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Effect of Fly Ash Fortification in the Manufacture Process of Making Concrete towards Characteristics of Concrete in Sulfuric Acid Solution

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Abstract

Fly ash is a silica or alumino silica material that can be used as a constituent of cement in the concrete manufacturing process. Utilization of fly ash aims to improve durability and minimize the reduction of concrete's compressive strength exposed to an acidic environment, which can be achieved through the pozzolanic reaction of fly ash with $Ca(OH)_2$ within concrete. The reduced content of $Ca(OH)_2$ through pozzolanic reaction will minimize the tendency of ettringite formation (compounds that cause deterioration and decrease the compressive strength of concrete). In order to determine the relation between fly ash replenishment into concrete with concrete's characteristics (compressive strength and durability) under acidic environment, the research is conducted by varying the fly ash composition ranging from 0%, 5%, 25%, 50%, up to 75%, and the concentration of H_2SO_4 solution as an immersion medium ranging from 0%, 5%, 10%, up to 15% (v/v). The research is carried out by immersing the concrete samples for 4 days in H_2SO_4 solution with various concentrations. Characterization of concrete's durability and compressive strength is reviewed from the concrete's weight loss percentage and reduction of concrete's compressive strength percentage after immersion. Based on the research results, for each variation of H_2SO_4 concentration used, the minimum concrete's weight loss percentage (maximum durability) and the minimum reduction of concrete's compressive strength percentage is found in the use of fly ash by 75%. For each concentration variations of H_2SO_4 solution as an immersion medium ranging from 5%, 10%, up to 15% (v/v), the minimum concrete's weight loss percentage was 0.47%, 0.87%, 1.28% (respectively), whilst the minimum reduction of concrete's compressive strength percentage was 5.71%, 14.29%, 17.14% (respectively). It was concluded that the use of fly ash can improve the durability and minimize the reduction of compressive strength of concrete exposed to an acidic environment.

Abstrak

Pengaruh Penambahan *Fly Ash* pada Proses Pembuatan Beton terhadap Karakteristik Beton di dalam Larutan Asam Sulfat. *Flyash* merupakan material *aluminosilica* yang dapat dimanfaatkan sebagai konstituen semen pada proses pembuatan beton. Pemanfaatan *flyash* bertujuan untuk meningkatkan daya tahan serta meminimalkan penurunan kekuatan tekan beton yang terpapar pada lingkungan asam. Hal ini dapat dicapai melalui reaksi *pozzolanic* antara *flyash* dengan $Ca(OH)_2$ yang ada di dalam beton. Menurunnya kandungan $Ca(OH)_2$ melalui reaksi *pozzolanic* akan meminimalkan terbentuknya senyawa *ettringite* (senyawa penyebab deteriorasi dan penurunan kuat tekan beton). Untuk mengetahui hubungan antara penambahan *flyash* terhadap karakteristik beton (kuat tekan dan daya tahan) pada lingkungan asam, maka penelitian dilakukan dengan memvariasikan komposisi *flyash* pada beton mulai dari 0%, 5%, 25%, 50%, hingga 75%, serta konsentrasi larutan H_2SO_4 sebagai media perendaman mulai dari 0%, 5%, 10%, hingga 15% (v/v). Penelitian dilakukan dengan merendam sampel beton selama 4 hari padal arutan H_2SO_4 dengan berbagai variasi konsentrasi. Karakterisasi daya tahan dan kuat tekan beton ditinjau melalui persentase kehilangan berat dan persentase penurunan kuat tekan beton setelah proses perendaman. Berdasarkan hasil penelitian, untuk setiap variasi konsentrasi larutan H_2SO_4 yang digunakan, diketahui bahwa persentase penurunan berat beton minimum (daya tahan maksimum) serta penurunan kuat tekan beton minimum ditemukan pada penggunaan *flyash* sebesar 75%. Untuk setiap variasi konsentrasi media perendaman larutan H_2SO_4 mulai dari 5%, 10%, hingga 15% (v/v), penurunan berat beton minimum secara berturut–turut adalah 0.47%, 0.87%, 1.28%, sedangkan penurunan kuat tekan beton minimum secara berturut–turut adalah 5.71%, 14.29%, 17.14%. Disimpulkan bahwa penggunaan *flyash* dapat meningkatkan daya tahan serta meminimalkan penurunan kuat tekan beton yang terpapar pada lingkungan asam.

Keywords: compressive strength, concrete, durability, fly ash, pozzolanic

1. Introduction

Coal is often used as a fuel in the various units of the power plant. The use of coal as a fuel, however, is impactful as it will produce hazardous waste. Therefore, this coal waste should be processed first by using solidification process to stabilize the hazardous component within waste and also prevent leaching to occur when the waste is disposed to the environment. The result of the coal waste solidification process is fly ash.

The addition of fly ash into concrete can improve the durability and compressive strength of concrete simultaneously. Increased durability and compressive strength of concrete occurs through pozzolanic reaction between fly ash with $Ca(OH)_2$ produced from cement hydration process, in which the product from pozzolanic reaction will fill the transition zone that exist in concrete [1]. Through the pozzolanic activity, the reaction between fly ash with $Ca(OH)_2$resulting from cement hydration process will produce a C-S-H compound, and then we know that there will be more C-S-H compounds formed in the concrete [2]. With more C-S-H compounds contained in the concrete, the compressive strength of concrete produced will increase. However, the development of compressive strength with the addition of fly ash additives through pozzolanic reaction will only be obtained after the concrete is more than 28 days old. This is due to the pozzolanic reaction that is running slower than the cement hydration process.

Along with the increasing number of C-S-H products formed by pozzolanic reaction of fly ash with $Ca(OH)_2$ from the cement hydration process, the density of concrete will increase. Increased density of concrete happens because more C-S-H compounds are formed. Then this additional C-S-H compounds will fill the transition zone in concrete so that the density of the concrete will increase. Along with the increase in density of concrete, the porosity and permeability of concrete will decrease as well, which in this case will increase the difficulty of acid to penetrate the concrete structure.

As discussed before, one way to utilize the fly ash waste is to use this material as a constituent of cement in concrete to improve durability and minimize the decrease in compressive strength of concrete exposed to an acidic environment. On the use of concrete as a construction material in the sewer in particular (acidic environment), certain characteristics must be fulfilled, e.g. concrete used must have a high resistance to acids, especially sulfuric acid so that the concrete does not easily deteriorate. This goal can be achieved bythe use of fly ash as a constituent of cement in concrete to improve its resistance to sulfuric acid [3]. However, the percentage of the addition of fly ash in concrete should also be noted because using too many fly ash can reduce the strength of the concrete produced [4]. Therefore, it is necessary to know the optimum composition of fly ash which can improve the durability of the concrete without compromising the compressive strength of concrete.

2. Experiments

Materials. Most chemical materials such as sand and Portland cement come from commercial products. The Portland cement comes from Semen TigaRoda brand. Meanwhile fly ash materialscomes from Suralaya electric steam power plant as a waste product. For the immersion media, a concentrated sulfuric acid solution (18 M) is used as a source solution which will be diluted.

Methods. This study begins with the stage of preparation of tools and materials.At this stage, there will be characterization of fly ash that will be used in this study. The test is conducted to determine the composition of fly ash quantitatively. This test is done by using X-Ray Fluorescence Spectrometer Systems (XRF Spectrometer Systems). The next step of theresearch will enter the stage of sample preparation. There are two samples that will be made here, which are concrete samples with variation of fly ash composition ranging from 0% (standard), 5%, 25%, 50%, and 75% (mass percentage) of the percentage of cement used in concrete (can be seen at Table 1) and H_2SO_4 solution samples with variation of concentrations ranging from 0% (standard), 5%, 10%, to 15% (percent by volume) (can be seen in Table 2). Size of the concrete samples used in this study is 5 x 5 x 5 cm. Time necessary for the concrete hardening process is 10 days (self-compacting concrete).

Table 1. Variations of Fly Ash Composition for Each Concrete Sample

Material	Standard (0% *fly ash*)	Sample 1 (5% *flyash*)	Sample 2 (25% *flyash*)	Sample 3 (50% *flyash*)	Sample 4 (75% *flyash*)
Cement	100 gr	95 gr	75 gr	50 gr	25 gr
Sand	120 gr	120 gr	120 gr	120 gr	120 gr
Water	50 gr	38 gr	30 gr	20 gr	10 gr
Fly Ash	0 gr	5 gr	25 gr	50 gr	75 gr

Table 2. Variations of Sulfuric Acid Concentration for Each Sulfuric Acid Solution

Material	Solution H_2SO_4 0% (v/v)	Solution H_2SO_4 5% (v/v)	Solution H_2SO_4 10% (v/v)	Solution H_2SO_4 15% (v/v)
Standard Sulfuric Acid Solution (18 M)	0 mL	25 mL	50 mL	75 mL
Distilled water	500 mL	475 mL	450 mL	425 mL
Total	500 mL	500 mL	500 mL	500 mL

After the concrete samples and H_2SO_4 solutions that will be used in this study were synthesized, theresearch will enter the stage of testing samples. At this stage, each sample of concrete with variation of fly ash composition ranging from 0% (standard), 5%, 25%, 50%, and 75% (mass percent) will be soaked in a solution of sulfuric acid with 4 different concentrations. Soaking process will be carried out for 4 days. To get each sample of concrete with variation of fly ash composition, 4 pieces of concrete samples willbe soaked into each solution of sulfuric acid with varied concentrations. It should be noted that additional samples will be used as one piece for each sample variation in the composition of fly ash. This is done because when the concrete has finished hardening process (curing) at day 10, there will be a test of compressive strength of concrete before it is finally soaked in a solution of H_2SO_4 with variation in concentration. Given that the compressive strength test performed is destructive, it is necessary to use five (5) additional samples, i.e. 1 piece of additional concrete sample for each type of concrete samples tested. So the total sample to be tested in this study were as many as 25 pieces of samples, 5 pieces were tested for compressive strength first after curing process while 20 pieces were used for soaking in varied concentration of sulfuric acid. Meanwhile for the immersion media, there will be 5 solutions for each sulfuric acid concentration, with 4 different sulfuric acid concentrations, so the total sample of sulfuric acid solution as an immersion media will be 20 solutions.

Characterizations. In this research, characterization process will cover about the durability of concrete as well as the value of reduction in concrete’s compressive strength as a result of immersion process of concrete in sulfuric acid solution. To characterize and determine the durability of concrete, an analysis of concrete weight loss percentage will be conducted. As it is known,any concrete samples which have undergone hardening process (after 10 days)will be immersed in a solution of $H_2SO_4$with variation in terms of concentration for 4 days. Before the immersion process starts, it is necessary to measure the value of the compressive strength of each concrete sample and measuring the weight of each sample of concrete. Only after that is done that the soaking process for each sample of concrete into H_2SO_4 solution with variation in concentration will begin. After immersion is carried out for 4 days, each concrete samples immersed in a solution of H_2SO_4 will be weighed again to determine the percentage of weight loss experienced by any concrete samples. Besides collecting data about weight of concrete sample, on day 4 after immersion process has completed, there will also be a testof compressive strength for each concrete sample in order to be able to determine the reduction of concrete compressive strength experienced by each concrete samples after immersion in H_2SO_4solution with varied concentration for 4 days.

3. Results and Discussion

Concrete compressive strength within sulfuric acid environment. Based on the data obtained by testing the compressive strength of concrete samples before and after immersion, it is known that the relationship between the addition of fly ash in concrete with the compressive strength of concrete at the immersion medium distilled water and H_2SO_4 solution will have different results. For concrete samples soaked in distilled water for 4 days, the concrete experience increasing compressive strength, while for concrete samples soaked in H_2SO_4 solution with various concentrations turned out to experience decreasing in the compressive strength (Figure 1).

The increased in compressive strength of concrete is also due to the use of distilled water as an immersion media, by using distilled water as an immersion media, the temperature of the concrete during the curing process (up to 28 days) is maintained in the range of 25 °C. Because the concrete temperature is at room temperature range, the development process of compressive strength runsoptimally. This occurs because the concrete compressive strength development process itself is influenced by the cement hydration reaction mechanism (hydration of C_3S and C_2S component to produce C-S-H compounds that contribute to the compressive strength of concrete), in whichthe hydration reaction is exothermic, and thus the heat of hydration released can cause the concrete experience thermal cracking process that will lead to cracking of the concrete [2]. With the presence of distilled water as the immersion medium of concrete samples, the heat of hydration released during the curing process can be minimized so that the temperature of the concrete samples is maintained stable. Therefore,

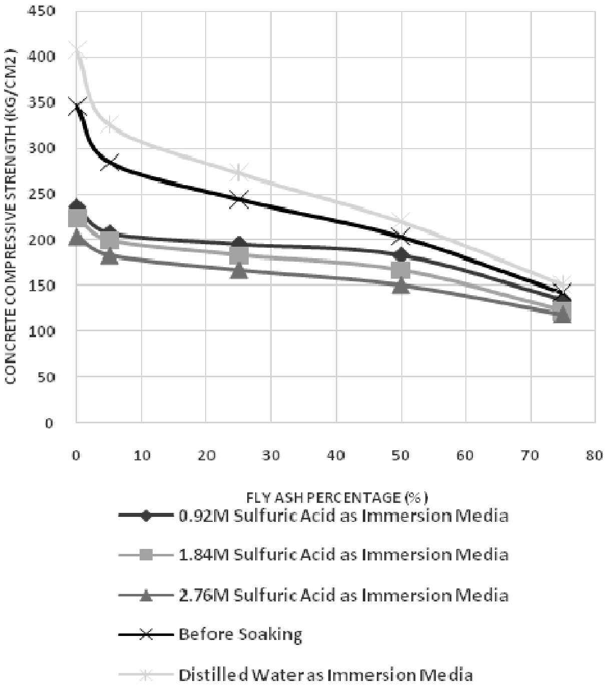

Figure 1. Relation of Fly Ash Replenishment in Concrete towards Concrete's Compressive Strength in Varied Immersion Media

the concrete compressive strength development process can run optimally without being affected by thermal cracking phenomena that may occur during the curing process.

The relationship between the percentages of fly ash utilization in concrete and compressive strength of concrete itself (prior to immersion) turned out to be inversely proportional. Based on the graph shown in Fig. 1, it can be seen that the higher percentage of fly ash used as a constituent of cement, the compressive strength of concrete produced will be lower. The lower percentage of fly ash used, the compressive strength of concrete will increase, approaching the compressive strength of standard concrete (without fly ash). The reduction in the value of compressive strength of concrete for the use of fly ash with high percentage occurs because less number of C-S-H ($3CaO.2SiO_2.3H_2O$) bonds were formed. As it is known, the compound that contributes to the compressive strength of concrete is a C-S-H compound (calcium silicate hydrate) that can be generated through two mechanisms: first through the mechanism of cement hydration (hydration component of tri-calcium silicate and di-calcium silicate) [5] (can be seen in Eq. 1 and Eq. 2), and second through the pozzolanic reaction between SiO_2 and Al_2O_3 components of fly ash with a compound of $Ca(OH)_2$ produced from cement hydration reaction (can be seen in Eq. 3). $Ca(OH)_2$compounds produced as a byproduct of the hydration reaction of tri-calcium silicate component and di-calcium silicate component will form calcium silicate hydrate compounds.

$$2(3CaO\bullet SiO_2)+6H_2O\rightarrow 3CaO\bullet 2SiO_2\bullet 3H_2O+3Ca(OH)_2 \quad (1)$$

$$2(2CaO\bullet SiO_2)+4H_2O\rightarrow 3CaO\bullet 2SiO_2\bullet 3H_2O+Ca(OH)_2 \quad (2)$$

$$2(Al_2O_3\bullet 2SiO_2)+7Ca(OH)_2\rightarrow 2(2CaO\bullet Al_2O_3\bullet SiO_2\bullet H_2O)+3CaO\bullet 2SiO_2\bullet 3H_2O \quad (3)$$

With the increasing percentage of fly ash used, the cement used in the concrete manufacturing process will decrease because the function of fly ash is as a constituent of cement in the concrete manufacturing process. By decreasing the amount of cement used, the compound of C-S-H and $Ca(OH)_2$ which is formed by the reaction of cement hydration (Eq .1 and Eq. 2) will be fewer. Fewer C-S-H compounds will lead concrete to have poor compressive strength, while fewer compounds of $Ca(OH)_2$ caused the product of C-S-H compounds derived from pozzolanic reaction (Eq. 3) tobe lessen [5]. With fewer total C-S-H compounds formed by two reaction mechanisms that exist, the concrete compressive strength will be lower for the use of fly ash with higher percentage. Please note that the pozzolanic reaction rate is much slower than the rate of cement hydration reaction, so the development of the compressive strength of concrete samples using fly ash will be longer when compared to concrete that does not use fly ash.

Another reason that contributes to the relationship between utilization of fly ash in concrete and concrete compressive strength (before the immersion process) is in terms of the type of fly ash used. Based on the results of XRF characterization for fly ash samples used in this study (as listed in Table. 3), it can be concluded that this

Table 3. Results of XRF Sample Characterization of Fly Ash Used

FlyAsh	
Chemical Component	Percentage (%)
SiO_2	45.99
Al_2O_3	20.99
Fe_2O_3	13.54
CaO	11.71
MgO	5.69
SO_3	0.59
Na_2O	0.74
K_2O	0.75

type of fly ash used in this study is categorized as type F. Classification of fly ash into the category of type C or type F depends on the CaO content within it. For type C fly ash, CaO content within it should be ranging at 15-30%. While the type F fly ash has CaO content less than 15%. The low content of CaO compounds in fly ash type F cause this type to be suitable for use as a constituent of cement in the concrete manufacturing process that will be exposed to an acidic environment [6]. However, the use of type F fly ash has a drawback in terms of compressive strength development. Concrete using fly ash type F will have the value of a low early setting strength, unlike the use of type C fly ash with high CaO content so the concrete have a good early setting strength.

For the immersion media used in the form of sulfuric acid solution with a variation concentration ranging from 0.92M, 1.84M, and 2.76M, it can be seen in Fig.2 that the use of sulfuric acid as an immersion mediawill decrease the value of concrete compressive strength. Due to a higher acid concentration, the decrease in terms of compressive strength of concrete samples that occurs will be even greater.The maximum reduction of compressive strength occurs at immersion media of sulfuric acid with concentration of 2.76M.

Based on the graph in Fig. 2, the largest reduction percentage in concrete compressive strength certainly occurs in the H_2SO_4 solution with the highest concen-tration (2.76M) as an immersion media. This happens because the higher the concentration of H_2SO_4 solution as immersion media is associated with the large amount of SO_4^{2-}ions within the solution. Increasing number of

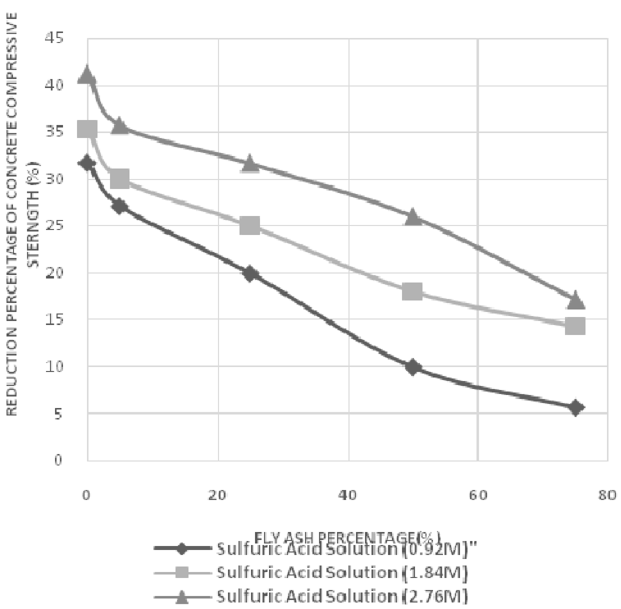

Figure 2. Relation of Fly Ash Utilization towards Reduction Percentage in Concrete Compressive Strength for H_2SO_4 Solution as Immersion Media

SO_4^{2-} ions content is causing the SO_4^{2-} ions topenetrate into the internal structure of concrete easier. Additionally,the possibility of SO_4^{2-} ions to react with the $Ca(OH)_2$ to form gypsum within concrete will also increase (can be seen in Eq. 4). The more gypsum formed in concrete will facilitate the formation of ettringitecompounds(can be seen in Eq. 5) which is a product of the reaction between gypsum with C-A-H ($3CaO.Al_2O_3.6H_2O$). The higher content of ettringite ($3CaO.Al_2O_3.3CaSO_4.12H_2O$) formed, the lower the compressive strength of concrete produced. As for the lower concentration of immersion media, it corresponds with less SO_4^{2-} ions that will penetrate into the internal structure of concrete to react with $Ca(OH)_2$ to form gypsum. The less gypsum formed means the less ettringite formed. This is why the smallerreduction percentage in concrete compressive strength corresponds to a low concentration of H_2SO_4 solution as the immersion medium.

$$H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 \bullet 2H_2O \quad (4)$$

$$\begin{aligned} &3(CaSO_4 \bullet 2H_2O) + 3CaO \bullet Al_2O_3 \bullet 6H_2O \\ &\rightarrow 3CaO \bullet Al_2O_3 \bullet 3CaSO_4 \bullet 12H_2O \end{aligned} \quad (5)$$

The decrease in the compressive strength of concrete in the immersion media of H_2SO_4 solution occurs through the mechanism of ettringiteformation. The formation of ettringiteoccurs via the reaction between gypsum ($CaSO_4.2H_2O$) and C-A-H compounds ($3CaO.Al_2O_3.6H_2O$) inconcrete [5]. While gypsum compounds formed as a result of the reaction between SO_4^{2-}ions (derived from H_2SO_4 solution) with $Ca(OH)_2$ which is a byproduct of cement hydration reaction [7]. With more $Ca(OH)_2$ components in concrete, gypsum formation will accelerate and trigger theformation ofplenteous ettringite compounds. Ettringite is a compound which has a low density, and therefore the presence of these compounds in the concrete can reduce the density of concrete and cause the concrete to experience the process of expansion and cracks that lead to the low value of compressive strength of concrete produced.

Change in concrete weight within sulfuric acid environment. Based on the data obtained, it can be seen that the relationship between the utilization of fly ash in concrete with weight loss percentage of concrete before and after immersion in the sulfuric acid solution is found to be inversely proportional relationship. The greater the percentage of fly ash utilization in concrete, the smaller the weight loss percentage of the concrete samples. This can be seen in Fig. 3. However, for the immersion media such as distilled water, we obtain that the relationship is directly proportional, in whichthe greater percentage of fly ash used, the bigger the weight gain percentage of concrete samples. For immersion media such as distilled water, the increasein concrete weight is due to the water that penetrates into the internal

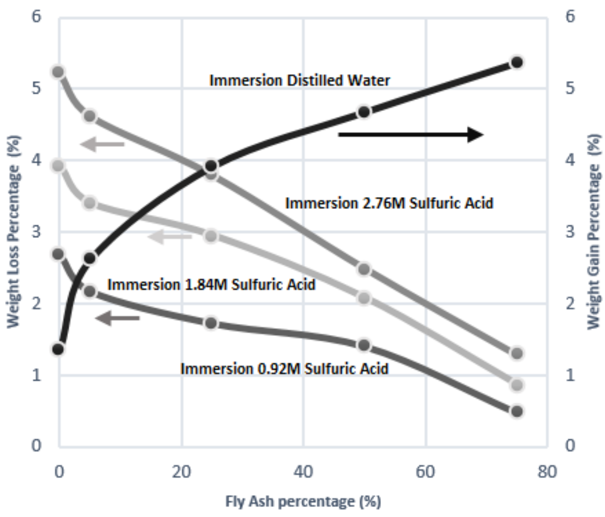

Figure 3. Relation of Fly Ash Replenishment in Concrete towards Concrete's Weight Change Percentage in Varied Immersion Media

structure of concrete, where there is a possibility of water entering into the internal structure of concrete that reacts with the cement components that have not undergone hydration process before.Thisleads to the formation of additional C-S-H compounds. It is still likely to happen considering that the concrete samples were immersed at the age of 10 days, whereas in the age of concrete that still undergoes development process in terms of compressive strength (until day 28). The presence of this additional C-S-H compounds cause the concrete to experienceweight gain for the use of distilled water as an immersion media.

Based on the graph in Fig. 3, it can be seen that the lowerpercentage of fly ash used in concrete, the lowerweight gain percentage of concrete for distilled water as immersion media. One thing we can observe from the graph is the porosity of the existing concrete samples. The less fly ash used, the more dense (low porosity) concrete structure will be. This is related to the amount of C-S-H compounds formed from the reaction of cement hydration. Due to the dense structure of the concrete samples with no / little use of fly ash, the amount of water that can penetrate into the internal structure of concrete is just a few, andthiscan be seen from the small percentage of weight gain of concrete samples. As for the samples of concrete using higher percentage of fly ash, there will be fewer C-S-H compounds that exist in the concrete, and thiscan be seen through the low value of compressive strength of concrete that corresponds to higher percentage of fly ash used as constituent materials (as in the discussion of section 3.1). Fewer C-S-H compounds formed with increasingthe percentage of fly ash used causes the internal structure of concrete to becomeless dense. This happens because the C-S-H compound is a compound that plays an important role in the nature of concrete density [8]. With less dense concrete, the concrete samples will certainly have a high porosity. This can be seen by an increase in the weight gain percentage of concrete after immersion in distilled water media for 4 days. The higher percentage of fly ash used in concrete will cause the weight gain percentage of concrete to increase.

For the immersion media used in the form of sulfuric acid solution, it can be seen in Fig. 3 that increasing the percentage of fly ash used in concrete will decreasethe weight loss percentage of concrete samples. This occurs because the use of fly ash with higher percentage indicates that the cement used for the manufacture of concrete will decrease. Decreasing the amount of cement used will result in a decrease on $Ca(OH)_2$ compound which is formed as a byproduct of cement hydration reaction (Eq. 1 and Eq. 2). Fewer $Ca(OH)_2$ formed from cement hydration reaction, coupled with the use of many fly ash, will also decrease the percentage of $Ca(OH)_2$ compound, wherein the $Ca(OH)_2$ compound will be consumed by fly ash through pozzolanic reaction to produce the additional C-S-H compounds (Eq. 3). Small amount of $Ca(OH)_2$ compounds are found in the internal structure of concrete because this compound is minimized in two ways – first by minimizing the use of cement (multiply the use of fly ash) and second through pozzolanic reactions that consume the $Ca(OH)_2$ compounds to produce C-S-H compounds (Eq. 3). It is why high number of fly ash used will have an impact on the low value of weight loss percentage of concrete samples because the presence of fly ash in concrete can minimize the formation of gypsum from the reaction between the SO_4^{2-} ions with $Ca(OH)_2$ (Eq. 4) by consuming $Ca(OH)_2$ through pozzolanic reaction [9]. The low percentage of gypsum compounds that exist in the concrete will also minimize the deterioration phenomena of concrete through the mechanism of ettringite formation (Eq. 5), where the deterioration of the concrete causes decreased in concrete weight.

Physical change of concrete within sulfuric acid environment. After immersion runs for 4 days, concrete samples are removed from the immersion medium and dried for 1 day in advance. After drying process is complete, it can be seen that for concrete samples soaked in a H_2SO_4 solution, physical surface of concrete samples becomes uneven and there is a hole in the surface of concrete samples. Roughness and holes in the surface of the concrete samples are more apparent on standard concrete samples (0% fly ash), sample 1 (5% fly ash), and sample 2 (25% fly ash) that were soaked in H_2SO_4 solution (Fig. 4). Physical changes that occur on concrete is due to exposure to an acidic environment that causes the concrete to undergo a process

Figure 4. Appearance of Concrete Samples after Immersion Process

Figure 5. Structures of Morphology of Concrete Surface (Magnification 35x) Soaked in Distilled Water (Left) and in 2.76M Sulfuric Acid Solution (Right)

of deterioration. Deterioration process occurs through the mechanism of ettringiteformation (Eq. 5), which in turn will lead concrete to undergo a process of expansion and cause holes and cracks on the surface of concrete samples.

To ensure the deterioration process of concrete samples that occur in the immersion media H_2SO_4 solution is through the mechanism of ettringite formation, the analysis is conducted against the morphology of concrete surface. Concrete sample to be analyzed is the standard sample (0% fly ash) that wassoaked in distilled water and H_2SO_4 solution with concentration of 2.76M. The selection of the sample to be analyzed is based on the physical appearance which is very distinctive between standard concrete samples soaked in distilled water and in H_2SO_4 solution with concentration of 2.76M. To see the better effect of H_2SO_4 solution to the ettringite formation deterioration, the chosen concrete samples that aregoing to be analyzed are the concrete samples that do not use fly ash.

Based on the results of the microscope photograph made with a magnification of 35 times, can be seen in Fig. 5, there are differences in the surface morphology of concrete samples soaked in distilled water media and H_2SO_4 solution with concentration of 2.76M. Concrete samples soaked in distilled water media show the surface morphology with larger pore structure when compared with concrete samples soaked in H_2SO_4 solution with concentration of 2.76M. Shrinking pore structure on the surface of concrete samples soaked in H_2SO_4 medium happens due to the formation of ettringite compounds (Eq. 5) as a result of the reaction between the gypsum (resulting from reaction between SO_4^{2-} ions with $Ca(OH)_2$ as stated in Eq. 4) and C-A-H within concrete [9]. Ettringite compounds is formed on the surface of concrete samples, andthis can be determined based on the change in color of the surface of concrete samples after immersion. After immersion, it is known that the surface color of concrete samples soaked in H_2SO_4 media tends to have a light gray color (nearly white), while the concrete samples soaked in distilled water media remains dark-colored (Fig. 4). Discoloration in concrete surface occurs due to the formation of ettringite compounds on the surface of concrete samples soaked in H_2SO_4 media, as it is known that the ettringite compound is categorized as sulfate hydrate compound which has a white color.

The downsizing process of the pore structure on concrete surface happensdue to the formation of ettringite. The downsizing pore structure of concrete surface can occur considering the nature of the ettringite compounds itself forthis compounds are categorized as amorphous compounds. Actually,ettringite compound itself was originally a compound useful for preventing the flash set of concrete when the concrete experiences the hydration process. For that purpose,gypsum is often added into the cement which aims to react with C_3A compounds to form ettringite. The aim of ettringite formation is to form a protective layer on the surface of C_3A compounds that are useful for reducing the permeability of C_3A compounds so that the hydration process of C_3A can be slowed in order to prevent flash set in concrete [5]. Nevertheless,ettringite formation caused by the influence of SO_4^{2-} ions originating from the acidic environment has a negative impact on the durability and compressive strength of concrete. Ettringite formed through a mechanism known as the acid attack is called delayed ettringite (Eq. 5). Formation of delayed ettringitecompounds ($3CaO.Al_2O_3.3CaSO_4.12H_2O$) will lead concrete to experience the expansion process so that there is accumulation of delayed etrringite compounds on the surface of concrete samples. Through this accumulation, the pore structure of concrete samples become smaller because it is the nature of ettringitecompounds to form a protective layer which serves to reduce the permeability of compounds overlaid.

4. Conclusions

The use of fly ash as a constituent of cement in the concrete manufacturing process can minimize the percentage of concrete weight loss (increase durability) and also can minimize the reduction of concrete compressive strength exposed in H_2SO_4 solution.This can be achieved through pozzolanic reaction between $Ca(OH)_2$ compounds in concrete andfly ash. Reduced $Ca(OH)_2$ compounds in concrete can minimize the formation of gypsum compounds which area precursor for ettringite compounds, and these ettringite compounds play a role to reduce the durability and compressive strength of concrete.Minimum weight loss percentage as well as minimum reduction of concrete compressive strengthoccurs in the sample of concrete with maximum usage of fly ash for as much as 75% for each variation of concentration of sulfuric acid solution used as immersion media (ranging from 0.92M, 1.84M, 2.76M), withthe minimum weight loss percentage of 0.47%, 0.87%, 1.28%, respectively, and the minimum reduction percentage of concrete compressive strength is 5.71%, 14.29%, 17.14%, respectively.

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