CHAPTER 1.

INTRODUCTION

1.1 INTRODUCTION

Portland cement concrete is one of the most popular construction materials for structural concrete. The principal difficulty with structural concrete is its shrinkage in hardening process. Shrinkage cracking is invisible to destroy the concrete. Shrinkage compensating cement or non-shrink cement is cement which increases in volume after setting and during hardening. And it is used extensively to eliminate or minimize cracking caused by drying shrinkage.

Normally, shrinkage compensating cement consists of a mixture of portland cement, an expansive agent in the form of sulphoaluminate cement and a stabilizing element which is usually fly ash. From many experiments, the mix proportion can be achieved by using trial mix for non-shrink cement. Many researchers have tried to investigate the mechanism of expansion. It is known that expansion is associated with the formation of ettringite. However, the mechanism of expansion has not been fully understood and remains controversial.

In this research, the processes of chemical reaction concerning the source of chemical compounds, the mechanism of ettringite expansion and optimum mix proportion are investigated from basic chemical theories.

1.2 LITERATURE REVIEW

The development of expansive cement originated with the investigations of **Candlot**[4]. His expansive cement was a result of the reaction of tricalcium aluminate, C_3A with calcium sulfate ($CaSO_4$). **Lufama, H.**[4] manufactured expansive cement by developing a mixture comprised of calcium sulfate ($C\underline{S}$), calcium aluminate (C_5A_3) and dicalcium silicate (C_2S). **Mikhailov**[9] reported that self stressing cement, termed SC, could be made out of any pure clinker portland cement, alumina cement, gypsum and additions. He used Alunite mineral which has a high alumina content as addition.

Klein, Karby and Polivka[1] at the University of California used an expansive clinker consisting mostly of anhydrous calcium sulphoaluminate ($C_4A_3\underline{S}$) compound by heating a mixture of bauxite, chalk and gypsum at about 2,400°F. This expansive agent consists of anhydrous calcium sulfoaluminate, calcium sulfate and lime. **Lossier, H.**[5] used a mixture of portland cement, an expanding agent in the form of sulphoaluminate cement, and a stabilizing element which is usually slag cement. The slag cement can stop the action of calcium sulfate by adsorbing the excess at the desired expansion; normally the expansion is stopped after 10-14 days. It was also found that the expansive agent could be controlled by the fineness of grinding of the expansive agent. A coarse grinding of expansive agent delays expansion.

Further study of calcium sulfoaluminate type cement was developed by **Ish-Shalom and Bentur**[7]. Calcium sulphoaluminate ($C_4A_3\underline{S}$) was made by burning a mixture of calcium carbonate, gypsum and aluminium oxide in stoichiometric ratios at 1,350°C for five and a half-hours. **Budnikov and Kosuireva**[9] found that the best composition for an expansive agent was a mixture of kaolin, slaked lime, calcium sulfate and portland cement. The mixture produced calcium sulphoaluminate ($3CaO.Al_2O_3.3CaSO_4$), which was the expansive source of this cement. The addition of granulated blast furnace slag considerably reduced the expansion of cement. **Shan-Ba, W., Xing, J.**[10] and **Hywell Evans**[29] found that the expansive agent could be produced from a mixture of calcium carbonate, aluminium oxide and gypsum burning at 1,380°C for four hours.

Ferrari[9] introduced three mixtures of expansive cement consisting of a mixture of portland cement which acted as the binder, sulphoaluminate anhydrate as the expansive agent and blast furnace slag as the regulating and stabilizing agent. This mixture did not give a high strength and high heat of hydration.

Folliard[25] studied the use of fly ash replacement in mixture. Fly ash tends to decrease in expansion, mostly due to the diluting effect of the replacement of the expansive agent with non-expansive pozzolans. The other effect is the characteristics of ettringite. Ettringite can be divided in two forms, needle-like with large crystals (low surface area) and poor crystalline (high surface area). Only poor crystalline ettringite leads to expansion and this form of ettringite is stable only in the presence of sufficient calcium and hydroxyl ions. The pozzolanic reaction, which consumes $Ca(OH)_2$ may yield a needle like ettringite, thus reducing the expansion.

1.3 OBJECTIVES

Development of shrinkage compensating cement is proposed in this research by determining the appropriate raw materials which cause cement expansion. The optimum proportion of the mixture will be determined. The physical, chemical and mechanical properties will be studied.

1.3.1 Develop shrinkage compensating cement with an expansive agent to compensate drying shrinkage of ordinary portland cement.
1.3.2 Determine appropriate raw material which has a hydration reaction causing cement expansion.
1.3.3 Determine optimum proportion of the expansive agent in a mixture that makes appropriate expansion in cement with time.
1.3.4 Study physical, mechanical and chemical properties of shrinkage compensating cement with time.
1.3.5 Study effects of shrinkage compensating cement on the durability of structural elements.

1.4 RESEARCH METHODOLOGY

The research methodology is composed of studying basic chemical and engineering theories, the proposed method to calculate the magnitude of shrinkage and expansion. Then experimental studies are carried out comparing with basic theories. After that, analysis test results and a conclusion are proposed.

1.4.1 Studying chemical reaction of shrinkage compensating cement. The reactions consist of hydration reaction of portland cement, hydration reaction of expansive agents and pozzolanic reaction of fly ash.
1.4.2 Studying the appropriate mix proportion of raw materials to develop an expansive agent from a basic chemical concept.
1.4.3 Studying the mechanism of shrinkage in portland cement, the expansion mechanism in the expansive agent related to ettringite and the effects of fly ash in the mixture.
1.4.4 Determining the chemical effects on the raw materials by X-ray diffraction method.

1.4.5 Developing an expansive agent from appropriate raw materials by determining the amount of Al_2O_3, $CaSO_4$, and CaO in a mixture and using a basic chemical concept to form Calcium Sulphoaluminate, $C_4A_3\underline{S}$, that is the source of hydration reaction in shrinkage compensating cement.

1.4.6 Determining the optimum mix proportion of expansive agent in a mixture to make suitable drying shrinkage by varying the amount of expansive agent and using fly ash as a stabilizing agent to produce shrinkage compensating cement.

1.4.7 Investigating shrinkage and expansion characteristics in the mixture of shrinkage compensating cement with time and the amount of chemical composition.

1.4.8 Investigating physical properties of cement paste, mortar and concrete, that is workability, slump, and flow from a mixture of shrinkage compensating cement.

1.4.9 Investigating mechanical properties of cement paste, mortar and concrete, that is compressive strength of a mixture.

1.4.10 Analyze test results and conclusion.

1.5 OUTCOME & BENEFITS

1.5.1 Shrinkage compensating cement will be developed by using an expansive agent to compensate the drying shrinkage of ordinary portland cement.

1.5.2 The optimum mix proportion of expansive agent in shrinkage compensating cement will be investigated.

1.5.3 Physical, mechanical and chemical properties of shrinkage compensating cement will be investigated with time.

1.5.4 The effects of shrinkage compensating cement on behaviors and durability of structural elements will be investigated.