HIGH PERFORMANCE CONCRETE USING ADMIXTURES

RAJEEV MISHRA

DEPARTMENT OF CIVIL ENGINEERING, SSSTUMS, Sehore(MP, India)

ABSTRACT

The High Performance Concrete refers to the new class of advanced cementious composite materials. This special type of concrete is better in many aspects when compared with the conventional concrete. The High Performance Concrete has compressive strength of nearly above 150MPa also the pre and post cracking tensile strength of above 5MPa. High performance concrete is generally used in the construction of various important structures which are susceptible to heavy loadings such as bridges and long span beams and slabs. The initial cost of HPC is higher than conventional concrete. Further research works are focused on optimizing its use by reducing the member thickness, changing concrete structural shapes and shortcomings. The HPC structures have longer service life and require less maintenance than the structures built with conventional concrete. This report includes the composition and properties of various materials involved in the production of High Performance Concrete along with the testing, structural designing and durability testing and the applications of High Performance Concrete.

Keywords: application, bridges, durability, fiber reinforced concrete, High performance concrete, HPC, infrastructure mechanical performance, structural performance.

I.INTRODUCTION

The High performance concrete exceeds the normal concrete properties used in the construction works. To manufacture the High performance concrete we need special materials which are combined in proper proportions for the required performance of the structures. The high performance concrete needs special mixing, placing and curing practices to produce them. These HPC is necessary for the construction of high rise buildings and long span bridges. To achieve this we need:

- High cement content
- Lowest water cement ratio which affect the workability of the mix.

It is noteworthy that high strength concrete and high performance concrete are not synonymous. Concrete is defined “high strength concrete” solely on the basis of its compressive strength measured at a given age. According to ACI “High performance concrete” is the concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing and curing practice.

International Journal of Advance Research in Science and Engineering
Volume No.06, Special Issue No.(01), December 2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

II.HPC CLASSIFICATION

The high performance concrete is classified based on the strength as below:

- Normal Strength 20-50MPa
- High Strength 50-100MPa
- Ultra High Strength 100-150MPa
- Especial > 150MPa
- Reactive Powder > 200

III.MATERIALS USED IN HIGH-PERFORMANCE CONCRETE

S. No.	Material	Primary Contribution/Desired Property
1	Portland cement	Cementing material/durability
2	Blended cement	Cementing material/durability/high strength
3	Fly Ash	
4	Slag	
5	Silica fume	
6	Superplasticizers	Flowability
7	High Range Water reducers	Reduce water to cement ratio
8	Hydration control admixtures	Control setting
9	Retarders	
10	Accelerators	Accelerate setting
11	Corrosion inhibitors	Control steel corrosion
12	Water reducers	Reduce cement and water content
13	Shrinkage reducers	Reduce shrinkage
14	ASR inhibitors	Control alkali-silica reactivity
15	Polymer/Latex Modifiers	Durability
16	Optimally graded	Improve workability and

	aggregate	reduce paste demand

3.1 Cements

• There are two important requirements for any cement:

a) Strength development with time

• Cement with compressive strength up to 60MPa for HSC

b) Facilitating appropriate rheological characteristics for the fresh concrete

• Experience has shown that low-C3A cements generally produce concrete with improved rheology.

• Cement contents between 400 and 550 kg/m3

• Cement should compatible with the chemical admixtures.

3.2 Aggregates

• The higher the targeted compressive strength, the smaller the maximum size of coarse aggregate.

• Up to 70MPa compressive strength can be produced with a good coarse aggregate of a maximum size ranging from 20 to 28 mm.

• To produce 100MPa compressive strength aggregate with a maximum size of 10 to 20mm should be used.

• Concretes with compressive strengths of over
125MPa have been produced, with 10 to 14mm maximum size coarse aggregate.

3.3 Mineral admixtures

- GGBS, fly ash and natural puzzolonas, not only reduces the production cost of concrete, but also addresses the slump loss problem.
- While silica fume is usually not necessary for compressive strengths under 70MPa, most concrete mixtures contain it when higher strengths are specified.
- Dosage rate 5% to 20% or higher by mass of cementing material.
- Some specs – silica fume 10% max.

3.4 Admixtures

- Use of admixtures is mandatory in high-performance concrete.
- Water reducers,
- Retarders,
- Superplasticizers,
- Air-entraining admixtures not necessary or desirable in protected high-strength concrete.
- Air is mandatory, where durability in a freeze-thaw environment is required i.e. bridges, piers, parking structures.
- Recent studies:
- H w/cm ≥0.30 - air required

- H w/cm < 0.25 - no air needed.

IV.SPECIAL METHODS FOR MAKING HSC

1. Seeding
2. Re-vibration
3. High Speed Slurry
4. Use of admixtures
5. Inhibition of Cracks
6. Sulphur Impregnation
7. Use of Cementitious aggregates

Special methods for making HSC

1. Seeding:

This involves adding a small percentage of finely ground, fully hydrated Portland cement to the fresh concrete mix.

2. Revibration:

Controlled revibration removes all the defects like bleeding, water accumulates, plastic shrinkage, continuous capillary channels and increases the strength of concrete.

3. High speed slurry mixing:

This process involves the advance preparation of cement - water mixture which is then blended with aggregate to produce concrete.

4. Use of admixtures:

Use of water reducing agents are known to produce increased compressive strength.

5. Inhibition of cracks:

If the propagation of cracks is inhibited, the strength will be higher. Concrete cubes made this way have yielded strength up to 105MPa.

6. Sulphur Impregnation:

Satisfactory high strength concrete have been produced by impregnating low strength porous concrete by Sulphur. The Sulphur infiltrated concrete has given strength up to 58MPa.

7. Use of Cementitious aggregates:

Cement found is kind of clinker. Using a slag as aggregate, strength up to 25MPa has been obtained with water cement ratio 0.32.

V.PROPERTIES OF HPC

• High modulus of elasticity
• High abrasion resistance
• High durability and long life in severe environments

International Journal of Advance Research in Science and Engineering
Volume No.06, Special Issue No.(01), December 2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

• Low permeability and diffusion

• Resistance to chemical attack

• High resistance to frost and deicer scaling damage

• Toughness and impact resistance

• Ease of placement

• Chemical Attack

• Carbonation

5.1 High modulus of elasticity

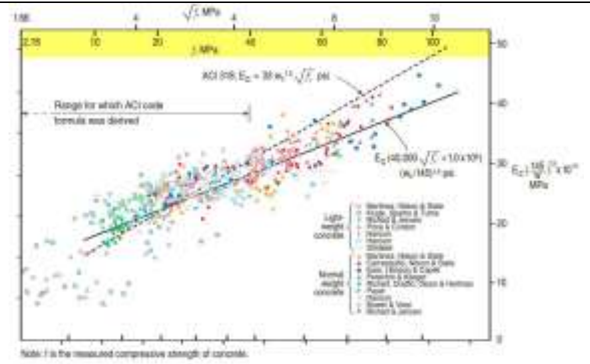


Figure C4.5-1. Modulus of elasticity versus concrete strength (ACI 363, Figure 5.1)

5.2 Low permeability and diffusion

Table 2: Characteristics of High Strength Concretes

	Regular	High Strength	Very High Strength
Compressive Strength (MPa)	<50	50-100	100-150
Water-to-cement ratio	>0.45	0.45-0.30	0.30-0.25
Chemical admixtures	Not required	Water-reducing admixture or superplasticizer	Superplasticizer
Mineral admixtures	Not required	Fly ash	Silica fume
Permeability (m/s)	$>10^{-12}$	10^{-13}	$<10^{-14}$

• The durability and service life of concrete exposed to weather is related to the permeability of the cover concrete protecting the reinforcement.

• HPC typically has very low permeability to air, water, and chloride ions.

• The dense pore structure of high-performance concrete makes it so impermeable.

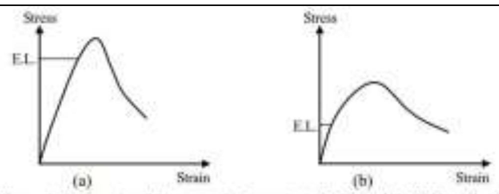


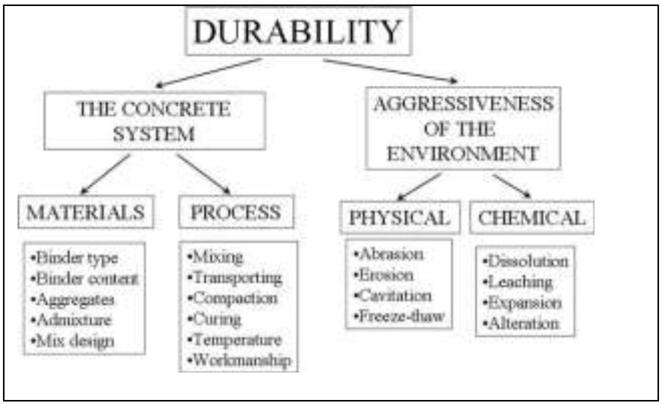
Figure 4: Schematic of Stress-strain Curve in (a) HPC and (b) NSC under Uniaxial Compression

• HSC is considerably more brittle than NSC.

International Journal of Advance Research in Science and Engineering
Volume No.06, Special Issue No.(01), December 2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

• HSC behaves linearly up to a stress level which is about 90% of the peak stress, whereas lower strength concrete shows nearly no linear part at all

• When the peak stress has been reached, the stress decays rapidly in high strength concrete.



5.3 Durability parameters

1. Water/ (cement + mineral admixture) ratio
2. Strength
3. Densification of cement paste
4. Elimination of bleeding
5. Homogeneity of the mix
6. Particle size distribution
7. Dispersion of cement in the fresh mix
8. Stronger transition zone
9. Low free lime content
10. Very little free water in hardened concrete

5.4 High abrasion resistance

• Abrasion resistance is directly related to the strength of concrete.

• This makes high strength HPC ideal for abrasive environments.

• The abrasion resistance of HPC incorporating silica fume is especially high.

• This makes silica fume concrete particularly useful for spillways and stilling basins, and concrete pavements or concrete pavement overlays subjected to heavy or abrasive traffic.

5.5 High durability and long life in severe environments

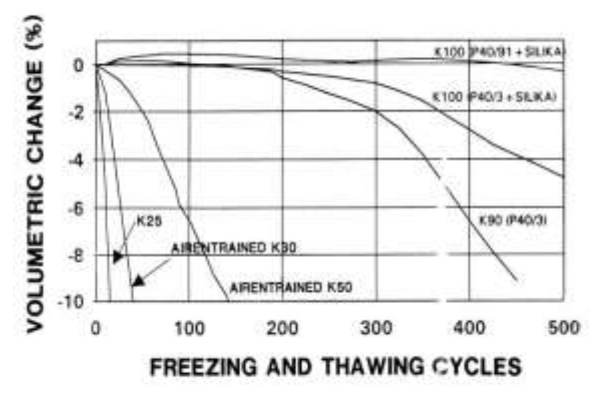
• Durability problems of NSC can be associated with the severity of the environment and the use of inappropriate high water/binder ratios.

• HPC that have a water/binder ratio between 0.30 and 0.40 are usually more durable than NSC not only because they are less porous, but also because their capillary and pore networks are somewhat disconnected due to the development of self-desiccation.

• In high-performance concrete (HPC), the penetration of aggressive agents is quite difficult and only superficial.

5.6 High resistance to frost and deicer scaling damage

• Because of its very low W/C ratio (<0.30), HPC should be highly resistant to both scaling and physical breakup due to freezing and thawing.



5.7 Resistance to chemical attack

• For resistance to chemical attack on most structures, HPC offers a much improved performance.

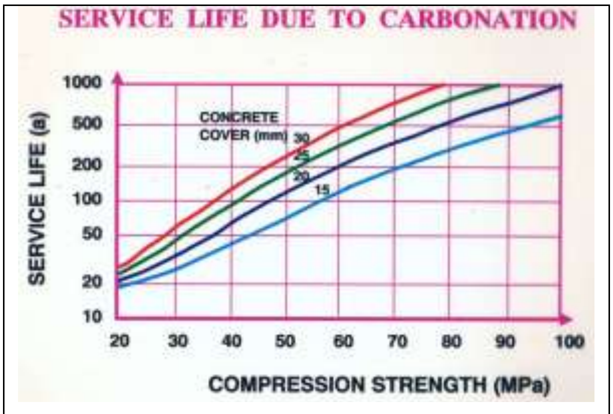
• Resistance to various sulfates is achieved primarily by the use of a dense, strong concrete of very low permeability and low water-to-cementing materials ratio; these are all characteristics of HPC.

• Similarly resistance to acid from wastes is also much improved.

5.8 Carbonation

• HPC has a very good resistance to carbonation due to its low permeability.

• In practical terms, non-cracked HPC cover concrete is immune to carbonation to a depth that would.



IJARSE
ISSN: 2319-8354

Properties – summary

Flowability/pumpability	Easier
Workability/compactability	Easier
Bleeding	None or negligible
Finishing	Quicker
Setting time	Slower up to 2 h
Early strength (up to 7-day)	Lower but can be accelerated
Ultimate strength- 90day +	Higher
Crack resistance	Higher
Plastic shrinkage	Higher(if unprotected)
Thermal shrinkage	Lower
Drying shrinkage	Lower
Resistance to penetration of chloride ions	Very high after 3 months
Electrical resistivity	Very high after 3 months
Durability	
Resistance to sulfate attack	Very high
Resistance to alkali-silica expansion	Very high
Resistance to reinforcement corrosion	High
Environmental benefits (reduced CO2 emission)	Very high

VI.HIGH-DURABILITY CONCRETE

Most of the attention in the 1970s and 1980s was directed toward high strength HPC; today the focus is more on concretes with high durability in severe environments resulting in structures with long life.
The following sections review durability issues that high-performance concrete can address.

6.1 Abrasion Resistance

Abrasion resistance is directly related to the strength of concrete. This makes high strength HPC ideal for abrasive environments. The abrasion resistance of HPC incorporating silica fume is especially high. This makes silica fume concrete particularly useful for spillways and stilling basins, and concrete pavements or concrete pavement overlays subjected to heavy or abrasive traffic.

The best result is obtained with a mix using slag cement, steel fibers, and silica fume. Mortar strengths ranged from 75MPa to 100MPa (11,000 psi to 14,500 psi). In addition to better erosion resistance, less drying shrinkage, high freeze-thaw resistance, and good bond to the substrate can be achieved.

Applications have included new pavements and overlays to existing pavements.

6.2 Blast Resistance

High-performance concrete can be designed to have excellent blast resistance properties. These concretes often have a compressive strength exceeding 120MPa (14,500 psi) and contain steel fibers. Blast-resistant concretes are often used in bank vaults and military applications.

6.3 Permeability

The durability and service life of concrete exposed to weather is related to the permeability of the cover concrete protecting the reinforcement. HPC typically has very low permeability to air, water, and chloride ions. Low permeability is often specified through the use of a coulomb value, such as a maximum of 1000 coulombs. The dense pore structure of high performance concrete makes it so impermeable, gives its characteristics that make it eminently suitable for use where a high quality concrete would not normally be considered. Latex-modified HPC is able to achieve these same low levels of permeability at normal strength levels without the use of supplementary cementing materials. A large amount of concrete is used in farm structures. It typically is of low quality and often porous and with a rough surface, either when placed or after attack by farmyard wastes.

6.4 Diffusion

Aggressive ions, such as chloride, in contact with the surface of concrete will diffuse through the concrete until a state of equilibrium in ion concentration is achieved. If the concentration of ions at the surface is high, diffusion may result in corrosion-inducing concentrations at the level of the reinforcement.

The lower the water-cementing materials ratio the lower the diffusion coefficient will be for any given set of materials. Supplementary cementing materials, particularly silica fume, further reduce the diffusion coefficient. Typical values for diffusion for HPC are as follows:

Type of Concrete Diffusion Coefficient

Portland cement-fly-ash silica fume mix: 1000 x 10-15 m2/s

Portland cement-fly ash mix: 1600 x 10-15 m2/s

6.5 Carbonation

HPC has a very good resistance to carbonation due to its low permeability. For the lower water cementing materials ratios common to HPC, significantly longer times to corrosion would result, assuming a crack free structure. In practical terms, uncracked HPC cover concrete is immune to carbonation to a depth that would cause corrosion.

6.6 Temperature Control

The quality, strength, and durability of HPC is highly dependent on its temperature history from the time of delivery to the completion of curing. In principle, favorable construction and placing methods will enable: (1) a low temperature at the time of delivery; (2) the smallest possible maximum temperature after placing; (3) minimum temperature gradients after placing; and (4) a gradual reduction to ambient temperature after maximum temperature is reached. Excessively high temperatures and gradients can cause excessively fast hydration and micro- and macro-cracking of the concrete. It has been a practice on major high-rise structures incorporating concretes with specified strengths of 70MPa to 85MPa (10,000 psi to 12,000 psi) to specify a maximum delivery temperature of 18°C (64°F). In summertime it is possible that this limit could only be met by using liquid nitrogen to cool the concrete. Experience with very-high-strength concrete suggests that a delivery temperature of no more than 25°C (77°F), preferably

20°C (68°F), should be allowed. In addition to liquid nitrogen, measures to cool HPC in the summer may involve using ice or chilled water as part of the mix water. The specifier should state the required delivery temperature. In HPC applications such as high-rise buildings, column sizes are large enough to be classed as mass concrete. Normally, excessive heat generation in mass concrete is controlled by using a low cement content. When high-cement-content HPC mixes are used under these conditions, other methods of controlling maximum concrete temperature must be employed.

6.7 Freeze-Thaw Resistance

Because of its very low water-cementing materials ratio(less than 0.25), it is widely believed that HPC should be highly resistant to both scaling and physical breakup due to freezing and thawing. There is ample evidence that properly air-entrained high performance concretes are highly resistant to freezing and thawing and to scaling.

Experiences prove that excellent durability of certain high-performance concretes to freeze-thaw damage and salt scaling, it is considered prudent to use air-entrainment. No well-documented field experiments have been made to prove that air-entrainment is not needed. Until such data are available, current practice for air-entrainment should be followed. It has been shown that the prime requirement of an air-void system for HPC is a preponderance of air bubbles of 200µm size and smaller. If the correct air bubble size and spacing can be assured, then a moderate air content will ensure durability and minimize strength loss. The best measure of air entrainment is the spacing factor.

6.8 Chemical Attack

For resistance to chemical attack on most structures, HPC offers a much improved performance. Resistance to various sulfates is achieved primarily by the use of a dense, strong concrete of very low permeability and low water-to-cementing materials ratio; these are all characteristics of HPC.

6.9 Alkali-Silica Reactivity

Reactivity between certain siliceous aggregates and alkali hydroxides can affect the long-term performance of concrete. Two characteristics of HPC that help combat alkali-silica reactivity are:

(1) HPC concretes at very low water to cement ratios can self desiccate (dry out) to a level that does not allow ASR to occur (relative humidity less than 80%). The low permeability of HPC also minimizes external moisture from entering the concrete.

(2) HPC concretes can use significant amounts of supplementary cementing materials that may have the ability to control alkali-silica reactivity. However, this must be demonstrated by test. HPC concretes can also use ASR inhibiting admixtures to control ASR. HPC concretes are not immune to alkali-silica reactivity and appropriate precautions must be taken.

6.10 Resistivity

HPC particularly that formulated with silica fume, has very high resistivity, up to 20 to 25 times that of normal concrete. This increases resistance to the flow of electrical current and reduces corrosion rates. Particularly if dry, HPC acts as an effective dielectric. Where cracking occurs in HPC, the corrosion is localized and minor; this is due to the high resistivity of the concrete which suppresses the development of a macro corrosion cell.

VII.SELF-COMPACTING CONCRETE

Self-compacting concrete (SCC), also referred to as self-consolidating concrete, is able to flow and consolidate under its own weight. At the same time it is cohesive enough to fill spaces of almost any size and shape without segregation or bleeding. This makes SCC particularly useful wherever placing is difficult, such as in heavily reinforced concrete members or in complicated formwork.

This technology, developed in Japan in the 1980s, is based on increasing the amount of fine material, for example fly ash or limestone filler, without changing the water content compared to common concrete. This changes the rheological behavior of the concrete. SCC has to have a low yield value to ensure high flowability low water content ensures high viscosity, so the coarse aggregate can float in the mortar without segregating. To achieve a balance between deformability and stability, the total content of particles finer than the 150µm (No. 100) sieve has to be high, usually about 520 to 560 kg/m3 (880 to 950lb/yd3). High-range water reducers based on polycarboxylate ethers are typically used to plasticize the mixture. SCC is very sensitive to fluctuation in water content; therefore, stabilizers such as polysaccharides are used. The viscosity required to inhibit segregation will then be adjusted by using a stabilizer. The combination type is created by adding a small amount of stabilizer to the powder type to balance the moisture fluctuations in the manufacturing process. Since SCC is characterized by special fresh concrete properties, many new tests have been developed to measure flowability, viscosity, blocking tendency, self-leveling, and stability of the mixture. A simple test to measure the stable and unblocked flow is the J-Ring test, which is a modified slump test. The J-Ring—300 mm (12 in.) diameter with circular rods is added to the slump test. The number of rods has to be adjusted depending on the maximum size aggregate in the SCC mix. The SCC has to pass through the obstacles in the J-Ring without separation of paste and coarse aggregates. The slump diameter of a well-proportioned SCC is approximately the same with and without the J-Ring; it is usually about 750 mm (30 in.). Therefore, the test surface has to be at least 1000 mm (40 in.) in diameter. Strength and durability of well-designed SCC are almost similar to conventional concrete. The production of SCC is more expensive than regular concrete and it is difficult to keep SCC in the desired consistency over a long period of time. However, construction time is shorter and production of SCC is environmentally friendly (no noise, no vibration). Furthermore, SCC produces a good surface finish. These advantages make SCC particularly interesting for use in precasting plants.

VIII.REACTIVE-POWDER CONCRETE

Reactive-powder concrete (RPC) was first patented by a French construction company in 1994. It is characterized by high strength and very low porosity, which is obtained by optimized particle packing and low water content. The properties of RPC are achieved by: (1) eliminating the coarse aggregates; just very fine powders are used such as sand, crushed quartz, and silica fume, all with particle sizes between 0.02 and 300µm (2) optimizing the grain size distribution to densify the mixture (3) post-set heat-treatment to improve the microstructure (4) addition of steel and synthetic fibers (about 2% by volume) and (5) use of superplasticizers to decrease the water to cement ratio—usually to less than 0.2—while improving the rheology of the paste. See Fig. below for a typical fresh RPC. The compressive strength of reactive-powder concrete is typically around 200MPa (29,000 psi), but can be produced with compressive strengths up to 810MPa (118,000psi). However, the low comparative tensile strength requires prestressing reinforcement in severe structural service. Table below compares hardened concrete properties of RPC with those of an 80-MPa (11,600psi) concrete. Also, the low porosity of RPC gives excellent durability and transport properties, which makes it a suitable material for the storage of nuclear waste. A low-heat type of reactive-powder concrete has been developed to meet needs for mass concrete pours for nuclear reactor foundation mats and underground containment of nuclear wastes.

IX.CONCLUSION

This paper provides an overview of fundamentals of High performance concrete (HPC) and its applications in the designing of heavy and tall structures. The manufacturing methods used in high performance concrete provide high strength and low permeability. The various advantages and limitations are discussed along with durability strength severe environmental conditions for the use of high performance concrete. In order to produce HPC of high ductility fiber reinforcement is used. Fly ash, Silica fume and Superplasticizers are used to manufacture High Performance Concrete. In order to produce HPC of high durability , low permeability and high strength there must be proper design mix proportions and proper curing should be done. Because of the various advantages of High Performance Concrete it is widely used in modern construction era.

REFERENCES

Books:

[1] P.C.Aitcin, High Performance Concrete [E & FN SPON-2004].

[2]M.S.Shetty, Advanced Concrete Technology [S. Chand-2015]

Journal Papers:

[3]Malathy, R. (2003), "Role of super fine fly ash on high performance concrete", Role of Concrete in Sustainable Development - Proceedings of the International Symposium dedicated to Professor Surendra Shah - Celebrating Concrete: People and Practice, 2003.

[4] Hossain and Lachemin (2007), "Strength, ductility and micro-structural aspects of high performance volcanic ash concrete", Cement and Concrete Research, v 37.

[5] Isaia, G.C., Gastaldini, A.L.G. and Moraes, R. (2003), "Physical and pozzolanic actions of mineral additions on the mechanical strength of high performance concrete", Cement and Concrete Composite, v 25.

[6] Kwan, A.K.H (2000), "Use of condensed silica fume for making high-strength, self-consolidating concrete", Canadian Journal of Civil Engineering, v 27, n 4, Aug, 2000.

[7] Wise, S., Satkowski, J.A., Scheetz, B., Rizer, J.M., McKenzie, M.L. and Double, D.D. (1985), "The development of a high strength cementitious tooling/molding material", Proceedings of Materials Research Society Symposium, v 42.

[8] Richard, P. and Cheyrezy, M. (1995), "Composition of reactive powder concretes", Cement and Concrete Research, v 25.

[9] Lee, K.M. and Buyukozturk, O. (1995), "Fracture toughness of mortar-aggregate interface in high-strength concrete", ACI Materials Journal, v 92, n 6.

[10] "The pedestrian/bikeway bridge of Sherbrooke", 4th International Symposium on Utilization of High-strength/High-performance Concrete, Paris.

[11] Shah, S. and Ahmad, S. (1994), "High performance concrete applications", Edward Arnold, London.

[12] "A constitutive model for normal- and high-strength concrete", ABK Report No. R 287, Dept. Struct. Eng., TU Denmark, Lyngby.

[13] Van Geel, E. (1998), "Concrete Behavior in Multiaxial Compression, Experimental Research", Doctorate Thesis, TU Eindhoven.