Chapter 1

Introduction

1.1 General

Concrete is a composite material, which is essentially a combination of a binding medium and embedded particles or fragments of relatively inert mineral filler. Properties of concrete change with age. Age of concrete can be classified into various states based on its time-dependent property variation. However, it is not reasonable to consider only some properties in some ages in designing mix proportion of concrete. The traditional method of mix proportioning of concrete mainly concerned with only workability and some mechanical properties at a specific age of concrete. However, it is known that properties of concrete can change upon age and the rate of change depends on its composition and environmental condition. If concrete is not designed and constructed by considering its behaviors and deterioration of its properties upon age and environment, unexpected repair or maintenance programs are required in order to extend the service life of the concrete structures. Therefore, concrete structure should be designed with the aim of satisfying the required performance during their service life. The design method that covers several properties of concrete during its service life is known as the performance based design.

Concrete is a porous material. Various substances can penetrate into concrete through the interconnected capillary pores. Some substances can cause deterioration of the concrete. Carbonation, the process that carbon dioxide in atmosphere penetrates into concrete and chemically reacts with calcium hydroxide, is one of the durability problems that are often found. Although carbonation is not harmful to plain concrete, the reaction affects the amount of calcium hydroxide, which is the product of the hydration reaction in concrete. Generally steels are protected from corrosion by a passive protective oxide film, which is formed on steel in an alkali environment between a pH of 12.5 and 13.5. In concrete, this condition of environment is significantly due to the existence of calcium hydroxide. When carbonation occurs, the alkalinity of the concrete pore water is reduced. Thus, the corrosion protection of reinforcing steel by high alkalinity is destroyed. As steel corrodes, it expands in volume and causes cracking, rust staining, and spalling of the concrete cover. Thereafter, the reinforced concrete structures may not be able to service throughout their design service life.

Based on the specified requirement of concrete subjecting to carbonation in many countries, the depth of carbonation tested by a standard accelerated carbonation method is limited by a specific value. This concept is set to ensure that the carbonation ingress will not reach the position of the reinforcing steel bar nearest to the concrete surface before the expected maintenance-free service life of the structure. For reinforced concrete structures, the onset of reinforcement corrosion is considered as one of the important stages for determining the service life of the concrete structure. The major role of concrete cover is to protect the steel from corrosion. In general, thickness of concrete cover varies with the type of structure, quality of the concrete cover, and environmental condition that the structure is to be subjected to. In many cases, congestion of reinforcement and poor construction practice can lead to small depths or low quality of concrete cover, which lead to early corrosion of steel reinforcement. This problem is more severe in the structures located in the environment that has high carbon dioxide concentration.

Cement is nowadays no longer the only cementitious material contained in concrete. Fly ash, the most common artificial pozzolan, is widely used as a cement supplementary material. Fly ash is generally finer than cement and mainly consists of glassy-spherical particles and some crystalline phases during cooling. Use of fly ash as a cement replacement material in concrete not only benefits in effective use of natural resources and reducing cost of concrete but also improves many properties of concrete such as workability, bleeding, segregation resistance, heat evolution, permeability, and also durability of concrete in some cases. The amount of fly ash substituting cement for achieving the required concrete properties varies and depends mainly on the properties of the fly ash, mix proportion, environment, type of structure, and construction difficulty.

1.2 Statement of Problems

Although many researches have pointed out the merits of fly ash in the sense of improving many concrete qualities and reducing environmental problems, the available mix proportioning methods of fly ash concrete still consider only workability in fresh state and some mechanical properties of concrete in hardened state. The major difficulty for using fly ash in concrete is the quality control of the fly ash. The properties of fly ash varies and depends on type of coal, characteristic of furnace, burning and collecting process, etc.

Moreover, properties of concrete can deteriorate upon age and the rate of deterioration depends on the quality of concrete and environmental condition. Carbonation is one of the durability problems that occurs when carbon dioxide reacts, in the presence of moisture, with calcium hydroxide in concrete. Specifying thickness of concrete cover to the reinforcing steel bars, maximum water to binder ratio and fly ash content are possible for making a durable concrete to carbonation. At present, engineers are still practicing based on their experiences and intensive trial mixings. It will be beneficial if a mix proportioning method for fly ash concrete that considers durability properties of concrete in long term, such as carbonation can be proposed.

1.3 Objectives and Scopes of This Study

The objectives of this study is to identify the roles of various parameters including mix proportion of concrete, curing period, type and content of fly ash, and environmental condition on carbonation resistance of fly ash concrete and mortar. However, the rate of carbonation in a real environment is usually slow due to low temperature and carbon dioxide concentration level in the environment. Hence, the accelerated carbonation test is a practical method used to assess the carbonation resistance of concrete within a reasonably short time. However, the accelerated method is only a comparison method. The actual carbonation resistance of concrete cannot be quantitatively determined. In order to formulate the performance based mix proportioning of fly ash concrete durable to carbonation, the experiment in real environment is also required.

In this study the experiments in both real and accelerated environments were conducted. The effects of the tested parameters were subsequently used to establish a semi-microscopic model for predicting the carbonation depth. This proposed model considers several chemical reactions within concrete and the influences of various parameters including type of fly ash and environmental conditions on carbonation resistance of concrete. Moreover, due to the complexity of the model, a simple mathematical approach to predict carbonation depth in real environments based on the accelerated tests and square-root-t-law was also proposed. Finally, the proposed models were combined together with the compressive strength prediction model proposed by Kaewkhluab (2002) and the slump prediction model proposed by Wangchuk (2003) in order to formulate the design charts for mix proportioning of fly ash concrete durable to carbonation.