Chapter 1
Introduction

1.1 General

Mass concrete is defined for large dimension construction such as dams, and mat foundations. In massive concrete structures, the temperature rise due to heat of hydration causes temperature gradients which can induce thermal cracks especially at early age. Thermal cracking of bridge piers, foundations, floor slabs, beams, columns, and other massive structures (such as locks and dams) can reduce load carrying capacity or service life of a structure by promoting early deterioration or excessive maintenance. Therefore, it is obviously necessary to manage such problem of early age thermal cracking to ensure the concrete structure meets its design performance. Furthermore, it should be recognized that the selection of proper mixture proportions is only one of the means of controlling temperature rise, and that other aspects of the concrete work should be studied and incorporated into the design and construction requirements.

To avoid cracking due to heat of hydration, one approach is to control the hydration heat of concrete by reducing cement content in the concrete mixture since the components of cement are responsible for the generation of heat. This reduction in cement content can be achieved by controlling the aggregate size and gradation, improving concrete workability by the use of chemical admixtures like superplasticizer, air-entraining agent, and by the proper use of a good pozzolanic material to replace cement. Fly ash is one of the pozzolanic materials which can be effectively used as a cement replacing material to reduce hydration heat of concrete.

The design of appropriate construction process is another essential process to avoid cracking. In some construction projects, thermal insulating blankets were used to minimize the interior and exterior concrete temperature gradient (Whittier et al., 2004). Generally, for crack control, maximum difference within the concrete mass should not exceed 20 ^{o}C (Neville, 1995), but with limestone aggregate, the difference can be allowed up to 31 ^{o}C (Portland Cement Association, 2003). In the case of massive concrete with very large size, casting usually can not be finished at one time. Technique of discontinuous casting typically layer casting or block casting was used in order to minimize temperature gradient of mass concrete. The selection of proper dimension and numbers of concrete blocks or layers in order to prevent thermal cracking is one of the important steps of the mass concrete construction. The use of different type of aggregate has an effect on thermal properties of concrete which influences semi-adiabatic temperature rise and thermal stress. The curing method and curing period are also important to prevent thermal cracking during the construction process. Many massive structures crack because of the application of unsuitable curing method and curing period.

To predict the thermal cracking of fly ash concrete, the quantitative evaluation of heat evolution during hardening as well as the thermal properties and related mechanical properties are necessary to be investigated. The development of a computerized program for predicting thermal cracking of mass concrete is beneficial to the construction process design. This developed program is used as a tool for engineer to design concrete mix proportion and construction process.

1.2 Statement of Problems

The ability to predict the temperature rise is essentially useful for thermal cracking analysis. Several techniques are reported in the literature for designer to evaluate the thermal cracking risk and appropriate construction technique. For example, the U.S. Army Corps of Engineers, in Engineering and Technical Letter (1997) and ACI 207.1 (2005) provide design guides for thermal analysis of mass concrete. However, those design guides are complicate for manual calculation and can not be used for various types of cementinious materials. On the other hand, many hydration heat prediction models have been developed in order to simulate the temperature of mass concrete (Isgor and Razaqpur, 2004; Kwak et al., 2006; Sarker et al., 1999; Maekawa et al., 1999; Wang and Dilger, 1994; Park et al., 2008; Faria et al., 2006; Jitvutikrai 2000). Some of them did not include the effect of fly ash (Isgor and Razaqpur, 2004; Park et al., 2008). Some included the effect of fly ash but still could not be applied for fly ash in Thailand.

Thermal properties such as specific heat, thermal conductivity, thermal expansion coefficient, convection heat transfer coefficient at the exposed surface, and mechanical properties like early age tensile strength, tensile strain capacity and modulus of elasticity are necessary for the prediction of thermal cracking. The environmental conditions such as wind speed, relative humidity and the effect of heat from sun light are also important factors for predicting heat loss from mass concrete.

Many researchers have investigated those thermal properties by conducting experimental observation. However, majority of the experiments were conducted at 28 days or longer (Xu and Chung, 2000; Klan, 2002; Neekhra, 2004). But in mass concrete, the most serious period is at early age. The properties of concrete at early age must be understood in order to prevent thermal cracking. In some cases (Demirboğa, 2003; Demirboğa et al.,2007), tests were conducted by using oven-dried samples then the moisture condition was not in the actual range in mass concrete. Some previously proposed thermal properties models can not be used to automatically predict thermal properties from the concrete mix proportion (Kim et al., 2003; Neville and Brooks, 1987). In such cases, thermal properties of paste or mortar must be tested. Few efforts had been made to quantitatively predict the thermal properties especially for fly ash concrete as well as to incorporate time dependent behavior. Nowadays, the constant thermal properties values of matured concrete have been traditionally used in analysis of thermal cracking problem. However, this is not realistic especially during very early age when the thermal cracking problem is the most serious.

Saengsoy and Tangtermsirikul (2003) proposed the adiabatic temperature rise. The adiabatic temperature rise model consisted of various sub-models such as degree of hydration and pozzolanic reaction model, hydration and pozzolanic reaction heat model, heat generation model of cement and fly ash, free water content model and specific heat model. All of those sub-models were proposed as time dependent properties. However, the physical effect of fly ash especially for the use of high volume fly ash was not included in the pozzolanic reaction model. In the real mass concrete structure, the heat loss from the structure is observed then the semi-adiabatic condition is prevailed.

The design of construction processes such as casting method and curing condition are important parameters to prevent thermal cracking. Because of the large size of mass concrete structure, the casting may not be finished at once. A mass concrete may be divided to cast in many layers or blocks. In the analysis of some previous researches, the whole mass concrete structure was assumed to cast and finish at once (Kwak et al., 2006; Faria et al. 2006). As a result, the restraint that occurs at the cold joint was not considered. The curing method and curing period are also important to prevent thermal cracking during the construction process. Many massive structures crack because of the application of unsuitable curing method and curing period. It is beneficial for engineers to have a proper tool for selecting the suitable dimension of casting block or layer and construction process to prevent thermal cracking.

1.3 Objective and Scope of Study

This study is aimed to prevent thermal cracking that occurs in mass concrete structures by providing a tool for engineers to select the suitable mix proportion, dimension of casting volume and construction process for mass concrete calculation. A computerized model for predicting the semi-adiabatic temperature and thermal cracking of mass concrete by taking into account the mix proportion, dimension of mass concrete structure and construction process was proposed for providing a numerical tool to evaluate the thermal cracking risk in mass concrete structure.

The adiabatic temperature rise model which was proposed by Saengsoy was modified by inducing the physical effect of fly ash especially for high volume fly ash. Thermal properties models which are specific heat model, thermal conductivity model and thermal expansion coefficient model were proposed as time, materials and mix proportion dependent of fly ash concrete. By the use of heat and thermal properties obtained from the proposed models together with a commercial finite element analysis software, semi-adiabatic temperature and restrained strain of mass concrete were predicted. The restrained strain obtained from the analysis was compared with the tensile strain capacity of concrete to evaluate the risk of thermal cracking. Finally, the appropriate mix proportion, dimension of mass concrete structure and construction process to prevent thermal cracking can be obtained.

The scope of this study is focused on the self-restraint problem in mass concrete. The effect of creep and shrinkage are still not included in the analysis. The effect of temperature steel was not included in the analysis. However, the use of temperature steel can prevent thermal crack when restrained strain is low. For mass concrete subjected to high restrained strain, the use of temperature steel may not be able to prevent thermal crack but cracks can be distributed to be within the acceptable limit. The computerized program is mainly developed by considering material properties especially cement and fly ash produced in Thailand.