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THE EFFECT OF FLY ASH UTILIZATION IN REINFORCEMENT CONCRETE: A REVIEW

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ABSTRACT: Indonesia signed the Paris Agreement on facing climate change. Carbon dioxide is the main issue contributing to the greenhouse effect. Most power plant in Indonesia uses non-renewable energy to generate electricity. Increasing demand for electricity makes increasing coal consumption for steam power plants and directly contributes to greenhouse gasses from coal combustion and produces fly ash as a waste product. Otherwise, fly ash from Steam Power Plant is classified as pozzolanic materials being a part of substitution ordinary portland cement (OPC) on making reinforcement concrete. Many Researchers studied reinforcement concrete from fly ash composition and others development using renewable energy resources such as biomass. This paper presents a literature review on focus studying the properties of various types of fly ash and their effect on the performance of concrete, including corrosion resistance.

KEY WORDS: Fly ash, and Reinforcement Concrete.

1. INTRODUCTION

growth. Sustainable development [1] requires durable and robust materials for supporting infrastructure. Terms of civil engineering work include design and construction, especially in building construction, roads, ports, airports, and irrigation buildings, which have benefits to improve the community's welfare and standard of living [2] in a country. In this case, concrete has an essential role as material construction in infrastructure.

The combination of concrete and steel is reinforced concrete [3], the primary construction material in the 20th century. Reinforced concrete is expected to remain the primary construction material in the 21st century. Reinforced concrete and having advantages in the characteristics of the material are also cheap in terms of economy. Therefore, reinforced concrete has become the primary construction material in infrastructure development commonly in our country today. For example, reinforced concrete that is rigid is chosen as a road pavement material because it is cheaper and of higher quality than asphalt.

At first, concrete [4] is a semi-permanent construction material. Semi-permanent properties are a material that can last until their service time without the need for special maintenance. However, the results of field investigations and laboratory studies show that concrete can be damaged by environmental conditions [5] in the vicinity if not adequately maintained [6].

Concrete has advantages including high compressive strength, easy to shape according to the needs of building structures, resistance to high temperatures, ease to obtain concrete constituent materials, especially in Indonesia, and low maintenance costs. Concrete also has drawbacks, namely workability and density to water (permeability) depending on the nature of the material, the formation of pores originating from the hydration process (water and cement), and the remaining water that evaporates in the concrete after the hydration process which causes the concrete to be impervious to water [7].

The increasing economic growth in a country has an impact on increasing infrastructure. In this case, cement for concrete has an essential role in infrastructure development. Fly ash is waste from the combustion process at the Steam Power Plant (PLTU) [8] with raw materials from coal. Based on statistical data from the Ministry of Energy and Mineral Resources, coal production in Indonesia in 2017 reached 461 million tons. The coal combustion process will produce about 5% of solid pollutants in ash, with about 10-20% in bottom ash and 80-90% in fly ash of the total ash produced [9]. Pozzolanic Portland Cement (PPC) production is more environmentally friendly than OPC, which produces global carbon emissions of around 7% [10]. Fly ash is used as pozzolanic materials to substitute OPC cement uses.

Fly ash utilization based on renewable energy from biomass could be part of the strategy in achieving the Renewable Energy Mix 23% 2025 in Indonesia [11] and could contribute to reducing CO_2 emission.

2. FLY ASH CONCRETE CHARACTERISTIC IMPROVEMENT

There have been many research works on the utilization of fly ash in improving the quality of concrete and decreasing global emissions. Fly ash utilization of coal waste combustion is developed in building materials technology with various mixtures to get higher-strength concrete [11]. In its utilization of high-quality concrete, fly ash has the size of smooth granules, and this makes concrete denser. This density prevents the formation of cavities between aggregates. Fly ash can minimize pore better compared to ordinary portland cement (OPC). As pozzolanic materials, fly ash can substitute non-renewable energy resources such as coal with renewable energy such as biomass [12], [13]. Below is some research that focuses on shifting characteristics with fly ash and portland cement mixture in concrete.

Table 1: Research on Fly Ash Utilization and its effect of concrete properties

References	Research Focus	Result
[14]	Investigate in Meta-kaolinite based geopolymer has been synthesized under activation of NaOH solution and sodium silicate solution, and its effect on the mechanical and chemical properties was investigated by infrared spectrometry, SEM, and XRD	Increasing concentration NaOH solution had an effect in increasing mechanical properties and capability in maintaining layer structure of Meta-kaolinite
[15]	Investigate durability concrete materials using class F fly ash and alkaline activators when immersed in a sulfate environment for five months.	Any increase of strength 4-12% indicate a more stable cross-linked aluminosilicate polymer structure
[16]	This study showed an effect of porosity, water absorption, and sorptivity on fly ash class F, which activated a mixture of NaOH and Na_2SiO_3 with fly ash ratio 0.33 as mortar in sulphuric acidic solution in 24 weeks.	Mortar with higher alkali content has lower water absorption, sorptivity, and porosity
[17]	This literature review informs geopolymer materials have a capability mixed with low alkali activating solution and be curable in exact time under ambient conditions.	With cost-effectiveness, geopolymer materials can also be used in rehabilitation works and repairs.
[18]	This study investigated the effect of increasing slag levels and activator dose on the sulfuric acid resistance of fly ash GP binder.	Increasing slag levels has an impact on porosity reduction and higher

		resistance of sulfuric acid caused by increasing alkaline activator
[19]	This research focuses on the structural behavior and composition of self-compacting concrete with sodium hydroxide-activated fly ash. Fly ash is partially replaced with ordinary Portland cement from 0 – 30%.	Activated fly ash-based SCC in terms of strength was found to substitute 10-15%, reduce production costs, and increase strength.
[12]	This research focuses on mechanical properties, weather resistance, and microstructure of harbor fly ash concrete containing a high volume of bagasse ash (BA) 50-70%.	The Pozzolan reaction increases the value of the properties, the resistance of chloride permeability, and compressive strength caused by pozzolanic reaction with optimum composition BA 50% and 20%FA.
[13]	Life Cycle Assessment Analysis and mechanical properties Biomass Fly Ash (BFA) from wood burning for concrete mortar in variation composition 10-70% with considering Environmental Issue	Until 20%, there is no significant loss in mechanical properties. For Environmental analysis with using BFA can give approximately 25% potential saving on reduction of energy consumption and CO_2 emission with an optimum 50% cementitious mixture
[20]	This research focuses on carbonation-induced water permeability and concrete cavity volume test using high volume F class fly ash. Concrete specimens were prepared by replacing ordinary Portland cement (OPC) with FA at a rate of (0-70%).	The results obtained by FA concrete showed an increase in compressive strength and ultrasonic pulse velocity for 365 days. In addition, the replacement of cement with FA solidifies the concrete matrix due to the formation of a large amount of calcium silicate hydrate gel.

3. CORROSION RESISTANCE IN REINFORCEMENT CONCRETE

Corrosion [21] decreases the quality of a metal due to an electrochemical reaction with its environment [22]. Corrosion of Concrete or Steel [23] can occur when sufficient water and air (oxygen) are available. In general, reinforced concrete that has been covered with concrete will not corrode because the concrete is very alkaline. Concrete is alkaline when the water in the concrete has a high concentration of sodium, potassium, and calcium. The alkaline nature of the concrete then forms a thin layer of $Fe(OH)_2$ (ferrous oxide) or a passive layer that coats the surface of the reinforcing steel of the concrete and protects it from corrosion of the concrete [24]. In this condition, the concrete has a pH > 13, then the pH of the concrete is between 12 and 13 [22]. Table 2 shows some research in the investigation of corrosion resistance on reinforcement concrete.

Table 2: Research in the investigation of corrosion resistance on reinforcement concrete

References	Research Focus	Result
[25]	This research focuses on the performance of steel reinforcement on portland cement and high volume fly ash (HVFA) concrete exposed in chlorine solution and investigated by EIS, half-cell potential, and linear polarization in 6 months.	Because of decreasing permeability, there is no apparent corrosion in steel embedded in HVFA concrete on 3.4% NaCl compared with OPC without fly ash mixture
[26]	This paper presents the results of orthogonal experiments from tests carried out on nine groups of 27 specimens to evaluate the effect of three parameters: steel fiber content, fly ash content, and corrosion inhibitor content on the resistivity of steel fiber reinforced concrete (SFRC).	Increasing fly ash content is followed by increasing resistivity of SFRC and durability of the structure

[27]	This paper aims to report the improvement of sustainability by increasing the corrosion resistance of reinforced concrete using a mixture of cement and fly ash.	There is a significant difference in corrosion rate between mixtures with different percentages of fly ash. Fly ash can also be used to substitute OPC.
[28]	This study presents a method to increase corrosion resistance by modifying fly ash concrete. Tests were carried out on four types of fly ash concrete specimens with and without nanoparticles.	Fly ash concrete with Nano $CaCO_3$ modified has a maximum polarization resistance, the lowest corrosion current density, and corrosion rate.
[3]	This study studied the corrosion behavior from the effect of silica fume and fly ash blended in the concrete of carbon steel (CS) AISI 1018 and stainless steel (SS) AISI 304 for 365 days	Stainless steel AISI 304 has the best corrosion behavior than AISI 1018
[29]	Studied chloride-induced corrosion in reinforcement concrete with the variation of fly ash types and immersion on NaCl 3% also investigated with half-cell potential and linear polarization resistance in 540 days.	Most of variation fly ash types have lower corrosion levels compared with OPC without fly ash and show the highest corrosion rate with geopolymer specimen with pH lower generate higher Cl^-/OH^-
[30]	This study used cement, phosphogypsum waste, fly ash, and quicklime for loss stabilization. The orthogonal test was used to evaluate the effect of additives on the softening coefficient, flexural strength, and compressive strength of samples stabilized at a drying temperature of 55 °C.	The curing temperature had the leading role in significant improvement of loess stabilization and showed the structure of C-S-H gels and ettringite
[24]	This research seeks to study corrosion behavior stainless steel embedded in concrete which mixed OPC and materials substitution by silicon fume (SF) and fly ash (FA)	EIS Indicated decreasing double-layer capacitance for both with increasing passive film thickness and a reduced corrosion rate as a result
[31]	This research was conducted to determine the effect of fly ash on the corrosion resistance of magnesium potassium phosphate cement (MKPC) paste in sulfate solution, pure MKPC paste (M0), and MKPC paste containing 20% fly ash (M1) prepared and immersed in water and aqueous solution. Na2SO4 5% for long-term immersion corrosion test.	Shows adding fly ash can improve capabilities of the long term corrosion resistance of hardened MKPC paste in sulfate and water solution
[21]	This research focuses on analyzing the results of the probabilistic model of steel corrosion in fly ash. The model was implemented to determine the corrosion probability of reinforced concrete using three different fly ash replacement rates (0%, 20, 50%).	Based on modeling, fly ash mixed concrete could improve long term durability and higher compressive strength and decrease the porosity
[10]	This research investigates the effectiveness of using municipal solid waste incinerator (MSWI), fly ash (FA) and MSWI bottom ash (BA), and rice husk ash (RHA) as partial materials for ordinary portland cement (OPC) in pervious concrete (PC) and comparing with Taiwan EPA	All replacement ashes met the requirements of Taiwan EPA. There is indicated pozzolanic reaction followed by increasing compressive strength otherwise lower porosity and water permeability
[32]	This paper represents supplementary cementitious material (SCM) with a mixture of Portland cement in producing corrosion-resistant concrete. Fly ash and GGBS are partially replaced in three different ratios based on cement weight. The compressive strength, chloride penetration, corrosion, sorptivity (FA-GGBS) were determined.	Water to Binder ratio 0.28 have significant durability than 0.55, which maintain passive layer on rebar and with 40% CEM 30% FA 30% GBS could reduce the permeability of chloride ion into concrete

4. FUTURE STUDY

Fly ash utilization for reinforcement concrete represents the feasibility of its materials, which practically impact building materials technology over OPC. In addition, determination about sustainability, economic, ecological especially climate change issue makes another alternative pozzolanic material comparing coals as classified F class from the power plant in Indonesia by using fly ash from Cofiring fuels (coal and biomass) as a strategic program of PT PLN (Persero) in Indonesia. Furthermore, extension works can be investigated by examining durability and its properties.

5. CONCLUSION

From the studies, it can be concluded that fly ash is used as pozzolanic materials to substitute OPC uses partially and reduce CO_2 emission of OPC production. Fly ash improves the concrete's mechanical properties by examining pore concrete structure and high acid and sulfuric attack resistance. The alkaline nature of the concrete then forms a thin layer of $Fe(OH)_2$ (ferrous oxide) or a passive layer that coats the surface of the reinforcing steel of the concrete and protects it from corrosion of the concrete.

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