ACI Committee 234 – Silica fume

Monday, October 28, 2002, 14:00 to 17:00

AGENDA

1. Welcome

2. Apologies for absence

3. Membership status and changes. Terry Holland

4. Revision 234 - R; Status. Per Fidjestol, Terry Holland

- Chapters 1,2,3,4,5,8,9,11

- Chapter 6, Per Fidjestol. A new draft is published on the web, and enclosed with the agenda

- Chapter 10, Per Fidjestol. The subheadings are enclosed. We should do a brainstorm on each of these, and work on this content.

- Preparation for vote on whole document, Per Fidjestol

5. Presentations (LCD projector available)

    - Per Fidjestol: Long term experience with silica fume concrete in marine environment

    - Others?

6. New business

7. Other business

8. Close meeting

MINUTES

ACI Committee 234: Silica Fume in Concrete
April 22, 2002

Detroit, Michigan

Per Fidjestol called the meeting to order at 2:10pm.

Attendance:

Members	Visitors
Per Fidjestol (Chair)	Paul St. John
Terry Holland	Steve Somerville
William Halczak	Jan Prusinski
Mohan Malhotra	Rob Lewis
J.C. Roumain	K. Obla
Mark Bury	Kevin Smith
Mike Thomas	Andrea Boddy
Rachel Detwiler	Oscar Tavares
Jan Olek	
Tony Kojundic (secretary)	
Mike Pistilli	
Bryant Mather	
Fouad Fouad	
Min-Hong Zhang	

1. Minutes from previous meeting

Minutes from Dallas meeting, fall 2001 approved as written.

2. Membership

Total members 45
Total voting members 24
General Interest 27
Users 5
Producer / supplier 13

3. Results of ballot

Summary of negative votes enclosed.

The purpose of the meeting was to address the negative votes on balloted chapters 3,5,6,and 8. Editorial comments that were submitted will also be considered for chapter inclusion.

Chapter 3 negative voters.
Detwiler – Delete footnote #1. No motion to vote non-persuasive, therefore footnote #1 deletion is accepted.

Chapter 5 negative voters.
Malhotra – P4, L5. Change line 5 to "the committee is of the opinion that the strength reductions reported are marginal and of no structural significance…"
-Debate; Mather – Is the strength reduction statistically significant?
Thomas suggested, "reductions are not significant…"
The Malhotra negative found persuasive, and the sentence will be editorially changed.

Thomas suggested editorial change to P4, L1, insert, "…aware of a limited number…"

Holland, P2, L31, persuasive negative to insert references that will support the statement.

Holland, P4, L13, Felt the statement regarding cylindrical test specimens is out of place in this discussion. As editorial the committee decided to create new bullets to explore why drying shrinkage is important.

Holland, P7, L21, rewrite to establish "what the committee believes" before giving reasons for improved durability. Word-smithing this sentence will satisfy Holland.

Holland, P8, L45, This sentence needs reworking. The committee agreed to rephrase, "…the reduction in chloride transport is very clear and the use of SF is a sure way of reducing chloride ingress and the risk of reinforcement corrosion due to chlorides."

Holland, P9, L11, We talk of cement replacement, but what about SF as an addition to the cement. The committee agreed to rework to include both replacement and addition options. Suggested …" up to 15% SF of the cementitious materials…"

Holland,P16, L35, 5.4.3, Suggested we include more wording re: cracking. Rationale "cracking " is more important to engineers v. resistivity, but the document is out of balance in the discussion of cracking. Detwiler will expand the section on cracking by extracting some references from the recent PCA work on cracking.

Zhang, P2, L36, Replace, "The "total" shrinkage…", with "The drying shrinkage…"

Chapter 8 negative voters.
Malhotra, P1,L10, Cementitious factors are too high to represent what is commonly taking place. The committee recommended to combine the 2 examples in 8.2 into one recommendation of "350-500 kg/M3 total cementitious.

Thomas, P1,L13-14, recommended to expand to advocate the use of fly ash and slag. The committee agreed to rework this sentence to eliminate concern from these combinations.

Thomas, P3, L24, add blended cements to the silica fume product "forms".
The committee agreed to reword this sentence.

Chapter 6 Applications of silica fume.
Holland and Fidjestol recommend we pull this chapter and create a new document solely for Applications/Case Histories of SF concrete Applications/Projects. The committee agreed to this recommendation, but wished to continue to include an abbreviated Chapter 6 down to a few paragraphs.

Holland, Morgan, and Thomas negatives can be summarized as *variable detailing*, *incomplete information*, and *variable forms* within the chapter.

Chapter 10 – What *research needs* still need to be met?
Debate – Olek, Chapter author recommends a reduced research needs chapter with bullet points instead of detailed paragraphs. Over the past 10 years the prolific research has addressed many of the items. The committee agreed and Olek will rework and condense the chapter.

Summary of further ballots
3 items for letter ballot ASAP.
Chapter and paragraph 5.4.3 – Detwiler.
Chapter 6 condensation – Fidjestol/Holland/Wolsiefer.
Chapter 10 condensation – Olek.

Complete document for ballot before next meeting, with some basic editing included.

4. New business.
Next Canmet Durability Conference Greece, June 2003.
ACBM call for papers on self-consolidating concrete, session Nov. 12-13, 2002.
1st Concrete Bridge Conference (part of the PCI convention), Call for papers May 24, Opreyland, Oct 7-9, 2002.

CHAPTER 6-- APPLICATIONS OF SILICA FUME IN CONCRETE

Silica fume was introduced to the concrete market in the mid to late 1970's. The use of the material increased during the eighties. As silica-fume concrete became recognized for high strength, low diffusivity, and high corrosion resistance, silica fume gained acceptance. It came to be widely used produce high-performance concrete. An estimate is that globally more than five million cubic meters silica fume concrete are produced each year.

Since the introduction of silica fume, extensive studies and use has generated a lot of experience. This chapter cannot even begin to make justice to the variety of spectacular and mundane structures that have been made using silica fume. A separate publication is needed to do justice to the use of silica fume, and indirectly many of the high performance concrete structures used around the world. Therefore, this chapter is limited.

Different regions of the world have different practices for using silica fume concrete. In North America, in recognition of the benefit of silica fume in chloride exposed structures, literally hundreds of parking structures that have been built with silica fume concrete. High strength concrete, concrete pavements, chemically resistant concrete and concrete for other applications, such as shotcrete, followed.

Since the +5 million cubic meters of concrete placed annually are placed for a variety of reasons, only four projects, with a global scope, will be presented here.

Tsing Ma bridge, Hong Kong

The Lantau Link, with a railway as well as roads, comprises the Tsing Ma suspension bridge linking Tsing Yi to Ma Wan; viaducts crossing Ma Wan and the Kap Shui Mun cable-stayed bridge linking Ma Wan to Lantau.

The Tsing Ma Bridge has become a major Hong Kong landmark. Its main span of 1,377 meters is the world's longest carrying both road and railway, and its concrete towers are 206 meters tall. Construction of Tsing Ma Bridge commenced in May 1992 and completed in May 1997.

Length	-- 2.2 kilometres
Main span	-- 1,377 metres
Shipping clearance	-- 62 metres
Tower height	-- 206 metres

Volume of concrete	-- 500,000 cubic metres

While the concrete in addition to slag contains silica fume, for fresh and hardened concrete properties; a legal issue has prevented the publication of the mixture design.

311 South Wacker Drive

311 South Wacker Drive in Chicago was built between 1988 and 1990. It has 65 floors above ground for a total height of 293 meters. When it was completed, it was the world's tallest reinforced concrete building. The complete plan for the block of 311 South Wacker featured three identical towers, all facing inward. Currently there is only the one tower, and the two side plots are reserved for future development.

Silica-fume concrete was mainly used to provide 12,000-psi (83-MPa) specified compressive strength concrete, some of the 10,000-psi (69-MPa) concrete also used silica fume (Robison 1988) .

Kuala Lumpur City Centre

Kuala Lumpur City Centre, also known as Petronas Towers. The Petronas Twin Tower buildings (95 stories)) were built in Kuala Lumpur, Malaysia. In 1997, at the time of completion, the towers, at 452 meters (1480 ft), were the tallest buildings in the world. Each tower building contained 218,000 m^2 (2.3 million ft^2) of development space. The building used high performance silica-fume concrete (Grade 80 MPa), in the lowest levels of columns, core walls, and ring beams to minimize column and wall size. The mixture proportions were portland cement 260 kg/m^3 (473 lb/yd3), blended fly ash (20/80 blend) cement 260 kg/m3 (437 lb/yd3) silica fume 30 kg/m3 (50 lb/yd3) and 10 l/m3 (2 gal/yd3) of HRWRA. The design cube compressive strength was 80 MPa (11,600 psi) at 56 days, however, average field cube strength was 105 MPa at 56 days (Thornton, 1998).

Kinzua Dam stilling basin

One of the first major applications of silica fume concrete in the United States was for repair of hydraulic structures subjected to abrasion erosion damage. The concrete in the stilling basin slab of Kinzua Dam in western Pennsylvania was severely damaged by abrasion erosion and repsired with 18 % silica fume concrete with a compressive strength over 13,000 psi (90 MPa) at 28 days (Holland et al. 1986). A ten-year performance assessment (Luther and Halczak 1995), indicated that the silica-fume concrete was performing well and projected a 20- year service life, as opposed to the previous 7- year life of portland cement concrete. Later diver inspection has proven up to 18 inches wear in some areas of the slab – after18 years. Thus the anticipated 20 year service life will likely be exceeded.

Stolma Bridge

A number of light weight aggregate bridges have been built in Norway over the last decade. A common denominator is the use of silica fume to stabilize the fresh concrete – and for chloride resistance. Stolma bridge is a typical representative and unique in the sense that it has the world's longest span (301 m) built by the balanced cantilever construction method. Located on the West Coast of Norway, the bridge links two islands in an archipelago south-west of Bergen.

(Photo courtesy of Bergens Tidende, photographer: Jan M. Lillebø)

Owned by the Norwegian Road Authorities, Hordaland County, Norway, the bridge was designed by Instanes A/S, Bergen and built by NCC Eeg-Henriksen a/s.

These spectacular structures serve as an illustration of the potentials of silica fume concrete-for strength, durability and constructability.

CHAPTER 10--RESEARCH NEEDS

The following topics have been identified as needing further research, either to allow for more advanced applications or to increase the effectiveness of and confidence in current applications. The research needs are presented from a practical point of view.

10.1--Frost resistance

10.2--Sulfate attack

10.3--Drying shrinkage and creep

10.4--Steel corrosion

10.5--Performance under high-temperature conditions

10.6--Long-term durability

10.7--Pore structure and permeability

10.8--Rheology and setting properties

10.9--Mechanism of strength development

10.10--Role of silica fume in special concretes

10.11--Effect of silica fume on hydration

10.12--Curing

10.13--Recommended field practice