AN OVERVIEW ON THE ADVANCES IN CONCRETE TECHNOLOGY

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ABSTRACT: *Concrete technology has been practice in the construction industry for over millennia by using cement, sand and aggregate. The compressive strength of about 30-50N/mm^2 was the maximum strength range achievable which is the limit capture by various codes of practice with the durability estimated on the basis of thickness of concrete cover. In today's technology, the compressive strength of up to 170N/mm^2 is achievable with the durability calculated on the basis to time for deterioration. Concrete section could be reduced by more than 1/3 of the conventional thickness of structural components.*

Keywords: Compressive Strength, Durability, Ultra High Performance Concrete, Fibre Reinforced Concrete.

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INTRODUCTION

Concrete construction has been practice for over millennia due to its mechanical properties coupled with it cost compared with other building materials such as steel sections. Reinforced concrete are the most commonly used structural material (Neville, 2008). It major constituent material consists of cement sand and aggregate which are combined at an appropriate water cement ratio based on design compressive strength. It ability to take any desired shape, colour and size makes it highly marketable and acceptable all over the world (Lyse, 1936). Concrete and steel are the two most commonly used structural materials which sometimes complement one another, and sometimes compete with one another so that structures of a similar type and function can be built in either of these materials. Various advances have been attempted by researchers to develop higher strength class of reinforced concrete structures by using various techniques: Self Compacting Concrete (SCC), Pre-Stress Concrete, Post Tension Concrete and so on. In Japan, Self-Compacting Concrete (SCC) has been attempted for large office complex and also for advanced types of extruded tunnels in combination with steel fibres (Persson, 2001). Use of SCC lowered the noise level on the construction site and diminished the effect on the environment. In Sweden, SCC had been used for 19 highway bridges so far and for slabs in a dwelling house where a 60% increase in productivity was observed (Persson, 2002). Use of SCC thus improved both the conditions for the labour on the work site and for the surroundings. Beside problems with building moisture, a more modern technique for production is an issue to be solved for concrete that is cast on site. Problems with building moisture have been solved by use of High-Performance Concrete (HPC; w/b<0.38) (Nilsson, 1998; Persson, 2003). Like Normal Compacting Concrete (NCC), SCC contains small quantities of super-plasticizer. Furthermore, in order to avoid separation of large particles in SCC, additives to increase the viscosity or fillers are used (Persson, 1999)(Byfors & Grauers, 1997; Nishio, Tamura, & Ohashi, 1998). An additive to increase the viscosity is often used when casting concrete under water and for SCC in tunnels.

CONVENTIONAL CONCRETES

Conventional Concretes are those concrete produced from combination of cement, aggregates and water only. The performance of the matrix is quite desirable based on the requirement of the level of technology in the early years. The compressive strength of the range of 30-50N/mm^2 was the maximum strength achieved and is the range the various codes of practice have provided for any reinforced concrete designs.

The British Standards (BS), European Standards BS EN, American Standards (ASTM) etc, have captured this strength class range. Table 1 show the strength class provided in the BS8110 part 3 (1997) while Table 2 revealed the durability consideration between 20-50mm as cover to reinforcement. The provision of this thickness of cover leads to very thick section of concretes and this approach is similar in all the standards practice today. This approach level of technology has limited the height limit of buildings and spans of bridges.

Table 1: Design Flexural Tensile Stresses in In-situ Concrete (BS8110 Part 5, 1997)

Grade of in-situ concrete	Maximum tensile stress N/mm^2
25	3.2
30	3.6
40	4.4
50	5.0

Table 2: Nominal Cover to All Reinforcement (Including Links) to Meet Durability Requirements (BS8110 Part 3, 1997)

Conditions of exposure (see 3.3.4)	Nominal cover mm				
Mild	25	20	20[a]	20[a]	20[a]
Moderate	—	35	30	25	20
Severe	—	—	40	30	25
Very severe	—	—	50[b]	40[b]	30
Most severe	—	—	—	—	50
Abrasive	—	—	—	See NOTE 3	See NOTE 3
Maximum free water/cement ratio	0.65	0.60	0.55	0.50	0.45
Minimum cement content (kg/m^3)	275	300	325	350	400
Lowest grade of concrete	C30	C35	C40	C45	C50

NOTE 1 This table relates to normal-weight aggregate of 20 mm nominal size. Adjustments to minimum cement contents for aggregates other than 20 mm nominal maximum size are detailed in Table 8 of BS 5328-1:1997.

NOTE 2 Use of sulfate resisting cement conforming to BS 4027. These cements have lower resistance to chloride ion migration. If they are used in reinforced concrete in very severe or most severe exposure conditions, the covers in Table 3.3 should be increased by 10 mm.

NOTE 3 Cover should be not less than the nominal value corresponding to the relevant environmental category plus any allowance for loss of cover due to abrasion.

[a] These covers may be reduced to 15 mm provided that the nominal maximum size of aggregate does not exceed 15 mm.
[b] Where concrete is subject to freezing whilst wet, air-entrainment should be used (see **5.3.3** of BS 5328-1:1997) and the strength grade may be reduced by 5.

The technology is fast moving in the global world, every sector is advancing revealing new novelties. In the electronic and auto mobile world, telephone head set and cars has been reduced to smallest possible size as shown in Figure 1 and Figure 2. Similar developments are witness in almost every sector. The construction industry is not left behind as the technology is also at the fore front leading to improvement in the mechanical and durability of concrete structures by using Ultra High Performance Concrete (UHPC).

Figure 1: Evolution of Cell Phone in the Telecommunication Industry

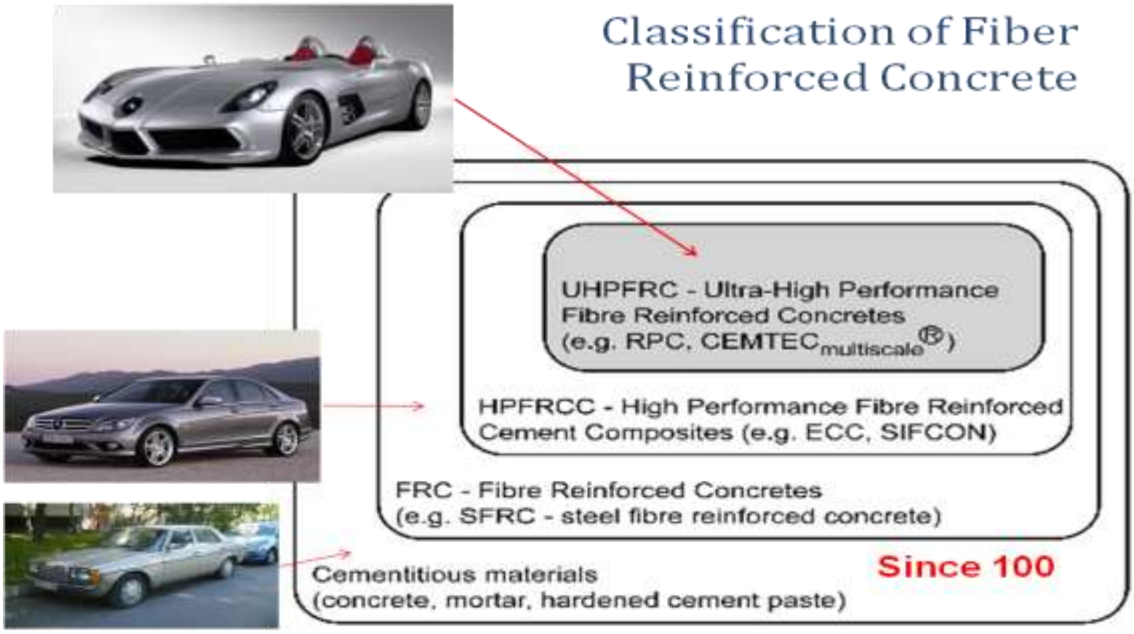

Figure 2: Evolution in the Auto Industry

RESEARCH OVERVIEW

The evolution of Self Compacting Concrete couple with the use of steel fibre reinforced concrete has broken a new ground in concrete technology. The reduction of voids in concrete volume is the major approach in SCC concretes which has leads to improve strength and durability of concrete structures. (Okamura & Ouchi, 2003) reported that Self-Compacting Concrete was first developed in 1988 which has led to achievement of durable concrete structures. Since then, various researches had been carried out which has been used in practical structures in Japan, principally by large construction companies. Investigations for establishing a rational mix-design method and self-compatibility testing methods have been carried out from the viewpoint of making Self-Compacting Concrete a standard concrete. (Su, Hsu, & Chai, 2001) researched to develop a new mix design method for Self-Compacting Concrete (SCC) and reported that the amount of aggregates, binders and mixing water, as well as type and dosage of Super-Plasticizer (SP) to be used are the major factors influencing the properties of SCC concrete. The incorporation of additives such as Super-Plasticizers (SP), Silica Fumes (SF), Ground Granulated Blast Furnace Slag (GGBS), fly ash etc has also influence the performance of concrete structures. Admixtures are used in concrete for numerous purposes which include improvement in mechanical properties, bond strength, freeze-thaw durability, permeability, corrosion control and workability. Admixtures include fine aggregates such as silica fume (Halamickova, Detwiler, Bentz, & Garboczi, 1995) and (Andrade, 1993). (Hou & Chung, 2000) reported that admixtures, namely silica fume, are most effective in resisting corrosion current density during immersion in Ca(OH)2 and NaCl solutions at Silica fume content of 15% by weight of cement due to decrease of water absorptive. This development has lead to improve compactness of concrete material with reduced porosity and increased strength. (Collepardi, 1998) revealed that placing characteristics of concrete can be enhanced by using plasticizing and super-plasticizing admixtures without any change in the water-cement ratio with respect to the plain mixture. The ingredients used to achieve the result were based on Sulfonated Melamine Formaldehyde (SMF) Condensate or Naphthalene Formaldehyde (CNF) condensate.

ULTRA HIGH PERFORMANCE CONCRETE (UHPC)

Further advancement was recorded when the use of steel fibre was discovered in concrete. (Qian & Stroeven, 2000) investigated the optimization of fibre size, fibre content, and fly ash content in hybrid polypropylene-steel fibre concrete with low fibre content based on general mechanical properties. It was discovered that a certain content of fine particles such as fly ash is imperative to evenly disperse fibres. The additions of a small fibre type had a significant influence on the compressive strength, but the splitting tensile strength was only slightly affected while larger fibre type resulted to opposite mechanical effects, which were further prepared by optimization of the aspect ratio. (Graybeal, 2011) revealed that Advances in the science of concrete materials have led to the development of a new class of cementitious composites refers to as ultra-High Performance Concrete (UHPC). The mechanical and durability properties of UHPC make it an ideal composite for use in developing new solutions to pressing concerns about infrastructure development, deterioration, repair, and replacement. (De Larrard & Sedran, 1994) investigated two models for predicting the packing density of a particle mix which is derived from the Mooney's suspension viscosity model. Maximum Paste thickness concept was considered which leads to choice of fine sand for optimizing the compressive strength of cementitious materials and optimal material is sought, based on the requirements: Fluid Consistency, Ordinary Aggregate, Sand, Portland cement, Silica Fume, Super-Plasticizer, Water, and Moderate Thermal Curing.

Ultra high performance is based on the following principle:

- Optimized Granular Packing
- Extremely Low W/C Ratio <0.2
- Inclusion of Very High Strength Micro-Fiber
- Enhanced Tensile Strength and Ductility
- Improved Impact & Abrasive Resistance
- Bridge Micro-Crack More Effectively

Currently, Ultra High Performance has been developed and optimised and the compressive strength of over 170N/mm^2 has being achieved.

Figure 3 shows the workability steel fibre in UHPC which saves about 80% weight, 330% material, 200% laying time and

Figure 4 revealed the difference in the mechanical properties between the old and the new technology. This technology has made it possible to increase heights of high rise buildings, spans of bridges and beams, thinners concrete sections and improve durability by over 300%.

Figure 5,

Figure 6 and

Figure 7 shows the currently standing structures build around the world using ultra modern technology achieved in civil engineering field.

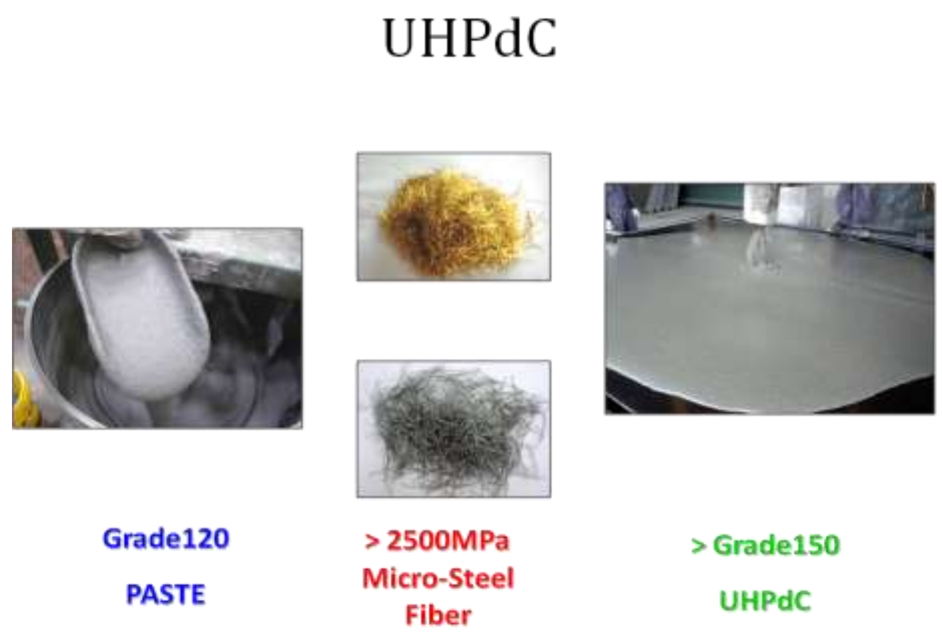

Figure 3: Steel Fibre and the Workability of UHPC at Water Cement Ratio of < 0.2 (UPM, Structures Lab)

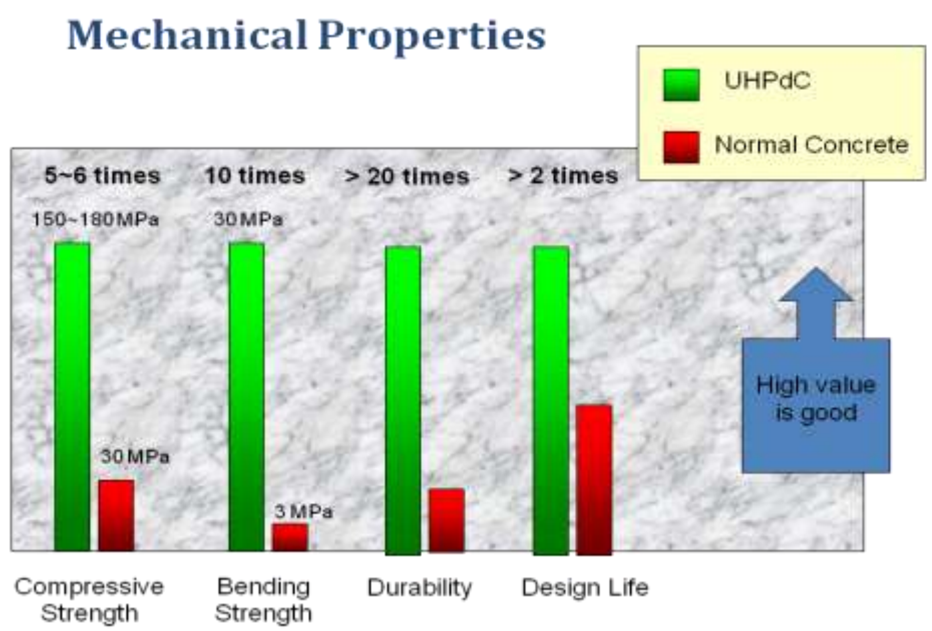

Figure 4: Mechanical Properties of UHPC Compared with Normal Concrete (UPM, Structures Lab)

Figure 5: Current Achievement in Concrete Technology

Figure 6: Simply Supported 50meters Bridge Build with UHPC
(Photo Taken in Malaysia)

Figure 7: 120m Foot Bridge Build with UHPC in South Korea (www.vsl-intl.com)

CONCLUSION

- High strength concrete could be produced of almost zero maintenance.
- Compressive strength of over 170N/mm2 is achievable using ultra high performance material.
- Greener and sustainable infrastructure could be delivered by imbibing the latest technology in civil engineering application.
- Highly ductile concrete could be produced with ductility as much as that of steel material.
- This technology has gone beyond provision by the current standards of practice and the need to work very much to meet up with the current developmental challenges is highly imperative.

REFERENCES

Andrade, C. (1993). Calculation of Chloride Diffusion Coefficients In

Concrete from Ionic Migration Measurements. *Cement and Concrete Research, 23*(3), 724-742.

Byfors, J., & Grauers, M. (1997). SCC: a large Step Towards A More Industrialized Type of Construction. *Belong, 4*(97), 8-10.

Collepardi, M. (1998). Admixtures Used to Enhance Placing Characteristics of Concrete. *Cement and Concrete Composites, 20*(2–3), 103-112. doi: http://dx.doi.org/10.1016/S0958-9465(98)00071-7

De Larrard, F., & Sedran, T. (1994). Optimization of Ultra-High-Performance Concrete by the Use of a Packing Model. *Cement and Concrete Research, 24*(6), 997-1009.

Graybeal, B. (2011). Ultra-High Performance Concrete.

Halamickova, P., Detwiler, R. J., Bentz, D. P., & Garboczi, E. J. (1995). Water Permeability and Chloride ion Diffusion in Portland Cement Mortars: Relationship to Sand Content and Critical Pore Diameter. *Cement and Concrete Research, 25*(4), 790-802.

Hou, J., & Chung, D. D. L. (2000). Effect of Admixtures in Concrete on the Corrosion Resistance of Steel Reinforced Concrete. *Corrosion Science, 42*(9), 1489-1507. doi: http://dx.doi.org/10.1016/S0010-938X(99)00134-1

Lyse, I. (1936). A Study of the Quality, the Design and the Economy of Concrete. *Journal of the Franklin Institute, 222*(1), 83-98.

Neville, A. M. (2008). *Concrete Technology*: Pearson Education India.

Nilsson, L. (1998). Is HPC a Solution to Moisture Problems? *Byggforskning, 2*(98), 40-41.

Nishio, A., Tamura, H., & Ohashi, M. (1998). Self-compacting Concrete with High-Volume Crushed Rock Fines. *ACI Special Publication, 179*.

Okamura, H., & Ouchi, M. (2003). Self-Compacting Concrete. *Journal of Advanced Concrete Technology, 1*(1), 5-15.

Persson, B. (1999). *Creep, Shrinkage and Elastic Modulus of Self-Compacting Concrete.* Paper Presented at the Proceedings of the 1st International RILEM Symposium on Self-Compacting Concrete, Stockholm.

Persson, B. (2001). A Comparison between Mechanical Properties of Self-Compacting Concrete and the Corresponding Properties of Normal Concrete. *Cement and Concrete Research, 31*(2), 193-198.

Persson, B. (2002). Compatibility between Flooring Materials and Concrete. *Materials and Structures, 35*(3), 170-182.

Persson, B. (2003). Sulphate Resistance of Self-Compacting Concrete. *Cement and Concrete Research, 33*(12), 1933-1938.

Qian, C. X., & Stroeven, P. (2000). Development of Hybrid Polypropylene-Steel Fibre-Reinforced Concrete. *Cement and Concrete Research, 30*(1), 63-69. doi: http://dx.doi.org/10.1016/S0008-8846(99)00202-1

Su, N., Hsu, K.-C., & Chai, H.-W. (2001). A Simple Mix Design Method for Self-Compacting Concrete. *Cement and Concrete Research, 31*(12), 1799-1807.

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