CHAPTER 1

INTRODUCTION

1.1 General

The deformation caused by the applied stress, volume change due to shrinkage and temperature variation are of considerably importance in concrete structure. Due to the partly or wholly restrained, induced stress will result. Restraint can induce both compression and tension but in most cases it is tension, which causes problem because concrete is very weak in tension and prone to cracking. Cracks must be avoided or controlled and minimized because they impair the durability and structural integrity and are also aesthetically undesirable.

Shrinkage effects on concrete take places in cementitious matrix since the volume change of most aggregates is negligible when compared with that of cementitious matrix. Aggregates are considered to restrain the shrinkage of paste in concrete. In paste phase, shrinkage is caused by loss of water by evaporation, or by hydration of cement and also by carbonation. Drying shrinkage is the volume reduction of concrete due to withdrawal of water from hardened concrete stored in unsaturated pores into the outer environment. Chemical shrinkage is the phenomenon in which the absolute volume of hydration products is less than the total volume of unhydrated cement and water before hydration. After initial setting, the phenomenon of macroscopic volume reduction of cement paste, mortar and concrete caused by chemical shrinkage and self-desiccation is referred to autogenous shrinkage. Autogenous shrinkage dose not include volume change due to loss or ingress of substances, temperature variation, application of an external force restraint.

Macroscopic volume reduction of cement paste occur from the cause of both chemical and physical phenomenon. Autogenous shrinkage of chemical phenomenon is from hydration reaction, and self desiccation of physical phenomenon. When the void created by hydration is not supplied with water from the surrounding environment, or the water vapor pressure reduces and the relative humidity in fine pores decrease, capillary tension due to self-desiccation is obtained.

In ordinary concrete, which has rather high water to binder ratio, autogenous shrinkage is very small when compared with the other types of shrinkage. However, it is reported that concretes with a lower water to binder ratio and a large amount of binder content such as high strength concrete and self-compacting concrete show greater autogenous shrinkage, and result in the occurrence of crack. It is known that autogenous shrinkage cannot be prevented by moisture curing during hydration, while drying shrinkage can be reduced by continuous curing to prevent the diffusion of water into the outer environment. The use of expansive agents is the effective way to compensate autogenous shrinkage, but it increases cost of concrete. The other effective way is the replacement of fly ash in cement.

Fly ash is one of the pozzolans that is used to improve various properties of concrete. It was found that fly ash with higher SO_3 resulted in lower autogenous shrinkage. Due to inconsistency of chemical and physical properties of fly ashes in Thailand, the study of properties of concrete utilizing fly ashes with different chemical composition, and different size and fineness has been made.

Cement characteristics such as chemical composition, potential minerals according to Bogue equations and Blaine fineness are needed for the modeling of autogenous shrinkage of the paste phase in this study. Type 1, type 3, and type 5 cement are used as different characteristics of cement. Type 3 cement in Thailand has almost the same chemical compositions as type 1 cement, but different in Blaine fineness. So the effect of cement fineness is studied. For type 5 cement, C_3A and C_3S are less than type 1 and type 3 cement, then we can get the effect of chemical compositions of cement.

The shrinkage was regarded to occur only in paste phase whereas the aggregate phase was considered to restrain the shrinkage by their particle interaction. A two-phase material (paste phase and aggregate phase) model, taking into account the restraint shrinkage due to aggregate particle interactive, has been proposed by Sudsangiam, S. et al (1993) is adopt in this study. This model involved the stiffness, equilibrium condition of stress and strain compatibility of paste phase and aggregate phase. However, the free shrinkage of cement paste equations and aggregate stiffness equations used in the model were still macroscopic. So, a more rational microscopic model is proposed in this study. A mathematical model for prediction concrete shrinkage is divided into two main parts, which are free shrinkage model and aggregate stiffness model. Free shrinkage model is proposed for shrinkage in cementitious matrix of different mix proportion and properties of materials without restraint from aggregates. The shrinkage restraint of aggregate phase was expressed in terms of stiffness of aggregate. The model for simulating the stiffness of aggregate phase was derived based on the particle contact density concept and two-dimensional constitutive condition.

1.2 Statement of Problem

It is known that autogenous shrinkage occurs only in paste, however, concrete consists of paste and aggregate. Sudsangiam (1993) proposed the model which concrete is considered to be composed of 2 phases which are paste phase and aggregate phase, also to study the interaction between the paste and aggregates. From the concept of 2-phase material with perfect paste-aggregate interaction, autogenous shrinkage of concrete can be derived as

$$\varepsilon_{conc} = \frac{\varepsilon_{po} E_p (1 - n_a)}{E_p + E_{av}} \tag{1.1}$$

where
ε_{po} = free shrinkage of paste in concrete
n_a = volume concentration of aggregate
E_p = paste stiffness (kg/cm^2)
E_a = aggregate stiffness (kg/cm^2)

Then, free shrinkage of the paste phase is one of the parameters, which need to consider to construct the model. However, this parameter has been proposed the model by Chanmeka (1999).

$$\varepsilon_{as}(t) = [\varepsilon_{as}'(t) \cdot \beta(\alpha_{av})] + \varepsilon_{FA}(t) - \varepsilon_{exp}(t) \quad (1.2)$$

where
$\varepsilon_{as}(t)$ = autogenous shrinkage strain of cement paste
$\varepsilon_{as}'(t)$ = autogenous shrinkage strain contributed by hydration of cement in the cement-fly ash at water to cement ratio of 30% and temperature 20°C ($\times 10^{-6}$)
$\varepsilon_{FA}(t)$ = autogenous shrinkage strain contributed by pozzolanic reaction of fly ash in the cement-fly ash paste ($\times 10^{-6}$)
$\varepsilon_{exp}(t)$ = chemical expansion strain contributed by fly ash in the cement-fly ash paste ($\times 10^{-6}$)
$\beta(\alpha_{av})$ = parameter expressing the effect of pore structure on autogenous shrinkage

As it is known that autogenous shrinkage occurs from the combination of chemical phenomenon according to hydration reaction of cement and physical phenomenon due to self-desiccation. In order to achieve these characteristics, the model is modified to be separated into to three parts. The first part is the autogenous shrinkage by chemical effect, the second one is by physical effect, and the last part is expansion due to chemical expansion of SO_3 in fly ash. Moreover, other parameters which affects the autogenous shrinkage such as fineness of cement and fly ash. According to high temperature rise during hydration reaction of concrete, it affects the microstructure of hydrated product. Then, curing temperature should be considered to obtain the autogenous shrinkage of concrete in actual situation.

From Chanmeka (1999) model, pore structure is considered only in the term of hydration. However, pore structure should be considered in terms of both hydration reaction and pozzolanic reaction. Also, autogenous shrinkage should be separated due to two mechanisms affected by chemical effect and physical effect.

The other parameter to complete the shrinkage model in Eq. (2.1) is aggregate stiffness. This parameter has been proposed the model by Deesawangnade (1994). The model for simulating the stiffness of aggregate phase was derived based on the stress due to particle contact density concept. However, previous aggregate stiffness model was not considered aggregate stiffness of binary as the summation of stress of fine and coarse aggregates.

1.3 Objective and Scope of Study

The objective of the study is to develop a model to predict autogenous shrinkage of concrete. The effect of various chemical compositions and Blaine fineness of cement and fly ash, water to binder ratio, aggregate contents, and curing condition on autogenous shrinkage will be taken into account. In order to concern the influential parameters that have been mentioned above, the following studies need to be carried out:

1. To investigate the effect of various chemical compositions, potential minerals according to Bogue equations and Blaine fineness of cement type 1, type 3, type 5 on autogenous shrinkage of pastes.

2. To observe the variation of autogenous shrinkage of cement paste by using different chemical composition (SiO_2, CaO and SO_3) of fly ash.

3. To examine the effect of various mix proportion with varied water to binder ratio, fly ash replacement, aggregate contents, and curing temperature on autogenous shrinkage of concrete.

4. To include the effect of pore structure variation during hydration reaction and pozzolanic reaction as a parameter to simulate autogenous shrinkage of paste.

5. To develop a model for predicting autogenous shrinkage of paste with various chemical compositions and fineness of cement and fly ash under the influencing parameters involved.

6. To develop a model for simulating aggregate stiffness which is effective for computing the restraint stiffness of fine aggregate, coarse aggregate, and combination of fine and coarse aggregate at different sand-aggregate ratio.