CHAPTER 3 METHODOLOGY

In this chapter, the materials used in this study and the details of test program are explained. The investigation of physical and chemical properties of calcium carbide residue, fly ash, palm oil fuel ash, and rice husk-bark ash are described. The method of study focuses on mix proportions to cast concrete and concrete brick. The test program of concrete consisted of setting times, heat evolution, compressive strength, modulus of elasticity, splitting tensile strength, and water permeability properties. The compressive strength and water absorption of concrete brick were also determined.

3.1 Materials

The materials used in this research were calcium carbide residue, fly ash, palm oil fuel ash, rice husk-bark ash, Portland cement type I, tap water, superplasticizer, and aggregates. The details of each material are described as follows:

3.1.1 Calcium Carbide Residue

Calcium carbide residue in slurry and dry form were obtained from a disposal area in a factory at Samutsakhon province, Thailand. Because the calcium carbide residue had a high moisture content (approximately 50%), it was sun-dried for approximately 3-4 days to reduce the moisture content to about 2-4% as shown in Figures 3.1.

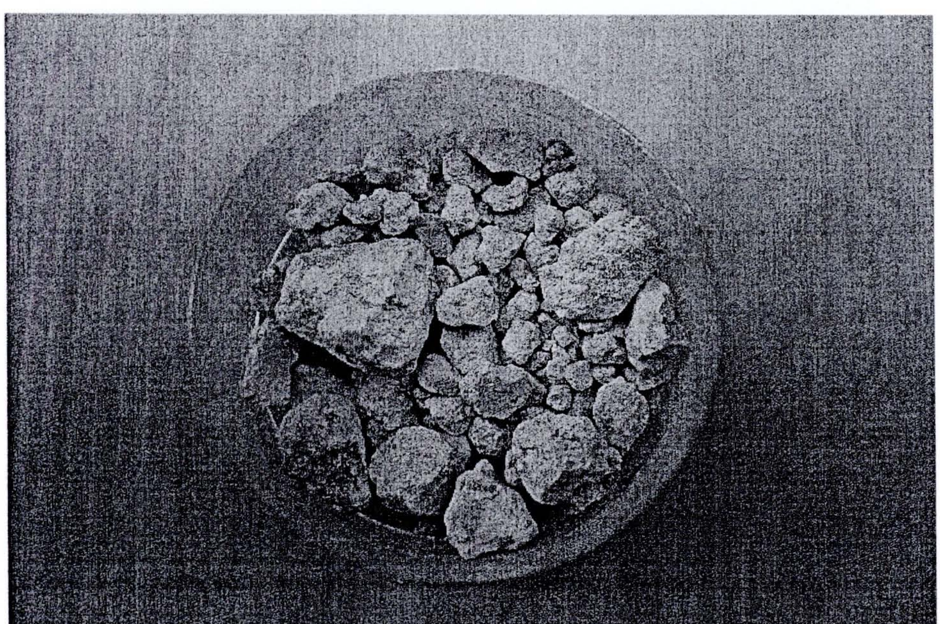


Figure 3.1 Calcium carbide residue after sun-dried for 3-4 days

3.1.2 Fly Ash

Two different sources of fly ash were used in this program. The first one was collected from Mae Moh power plant at Lumpang province in the northern part of Thailand. The Mae Moh fly ash is burnt by pulverized coal combustion process at temperature of 1300-1400°C. Figure 3.2 shows the landfill area of Mae Moh fly ash, disposed of and backfilled with the amount excess of fly ash consumption.

The second fly ash was collected from NPS power plant in central part of Thailand where sub-bituminous coal is burnt at controlled temperatures of 800–900 °C with a fluidized bed burning process (see Figure 3.3).

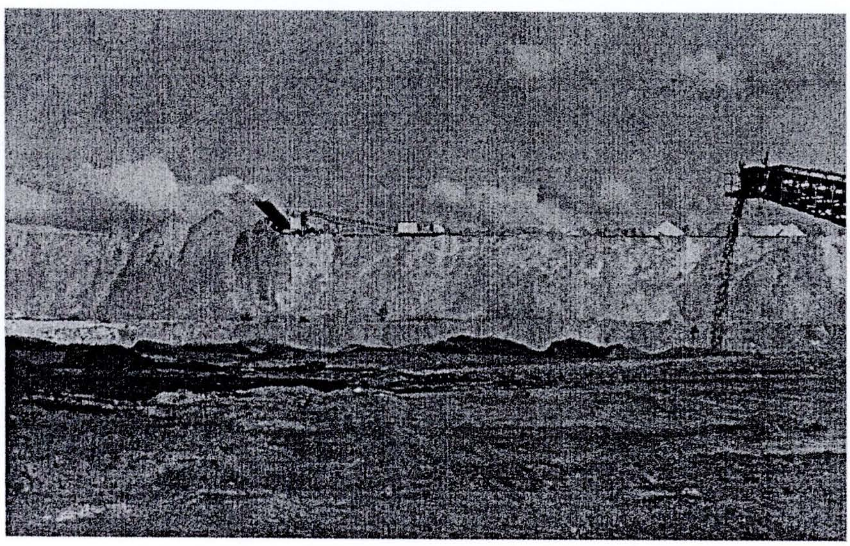


Figure 3.2 Landfill of Mae Moh power plant in northern part of Thailand

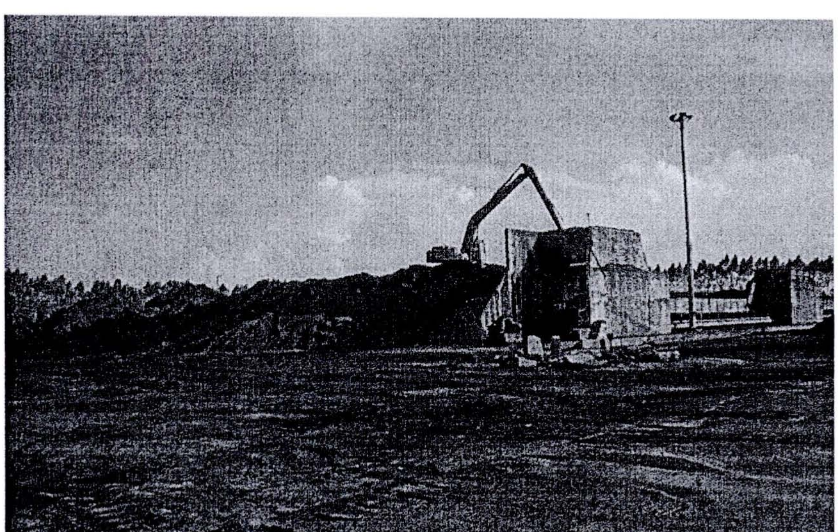


Figure 3.3 Fly ash of NPS power plant in central part of Thailand

3.1.3 Palm Oil Fuel Ash

Palm oil fuel ash is a by-product obtained from a biomass power plant, which palm oil residue such as fibers, shells, and empty fruit bunches are burnt as fuel to produce stream for electricity generation. In this study, palm oil fuel ash was collected from an industry located in the southern part of Thailand. The burning temperature of palm oil solid waste is approximately 800-1000°C. The palm oil fuel ash at a disposed of position is shown in Figure 3.4.

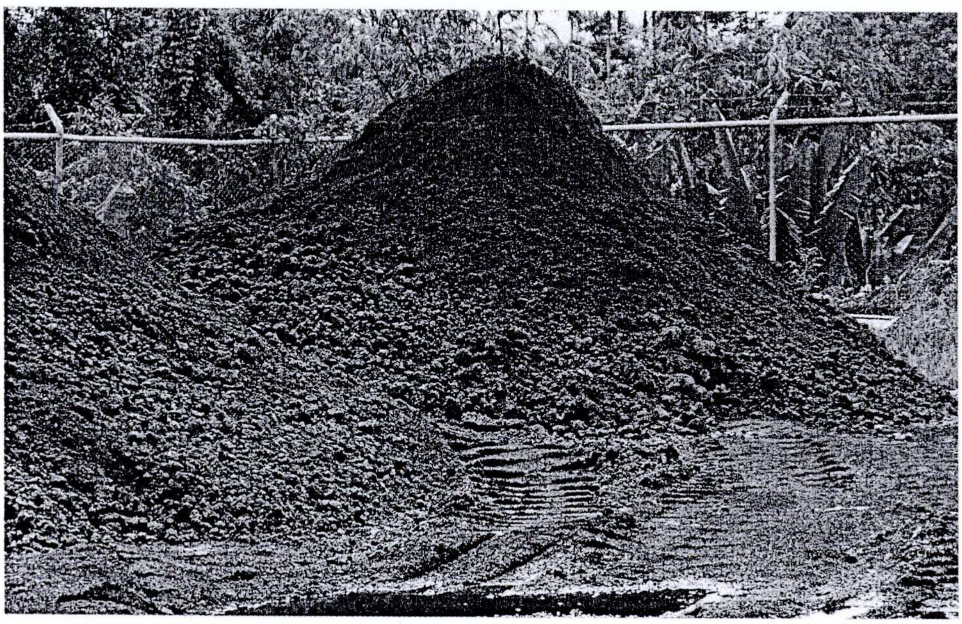


Figure 3.4 Palm oil fuel ash heap

3.1.4 Rice Husk-Bark Ash

Rice husk-bark ash was collected from a biomass power plant in central part of Thailand which 65% of rice husk and 35% of eucalyptus bark by weight are used as fuel for electricity generation. The rice husk and bark are burnt together at controlled temperature about 800-900°C. Figure 3.5 shows disposal area of rice husk-bark ash at Chachoengsao province, Thailand.

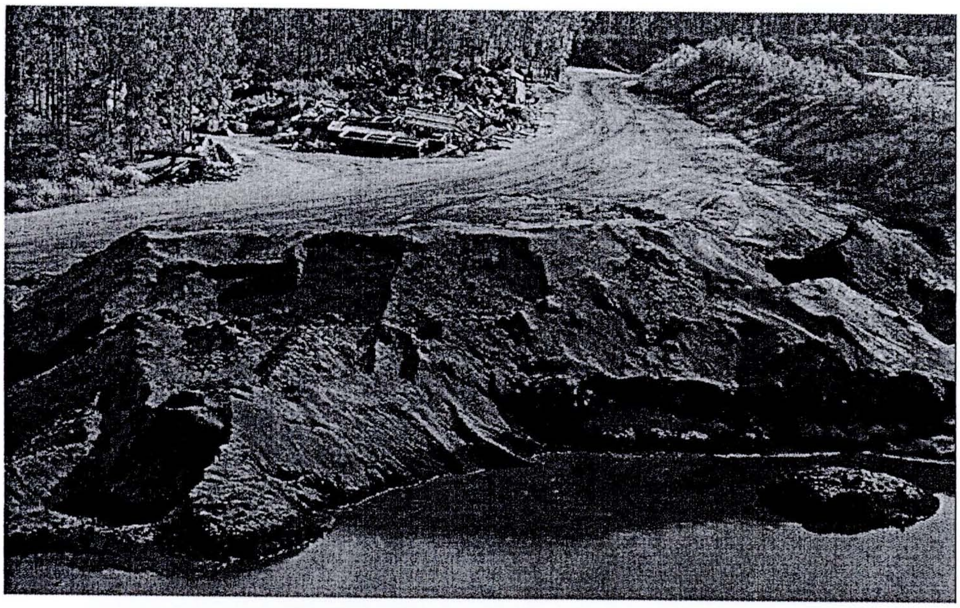


Figure 3.5 Disposal area of rice husk-bark ash

3.1.5 Portland Cement Type I

Ordinary Portland cement Type I was used to enhance the strength of calcium carbide residue and pozzolanic materials concrete.

3.1.6 Water

Tap water was used throughout the experimental program.

3.1.7 Superplasticizer

Commercial available naphthalene formaldehyde superplasticizer (Type A&F) conforming to ASTM C494 (2010) was employed in mixture of normal-strength concrete. For high-strength concrete mixture, polymer-based high range water-reducing admixture (Type F) conforming to ASTM C 494 was also employed.

3.1.8 Aggregates

Local river sand with a fineness modulus of 3.20 and a specific gravity of 2.61 was used as a fine aggregate. Crushed limestone was used as a coarse aggregate; it had a maximum size of 20 mm, a fineness modulus of 6.90, and a specific gravity of 2.73. The water absorptions of fine and coarse aggregates were 0.69% and 0.45%, respectively. For high-strength concrete, crushed limestone with maximum size of 10 mm, specific gravity of 2.72, and water absorption of 0.8% was used as a coarse aggregate.

For concrete brick, the river sand was used as a fine aggregate. The coarse aggregate was crushed fine stone which had a fineness modulus of 3.40 and a specific gravity of 2.73. The water absorption of crushed fine stone was 2.43%.

3.2 Method of Study

All pozzolanic materials as received from power plants and calcium carbide residue were ground separately by grinding machine with ball mill until median particle sizes ranged from 4.4 to 6.2μm. After grinding process, the powder of calcium carbide residue is shown in Figure 3.6. The overview of test program is shown in Figure 3.7.

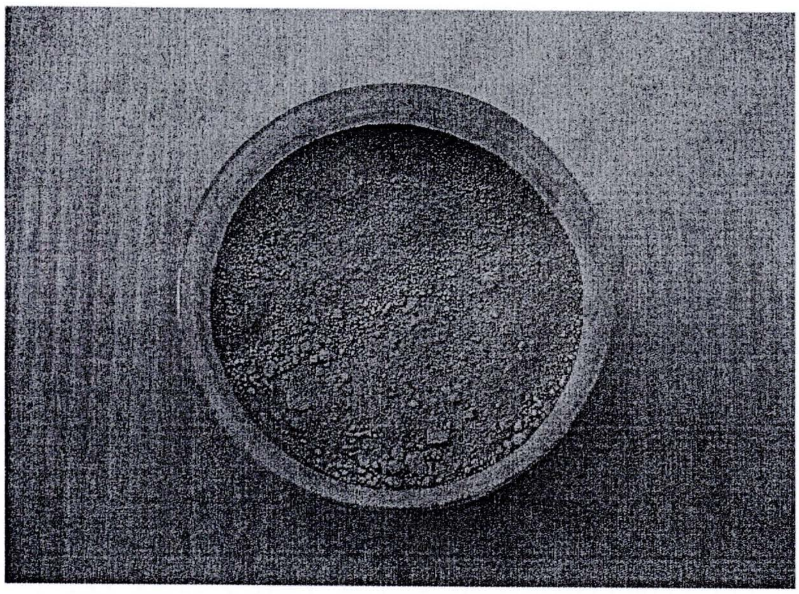


Figure 3.6 Powder of ground calcium carbide residue

3.2.1 Material Properties

Physical and chemical properties of calcium carbide residue, fly ashes, palm oil fuel ash, and rice husk-bark ash were investigated. Their morphologies were studied by using scanning electron microscope (SEM). Chemical compositions were tested by X-ray fluorescence spectrometer. In addition, specific gravity, weight of materials retained on a 45-μm sieve, median particle size, and fineness of the calcium carbide residue as well as the pozzolanic materials were also investigated.

3.2.2 Mix Proportions of Concrete

The mixture proportions of Portland cement concretes and calcium carbide residue-pozzolans concretes are summarized in Table 3.1. In this experiment, the ground calcium carbide residue (CR) was mixed separately with ground pulverized coal combustion fly ash (FM), ground fluidized bed combustion fly ash (FN), ground palm oil fuel ash (POFA), and ground rice husk-bark ash (RHBA) at the ratios of 30:70, 30:70, 40:60, and 50:50 by weight, respectively for using as a binder in concrete.

Portland cement Type I was used in concrete by partially replacement at 10% by weight of binder. Three proportions of concrete mixtures were designed to evaluate the effects of W/B ratios (0.65, 0.45, and 0.25) on fresh properties and mechanical properties of the concrete. A ratio of fine to coarse aggregate was kept as a constant at 45:55 by volume. Naphthalene formaldehyde superplasticizer (Type A&F) was employed in normal-strength concrete mixture to maintain the same slump of fresh concrete between 50 and 100 mm, while the slump of high-strength concrete mixture was maintained between 150 and 200 mm using polymer-based high range water-reducing admixture (Type F). The slump of fresh concrete and setting times of all concrete mixtures were measured. The initial and final setting times of fresh concretes were determined in accordance with ASTM C 403 (2010). For concrete mixtures with W/B ratio of 0.45, water permeability was evaluated at 28 and 90 days of curing ages. Heat evolution of fresh concrete was also monitored in all of high-strength concrete mixtures (W/B = 0.25).

Table 3.1 Mix proportions of concrete

Concretes	Mixture Proportions (kg/m^3)										W/B	Slump
	CR	FM	FN	PA	RA	OPC	Sand	C-Agg.	Water	Super P.		(mm)
CR-FN(0.65)	90	-	210	-	-	-	800	1020	194	2.8	0.65	85
CR-FN(0.65)10	81	-	189	-	-	30	800	1020	194	2.2	0.65	70
NC(0.65)	-	-	-	-	-	300	825	1055	195	-	0.65	70
CR-FM(0.45)	135	315	-	-	-	-	735	940	203	-	0.45	100
CR-FM(0.45)10	121.5	283.5	-	-	-	45	735	940	203	-	0.45	90
CR-FN(0.45)	135	-	315	-	-	-	705	905	198	9.0	0.45	65
CR-FN(0.45)10	121.5	-	283.5	-	-	45	710	910	199	6.9	0.45	90
CR-PA(0.45)	180	-	-	270	-	-	710	910	201	2.9	0.45	80
CR-PA(0.45)10	162	-	-	243	-	45	710	910	201	2.8	0.45	85
CR-RA(0.45)	225	-	-	-	225	-	700	895	197	10.1	0.45	75
CR-RA(0.45)10	202.5	-	-	-	202.5	45	700	895	200	6.0	0.45	70
NC(0.45)	-	-	-	-	-	450	760	975	203	-	0.45	90
CR-FM(0.25)	165	385	-	-	-	-	765	980	135	3.9	0.25	185
CR-FM(0.25)10	148.5	346.5	-	-	-	55	770	985	135	4.4	0.25	185
NC(0.25)	-	-	-	-	-	550	800	1020	135	4.1	0.25	195

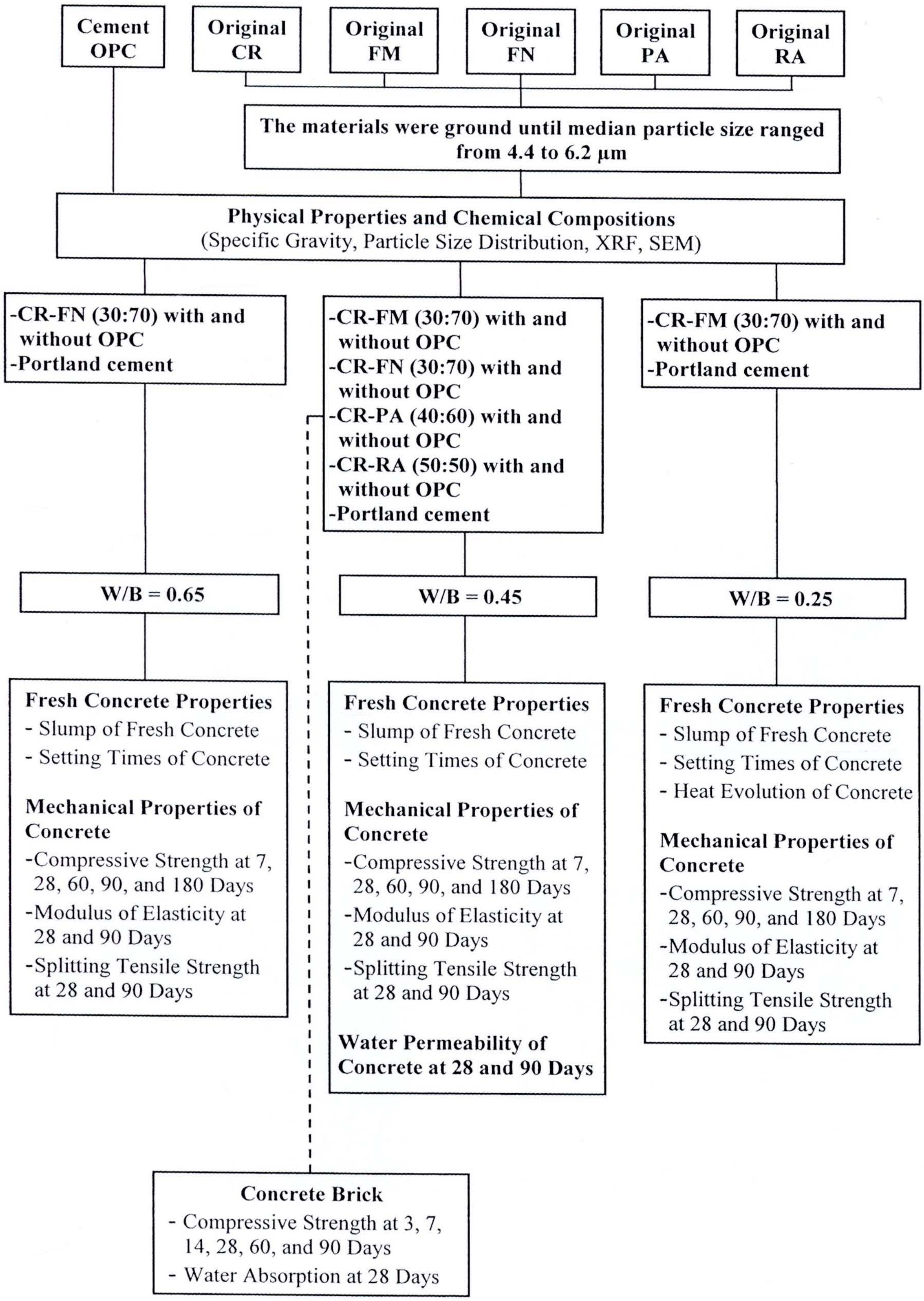
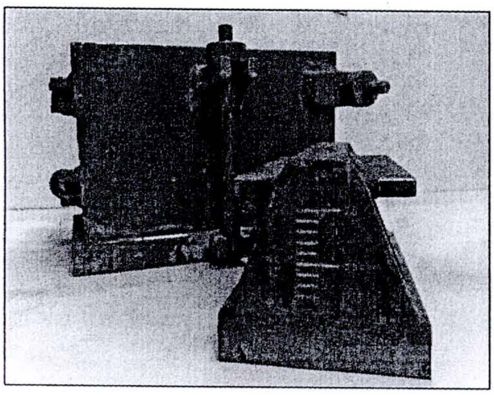


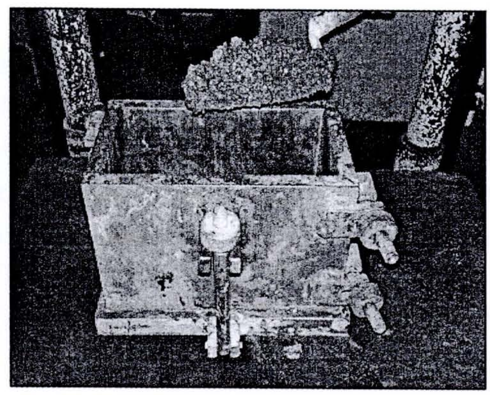
Figure 3.7 Test program

3.2.3 Mix Proportions and Formation of Concrete Brick

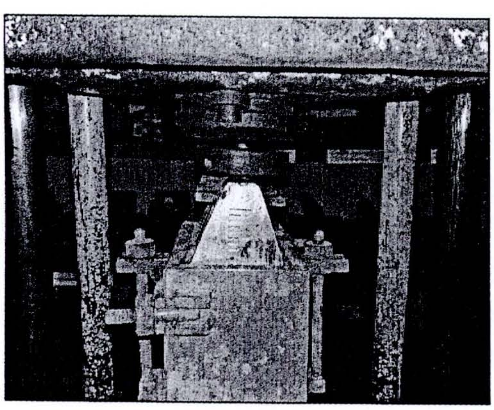
Mix proportions of concrete brick are summarized in Table 3.2. The ratios of CR and pozzolanic materials mixtures were used as same as the concrete mixture. Concrete brick mixtures were prepared with binder, sand, and crushed fine stone in a proportion of 1.5:2:2.5 by weight. All mix proportions of concrete brick had a binder content of 550 kg/m^3 with a water to binder ratio of 0.50. The concrete brick specimens (100 mm in width, 200 mm in length, and 100 mm in depth) were prepared according to Figure 3.8. A compressive force of 12 tons from universal testing machine was applied and sustained for 1 minute to compact the mixture in the mold (see Figure 3.8). This force creates a pressure of 6 MPa to compact the specimen. After that the concrete bricks were removed from the molds and cured with wet burlap for 1 day, and then they were transferred to cure in water.



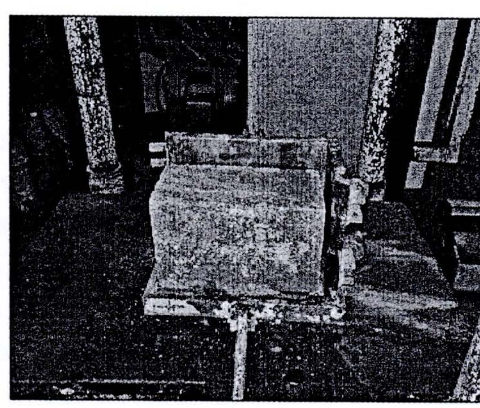
(a) Concrete brick mold



(b) Placing mixture in mold



(c) Applied force to compact material



(d) Concrete brick after compaction

Figure 3.8 Fabrication of concrete brick specimen

Table 3.2 Mix proportions of concrete brick

Sample	Mix Proportions (By Weight)								W/B
	CR	FM	FN	PA	RA	OPC	Sand	Crushed Fine Stone	
CR-FM	0.45	1.05	-	-	-	-	2.00	2.50	0.50
CR-FN	0.45	-	1.05	-	-	-	2.00	2.50	0.50
CR-PA	0.60	-	-	0.90	-	-	2.00	2.50	0.50
CR-RA	0.75	-	-	-	0.75	-	2.00	2.50	0.50
NB	-	-	-	-	-	1.50	2.00	2.50	0.50

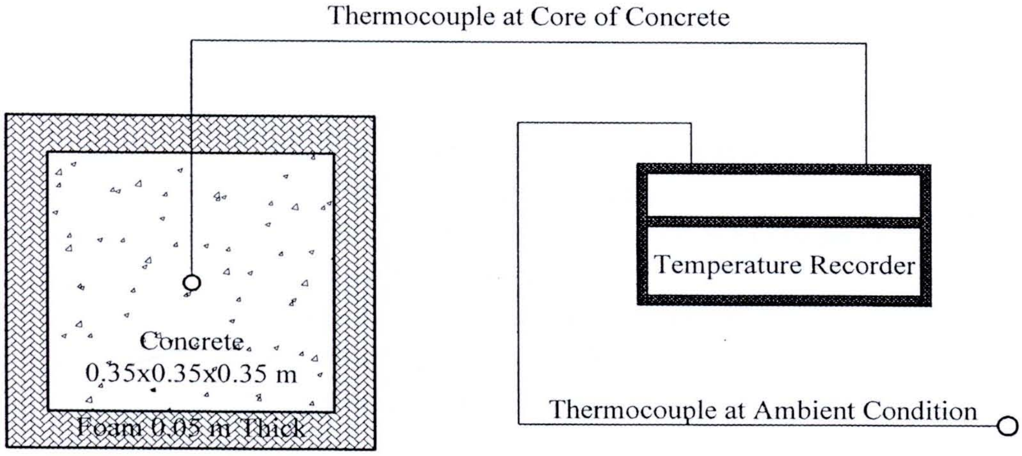
3.2.4 Test Program

3.2.4.1 Mechanical Properties of Concrete

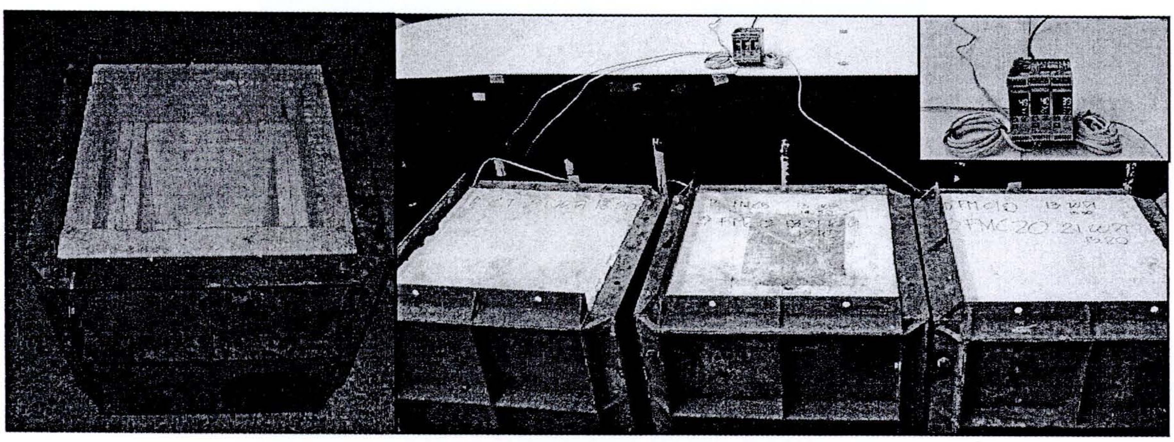
Cylindrical concrete specimens (100 mm in diameter and 200 mm in height) were cast and were compacted by using a vibrating table. After that, they were covered with burlap immediately, and then the concrete specimens were allowed to set for 72 hours before removed from the molds. Next, they were cured in tap water at room temperature until the testing date. The compressive strengths were determined at 7, 28, 60, 90, and 180 days; the elastic modulus of concretes (ASTM C469, 2010) were determined at 28 and 90 days; and the splitting tensile strengths (ASTM C496, 2010) were determined at 28 and 90 days.

3.2.4.2 Heat Evolution Test

The objective of this test is to measure, by using thermocouples, the temperatures rise in calcium carbide residue-fly ash concrete. The heat evolution test was consisted of determining time versus temperature rise for high-strength concretes; CR-FM(0.25), CR-FM(0.25)10, and NC(0.25) concretes. The detail of experimental setup for testing heat evolution of high-strength concrete was shown in schematic diagram of Figure 3.9(a). Each mixture of high-strength concrete was poured in a 450 mm cubic mould. In order to test under a small amount of heat-loss system (semi-adiabatic condition), the mold was coated by the lining insulator 50 mm of thickness at each side before casting as shown in Figure 3.9(b). A thermocouple was embedded at the center of the specimen (350x350x350 mm^3). The heat evolution of concrete in term of temperature rise was measured immediately after casting for a period of 168 hours (7 days).



(a) Schematic diagram of heat evolution of concrete test



(b) Molds for casting concrete

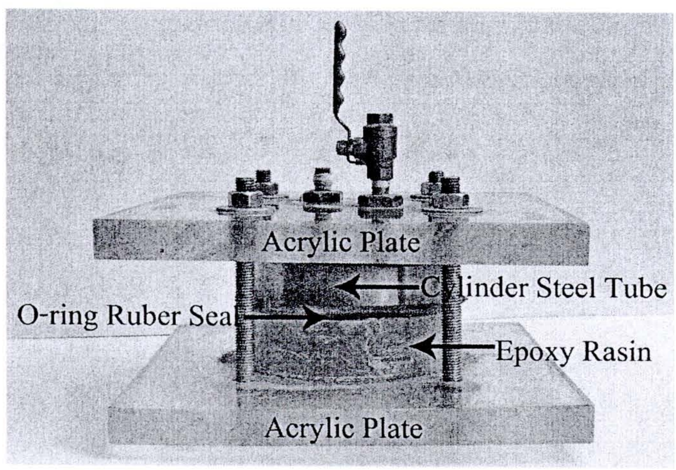
Figure 3.9 Heat evolution of concrete test

3.2.4.3 Water Permeability of Concrete

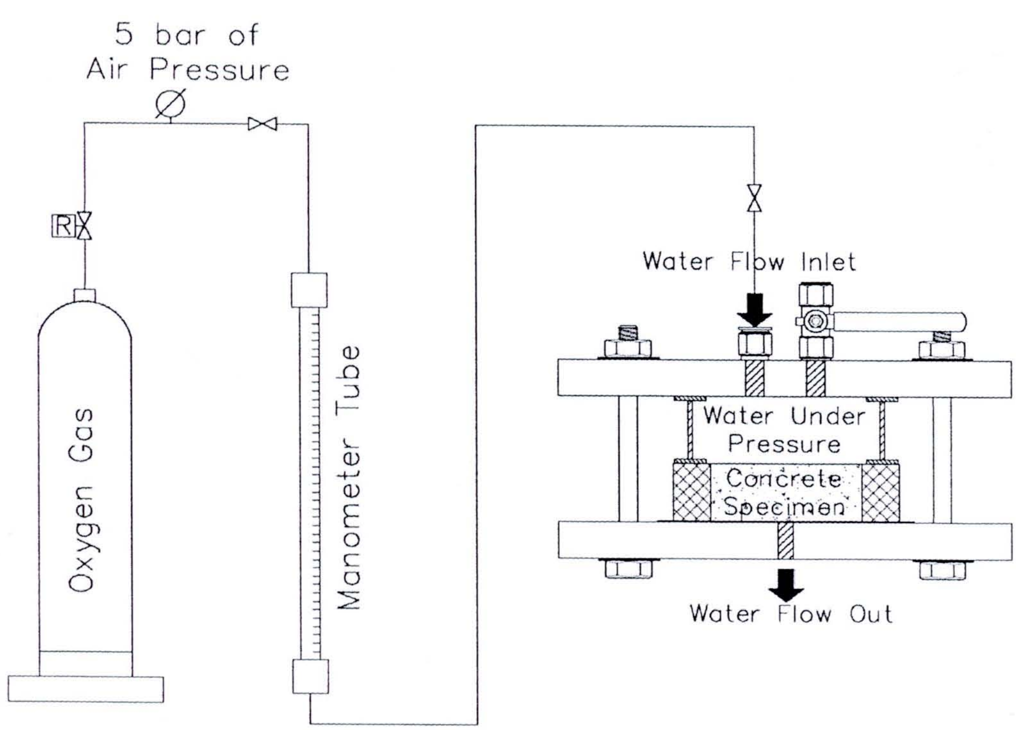
The water permeability samples were prepared by sawing 40 mm thick slice at middle height of 100x200 mm cylindrical concrete specimens. The non-shrinkage epoxy resin 25 mm thick was cast around dry surface of the sample to prevent water leakage, and next allowed to harden for 24 hours. The samples were installed in the housing cell as shown in Figure 3.10(a) at testing date, and then a water pressure of 0.5 MPa (5.0 bar) was applied through the cell. The detail of experimental setup for testing water permeability of concrete was shown in schematic diagram as Figure 3.10(b)), similar to those as recommended by Chindaprasirt et al. (2007) and Chusilp et al. (2009). The water flow rate through the concrete specimen was monitored by recording the drop in water level within manometer tube. The cumulative water flowing and the cumulative time was plotted to determine the steady-state flow of water. At steady-stage, the steady flow rate was obtained and the coefficient of water permeability was calculated by using Darcy's law and continuity equation, as shown in equation 3.1. The water permeability coefficients of concretes were investigated and compared with that of concrete containing 300 kg/m^3 of Portland cement (NC(0.65)).

$$K = \frac{\rho L g Q}{PA} \tag{3.1}$$

where K = Coefficient of permeability (m/sec)
ρ = Density of water (kg/m^3)
g = Acceleration due to gravity, 9.81 (m/sec^2)
Q = Net flow rate (m^3/sec)
L = Thickness of concrete specimen (m)
P = Water pressure [$(kg\ m\ s^{-2})/(m^2)$]
A = Cross sectional area of concrete sample (m^2)



(a) Permeability housing cell



(b) Schematic diagram of water permeability apparatus

Figure 3.10 Water permeability setup for testing concrete

3.2.4.4 Compressive Strength and Water absorption of Concrete Brick

At the ages of 3, 7, 28, 60, and 90 days, the compressive strengths of concrete brick specimens were determined by using compression machine. At 28 days, the water absorption of concrete brick was also determined by heating the specimens at a controlled temperature in oven for 24 hours. The specimens were cool in ambient condition for determining dry weight. Next, they were submerged in clean water for 24 hours, and then they were wiped off the surface water for determining saturated weight of the specimens. The testing results of compressive strength and water absorption were compared with the ASTM C55 (2010) for concrete building brick and ASTM C1634 (2010) for concrete facing brick.

3.3 List of Abbreviations

3.3.1 Concrete

Concrete symbol {CR-FM, CR-FN, CR-PA, CR-RA, NC} {(0.65, 0.45, 0.25)} {10}

where: CR	=	Ground calcium carbide residue
CR-FM	=	30% by weight of ground calcium carbide residue and 70% by weight of ground pulverized coal combustion fly ash mixture
CR-FN	=	30% by weight of ground calcium carbide residue and 70% by weight of ground fluidized bed fly ash mixture
CR-PA	=	40% by weight of ground calcium carbide residue and 60% by weight of ground palm oil fuel ash mixture
CR-RA	=	50% by weight of ground calcium carbide residue and 50% by weight of g round rice husk-bark ash mixture
NC	=	Normal concrete in which Portland cement was used as a binder
(0.65, 0.45, 0.25)	=	Water to binder ratios of 0.65, 0.45, and 0.25, respectively
10	=	Portland cement was used to replace binder at 10% by weight

3.3.2 Concrete Brick

Concrete brick symbol {CR-FM, CR-FN, CR-PA, CR-RA, NB}

where: NB	=	Portland cement concrete brick in which Portland cement was used as a binder