Development of modern Rapid Chloride Permeability in concrete testing Apparatus

BY

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ABSTRACT

The construction industry mostly uses concrete in construction. The building that is built close to the water resource area is affected by chloride. The chloride has penetrated a concrete causing it to erode and damage the reinforced steel. This research has an objective to develop the ability of rapid chloride permeability measurement apparatus in the concrete. The improved apparatus has more convenience to fill the solution for testing equipment. Additionally, it can store the data in the experiment and process for accessing the information by online system in real-time according to the standards of concrete inspection. The developed apparatus includes a power supply set, load cell set, and processing software, which was tested with the concrete that has a compressive strength between 250 - 300 ksc, after curing with a period of 28 days. This power supply can generate DC power up to 60 V, there is an accurate error lower than 1% or ± 6 mA. it makes a result which has the error value maximum of 45 coulombs from the power supply. The apparatus has efficient performance in rapid chloride permeability and more convenient to use. The result is according to the standard ASTM C1202 for determining the rapid chloride permeability in concrete.

Keywords: Apparatus, Rapid chloride permeability, ASTM C1202

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Organizers

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LIST OF SYMBOLS/ABBREVIATIONS

Symbols/Abbreviations	Terms
ASTM	American Society for Testing and Materials

CHAPTER 1
INTRODUCTION

1.1 Background and importance of the problem

From the past to the present, concrete still is the primary material used in construction work. The different environment in each area is affected to the concrete in many ways. The researcher sees that chloride is very effective the concrete especially the building that nearby the sea or environment that has a high volume of chloride, it needs to consider the usage and period of the concrete because the area near the sea has chloride that permeability to the concrete to make reinforcing steel inside the concrete losing efficiency of usage and aging. When considering the safety of construction for age and usage of the concrete need to analyze the permeability of chloride are concrete mixes and mixing ratios including a concentration of each volume of chloride in the water source, such as bridges across rivers and seaports, etc. For concrete column that builds at the water, need to have the resistance of the permeability of chloride more than normal concrete, but the elevation of the column at the water source has different of the permeability of chloride if distance closer to the water source will have more chance that the chloride will permeate the concrete to the steel inside and reduce the age of use.

The concrete nearby a water source needs to consider the rate of the permeability of chloride in concrete. The beginning of cooperating for doing research, design, and development the chloride permeability resistance tool for the concrete by using rapid chloride penetrability test for the main research operation and for this reason the standard for calculating the chloride permeability in concrete was proposed with the ASTM C 1202: Rapid chloride Permeability, which is concrete checking to find the resistance of chloride permeability in concrete which will be used to construct buildings near water sources by using standard system ASTM C 1202: Rapid chloride Permeability to decide and classify the type of concrete be more suitable for use.

1.2 Objectives of the study

1. To create a chloride measurement apparatus in the concrete according to ASTM C 1202: Rapid chloride Permeability.
2. To develop the function of the equipment to be technologically advanced and user-friendly.

1.3 Research hypothesis

Nowadays, the construction of buildings is mostly used concrete, which concrete has chloride that permeates, if concrete contains more chloride will decrease the lifetime and compression of steel. To make it safe in the building, the research group will create a chloride measuring tool in concrete to measure chloride before the construction.

1.4 Research scope

Nowadays, the construction of buildings is mostly used concrete, which concrete has chloride that permeates, if concrete contains more chloride will decrease the lifetime and compression of steel. To make it safe in the building, the research group will create a chloride measuring tool in concrete to measure chloride before the construction.

1. Concrete in this research use cement Portland type 1 by mix admixture with chloride resistance additive and without chloride resistance additive
2. Study of chloride penetration in concrete is in this research refer to standard system ASTM C 1202: Rapid chloride Permeability.
3. Study specifical to specimen cylinder shape that has diameter 10 centimeter and high 5 centimeters, by doing each experiment use only 6 hours and use specimens that incubate only 28 days according to ASTM C 1202: Rapid chloride Permeability.

1.5 Methodology

1. Study theory and relative research about resistance to permeability of chloride according to ASTM C 1202.
2. Create a new model of ASTM C 1202: Rapid chloride Permeability machine.
3. Estimate material cost in creating a new model to find permeability of chloride in concrete.
4. Creating a new model that finds the permeability of chloride in concrete.
5. Setting measurement to find permeability resistance of chloride in the concrete according to ASTM C 1202: Rapid Chloride Permeability.
6. Analyze information that is obtained from the machine and compare the information in the experiment.
7. Conclude this research.

1.6 Expected benefits.

1. Create a tool for crafting models to find permeability of chloride in the concrete according to ASTM C 1202: Rapid Chloride Permeability.
2. The machine can show the information through application via phone in real-time.

CHAPTER 2
THORETICAL BACKGROUND AND LITERATURE REVIEWS

2.1 Concrete

In the present day, the engineer found that concrete is still being used continuously. Because concrete is more suitable for construction than other materials, whether in terms of price or features by considering the concrete into 2 parts.

1. A connector such as cement and water and concrete admixture.
2. Aggregate such as sand, stone, or gravel.

when combined, will get concrete that is ready for use in various ways. After that, the concrete changes from liquid to semi-solid and eventually become a solid, which can apply more compression until the moment that the compressive strength will reach a constant.

2.1.1 The elements of concrete

Normally, the concrete mix consists of cement, stone, water, sand, and concrete admixture, when combined that we will use that materials name such as the cement mixed with water and the concrete admixture is cement paste, cement paste mixed with sand is the mortar, mortar mixed with stone or gravel is concrete.

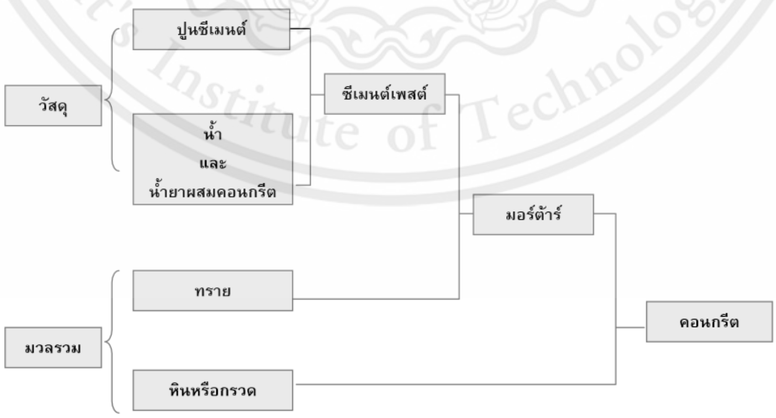


Figure 2.1 Diagram of elements when mixed in each phase.

2.1.2 Functions and properties of ingredients

- Cement is giving the strength of the concrete and lubricate the concrete by reacting with hydration to become a viscous liquid. To be able to pour together and hold the total mass together and the properties will depend on the chemical composition and the fineness of the cement.
- Aggregate Serves to help the concrete to be durable and reduce the shrinkage of concrete. Which the properties of aggregate must be strong Resistant to chemical reactions Resistant to impact and abrasion etc.
- Water acts as a hydration reaction with the cement and is a lubricant by putting the concrete in a liquid state. The water chosen must be clean, colorless, and have neutral acid-base properties.
- Concrete admixtures are responsible for improving various properties of concrete to be suitable for use in various jobs. This chapter discusses the state-of-the-art of blah and blah and any blah considered during the analysis and design phase of this project. The investigation served n purposes: firstly, we wished to identify blah blah blah (section 2.1); and secondly, we wished to establish blah blah blah (section 2.2). Finally, section 2.3 summarizes the chapter.

2.1.3 Types of cement

Portland cement according to TIS 15 separative 5 types.

- Type 1 Ordinary Portland cement, used for general construction, Such as ปูนซีเมนต์ตรา TPI สีแดง, ตราช้าง, ตราอินทรีย์เพชร.
- Type 2 Modified Portland Cement is used for concrete that is resistant to heat and moderate Sulphate, currently not sold and manufactured in Thailand.
- Type 3 High Early Strength Portland Cement is used for fast compressive strength applications such as foundation foundry, precast floor, such as ปูนซีเมนต์ตรา TPI สีดำ, ตราเอราวัณ, ตราอินทรีย์ดำ.

- Type 4 Low Heat Portland Cement is used for applications that require low heat concrete. Currently, there is no production in Thailand.
- Type 5 Sulphate Resistant Portland Cement is used on land or underwater areas with high Sulphate content such as ปูนซีเมนต์ตรา TPI สีฟ้า, ตราช้าง สีฟ้า, ตราอินทรีย์ฟ้า.
- Mixed Portland cement produced according to TIS. 80.

Produced by grinding Portland type 1 cement with sand or limestone, resulting in less stretching, and reducing cracking on the surface of the cement. Therefore, not suitable for jobs that are highly compressive, such as green TPI cement brand, tiger brand, organic red brand (TPI Concrete Company Limited, 2008).

2.1.4 Concrete Mixing Method

- Hand mixing is mixed with normal tools that can be found. Such as a shovel or a shovel to mix cement this method is suitable for applications that use little concrete.
- Mixing by a small concrete mixing tool using a motor driven.
- Mixing with a large mixer from the factory or in a cement truck with a rotating mill to prevent the concrete from hardening. (Thaweesak Kaewpradab, 2012)

2.1.4.1 Standard of concrete design

In designing, concrete must be designed to be more compressive strength than compressive strength in work. As this equation

$$f_{cr} = fc' + ks \quad (1)$$

F_{cr} = Target Strength (kg/cm^2)

F_c' = Required Strength (kg/cm^2)

k = Factor k

s = Standard deviation of the concrete compressive strength test results (kg/cm^2)

Table 2.1 Factor for mixed design concrete

Factor k	A hundred of the lower compression forces.
1.282	10
1.645	5
1.960	2.5
2.054	2
2.326	1
3.000	0.15

Table 2.2 Allowance when no compressive strength of the concrete test.

Specified compression value (fc')	Compressive strength to be added
Less than 210	70
210 - 350	85
350 or more than	100

2.1.4.2 Concrete mix design theory according to American standards.

In the process of designing mix proportions in conventional concrete, designers need to know the properties of the components in order to use the information in the design process. Therefore, the designer needs to know the properties of the cement and its aggregates.

1. Cement.

- Specific gravity tested according to ASTM C 188. But allow using 3.15 from normal Portland Cement.

2. Aggregates.

- Gradation should according to ASTM C 33
- Specific gravity

  Fine aggregates tested according to ASTM C 128

  Coarse aggregates tested according to ASTM C 127

- Surface moisture tested according to ASTM C 70 and ASTM C 566
- Sand fineness tested according to ASTM C 125

- Weight unit of aggregates tested according to ASTM C 29

After passing the test according to the above standards, the designer will obtain the values of the properties that can be applied to those properties in the concrete mix proportion design, described in a flowchart form as shown in the figure.

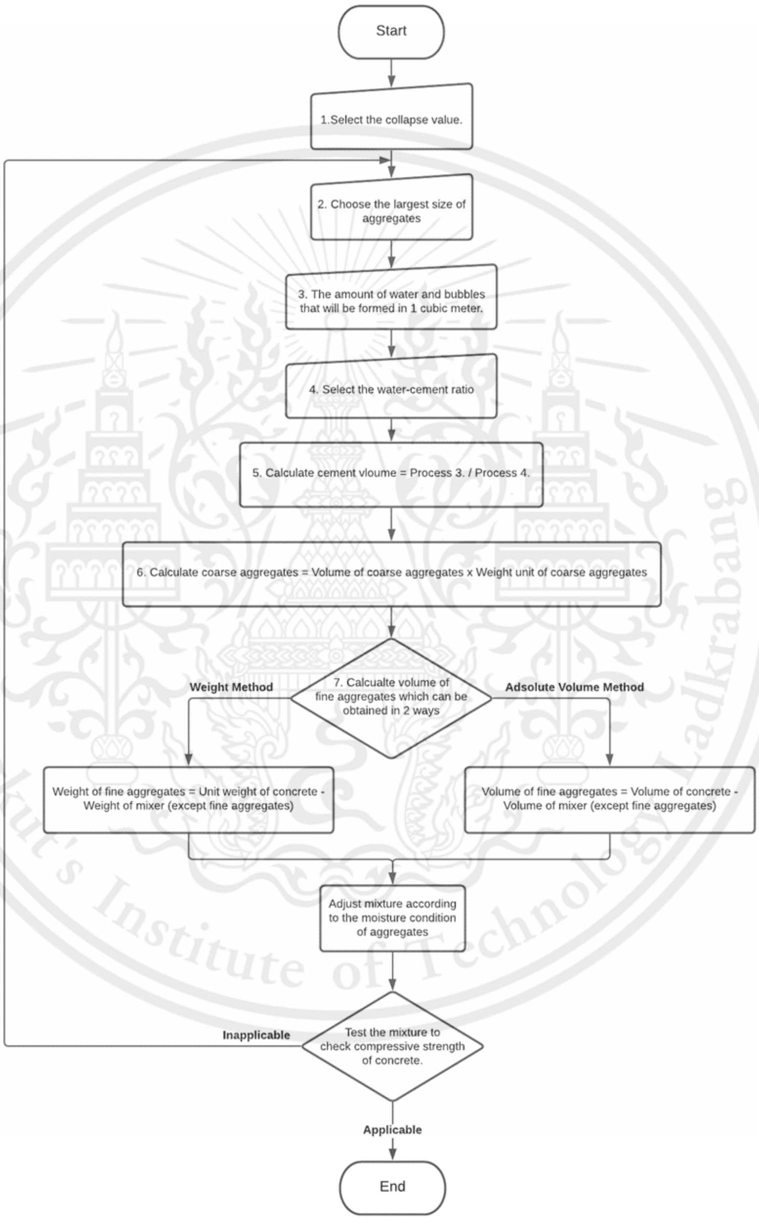


Figure 2.2 Concrete proportioning diagram

Table 2.3 Collapse value of concrete used for different construction types.

Type of concrete work	Collapse value	
	Highest value	Lower value
Reinforced concrete foundation work	8.0	2.0
Concrete foundation works without steel, underwater construction.	8.0	2.0
Floor, beam, and reinforced concrete wall work	10.0	2.0
Reinforced concrete columns work	10.0	2.0
Reinforced concrete road work	8.0	2.0
Large concrete work	5.0	2.0

Table 2.4 Volume of water using for collapse value and mixture.

Collapse value (Centimeter)	Volume of water (Liter per concrete 1 cubic meter)							
	3/8" (10 mm)	1/2" (12.5 mm)	3/4" (20 mm)	1" (25 mm)	3/2" (40 mm)	2" (50 mm)	3" (75 mm)	6" (150 mm)
Non-Air Entraining Concrete								
3 - 5	205	200	185	180	160	155	145	125
8 - 10	225	215	200	195	175	170	160	140
15 - 18	240	230	210	205	185	180	170	-
Number of bubbles (%) By volume	3	2.5	2	1.5	1	0.5	0.3	0.2
Air Entraining Concrete								
3 - 5	180	175	165	160	145	140	135	120
8 - 10	200	190	180	175	160	155	150	135
15 - 18	215	205	1906	185	180	165	160	-
Number of bubbles (%) By volume	8	7	6	5	4.5	4	3.5	3

Table 2.5 The water-cement ratio and ultimate compressive strength relationship.

The ultimate compressive strength of concrete at 28 days (kg/cm^2)	Water-Cement ratio by weight	
	Concrete does not spill air bubbles.	Concrete does spill air bubbles.
450	0.38	-
400	0.43	-
350	0.48	0.40
300	0.55	0.46
250	0.62	0.53
200	0.70	0.61
150	0.80	0.71

Table 2.6 The volume of the coarse mixture per unit volume of concrete.

Largest size of coarse aggregates	Volume of dry coarse aggregates and compact per volume unit of concrete for fineness modulus of fine aggregates			
	2.40	2.60	2.80	3.00
3/8" (10 mm)	0.50	0.48	0.46	0.44
1/2" (12.5 mm)	0.59	0.57	0.55	0.53
3/4" (20 mm)	0.66	64.00	0.62	0.60
1" (25 mm)	0.71	0.69	0.67	0.65
3/2" (40 mm)	0.76	0.74	0.72	0.70
2" (50 mm)	0.78	0.76	0.74	0.72
3" (75 mm)	0.81	0.79	0.77	0.75
6" (150 mm)	0.87	0.85	0.83	0.81

Example of determining the mix ratio according to American standards.

Determine the ratio of the concrete mixture for reinforced concrete columns by average ultimate compressive strength (fc') of cylinder concrete aged 28 days equal to 250, by giving the chance that the sample is less than 5% lower than the designed design (k = 1.645) and s value is 30 kg/cm2. Requirements to use Portland Cement Type I have specific gravity equal to 3.15. The biggest coarse aggregate is 20 mm has specific gravity equal to 2.70, absorption value is 0.5%, and the weight unit is 1600 kg/m3. The fine aggregate has specific gravity equal to 2.60, absorption value is 0.7%, and fineness modulus is 2.80.

Solution

1. Produce Compressive = fc' +ks

   = 250 + (1.645 x 30)

   = 300
2. From table 2.3 should use a collapse value of about 8 – 10 cm.
3. Requirement for a maximum size of coarse aggregate is 20 mm.
4. From table 2.4 the maximum size of coarse aggregate is 20 mm and collapse value about 8 – 10 cm, no substance needed to trap air bubble distribution will get the volume of water required is 200 liters/m3 if concrete.
5. From table 2.5 for concrete that needs the compressive strength of 300 kg/cm^2, will get the water-cement ratio about 0.55.
6. Required volume of cement = 200 / 0.55

   = 364 kg
7. Find the volume of coarse mixture from table 2.6 when fineness modulus is 2.80 and maximum size of coarse aggregate is 20 mm, will get the volume of dry and compact coarse mixture equal to 0.62 m^3/m^3 of concrete.

   The weight unit of coarse aggregate is 1600 kg/m^3.

   Thus, weight of coarse mixture that used = 0.62 x 1600

   = 922 kg/m^3 of concrete
8. Find volume of fine mixture.

   The intrinsic volume of the mixture:

   Volume of water = 200 / 1000 = 0.20 m^3

   Volume of cement = 364 / (3.15 x 1000) = 0.116 m^3

Volume of coarse mixture = 922 / (2.7 x 1000) = 0.367 m^3

Volume of air bubble = 0.02 x 1.0 = 0.02 m^3

Thus, volume of all mixture except fine aggregate = 0.703 m^3

Volume of require fine aggregate = 1 – 0.703 = 0.297m^3

Weight of dry fine aggregate = 0.297 x 2.60 x 1000 = 722 kg

Therefore, concrete 1 m^3 use:

Cement	364	kg
Water	200	kg
Coarse mixture	922	kg
Fine mixture	772	kg
Total weight	2,328	kg

2.1.4.3 Mixture design that suitable for Thailand

The mixture design of concrete in Thailand is the design applying American and British design standards to the condition of materials in Thailand, the properties of materials used in Thailand were tested and collected for average values from table 2.7.

Table 2.7 Standard value for design.

Material	Specific gravity	Absorption value
Cement	3.15	-
Sub rock	2.70	0.50
River sand	2.65	0.70

2.1.5 Material mix ratio.

Material mixing ratio to mix good quality concrete, it must be mixed in a standard ratio. Which can specify the ratio in two types which.

Table 2.8 Mixing ratio by measuring volume

Mixed Ratio			Description
Cement	Sand	Sub rock	
1	1.5	3	Cast pillars and structural parts to be tightly waterproof.
1	2	4	General structures such as columns, beams, and stairs
1	2.5	4	Work in roads, foundations, buildings, dams, and footpath
1	3	5	Large concrete castings such as large foundations and concrete walls

Table 2.9 The ratio of water and cement (building material, 1997)

Concrete			Stone description	Volume used
Concrete	Sand	Sub rock		
1	3	6	Dry	32liter: 1 Cement bag (50 kg)
1	3	6	Moist	28liter: 1 Cement bag (50 kg)
1	2	4	Dry	26liter: 1 Cement bag (50 kg)
1	2	4	Moist	23liter: 1 Cement bag (50 kg)

2.2 Chloride

As is known, the corresponding structure is not only affected by sulfates. But is also affected continuously by chloride as well. In the beginning, some people mistakenly thought that the concrete structure damaged by chloride Is the effect of sulfate. The advancement of modern technology can negate this belief and there are ways to deal with these problems.

Chloride damage that affects the concrete structure can occur either from the inside of the concrete or from the chloride penetrating through the exterior surface of the concrete structure into the concrete inside. Which can be classified as follows.

The chloride inside the concrete structure is most likely caused during the casting process or the mixing process. By the following methods

- Using seawater for the concrete mixing process
- Using calcium chloride as an additive to increase the setting time.
- The use of aggregates containing chlorides that are not washed for mixing.
- The total mass whose chloride content exceeds the limits specified in the specification.

Chloride that penetrates the concrete structure from the external environment to the internal concrete due to the following reasons

- The exposure of concrete to seawater.
- Use salt to defrost.
- The presence of chloride in the substance that is stored.

When comparing the two methods in which chloride penetrates from the outside into the inside the probability of occurrence is considered to be higher than that of chloride occurring from within and in most cases, offshore structures are severely damaged by the reaction of chlorides. This causes corrosion of the steel reinforcement inside the concrete structure. The action of chloride is to stimulate the erosion of steel reinforcement in the concrete structure, which is more serious than other reasons. Some people may understand that it is the effect of sulfate, while chloride itself is damaging the iron (Gopal Mishra, 2013).

2.2.1 Total chloride content in the concrete.

Bound chloride is a part of chloride that is captured in the product of a hydration reaction. Which will change in the form of Calcium Chloroaluminate Hydrate (Friedel's salt) or may be absorbed by gel pore. This type of chloride will not affect rusting.

Free chloride is a chloride that dissolves in water in the spaces of concrete. Chloride in this section can be distributed into concrete with lower chloride concentration. Which, if we can handle this part of the chloride in a large amount, will be able to reduce the time to rust of the reinforcing steel (Subcommittee on Concrete and Materials, 2000)

The movement of chloride in concrete is generally called "Chloride penetration" (Salt infiltration) occurs by means of different charges. Chloride salt and water pressure There is also an infiltration that occurs naturally. Therefore, chloride infiltration can be divided into 4 main methods: diffusion, ionic attraction, capillary attraction, and water pressure (Thaweechai Samranwanit, 2012).

1. Diffusion: occurs because of the difference between the amount of concentration of chloride in concrete.
2. Migration: Occurs due to the difference in electric potential (or a number of ions) in the concrete.
3. Convection: Occurs due to the effect of a wet and dry cycle in concrete. Which leads to the process of capillary suction itself.
4. Permeation (Permeability occurs because of hydraulic pressure differences in concrete. Professor Sermphan Iambok (U.K.P., cited in the Concrete and Materials Subcommittee (2000), Thaweechai (2004)).

2.2.2 The effect of chloride on reinforcing steel in concrete

Free chloride is one of the main reasons why steel reinforcement in concrete is rusted. And rusting of steel will cause the concrete to lose the clamping force on the reinforcing steel Which causes the loss of the steel surface and causing the structure to collapse. If any of the chloride ions penetrate the oxide film of the reinforcing steel in concrete, the thin film layer will be destroyed until the critical level, the steel will rust. Up which is called “The depassivation” and at the same time, if the area has the right amount of oxygen and moisture Electrical-chemical processes will take place. The area in which the film is destroyed has a negative electrical potential called "Anodic Reaction." Can be written as the following equation.

$$Fe \;=\; Fe^{2+} + 2e^{-}(Anodic\ Process) \tag{2}$$

Electrons e^{-}that occur Will move to the area where the film has not been destroyed, which has an electric potential as an anode (Catholic), and if reacted with oxygen and water, it will produce "hydroxyl ion $[(OH)^{-}]$ "as in this equation.

$$4e^{-} + O_2 + 2H_2O = 4[OH]^{-}(Cathodic\ Process) \tag{3}$$

Fe^{2+}will react with Cl^{-} Born as "ferric chloride’’($FeCl_2$) then when the compound reacts with water Will rust the steel further, as the equation

$$Fe^{2+} + 2Cl^{-} = FeCl_2 \tag{4}$$

$$FeCl_2 + 2H_2O = Fe(OH)_2 + 2HCI \tag{5}$$

Prof. Sermphan Iam Chabok (U.K.P., cited in the Concrete and Materials Subcommittee (2000), Chai Chan (2003))

2.3 Coal ash

Coal ash is the waste from the burning process in the electrical industry. The component and shape of coal ash are up to the type of material is used as fuel such as coal, biomass, oil, etc. When burning the coal by an average of 80% weight of coal will transform into 2 types of coal ash such as fly ash, bottom ash that have an average of 10-20% of the overall weight of coal, will be defined in 4 types to create the heat.

- Anthracite
- Bituminous
- Sub-bituminous
- Lignite

The best coal quality is anthracite because it can produce high heat and have low moisture, followed by bituminous and lignite. The general property of coal ash is in ash particle have circle shape there are both solid and hollow. Coal ash mostly has an amorphous structure, and hydrocarbon groups in fly ash are angular particles.

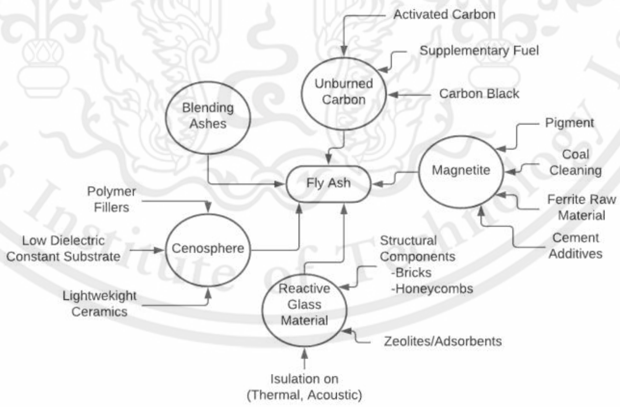


Figure 2.3 Composition of Fly Ash

2.3.1 Chemical component

The main component of coal ash is silica oxide (SiO_2), alumina oxide (Al_2O_3), and ferric oxide (Fe_2O_3). The oxide ratio of the 3 types depends on the coal type, temperature, and burning environment, which have 2 types of coal ash such as F type and C type. F types have volume SiO_2, Al_2O_3, and Fe_2O_3 more than 70% by weight, in C type have volume SiO_2, Al_2O_3, and Fe_2O_3 between 50%-70% by weight. When burning anthracite and bituminous mostly got F type coal, normally F type coal has 5% volume of calcium oxide called Low-Calcium Fly Ash. When burning sub-bituminous and lignite mostly got C type, normally C type coal has 10% volume of calcium oxide called High-Calcium Fly Ash. Which have the property of cement and Pozzolans in themselves.

Chemical Component	Fly Ash (Percentage by weight)
SiO_2	41.16
Al_2O3	22.30
Fe_2O_3	11.51
CaO	15.27
MgO	2.70
SO_3	1.43
LOI	0.20
Na_2O	1.66
K_2O	2.93
TiO_2	0.39
P_2O_3	0.19
Mn_2O_3	-
ZrO_2	-

Table 2.10 Chemical composition of fly ash of Mae Moh Power Plant.

2.3.2 Coal ash used in concrete applications

The benefit of coal ash used in concrete applications such as durability, resistance to chloride penetration, reduce heat in concrete, decrease effects of separation, decrease contraction, reduce water permeability, and increase compressive or tensile of concrete. The disadvantage is that the increase in the compression rate in the first phase is reduced. This reduced resistance to water coagulation and dissolution conditions alternately and resulted in more air bubbles being used to achieve the concrete with the same amount of air bubbles as the concrete without coal ash.

The permeability of chloride reacts between cement and water, cause the mixture to have a high base and prevent rust from reinforce steel by forming a thin layer of ferric oxide (-Fe2O3) coat around reinforce steel surface. When chloride ions can destroy this layer, chloride permeates into the concrete and when its content is higher than the critical level (Chloride Threshold Value) will cause the reinforcing steel to start to rust. The use of coal ash can reduce the amount of chloride that can penetrate the concrete, and fine coal ash can better resist the permeability of chloride.

2.4 Literature reviews

2.4.1 Chloride infiltration resistance in concrete mixed with bottom ash.

สมชาย อินทะตา และ เรืองรุชดิ์ ชีระโรจน์ (2551) studied about Chloride infiltration resistance in concrete mixed with bottom ash, finely ground which is taken from Mae Moh which replaced the bottom ash with cement at the ratio of 0, 10, 20, 30 and 40. by weight Which was used to improve the quality by grinding to have the bottom ash particles remaining on the standard sieve no. 325 Less than 5 percent by weight After that it was tested for chloride infiltration resistance in concrete aged between 28, 60 and 90 days. By the method of measuring the flow of electric current in coulombs in accordance with ASTM C1202 and immersion sodium chloride solution 3% by totally overwhelmed It also tested the compression testing at 200, 300, 400 kg/(cm)^2 to find the relationship between compressive strength and chloride infiltration And found that the chloride infiltration test using electric current flow measurement in coulombs in accordance with ASTM C1202 It was found that the amount of electric current of the concrete replaced with ashes is less than the amount of electric current of the controlled concrete at every mixing ratio. By the amount of cement substitution with finely bottom ash in the ratio of 10, 20, 30 and 40 by weight of binder Causing the chloride permeability from very high to be reduced to medium-high, medium, medium-low and low-very low in addition, the number of days in incubation also contributes to increased resistance to chloride infiltration.

From Figure 2.4 shows that the concrete with the bottom ash content in the ratio of 40% at the 90 days curing period can resist the highest chloride infiltration. The next method is infusion of sodium chloride solution 3 all sunk. It results that the duration of the sodium chloride infusion solution affects the absorption of chloride. And the permeability phase of the concrete that has been replaced by

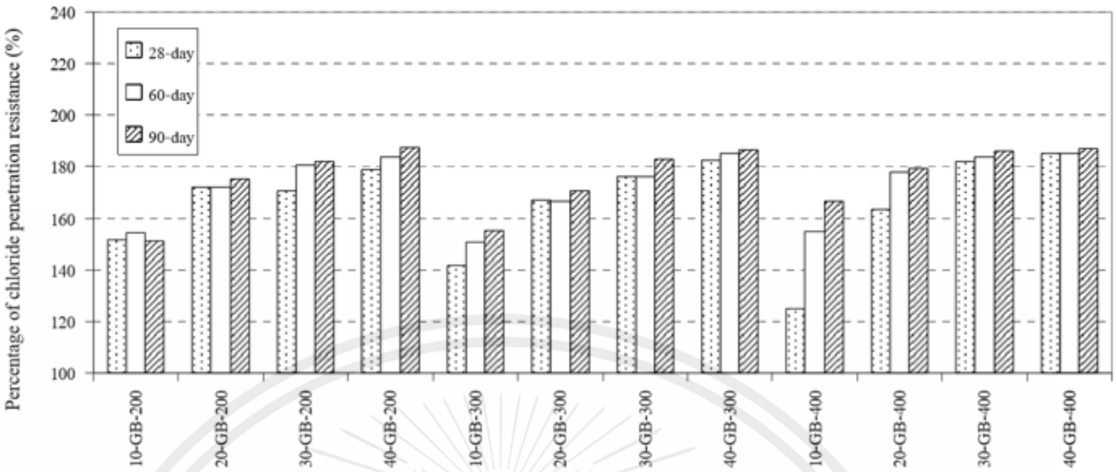


Figure 2.4 Percentage of chloride penetration resistance in concrete

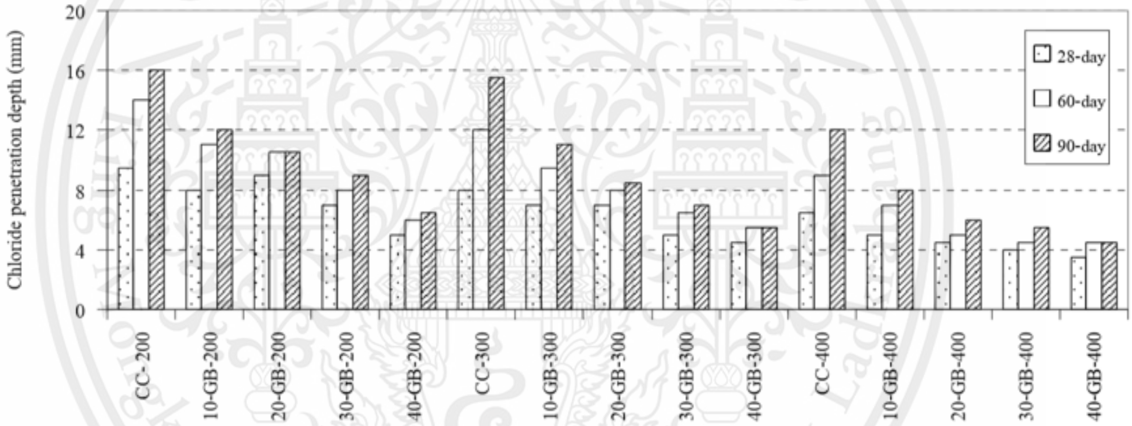


Figure 2.5 Chloride penetration depth

The bottom ash is less than the controlled concrete phase in the higher ratio of bottom ashes, respectively. In other words, the higher the ash content, the stronger the concrete can withstand infiltration. Therefore, from Figure 2.5, it is found that every ingredient of concrete with a bottom ash content of 40 percent has the smallest chloride infiltration period. Therefore, when comparing data from both methods, the data tend to be the same, namely the higher percentage of ash in the concrete results in less. Therefore, concluded that Concrete mixed with ash at the ratio of 40 per cent of all compressive strength designed to withstand the maximum chloride infiltration and found that the higher compressive strength can increase the resistance to infiltration of concrete as well.

2.4.2 Chloride infiltration in concrete with 45% finer size selected fly ash (45FA) and super fine size 10% (10FA) and non-selective size (100FA)

ชัยชาญ โชติถนอม, บพิธ บุปผโชติ และปริญญา จินดาประเสริฐ (2549) studied about Chloride infiltration in concrete with 45% finer size selected fly ash (45FA) and super fine size 10% (10FA) and non-selective size (100FA). In this experiment, Portland cement type 1 was used instead of 30% in every mixture. In addition, this experiment examined the chloride infiltration rate by Coulomb's electric current flow measurement method according to ASTM C 1202 And partial and total immersion in 3% sodium chloride solution by Coulomb's electric current flow measurement method It was found that electric charges flow through concrete that does not contain fly ash the most. Gradually decrease according to the fineness of the fly ash which is 100FA 45FA 10FA respectively.

Table 1.1 The charge moves through the total average of the concrete mixes.

Age (Day)	OCP concrete		100FA concrete		45FA concrete		10FA concrete	
	Charge (Coulomb)	Level	Charge (Coulomb)	Level	Charge (Coulomb)	Level	Charge (Coulomb)	Level
7	9780	High	5100	High	3643	Medium	1770	Low
28	5880	High	2780	Medium	2290	Medium	690	Very low
90	6430	High	3480	Medium	1660	Low	480	Very low

The table 11 shows that the curing time of concrete also affects the flow of electric charge. Even longer Increasing ability to resist chloride But found that the duration of 28 days and 90 days is not much different and can be seen that the concrete that is replaced by fly ash per cementite percentage 10 (10FA), which has a curing period of up to 90 days, is best able to resist chloride infiltration. For partial immersion in 3 percent sodium chloride solution in 3 months, found that Chloride infiltration phase is reduced in order of resolution. The concrete that was not replaced by fly ash had a chloride permeability of 25 millimeters and the concrete that was replaced with fly ash per cementite percentage. 10 (10FA) has a permeability of 4 millimeters and when immersed in 3% sodium chloride solution during 6 months, the absorption of chloride in concrete increased more than in 3% sodium chloride solution in 3 months and have a similar tendency, in which the concrete that is not replaced by fly ash has a chloride permeability period of 34 millimeters and the concrete that has replaced fly ash with cement content of 10 percent (10FA) has a permeability equal to 6 mm.

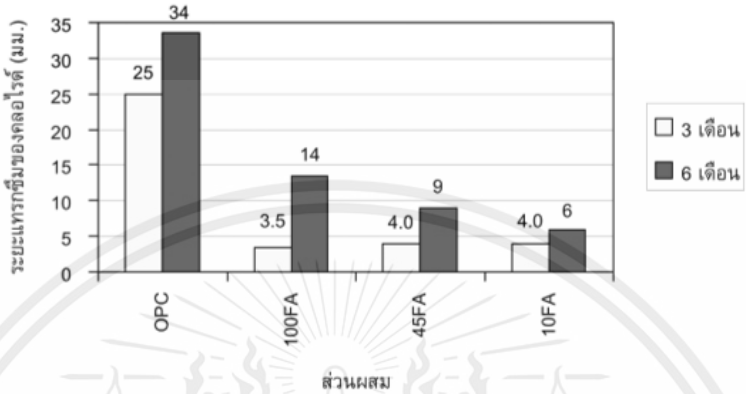


Figure 2.6 Distance to chloride permeability.

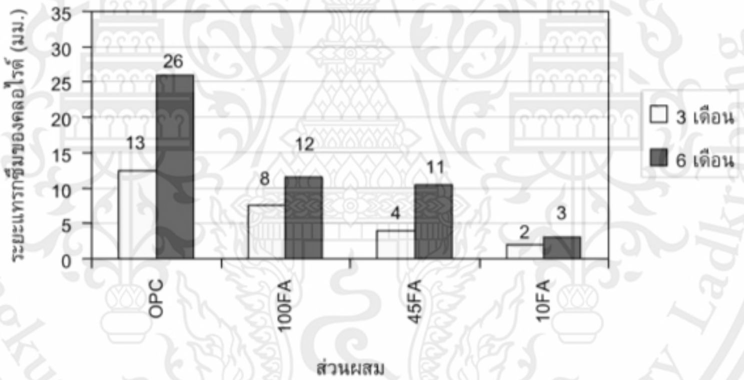


Figure 2.7 Distance to chloride permeability

For immersion methods in 3 percent sodium chloride solution all sinking is likely the same as partial immersion. In 3 months, the concrete without fly ash mixed with chloride absorption period is 13 millimeters. And concrete without replacing fly ash with cement content 10% (10FA) has a chloride infiltration period of 2 millimeters, and in a 6 month period, concrete without fly ash mixed has a chloride infiltration period Is equal to 26 millimeters and concrete that has not been replaced by fly ash on cement content of 10% (10FA) has a chloride permeability equal to 3 millimeters. When comparing the information, it is found that the 2 data (Figure 2.6 to 2.7) have the same tendency in which the concrete that has been replaced by fly ash with cement content of 10% (10FA) has the best ability to resist chloride. And the infiltration phase of partial immersion chloride is greater than total sinking due to the relative humidity.

Therefore, some of the concrete that is soaked in the solution will not absorb the compressive strength and the chloride resistance depends on the size of the cavity system rather than the compressive strength. Therefore, it can be concluded that the high-resolution fly ash results in increased chloride resistance in concrete than the low-resolution fly ash and concrete without fly ash mixed at all.

2.4.3 The durable properties of mortar and concrete extruded additives

[13] (Krammart, P.Maneerat, T.Julnipitawong, P. ManeecharoenJ. & Tangtermsirikul, S., 2016) This research is an educational study of the properties of compressive strength, as well as finding the right amount of the best amount to use the extruded extruder effectively. Study the durable properties of concrete, including dry shrinkage of mortar and strong infiltration resistance. The solder ingress materials used are Portland cement type. 1 and type 5 According to TIS standards. 15-2555[14] Ash floats from Mae Mo district, Lampang province according to TIS. 2135-2545[15] And compressive reinforcement, dry shrinkage of mortars mixed with compressive energy additives. There is a mix in 2 Characteristics are mixed by additions and mixed by replacing It was found that the dry contraction of mortar mixed with fly ash (percent was found. 30) With less motorization of Portland cement that type. 1 It is clear. This is because the pozzolan reaction of the fly ash tightens. Therefore, the loss of moisture is more difficult. As a result, the contraction has decreased. Mortar's dry shrinkage is mixed with compressive add-ons both by addition and by replacing the shrinkage of the less-than-mortar of the Portland cement type.1. And if comparing mortar mixes compressive reinforcements between by adding and replacing them, you are not going to be It is noted that the dry contraction of mortar by more is less likely than that by replacing. In the study of resistance to the penetration of chloride of concrete samples, carried out according to the standards. ASTM C 1202[16] Using an accelerated test kit for the penetration of chloride ions and standardized testing. ASTM C 1202 In order of the electrical charge moving through the concrete samples, the amount of electrical charge is found moving through the concrete samples that mix the floating ash. (Percentage 30) and concrete samples mixed with compressive strength. Is less valuable

than the Portland cement category. 1 The compressed extruder reacts as a binder, making the pest firmer and strengthening the structure of the concrete. As a result, the amount of electrical charge that comes through is more difficult. Especially when mixing compressive strength in greater quantities. As shown on the graph.

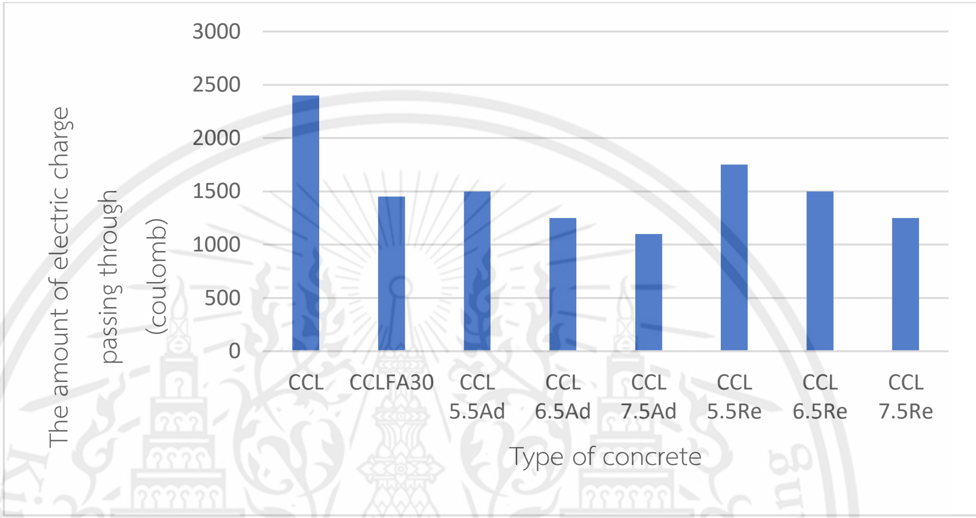


Figure 2.8 Amount of electric charge passed (electric charge)

This experiment has shown that the greater the amount of compressed energy mixed in concrete increases the compressive strength. This makes the concrete structure tighter and stronger and can withstand higher chloride infiltration. If comparing concrete mixed with compressive strength between adding and replacing can be noted that the number of flowing flows through the mixed concrete increases the compressed force by promising less by replacing it, it may be possible by adding without reducing. The amount of cement, which results in better synchronization.

2.4.4 The penetration of chloride in reinforced concrete structure sits in a marine environment.

[17] (ชูศักดิ์ คีรีรัตน์, ศุภชัย ไทยพุ่ม, 2016) This research studies the permeability of chloride in coastal and nearby structures that affect structures to provide solutions for the problem of reinforced concrete structures on the coast and nearby that deteriorate rapidly and thus a long service life and increases efficiency for chloride study of reinforced concrete structures to collect concrete samples from bridges. On the coast and nearby, not more than 10 kilometers from the coast in Hua Hin and Pranburi,

Prachuap Khiri Khan. In Hua Hin District, 5 bridges and 5 Pranburi bridges, the process of gathering concrete powder at each level is the depth of the reinforced concrete structure. Start by exploring the area and selecting the target position of the structure that must be sampled, and then test the compressed force of concrete as well. Hammer's Schmidt is in a nine-point selection position before using a drill to drill on concrete in the same spot as the compression test reaches a depth of 2 cm, and then dust in the bag. Collect samples of concrete powder at various depths and put them in a moisture-free envelope, after which the plaster is used to close the hole and finish the surface of the concrete. Then prepare the chemical used for finding chloride by preparing a standard solution of 0.05 N, 100 ml sodium chloride and a standard solution of 0.05 N silver nitrate 1,000 ml. Use standard sodium chloride pipettes 0.05 ml. Add 150 drops of distilled water and 1% potassium chromate 5% w/v before titration with silver nitrate solution. Standard solution and note the volume of the solution. The standard is used to calculate the exact concentration of silver nitrate solution from the equation.

$$N = \frac{0.25}{V} \quad (5)$$

Determination of the total amount of salt chloride using solvent acid by distillation take 10 g of concrete powder, then add 75 ml of distilled water to the beaker, add 25 ml of nitric acid solution, then stir to dissolve the concrete powder. Take the packed glass cup, cover the glass and boil until it boils for 2 to 3 minutes, then let the temperature drop to room temperature. Take the sample solution filtered with filtered paper and use a pipette to absorb the 10 ml solution that is finished in a pink-shaped bottle. Dilute with 40 ml of distilled water, add 10% sodium bicarbonate solution to 10 ml to adjust the acid-based solution of the ideal solution for titration, add 5% 1 ml potassium chromate solution to the sample solution, and then the solution is titration with silver nitrate solution until the formation of red brick sludge, then save the amount of silver nitrate solution used to calculate the amount of chloride in the sample concrete powder. Examine the empty solution using distilled water in volume, which is equal to the volume of sample titration. Add 5 ml of potassium chromate solution and titration with 1 ml of silver nitrate solution, recording the amount of silver nitrate solution, which is used to calculate chloride content in concrete samples.

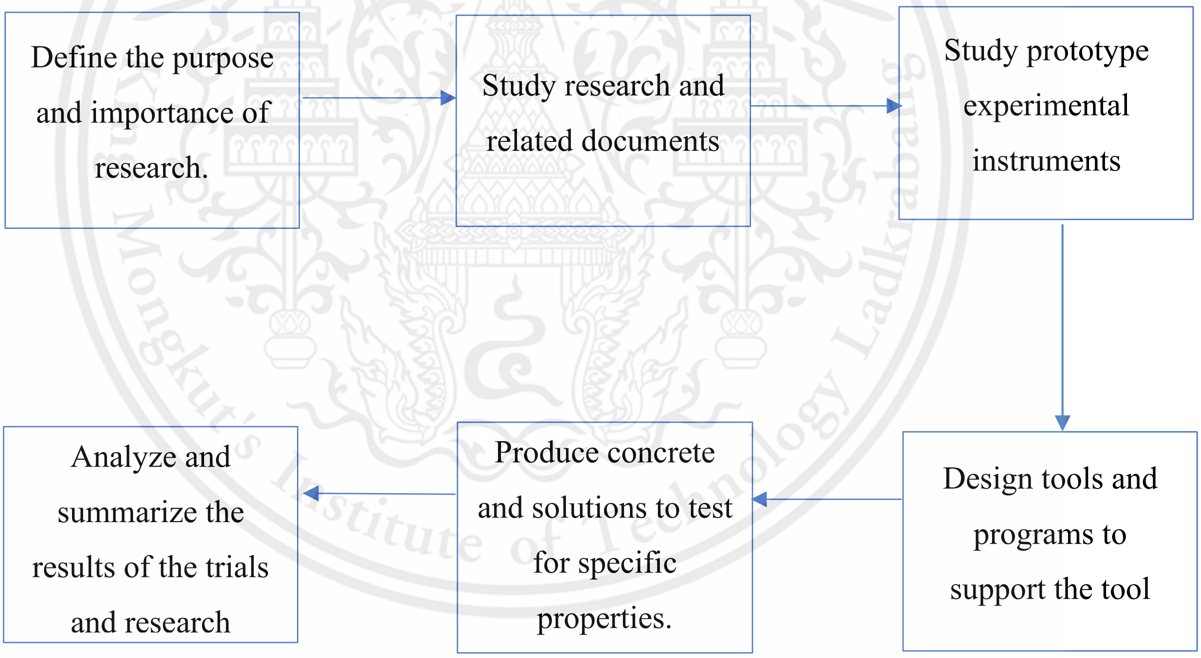
$$Cl^{-}(\%) = \frac{3.545(V_1 - V_2)N}{W} \quad (6)$$

In chloride testing in reinforced concrete structures around the coast and nearby. It is known that the distance from the coast affects the infiltration of chloride in the structure. Chloride content in both Hua Hin and Pranburi districts tends to decrease as the distance from the shore increases in the creek three thousand, because the water source is not directly connected to the sea, thus the chloride content of chloride from the sea does not affect the amount of chloride in the water source when the reinforced concrete structure is more distanced from the shore, the infiltration volume of chloride is reduced. The depth from the surface of the structure affects the penetration of chloride in reinforced concrete structures, whereby the chloride volume is reduced when the depth from the surface increases, but when the reinforced concrete structure is damaged due to cracks, there is a greater accumulation of chloride than other areas with the above information, it is known that when considering the chloride content in the reinforced concrete structure. Damage to the structure should also be considered.

CHAPTER 3
METHODOLOGY

In this research, the measurement of chloride properties in concrete was created in accordance with ASTM C 1202 standards, with the aim of developing chloride properties in concrete to teach the current technology and developing a program of chloride measurement instruments in concrete in line with modern applications.

Based on studies of chloride properties measurement instruments in concrete, we can develop experimental tools by changing the material of the machine for hassle-free use and developing a program of machine data to display the results of the data. and improve the visibility of information online.



3.1 Experimental Tool Design

Based on the study of related data, the cell experimental tool was designed as follows:

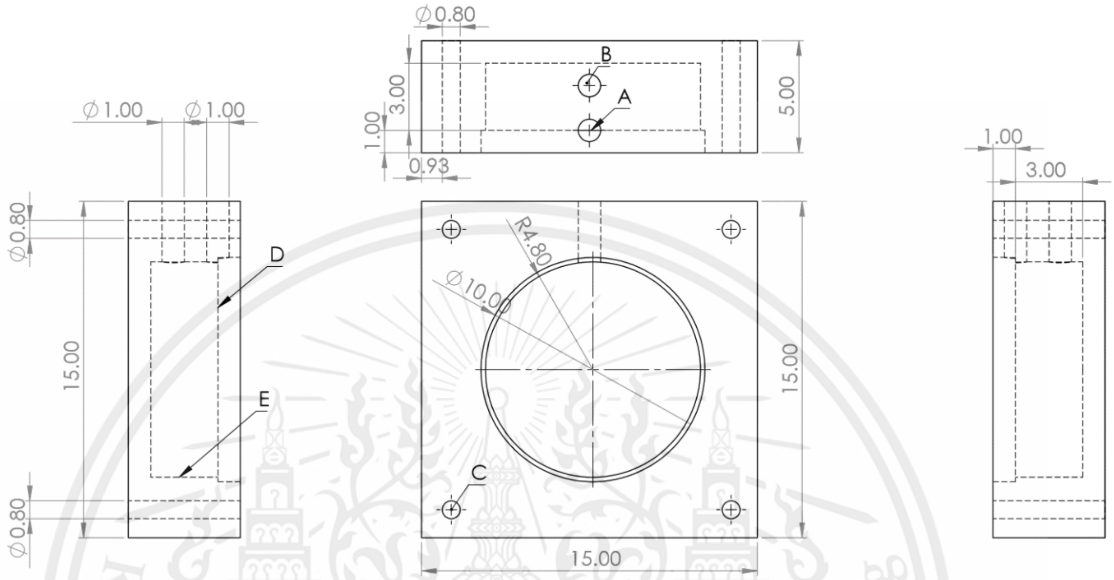


Figure 3.1 Load Cell

Table 3.1 Load Cell function data

Position	Description
A	Power plug hole
B	Slurry filling hole
C	Lock ingress hole
D	Experimental Material Slot
E	Slurry slot

3.2 The experiment for properties required for designing concrete mixes

3.2.1 Gradation of Aggregates by Sieve Analysis

3.2.1.1 Equipment

1. U.S. Sieves for sifting fine aggregates size 4, 8, 16, 30, 50, 100.

Figure 3.2 U.S. Sieves for sifting fine aggregates size.

2. U.S. Sieves for sifting coarse aggregates size 2”, 1 ½ “, 1”, 3/4” ,1/2”, 3/8” and 4

Figure 3.3 U.S. Sieves for sifting coarse aggregates size.

3. Weighing machine capable of weighing 0.1 gram.

Figure 3.4 Weighing machine.

4. Sieve cleaning brush.

Figure 3.5 Sieve cleaning brush.

5. Fine aggregate strainer

Figure 3.6 Fine aggregate strainer

6. Coarse aggregate strainer

Figure 3.7 Coarse aggregate strainer

3.2.1.2 Procedure

1. Weigh the sand used for testing 500 grams, divided into 4 parts. Be careful not to lose any aggregates.
2. Put each number of sieves to be stacked in sets. With a large sieve at the top and small size is at the bottom. Pour the aggregates onto the top rack and put them into the strainer.
3. Open the machine to sift the total mass. It will take about 10 minutes, and then turns off the switch.
4. Weigh the remaining total mass on the sieve for each number. Including the weight of the sand that escaped through the sieve.

Figure 3.8 Total mass on the sieve.

5. Clean the sieve with a brush.
6. Calculate the total mass accumulated on each sieve as a percentage.
7. Calculate the modulus of resolution by finding the percentage of the cumulative weight of the total mass left on the sieve from number 4 to 100 and divide by 100.
8. Take the cumulative percentage of total mass left on each sieve and standard sieve size. To write as a graph.

3.2.1.3 Result

Table 3. 2 The finesse modulus of the coarse aggregates calculation.

Size of sieve (Inches)	Aggregates + Sieve Weight (g)	Aggregate Weight (g)	Sieve Weight (g)	Percentage retained	Cumulative retained
2	4862	0	4862	0	0
2 1/2	4525	0	4525	0	0
1	4679	0	4681	0	0
4-Mar	5019	154	4865	3	3
2-Jan	7025	2239	4784	45	48
8-Mar	6551	1170	5381	23	71
4	6077	1330	4747	27	98
Pan	3633	107	3526	2	100
sum		5000		100	220
Finesse Modulus = 220.18/100 = 2.2					

Table 3. 3 The finess modulus of the fine aggregates calculation.

Size of sieve (Inches)	Aggregates + Sieve Weight (g)	Aggregate Weight (g)	Sieve Weight (g)	Percentage retained	Cumulative retained
8-Mar	4860	0	4860	0	0
#4	4523	0	4523	0	0
#8	4697	16	4681	0	0
#16	4914	49	4865	1	3
#30	6186	1402	4784	28	29
#50	6940	1559	5381	31	60
#100	5710	963	4747	19	79
Pan	4537	1011	3526	20	100
sum		5000		100	271
Finesse Modulus = 271/100 = 2.7					

3.2.2 Standard Test Method for Relative Density

3.2.2.1 Equipment

1. Weighing machine capable of weighing 0.1 gram.

Figure 3.9 Weighing machine.

2. Volumetric flask size 500 milliliter.

Figure 3.10Volumetric flask size 500 milliliter.

3. Metal cone diameter 3.75 centimeters. bottom diameter 8.9 centimeter's, height 7.4 centimeters, and made of sheet metal about 0.9 millimeters thick and smooth tip pushrod diameter 2.5 centimeters, and weight 340 gram.

Figure 3.11Metal cone and smooth tip pushrod.

4. Steel wire basket

Figure 3.12 Steel wire basket

5. Metal tray.

Figure 3.13 Metal tray.

6. Oven.

Figure 3.14 Oven.

3.2.2.2 Procedure

1. Take needed coarse and fine aggregates approximately as needed.

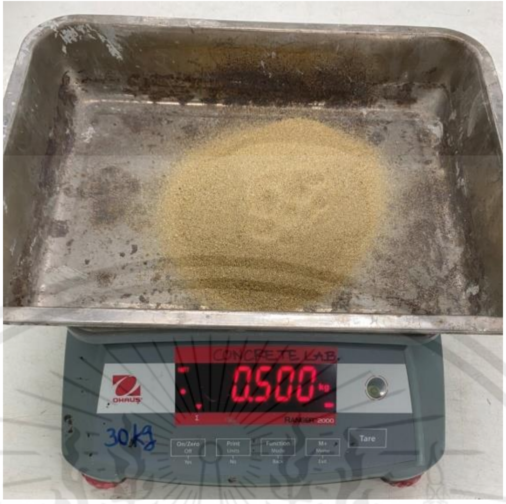


Figure 3.15 Fine aggregates

Figure 3.16 Coarse aggregates

2. Take both types of aggregates to clean. Coarse aggregates washed with water and then wait to dry. And the fine aggregates spread over a metal tray and wait to dry.
3. Put 500 grams of fine aggregates into a volumetric flask and add water to the limit of 450 milliliters.
4. Shake to expel bubbles, then add water until 500 milliliters.

Figure 3.17 Fine aggregates in a volumetric flask.

5. Weight of the volumetric flask of the fine aggregates and weigh the coarse aggregates in the saturation state.
6. Pour the fine aggregates into a metal tray and pour the coarse aggregates into a steel wire basket and weighed in the water at 23 ° C.

Figure 3.18 Weight the coarse aggregates in the water.

7. Put both types of aggregates in an oven at 100-110 degrees Celsius until the weight is stable, then cool it down for 1-1.5 hours.
8. Weigh the fine aggregates in a volumetric flask with 500 ml of water at 23 ° C and the coarse aggregates are normally weighed.

3.2.2.3 Results

Table 3. 4 The specific gravity of the fine aggregates calculation.

Determination	1	2
S: Weight of Saturated Surface-Dry Sand (g)	500.00	500.00
A: Weight of Oven-Dry Sand (g)	499.45	499.56
B: Weight of Glass Graduate + Water (g)	651.82	652.68
C: Weight of Glass Graduate + Water + Sand (g)	963.00	964.02
Bulk Specific Gravity (Oven-Dry)	2.65	2.65
Bulk Specific Gravity (SSD)	2.65	2.65
Apparent Specific Gravity	2.65	2.65
Absorption (%)	0.11	0.09
Average Bulk Specific Gravity (Oven-Dry)	2.65	
Average Bulk Specific Gravity (SSD)	2.65	
Average Apparent Specific Gravity	2.65	
Average Absorption (%)	0.10	

Table 3. 5 The specific gravity of the coarse aggregates calculation.

Determination	1	2
A: Weight of Oven-Dry Sample in Air	335.81	334.38
B: Weight of Saturated Surface-Dry Sample (g)	336.74	336.54
C: Weight of Sample in Water (g)	212.6	211.74
Weight of Container in Water (g)	173	173
Weight of Container + Sample in Water (g)	385.6	384.74
Bulk Specific Gravity (Oven-Dry)	2.705091	2.679327
Bulk Specific Gravity (SSD)	2.712583	2.696635
Apparent Specific Gravity	2.725509	2.726517
Absorption (%)	0.276942	0.645972
Average Bulk Specific Gravity (Oven-Dry)	2.69	
Average Bulk Specific Gravity (SSD)	2.70	
Average Apparent Specific Gravity	2.73	
Average Absorption (%)	0.46	

3.2.3 Standard Test Method for Surface Moisture in Fine Aggregate

3.2.3.1 Equipment

1. Weighing machine capable of weighing 0.1 gram.

Figure 3.19 Weighing machine.

2. Experimental flask with 500 milliliters.

Figure 3.20 Experimental flask with 500 millilitres.

3.2.3.2 Procedure

1. Prepare 200 grams of sample and weigh to record W_1.
2. Pour the water into the empty bottle to the specific level and weight to record W_2.
3. Put the sample in an empty flask and fill it with water until it covers the sample and shakes it to expel air bubbles.
4. Add water up to the mark then weigh to record W_3.

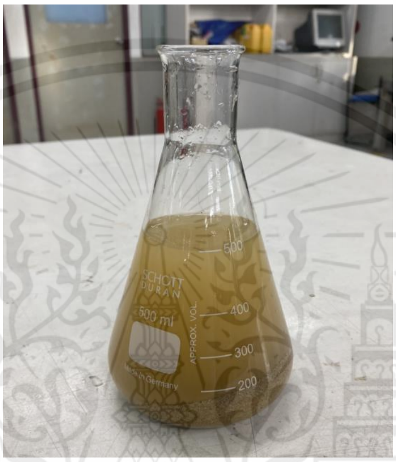


Figure 3.21 Add water up to the mark.

5. Find the volume of water by the formula.
6. Calculate the surface moisture based on the saturated dry condition from the formula.
7. Calculate the surface moisture from the drying condition from the formula.

3.2.3.3 Results

Table 3. 6 Surface moisture in fine aggregate calculation.

Determination	1	2
W1: Weight of Sample (g)	200.00	200.00
W2: Weight of Container + Water (g)	649.48	650.04
W3: Weight of Container + Sample + Water (g)	772.20	770.50
W: Weight of Water Displacement by the Sample (g)	77.28	79.54
Percentage of Surface Moisture (SSD)	1.45	3.36
Percentage of Surface Moisture (Oven-Dry)	1.46	3.36
Average Percentage of Surface Moisture (SSD)	2.41	
Average Percentage of Surface Moisture (Oven-Dry)	2.41	

3.2.4 Standard Test Method for Total Evaporable Moisture Content of Aggregates

3.2.4.1 Equipment

1. Coarse aggregates 2 - 6 kilogram

Figure 3.22 Coarse aggregates

2. Weighing machine capable of weighing 0.1 gram.

Figure 3.23 Weighing machine.

3. Gas stove and pan

Figure 3.24 Gas stove and pan

4. Metal tray.

Figure 3.25 Metal tray.

3.2.4.2 Procedure

1. Weigh the moist aggregates that used, then put it on the gas stove and steady control temperature, stir periodically so that the aggregates are thoroughly heated.
2. When the aggregates are completely dry, bring to weigh.
3. Find the moisture content in the aggregate.

3.2.4.3 Results

Table 3. 7 The moisture content in the aggregate calculation.

Determination	1	2
Weight of Sample before Drying (kg)	1.00	1.00
Weight of Sample after Drying (kg)	0.96	0.97
Moisture Content (%)	4.17	3.09
Average Moisture Content (%)	3.63	

3.2.5 Standard Test Method for Bulk Density

3.2.5.1 Equipment

1. The total aggregate is prepared about 125 - 200% of the required amount, after putting in the oven at 110 degrees Celsius.

Figure 3.26Total aggregate.

2. Weighing machine capable of weighing 0.1 gram.

Figure 3.27 Weighing machine.

3. Tamping rod

Figure 3.28 Tamping rod.

4. The container for measuring units of weight, smooth cylindrical container, and have a handle on both sides.

Figure 3.29 Smooth cylindrical container.

3.2.5.2 Procedure

A) Finding the Weight Unit of Water

1. Fill the container with water and make no air bubbles, then cover the lid with a piece of clear glass.
2. Measure the temperature of the water to calculate the weight unit and compared it with the table showing the unit weight of water.
3. Find the factor by dividing the weight of the water in the container by the water weight unit.

B) Find the weight unit when the total mass is compacted.

1. Pour the total aggregate into a weighed container and divide it into 3 parts so that each part is approximately one-third the height of the container, then smooth the surface and tamping the aggregate almost to the bottom about 25 times.
2. Add the total aggregate to the second layer and tamping again, then add the total mass to another layer, tamping 25 more times and then clean the surface to be smooth.
3. Weigh the container containing the aggregate to calculate the specific weight of the total aggregate by weight accuracy is equal to 0.1% and then multiplied by the factor obtained in step 3 in step A) to obtain the weight of the total aggregate when compacted.

3.2.5.3 Results

Table 3.8 The mass unit weight of the total aggregate in procedure A.

Determination	1	2
Unit Weight of water (kg/m^3)	997	997
Weight of Water (kg)	9.11	9.14
Factor of Water	0.009137	0.009168

Table 3.9 The mass unit weight of the total aggregate in procedure B

Determination	1	2
V: Volume of Container (m^3)	0.009137	0.009168
W: Weight of Sample + Container (kg)	22.759	22.81
W1: Weight of Container (kg)	8.14	8.14
W-W1: Weight of Sample (kg)	14.62	14.67
W-W1/V: Unit Weight (kg/m^3)	1599.906	1600.218
Average Unit Weight	1600.06	

3.3 Determining components that determine the properties of the sample.

[18] The design of concrete components is used in accordance with the ACI Method production (CPAC, 2003) process. 300 kg/cm2in order, the program "Concrete Mix Design" is used. In design, the following steps are available.

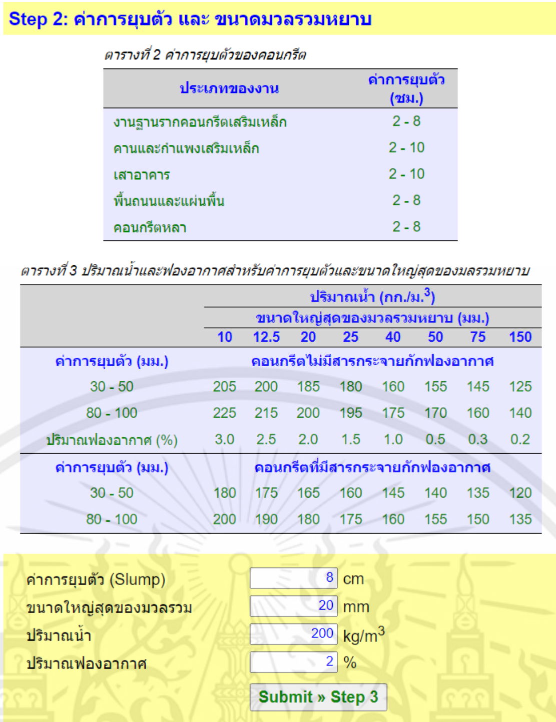
3.3.1 Stage concrete design with compressive strength 300 kg/cm^2

1. Since there is not enough test samples in this experiment to find the standard deviation, the target strength must be obtained by this equation.

$$f_{cr} = f_c' + 85 \quad (7)$$

$$f_{cr} = 385\ kg/cm^2$$

2. This procedure selects the collapse of the concrete according to the type of work according to the table (3), and then compares the largest value of the coarse aggregate in the table (4) in order to determine the water content and the bubble volume.



Step 2: ค่าการยุบตัว และ ขนาดมวลรวมหยาบ

ตารางที่ 2 ค่าการยุบตัวของคอนกรีต

ประเภทของงาน	ค่าการยุบตัว (ซม.)
งานฐานรากคอนกรีตเสริมเหล็ก	2 - 8
คานและกำแพงเสริมเหล็ก	2 - 10
เสาอาคาร	2 - 10
พื้นถนนและแผ่นพื้น	2 - 8
คอนกรีตหลา	2 - 8

ตารางที่ 3 ปริมาณน้ำและฟองอากาศสำหรับค่าการยุบตัวและขนาดใหญ่สุดของมลรวมหยาบ

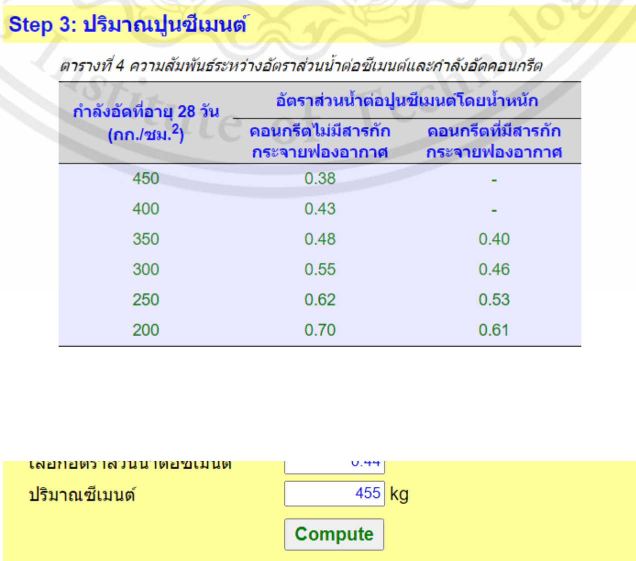
	ปริมาณน้ำ (กก./ม.^{3})							
	ขนาดใหญ่สุดของมวลรวมหยาบ (มม.)							
	10	12.5	20	25	40	50	75	150
ค่าการยุบตัว (มม.)	คอนกรีตไม่มีสารกระจายกักฟองอากาศ							
30 - 50	205	200	185	180	160	155	145	125
80 - 100	225	215	200	195	175	170	160	140
ปริมาณฟองอากาศ (%)	3.0	2.5	2.0	1.5	1.0	0.5	0.3	0.2
ค่าการยุบตัว (มม.)	คอนกรีตที่มีสารกระจายกักฟองอากาศ							
30 - 50	180	175	165	160	145	140	135	120
80 - 100	200	190	180	175	160	155	150	135

ค่าการยุบตัว (Slump) 8 cm
ขนาดใหญ่สุดของมวลรวม 20 mm
ปริมาณน้ำ 200 kg/m^3
ปริมาณฟองอากาศ 2 %
Submit » Step 3

Figure 3.30 Compressive concrete mix design 300 kg/cm2 in step 2, https://engfanatic.tumcivil.com/tumcivil_2/DRMK/MixDesign/MixDesign.html

3. Use the table (5) to find the water-to-cement ratio, at this stage to get the cement volume out of the equation (8)[18]

$$Preferred\ Cement\ Volume = \frac{Water\ Content}{W/C\ Ratio} \quad (8)$$



Step 3: ปริมาณปูนซีเมนต์

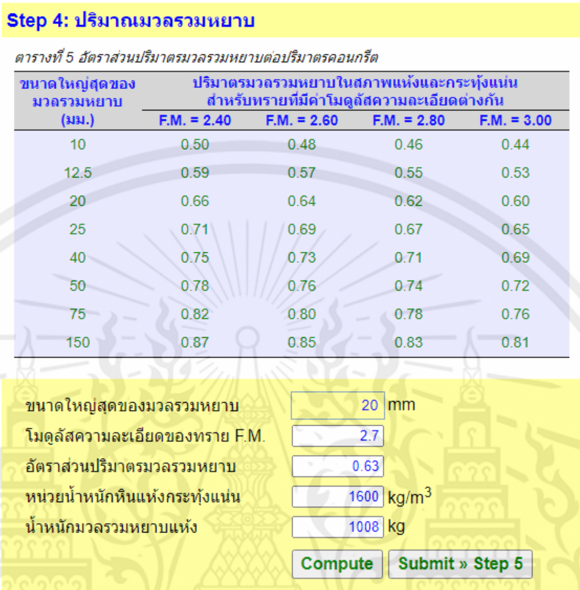
ตารางที่ 4 ความสัมพันธ์ระหว่างอัตราส่วนน้ำต่อซีเมนต์และกำลังอัดคอนกรีต

กำลังอัดที่อายุ 28 วัน (กก./ซม.^{2})	อัตราส่วนน้ำต่อปูนซีเมนต์โดยน้ำหนัก	
	คอนกรีตไม่มีสารกักกระจายฟองอากาศ	คอนกรีตที่มีสารกักกระจายฟองอากาศ
450	0.38	-
400	0.43	-
350	0.48	0.40
300	0.55	0.46
250	0.62	0.53
200	0.70	0.61

ปริมาณซีเมนต์ 455 kg
Compute

Figure 3.31 Compressive concrete mix design 300 kg/cm2 in step 3, https://engfanatic.tumcivil.com/tumcivil_2/DRMK/MixDesign/MixDesign.html

4. Use the table (6) to bring the relationship between the size of the coarse aggregate and the modulus value, the resolution of the fine aggregate comes against and then the ratio of coarse aggregate to the calculation of the coarse aggregate weight.


Step 4: ปริมาณมวลรวมหยาบ

ตารางที่ 5 อัตราส่วนปริมาตรมวลรวมหยาบต่อปริมาตรคอนกรีต

ขนาดใหญ่สุดของมวลรวมหยาบ (มม.)	ปริมาตรมวลรวมหยาบในสภาพแห้งและกระทุ้งแน่น สำหรับทรายที่มีค่าโมดูลัสความละเอียดต่างกัน			
	F.M. = 2.40	F.M. = 2.60	F.M. = 2.80	F.M. = 3.00
10	0.50	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
20	0.66	0.64	0.62	0.60
25	0.71	0.69	0.67	0.65
40	0.75	0.73	0.71	0.69
50	0.78	0.76	0.74	0.72
75	0.82	0.80	0.78	0.76
150	0.87	0.85	0.83	0.81

Figure 3.32Compressive concrete mix design 300 kg/cm2 in step 4, https://engfanatic.tumcivil.com/tumcivil_2/DRMK/MixDesign/MixDesign.html

5. Calculate the volume of fine mixing objects by obtaining the volume of water, cement, coarse mixing material and volume of air bubbles to calculate the weight of the sand further.

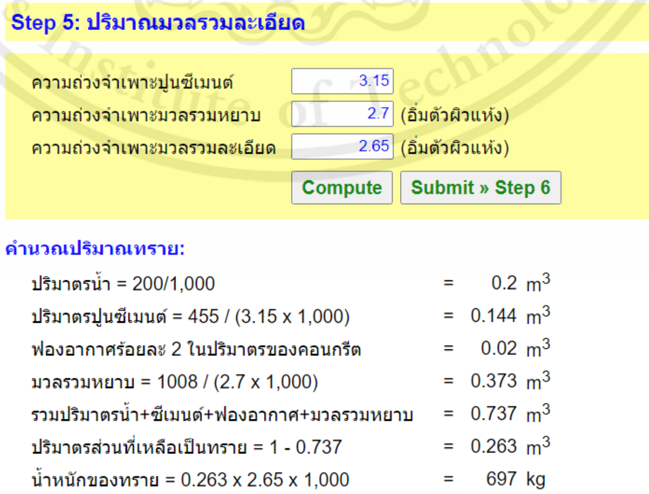


Figure 3.33 Compressive concrete mix design 300 kg/cm2 in step 5, https://engfanatic.tumcivil.com/tumcivil_2/DRMK/MixDesign/MixDesign.html

6. Ingredient adjustment process due to humidity

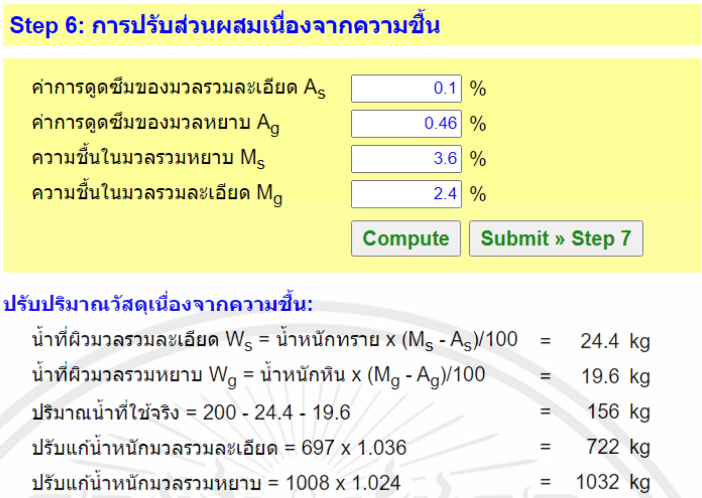


Figure 3.34 Compressive concrete mix design 300 kg/cm2 in step 6, https://engfanatic.tumcivil.com/tumcivil_2/DRMK/MixDesign/MixDesign.html

7. This procedure will rate the mixture of concrete with a volume of 1 m3. Take the value to the trip to apply the composition in the right amount to the size of the mole.

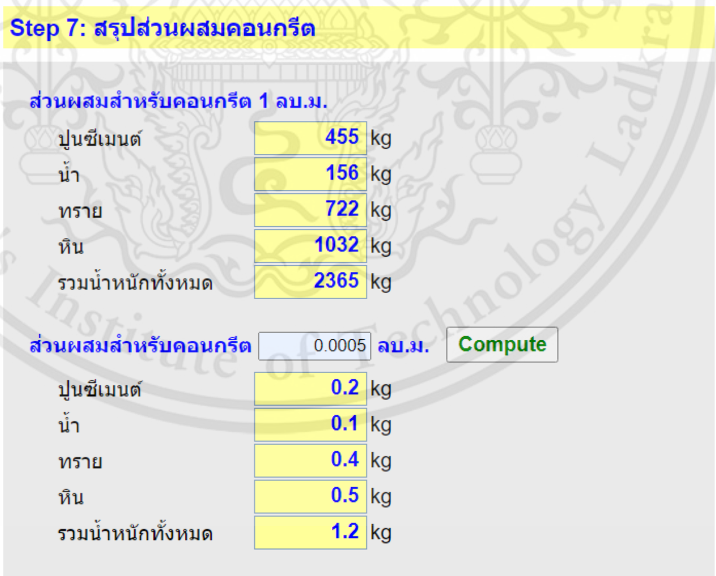


Figure 3.35 Compressive concrete mix design 300 kg/cm 2 in step7, https://engfanatic.tumcivil.com/tumcivil_2/DRMK/MixDesign/MixDesign.html

3.3.2 Preparation of concrete samples containing chloride-resistant compounds.

The concrete preparation that adds chloride resistance additive is similar to the normal mixture. The calculate the volume of using solution needs to correct for contain property of the concrete. The author selects a chloride resistance and compressive strength mixture for testing, which mixed with bottom ash by replacing the binder or cement at a 40% ratio of binder weight. Which has concrete mix as in the table.

Table 3.10 Mix proportion of bottom fly ash concrete.

Type of Concrete	Mix Proportion (kg/m^3)					W/C
	Water	Cement	Bottom Ash	Sand	Stone	
40% Bottom Ash	195	189	126	732	1012	0.62

3.4 Experimental Preparation Process

Preparing concrete samples in experimental experiments by removing the mixed concrete and pouring into a cylindrical mole 10 cm in diameter, 20 cm high.

Figure 3.36 Concrete casting moles 10 cm in diameter and 20 cm in high.

After the trial sample has dried, remove it from the mole. Soak in water for 28 days.

Figure 3.37 Complain concrete in water.

After the soaking, take a sample for a while. 1 day and after that, the experimental sample is cut to a height of 5 centimeters, coated with a waterproofing agentt (epoxy) around the workpiece and left to dry for 1 day, using scotch (tape, ducted around the intersecting face, preventing the glue from seeping off the workpiece and then attaching it to the cells in the next step.

Figure 3.38Concrete Coated with Waterproofing Agent (Epoxy)

3.5 Calculation of the concentration of the solution

In this experiment, we need to use two different solutions:

1. NaCl (Sodium Chloride) Concentrate 3.0% (by mass per volume)
2. NaOH (Sodium Hydroxide) 0.3 Molarity (0.3 M)

By the way, finding the concentration of these two solutions is done using distilled water in experiments. 1 liter or 1000 ml the process of determining the amount of NaCl (Sodium Chloride) to a concentration of 3.0.% (by mass per volume) by the percentage equation by mass per volume.

$$\% = \frac{Mass\ of\ the\ solute(g)}{Volume\ of\ the\ solotion(ml)} \times 100 \quad (9)$$

Requires a solution with a concentration of 3% in 1000 ml of water,

$$3 = \frac{Mass\ of\ the\ solute(g)}{1000\ ml} \times 100$$

$$Mass\ of\ the\ solute(g) = \frac{3 \times 1000}{100}$$

$$Mass\ of\ the\ solute = 30\ g$$

The amount of NaCl (Sodium Chloride) used to obtain a solution with a concentration of 3.0% is 30 g. The procedure for obtaining the amount of NaOH (Sodium Hydroxide) to have a concentrated 0.3 Molarity (0.3 M) by the molarity equation.

$$Molarity = \frac{The\ number\ of\ moles(mole)}{Volume\ of\ the\ solution\ (liters)} \quad (10)$$

$$0.3M = \frac{The\ number\ of\ moles(mole)}{1\ liter}$$

$$The\ number\ of\ moles(mole) = 0.3 \times 1$$

$$The\ number\ of\ moles = 0.3\ mole$$

Instead of a value in the next equation to calculate the number of melts.

$$The\ number\ of\ moles(M) = \frac{Mass\ of\ the\ solute(g)}{Molecular\ weight(\frac{g}{mol})} \quad (11)$$

Molecular mass of NaOH (Sodium Hydroxide)

- Na (Sodium) = 23 g/mol
- O (Oxygen) = 16 g/mol
- H (Hydrogen) = 1 g/mol

combined equal to 40 g/mol.

$$0.3(M) = \frac{Mass\ of\ the\ solute(g)}{40\ (\frac{g}{mol})}$$

$$Mass\ of\ the\ solute(g) = 0.3 \times 40$$

$$Mass\ of\ the\ solute = 12\ g$$

The amount of NaOH (Sodium Hydroxide) used to obtain a solution with a concentration of 0.3M is 12 grams.

3.6 The process of using the tool in the experiment.

1. Assemble the load cell by place the stainless wire mesh in the slot and overlay with a ring shape steel plate.
2. Take the O-ring to put in the epoxy-coated concrete sample, then place it in the stainless wire mesh. Lock both sides of the load cell by wing screws on all four sides.
3. Mix the two solutions to 1000 milliliters, add sodium chloride (NaCl) solution to the negative cell while sodium hydroxide (NaOH) to the positive cell.
4. Connect the saline tube from the solution reservoir, then adjust the solution dropper count to the specified amount.
5. Connect an electric wire from the power supply to the load cell, then verify the voltage in the wire or solution has a constant of 60 voltage.
6. Open the program to enter the experiment information include the date, material, detail, and implementation.
7. The program will record the electric current that passing through in real-time and display the result in a graph as the relationship between electric current and time (units of seconds) from the beginning of the test (unit of milliamp).
8. After 6 hours, the program will export the data as a table in Microsoft Excel and show results in report format. While testing, the tester can access the information from the online system at any time during the test.

Caution: Before starting the program, make sure the voltage of the power supply is stable. If the voltage is not stable, it should be corrected by turning the power supply detailed knob to stabilize the current, then perform the test. Caution Before starting the program, check the potential difference of the power supply, if not fixed, fix the power supply by adjusting the power supply, and the most important precaution during the experiment is to check the solution less than required because it makes a constant potential disparity, which may result in a mistake in taking note of the data. Therefore, the solution should always be filled.

3.7 Program development tools

Developer use Visual Studio 2017 program for receive data to upload and use XAMPP program for receive and display data in website application form.

3.7.1 Programming procedure

1. Study basic computer languages such as C # and HTML.
2. Study programming in each language to check how difficult it is to write in a particular language to decide the right one for use in program design.
3. Decide on the language that suits you best. We selected C# Language.
4. Study the transmission of data in the Serial Port format.
5. Study the determination of chloride in concrete.
6. Study how to import data into the database.
7. Write a program that interfaces with the Hardware and the user (Graphical User Interface, GUI).
8. Write a program to manage data in report format.
9. Check the correctness of the results. And improve the program.
10. Make a program that can be used on a web application system.

3.7.2 Program development process

1. Receive data from power supply in serial port format.
2. Display the data and convert the data into a graph format in the program.
3. Send data to XAMPP program and store data in serial port.
4. Bring the stored values to display results in a graph format.
5. To collect test data on web application
6. Manage all data into report format.

CHAPTER 4
EXPERIMENTAL RESULT

4.1 Testing result.

The author conducted tests of the discharge source from the power supply and the solution reservoir including storage the ability to resist the penetration of chloride into concrete by the store the current flowing through the three specimens for six hours. The new apparatus has been developed to analyze the data to calculate the tolerances of the electric current. And for the accuracy also according to the standard

4.2 Testing the power supply.

The power supply has been designed to release a stable electric current at 60 volts, with an error lower than 1% or ±6 milliamp. The author's added the SSD card for storing the data to calculate electric charge in coulomb up to 4 gigabytes. The result has a maximum discrepancy of 45 coulombs.

4.3Testing the cubic acrylic cell.

From the surface leakage test of the waterproofing rubber and the specimen by combining the concrete into a solution-filled cell block, then leave it for 6 hours. Found that the solution does not permeate through the cell block.

Figure 4.1 The cubic acrylic cell.

4.4 Testing the solution reservoir.

For solution reservoir designed from the medical saline line and laboratory wash bottle, still lacking test results for usability such as durability of saline line to the prolonged high heat solution, and volume of solution used in the whole experiment. Initially, the author designed was able to fill the solution to the cellblock but there is no stand for placing the solution reservoir.

Figure 4.2 Solution reservoir

4.5 Testing the chloride permeability in concrete specimens.

In the experiment, use two concrete samples for the test, one specimen per experiment.

Sample 1

- Normal mixture concrete (Non-fly ash concrete)

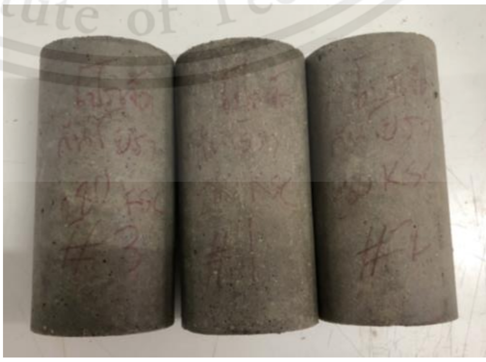


Figure 4.3 A cylinder concretes.

Sample 2

- Fly ash concrete

Figure 4.4 A cylinder concretes mixed fly ash.

The rapid chloride permeability test is lengthy, especially the curing process. After the curing process, rest the concrete specimen for 24 hours. Then cut it into 5 centimeters height and coating epoxy around the side edge. When the epoxy is dry and ready, assemble the specimen with the cell block and add sodium chloride (NaCl) solution to the negative cell while sodium hydroxide (NaOH) to the positive cell. Then connect an electric wire from the power supply to the load cell, then verify the voltage in the wire or solution has a constant of 60 voltage. Perform tests and collect data every 30 minutes until 6 hours are complete.

Figure 4.5 Chloride penetration test of sample *1*

Table 4.1 Chloride permeability test result from concrete sample 1

Order	Time (minutes)	The amount of accumulated current that flows through the concrete		
		Load cell no.1	Load cell no.2	Load cell no.3
0	0	324.4	328.4	327.9
1	30	381.3	385.2	371.2
2	60	429.3	433.0	421.4
3	90	477.3	481.0	469
4	120	522.3	529.0	517.4
5	150	573.3	577.0	565
6	180	621.3	622.1	613.0
7	210			
8	240			
9	270			
10	300			
11	330			
12	360			
	Total Electric currents	3329.2	3355.7	3284.9
	Average	554.9	559.3	547.5

$$Q = 900(I_0 + 2I_{30} + 2I_{60} + \ldots + 2I_{300} + 2I_{330} + I_{360})$$

$Q_{Load\ cell\ no.1}$= 900(324.4 + 2(381.3) + 2(429.3) + 2(477.3) + 2(522.3) + 2(573.3) + 621.3) = 5141430 coulombs.

$Q_{Load\ cell\ no.2}$= 900(328.4 + 2(385.2) + 2(433) + 2(481) + 2(529) + 2(577) + 622.1) = 5184810 coulombs.

$Q_{Load\ cell\ no.3}$= 900(327.9 + 2(371.2) + 2(421.4) + 2(469) + 2(517.4) + 2(565) + 613) = 5066010 coulombs.

As a result of the chloride resistance test of test piece no. 1 found that electric current flowed through it so quickly. The apparatus had to stop automatically when the coulomb exceeded the resistance check standard at 4000 coulombs.

4.6 Testing the program of the chloride permeability test.

After developing a program from C # for sending data via Serial port system to store SQL database and display the data on web browser, Shown in Figure 4.6.

4.6.1 Importing data into the database

The data collection using open-source PHP my admin and Apache web server through a management program called XAMPP which stores the data in the form of a table in Figure 4.6 via the manager in PHP my admin and then displayed through the web page. That shown in Figure 4.8 - 4.15.

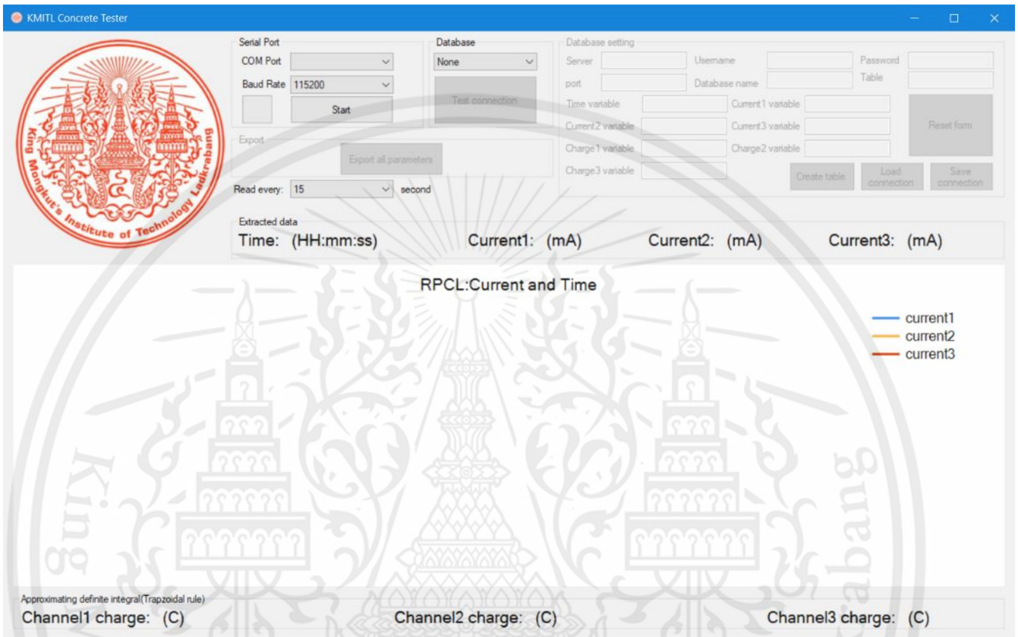


Figure 4.6 Transitional serial port from Power Supplt to database

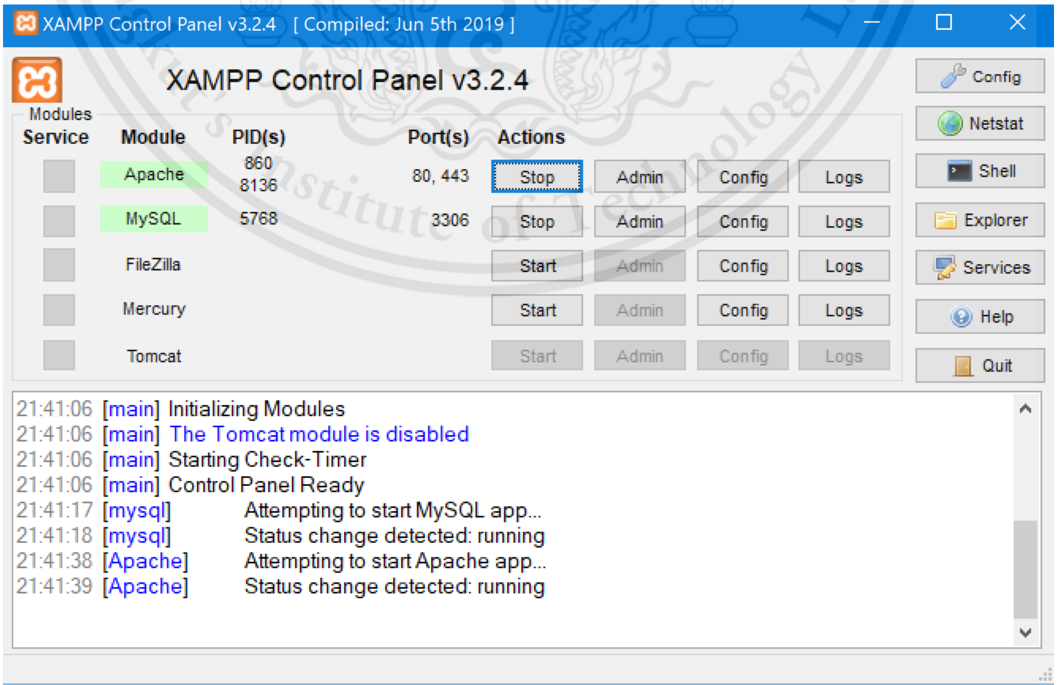


Figure 4.7 Control panel window for controlling database and web server.

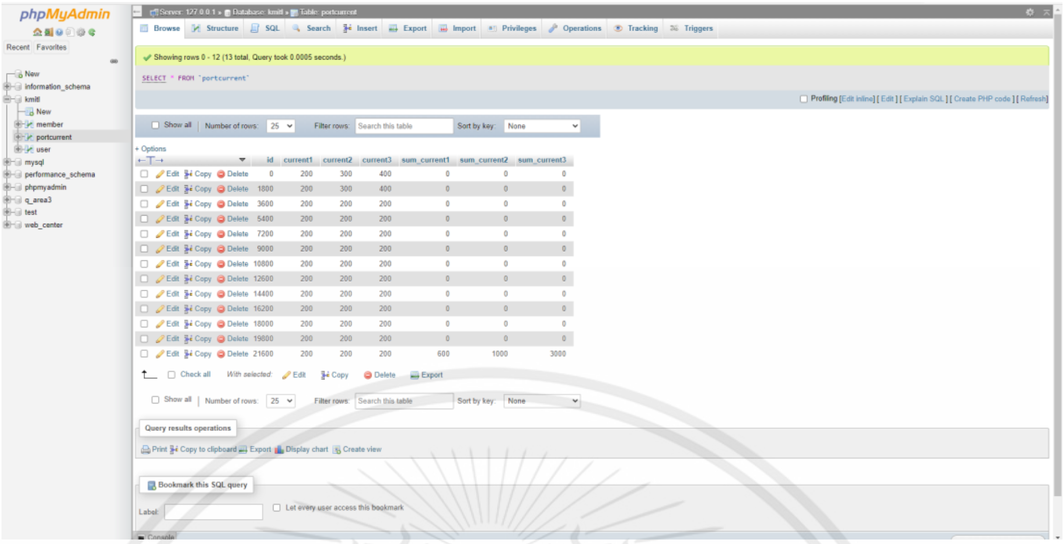


Figure 4.8 Database for collecting data before displaying on the web page.

1. Login window to log in where the user will have a different username and password.

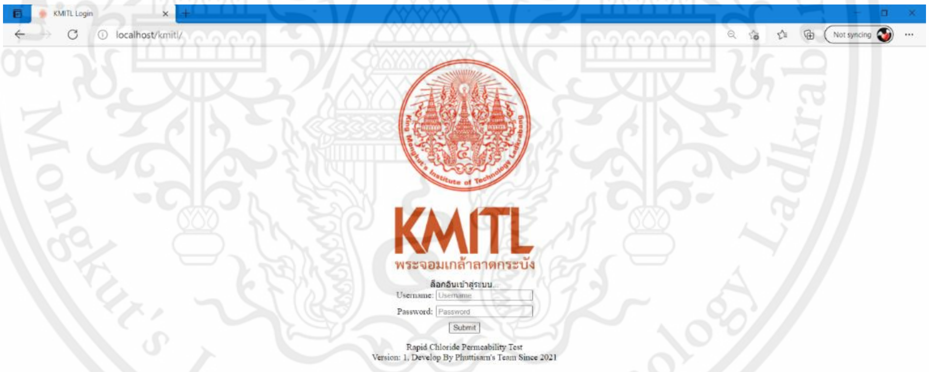


Figure 4.9 Login window

2. Before testing, click on the Manage Data window and click on Add experimental data. Fill in the information about the specimen, this information will be linked to the test data window for exporting data as a document form as shown in Figure 4.13.

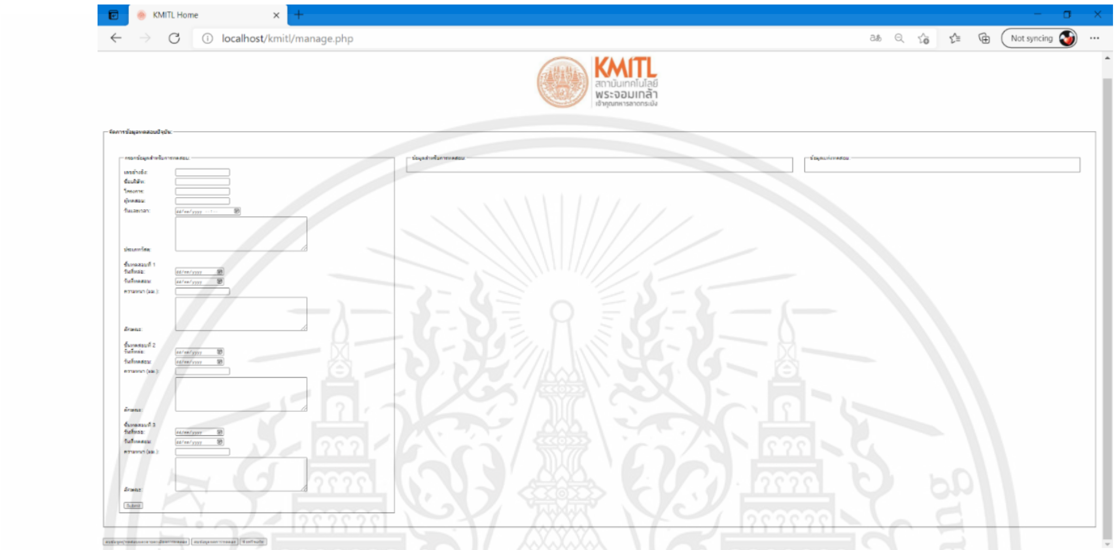
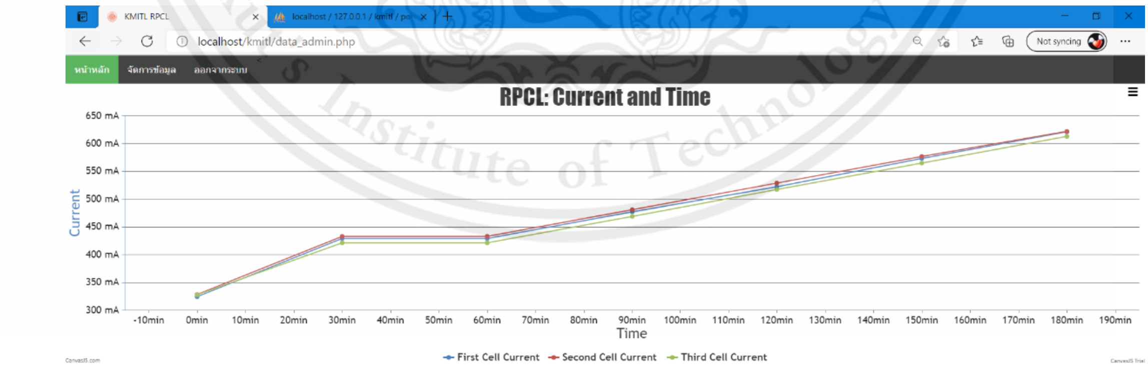


Figure 4.10 Add data for the experiment window.

3. After logging in, the main page window will display a graph of the values between the current and the time of the three test specimens and will display real-time data as shown in the figure below.



Time(second)	First cell current(mA)	Second cell current(mA)	Third cell current(mA)	First Charge Passed(C)	Second Charge Passed(C)	Third Charge Passed(C)
10800	621.3	622.1	613	6450.84	6475.14	6361.2
9000	573.3	577	565	4930.2	4977	4870.8
7200	522.3	529	517.4	3598.56	3636	3551.04
5400	477.3	481	469	2447.82	2467.8	2404.08
3600	429.3	433	421.4	1459.08	1472.76	1426.68

Export Table data into Excel

Figure 4.11 Main page window

4. Once the test is complete, the test data will be displayed in the form as shown in Figures 4.13 and 4.13, the information below can be edited at the Add Data Window for Experiments as shown in Figures 4.9 and 4.10.

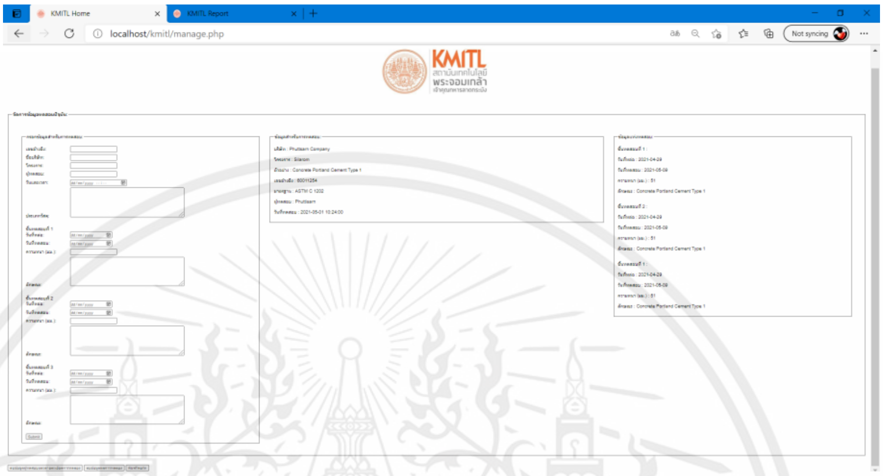


Figure 4.12 Testing information window.

5. In the Manage Data window in Figure 4.9, there is also a feature that can delete the completed data by pressing Delete to delete data for the experiment. To clear the chloride permeability test results or delete the data recorded in the table. Data for testing (Figure 4.13 and 4.14) with a note warning that unable to recover the data, once start to delete process, a pop-up will be prompt to confirm the deletion again.

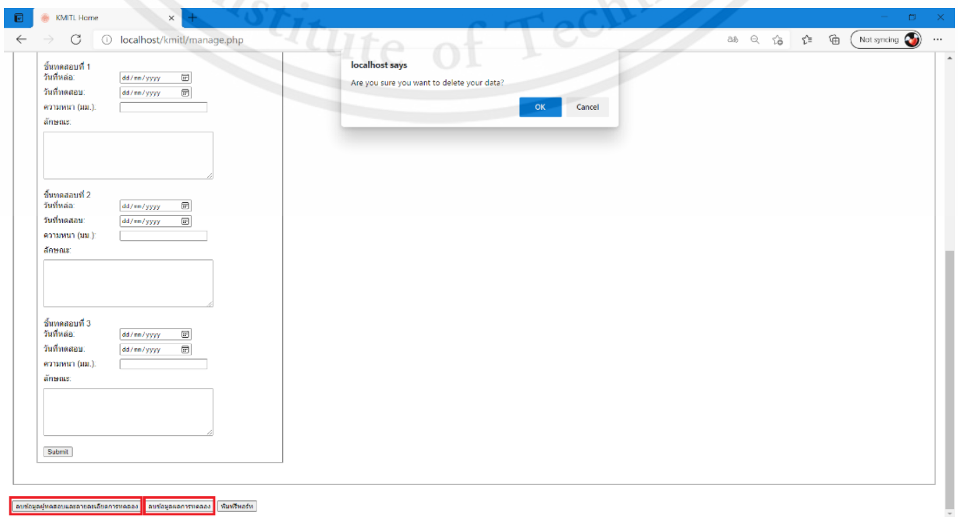


Figure 4.13 Data deleting management window.

6. Print the report page by clicking on the Print Report button. The report page will appear.

รายงานผลการทดสอบ
การซึมผ่านของคลอไรด์-(ASTM-C1202)

เสนอ

บริษัท Phuttisarn

โครงการ Silarom

โดย

คณะทำการทดสอบ ภาควิชาวิศวกรรมโยธา
คณะวิศวกรรมศาสตร์ สถาบันเทคโนโลยีพระจอมเกล้าเจ้าคุณทหารลาดกระบัง

ภาควิชาวิศวกรรมโยธา
คณะวิศวกรรมศาสตร์
สถาบันเทคโนโลยีพระจอมเกล้าเจ้าคุณทหารลาดกระบัง

สำหรับ	Phuttisarn
โครงการ	Silarom
ตัวอย่าง	Cement Portland Type 1
เลขอ้างอิง	60011254
มาตรฐาน	ASTM C 1202
ผู้ทดสอบ	Phuttisarn
วันที่ทดสอบ	2021-05-24 00:07:00

การทดสอบค่าการซึมผ่านคลอไรด์ ได้ทดสอบตามมาตรฐาน ASTM-C1202-94-(Standard-Test-Method-for-Electrical-Indication-of-Concrete's- Ability-to-Resist -Chloride-Ion-Penetration)- โดยบันทึกค่ากระแสไฟฟ้าที่ไหลผ่านแท่งทดสอบเป็นเวลา- 6- ชั่วโมง แล้วแปลงค่ากระแสไฟฟ้าให้เป็นจำนวนประจุ- โดยทดสอบกับแท่งทดสอบ- 3-แท่ง ดังรายละเอียดตารางที่- 1- สำหรับตารางที่- 2- ได้แสดงผลการทดสอบค่ากระแสไฟฟ้าผ่านในช่วงเวลาทดสอบ- 6-ชั่วโมง-พร้อมกับการประเมินระดับการซึมผ่าน- จากตารางที่ 3- ดังแนบ

Figure 4.14 Document form (first page)

ตารางที่-1 รายละเอียดแท่งทดสอบ

ข้อมูลจากผู้นำส่งตัวอย่าง		ข้อมูลจากผู้ทดสอบ		
ชิ้นทดสอบ	วันที่หล่อ	วันที่ทดสอบ	ความหนา (มม.)	ลักษณะ
1	2021-05-24	2021-05-24	501	Cement Portland Type 1, Fly ash 30%
2	2021-05-24	2021-05-24	510	Cement Portland Type 1, Fly ash 30%
3	2021-05-24	2021-05-24	511	Cement Portland Type 1, Fly ash 30%

ตารางที่-2 ผลการทดสอบ

เวลา	ปริมาณประจุไฟฟ้าสะสมที่ไหลผ่านแท่งทดสอบ-(Coulombs)		
นาที	ลำดับที่ 1	ลำดับที่ 2	ลำดับที่ 3
0	20.00	30.00	20.00
30	50.00	50.00	50.00
60	70.00	70.00	70.00
90	90.00	90.00	90.00
120	110.00	110.00	110.00
180	200.00	200.00	200.00
210	120.00	125.00	122.00
240	150.00	153.00	159.00
270	250.00	250.00	250.00
300	275.50	270.00	270.00
330	300.00	300.00	300.00
360	320.00	320.00	320.00

ปริมาณประจุไฟฟ้าสะสมที่ไหลผ่านแท่งทดสอบ-(Coulombs)			
ประจุไฟฟ้า(Coulombs)	ลำดับที่ 1	ลำดับที่ 2	ลำดับที่ 3
	900.00	900.00	900.00
ค่าเฉลี่ยแต่ละชนิด(Coulombs)	900.00		
ระดับการซึมผ่าน	Very - Low		

ตารางที่-3 ผลการทดลอง

Charge-Passed-(Coulombs)	Chloride-Ion-Penetrability
More Than 4,000	High
2,000 - 4,000	Moderate
1,000 - 2,000	Low
100 - 1,000	Very - Low
Lower Than 100	Negligible

Figure 4.15 Document form (second page)

CHAPTER 5
CONCLUSION

5.1 Conclusion

- The power supply can apply an electrical current of 60 volt into the concrete. Able to receive test results through the program Kmitl_Concrete_Tester that designed and manual data by USB. Both of these will provide the data as a Microsoft Excel file that can be placed into a form for immediate editing and printing.
- After non-fly ash concrete and 28 days curing tested, obtained a very high electrical conductivity value. As a result, this specimen has the sum of charge that exceeds the standard for testing the resistance of chloride permeability in concrete.
- When the tested specimen is highly electrically flowing over the standard, the designed power supply will automatically stop the test if the electric charge peaks over 650 mA during the test.
- The created software is delivered online with a delay of 1 to 2 minutes, and the delay depends on the user's internet signal.

5.2 Suggestion

- Due to the problem of the spread of the COVID-19 virus, the university has issued measures to prevent the spread of the virus. According to the 24th edition of the COVID-19 Prevention and Monitoring Committee, further testing could not test, so there was no information on the results of the tests to be compared.
- Should test the concrete specimen, which has many types of fly ash to compare the test results to find the accuracy of the apparatus. In the concrete preparation, when removing concrete from the mold, should clean the concrete specimen thoroughly before storing them to prevent tolerances the diameters and make it easier to assemble with cell blocks.
- The solution reservoir is made from a medical saline line with a wash bottle for the laboratory. Test results still lacking usability in various fields such as durability of the saline line to a solution of prolonged temperatures, and the volume that allows the solution to complete the experiment. Initially, what the authors designed was able to insert the solution and dispense it into the cell block, but there was no stand for the reservoir.
- The apparatus should be cleaned in all parts, avoiding solid brushes or aluminum scrubbing brushes to prevent scratching of the tools.

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APPENDICES

APPENDIX A

Test data for concrete

Test data for concrete without fly ash at the load cell no.1

{ x: 0 , y: 324.4 },
{ x: 1 , y: 325.1 },
{ x: 2 , y: 325.1 },
{ x: 3 , y: 325.2 },
{ x: 4 , y: 327.8 },
{ x: 5 , y: 328.3 },
{ x: 6 , y: 328.9 },
{ x: 7 , y: 340.0 },
{ x: 8 , y: 341.5 },
{ x: 9 , y: 342.1 },
{ x: 10 , y: 349.3 },
{ x: 11 , y: 350.9 },
{ x: 12 , y: 352.5 },
{ x: 13 , y: 354.1 },
{ x: 14 , y: 355.7 },
{ x: 15 , y: 357.3 },
{ x: 16 , y: 358.9 },
{ x: 17 , y: 360.5 },
{ x: 18 , y: 362.1 },
{ x: 19 , y: 363.7 },
{ x: 20 , y: 365.3 },
{ x: 21 , y: 366.9 },
{ x: 22 , y: 368.5 },
{ x: 23 , y: 370.1 },
{ x: 24 , y: 372.0 },
{ x: 25 , y: 373.3 },
{ x: 26 , y: 373.9 },

{ x: 27 , y: 376.5 },
{ x: 28 , y: 378.1 },
{ x: 29 , y: 378.7 },
{ x: 30 , y: 381.3 },
{ x: 31 , y: 382.9 },
{ x: 32 , y: 384.5 },
{ x: 33 , y: 385.1 },
{ x: 34 , y: 387.7 },
{ x: 35 , y: 389.3 },
{ x: 36 , y: 391.9 },
{ x: 37 , y: 392.5 },
{ x: 38 , y: 393.5 },
{ x: 39 , y: 395.7 },
{ x: 40 , y: 397.3 },
{ x: 41 , y: 398.9 },
{ x: 42 , y: 400.5 },
{ x: 43 , y: 401.1 },
{ x: 44 , y: 403.7 },
{ x: 45 , y: 405.3 },
{ x: 46 , y: 405.3 },
{ x: 47 , y: 408.5 },
{ x: 48 , y: 410.1 },
{ x: 49 , y: 411.7 },
{ x: 50 , y: 412.5 },
{ x: 51 , y: 412.5 },
{ x: 52 , y: 416.5 },
{ x: 53 , y: 417.1 },
{ x: 54 , y: 419.7 },
{ x: 55 , y: 421.8 },
{ x: 56 , y: 422.9 },
{ x: 57 , y: 424.5 },
{ x: 58 , y: 426.1 },

{ x: 59 , y: 426.3 },
{ x: 60 , y: 429.3 },
{ x: 61 , y: 430.9 },
{ x: 62 , y: 432.5 },
{ x: 63 , y: 432.5 },
{ x: 64 , y: 435.7 },
{ x: 65 , y: 437.3 },
{ x: 66 , y: 438.9 },
{ x: 67 , y: 438.5 },
{ x: 68 , y: 439.3 },
{ x: 69 , y: 440.5 },
{ x: 70 , y: 445.3 },
{ x: 71 , y: 446.9 },
{ x: 72 , y: 448.2 },
{ x: 73 , y: 450.0 },
{ x: 74 , y: 451.7 },
{ x: 75 , y: 453.3 },
{ x: 76 , y: 454.6 },
{ x: 77 , y: 454.6 },
{ x: 78 , y: 456.2 },
{ x: 79 , y: 456.2 },
{ x: 80 , y: 461.3 },
{ x: 81 , y: 462.9 },
{ x: 82 , y: 464.5 },
{ x: 83 , y: 464.6 },
{ x: 84 , y: 467.7 },
{ x: 85 , y: 469.3 },
{ x: 86 , y: 470.8 },
{ x: 87 , y: 471.5 },
{ x: 88 , y: 474.3 },
{ x: 89 , y: 474.8 },
{ x: 90 , y: 477.3 },

{ x: 91 , y: 478.9 },
{ x: 92 , y: 480.5 },
{ x: 93 , y: 482.2 },
{ x: 94 , y: 482.2 },
{ x: 95 , y: 482.3 },
{ x: 96 , y: 486.9 },
{ x: 97 , y: 486.9 },
{ x: 98 , y: 490.1 },
{ x: 99 , y: 491.7 },
{ x: 100 , y: 493.3 },
{ x: 101 , y: 494.9 },
{ x: 102 , y: 496.5 },
{ x: 103 , y: 498.1 },
{ x: 104 , y: 499.7 },
{ x: 105 , y: 501.3 },
{ x: 106 , y: 502.9 },
{ x: 107 , y: 502.9 },
{ x:108 , y: 502.9 },
{ x: 109 , y: 502.9 },
{ x: 110 , y: 507.7 },
{ x: 111 , y: 510.9 },
{ x: 112 , y: 512.5 },
{ x: 113 , y: 514.1 },
{ x: 114 , y: 514.3 },
{ x: 115 , y: 514.3 },
{ x: 116 , y: 518.9 },
{ x: 117 , y: 520.0 },
{ x: 118 , y: 520.6 },
{ x: 119 , y: 522.9 },
{ x: 120 , y: 522.3 },
{ x: 121 , y: 526.9 },
{ x: 122 , y: 528.5 },

{ x: 123 , y: 530.1 },
{ x: 124 , y: 531.3 },
{ x: 125 , y: 533.3 },
{ x: 126 , y: 533.3 },
{ x: 127 , y: 533.3 },
{ x: 128 , y: 538.1 },
{ x: 129 , y: 539.7 },
{ x: 130 , y: 540.1 },
{ x: 131 , y: 542.2 },
{ x: 132 , y: 543.7 },
{ x: 133 , y: 546.7 },
{ x: 134 , y: 547.3 },
{ x: 135 , y: 547.2 },
{ x: 136 , y: 549.3 },
{ x: 137 , y: 552.1 },
{ x: 138 , y: 554.6 },
{ x: 139 , y: 554.2 },
{ x: 140 , y: 555.3 },
{ x: 141 , y: 558.2 },
{ x: 142 , y: 560.7 },
{ x: 143 , y: 562.7 },
{ x: 144 , y: 563.3 },
{ x: 145 , y: 563.2 },
{ x: 146 , y: 564.3 },
{ x: 147 , y: 568.1 },
{ x: 148 , y: 569.6 },
{ x: 149 , y: 570.2 },
{ x: 150 , y: 573.3 },
{ x: 151 , y: 573.2 },
{ x: 152 , y: 576.5 },
{ x: 153 , y: 576.5 },
{ x: 154 , y: 579.7 },

{ x: 155 , y: 581.0 },

{ x: 156 , y: 582.0 },

{ x: 157 , y: 584.3 },

{ x: 158 , y: 586.1 },

{ x: 159 , y: 587.7 },

{ x: 160 , y: 589.3 },

{ x: 161 , y: 590.9 },

{ x: 162 , y: 592.5 },

{ x: 163 , y: 594.6 },

{ x: 164 , y: 595.3 },

{ x: 165 , y: 597.3 },

{ x: 166 , y: 598.9 },

{ x: 167 , y: 600.5 },

{ x: 168 , y: 602.1 },

{ x: 169 , y: 603.3 },

{ x: 170 , y: 604.5 },

{ x: 171 , y: 606.9 },

{ x: 172 , y: 608.5 },

{ x: 173 , y: 610.7 },

{ x: 174 , y: 611.3 },

{ x: 175 , y: 611.2 },

{ x: 176 , y: 611.3 },

{ x: 177 , y: 618.1 },

{ x: 178 , y: 618.6 },

{ x: 179 , y: 617.2 },

{ x: 180 , y: 621.3 },

X = Time (Minute)

Y = Current (mA)

Test data for concrete without fly ash at the load cell no.2

{ x: 0 , y: 328.4 },

{ x: 1 , y: 326.2 },

{ x: 2 , y: 326.7 },
{ x: 3 , y: 328.7 },
{ x: 4 , y: 328.3 },
{ x: 5 , y: 328.2 },
{ x: 6 , y: 328.3 },
{ x: 7 , y: 329.1 },
{ x: 8 , y: 343.6 },
{ x: 9 , y: 344.2 },
{ x: 10 , y: 349.3 },
{ x: 12 , y: 349.5 },
{ x: 13 , y: 357.4 },
{ x: 14 , y: 359.5 },
{ x: 15 , y: 361.3 },
{ x: 16 , y: 361.3 },
{ x: 17 , y: 361.3 },
{ x: 18 , y: 365.9 },
{ x: 19 , y: 367.8 },
{ x: 20 , y: 369.8 },
{ x: 21 , y: 370.2 },
{ x: 22 , y: 372.7 },
{ x: 23 , y: 373.7 },
{ x: 24 , y: 375.3 },
{ x: 25 , y: 377.2 },
{ x: 26 , y: 378.3 },
{ x: 27 , y: 380.1 },
{ x: 28 , y: 380.6 },
{ x: 29 , y: 383.2 },
{ x: 30 , y: 385.2 },
{ x: 31 , y: 386.2 },
{ x: 32 , y: 386.7 },
{ x: 33 , y: 389.7 },
{ x: 34 , y: 391.3 },

{ x: 35 , y: 393.2 },
{ x: 36 , y: 394.3 },
{ x: 37 , y: 396.1 },
{ x: 38 , y: 397.6 },
{ x: 39 , y: 399.2 },
{ x: 40 , y: 401.2 },
{ x: 41 , y: 401.2 },
{ x: 42 , y: 404.7 },
{ x: 43 , y: 405.7 },
{ x: 44 , y: 405.3 },
{ x: 45 , y: 405.2 },
{ x: 46 , y: 410.3 },
{ x: 47 , y: 410.1 },
{ x: 48 , y: 411.6 },
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{ x: 52 , y: 420.7 },
{ x: 53 , y: 420.7 },
{ x: 54 , y: 421.3 },
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{ x: 56 , y: 426.3 },
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{ x: 58 , y: 429.6 },
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{ x: 60 , y: 433.0 },
{ x: 61 , y: 433.2 },
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{ x: 66 , y: 442.3 },

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{ x: 72 , y: 450.7 },
{ x: 73 , y: 453.7 },
{ x: 74 , y: 455.3 },
{ x: 75 , y: 457.2 },
{ x: 76 , y: 458.3 },
{ x: 77 , y: 460.1 },
{ x: 78 , y: 461.6 },
{ x: 79 , y: 463.2 },
{ x: 80 , y: 465 },
{ x: 81 , y: 466.2 },
{ x: 82 , y: 466.7 },
{ x: 83 , y: 469.7 },
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{ x: 88 , y: 478.6 },
{ x: 89 , y: 478.9 },
{ x: 90 , y: 481.0 },
{ x: 91 , y: 481.2 },
{ x: 92 , y: 481.7 },
{ x: 93 , y: 485.7 },
{ x: 94 , y: 487.3 },
{ x: 95 , y: 489.2 },
{ x: 96 , y: 489.3 },
{ x: 97 , y: 492.1 },
{ x: 98 , y: 493.6 },

{ x: 99 , y: 495.2 },
{ x: 100 , y: 497 },
{ x: 101 , y: 498.2 },
{ x: 102 , y: 499.7 },
{ x: 103 , y: 501.7 },
{ x: 104 , y: 502.3 },
{ x: 105 , y: 505.2 },
{ x: 106 , y: 506.3 },
{ x: 107 , y: 506.4 },
{ x:108 , y: 509.8 },
{ x: 109 , y: 511.2 },
{ x: 110 , y: 513.0 },
{ x: 111 , y: 514.2 },
{ x: 112 , y: 514.7 },
{ x: 113 , y: 517.7 },
{ x: 114 , y: 519.3 },
{ x: 115 , y: 521.2 },
{ x: 116 , y: 522.3 },
{ x: 117 , y: 524.1 },
{ x: 118 , y: 525.6 },
{ x: 119 , y: 527.2 },
{ x: 120 , y: 529.0 },
{ x: 121 , y: 529.2 },
{ x: 122 , y: 532.7 },
{ x: 123 , y: 532.7 },
{ x: 124 , y: 535.3 },
{ x: 125 , y: 537.2 },
{ x: 126 , y: 537.3 },
{ x: 127 , y: 540.1 },
{ x: 128 , y: 541.6 },
{ x: 129 , y: 542.2 },
{ x: 130 , y: 545.0 },

{ x: 131 , y: 545.3 },
{ x: 132 , y: 546.7 },
{ x: 133 , y: 546.7 },
{ x: 134 , y: 549.3 },
{ x: 135 , y: 551.2 },
{ x: 136 , y: 551.3 },
{ x: 137 , y: 551.6 },
{ x: 138 , y: 552.6 },
{ x: 139 , y: 559.2 },
{ x: 140 , y: 561.0 },
{ x: 141 , y: 562.2 },
{ x: 142 , y: 564.7 },
{ x: 143 , y: 565.7 },
{ x: 144 , y: 567.3 },
{ x: 145 , y: 569.2 },
{ x: 146 , y: 570.3 },
{ x: 147 , y: 570.1 },
{ x: 148 , y: 572.6 },
{ x: 149 , y: 573.2 },
{ x: 150 , y: 577.0 },
{ x: 151 , y: 577.2 },
{ x: 152 , y: 577.7 },
{ x: 153 , y: 581.7 },
{ x: 154 , y: 583.3 },
{ x: 155 , y: 585.2 },
{ x: 156 , y: 586.3 },
{ x: 157 , y: 588.1 },
{ x: 158 , y: 588.6 },
{ x: 159 , y: 589.2 },
{ x: 160 , y: 591 },
{ x: 161 , y: 593.2 },
{ x: 162 , y: 596.7 },

{ x: 163 , y: 597.7 },
{ x: 164 , y: 599.3 },
{ x: 165 , y: 601.2 },
{ x: 166 , y: 602.6 },
{ x: 167 , y: 602.7 },
{ x: 168 , y: 602.6 },
{ x: 169 , y: 607.2 },
{ x: 170 , y: 609.0 },
{ x: 171 , y: 609.2 },
{ x: 172 , y: 610.7 },
{ x: 173 , y: 612.7 },
{ x: 174 , y: 615.3 },
{ x: 175 , y: 617.2 },
{ x: 176 , y: 618.3 },
{ x: 177 , y: 620.1 },
{ x: 178 , y: 620.6 },
{ x: 179 , y: 623.2 },
{ x: 180 , y: 622.1 },
X = Time (Minute)
Y = Current (mA)

Test data for concrete without fly ash at the load cell no.3
{ x: 0 , y: 327.9 },
{ x: 1 , y: 331.0 },
{ x: 2 , y: 332.4 },
{ x: 3 , y: 333.1 },
{ x: 4 , y: 333.3 },
{ x: 5 , y: 333.4 },
{ x: 6 , y: 336.0 },
{ x: 7 , y: 337.4 },
{ x: 8 , y: 339.6 },
{ x: 9 , y: 339.8 },

{ x: 10 , y: 341.3 },
{ x: 12 , y: 343.5 },
{ x: 13 , y: 344.4 },
{ x: 14 , y: 346.5 },
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{ x: 159 , y: 579.2 },
{ x: 160 , y: 581.4 },
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{ x: 175 , y: 603.2 },
{ x: 176 , y: 603.3 },
{ x: 177 , y: 603.1 },
{ x: 178 , y: 610.6 },
{ x: 179 , y: 609.2 },
{ x: 180 , y: 613.0 },

X = Time (Minute)

Y = Current (mA)