Effect of Alum Sludge and Metakaolin as a Partial Replacement Cement Adding Superplastizer

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Abstract. The most important activities that improve the economy of Malaysia is the construction industry. Hence it will cause the usage of the concrete increase. When the concrete usage increase, it also increase the cement use because cement is the primary material that forms the concrete and during the production of the cement, it will cause the emission of carbon dioxide which will harm the environment as well as people in Malaysia. After that, alum sludge also caused a lot environment problem because it is lack of potential to be reused in other industry and it needs to be treated before it disposed of, which will cause the financial problem to the government. After the treatment, the economical ways to dispose of it is by using landfill method. But due to a limited landfill site in Malaysia and it is the temporary solution for the disposal of the waste, it becomes a problem to Malaysia and the number of the alum sludge keeping increase year by year because of the population increase year by year too. The purpose of the study is to find out the effectiveness of this combination. The research method that use in this study is by taking out some experiment such as slump test also known as workability test, compressive strength test, flexural strength test, ultrasonic pulse velocity (UPV) test (direct and semi-direct method) and scanning electron microscope (SEM) with the concrete day-age 7, 14 and 28 days. The result gets these test is the 10% alum sludge as a partial replacement for metakaolin in concrete adding superplasticizer (Sika Viscocrete 208) is the best replacement level in term of the workability, compressive strength, Flexural strength, speed of the UPV and in scanning electron microscope. After 10% replacement level, the reading all suffer a downturn. Additionally, when the day-age of the concrete increase, the reading will be increase too. This happens to all the replacement level and the 10% replacement level with 28 day-age achieve the highest reading in this study. The contribution and implications of the findings are the using the 10% of the alum sludge as a partial replacement for metakaolin in concrete adding superplasticizer (Sika Viscocrete 208) is the best replacement level compare to others.

1. Introduction
Metakaolin is the pozzolan material that is very effective and it will enhance the strength of concrete [1]. It helps to deduct the use of cement in concrete and in the same time it also enhance the strength of concrete when the metakaolin use in concrete carried the experimental test that related to the replacement of the cement with metakaolin, [2] the results showed that the compressive strength of mortar increase about 50% when the cement by metakaolin, the result showed that the compressive strength started to decrease. Alum sludge is a waste that generated during the process of purification of domestic and industrial waste water. As the population increases every year, the generation of alum
sludge waste in Malaysia has been rapidly increasing 3.2 million cubic meters of domestic sludge every year that produces by Malaysia and increases up to 4.3 Million cubic metres in 2005. A lot of researchers have been cooperation to create the new and suitable solutions in order to fix the problem that causes by the alum sludge. They also cooperate with the conventional treatments to show health and environmental hazards[3]. In current years, the alum sludge only handle through filling and application in land, disposal to the ocean and use for agriculture. The most economical method of the alum Sludge disposal is land disposal. By using land disposal method, the crops will be available to grow on the poor land. According to [4] they say that the sludge is the biggest scale poor land. According to [4], they say that the sludge is the biggest scale compared to other by-products that produced in the process of sewage treatment and they also found that the sludge contains of heavy metals.

2. Problem Statement
Nowadays, the construction industry is one of the most important activities that improve the economy of Malaysia. With the increase of the construction activity, the use of concrete will increase and this will cause the cement needs also increase. In order to replace the cement used, metakaolin takes an important role in this replacement. With this replacement, the emission of the carbon dioxide will decrease because it is replaced the cement used in concrete. Other than that. It also will Increase the service life of the building. This is because when metakaolin replaced the cement, it will increase the durability and strength properties of the concrete [5] then, the alum sludge caused a lot of environmental problem and it is the largest waste produce per years in Malaysia. The reason that the alum sludge is increasing every tear is that the population of the Malaysia always increase and this causes the alum sludge increase too. According to [6], they say that Malaysia generated about 4.5 million cubic meters of domestic sludge since 2005 and it is keeping raising annually. Even there have some methods to stabilize and dewater the alum sludge, but the landfill is the method that most of the sludge is ended up to be disposed of even after treated. This is because it is the most economical ways to dispose of the waste. However, the landfill is only a temporary solution for the disposal of alum sludge waste because there is limited space for the sludge waste to be disposal of. Due to this problems, some researches had been carried out to determine the potential use of alum sludge as partial cement replacement materials, in bricks, clay and ceramic materials in order to increase the use of alum sludge. The increased importance of the reuse of alum sludge becomes very useful to reduce the environmental impact. The alum sludge can be used in cement manufacture by reuse the sludge as cement partial [7]. But alum sludge is a waste material that is no stable. Considering the pozzolanic properties of metakaolin and the possibility of fixing heavy metals in the pozzolanic hydrates, the use of metakaolin should help to improve the properties of concrete containing alum sludge [8]

3. Literature Review

3.1 Pozzolanic Materials

3.1.1 Metakaolin. Metakaolin is one of the most widely used mineral admixtures these days for high-performance concrete mixes. It helps concrete to gain both higher performance and economy. However, metakaolin is different from other mineral admixtures, it is not an industrial by-product as the others. Kaolin is one of the most abundant natural minerals and when it is heat-treating, it will become metakaolin. Instead, it is specially produced by high-quality kaolin using thermal treatment technology yielding a highly reactive amorphous material with pozzolanic and latent hydraulic reactivity that is very suitable for cementing applications especially for the high-performance concrete. Metakaolin typically contains 50-55% silicon dioxide (SiO2) and 40-45% aluminium oxide (Al2O3) [9]. When the cement is replaced by metakaolin, the result showed better performance than control mortar, particularly in terms of mechanical properties. Saving up to 40% of clinker reduces energy consumption and the amount of carbon dioxide emissions to the atmosphere.
3.1.2 Alum sludge. Alum sludge is a by-product and it is one of the final products of wastewater treatment at Sewage treatment plants. Polyaluminium chloride (PACl) and large amount inorganic matters. Alum sludge acted as a chemical conditioner and physical conditioner improved the alum sludge dewatering. It indicated that the addition of alum sludge reduced the dosage of polyacrylamide (PAM) and decreased the moisture content of alum sludge. Investigated the possibility of the alum sludge to reuse in the cement industry. They discovered that the alum sludge has a similar particle size and chemical composition with Portland cement. 10 to 30% of alum sludge are used to replace the cement use in mortars and the mechanical strength of the mortars is investigated by them. From the results, the mixes are lower than the control cement and the slump is decline. With the result, they found that the chemical compositions are the most important factor that affect the alum sludge to be reuse.

4. Result and Discussion

4.1 Workability

For the slump test, the concrete that using alum sludge act as the partial replacement for metakaolin in the concrete by using water content ratio 0.48 with adding superplasticizer into the concrete. The fresh concrete result for all the mix is already recorded and showed in figure 1. From the table below, the slump level for the concrete that contains 20% metakaolin is 270mm. After that, the alum sludge is added into the concrete to replace the metakaolin content, the slump level increase by 20mm by replaced 5% of the alum sludge to the metakaolin and keep increasing up to 310mm in 10% of the replacement. But after the replacement of the 10%, The slump level is continuously dropping and in the 20% of the replacement of the alum sludge to the metakaolin, it suffered a very big decline up to 150mm, which is the lowest slump level compare to other the result find that by using 15% of the alum sludge replaced the metakaolin and combined with the superplasticizer in the concrete. The slump level is achieved 80mm and this is the highest level that they reached. But in this test, the highest slump level achieved is 310 mm and only by using 10% replacement, the slump level is dropping. In conclusion, the 10% of the alum sludge mix with 10% of the metakaolin will reach highest slump level.

4.2 Compressive Strength Test

For the compressive strength test 7, 14 and 28 day-age cubes form in the 150mm × 150mm × 150mm cube mould. The figure 2 below shows the result of the 20% of the metakaolin. 5%, 10%, 15% and 20% of the alum sludge that replace the metakaolin contest is the concrete cube. In the day-age for each of the control mix, there are different result Compare to the other day-age of the cube. They age cube is 16.35 MPa, it is keeping increasing about 12.00 MPa when the they-age increase and in 28 day-age, it obtains 42.30 MPa compressive strength. Then for the 10% of the replacement in 7 days to 14 days, the compressive strength of it increase about 22.00 MPa, which is the highest increasing compared with another control mix. After the 14 days, it is increased mostly compared to another
control mix that after 14 days. The replacement for the metakaolin in 7 day-ago concrete. The Compressive strength of the cube is 16.35 MPa. After replaced by 5% of the alum sludge to the metakaolin it becomes increase up to 18.34 MPa and keeping increasing up to 23.85 MPa when replacing 10% of the alum sludge. However, after 10% of the replacement it drops to 15.98 MPa and when the alum sludge is fully replaced the metakaolin content in the concrete, the strength of it is 13.15 MPa, which is lower than 20% of the metakaolin concrete.

4.3 Splitting Tensile Strength Test

In flexural strength test 7, 14 and 28 days cubes are carried out in order to obtain the result. Figure 3 shows the result of the 5%, 10%, 15% and 20% of the alum sludge that replace the metakaolin content and last 20% of the metakolin in concrete. It is same as the result of compressive strength test, which is the result of the different day- age for each of the control mix are different. In the 7 day -age if the 20% of the metakolin concrete, the flexura strength of it is 2.40 MPa. It is keeping increase more than 2MPa when the day-age when the day-age increase. In 28 day-age, it obtains 7.50 MPa flexural strength. For 10% alum sludge that replaces the metakaolin content in concrete, the flexural strength of the 7 day-age concrete is 6.65 MPa and in 14 day-age the strength is 9.45 MPa. Futhermore, in 28 day-age concrete, the strength if it is 11.45 MPa and the difference compared to 14 day-age is about 2.00 MPa. Next, for the comparison of the control mix with the same day-age, before the replacement for metakaolin in 7 day-age concrete, the flexural strength of the concrete is 2.40 MPa. After the 5% of the alum sludge the metakaolin, it becomes increase up to 3.05 MPa. Flexural strength is keeping increase when the alum sludge content is increased, which is 10%of the alum sludge replacement obtain 6.65 MPa. However, after 10% of the replacement, the strength is starting to drop up to 4.20 MPa and when the alum sludge is fully replaced the metakaolin content in the concrete, the strength of it is 2.10 MPa. Compare with 20% of the metakaolin, 20% of alum sludge is better than it and the
difference strength between them is about 0.30 MPa. For 28 day-age concrete, 10% of the alum sludge achieve the highest strength, which is 11.45 MPa and the difference between 5% of the replacement is about 2.25 MPa.

4.4 Ultrasonic pulse velocity (UPV)

![Figure 4: Direct method](image)

This method is the most sensitive compared to the indirect method and it is used to detect the void that contains the concrete block. When the transmitter placed opposite of the receiver, it will provide maximum sensitivity, give a clear path length and more accurate. In this test, the material used is same as the previously conducted test. Figure 4 showing the comparison of the day-age for 20% metakaolin concrete, the reading of it is 32.90 us. It is a continuous increase but not so much when the day-age increase and in 28 day-age, the reading of it is 35.30 us. This situation is same for 5% and 15% of the alum sludge that replace the metakaolin in the concrete. For the 10% of the replacement, at 7 day-age the reading of it is 37.90 us. When the concrete block is up to 28 day-age, the reading is increased about 28 us. Which is up to 67.40 us and this is the highest increment compared to others control mix. Next is the comparison of the same day-age but different control mix. For 7 ay-age of 20% of metakaolin concrete, the reading of it is 32.90 us. With the replacement up to 10% of the alum sludge, the reading is keeping increase but not so much and it is up to 37.90. However, in 15% of the replacement, the reading is dropping about 6 us. When the metakaolin is fully replaced by the alum sludge in concrete, the reading for the ultrasonic pulse velocity drops a lot, which is up to 4.40 us. This is the reading that suffers most decrements compare to others control mix in the same day-age. However, in 28 day-age 10% of the replacement, the reading is 67.40 us, which have about 30 us difference compared to 5% of the replacement, which is the highest increment and it is the highest reading compare to others control mix.

5. Conclusion and Recommendation

The performance of alum sludge as a partial replacement for metakaolin adding superplasticizer in concrete is still new in the construction industry. This is because there only has one test that done relating to this topic. The engineering properties, physical & mechanical properties and the optimum value of in this replacement will be drawn out in this chapter. The engineering, physical and mechanical properties test like workability test, compressive strength test, tensile strength test, ultrasonic pulse velocity (UPV) test and scanning electronic microscope (SEM) test are carried out to achieve the objective of the study. The laboratory test was carried out according to the method that discovers in literature review and result will answer the issue that state in the objectives.

1. To investigate the engineering properties of the combination of concrete.
2. To determine and assess the physical and mechanical properties of alum sludge when cooperating with metakaolin in concrete by replacement 5%, 10%, 15%, 20%
3. To identify the optimum value 5%, 10%, 15% and 20% of alum sludge to replace for metakaolin.

Through the laboratory, the objectives of the study were determined and discovered from the test result that obtains in the test. Therefore, conclusion and recommendation on the performance of alum sludge as a partial replacement for metakaolin adding superplasticizer in concrete were extracted. The finding of this study will be summarized and concludes in this chapter. Recommendations to improve the performance of alum sludge as a partial replacement for metakaolin adding superplasticizer in concrete. Here has some recommendation that can be suggested after done this study. This recommendation can further improve the performance of the control mix concrete. There are: Strength properties of concrete with partial replacement of metakaolin with alum sludge need investigation for a longer period (56, 90, 180 days). More studies have to be carried on the effect of using superplasticizers on the percentage reduced of cement content on the concrete mixes. In the present study, 20 percent replacement of cement has been considered. The other percentages like 30, 40, and 50 percent need to investigate. It should be investigated whether alum sludge is possible to mix with others by-products. Further studies need to be carried out that by using 0.60 water content for the concrete mix.

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