Use of High Performance Concrete in Pavement Construction

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Abstract— Performance of concrete is substantially higher than that of normal type concrete, such concrete is regarded as high performance concrete (HPC). Three of the key attributes to HPC are discussed in this paper. They are: strength, ductility and durability. In order to know the intrinsic differences between normal type concrete and high performance concrete, micro-structure and composition of HPC are studied. Stress strain behavior of HPC under biaxial and triaxial loading are described. Finally, the application of HPC in tall building construction is discussed. This paper provides a general overview of the development of HPC, covering the topic from the laboratory testing to the industrial application.

Key words: High Performance Concrete (HPC), Pavement Construction

I. INTRODUCTION

High performance concrete (HPC) is regarded as synonymous with high strength concrete (HSC). It is because lowering of water-to-cement ratio, which is needed to attain high strength, also generally improves other properties. However, it is now recognized that with the addition of mineral admixtures HPC can be achieved by further lowering water-to-cement ratio, but without its certain adverse effects on the properties of the material. Hence, it is important to understand how concrete performance is linked to its microstructure and composition. In fact, performance can be related to any properties of concrete. It can mean excellent workability in fresh concrete, or low heat of hydration in case of mass concrete, or very quick setting and hardening of concrete in case of spray concrete which is used to repair roads and airfields, or very low imperviousness of storage vessels. However, from a structural point of view, one understands usually that high strength, high ductility and high durability, which are regarded as the most favorable factors of being a construction material, are the key attributes to HPC. Decades ago, HSC was only tested in laboratory without real applications because there were still many uncertainties on the structural behavior of HSC at that time. Up to the present, HPC has been widely used in tall building.

A. Composition of High Performance Concrete

The composition of HPC usually consists of cement, water, fine sand, superplasticizer, fly ash and silica fume. Sometimes, quartz flour and fiber are the components as well for HPC having ultra-strength and ultra-ductility, respectively. The key elements of high performance concrete are:

- Low water-to-cement ratio
- large quantity of silica fume
- small aggregates and fine sand and high dosage of superplasticizers.

B. Key Features of High Performance Concrete

HPC have a better performance when compared to normal strength concrete. Three of the key attributes to HPC are discussed in this part. They are:

- Strength
- ductility and durability

We identify these three areas for discussion because they are the most important performance that a construction material should possess.

II. STRENGTH

Concrete with a compressive strength less than 50MPa is regarded as NSC, while high strength concrete (HSC) may be defined as that having a compressive strength of about 50MPa. Recently, concrete with the compressive strength of more than 200MPa has been achieved. Such concrete is defined as ultra-high strength concrete. As the compressive strength of concrete has been steadily increasing with ample experimental validation, the commercial potential of high strength concrete became evident for columns of tall buildings.

III. ELASTIC LIMIT

The elastic limit of FRC is influenced by the tensile strength of the matrix itself and the fibers primarily control deformation after cracking. Recently, it was reported that fibers can enhance the elastic limit provided that they effectively bridge the matrix microcracks. The effectiveness of the fiber-bridging action will depend on volume fraction, length, diameter, and distribution of fibers, as well as the properties of the fiber matrix. It was found that the inherent tensile strength and strain capacity of the matrix itself was enhanced when small fibers were used. When 4% (by volume) of carbon fibers were added, the first cracking, indicating the elastic limit, was observed at about 30% of the maximum tensile load.

IV. DURABILITY

Many investigations have been conducted related to concrete durability and have provided results that the majority of concrete durability problems are related to the resistance of concrete to permeation of water and chemical ions. Such problems include corrosion of steel reinforcement, freeze-thaw damage, and alkaline-silica reaction. The durability evaluation of concrete may be inferred by measuring the resistance of cover layer to transport mechanisms such as diffusion coefficient, coefficient of permeability, rate of absorption, concrete resistivity and corrosion rate. The permeability of concrete is a key factor influencing the durability of concrete. Concrete permeability is dependent on permeability of each constituent material and its geometric arrangement. The permeability of cement paste is primarily related to pore structure, which includes porosity, pore size and connectivity; while pore structure is a function of the water-to-cement ratio and the degree of hydration. The aggregates have a much lower permeability than cement pastes. However, they affect the permeability of concrete in four ways: dilution, tortuosity, interfacial transition zone and percolation. The dilution effect occurs because the aggregates are less permeable than the paste. As a result, the aggregate particles block the flow paths and effectively reduce the permeable area in a cross section of concrete. The tortuosity effect occurs as a result of the impermeability of the aggregates which forces flow around the aggregate particles, and therefore increasing the length of flow paths and decreasing the flow rate.

V. CONCLUSION

In this paper the microstructure of HPC and its influence on concrete performance is presented. In manufacturing the material the use of densified small particle systems contribute to the high strength and low permeability of HPC. The three key attributes of HPC, strength, ductility and durability are discussed. Fly ash, silica fume and superplasticizer are important ingredients to manufacture high strength concrete. In order to produce HPC with high ductility, fiber is a critical element which should be present in the design mix. In order to create durable HPC, it is necessary to use a proper mix design and apply an effective curing. It is suggested that three criteria should be considered to produce durable concrete. These criteria are strength, permeability and cracking resistance. Because of its advantageous characteristics, HPC is now widely used in tall building construction. In this paper, Taipei 101 is used as an example to demonstrate the application of HPC in tall building construction.

REFERENCES

[1] 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, p 69-76
[2] 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, p 620-627
[3] Richard, P. and Cheyrezy, M. (1995), “Composition of reactive powder concretes”, Cement and Concrete Research, v 25, n 7, p 1501-1
[4] Sellevold, E.J. and Nilsen, T. (1987), “Condensed silica fume in concrete: a world review”, Supplementary Cementing Materials for Concrete, ed. By V.M. Malhotra, CANMET, Ottawa, Canada, p167-246
[5] Shah, S. and Ahmad, S. (1994), “High performance concrete applications”, Edward Arnold, London.
[6] very high strength concrete”, ACI Structural Journal, v 90, n 6, p 632-641
[7] Balaguru, P.N. and Shah, S.P. (1992), “Fiber Reinforced Cement Composites”, McGraw Hills, Inc., Publishers, New York
[8] Shah, S.P. (2000), “High performance concrete: past, present and future”, Proceedings of High Performance Concrete - Workability, Strength and Durability, Hong Kong, v 1, p 3-29

