (in cooperation with M. Acito)

- Two SCCs (HPC, f_c = 70 and 80 MPa) to be investigated with reference to:
  1. compressive strength;
  2. elastic modulus;
  3. sonic tests (for the purpose of NDT);
  4. stress-strain curves in compression (T = 400 and 600°C).
- test conditions: after cooling (residual properties)
- reference temperatures: T = 20, 200, 400 and 600°C

Peculiar features

Dives in Misericordia, Roma, Arch. R. Meier

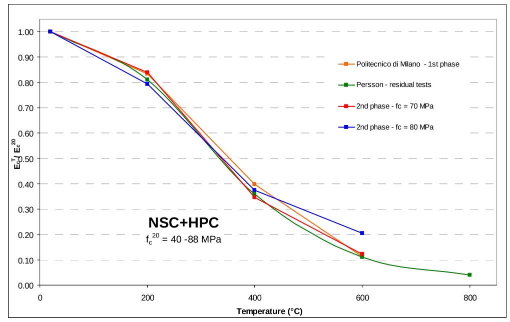
White concrete

Photocatalitic action

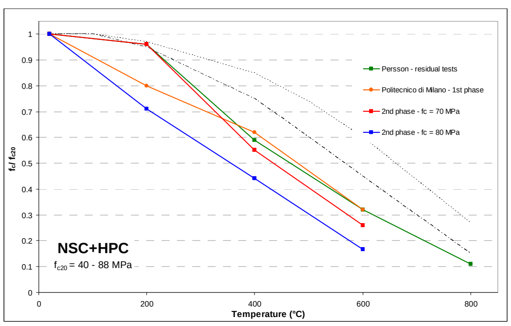
Mix Design

Concrete No. and type	1 - HPC	2 - HPC
Cement type	I 52.5	I 52.5
Cement content (c) [kg/m^3]	200	450
Blast furnace slag	300	-
Superplasticizer/cement	0.5%	1.0%
Water [kg/m^3] (w/c)	175 (0.35)	200 (0.45)
Aggregate - d_a [mm]/mass [kg/m^3] Type	14/1700 siliceous	14/1650 calcareous
f_c [MPa]	70	80

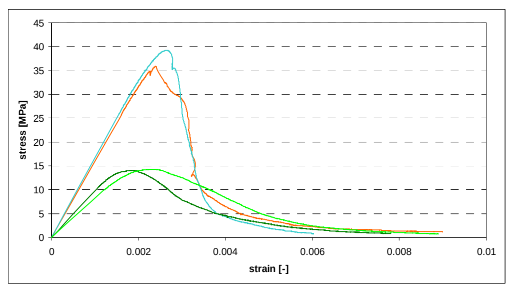
Test results
Elastic modulus



Test results
Residual strength in compression



Stress-strain curves at 400 and 600°C
Calcareous-based concrete



Spalling
(previous tests carried out in 2006)

- Heating rate = 60°C/h = 1°C/min
- Tests on cubes

The results on spalling in SCC are somewhat controversial, and surely need further investigations.

Concluding Remarks

- Hot strength in compression: in SCC the hot strength agrees with EC-2 envelopes for ordinary VC, more below 80 MPa and less above 90 MPa.
- Elastic modulus: at high temperature it is lower and more thermally-affected than in residual conditions.
- Hot and residual deformability in compression: the peak strain is higher in hot conditions.
- Thermal diffusivity: the results are comprised between the two limit curves suggested by the Eurocode 2
- **Generally speaking, there are no sizable differences between the high temperature behavior of VC and SCC.**

Assem Hassan is a registered PE in Ontario, Canada, and is currently a postdoctoral fellow at Ryerson University. He earned BSc and MSc degrees in Civil Engineering from Ain Shams University, Cairo, Egypt, and a PhD in Civil Engineering in 2008 from Ryerson University. During his graduate studies, Mr. Hassan won the Ryerson excellence award, NSERC and OSG awards, and an award for best PhD thesis. In 2005, he began teaching undergraduate courses in the department of Civil Engineering. His research activities and publications deal with the rheological, mechanical, and durability properties of self - consolidating concrete (SCC), highlighting the areas of shear, bond, and the susceptibility of rebar's corrosion in SCC.

Durability Characteristics of SCC Incorporating Metakaolin

Dr. Assem Hassan and Dr. Mohamed Lachemi
Ryerson University

ACI WEB SESSIONS

Introduction

- Pure metakaolin (MK) has been successfully used in concrete as a supplementary cementing material (SCM) since 1990
- Recently, one of the largest deposits of metakaolin in North America was discovered in southern Saskatchewan (known as whitemud resources)
- Similar to SF, MK has a superior pozzolanic reactivity in concrete
- MK reacts with the calcium hydroxide formed during cement hydration, creating additional cementitious products which enhance the overall mechanical and durability performance of concrete

ACI WEB SESSIONS

Introduction

- Previous studies indicated that compressive and indirect tensile strengths were slightly improved in MK mixtures compared to SF mixtures at 5 to 10% cement replacements
- Also, drying shrinkage, permeability, chemical resistance, and freezing/thawing durability of MK mixtures were found to be similar or slightly better than those of SF mixtures
- Other aspects of durability, such as sulphate resistance, rapid chloride ion permeability, and expansion due to alkali-silica reaction all reported improvement in MK mixtures compared to control and SF mixtures

ACI WEB SESSIONS

Introduction

- Despite the superior effect of SF, utilizing SF in SCC mixtures is of a limited use because of the difficulty in obtaining the desired SCC workability
- Metakaolin has a particle size that is much finer than cement but not as fine as SF
- Hence, MK is expected to offers better workability and require smaller amounts of high-range water-reducing admixture to obtain slump that is comparable to that of SF concrete
- MK has a creamier texture, generates less bleed water, and has better finishability than for concrete with SF
- Therefore, developing SCC containing MK is beneficial and requires more investigation

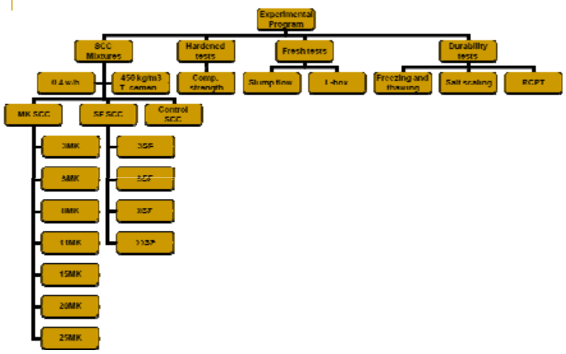
ACI WEB SESSIONS

Introduction

- Currently, very little information about the properties of SCC containing MK
- The main objective of this study was to develop and evaluate different SCC mixtures containing various amounts of MK and SF as partial replacements of cement
- The tested mixtures were evaluated based on their fresh properties (slump flow and L-box), compressive strength, and durability performance such as freezing and thawing, salt scaling, and rapid chloride permeability

ACI WEB SESSIONS

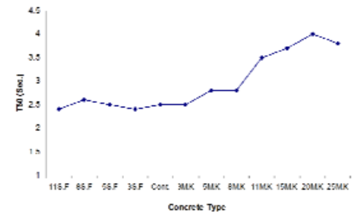
Experimental program



ACI WEB SESSIONS

Results and discussions

Fresh properties (slump flow)

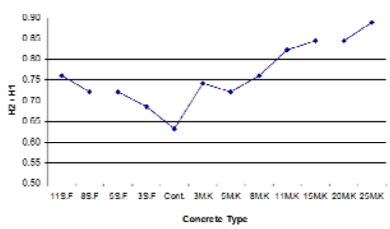


- The target slump flow for all mixtures was 650mm
- All mixtures achieved slump flow values in the order of 650 +/- 10 mm using different percentages of HRWR
- The result could be an indication that the addition of MK increases the viscosity of SCC mixture
- SF appears not to affect the concrete viscosity

ACI WEB SESSIONS

Results and discussions

Fresh properties (L-box)

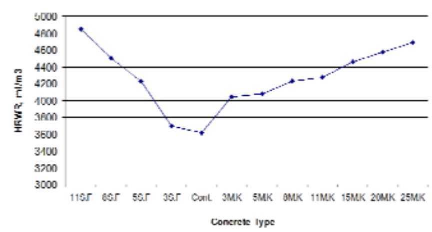


- All mixtures exhibited acceptable values of passing ability H2/H1 except for the control mixture which showed slightly less than the minimum desired value for SCC
- An increased amount of SCM increases deformability and passing ability of SCC mixtures

ACI WEB SESSIONS

Results and discussions

Fresh properties (HRWR content)

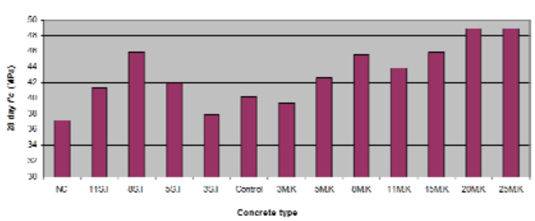


- The addition of MK increases the demand for HRWR
- The addition of MK appears to require less HRWR than the addition of SF
- 25MK consumed 30% extra HRWR than the control mixture
- 11SF consumed 34% extra HRWR than the control mixture
- 11MK consumed 18% extra HRWR than the control mixture

ACI WEB SESSIONS

Results and discussions

hardened properties (compressive strength)



- The addition of MK increases the 28-day compressive strength of SCC, and that increase is comparable to that of an SCC mixture containing SF
- Replacing cement by up to 15% MK enhances the strength of the control mixture by about 14% (the same percentage as the addition of 8% SF)
- 25% MK enhances the strength of the control mixture by 21%

ACI WEB SESSIONS

Results and discussions

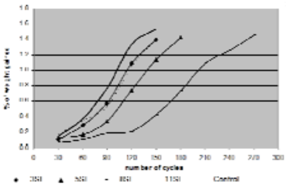
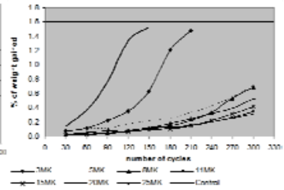
Freezing and thawing (weight gained)

- ASTM C 666 Procedure A
- The specimens were subjected to 14 days of moist curing then 14 days of dry curing
- The specimens first immersed in water for 24 h then subjected to rapidly-repeated cycles of freezing (–18 ° C) and thawing (4 ° C) in water
- Each 30 cycle the specimens were examined using weight gained and pulse velocity techniques

ACI WEB SESSIONS

Results and discussions

Freezing and thawing (weight gained)

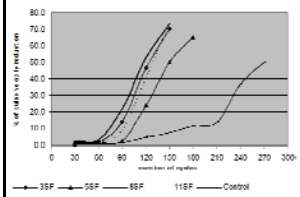
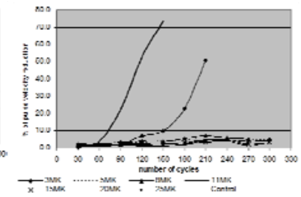



- The weight gained each cycle is an indication of the specimen deterioration,
- The weight gained represent the amount of moisture that had been absorbed due to cracking caused by expansion of the cement paste
- The weight gained increased as the number of the cycles rose
- 20MK mixture exhibited the lowest weight gained indicating that it absorbed less water than the other specimens

ACI WEB SESSIONS

Results and discussions

Freezing and thawing (pulse velocity reduction)

- Pulse velocity readings were taken at four points around the perimeter of the specimen and the average value was recorded
- The reduction of the pulse velocity increased as the number of the cycles rose
- The 20MK mixture exhibited the lowest pulse velocity reduction, indicating that it had fewer internal cracks

ACI WEB SESSIONS

Results and discussions

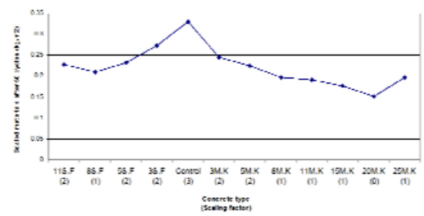
Salt scaling

- ASTM C 672
- The specimens were subjected to 14 days of moist curing then 14 days of dry curing
- The surface of the specimen was cover with approximately 6 mm of calcium chloride and water (100mL of solution contains 4g of calcium chloride)
- The specimens were placed in a freezing environment for 16 to 18 h then in the laboratory air for 6 to 8 h
- The loose particles and any spalled material at the surface of the specimen were collected
- After 50 cycle, the specimens were evaluating using the accumulated mass loss and a visual rating (scale of 0 to 5)

ACI WEB SESSIONS

Results and discussions

Salt scaling



- As the percentage of MK or SF increased, the weight of the scaled materials was reduced
- The lower value of the scaled materials was recorded for 20MK, which had 46% of the scaled materials of the control mixture
- SCC with 8% MK exhibited 7% less scaled materials weight than SCC with 8% SF

ACI WEB SESSIONS

Results and discussions

Salt scaling


Control (0.33 kg/m2) [3]


MK3 (0.246 kg/m2) [2]


MK5 (0.225 kg/m2) [2]

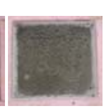

MK8 (0.197 kg/m2) [1]


MK11 (0.192 kg/m2) [1]


MK15 (0.178 kg/m2) [1]


MK20 (0.152 kg/m2) [0]


MK25 (0.197 kg/m2) [1]


SF3 (0.274 kg/m2) [2]


SF5 (0.233 kg/m2) [2]


SF8 (0.211 kg/m2) [1]


SF11 (0.229 kg/m2) [2

ACI WEB SESSIONS

Results and discussions

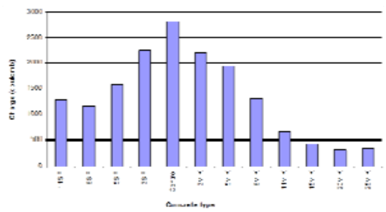
Rapid chloride permeability test, RCPT

- ASTM C 1202
- The 100 x 200mm concrete cylinder was cut into 50mm thick specimens
- Each specimen was placed between two cells filled with 0.3 N NaOH and 3.0% NaCl solutions
- The resistance of the specimen to chloride ion penetration was the total charge in coulombs passed in six hours

ACI WEB SESSIONS

Results and discussions

Rapid chloride permeability test, RCPT



- The total charge passed in coulombs is significantly reduced with the increased percentage of MK and SF.
- The addition of 20% MK reduced the total charge of the control mixture by 89%.
- 5SF and 8SF showed a lower total charge passed than 5MK and 8MK respectively, while 11SF had higher charge passed than 11MK

ACI WEB SESSIONS

Conclusions

- The addition of MK appears to increase the viscosity of SCC mixtures. This conclusion is based on the increase values of T50 of the slump flow
- The addition of MK enhances the passing ability of SCC mixtures. When the percentage of MK increased from 0 to 25%, the values of H2/H1 (L-box index) increased by 41%
- The passing ability of SCC containing MK was better than that of SCC containing SF at the same level of cement replacement
- The addition of MK increases the demand for HRWR in SCC mixtures. The amount of HRWR increased by about 30% when MK content increased from 0 to 25%. However, the addition of MK appeared to demand less HRWR than the addition of SF
- The addition of up to 25% MK increases the 28-day f'_c of the control SCC by 21%. Also the addition of 15% MK was comparable to the addition of 8% SF and both increased the 28-day f'_c of the control SCC by 14%

ACI WEB SESSIONS

Conclusions

- The addition of MK to SCC mixtures improves resistance to freezing and thawing. As the percentage of MK increased, resistance increased as well
- Freezing and thawing resistance was higher with MK compared to SF at the same level of cement replacement
- The scaling resistance of SCC is greatly enhanced by the addition of MK. Adding 20% MK reduced the weight of the scaled materials of the control mixture (after 50 cycles) by 46%. MK also proved to be more effective than SF in terms of scaling resistance at the same level of cement replacement
- MK significantly reduces the chloride permeability of SCC. The chloride permeability of the control mixture was reduced by 89% when 20% MK was added to the SCC mixture. However, SF reduced the chloride permeability of SCC more than MK at 8% cement replacement
- The optimum percentage of MK in SCC mixture appear to be 20% also the optimum percentage of SF is 8%

ACI WEB SESSIONS

Thank You

ACI WEB SESSIONS

Related Documents

Self-Consolidating Concrete

- ACI 237R-07: Self-Consolidating Concrete
- SP-233: Workability of SCC: Roles of Its Constituents and Measurement Techniques
- SP-247: Self-Consolidating Concrete for Precast Prestressed Applications

Durability

- ACI 201.2R-08: Guide to Durable Concrete
- SP-212: Sixth CANMET/ACI: Durability of Concrete
- SP-234: Seventh CANMET/ACI International Conference on Durability of Concrete

Visit Bookstore

ACI WEB SESSIONS

Click on the text below to go to the web page.

Seminar Schedule

Bookstore

Web Sessions

Conventions

Online CEU Program

ACI eLearning

Concrete Knowledge Center

ACI WEB SESSIONS