CHAPTER 1 INTRODUCTION

1.1 Problem Statements

The clinker manufacturing process in the cement industry is known to contribute to the greenhouse effect, through the release of CO_2 gas into the atmosphere: about 0.9 tons of CO_2 is released during the production of every ton of clinker (Mehta, 2009). In 2010, the production of cement was released as much as 2.07 billion tons of CO_2 into the atmosphere. To address this issue, cement manufacturers have tried to reduce CO_2 emissions by using supplementary cementitious materials such as fly ash and natural pozzolans in producing Portland cement clinker (Gartner, 2004; Damtoft, et al., 2008). Damineli, et al., (2010) proposed two indicator indices (binder intensity and CO_2 intensity) for measuring the efficiency of cement use in concrete factory. In addition, the new cementitious materials have been studied such as geopolymer-based material (Hardjito, et al., 2004; Li and Liu, 2007) and calcium carbide residue-rice husk ash (Jaturapitakkul and Roongreung, 2003) to use as a binder in concrete instead of Portland cement. However, reducing the problem of climate change will require not only cement manufacturers, but also concrete producers and researchers to focus on these environmental issues.

Calcium carbide residue is a by-product from an acetylene gas (C_2H_2) production process. This gas is used as a fuel for lighting, welding, metal cutting, space heaters, and to ripen fruit. Calcium carbide residue is produced by a simple process, which is obtained from the reaction between calcium carbide (CaC_2) and water (H_2O) according to the following equation:

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2 \qquad (1)$$

The main oxide of calcium carbide residue is calcium hydroxide ($Ca(OH)_2$) in a slurry form. The huge amount of calcium carbide residue in Thailand has accumulated over time. An acetylene gas factory, which provided the calcium carbide residue for this study, produces approximately 1,000 metric tons/month or about 12,000 metric tons/year of calcium carbide residue, and a use for the residue is rarely found. Most of the residue is disposed of as waste and is sent to landfills, causing many environmental problems, especially in terms of the groundwater pollution due to high alkaline contamination.

Several pozzolans such as fly ash, palm oil fuel ash, and rice husk-bark ash, which are by-products from industries, are found in Thailand. Many studies found that these pozzolans can be used to replace some portion of cement to achieve high compressive strength of concrete (Kiattikomol, et al., 2001; Sata, et al., 2007). However, their utilizations are limited because of insufficient data and lack of confidence; thus, most of them are disposed of in landfills.

Therefore, the aim of this research focused on development of calcium carbide residue and pozzolanic materials in Thailand as mixtures for a binder in concrete. Krammart, et al., (1996) and Jaturapitakkul and Roogreung, (2003) believed that $Ca(OH)_2$ in calcium carbide residue could react with silica, alumina, and ferric oxides in pozzolan by pozzolanic reaction to form C-S-H, similar to those obtained from cement hydration process. However, the compressive strengths of calcium carbide residue and pozzolan mortar from previous researches were rather low because of the slow nature of pozzolanic reaction (Khedr and Abou-Zeid, 1994). Therefore, it is necessary to find out acceleration method of the reaction between calcium carbide residue and pozzolanic materials to enhance the compressive strength.

In this study, the techniques for accelerating strength such as increasing binder content and lowering water to binder ratio in mix design were introduced. Further, ordinary Portland cement was also used to enhance the compressive strength of concrete. Moreover, the temperature rise of the concrete was monitored. The use of a mixture from calcium carbide residue and pozzolanic materials will encourage concrete researchers and users to utilize the two industrial wastes as a binder material in concrete. Use of these materials rather than sending them to landfills will be environmentally beneficial. Finally, the use of these materials will reduce environmental problems related to CO_2 emissions from the clinker manufacturing process and from the disposal of calcium carbide residue as well as the pozzolanic materials.

1.2 Objectives

The objectives of this research are drawn as follows:

1. To develop a concrete binder from a mixture of calcium carbide residue and pozzolanic materials.

2. To evaluate the effects of various pozzolanic materials, binder content, water to binder ratio, and replacement of ordinary Portland cement at 10% by weight of binder on setting times, compressive strength, elastic modulus, and splitting tensile strength of the concrete.

3. To investigate the water permeability of concrete at W/B ratio of 0.45.

4. To investigate heat evolution of fresh concrete for high-strength concrete mixture.

5. To evaluate the use of the binder from calcium carbide residue and various pozzolanic materials for concrete brick.

1.3 Scope of Study

This research was separated into three main parts. The first part was studied in fresh concrete properties such as requirement of superplasticizer, setting times, and heat evolution of the concrete. The second part, the mechanical properties of the concrete were tested and evaluated to use in appropriate concrete work. For the third part, the water permeability coefficient was determined to evaluate the serviceability of the concrete.

Calcium carbide residue was collected from a disposal area in acetylene gas factory, at Samutsakorn province. The various pozzolanic materials such as pulverized fly ash, fluidized bed fly ash, palm oil fuel ash, and rice husk-bark ash were collected from power plants. All of the industrial wastes were ground separately by ball mill until median particles sizes ranged from 4.4 to 6.2μm, and the abbreviations of these materials were assigned as CR, FM, FN, PA, and RA, respectively. Physical properties such as specific gravity and particle size distribution were studied. Chemical compositions by X-Ray Fluorescence (XRF) and images of particles by scanning electron microscopy (SEM) were also investigated.

In this study, the CR was mixed separately with FM, FN, PA, or RA at ratios of 30:70, 30:70, 40:60, and 50:50 by weight for using as a concrete binder, respectively. Moreover, 10% by weight of ordinary Portland cement type I (OPC) was used to replace binder content in order to accelerate the reaction between CR and pozzolanic materials in concrete. The effects of various pozzolanic materials, water to binder ratios (W/B), and replacement of OPC on requirement of superplasticizer, setting times, heat evolution, compressive strength, modulus of elasticity, splitting tensile strength, and water permeability of concrete were investigated.

Concrete brick mixtures were also prepared with binder, sand, and crushed fine stone in proportion of 1.5:2:2.5 by weight without using Portland cement. All mix proportions of concrete brick had a binder content of 550 kg/m^3 with a water to binder ratio of 0.50. The mold specimens (100 mm in width, 200 mm in length, and 100 mm in depth) were prepared to cast concrete brick. The compressive strengths of concrete brick were determined at the ages of 3, 7, 28, 60, and 90 days while the water absorptions were determined at 28 days. The testing results were also compared with the standard specifications for concrete building brick (ASTM C55, 2010) and concrete facing brick (ASTM C1634, 2010).

1.4 Details of the Dissertation

This dissertation composed of five chapters and seven appendices. The first chapter introduces problem statements, objectives, and scope of the study. In chapter 2, the literature review was performed. The use of binder from calcium carbide residue and pozzolanic materials together in concrete was carefully reviewed. In addition, the basic mechanical and durability properties of plain concrete were also reviewed. In chapter 3, the methodology and details of study were informed. Chapter 4, the results and discussions of fresh concrete properties, mechanical properties, and water permeability of the concrete were reported and discussed. Conclusions and future works were summarized in chapter 5. Finally, references and appendices were also presented at the end of the dissertation.