The potential of Lawin Tuff for Generating a Portland fly ash Cement to be Used in Oil Well Cementing

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***Abstract*-- This paper is about doing research using tuff in Lawin, Grik, Perak to generate Portland Fly Ash cement to be used in oil well cementing. Several tests are carried out according to API standard to determine the best proportion of tuff used to mix with Portland cement and generate best results. Results indicate it will increase the long term compressive strength, reduce fluid loss, good resistance to sulphate attack, less CO2 emission, Less permeable and more environmental friendly compare to coal fly ash. Future cement production should focus on Green Cement which is less hazardous.**

***Index Term*-- Tuff, fly ash, cement**

I. INTRODUCTION

a) Background Study

This project is done by doing research to use Lawin Tuff as substitute for Portland Fly ash cement in oil well cementing process. For the current time, there is no economic value for using tuff in Lawin. The study of the rock (tuff) characteristic and the new cement formed is important for both geological field and oil and gas cementing industry. The current Portland Fly Ash cement is made from industrial fly ash (Hossain, 2003; 2004; 2005) and since tuff is from volcanic ash, most probably tuff can replace fly ash and exhibit same characteristic in mix cement.

b) Significant of the Project

The meaningful use of volcanic tuff can not only transform it into a natural resource to produce low-cost cementing materials but also can help to decrease environmental hazards (created due to the deposition of volcanic materials on the land), leading to sustainable development. According to the Environmental Protection Agency (EPA), industry fly ash contains heavy metals, including nickel, vanadium, arsenic, beryllium, cadmium, barium, chromium, copper, molybdenum, zinc, lead, selenium and radium (Abali, et al, 2006). Additionally, traces of radioactive materials are present in fly ash. Given the large quantities of fly ash that are produced, a tremendous amount of radioactive waste is generated. This radioactivity is due to the elements in the decay chain of uranium and thorium, the radium is of great concern as 226Ra decays to form radon (222Rn) which has a half-life of days and is able to form mobile daughter radioisotopes.

The development of less expensive and environmentally friendly (the use of volcanic tuff as a cement replacement can lower greenhouse gas emissions associated with the production of cement as well as provide a safe way for the removal of such debris) volcanic tuff-based concrete with acceptable strength and durability characteristics can be extremely helpful in the development and rehabilitation of volcanic disaster areas around the world.

II. PROCEDURE

A) Sample Collection and Grinding

Lawin Tuff was collected at Grik, Perak. Approximately 10-13 kg of fresh volcanic tuff was collected from Lawin. The tuff is in big pieces and easily fractured. After that, raw materials are homogenized by crushing, grinding and blending using Mortar Grinder. The fine powder of tuff was then using 45 µM. At least 80% of the tuff must pass through 45µM sieve. It is recommended to sieve using 45 µM. This is because the fineness of tuff will greatly affect the properties of cement.

b) XRF Analysis

Chemical composition of the Lawin tuff will be analyzed using with **X-ray fluorescence (XRF)** (XRF) which is the emission of characteristic "secondary" (or fluorescent) X-rays from a material that has been excited by bombarding with high-energy X-rays or gamma rays.

c) *Preparation of Cement Slurry*

The absolute density of the pozzolan (Cavdar and Yetgin, 2005) and Portland type G cement are required to perform the calculation of tuff and cement needed for different mixing ratio. When used with Portland cement in oil well cementing, the amount of pozzolan is based on the absolute replacement of a portion of the Portland cement by an equivalent absolute volume of ash. These are designated by a ratio of percentages such as (35:65). The first number refers to pozzolan and the second number refers to Portland cement. The cement are mix with water ratio of 44% using Model 7000 Constant Speed Mixer.

TABLE I
VARYING PERCENTAGE OF TUFF IN CEMENT

Percentage of Tuff	Volume of Ash,gal	Volume of Cement,gal	Mass of Ash,lbm	Mass of Cement, lbm
0%	0.000	3.620	0.000	0.000
10%	0.362	3.258	7.421	84.708
20%	0.724	2.896	14.842	75.296
30%	1.086	2.534	22.263	65.884
40%	1.448	2.172	29.684	56.472

d) *Compressive Strength Test*

Compressive Strength is the force per unit cross sectional area that need to crush the cement specimen. In oil cementing, there are generally 2 types of cementing. One is lead slurry and the minimum compressive strength required to hold the casing is around 250-300psi while for tail slurry it requires higher density and larger minimum compressive strength of 500 psi for 24 hours (API Recommended Practice 10B-2). Three samples (cement cube) for each ash percentage variation will be tested. When cement has developed 500 psi compressive strength in 24 hours, the strength is usually sufficient to hold the pipe or casing in the well. The machine used for compressive strength test is OFITE Compressive Strength Tester Vr 2.03 Beta (Destructive)

e) *Fluid Loss Test*

Fluid Loss is the measurement of the water loss of the cement expressed in volume per unit time under reservoir pressure and temperature. The fluid loss will be directly proportional to the water cement ratio. In this experiment, we will fix the water cement ratio as **44%.** API fluid loss is double the filtration volume as long as blowout is not occurred during the test.

The volume of water obtained from the slurry will be collected and recorded manually using the OFITE Low Pressure Low Temperature (LPLT) Filter. The fluid loss tester is not advisable to be used for slurry samples which are to be tested below 250˚F because the OFITE LPLT Filter will yield similar result with lesser and simple procedures.

f) Thickening Time Test

Thickening time is a measurement of time during which cement slurry remain in a fluid state and is capable of being pumped. This is assessed under simulated downhole conditions using a pressurized consistometer that can measure the consistency of slurry over time. The end of thickening time is considered to be 100 Bc (API Recommended Practice 10B-2). Bearden Unit of Consistency (Bc) is a rheological properties of matter which is related to cohesion of individual particles of material ability to deform and resistance to flow.

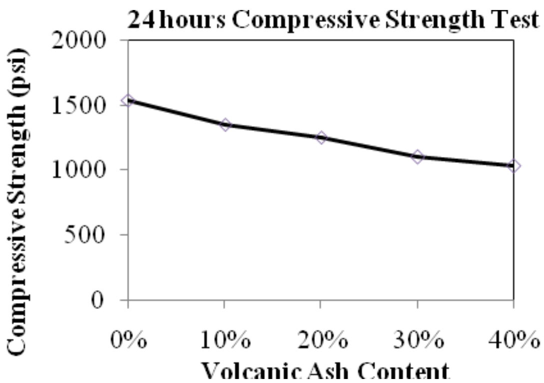
III. RESULTS AND DISCUSSION

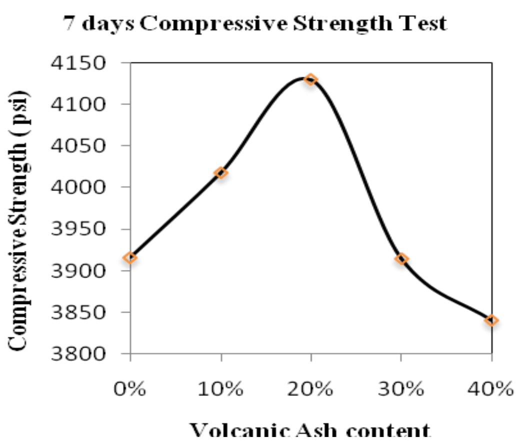
a) TABLE II
XRF Analysis

SiO_2	34.90%
Al_20_3	19.50%
Fe_2O_3	0.54%
CaO	21%
MgO	3.30%
K_2O	4.27%
Na_2O	0.60%
$S0_3$	2.80%

From the result, the composition of SiO_2 is about 34.9%. The value is less than the expected value because previous tuff collected from same location has shown average 50%-60% of SiO_2 (Personal Communication). The total silica composition which includes Al_20_3 and SiO_2 account for 54.4% and are suitable to be used as cement admixture. Studies have shown that the amount of SiO_2 is proportional to the compressive strength. The higher the SiO_2 content, the higher the compressive strength. Since the amount of SiO_2 is less, the compressive strength of the cement in the test is definitely less if compared to other types of volcanic tuff. However, the compressive strength of cement largely depends on the finest of the ash particles as well. Generally, there are two types of cement. Normal cement is hydraulic cement while those using ash is pozzolanic. From the XRF chemical analysis, the CaO content is quite high thus the Lawin tuff will poses both between pozzolanic and hydraulic reaction.

b) Compressive Strength



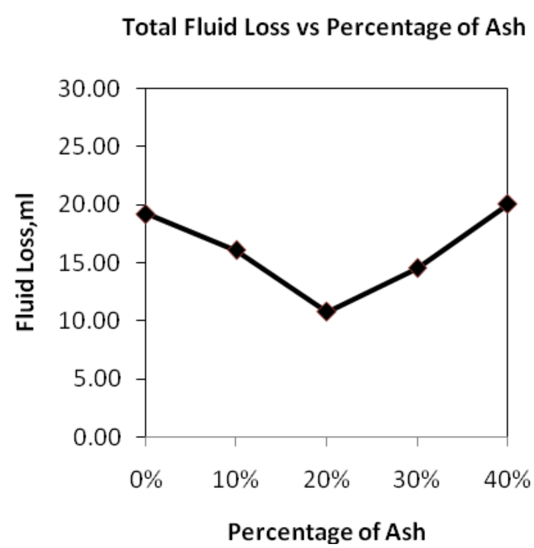


When cement and water react, the process is called **hydration**. Hydration of cement produces C-S-H gel, the strongest part of the "paste" in concrete, and it also produces calcium hydroxide, or free lime. Theoretically, excessive free lime can cause concrete to be too porous, but volcanic ash binds free lime over a long period of time, *increasing* compressive strength. Thus, adding volcanic ash *generally* creates a longer lasting concrete structure.

Benchmarks evaluating cement performance with respect to strength and permeability show that adding ash makes concrete *denser* by reducing water demand in cement. Cement with ash reaches its maximum strength more slowly than traditional cement, but the compressive strength is generally *greater* due to reduced permeability. Also, it substantially contributes to chemical resistance of concrete.

From the graph plot, the reduce strength for the 24 hours compressive strength test (early strength) after mixing cement and ash can be explained by the lower SiO_2 content in Lawin tuff. Calcium and silicon are present in order to form the strength-producing calcium silicates. Besides, due to equipment limitation, the mortar grinder could not used to grind rocks into fine powder as compared to grinder in cement industry. Since finest of ash will greatly affect the compressive strength of cement because ash will fill the void space between cement. From the 7 days compressive strength (long term strength) graph, we can see that 20% of volcanic ash will increase the long term compressive strength of cement. Thus, we can conclude that substitution of volcanic tuff will increase the long term compressive strength. If the volcanic tuff is able to grind finer, the compressive strength might reach higher value

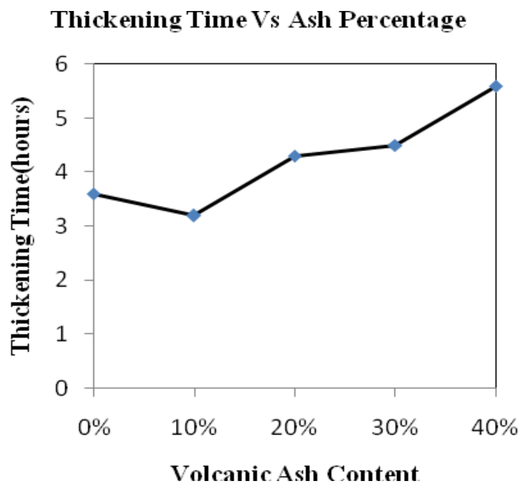
C) Fluid Loss Test



Higher Fluid loss indicates that the when cement is pumped into the well, it might require secondary cementing. The fluid will escape faster from cement and cause the hole to slough. In the fluid lost test, OFITE LPLT is preferred because no fluid lost material is added into the cement slurry and no pressure will be required to drain out the free water in the slurry. The amount of fluid lost is shown at the following table and graph.

It was found that cement slurry with ash will released less water as compared to the class G cement. The minimum fluid loss is cement with 20% ash and at 30- 40% fluid loss start to increase due to insufficient strength. It proves that during the cement reaction with water, fine particles of ash will react with excess calcium oxide and calcium hydroxide produce during the early reaction to form additional cementitious material of tricalcium silicate hydrates which filled the existing voids and thus reduce the porosity and also permeability of the cement slurry.

D) Thickening Time



Thickening time is time measurement where the cement slurry reaches the consistency of 100 BC. At field or laboratory, the slurry must be tested within 5 minutes after mixing. The cement slurry is placed in. It was found that 10% of ash cement will set at a faster time than Portland Type G cement. One key note here is Portland Type G cement is a slow reacting cement due to low heat of hydration. The reason is because in oil well, the depth of the well is very deep and requires time to be pumped into the desired depth. Thus, we would choose cement that has a longer thickening time or set longer. With the difference in the content of fast reacting substance between ash and G- cement which is tricalcium aluminate- higher rate of reaction during hydration period and therefore set at a faster time.

IV. CONCLUSION

Volcanic tuff in Lawin can increase the long term compressive strength of cement with addition of tuff up to 20%. However, finest of the tuff is important because it will greatly affect the compressive strength. For fluid loss, 20% of ash will have minimum fluid loss. In terms of thickening time, 10% of ash added to cement will increase the setting time.

Further analysis can be done to further confirm whether Lawin tuff is suitable to produce fly ash cement such as chemical and mineralogy analysis, pozzolanic activity test, strength activity index. Finally, economic evaluation can be done to estimate the profitability of using volcanic tuff in Lawin for generating Portland Fly ash cement. Future cement production should focus on Green Cement which is less hazardous.

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