CHAPTER III

BASIC THEORY

3.1. <u>Geopolymer Concrete</u>

Geopolymer concrete is concrete which uses different materials and are environmental friendly during the production process. There are several advantages of the materials; such as anti-fire, used as a cover material for the exterior of mechanical equipment, durable and environment friendly.

Geopolymer concrete was established by Joseph Davidovits in 1970. At that time, Davidovits investigated the materials which were in the pyramid. He found that the cement used in the pyramid consist of several different materials. At that time it was called geopolymer, which was obtained from fly ash as a result of geo-polymerization reaction mix with NaOH, KOH and so on. In the process of geopolymer, there is a chemical reaction between alumina-silicate oxide (Si_2O_5, Al_2O_2) with alkali poly-silicates which produces Si-O-Al bonds. Poly-silicate is generally in the form of sodium or potassium silicate obtained from the chemical industry or fine silica powder as a byproduct of the process ferro-silicon metallurgy. From the reactions that mix together in the geopolymer, there will be H_2O or water that has been released.

From the equation, it can be shown that the chemical reaction of compound formation geopolymer also produces water that will be removed during the curing process. (Davidovits, 1999; Hardjito & Rangan, 2005)

Actually, geopolymer concrete can be produced no only from fly ash but geopolymer can be also produced with silica and materials rich in alumina. Several studies have reported the use of geopolymer in concrete is beneficial. Most of the studies investigated the use of alkali activators containing sodium hydroxide and sodium silicate; or potassium hydroxide and potassium silicate.

Different with the material that is used above, Cheng and Chiu (2003) reported the production of geopolymer concrete using slag and metakaolin with potassium hydroxide and sodium silicate as the alkaline medium. Some of people using fly ash as a material in geopolymers with sodium hydroxide and sodium silicate as well as with potassium hydroxide with potassium silicate combinations. The results from the studies show that the formation of geopolymer is excellent. It can be noted that the presence of calcium content in fly ash, played a significant role in compressive strength development. The addition of calcium ions, provide a faster reaction and thus produces good hardening of geopolymer in shorter curing time.

"Polymers are sensitive towards heat and can form a stronger chain due to polycondensation. It is noted from the basic chemical reaction when subjected to heat causes silicon and aluminium hydroxide molecules to polycondense or

polymerizes, to form rigid chains or nets of oxygen bonded tetrahedra." (Hindawi, 2013)

Davidovits (1988) reported that geopolymer can harden rapidly at room temperature and can gain the compressive strength up to 20 MPa. Geopolymer cement was discovered to be acid resistant, because, unlike the Portland cement, geopolymer cements does not depend on lime and are not dissolved by acidic solutions.

3.2. <u>Metakaolin</u>

Metakaolin is a dehydroxylated form of the kaolin. Kaolin is a clay material with low iron content, and generally white in color. Kaolin has a composition of hydrous aluminum silicate ($2H_2O.Al_2O_3.2SiO_2$), along with other minerals.

Kaolin will be transformed under when affected by heat at atmospheric pressure. If kaolin is burn at temperatures of 550-800°C, kaolin will be dehydroxylated and produce disorder metakaolin ($Al_2Si_2O_7$). However, if the kaolin is burnt at temperature of 900°C, it will cause the loss of hydroxyl continuously and gradually oksolasi on metakaolin. This makes metakaolin has a complex mixture of amorphous silica (SiO_2) and alumina (Al_2O_3).

If the kaolin is burnt up to 925-950°C, it will change from metakaolin to be aliminium-silicon spinel ($Al_3Si_4O_{12}$), which is also known as a gamma-alumina structure

If the kaolin is burnt up to 1050°C, it will cause spinel phase ($Si_3Al_4O_{12}$) nucleate and transformed into mullite ($3Al_2O_3$. $2SiO_2$), and crystalline cristobalite (SiO_2).

So, the best combustion of kaolin is in the heat of 550-800°C

3.2.1. <u>Advantages of Metakaolin</u>

The advantages of metakaolin are:

- Increase compressive and flexural strengths
- Reduce permeability (including chloride permeability)
- Reduce potential for efflorescence, which occurs when calcium is transported by water to the surface where it combines with carbon dioxide from the atmosphere to make calcium carbonate, which precipitates on the surface as a white residue.
- Increase resistance to chemical attack
- Increase durability
- Reduce effects of alkali-silica reactivity (ASR)
- Reduce shrinkage, due to "particle packing" making concrete denser
- Improve color by lightening the color of concrete making it possible to tint lighter integral color.

3.2.2. Use of Metakaoline

- High performance, high strength, and lightweight concrete
- Precast and poured-mold concrete
- Fibercement and ferrocement products
- Glass fiber reinforced concrete
- Countertops, art sculptures
- Mortar and stucco

3.3. Silica Fume

Silica Fume Is a high performance pozzolan with unique chemical and physical properties that enable cement based systems and mix designs to achieve higher levels of performance and durability.

Silica fume is a byproduct of silicon metal and ferrosilicon alloy product. "*By-products of the production of silicon metal and the ferrosilicon alloys having silicon contents of 75% or more contain 85–95% non-crystalline silica. The by-product of the production of ferrosilicon alloy having 50% silicon has much lower silica content and is less pozzolanic.*Silica fume usually contains of 90% SiO_2." (Vishnumaya 2014)

Silica Fume will greatly increase concrete strength and reduce permeability which in turn contributes to increased durability for chemical resistance, chloride attack, sulfate attack, and abrasion resistance.

Silica fume is an ultrafine material with spherical particles less than 1 μm in diameter, the average being about 0.15 μm. This makes it approximately 100 times smaller than the average cement particle

Silica fume is like an addition in the cement to improve its properties; compressive strength of the cement, abrasion resistance, and bond strength. The silica fume that is added to the cement can reduce the permeability of the concrete to chloride ions. It can protect the reinforcing steel of concrete from corrosion, especially in the chloride-rich environments.

Because of the addition of silica fume to the cement, the slump loss with time is directly proportional to the increase in the silica fume content, due to the introduction of large surface area in the concrete mix by its addition. Although the slump decreases, the mix remains highly cohesive.

Silica fume reduces bleeding significantly, because the additional water is consumed in wetting of the large surface area of the silica fume and hence the free water left in the mix for bleeding also decreases. Silica fume also blocks the pores in the fresh concrete so water within the concrete will not flow out.

3.4. Alkali Activator

The combination of liquid sodium silicate and sodium hydroxide are used to aid the chemical reaction with aluminum and silica contained in metakaolin and silica fume.

Sodium hydroxide is an alkaline compound that is highly reactive when mixed with water or distilled water. Sodium Hydroxide is solid and is used to reacts Si and Al, which in turn produce a strong bond polymerization. Sodium Silicate is like a gel and serves to accelerate the polymerization reaction. When dissolved in water or distilled water, sodium silicate will form an alkaline solution.

3.5. Aggregate

The number of aggregate in the concrete mixture is usually 60% - 70% of the weight of the concrete. It is because the size of aggregate is huge. So, it can fill the cylinder properly.

The use of Aggregate

- Reduces the use of pozzolan or alkali activator.
- Produce a strong concrete.
- Reduces shrinkage in the concrete hardening.
- Achieving solid concrete composition.
- Control the workability of the concrete.

Based on the size classification, aggregates are divided into two types; coarse aggregate and fine aggregate. Coarse aggregates are rock aggregates with the size of aggregates larger than 4.75 mm. Fine aggregates are smaller than 4.75 mm called sand. Aggregates with the size smaller than 1.2 mm are called fine sand. Aggregates that are smaller than 0.075 mm are called silt. Aggregates that are smaller than 0.002 mm are called clay. In general, aggregates are classified into 3 types:

- Stone, size larger 40 mm.
- Gravel, with size ranges from 5 to 40 mm.
- Sand, the size ranges between 0.15 to 5 mm

Coarse aggregate also divided into 3 types based on weight:

- Heavy aggregate

  Specific gravity of heavy aggregate is more than 2.8 g/cm3. Example of heavy aggregate is magnetil (Fe_3O_4), barites ($BaSO_4$) or iron filings. The resulting concrete has a high density that is up to 5 g / cm3 is used as a protective wall.
- Normal Aggregate

  Specific gravity of normal aggregate is between 2.5 - 2.7 g/cm3. This aggregate is usually derived from granite, basalt, quartz and so forth. The resulting concrete has a weight of 2.3 g/cm3.
- Lightweight aggregate

  Lightweight aggregate is aggregate with the specific gravity less than 2 g/cm3, for example ground fuels (Bloated clay), fly ash, and blast furnace slag foam. This aggregate is usually used for lightweight concrete which is usually used for non-structural elements.

Viewed from the surface texture, the surface condition of the aggregate will affect the ease of work. The more slippery surface concrete aggregate will be the more easily done. However, the type of aggregate with a rough surface is preferred because it will produce a strong bond between aggregate and cement paste. (Mulyono, 2004).

3.6. Distilled Water (Aquades)

Distilled water is water distillation. Distilled water is used to dissolve the Natrium Oxide and as the addition water of the mixture.

3.7. Compressive Strength

Compressive strength of concrete is the ability of concrete to receive a compressive force per unit area. Compressive strength of the concrete identifies the quality of a structure. The higher power of the structure so the higher quality of concrete that will be resulting (Mulyono, 2004). The area of concrete is cylinder. It can be seen from the figure 3.1; the height (h) and the diameter (d) are the factors which will be used to measure the area of the cylinder. The formula for area is:

$$A = \pi r^2 \quad (3\text{-}1)$$

with :

$\pi = \frac{22}{7}$

r = Radius (cm^2)

The load (p) is needed to test the compressive strength of the concrete. The load will be used to compress the concrete until the concrete is crack. The cylinder can be seen in figure 3.1

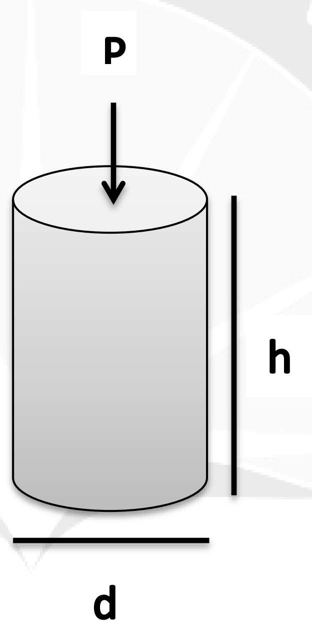

Figure 3.1. Cylinder Sample

The formula that will be used to find the magnitude of the compressive strength of concrete is:

$$fc' = \frac{P}{A} \tag{3-2}$$

with :

P = Maximum load (kg).

A = Cross-sectional area of the specimen (cm^2).

fc '= Characteristic concrete compressive strength (kg/cm^2).

3.8. Modulus of Elasticity

The modulus of elasticity is often referred to as the Young's modulus which is a comparison between stress and axial strain in the elastic deformation. So modulus of elasticity showed a tendency of a material to deform and back again to its original shape when under load (SNI 2826-2008).

3.9. Slump Value

Slump value is used to measure the ropy level of concrete mixture which has an effect with the workability of the concrete mixture process. If the value of the slump test is large then the concrete is liquid and easier to work with, otherwise if the value of the slump is small, the concrete will be more viscous and more difficult to work with.

3.10. Workability

Workability of concrete workmanship is the ease condition in mixing, stirring, pouring into molds and being compact without reduce the homogeneity of the concrete and bleeding concrete (separation) excessively to achieve the higher concrete strength.

Characteristics of Workability

- Consistency

  Workability is depends on the composition of the fresh concrete, physical characteristic from the mixture and aggregate.

- Mobility

  Ease to mix the mixture, put the mixture into the mold, and compaction.

- Compact ability

  Ease to compact the mixture so that the air cavities can be reduced.

- Stability

  The ability of the concrete to always homogeneous, always binding (coherent), and there will be no grain separation (segregation and bleeding).

- Finish ability

  Ease of the concrete to reach the final stage which is hardened with good conditions.

3.11. The Age of Concrete

The age of concrete is important to be considered in the experiment because the strength of the concrete will rise for every day. At the first time the strength of the concrete will be increase very fast and after that it will be relatively small in the age of 28 days. The age of concrete is calculated from the time when the concrete is removed from the mold.