Performance of Alum Sludge as partial replacement for cement adding superplasticizer

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Abstract. The production of alum sludge from waste water treatment plant is increasing all over the world. Disposal of alum is becoming a serious environmental problem. Another alarming issue is attributed to the high usage of concrete in the construction industry where concrete is one of its main material. This will lead to increased cement production and emission of carbon dioxide emission. Hence, the research for replacement of cement by alum sludge is essential to reduce both the emissions of carbon dioxide and the disposal problem of alum sludge. An attempt has been made to investigate the use of sewage sludge ash as partial cement replacement in concrete. The alum sludge is incinerated at the temperature of 600 and a duration of 3hours. The incinerated alum sludge is sieved through size of 150. Four different percentages of 5%, 10%, 15% and 20% of alum sludge (AS) is used to replace the cement in the concrete. XRD and XRF tests were carried out to determine the similarity component present in the AS. Water absorption test and slump test has also been carried out to check the capacity of water absorption, durability and workability of the AS concrete. The compressive strength of AS concrete is also determined through rebound hammer and compression test. Result show that AS has the potential to replace cement as the major chemical component of AS is similar to that of cement. 10% of AS concrete shows a lower absorption value than the control sample which shows that 10% SSA would have a better durability. However, an increase in the percentage of AS decrease the workability and compressive strength and yet, the 10% AS concrete possesses compressive strength higher than 25N/mm² which can be applied in structural application. The findings suggested that the suitability of alum sludge concrete in different cement replacement ratio is applicable for different usage. The application of alum sludge in concrete will directly reduce the quantity of the cement used which also decreases the emission of carbon dioxide and solving the disposal problem of alum sludge.

1. Introduction
This project is about on the replacement of alum sludge as part of the cement in concrete. Alum sludge is a waste product produce of water treatment plant. Because of the urbanization and development of populace, the measure of alum sludge has expanded quickly finished the years and is required to increment further [1]. Higher measures of alum sludge may influence the earth. In ebb and flow inclines, the alum sludge is arrange through land filling, sea disposal, arrive application and farming use. Late research has discovered that flow disposal strategies acted ecological issues such like water, air and air contamination. Land disposal is the least expensive approach to arrange the alum sludge among the strategies for the disposal since it likewise help to treat the land for developing products. Sludge really has the greatest amount when contrasted with the other item created by the procedure of
alum treatment, and it is discovered that it contains substantial metals in its synthesis[2]. Other than that, this report consists of the three chapters: Chapter 1, Introduction; Chapter 2, Literature Review; and Chapter 3, Research Methodology. After the three chapters, the experiment will show the result of the strength and workability of the concrete that mix with alum sludge.

Cremation wound up noticeably one of the options for the disposal of alum sludge. One of the researches at the Nanyang Technological Institute demonstrates that 550°C is a great condition for sludge cremation. The alum sludge was dewatered amid the filtration procedure from different water treatment plants in Singapore and was auto warm amid burning at 550°C. The motivation behind burning alum sludge at the temperature over 550°C is to expel any natural issue which is not appropriate in concrete generation.

2. Problem Statement

Expanding in populace will impact that more alum sludge will be produced. Thus, disposal of residential alum sludge turns into a huge issue because of time and space required and it is expanding the budgetary weight of wastewater treatment organizations. Disposal of local alum sludge without any appropriate way may cause various natural and wellbeing hazard related issues. Along these lines, the disposal of alum sludge must be direct to keep some significant issues in our nation. From the exploration we anticipated that in the time of 2020 that the created of alum sludge is around 1.32 billion every year. From the data of Indah Water Konsortium Malaysia, expressed that Malaysia creates more than 4.5 million cubic meters of residential alum sludge every year since 2005 and the volume of the alum sludge produce is expanding step by step. Alum sludge is one of the biggest waste material in Malaysia. Alum Sludge additionally a neighborhood ecological issue. The general sludge treatment had been forms before the sludge cake is transported to endorsement site for disposal. One of the real difficulties in the preparing of local alum sludge is much related with the administration of high dampness content. It is an exceptionally shaky natural issue in which set out to create awful gasses. The utilization of alum sludge as a non-customary development material had been examined and investigate because of the issues and confinements of disposal. The alum sludge is utilized as a filler and mixed cement material for concrete and it had been utilized as crude material to deliver development items, for example, blocks, lightweight total, tiles and clearing squares, and cementitious material.

3. Literature Review

3.1 Pozzolanic Materials

3.1.1 Alum Sludge

Alum sludge is a by-product of water treatment plant. Due to the urbanization and growth of population, the amount of alum sludge has increased rapidly over the years and is expected to increase further. Higher amounts of alum sludge may affect the environment. In current trends, the alum sludge is disposed through land filling, ocean disposal, land application and agriculture use. Recent research has found that current disposal methods posed environmental issues such as water, air pollution. Land disposal is the cheapest way to dispose the alum sludge among the methods of the disposal because it also helps to fertilize the land for growing crops. Sludge really has the greatest amounts when contrasted with the other item delivered by the procedure of alum treatment, and it is discovered that it contains substantial metals in its structure. Other than that, there are some insoluble issue likewise found in alum sludge, for example, natural issue, pathogens supplements, and metals. Alum sludge additionally contains solvent substances, for examples are minerals, salts and natural chemicals. Incineration became one of the alternative solutions for the disposal of Alum sludge[3]. One of the researches at the Nanyang Technological Institute shows that 550°C. The purpose of incinerating alum sludge was dewatered during the filter process from various water treatment plants in Singapore and
was auto-thermal during combustion at 550°C. The purpose of incinerating alum sludge at the temperature above 550°C is to remove any organic matter which is not suitable in concrete production.

3.1.2 Superplasticizer
SuperPlasticizer or also known as a high range water reduces. It is a chemical admixtures utilized where very much scattered molecule suspension is required. It utilized as dispersants to maintain a strategic distance from molecule isolation (Gravel, coarse and sands), and to enhance the stream qualities of suspensions. For example, in solid applications. When it includes into cement or mortar, it enables the lessening of the water to cement proportions however it does not influence the workability of the hardening of the fresh concrete. From research, we know that the strength of concrete increase when the water to cement ratio decreases. The addition of SuperPlasticizer in the truck during delivering the concrete is a fairly new development within the industry. Admixtures added in transit through automated slump management systems, such as Verify allows concrete producers to maintain slump until discharge without reducing concrete quality.[4]

3.1.3 Use of alum sludge as construction materials
Sludge that deliver from a water treatment plant may influence the groundwater quality and making domain issue. To tackle this sort of issue, the sludge can be utilized for concrete as fine total in the development territory that can decrease the negative impact on lands and can approach towards eco-accommodating development [5]. Research centre scale tests were done which cantered around the properties of alum sludge fiery debris as replacement materials in their capability to be utilized as to blend with cement. In the outcome demonstrate that STP sludge have a compound quality to the cement. Howard examined experimentally reuse water treatment infrastructure university kuala lumpur research journal vol 2 no.1 (2014).26 sludge from water treatment plant had been use as fine aggregates. Utilizing 10% and 20 % of water treatment sludge as a blend to make a heap bearing concrete piece [6]. The outcome demonstrate that it can decrease the cost and half water treatment sludge proportion in the blend. This could expedite a considerable measure of favourable circumstances transfer it will be the most noteworthy esteem workable for years to come. [7]

4. Result and Discussion

4.1. Workability
Workability is defined as the easement of the freshly mixed concrete can be placed, compacted and finished. In this study, slump test was chosen as the workability test for the fresh concrete. Every different batch of concrete. Due to its simplicity and convenience, slump test was carried out before the moulding of the fresh concrete. The slump test result is shown in Table 1

| Alum Sludge | Slump Level, mm |
|-------------|----------------|
| 0%          | 130            |
| 5%          | 115            |
| 10%         | 280            |
| 15%         | 164            |
| 20%         | 157            |

When we replace 5% cement with alum sludge, the value of slump result is 90mm but the slump is started to increase with replacement of 10% alum sludge, the result shows the slump level reach 120mm. The slump level reached the highest point which is 280mm when the replacement of alum sludge reached 15%. 15% of replacement is the best workability when concrete mix with alum sludge
as replacement of cement. Unfortunately, the slump level start to decrease to 157mm at 20% replacement as table shows. Alum sludge which have the ability to absorb water compared to cement powder has slightly reduced the slump of the concrete mix. The decrease in workability can be explained by two factors, which is the irregular morphology of alum sludge particle surface. The shape of alum sludge particles is not spherical which caused negative influence on workability. Alum sludge could slightly decrease the workability and strength of cement concrete due to high water demand of alum sludge.

4.2. Compressive Strength Test
Compressive strength test compressive strength of concrete is the most common performance measure used by the engineer in designing building and other structures. In this study, the test age of the concrete was 7 days, 14 days and 28 days 3 cubes were tested for each of the same concrete proportion in order to obtain the average data. The compressive strength result of various. Based on the result shown in Figure 1 the product which mix with alum sludge shown lower initial strength as compared with the control. The cement replacement of 10% alum sludge has shown the highest compressive strength of 36.41 Mpa at 28 day while the lowest compressive strength is the 20% replacement of cement, which is 15.48 Mpa. The replacement of alum sludge at 5% has increase the compressive strength up to 10% as compared with the control concrete. The compressive strength decrease as the percentage of cement replacement by alum sludge increases. The alum sludge concrete shows increase compressive strength with curing time and the compressive strength loss is proportional to the percentage increment of sludge.

4.3. Ultrasonic pulse velocity (UPV)
The results UPV test of high performance concrete made from thermally activated alum sludge and pozzolanic materials in binary and ternary blended binders that were tested and cured at 7 days, 14 days and 28 days show ranges from 15us to 35us, with readings that increase with age and curing time. Also all the measured UPV values were greater than 34us. The results are comparable with previous works for concrete with pozzolanic materials with the replacement of 5%, 10%, 15% and 20%. Based on the line graph above, the best result of UPV test is at the 10% of replacement. Result indicate that the trend of the UPV result of binary and ternary blended binders in high performance concrete with alum sludge is similar to the trend of compressive strength. It is found that the trend in UPV values shows an increase with increasing compressive strength for all the mixture. In other words, an increase in UPV is accompanied by an increase in the compressive strength. Other researchers have results have obtained similar results too.
Table 2. Ultrasonic Pulse Velocity Test at different curing age

| Percentage replacement | 7th days | 14th days | 28th days |
|------------------------|---------|-----------|----------|
|                        | Direct  | semi-direct | Direct  | semi-direct | Direct  | semi-direct |
| 0%                     | 25.23   | 19.67      | 28.2    | 21.57       | 29.27   | 21.11       |
| 5%                     | 32.1    | 21.4       | 32.3    | 21.2        | 32.43   | 22.53       |
| 10%                    | 32.9    | 22.9       | 33.4    | 23.8        | 34.7    | 24.32       |
| 15%                    | 21.9    | 20.46      | 22.87   | 21.26       | 24.09   | 22.24       |
| 20%                    | 25.34   | 19.63      | 26.77   | 19.86       | 28.08   | 20.15       |

4.4. Splitting Tensile Strength Test

The test result for the HPC across all mixtures are presented in Figure 2 that the tensile strength of behaved similarly to the compressive strength. The average tensile strength was within the permissible values, in accordance with design specification. The result revealed that concrete containing 6% AS has greater splitting tensile strength than the control concrete across all ages. Beyond this replacement level, the tensile strength decrease. The ratio of splitting tensile strength to compressive strength at 28 days was between 6.7 % and 7.2 %, which is lower than the result obtained from normal and medium strength concrete, which range from 8% to about 10 %. This result indicates that as the compressive strength of concrete increase, the ratio of splitting tensile strength to compressive strength decreases, which is consistent with the result of order studies on high strength concrete.

Figure 2. Splitting Tensile Strength Test Different Curing age

4.5. SEM Test

Microstructures of sewage sludge concrete. After SEM analysis of alum sludge concrete it can be observed the surface of the sludge concrete has dense enamel layer, SEM picture, the surface is almost not observed the existence of tiny openings hole. This surface characteristic determined the low water absorption of the self-made concrete. In the Figure 3, through the internal pore structure inside. The honeycomb pore structure wide speared in concrete which speared in concrete which determined high strength and light performance characteristics. Sludge concrete X-ray diffraction analysis shown in figure 3 & 4. From the enamel layer of alum sludge concrete wean found XRD pattern the main crystalline phases of the surface on self-made concrete is mullite. Millit is a very important product for sintering concrete, it is skeleton for concrete as strength microstructure formation. Cristobalite and mullite make the concrete have high strength and low water absorption, Sludge concrete performance. Using alum sludge can produce green high performance concrete. Internal pore structure of workability mineral admixtures make strength and workability of light weight aggregate concrete improve, but excessive addition could reduce concrete strength particularly in the early stage, so there is a reasonable dosage light strength concrete strength is increase with the decrease of water cement ratio, but for the limit of strength of light weight aggregate is not obvious when water cement ratio
reduced to a certain extent increasing sand ratio can improve concrete strength, but have adverse impact on the workability of fresh concrete. Using the study results, optimized the concrete mix proportion and prepared grade 40 light weight aggregate concrete with density level 1700 kg/m³ slump degree over 18 cm, extended degree over 50 cm.

5. Conclusion and Recommendation

The overall objective of the work was to investigate the feasibility of incorporating alum sludge as an additive material to concrete mix. This study included the preparation of concrete mixes containing alum sludge and the evaluation of sludge concrete properties in fresh and hardened states. The studying properties involved mix workability, compressive strength and density. According to experimental results, the usage of alum sludge in concrete mixes as an alternative of disposal for alum sludge is possible. The current type of sludge accumulated in dumping sites and the expected future type were used in making concrete mixes. The influence of both types on concrete properties was studied. In all cases there was an optimum quantity of sludge which can be used without introducing any change in mix preparation and acceptable properties were still be produced. The study showed that the dry sludge can be used in interlock brick production without changing the normal industrial process. Recommendation for further research The following recommendations are proposed for further research and study in order to from a complete picture of using sewage sludge in concrete mixes:

1) The durability of sludge concrete need comprehensive researches
2) Further research is needed to determine alum sludge effects on reinforcement if sludge concrete
3) The effect of drying temperature of alum sludge on concrete properties needs further research
4) Other studies are encouraged to obtain the effect of using different percent of sludge with concrete.

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