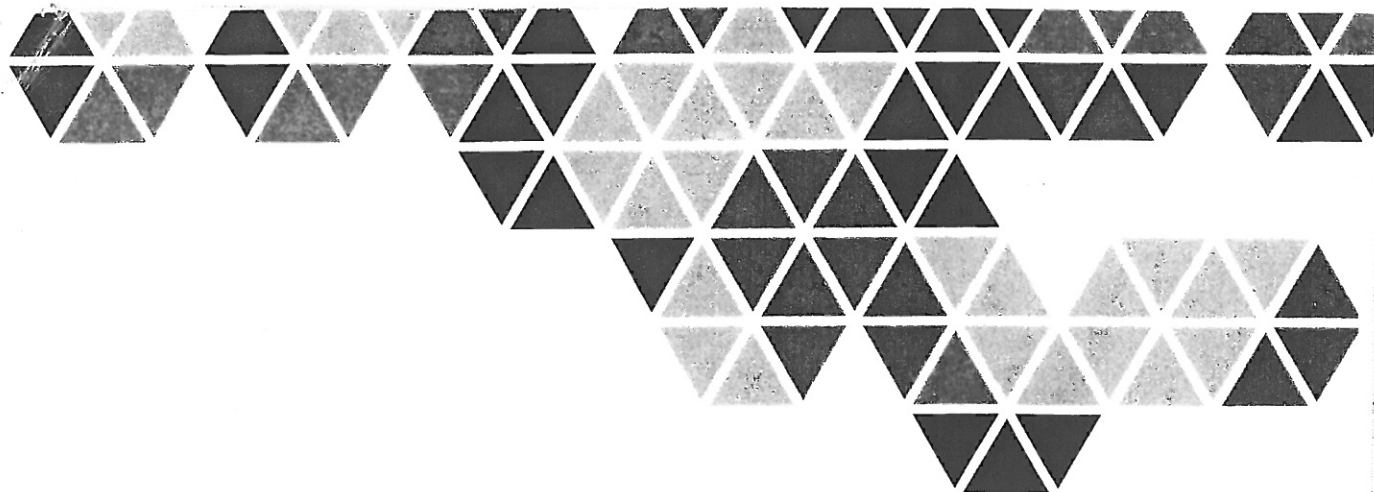
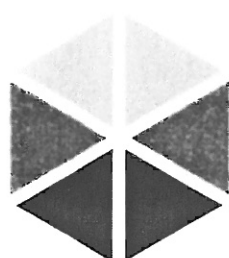




g-Clos's
/

→ 2011

re.c



**9th International Symposium
on High Performance Concrete**
Design, Verification & Utilization



NZCS

Hosted by the New Zealand Concrete Society

ABSTRACTS OF THE

**9th International Symposium
on High Performance Concrete**
Rotorua, New Zealand

9-11 AUGUST 2011

Abstracts of the

9th International Symposium on High
Performance Concrete
Rotorua, New Zealand

9-11 August 2011

Editors:

Michael Khrapko and Olafur Wallevik

Copyright © 2011

Abstracts of the 9th International Symposium on High Performance Concrete

Reprints of all or parts of these Abstracts may be made on the condition that credit is given to the author(s) and reference is made to the Abstracts of the 9th International Symposium on High Performance Concrete.

IMPORTANT NOTICE

The organisers of the 9th International Symposium on High Performance Concrete, its sponsors (as listed), its host (NZ Concrete Society Incorporated) and members of the various conference committees are not responsible for any opinions, findings, conclusions or recommendations expressed by the authors of the contributed papers in these abstracts. These abstracts are derived from contributed content that was prepared using a variety of computer software and operating systems. Whilst considerable care was taken to ensure the accurate processing and assembly of this content, it is possible that errors may have been introduced during processing and assembly. We regret any inconvenience that these errors may cause; however, we do not warrant the reliability of these abstracts. Mention of trade names and commercial products does not constitute endorsement or recommendation for use.

Abstracts of the 9th International Symposium on High Performance Concrete
ISBN-number: 978-0-473-19028-6

- 2 **PRIMARY**
'Example of calculation of flexural crack width of RC box girder considering shrinkage property of concrete'
Satoshi Komatsu / Akira Hosoda – Yokohama National University, Japan
- 3 **PRIMARY**
'Early shrinkage in self-compacting mortars using secondary raw materials'
Thomas A Bier – Institute of Ceramic, Glass & Construction Materials; Germany; Syed Ali Rizwan – School of Civil & Environmental Engineering, Pakistan
- 4 **PRIMARY**
'Mechanism of early heat curing influence on compressive strength and autogenous shrinkage of over 200MPa-class ultra-high-strength concrete'
Taku Matsuda – Sumitomo Mitsui Corporation Co Ltd / University of Tokyo, Japan; Takafumi Noguchi – University of Tokyo, Japan; Koichi Hasuo – Sumitomo Mitsui Corporation Co Ltd, Japan; Takao Koide / Yasunori Suzuki – Sumitomo Osaka Cement Co, Japan
- 5 **PRIMARY**
'Creep Buckling Analysis of High-Strength Concrete Panels'
Ehab Hamed / Yue Huang / Stephen J Foster – The University of New South Wales, Australia

7.00 pm – 11.00 pm Informal Dinner at Mystery Location with NZ flavour

Wednesday 10 August

7.30 am – 8.00 am Registration

8.00 am – 8.30 am **Plenary Lecture 3:**
'Shear design and evaluation of concrete structures'
Professor Michael Collins / Evan C Bentz – University of Toronto, Canada

8.30 am – 9.00 am **Plenary Lecture 4:**
'Recent Development of High-Strength Concrete in Japan'
Professor Mitsutaka Hayakawa – Tokyo Polytechnic University, Japan

9.00 am – 10.45 am **Session A4: Concrete Durability continued**

- 1 'Evaluation of Water-Penetration, RCPT and Electrical Resistivity Relations in Concretes'
Ali A Ramezaniapour / Amir Pilvar / M Mahdikhani / F Moodi – Amirkabir University of Technology, Iran
- 2 **PRIMARY**
'Design of Concrete with High Resistance to Stray Current Corrosion in Subway Reinforced Concrete Structure'
Caijun Shi / Xiaopeng An / Dehui Wang – Hunan University, China; Fuqiang He – Xiamen University of Technology, China
- 3 'Monotonic and Cyclic Bond Testing of Heavily Corroded Reinforcing High Strength Concrete'
Allan Scott / Alessandro Palermo / A Kivell – University of Canterbury, NZ
- 4 'Fire protection of high strength concrete by modifying its cover composition'
Cristina Rodriguez / M C Alonso / O Rio / V D Nguyen – Research Centre on Safety and Durability of Structures & Materials, Spain
- 5 'Concrete with Silica Fume at Elevated Temperatures'
Eva Lubloy / L Gyorgy Balazs / Oliver Czoboly / Bela Harman / Nehme Salem Georges – Budapest University of Technology and Economics, Budapest

9.00 am – 10.45 am **Session B4: Fibre Reinforced Concrete continued**

- 1 'Reliability considerations for FRP-reinforced concrete beam design'
Sofia M C Diniz / Sidnea E C Ribeiro – Federal University of Minas Gerais, Brazil
- 2 **PRIMARY**
'Mechanical properties of ultra high strength fiber reinforced cementitious composite using Aramid Fiber'
Yuichi Uchida / Nguyen Khanh Thy – Gifu University, Japan
- 3 'Comparison of bending behaviour of different high performance fibre reinforced concretes'
Torsten Mueller / K Holschemacher / H Kieslich – University of Applied Sciences, Germany



CONCRETE WITH SILICA FUME AT ELEVATED TEMPERATURES

Éva Lublóy, L. György Balázs, Olivér Czoboly, Béla Harman, Nehme Salem Georges

Budapest University of Technology and Economics, Department of Construction Materials and Engineering
Geology

ABSTRACT

The composition and structure of hardened cement paste have an important influence on the properties of concrete exposed to high temperatures. In case of UHPC the application of silica fume is often necessary.

Characteristics of concrete during and after the heating process depend mainly on: the type of cement, the type of aggregate and the interaction of them.

An extensive experimental study was carried out at the Budapest University of Technology and Economics to analyse the post-heating characteristics of concrete with silica fume subjected to temperatures up to 1000°C. Major parameters of our experimental study were the silica fume content of cement, water-cement ratio and water-binder ratio.

During fire, the heated surface region of concrete loses its moisture by evaporation from the surface. In case of high strength concrete the evaporation of moisture often causes spalling of the concrete cover, and due to high temperatures, the structure and chemical composition of the concrete changes.

CONCRETE WITH SILICA FUME AT ELEVATED TEMPERATURES

Éva Lublóy (1), L. György Balázs (1) Olivér Czoboly (1), Béla Harman (1), and Nehme Salem Georges (1)

(1) Budapest University of Technology and Economics, Department of Construction
Materials and Engineering Geology

Abstract

The composition and structure of hardened cement paste have an important influence on the properties of concrete exposed to high temperatures. In case of UHPC the application of silica fume is often necessary.

Characteristics of concrete during and after the heating process depend mainly on: the type of cement, the type of aggregate and the interaction of them.

An extensive experimental study was carried out at the Budapest University of Technology and Economics to analyse the post-heating characteristics of concrete with silica fume subjected to temperatures up to 1000°C. Major parameters of our experimental study were the silica fume content of cement, water-cement ratio and water-binder ratio.

During fire, the heated surface region of concrete loses its moisture by evaporation from the surface. In case of high strength concrete the evaporation of moisture often causes spalling of the concrete cover, and due to high temperatures, the structure and chemical composition of the concrete changes.

1 INTRODUCTION

Studies on the performance of silica fume in concrete began in the 1950s [1, 2]. Silica fume is a by-product resulting from the reaction of high-purity quartz with coal in electric arc furnaces in production of ferro-silicon alloys and silicon metal [3]. It is well known that silica fume improve the mechanical properties and durability of concrete. The high amount of amorphous silicon dioxide and very fine spherical particles are the main reasons for its pozzolanic activity [2]. The silica fume is the most well known additive material in high-strength concrete.

The application of concrete with silica fume in the future is an important assignment for engineers. For high rise buildings the concrete grade is especially important. In case of UHPC the application of silica fume is often necessary. For example: South Wacker Drive 311 was built by application of 16 m_c% silica fume (*Figure 1*), W-Comfort Towers (Tokyo) was built with silica fume [4] (*Figure 2*), Burj Dubaj (Dubaj Tower) was built with silica fume too [5] (*Figure 3*). In case of high rise buildings the fire resistance is very important.



Figure 1:
South Wacker Drive 311



Figure 2:
W-Comfort Towers [4]



Figure 3:
Burj Dubaj [5]

Several research projects [6, 7, 8, 9] were directed to study the behaviour of concrete with silica fume after exposure to elevated temperatures. The main aim of these studies was to test the risk of explosive spalling in case of high strength concrete with silica fume.

Phan and Carino [7] reported that concretes containing 10 m_c% silica fume showed better performance than normal strength concrete at 100°C and 200°C, but higher relative strength losses were observed in concretes containing silica fume after subjected to temperatures of 300°C and 450°C.

Saad et al [8] made experiments with 10 m_c%, 20 m_c% and 30 m_c% silica fume. The water to cement ratio was 0.4. They concluded that concrete specimens with 10 m_c% silica fume produced lower porosity values at all temperatures of heat treatment than specimens without

silica fume. Concrete specimens made with 10 mc% silica fume produced the highest compressive strength values at all temperatures of thermal treatment while more CSH was formed with stronger internal binding and sufficient thermal stability.

Benhood and Ziari [9] suggested that the dosage of silica fume has no significant effect on the relative compressive strength at 100°C and 200°C. In their tests above 300°C the amount of silica fume had significant effects on the residual compressive strength.

2 EXPERIMENTAL PROGRAMME

Present study is directed to the analysis of simultaneous effects of high temperatures as well as silica fume in concrete. It is an important study because high temperatures produce changes of the structure and chemical composition of concrete.

Test variables were in case of concrete specimens: silica fume content (0, 3, 9 mc%), water-binder ratio (0.35; 0.33; 0.30), water-cement ratio (0.35; 0.36; 0.38) and maximum temperature (20°C; 50 C; 150°C, 300°C, 500°C, 1000°C). The tested concrete compositions are given in *Table 1*. Studied characteristics were: surface cracking, reduction of compressive strength and reduction of flexural strength.

Table 1: Constituents of tested concrete mixes (kg/m³)

	Mix1	Mix2	Mix3	Mix4	Mix5	Mix6
cement (CEM I 42.5N)	400	400	400	436	400	400
silica fume	-	12	36	-	12	36
water	140	140	140	153	144	153
aggregate 0-4 mm	755	748	736	728	841	730
aggregate 4-8 mm	472	468	460	455	467	456
aggregate 8-16 mm	661	655	644	637	560	639
plastificator	5	5	4.48	4,6	4.8	3
w/c	0.35	0.35	0.35	0.35	0.36	0.38
w/b binder=cement+k*silica fume where k=1	0.35	0.33	0.30	0.35	0.35	0.35

After removing the specimens from the formwork they were stored in water for 7 days then kept at laboratory conditions until testing. The specimens were 28 days old by testing.

In case of experiments with high temperatures the temperature history and the time of testing are very important. Our heating curve was similar to the standard fire curve (according to Eurocode) for buildings up to 1000°C. After the heating process the specimens were kept for two hours at maximum temperatures (20°C; 50°C; 150°C; 300°C; 500°C; 1000°C). Then the specimens were slowly cooled down to laboratory conditions. Specimens were tested at room temperature. In present study 6 different mixes were tested.

3 TEST RESULTS

Main purpose of our experimental study was to determine the influence of silica fume content on post-heating characteristics of concrete.

3.1 Visual observation before compressive tests

Results indicated that the risk of spalling was higher for specimens in form of prisms compared to specimens in form of cylinders (*Figure 4*). That could be explained by the different layout of isotherm lines caused by the different shapes of the specimens. Mix1: (0 m_c% silica fume) two prisms exploded; Mix2: (3 m_c% silica fume) of one prism spalled; Mix3: (9 m_c% silica fume) the prisms did not crack; Mix4 (0 m_c% silica fume) only one prism exploded; Mix5 (3 m_c% silica fume) two prisms spalled; Mix6 (9 m_c% silica fume) the prisms did not crack.

These observations indicate that increased silica fume content reduced the *risk of spalling* within the standard range of replacement of up to 10 m_c%.

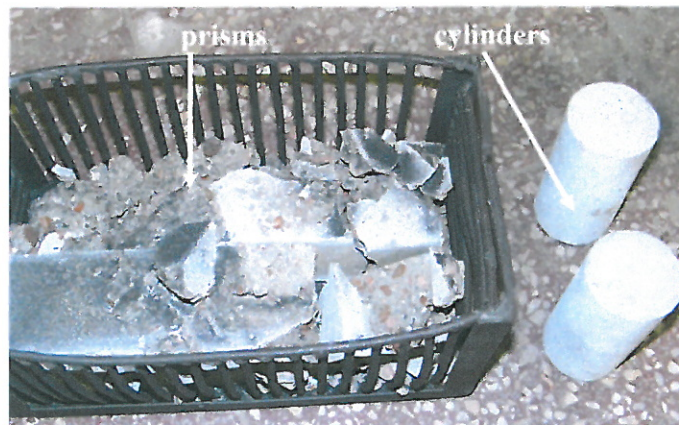


Figure 4: Specimens after 1000°C temperature loading

3.2 Compressive strength

Average compressive strength of reference concrete (Mix1) was 57.4 N/mm². Average compressive strengths of concrete mixes Mix2 to Mix6 were 68.0 N/mm², 72.9 N/mm², 55.8 N/mm², 72.8 N/mm², 61.0 N/mm², respectively.

Figure 5 indicates the measured relative residual compressive strength values of different concrete mixes as a function of maximal temperature up to 1000°C.

- A strength valley seems to appear (observed also by other researchers [10]) for relatively low values of maximal temperatures, i.e. a small strength decrease then small increase between 20°C to 300°C. This valley might be explained by the relatively high pore water content of tested concrete specimens at the age of 28 days.

- The strength valley ends up at 300°C with a relative compressive strength 1.23 in case of Mix1; 1.4 in case of Mix2; 0.83 in case of Mix3; 1.01 in case of Mix4; 0.86 in case of Mix5 and 1.00 in case of Mix6.
- This valley is followed by decrease of compressive strength at higher values of maximal temperatures.
- The relative residual compressive strength value at 1000°C was 0.07 for Mix1; 0.09 for Mix2; 0.1 for Mix3; 0.096 for Mix4; 0.12 for Mix5 and 0.09 for Mix6, respectively.

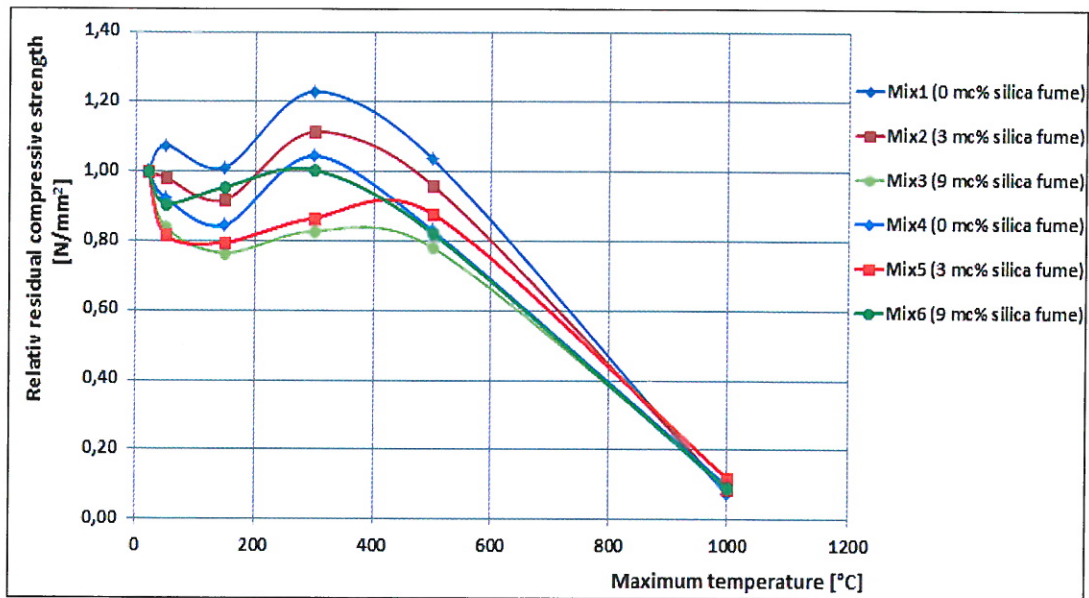


Figure 5: Relative residual compressive strength for the different concrete mixes as a function of maximal temperature (every point is an average of 3 measurements).

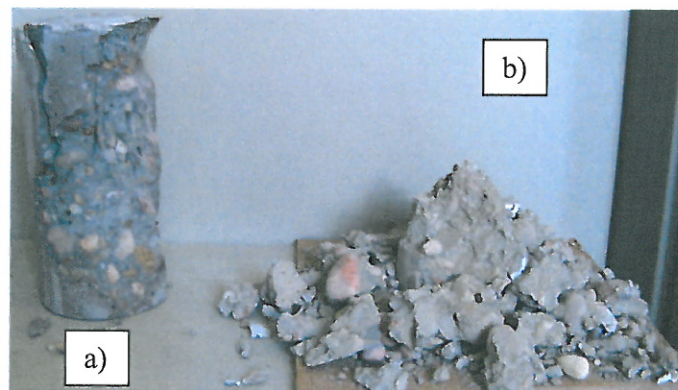


Figure 6: The specimens after the compressive strength measurement

($\varnothing=60$ mm, $h=120$ mm)

a) 20°C

b) after temperature loading up to 1000°C

Figure 6 indicates failure modes in compression at 20°C and after 1000°C, temperature loading, respectively. 20°C the cracks were almost parallel and some aggregates cracked through. After 1000°C temperature loading the specimens failed into pieces owing to the considerable reduction of internal binding forces. The chemical changes of concrete at high temperatures are also reflected by the changes in colour.

At laboratory temperature (20°C) some of the aggregates were cracked because the cement paste had higher strength than the aggregates. (Figure 5. a). There is a significant difference in case of the compressive tests after 1000°C temperature loading. The failure was caused by the cement paste while the aggregates did not crack. (Figure 5. b). It can be explained by the strength loss of the cement paste at elevated temperature.

3.3 Flexural strength

In Figure 7 test results are presented up to 500°C maximum temperature, because the specimens completely failed between 500°C and 1000°C.

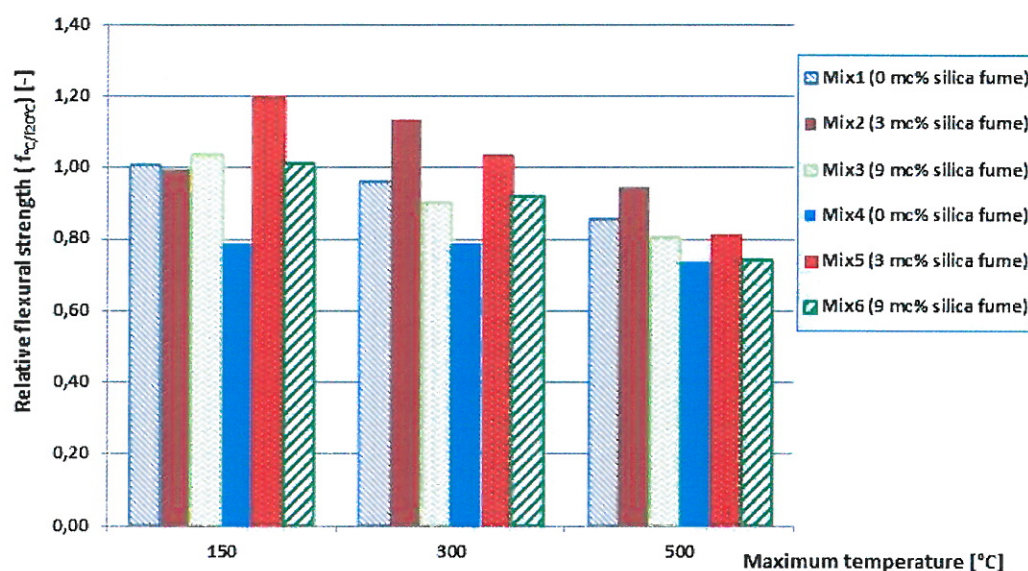


Figure 7: Relative flexural strength for the different concrete mixes as a function of maximal temperature (every point is an average of 3 measurements)

Relative flexural strength values are presented in Figure 5 according to maximal temperature values (150°C, 300°C, 500°C) for the various mixes (Mix1, Mix2, Mix3, Mix4, Mix5, Mix6). Observed flexural strength values are rather similar to 0 m_c% and 9 m_c% silica fume contents, however somewhat better for 3 m_c% silica fume content.

3.4 Visual observation after flexural tests

Figure 8 presents cracked surfaces of prisms after flexural failure. Clear differences in colour can be observed. Section of specimens after 1000°C temperature loading shows light grey colour compared to the normal colour of concrete at 20 °C temperature.

In case of the tests at laboratory temperature (20°C) some of large aggregates cracked through owing to the relatively high strength of cement paste (Figure 8. a). On the other hand Figure 8. b indicates debonded aggregates without cracking of the aggregates.

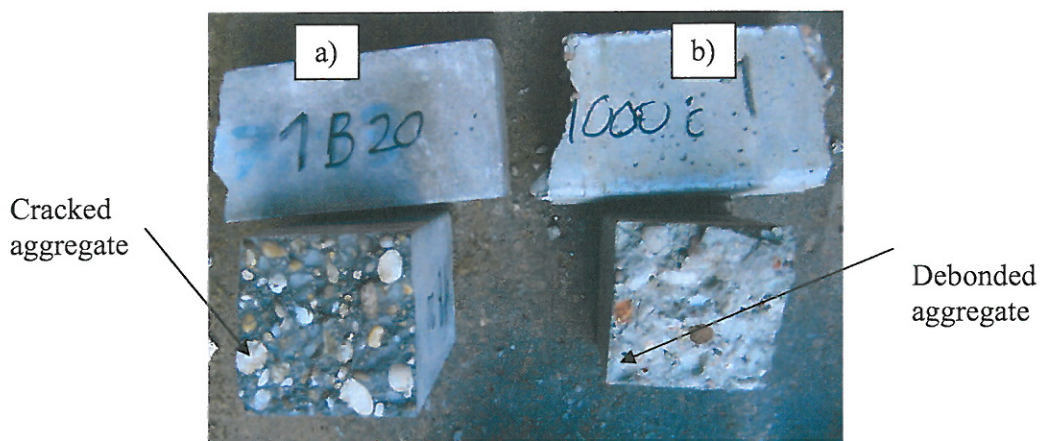


Figure 8: Cracked surface of flexural specimens after failure (70*70*250 mm)
a) 20°C b) after temperature loading up to 1000°C

4 CONCLUSIONS

Main purpose of our experimental study was to determine the influences of silica fume content on post-heating characteristics of concrete.

Test variables were silica fume content (0, 3, 9 m_c%), water-cement ratio (0.35; 0.36; 0.38), water-binder ratio (0.35; 0.33; 0.30) and maximum temperature (20, 50, 150, 300, 500, 1000°C). Studied characteristics were: surface cracking, spalling, residual compressive strength and residual flexural strength. Cylinder specimens (Ø=60 mm, h=120 mm) were used for the measurement of compressive strength. The flexural strengths were measured on prisms (70 x 70 x 250 mm).

The increase of the silica fume content decreased the risk of the *explosive spalling* of the concrete specimens.

The risk of spalling was higher for *prisms* than for *cylinders*. That could be explained by the different shape of the specimens.

Considering *flexural strength*, the highest value was observed by using relatively low amount (3 m_c%) of silica fume.

Silica fume content did not necessary result in higher residual strength after high temperatures. For some compositions even reduction of residual strength was observed.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of research by the Holcim Hungary Co.

REFERENCES

- [1] ACI Committee 363. State-of-the-art report on high strength concrete. Detroit: American Concrete Institute; (1993)
- [2] ACI Committee 363. Guide for the use of silica fume in concrete. Detroit: American Concrete Institute; (1994)
- [3] Malhotra, V. M., 'Fly ash, slag, silica fume, and rice-husk ash in concrete', Concrete Institute, (1993)
- [4] 'Elkem Microsilica concrete, C4-32 Reference project' (2003)
<http://www.elkem.no/dav/9e708ed5f6.pdf>
- [5] Baker, W. F., 'The World's Tallest Building, Burj Dubai, U.A.E.', CTBUH (2004) 1168-1169
<http://www.scribd.com/doc/21652632/Burj-Dubai-Technical-Info>
- [6] Hertz, K.D., 'Heat-induced explosion of dense concretes', Institute of Building Design, 166 (1984)
- [7] Phan, L. T. and Carino, N.J., 'Effects of test conditions and mixture proportions on behaviour of high-strength concrete exposed to high temperatures', ACI Mater J, 99 (2002) 54-66
- [8] Saad, M. and Abo-El-Eneint, S.A. and Hanna, G.B. and Kotkata, M.F., 'Effect of temperature on physical and mechanical properties of concrete containing silica fume', Cement and Concrete Research, 26 (10) (1996) 1479-1484
- [9] Benhood, A. and Ziari, H., 'Effects of silica fume addition and water to cement ratio on the properties of high-strength concrete after exposure to high temperatures', Cement & Concrete Composites, 30 (2008) 106-112
- [10] Schneider, U., Lebeda C., 'Fire protection of engineering structures', ISBN 3-17-015266-1 (2000). W. Kohlhammer GmbH, Stuttgart