

STRENGTH OF SOFT CLAY REINFORCED WITH SINGLE CRUSHED  
POLYPROPYLENE (PP) COLUMN

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## ABSTRACT

The strength of the kaolin clay increases when being reinforced with a material that are stronger than itself. The reason for conducting this study is to solve certain problem that related to the bearing capacity of the soft clay on the ground. Besides of throwing out an excessive amount of uncycled material, this study proposed to save an environment by re-use the excessive material to strengthen up the soft clay. There is two objective of this study that need to be completed by the end of the research. The first one is to determine the physical characteristics of kaolin clay and PP and morphological characteristic of PP. The second objective is to determine the undrained shear strength of soft clay reinforced with various dimensions of single PP column. Generally, soft clays can be defined as a disturbed cohesive soil that its water content is higher than its liquid limit. Soft clay also is one of the fine grained soils types that experiences the change in volume when it is different from elastic deformation, consolidation and secondary compression. Rock that rich in kaolinite are known as kaolin or china clay. Kaolin or china clay is a hydrated aluminium silicate crystalline mineral (kaolinite) formed over many millions of years by the hydrothermal decomposition of granite rocks. Kaolin clay is a versatile industrial mineral and generally used as fillers or raw material in ceramic, paints, plastics, paper, rubber, ink, catalyst, insecticide, pharmaceutical formulation and etc. Kaolin clay was familiarly experience with a various type of soil failure because of its characteristics due to the weak in strength. The failure that frequently happened to this kind of soil was the settlement failure. It is because the soil can't resist the large amount of loads through the member of the structure. Many improvement of soft clay has been discovered in order to make the strength of the kaolin clay rise. Meanwhile, Polypropylene (PP) are the general class of thermoplastics produced from propylene gas. Propylene gas is derived from the cracking of natural gas or petroleum by-products. The symbol for this polymer was  $(C_3H_6)_n$ . Production of PP takes place by slurry, solution or gas phase process, in which the propylene monomer is subjected to heat and pressure in the presence of a catalyst system. Polymerisation is achieved at relatively low temperature and pressure and the product yielded is translucent, but readily coloured. Differences in catalyst and production conditions can be used to alter the properties of the plastic. As for the testing, there is six (6) basic tests that need to be conducted towards the kaolin clay and two (2) basic tests for PP. The UCT will be proceed after all the basics test of the material has been done. A total of 28 sample need to be tested using the UCT. Four of the 28 sample was taken out to be the controlled sample. The other 24 samples with the PP column are tested and the results was compared to the controlled sample. If the results of the 24 samples showing an improvement of soil strength, the experiment was considered successful.

## ABSTRAK

Kekuatan tanah liat kaolin akan bertambah apabila distrukturkan dengan bahan yang lebih kuat daripada kekuatan tanah itu sendiri. Antara tujuan menjalankan kajian ini adalah untuk menyelesaikan sesetengah masalah yang berkaitan dengan keupayaan gelas tanah lembut di permukaan bumi. Selain daripada melupuskan barangan yang tidak boleh dikitar semula, kajian ini dijalankan juga bertujuan untuk menyelamatkan alam sekitar dengan menggunakan semula bahan buangan tersebut untuk menguatkan keupayaan gelas tanah lembut. Terdapat dua (2) objektif mengenai kajian ini untuk diselesaikan di pengakhiran kajian ini. Objektif yang pertama adalah untuk mengenalpasti ciri-ciri fizikal tanah lembut kaolin dan PP dan ciri-ciri morfologi PP. Manakala, objektif yang kedua pula adalah untuk menentukan kekuatan ricih tanah liat lembut yang tidak teralir, yang diperkukuhkan dengan pelbagai dimensi tiang PP tunggal. Secara umumnya, tanah liat lembut boleh didefinisikan sebagai tanah padu yang terganggu dimana kandungan airnya adalah lebih tinggi daripada limit cecair. Tanah liat lembut juga merupakan salah satu jenis tanah halus yang mengalami perubahan isipadu apabila ianya berbeza dari segi bentuk elastik, konsolidasi dan mampatan sekunder. Batu yang kaya dengan kaolinit dikenali sebagai kaolin atau tanah liat china. Kaolin china adalah aluminium silikat mineral kristal terhidrat (kaolinit) yang terbentuk lebih berjuta-juta tahun oleh penguraian hidrotermal batuan granit. Tanah liat kaolin adalah mineral perindustrian serba boleh dan biasanya digunakan sebagai pengisi atau bahan mentah seramik, cat, plastik, kertas, getah, dakwat, pemangkin, racun serangga, perumusan farmaseutikal dan lain-lain lagi. Tanah liat kaolin selalunya akan mengalami pelbagai jenis kegagalan tanah kerana ciri-cirinya yang lemah dari segi kekuatan. Kegagalan yang sering berlaku kepada ini jenis tanah ini adalah kegagalan mendapan. Ini adalah kerana tanah sendiri yang tidak dapat menahan jumlah beban yang besar termasuklah anggota struktur bangunan. Banyak penambahbaikan tanah liat lembut yang telah ditemui untuk membuatkan kekuatan tanah liat kaolin ini meningkat. Sementara itu, PP dikelaskan sebagai termoplastik yang dihasilkan daripada gas propylene. Gas propylene berasal dari pemecahan gas asli atau petroleum oleh produk. Simbol bagi polimer ini adalah  $(C_3H_6)_n$ . Penghasilan PP berlaku secara berlumpur, larutan atau proses fasa gas, di mana monomer propylene dikenakan haba dan tekanan terhadap sistem pemangkinnya. Pempolimeran ini dicapai pada suhu dan tekanan yang rendah dan menghasilkan produk yang lutcahaya, tetapi mudah berwarna. Situasi perbezaan pemangkin dan penghasilan boleh digunakan untuk mengubah sifat-sifat plastik. Terdapat enam (6) ujian asas yang perlu dilakukan terhadap tanah liat kaolin dan dua (2) ujian asas untuk PP. Ujian UCT akan diteruskan selepas semua ujian asas bahan telah dilakukan. Sebanyak 28 sampel perlu diuji menggunakan UCT. Empat (4) daripada 28 sampel diambil dan dijadikan sampel kawalan. Seterusnya, bagi selebih 24 sampel dengan bertiangkan PP hancur akan diuji dan keputusannya akan dibandingkan dengan sampel kawalan. Jika hasil keputusan 24 sampel itu menunjukkan peningkatan kekuatan tanah, eksperimen itu dianggap berjaya

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**LIST OF SYMBOLS**

|                |                                     |
|----------------|-------------------------------------|
| $D_{10}$       | Effective size                      |
| $C_u$          | Uniformity coefficient              |
| $C_c$          | Coefficient of gradation            |
| $S_0$          | Sorting Coefficient                 |
| $v$            | Velocity of the particle settlement |
| $\rho_s$       | Density of soil particles           |
| $\rho_w$       | Density of water                    |
| $\eta$         | Viscosity of water                  |
| $D$            | Diameter of soil particles          |
| $K$            | Coefficient of permeability         |
| $L$            | Average height of the sample        |
| $A$            | Cross-sectional area of the sample  |
| $t$            | Elapsed time                        |
| $W$            | Weight of the material              |
| $V$            | Volume of the material              |
| $w$            | Percentage of moisture content      |
| $G_s$          | Specific gravity of soil            |
| $\gamma_w$     | Unit weight of water                |
| $C_m$          | Meniscus Correction                 |
| $\rho_d$       | Dry density                         |
| $\gamma_d$     | Dry unit weight                     |
| $\rho_{d-min}$ | Minimum dry density                 |
| $\rho_{d-max}$ | Maximum dry density                 |

**LIST OF ABBREVIATIONS**

|        |   |
|--------|---|
| PP     | Polypropylene   |
| UCT    | Unconfined Compression Test                               |
| AASHTO | Association of State Highway and Transportation Officials |
| USCS   | Unified Soil Classification System                        |
| HDPE   | High Density Polyethylene                                 |
| PS     | Polystyrene   |
| PET    | Polyethylene Terephthalate                                |
| PVC    | Polyvinyl Chloride  |
| LDPE   | Low Density Polyethylene                                  |
| ABS    | Acrylonitrile Butadiene Styrene                           |
| PAN    | Polyacrylonitrile   |
| PVA    | Polyvinylalcohol  |
| PSD    | Particle Size Distribution                                |
| BSCS   | British Soil Classification System                        |
| UMP    | University Malaysia Pahang                                |
| SG     | Specific Gravity  |
| ASTM   | American Society for Testing and Materials                |
| BS     | British Standard  |
| UU     | Unconsolidated Undrained Triaxial Test                    |
| SPC    | Standard Penetration Cone                                 |
| PI     | Plasticity Index  |
| LL     | Liquid Limit  |
| PL     | Plastic Limit   |

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 BACKGROUND OF STUDY**

Malaysia is one of the country that was located under the equator line which is only experience a tropical climate. Different climate around the world causing the strength of soil at a certain place is different and surely it may affect the method of constructing and designing a building above that soil. To ensure that the ground was strong enough resist any resistance that came from the tropical climate, many ground improvement has been done in order to increase the amount of construction work around this country. The actual purpose for an engineer to make a ground improvement is to produce a better place for human to live and have a better facilities at the future.

The civil engineering course has been widely known among the citizen of Malaysia. Unfortunately, not many of them have a courage to take this course because the civil engineering job was one of the most risky job in the world. The error from the design of a structure or miscalculating the ground strength may lead to the loss of life to many people. To avoid this situation from happen, many researcher has discovered an alternative way to improve the strength of soil such as, reuse the recycling material to be mixed with the soil in order to improve its strength. For an example the strength of soil has been improvised by mixing it with the cement and lime. Based on the experiment that has been done, a conclusion has been made that the strength and stability of soil will be increase as the amount of admixtures is increasing (Ahmed *et al.*, 2013).



**Figure 1.1:** The location of Malaysia country

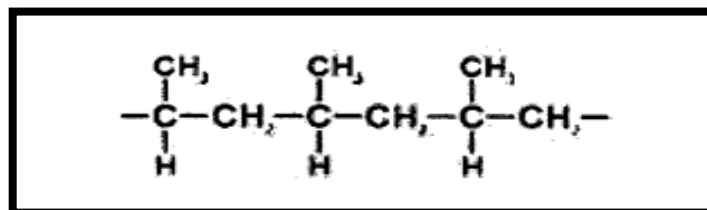
Source: Handayani *et al.* (2012)

Soil investigation is the most important things that need to be considered before the construction work begin. As a base of a building, soil must have several characteristics such as strong, able to resist failure and support large amount of load, in order to make the building long lasting. Due to this situation, a proper study and analysis of soil need to be carried out to identify the current condition of the soil at that construction site. This is the most challenging task for an engineer as they have to become more careful because the soil have many characteristics and type. If an engineer made a mistake during the soil analysis stage, the problem such as settlement and collapse of soil can be occur through time.

Soft clay is the type of soil that were typically found at Malaysia ground surface. Soft clays can be defined as a disturbed cohesive soil that its water content is higher than its liquid limit. Soft clay also is one of the fine grained soils types that experiences the change in volume when it is different from elastic deformation, consolidation and secondary compression (Mohd Yusof *et al.*, 2006). The main characteristic of the soft clay that has been proven by many researcher was, it have low strength and compressibility. Therefore, soil investigation on the basic properties and shear strength need to be carried out for any type of soil, so that an engineer can improvised the weakness of the soil.

The famous incident that happened at Malaysia on 11<sup>th</sup> December 1993 which is the collapse of the Highland Tower, has opened the engineers' eyes about the importance of soil study cannot be negligible. It happened because the self-characteristics of soil which is low strength, causing a lot of failure to a structure. According to McCarthy (1963), clay soil has particle sizes less than about 0.005mm. Due to the small particle size and small opening, the soft clay cannot be separated when it was tested by sieve analysis. There is another way that the soft clay can be tested which is by observing settling velocities of a particle in a water mixture. Soft clay soil is also subjected to be high plasticity when mixed with optimum amount of water.

In order to reduce the waste that was produced by Malaysia citizen, a proper steps have been taken to save our country from a mountain of garbage. From the soil mechanics and geotechnical perspective, a lot of waste can be reusable in order to make the strength of soil increase. Polypropylene (PP) is a thermoplastic polymer which is can be recycled. It was used in a wide variety of applications, including food packaging, textiles, plastic parts, reusable containers, and automotive components (Abd Raop, 2007).



**Figure 1.2:** Polypropylene chain structure

Source: Abd Raop (2007)

This study is mainly about the determination of physical properties and morphological properties of kaolin clay. There is a lot of problem need to be considered while constructed a building above this type of soil. Kaolin clay (soft clay) was familiarly experience with various type of soil failure because of its characteristics due to the weak compressibility. All of this problem can be overcome if an improvement of soil is been carried out in order to make a construction work occur above this type of soil. Among the



failure that frequently happen to this kind of soil was the settlement failure. It is because the soil cannot resist the large amount of loads through the member of the structure.

## 1.2 PROBLEM STATEMENT

The properties of soil plays an important role when it comes to constructing a structure of the building. The most important things was it can provide an enough strength to resist load that come from the building. The weak properties of soft clay are believed to give a big contribution of the failure to the structure. Therefore, the characteristics of soft clay need to be analysed and studied for people to gain an idea on how to improve the soft clay strength and compressibility, so that the construction phases can runs smoothly with any problem. The increasingly population on Malaysia people make the researcher enthusiastic to improve the strength and compressibility of soft clay so that the people can have a better shelter above this type of soil.

As we know, all soil are compressible and experienced several changes in volume based on the different stress that applied on it. This situation shall affect the structure of building if the study of soil does not been carried out. As been mentioned before, the famous failure that occur on this type of soil was the settlement failure. Many residential building and commercial building experienced a defects such as cracking on the wall due to the settlement of soil at that area. This problem was caused by the disregard of the soil properties and improperly compacted of soil during the construction phases of the building. All the building that was built above the soft soil was very risky and with a weak foundation may lead the structure to failure.

Nowadays, geotechnical engineer faced many problem in order to construct a building without experienced any excessive differential settlement. The properties of soft clay which is very fine, make the clay cannot be truly undrained. This situation causing a problem especially during the raining season at Malaysia. The water does not absorb through the soil and most probably cause a flood to that area. Soft clay also deals with the problems such as negative skin friction and bearing capacity failure (Tan *et al.*, 2005). Previously, piles were introduced to address the issue of bearing capacity and excessive differential settlement. But, this solution only lead to short-term problem associated with

soft clay, as pile bearing capacity significantly reduced with time due to negative skin friction. Negative skin friction is actually a phenomenon that arises from a settlement of soil in the vicinity of a pile. The soil deforming around the pile tends to pull the pile downwards thus reducing its bearing capacity for a given pile settlement.

Besides from finding ways to improve the strength of soil, many idea on recycling the waste material had been issued by several people. It is because a lot of production of this waste make the landfill packed with a lot of indestructible material. Based on this study, the crushed PP have been chosen in order to prove that the soft clay can be strengthened when it is reinforced with this kind of waste. Nowadays the PP was widely used in our daily lives. It has a lot of advantages in order to make human life easier. But, a lot of production of this things caused an excessive trash that can cause a problem for human to dispose it. The advantages and the excessive amount of this polymer can be reuse in many things in order reduce its waste on the earth surface.

Day by day worldwide use of plastics is increasing because of their light weight and durable characteristics. Waste plastics are major environmental problems all over the world. Waste PP are not bio-degradable, it remains in the landfill for a long period of time causing vegetation and aquatic ecosystem dilemmas. Abandoned waste PP that thrown into the ocean causes friction of ocean waves and then broken down by sunlight into small pieces and takes the shape of plastic. To avoid severe environmental degradation problems of waste plastics, some countries and big cities banned or restricted the use of plastic products (Sarker *et al.*, 2012).

In Malaysia, the average components of municipal solid waste are consisting of food waste (45%), plastic (24%) followed by paper (7%), iron (6%) and lastly 3% for glass and others (Tarmudi *et al.*, 2009). This statistics shows that the plastic is one of the largest waste product that has been produced by Malaysian people. Therefore, a continuous effort is required to identify the most suitable alternative for long terms solutions to reduce the burden of existing municipal solid waste disposal systems such as open dumping or landfilling

### **1.3 OBJECTIVE OF STUDY**

- a) To determine the physical characteristics of kaolin clay and Polypropylene (PP) and morphological characteristic of PP;
- b) To determine the undrained shear strength of soft clay reinforced with various dimensions of single PP column.

### **1.4 SCOPE OF STUDY**

This study was focuses on Kaolin clay and crushed PP waste material. Since a lot of century before, the study of soft clay was very familiar among the geotechnical engineer. Roughly, we can see that the soft clay ground was not safe to conduct a construction above it. However, after a lot of research and testing has been carried out, the soft clay can be strengthen by adding some admixture within it. This was proved by the research that have been done by former researcher regarding the strength of kaolin clay.

There is five basic test that need to be conduct in order to determine the basic properties of that kaolin clay. Among of it was the Sieve Analysis, Standard Proctor (compaction) test, Specific Gravity test, Atterberg Limit Test, and Falling Head (permeability) test. All of this test need to be conducted first to analyse the parameter of that soil. For an example, to determine the specific gravity of a soft clay is by divided the density of substance with the density of water. These test was very important since all the parameters that obtained from these tests was been used for the main experiment.

After all the basic test to determine the basic properties of the kaolin clay has been conducted, the main test was continued by reinforced the clay sample with crushed PP column. The main test that was chosen is the Unconfined Compression Test (UCT). The main purposes of UCT was to determine the shear strength of soil and to observe the mode failure of the soil specimen. This purposes of the test predicted to be answered the objective of this study.

For UCT, the column of the kaolin clay specimen was about 100 mm height and 50 mm diameter. After the soft clay has been shaped into the column size, the centre of the specimen was drilled out to make a hole to be inserted with a crushed PP recycled waste. The diameter of the hole was the variable factor in this test. The suggested diameter for the hole is 10 mm and 15 mm. The crushed PP waste material that available in the market was in the pellet shape and it was been used as a material to conduct this experiment.

## **1.5 RESEARCH SIGNIFICANCE**

Kaolin has been widely used both in fundamental studies of soil behaviour and in physical model tests (Rossato *et al.*, 1992). The uncontrollable development of this country has forced the improvement of the strength and compressibility of kaolin clay need to be done. The failure condition to the structure due to the less bearing capacity of the soft clay, supposedly occur due to this issue if it was been ignored.

In this research, the test was conducted to identify whether the strength of soft clay can be improved if it was reinforced with the crushed PP column. Applications of this method have recently been used by other researcher. However, the soft clay was reinforced with another material such as stone column, geosynthetic column, bottom ash column and many more. For this test, the soft clay was reinforced with crushed PP waste is because of its main characteristics which is able to resist corrosion, abrasion and chemical resistance.

Theoretically, the soft clay and crushed PP column was actually an appropriate combination to increase the bearing capacity of the soft clay. But, the effectiveness of this combination need to be tested on the laboratory to gain some evidence to support the theory. Based on the characteristic of the soft clay and the crushed PP column, it is shown that the material was completing each other disadvantages. For an example, the soft clay is low in strength but the crushed PP was high in strength. Apart from strengthen the soft clay, the crushed PP also can reduce its waste on the landfills by reuse it to be planted into the ground.

The fact that the soft clay were bringing a lot of problem to engineering design and foundation failure in soft clay are no longer a big problem. It is because, a lot of alternative can be explore to make the soft clay more stable. This is why, a strict precaution need to be taken out to avoid the unnecessary things from happen in the future. A detailed understanding of soil investigation need to be done by civil engineer to ensure that they are supposedly not make a mistake in the future. Furthermore, if the soil was fail, it costs a lots of innocent lives to experience various kind of damage. The result from this study can be used by other engineers as a guideline to improve the compressibility and strength of soil when it was been reinforced inside the kaolin clay.

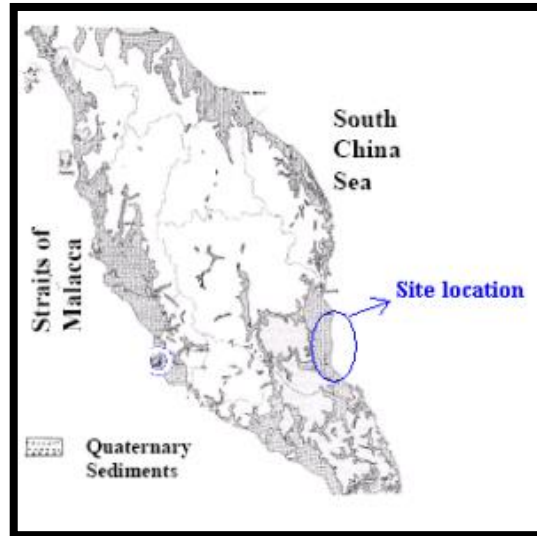
## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 INTRODUCTION**

Soil can be defined as the upper layer of earth in which the plants grow with black or dark brown material typically consisting of a mixture of organic remains, clay, and rock particles. It was used in various civil engineering projects and mostly it supports the foundation of the buildings (Das *et al.*, 2010). Soil deposits can be divided into two groups. The first group is residual soil, in which the soil is created and formed from the weathering process of rock and remains at the location of origin. Another one is transported soil where soil that moved from their place of origin (McCarthy, 1963).

Typically, the land of Malaysia contains soft clay soil geography especially at the West Coast of Malaysia such as, Johor, Malacca, Klang Valley, Alor Setar and a few places at Terengganu (Mohd Yusof *et al.*, 2006). It contributes a major distribution of soft clay percentage among another type of soil. Since the location of Malaysia was located near the equator line, Malaysia's climate can be categorized as an equatorial or tropical rainforest climate, which is being hot and humid throughout the year. Furthermore, Malaysia faces two monsoon wind seasons that are popularly known as the Southwest Monsoon which occurs from late May to September and the Northeast Monsoon from November to March. This monsoon causes many problems to this country such as landslides, floods, settlement of buildings and many more.



**Figure 2.1:** Soft clay area at Malaysia Peninsular

Source: Tan *et al.* (2005)

Any structure built on soil are subjected to settlement. The possibilities for a soil to settle was greater in the soft clay soil. Excessive settlement is tipped to be a big problem as it often exceeds the permissible limit (Mehmet, 2008). There is undeniable that the settlement will affect the stability of a structure. The typical damage that happen to a structure are normally subjected to cracking on the foundation and columns. As the building loads are applied to the ground, there are possibilities of settlement to occur as a result of instantaneous compression of the soil. Under certain conditions, however, fine-grained soils will continue to compress under constant load for many years (Sa'adon 2009).

To overcome this problem, the study about soil has been upgraded by making various tests towards the soil which has been taken at site. By investigation of soil, it is not possible that a building can be constructed above any type of soil at this country. This is why this study was focused on the study of Kaolin clay. If this study was successful, many ground or land at Malaysia can be improved so that the construction of the building can be runs smoothly. Also, this study can be related with reusable of recycling waste that will be explained details in the next topics.

This chapter was divided by two main parts which is kaolin clay and crushed PP. First part of this chapter is the review on the kaolin clay. This part will be reveal on the kaolin clay basic properties, origin of kaolin clay, past research on kaolin clay and etc. The second part of this chapter will be discuss on the crushed PP. In this part, several information regarding the crushed PP and its abilities to withstand a load were explained. The comparison between the strength of kaolin clay and the PP itself will be brief in this part. Details explanation was been given out so when the actual tests happen, a full knowledge about the tests have been explored.

## 2.2 KAOLIN CLAY

Soft clays were a type of fine-grained soils which change volume when different from elastic deformation, consolidation and secondary compression. Soft clays defined as a disturbed cohesive soil whose water content is higher than its liquid limit; such materials display extremely low yield stresses and represent difficult construction conditions (Mohd Yusof *et al.*, 2006). It is produced by the chemical decomposition of rocks or the deposit of fine rock particles in water.

Normally, soft clay was used in the manufacture of bricks, pottery, and other ceramics. People easily get confused with the soft clay and the silt clay. Silt clay can be classified into the fine-grained soil, but it have a lot of differences with soft clay especially in a term of size and mineralogy. Roughly, the silt clay tends to have a larger particle size than soft clay. The separation between soft and silt clay was very hard. Many geologists and soil scientists consider the separation to occur at a particle size of 2  $\mu\text{m}$  which the clays is being finer than silts (Hewaarachchi, 2014).

Rock that rich in kaolinite are known as kaolin or china clay. Kaolin clay is a versatile industrial mineral and generally used as fillers or raw material in ceramic, paints, plastics, paper, rubber, ink, catalyst, insecticide, pharmaceutical formulation and etc (Ariffin *et al.*, 2008). Kaolin is the part of the industrial minerals with the chemical decomposition of  $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$ . It is a layered silicate mineral, with one tetrahedral sheet linked through oxygen atoms to one octahedral sheet of alumina octahedral.