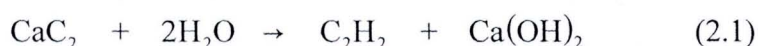


CHAPTER 2 LITERATURE REVIEW

This chapter presents literature reviews of the investigation and conclusion on calcium carbide residue, pozzolanic materials, high-strength concrete, and water permeability of concrete. All literature reviews of each topic are summarized as follows:

2.1 Calcium Carbide Residue

Calcium carbide residue is a by-product of acetylene gas production. This gas is used as a fuel for lighting, welding, metal cutting, and to ripen fruit. The calcium carbide residue is produced by a simple process, which is obtained from a reaction between calcium carbide (CaC_2) and water (H_2O) to form acetylene gas (C_2H_2) and calcium hydroxide ($\text{Ca}(\text{OH})_2$), as shown by the following equation (McKetta, 1993):



Calcium carbide residue mainly consists of calcium hydroxide, ($\text{Ca}(\text{OH})_2$), in a slurry form which is released to disposal area every day as shown in Figure 2.1. Jaturapitakkul and Roongreung (2003) reported that 64 g of calcium carbide (CaC_2) provides 26 g of acetylene gas (C_2H_2) and 74 g of calcium carbide residue in terms of $\text{Ca}(\text{OH})_2$. Thailand has a huge amount of calcium carbide residue due to acetylene gas production, and the residue has accumulated over time. From 2002-2011, one acetylene gas factory produced approximately 1,000 tons/month or about 12,000 tons/year of calcium carbide residue, and very little of this residue has been utilized. Thus, most of the residue is sent to landfills, causing many environmental problems such as awful smell and high alkalinity of the disposal area (see Figure 2.2).

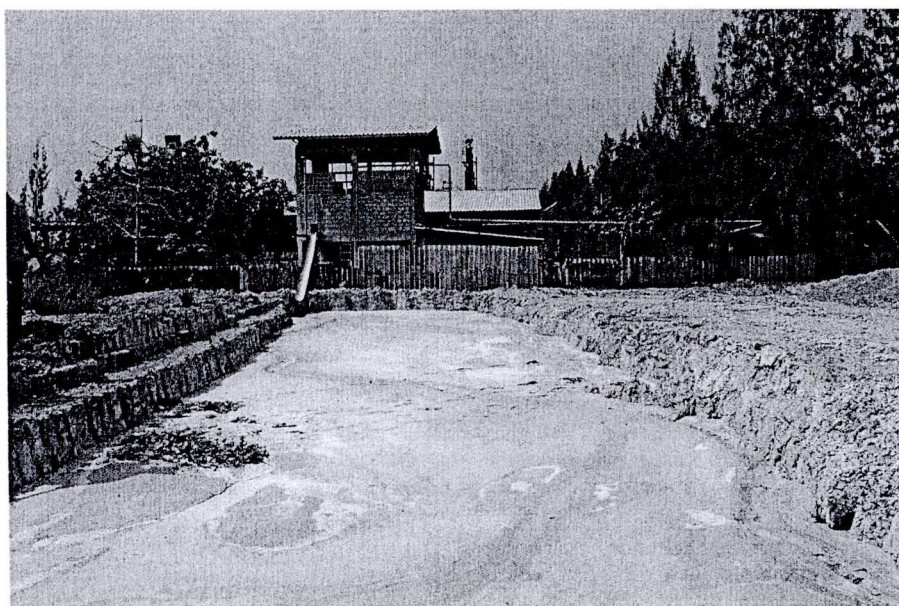


Figure 2.1 Calcium carbide residue is released from factory



Figure 2.2 Disposal area of calcium carbide residue

Previous researches indicated that the rich of $\text{Ca}(\text{OH})_2$ in calcium carbide residue can react with siliceous or siliceous and aluminous materials in pozzolanic materials to form C-S-H, similar to those obtained from the cement hydration process (Krammart, et al., 1996; Namarak, et al., 2002; Jaturapitakkul and Roongreung, 2003; Airdeaw, et al., 2010). In 1996, Krammart, et al. (1996) found that an optimal ratio of calcium carbide residue to fly ash of 30:70 by weight yielded the highest compressive strength of mortar, 20.9 MPa at 90 days. Although the mixture could produce compressive strength, it had much longer setting times than cement paste.

Furthermore, 50:50 by weight for calcium carbide residue and rice husk ash produced the highest compressive strength of mortar (19.1 MPa at 180 days), which was observed by Jaturapitakkul and Roongreung (2003). Results of Namarak, et al., (2002) showed that a mixture of calcium carbide residue and classified Mae Moh fly ash mixture could be used as a binder for concrete with the compressive strength as high as 20.5 MPa at 90 days. Calcium carbide residue was mixed with fly ash at a same ratio of 30:70 by weight to cast concrete specimen. Moreover, 5% of CaCl_2 and 10% of Portland cement Type I by weight of binder were used as admixtures to accelerate compressive strength of concrete. They also reported that the addition of CaCl_2 in concrete did not have much effect on compressive strength and seemed that the concrete without CaCl_2 gave the compressive strength higher than those incorporating of CaCl_2 . Airdeaw, et al., (2010) reported that use of ordinary Portland cement as an strength accelerator for calcium carbide residue and palm oil fuel ash concrete could reduce setting times and increase compressive strength of the concrete. Moreover, their study indicated that at various replacements of Portland cement ranging from 5 to 20% by weight of binder did not

have much difference in compressive strength of calcium carbide residue-palm oil fuel ash concrete.

From previous studies, it was shown that calcium carbide residue and pozzolanic material mixtures could be used as a new binder for casting concrete. In addition, the compressive strengths of concrete made from calcium carbide residue and pozzolanic materials 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. The techniques for accelerating strength, such as increasing binder content and lowering water to binder ratio in mix design were introduced in this experiment. Furthermore, 10% of ordinary Portland cement Type I was used by replacing binder content in order to accelerate the pozzolanic reaction and enhance the compressive strength of the concrete. Moreover, to increase the degree of confidence in using calcium carbide residue with pozzolanic materials for concrete binder, several pozzolans such as pulverized coal combustion fly ash, fluidized bed combustion fly ash, palm oil fuel ash, and rice husk-bark ash, which are agricultural or industrial by-products in Thailand, are selected to study.

2.2 Pozzolanic Material

Several pozzolanic materials, by-products from industry in Thailand, such as fly ash, palm oil fuel ash, and rice husk-bark ash have been discovered to replace some portion of cement to achieve high compressive strength of concrete (Sata, et al., 2007). However, the pozzolanic materials are still disposed of as wastes in landfills and the quantities are increased annually. It is important to utilize large amounts of worthless pozzolanic materials in concrete industry. It is also expected that the utilization of these industrial waste ashes mixed with calcium carbide residue in concrete can improve the concrete properties.

ASTM C 618 (2010) defines pozzolanic material is a material containing siliceous or siliceous and aluminous material by composition. In general, a pozzolanic material has little or no cementing property, however when it has high fineness and in presence of moisture, can react with calcium hydroxide at ordinary temperatures to provide the cementing property. Use of pozzolanic materials as the cement replacement in concrete has been introduced for many decades and for many reasons, such as cost benefit, increase durability and ultimate strength of concrete, reducing the amount of cement required for making concrete, conserving the energy, and more environmental friendly.

2.2.1 Fly Ash

Pulverized Mae Moh fly ash is a by-product from pulverized combustion of lignite coal in a power plant. Mae Moh power plant produces pulverized fly ash about 3.0 million tons/year. Although, approximately 1.5 million tons/year of that fly ash is used as a

pozzolanic material in concrete for construction (Jaturapitakkul and Cheerarot, 2003), it is fractionally consume comparing to the amount of fly ash production. Therefore, the excess fly ash remains to dispose of in landfills every day, which causes many environmental problems. The use of pulverized coal fly ash is limited in transportation issue because the thermal power plant is located in the northern part of Thailand, far from Bangkok, where most construction sites are located.

Hence, this research introduced fluidized bed fly ash, produced in the central part of Thailand, near Bangkok. Bituminous and sub-bituminous coals were burned at temperatures of 800 – 900 °C with a fluidized bed burning process. Approximately 400,000 – 500,000 tons of the fluidized bed fly ash is produced from powers plant annually but the fly ash has been rarely used because it had large particles and high porosity which is not met the limit specified by ASTM C618 (2010). However, Sata, et al., (2007) found that high fineness of fly ash from fluidized bed combustion can be used to make high-strength concrete, producing compressive strengths ranging from 85.0 to 91.4 MPa at 28 days. Use of fly ash in concrete is constantly increasing because it improves the properties of concrete, namely workability, strength of hardened concrete, and durability in long term. Generally, the fly ash from pulverized combustion process has spherical particle and round surface. However, some fly ash particles have irregular or angular shape such as fly ash from the fluidized bed combustion. The size and shape of fly ash particles vary depending on the sources and combustion condition. The chemical composition of fly ash also depends on the characteristics of coals and burning condition. The major constituents of fly ash are SiO_2 , Al_2O_3 , Fe_2O_3 , and CaO . Other minor elements are MgO , Na_2O , K_2O , and SO_3 .

Many researches have been demonstrated that use of grinding pulverized Mae Moh fly ash (high fineness) in concrete can improve compressive strength and durability (Kiattikomol, et al., 2001; Jaturapitakkul, et al., 2004; Chalee, et al., 2007). The Mae Moh fly ash is a good pozzolan because it has high content of silica, alumina, and ferric oxides. In addition, spherical in shape and round surface are important factors to reduce water requirement and enhance workability of fresh concrete. Angsuwattana, et al., (1998) found that the use of very fine Mae Moh fly ash (median particle size of 2.8 μm) from classified procedure produced higher compressive strength than that of Portland cement concrete after 7 days. At later age of 365 days, concretes containing 15 and 25% replacement of the very fine fly ash had compressive strengths of 89.6 and 88.3 MPa or about 115 and 113% of the Portland cement concrete. Next, Kiattikomol, et al., (2001) evaluated coarse fly ash from five sources in Thailand. Coarse fly ash from air classifier was ground to have median particle sizes of 1.9 to 17.2 μm . Mortar cubes were cast with 20% replacement of fly ash by weight of binder. The compressive strength of mortars increased with increasing of fineness of the fly ash. The results showed that the fineness of fly ash was the major factor affecting the strength activity index of mortar. In 2004, Jaturapitakkul, et al., (2004) improved quality of Mae Moh fly ash in order to replace condensed silica fume to make high strength concrete. Coarse fly ash from air

classifier was ground to have a high fineness (median particle size of 3.8 μm) and was used to replace Portland cement type I at 15, 25, 35, and 50% by weight of binder. The test results showed that the use of ground coarse fly ash replacement between 15 and 50% can produce high-strength concrete and 25% replacement gave the highest compressive strength. In addition, the use of ground coarse fly ash concrete at 15-35% as a cement replacement exhibited equal or higher compressive strength after 60 days than those of condensed silica fume concretes.

For fly ash from fluidized bed combustion, Sata, et al., (2007) reported that high fineness of fly ash from the fluidized bed combustion can be used to make high-strength concrete, producing compressive strengths ranging from 85.0 to 91.4 MPa at 28 days. However, little of fluidized bed fly ash research in Thailand has been found when compared with pulverized fly ash research. In this study, the fluidized bed fly ash in the central part of Thailand was also used as another fly ash to evaluate the concrete properties. Both fly ashes were mixed with calcium carbide residue without using Portland cement or used cement at 10% by weight of binder to create new binder which contrasted in the previous researches. The disposed of pulverized coal combustion fly ashes is not only be solved from using excess fly ashes in new binder, but also contributed to use the fluidized bed fly ash in the concrete.

2.2.2 Palm Oil Fuel Ash

Palm oil industry is one of the major agro-industries in Thailand. The raw materials in form of fresh fruit bunches are supplied to the palm oil industry and its process produces a large amount of solid waste materials in form of fibers, shells, and empty fruit bunches. Their amount was approximately 2.1 million tons in 2001. These solid waste materials were used as fuel to produce steam for generating electricity for palm oil extraction process. After combustion, about 100,000 metric tons of palm oil fuel ash is produced (about 5% by weight of the solid wastes). Due to limited utilization of the palm oil fuel ash, it has to be disposed of as landfill materials, leading to a potential future environmental problem.

Tay (1990) used ash from palm oil waste to replace Portland cement for making blended cement concrete. He showed that palm oil fuel ash had low pozzolanic properties and recommended that the palm oil fuel ash should not be used as a cement substitution in any quantity higher than 10% by weight of binder. However, the low pozzolanic property of palm oil fuel ash from Tay's report was due to the large particle of the ash, resulted in a very low rate of pozzolanic reaction. After that, Hussin and Awal (1996) studied on concrete containing palm oil fuel ash in range of 10-60% by weight of binder. They reported that the concrete containing 30% of palm oil fuel ash gave the highest strength and could be used to replace cement up to 40% to obtain the same compressive strength as that of concrete made from Portland cement.

In Thailand, many researchers found that palm oil fuel ash had pozzolanic properties and could be used to partially replace cement in concrete. Sukantapree, et al., (2002) reported that the large particle and high porosity of original palm oil fuel ash affected lower the compressive strength of mortar. However, ground palm oil fuel ash with particles retained on a 45- μm sieve of less than 5% by weight produced mortar with the compressive strength higher than that of the Portland cement mortar at the ages of 7 and 28 days. Tangchirapat, et al., (2003) also found that the ground palm oil fuel ash with high fineness was a reactive pozzolanic material and the use of 10 to 20% by weight of binder to replace cement in mortar gave higher compressive strength than that of cement mortar after 60 days. In 2004, Sata, et al., (2004) increased fineness of palm oil fuel ash and used it as a pozzolanic material to produce high-strength concrete. The palm oil fuel ash was ground until the median particle size was about 10 micron, and was replaced Portland cement at 10, 20 and 30% by weight of binder. They reported that the highest compressive strength was 85.9 MPa when 20% of ground palm oil fuel ash was used to replace cement. In addition, at 30% of cement replacement by ground palm oil fuel ash, the concrete had similar compressive strength as compared with the concrete containing 5% of silica fume. Next, Tangchirapat and Jaturapitakkul (2010) studied on compressive strength and water permeability of palm oil fuel ash concrete. They showed that the compressive strength of concrete increased with the fineness of palm oil fuel ash. In addition, this study indicated that the value of water permeability of the concrete decreased as the compressive strength increased. The water permeability of palm oil fuel ash concretes were 2.8×10^{-13} and 1.2×10^{-13} m/sec at 28 and 90 days, respectively.

Due to pozzolanic properties of palm oil fuel ash, it was used with calcium carbide residue together as another binder to cast concrete in which contained no Portland cement or contained low amount of Portland cement (10% by weight of binder). This can help eliminate the disposed of palm oil fuel ash by using with calcium carbide residue as a binder for concrete.

2.2.3 Rice Husk-Bark Ash

Rice husk-bark ash is another by-product from biomass power plants which rice husk and eucalyptus bark are burnt together as fuel at controlled temperature about 800–900°C in order to produce steam for electricity generating. The quality of original rice husk-bark ash is quite uniform. The amount of rice husk-bark ash from a biomass power plant has been produced approximately 110,000 metric tons annually while the utilization of rice husk-bark ash is very little. Thus, most of rice husk-bark ash has been disposed of as waste in landfills, which also causes environmental problems.

Nowadays, it is well-known that rice husk ash is one common pozzolanic material obtained from rice milling. It can be estimated that 1,000 kg of rice grain produces 200 kg of rice husk. Then, 20% of the rice husk or 40 kg becomes rice husk ash (Mehta, 1977). In 1977, Mehta (1977) pointed out that rice husk ash is a highly reactive

pozzolan and consists of high amount amorphous of SiO_2 that could give the compressive strength of mortar higher than that of Portland cement mortar. Consequently, several researchers intended to develop pozzolanic property of rice husk ash by attempting to find out the burning process in order to obtain high quality of rice husk ash. In 1990, Boateng and Skeete (1990) found that when maintained the bed temperature in the range of 800-900°C that causes form the amorphous product and highly reactive of silica in rice husk ash. Singh, et al., (1995) observed that the burning rice husk in an open heap, the silica was also in amorphous form. Zhang and Malhotra (1996) suggested that due to highly pozzolanic of rice husk ash, it could be used as a supplementary cementing material to produce high-performance concrete. This is consistent with Ismail and Waliuddin (1996), who reported that the compressive strength gained more than 80 MPa of high-strength concrete which obtained from 10% replacement of Portland cement by rice husk ash.

In Thailand, Chatveera and Nimityongskul (1996) investigated the high-strength concrete incorporating of rice husk ash with W/B ratio of 0.33 and slump of 10 ± 2 cm. They concluded that the high quality concrete could be developed by using high fineness of rice husk ash to replace cement of 20% and using 1.43% of superplasticizer by weight of binder. Jaturapitakkul, et al., (2002) investigated pozzolanic property of rice husk-bark ash, which rice husk from rice milling and eucalyptus bark were burnt together as fuel at controlled temperature about 800-900°C in electric power plant. They reported that the sum of the components SiO_2 , Al_2O_3 , and Fe_2O_3 was 84.91%. The loss of ignition (LOI) and SO_3 were 3.72% and 0.60%, less than 10% and 4%, respectively. The compressive strength of mortar containing original rice husk-bark ash was low. However, the compressive strength of mortar could be increased when the ground rice husk-bark ash was used. The compressive strength of mortar containing very high fineness of rice husk-bark ash was the same as or higher than that of Portland cement mortar, when the cement replacement was up to 30% by weight of binder. The strength activity index of ground rice husk-bark ash mortar was over 98% at the age of 7 days. After that, Makaratat, et al., (2004) used rice husk-bark ash as a cement replacement in concrete. They ground rice husk-bark ash into 3 levels of fineness particles and used them to replace Portland cement up to 40% by weight of binder. It was found that concrete containing rice husk-bark ash caused significant delay in both initial and final setting times. The compressive strength of concrete was affected by the fineness and the amount replacement of cement by rice husk-bark ash. The results also revealed that the high fineness of rice husk-bark ash could be used up to 40% to replace cement and gave the compressive strength of 27 MPa or about 86% of the Portland cement concrete at 28 days. Chindaprasirt, et al., (2007) investigated the water permeability of concrete containing rice husk-bark ash. They concluded that ground rice husk-bark ash could be used up to 40% replacement in Portland cement while the water permeability of the concrete was lower than that of Portland cement concrete. In addition, the water permeability of rice husk-bark ash concrete tended to increase when the water to binder ratio decreased.

Although, rice husk-bark ash is a good pozzolanic material, it needs to partially replace in Portland cement for cast concrete. Nevertheless, this research studied concrete in which contained no Portland cement or contained Portland cement at 10% by weight of binder and used calcium carbide residue and rice husk-bark ash as a binder. Therefore, the strength gain of the concrete was major expected from pozzolanic reaction of the calcium carbide residue and rice husk-bark ash.

2.3 High Strength Concrete

In 1950, concrete with a compressive strength of 34 MPa was considered as high-strength. In 1960, concrete with 41 and 52 MPa compressive strengths were used commercially. More recently, compressive strength approaching 138 MPa has been used in cast-in-place building (ACI 363, 2003). The definition of high-strength concrete according to ACI 363 (2003) is a concrete having compressive strength of 40 MPa or greater. Typically, high-strength concrete has low water to binder ratio of 0.20 to 0.45 (Kosmatka, et al., 2002) and superplasticizer is used to increase workability of concrete. Supplementary cementing materials such as fly ash and silica fume are normally used in order to create extra strength by pozzolanic reaction, reduce permeability, and improve concrete durability. There have been many reported studies of high-strength concrete using pozzolanic materials as cement replacement as follows:

Haque and kayali (1998) used a class F fly ash with a fineness of 99% passing a 45- μm sieve to produce high-strength concrete. Concrete mixtures were prepared with total binder contents of 400 and 500 kg/m^3 , cement replacements by Class F fly ash at 10, and 15% by weight of binder, and water to binder ratio ranged from 0.25 to 0.38. They found that the optimum cement replacement by fly ash was 10%. The maximum compressive strengths at 28 days were occurred in two mixtures, 94 and 110 MPa with the slump of 45 and 85 mm, respectively. The modulus of elasticity of all concretes varied between 40 and 46 GPa, and increased with increasing of the compressive strength. Their experimental results showed that concrete with a compressive strength more than 80 MPa at 28 days could be obtained with the water to binder ratio of 0.25 with 15% replacement of cement by fly ash.

Wee, et al., (1995) studied the effect of silica fume, ground granulated blast furnace slag, and ettringite-based cementitious materials on the compressive strength of high-strength concrete. The test results were found that at the same water to binder ratio of 0.30, the tilting drum mixer could be performed in producing high-strength concrete with compressive strength higher than 100 MPa. Shanag (2000) used various combinations of a local natural pozzolan and silica fume to produce high-strength concretes with total binder content between 400 and 480 kg/m^3 . The test results demonstrated that the combination of natural pozzolan and silica fume in concrete improved concrete properties more than those of natural pozzolan or silica fume alone with compressive strength in the range of 69 and 85 MPa at 28 days.

High-strength concrete with compressive strength above 70 MPa using high fineness of rice husk ash to partially replace cement was investigated by Ismail and Waliuddin (1996). At 10-30% of rice husk ash passing 75- μm sieve and 45- μm sieve were replaced into cement for making high-strength concrete. The results confirmed that it was possible to make high-strength concrete economically using rice husk ash. Although rice husk ash was used in the form of crystalline, the good results might be obtained when rice husk ash was ground to have high fineness. The optimum cement replacement by high fineness of rice husk ash was about 10-20% by weight of binder. Chatveera and Nimityongskul (1995) investigated the mechanical properties of high performance concrete incorporating of rice husk ash. The rice husk ash was ground by grinding machine to increase fineness of particles. The modified mixing of rice husk ash in concrete mixture was introduced into 3 types for casting concrete specimens. They found that at 30% replacement of Portland cement Type I by ground rice husk ash, concrete had the compressive strength of 70 MPa at 28 days. The highest compressive strengths of rice husk ash concretes were higher or slightly less than those of concretes containing 10% replacement of condensed silica fume.

Zhang, et al., (2002) investigated the influence of water to binder ratio, superplasticizer, and mineral admixtures on the heat of hydration from binder paste in high performance concrete. The testing results showed that water to binder ratio had great impact on the heat of hydration from the binder paste. The heat of hydration decreased with decreasing of water to binder ratio and was not reduced in the presence of superplasticizer containing retarding component, but the heat of hydration process was delayed. The incorporation of mineral admixtures greatly reduced heat of hydration and retarded the arrival time of highest temperature rise of the binder paste.

In 2004, Sata, et al., (2004) used palm oil fuel ash to produce high-strength concrete. The palm oil fuel ash was ground by ball mill until the median particle size was 10 μm and was used to replace Portland cement at 10, 20, and 30% by weight of cementitious materials. Their result showed that the optimum replacement of ground palm oil fuel ash was 20% and gave the highest compressive strength. Concretes containing 10, 20, and 30% of ground palm oil fuel ash had compressive strengths of 89.1, 91.5, and 88.7 MPa at 90 days, respectively. Modulus of elasticity of ground palm oil fuel ash concrete increased with increasing of the compressive strength. Use of ground palm oil fuel ash reduced the highest temperature rise of concrete under semi-adiabatic conditions. In addition, the reduction in cement content by increasing replacement of ground palm oil fuel ash tended to reduce the total heat released.

For this research, it is expected that a mixture from calcium carbide residue and pulverized coal combustion fly ash can be used as a binder to produce high-strength concrete. The techniques for increasing compressive strength such as increasing binder content and lowering water to binder ratio in mix design were introduced in this experiment. Furthermore, compressive strength of the concrete more than 40 MPa at 90 days was expected. Moreover, heat evolution of high-strength concrete contained no

Portland cement or contained Portland cement at 10% by weight of binder was also investigated.

2.4 Water Permeability

Permeability, which can be defined as the external substances such as liquids and gases penetrate into concrete, is considered to be one of the most important properties affecting concrete durability. Concrete with the higher permeability allows faster penetration of aggressive solutions such as chlorides and sulfates, resulting in rapid corrosion of the reinforcing steel and cause of the weakness in concrete strength. Also the other forms of concrete deteriorations governed by the fluid transportation.

Ludirdja, et al., (1989) presented a simple method to measure the permeability of concrete. They used water under gravity passed through the concrete specimen and monitored the flow rate for 20 days to estimate the permeability. They pointed out that the permeability coefficient can be determined within 7 days. In addition, the use of silica fume reduced permeability of concrete as compared with Portland cement concrete. Khatri and Sirivivatnanon (1997) studied on the two test methods, used to determine water permeability of concretes with different types of binder. The methods were based on the determining of coefficient of permeability using a constant flow and depth of penetration. They reported that the flow method had generally been found to suit concretes with higher permeability, while the penetration method was used for concretes with very low permeability. Binder types did not appear to significant affect the coefficient of permeability measured by the two methods.

EI-Dieb and Hooton (1995) measured the water permeability of high-performance concrete by using a high pressure triaxial cell with a sensitive and automated measurement capability. Special analysis procedures were developed to obtain useful data from the extremely low volume of water being measured. They reported that this method was able to measure a wide range of permeability values from 10^{-12} m/s to 10^{-16} m/s, with repeat measurements on replicates. Chindapasirt, et al., (2007) studied water permeability of concrete containing palm oil fuel ash and rice husk-bark ash. The palm oil fuel ash and rice husk-bark ash were ground and incorporated into concrete at the levels of 20, 40, and 55% by weight of cementitious material. Ground rice husk-bark ash concrete produced higher compressive than ground palm oil fuel ash concrete at all cement replacement rate, although lower permeability of concrete was obtained with ground palm oil fuel ash concrete. Water permeability of ground palm oil fuel ash and rice husk-bark ash concretes depends on cement replacement rates, and age of concretes. Moreover, permeability of concrete reduced with increasing in compressive strength as well as age of concrete.

Durability property in term of water permeability of concretes which made from calcium carbide residue and pozzolanic materials such as pulverized coal combustion fly ash, fluidized bed fly ash, palm oil fuel ash, and rice husk-bark ash as a binder are

not found in the literatures survey. As a result, the water permeability coefficients of calcium carbide residue-pozzolans concretes at W/B ratio of 0.45 were proposed to be determined.

2.5 Concrete Brick

ASTM C55 (2010) specified concrete building brick that it is used in non-facing utilitarian applications for use where moderate strength and resistance to moisture penetration are required. The compressive strength, absorption, and density classification requirement for concrete building brick according to ASTM C55 are given in Table 2.1.

Table 2.2 shows the compressive strength, absorption, and density classification requirements for concrete facing brick according to ASTM C1634 (2010). This specification differs from ASTM C55 specification in that it includes expanded consideration for properties of concrete brick used in facing applications and other exposures. Generally, the concrete facing brick is used as architectural veneer and facing units in exterior walls and for use where high-strength and resistance to moisture penetration are desired.

Table 2.1 Strength, absorption, and density classification requirements for concrete building brick (ASTM C55, 2010)

Density Classification	Oven-Dry Density, kg/m ³	Maximum Water Absorption, kg/m ³		Minimum Net Area Compressive Strength, MPa	
	Average of 3 Units	Average of 3 Units	Individual Units	Average of 3 Units	Individual Units
Lightweight	1680	288	320	17.2	13.8
Medium Weight	1680-2000	240	272	17.2	13.8
Normal Weight	2000 or more	208	240	17.2	13.8

Table 2.2 Strength, absorption, and density classification requirements for concrete facing brick (ASTM C1634, 2010)

Density Classification	Oven-Dry Density, kg/m ³	Maximum Water Absorption, kg/m ³		Minimum Net Area Compressive Strength, MPa	
	Average of 3 Units	Average of 3 Units	Individual Units	Average of 3 Units	Individual Units
Lightweight	1680	240	272	24.1	20.7
Medium Weight	1680-2000	208	240	24.1	20.7
Normal Weight	2000 or more	160	192	24.1	20.7

As described in the above literatures survey, it is indicated that most research pointed out on the use of pozzolanic materials to improve both strength and durability of concrete properties, while the use of calcium carbide residue and pozzolanic materials as a binder to obtain the strength of concrete is not well-known and lack of knowledge to create confidence. Therefore, this research focuses on development of blended calcium carbide residue and pozzolanic materials for using as a binder in concrete and concrete brick, which contains no cement or consumes small amount of cement.

The technique for improving strength such as increasing binder content and lowering water to binder ratio were introduced in this experiment. In addition, ordinary Portland cement type I at 10% by weight of binder was used to enhance fresh and hardened concrete properties. Moreover, it is expected that some mixtures can be used to make high-strength concrete and produce a good performance in durability properties. The results from this research will encourage researchers or concrete users to utilize the two wastes mixture as a binder in concrete. This new concrete, made from calcium carbide residue and pozzolanic materials, not only reduces CO₂ emissions by not using or use small amount of Portland cement, but also reduces the environmental problems associated with disposal of these waste materials in landfills.



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