THE USE OF SILICA FUME WASTE IN THE MIXTURE IN AN EFFORT TO APPLY GREEN CONCRETE

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The construction of building structures in developing countries today continues to be encouraged to support the progress of a country, for example in Indonesia. Development is essentially aimed at improving the welfare of the community by building various supporting facilities and assets in community life such as the construction of high-rise buildings, bridges, infrastructure, and many more.

There are many materials used in construction projects, and concrete is one of them. Concrete is the most widely used material in construction work today. Because concrete has several advantages compared to other materials, such as being easy to form, resistant to weather changes, high compressive strength, and long-lasting life.

In concrete technology, silica fume (SF) is used as a partial substitute for cement or as an additive material in concrete mixtures. Silica fume is a waste product of silicon metal or ferrosilicon alloy. According to the standard, "Specification for Silica Fume for Use in Hydraulic Cement Concrete and Mortar" (ASTM. C. 1240, 1995: 637-642), silica fume is a fine pozzolan material, where the composition of silica is more produced from the rest of the manufacture of silicon and silicon iron alloy.

Green concrete is concrete composed of materials that do not damage the environment. One of them is in the form of replacing the aggregates that makeup concrete with materials that do not damage the environment. for example, the use of silica fume waste as an added or substitute material for cement material. The increasing demand for concrete materials has triggered the mining of limestone, one of the constituent materials of concrete as cement, on a large scale which has led to a decrease in the amount of natural resources available for concrete purposes. In green concrete, the use of cement as a constituent of concrete can be replaced with silica fume derived from silicon iron alloy waste.

Cement is a hydraulic adhesive building material, meaning it will be an adhesive when mixed with water. The basic material of cement, in general, there are 3 types of clinker/slate cement (70% to 95%, is the result of processed burning of limestone, silica sand, iron sand, and clay), gypsum, and third materials such as limestone, pozzolan, fly ash, and others. If the third element is not more than about 3% generally still meets the OPC (Ordinary Portland Cement). But if the content of the third material is greater to approximately 25% maximum, then the cement changes category to PCC (Portland Composite Cement). Cement cannot react without water as a reaction. Cement and water are included in adhesives which after being mixed undergo a chemical reaction to form a paste and within a few hours it begins to harden and within a few days becomes hard. The chemical reaction between cement and water can be written as follows:

$$2(3CaO.SiO_2) + 6H_2O \rightarrow 3CaO.2SiO_2.3H_2O + 3Ca(OH)_2$$

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

Where :

$CaO.SiO_2$ = Elements in cement (calcium silicate).

H_2O = Water.

$CaO.SiO_2.H_2O$ = Tobermorite, the result of a strong reaction.

$Ca(OH)_2$ = Free lime, byproducts.

Based on the Specification for Silica Fume for Use in Hydraulic Cement Concrete and Mortar (ASTM-C618-86) standard, silica fume is a material that contains SiO_2 greater than 85% and is a very smooth round material and 1/100 diameter of cement (Kusumo, 2013). The particles can fill an empty cavity so that in theory they can add a strong press on concrete [1]. The results of porosimeter testing using mercury absorption procedures, obtained a median size distribution of 8.53-micron meters, an average pore radius of 0.13-micron meters, and a special surface area of 216.0 m^2/ gram. Silica content (SiO_2) is very high at 93.09%, and the provision regarding ASTM C 1240-93 requires a minimum of 85% [2].

Silica fume has an important role to play in the influence of the chemical and mechanical properties of concrete. Judging from its chemical properties, geometrically silica fume can fill cavities between cement materials, and cause the diameter of the pore to shrink and the total volume of the pore is also reduced. While from its mechanical properties, silica fume has a reaction that is pozzolan that reacts to limestone released cement. Because the content of SiO_2 is high enough, hydration of water and cement will make $Ca(OH)_2$ react with silica oxide (SiO_2) to produce calcium silicate hydrate, where C-S-H affects the hardness of concrete.

Table Chemical composition and physical properties of the cement, fly ash, and silica fume.

Chemical composition (% by mass)	Cement	Fly Ash	Silica Fume
Silica (SiO_2)	21.14	54.46	85.32
Alumina (Al_2O_3)	5.38	21.70	0.84
Iron oxide (Fe_2O_3)	3.22	8.85	0.91
Calcium oxide (CaO)	63.24	4.45	0.56
Magnesium Oxide (MgO)	1.19	1.48	0.45
Sodium Oxide (Na_2O)	0.28	1,03	1,04
Potassium Oxide (K_2O)	0.54	3.85	1,01

Sulfur Trioxide (SO3)	2.34	0.59	0.66
Specific gravity	3.24	2.21	2.19
Blaine fineness (cm2 /g)	3429	3850	165

According to (Bantot Sutriono Google Scholar) a mixture of concrete that uses silica fume at the age of 28 days, the mixture that has the maximum compressive strength is found in the mixture which has a silica fume percentage of 8%, which is 312.574 kg/cm2. The compressive strength increased by 3.8% from the control concrete compressive strength of 271,290 kg/cm2. This is due to the pozzolanic effect contained in silica fume. Silica fume reacts with calcium hydroxide produced in the reaction between cement and water to form a new calcium silicate hydrate (C-S-H) gel in the mixture which can increase the bond between the cement paste and the aggregate, in addition to that the diameter size of silica fume which is about 1/100 of cement has a The advantage is that it can fill the voids in the transition zone between the paste and the aggregate, and the lowest compressive strength was obtained in a mixture with a percentage of 15% silica fume, which was 209.365 kg/cm2. The decrease in strength occurs because the higher the percentage of silica fume as a partial cement replacement material causes less cement material to react with water to form CSH gel and calcium hydroxide, in addition to the higher percentage of silica fume, which causes a lot of residual silica fume not to react with calcium hydroxide and form CSH gel is new and only functions as a filler in the cavity between the cement paste and the aggregate [3].

According to (Retno Trimurtiningrum Google Scholar) The addition of added material in the form of silica fume has an effect on the compressive strength of concrete compared to a mixture without the addition of silica fume. This can be explained scientifically that the nature of silica fume can react with Ca(OH)2 (calcium hydroxide) which is the residue from the hydration of cement. The reaction of the two produces CSH (calcium silicate hydrate). This reaction of CSH fills the empty spaces in the cement paste, thereby making the concrete denser and the permeability of the concrete to be low. Having low permeability properties can improve the quality of concrete and make concrete more impermeable and protected from substances that damage concrete such as chloride ions [4].

Research conducted by (Ariningrum et al, 2021) [5] Replacement of cement with silica fume with variations of 5%, 10%, and 15% for cement, compressive strength concrete age 90 days in a row is 42.24 Mpa, 43.53 Mpa, and 45.42 Mpa. Compressive strength concrete with silica fume instead of cement can increase the optimal compressive strength value by 15%, which is 45.42 Mpa at 90 days. Concrete that uses silica fume as a substitute for cement has low permeability because silica fume can fill empty spaces and cause concrete mixtures to undergo a saturated process or become tighter than can increase press strength.

Research by (Xiadong Ma et al, 2021) [6] The strength of the sample increased by silica fume may be attributed to the physical effect and chemical reaction of silica fume itself. The fine particles of silica fume itself increased the compactness and reduced the porosity by filling the voids between the particles of the matrix, making the stacking between the particles of different materials closer, which was its physical effect of having a positive effect on the growth of strength. The amorphous silica can react with the hydration product CH of cement and consume CH to produce C-S-H, which can be the chemical reaction of silica fume. In addition, silica fume can act as a nucleation site for the induced hydration products due to its extremely fine particles, accelerating the reaction and forming smaller CH crystals. However, in this experiment, the increase of silica fume has no significant effect on the early strength of the sample until 7 days, which may be caused by the large porosity of the matrix itself, the minimum content of silicon powder (≤ 3.0%), and the filling and reaction capacity of silicon powder only equal to or even less than the amount required by the matrix itself. Therefore, the early gain effect was not obvious. Generally speaking, the gain effect of silica fume on strength is not reflected until 7 days.

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