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Effect of Palm Oil Fuel Ash as Partial Replacement of Cement on the Properties of High Strength Concrete

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ABSTRACT:Concrete industry consumes considerable quantities of natural resources and releases toxic gases, such as carbon dioxide, into the atmosphere. Using alternative renewable resources to produce concrete, such as palm oil waste, would increase sustainability in the concrete sector. Using palm oil fuel ash (POFA) instead of cement in concrete is an effective practice for reducing costs and environmental impact when using waste materials such as palm kernel shells, palm oil fibers, and palm oil husks. the study aims to examine the effects w/b ratios and grounded palm oil fuel ash (POFA) on mechanical properties, chloride resistance, and water permeability of concrete. POFA grounded to size 75-micron and used as a partial replacement for cement at a rate of 12%, 24%, and 36% by weight of the binder to cast high strength concrete (HSC). And, the water to binder ratio (w/b) was ranged between 0.45 to 0.52. Properties such as mechanical strength, water permeability, and chloride resistance of HSC were determined at 7, and 28days. The pozzolanic reaction of grounded POFA increases with an increase in the replacement rate of cement and with the age of concrete. The results indicate that POFA is a reactive pozzolana and can be used as supplementary cementitious material by partially replacing cement in OPC.

KEYWORDS: Palm Oil Fuel Ash(POFA), High strength concrete, Mechanical Properties, Agriculture West By Products

I. INTRODUCTION

Biomass power plants generate electricity by burning palm oil residues such as fibers, seeds, and shells. Ash is a by-product of biomass power plants. The amount of palm oil residues produced in Thailand in 2013 was about 6.25 million tons. Around 312,500 tons of POFA were produced after combustion, or about 5% by weight of the palm oil residue [1]. Biodiesel is mainly produced from palm oil, so the amount of palm oil fuel ash produced annually has tended to increase, whereas POFA has been mainly used in biodiesel production so far. POFA is typically disposed of in landfills, which can cause many environmental issues. Due to its large particles and high porosity, palm oil fuel ash in its original size is not suitable as a good pozzolan due to its chemical composition of silicon dioxide (SiO2) [1]. But high-fineness POFA is an excellent pozzolanic material. It is therefore necessary to grind the POFA into a finer powder before it can be utilized in place of OPC in concrete [2-4]. In previous studies, pozzolans like fly ash, silica fumes, rice husk ash, and bagasse ash have been reported to partially replace OPC in concrete mixtures. [5-10]. Most studies of POFA have focused on its mechanical properties such as compressive strength and modulus of elasticity. POFA has been introduced as a pozzolanic material in concrete [1-4]. Also, POFA has been used as a binder to improve the compressive strength of geopolymer mortar and concrete by replacing cement [11-13]. In some studies, the penetration of chlorideions into concrete has been examined [14,15]. and corrosion resistance of high strength, high workability concrete [16]. Once chloride ions penetrate into concrete and their concentrations around the reinforcing steel exceed a critical level, they will break down the protective film, which leads to the beginning of steel corrosion.

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II. EXPERIMENTATION

2.1. materials

The Raw POFA has been collected from Kerala. It can be prepared in different ways based on the burning process. Initially, POFA was dried in an oven at 105 ± 5C to remove moisture, and then through a 75micron sieve to remove foreign and coarse particles, as well as to dispose of kernels and fibers that did not burn. In the second step, POFA particles were ground into fine particles followed by combustion in a gas furnace at high temperatures (500 ± 50 C) to remove unburnt carbon and obtain very fine POFA. Similarly to the previous step, the third step involved grinding POFA to obtain UPOFA.

Ordinary Portland cement (OPC), natural river sand with a fineness modulus of 3.09, crushed limestone with a maximum size of 19 mm were used in this study. The physical properties of the OPC and POFA are shown in Table 1.

As shown in Table 2, the chemical compositions indicate that the sums of SiO2, Fe2O3, and Al2O3 in the ground POFA were 70% (55.4 + 9.1 + 5.5) by weight, whereas the values of LOI and SO3 were 7.9 and 2.3%, respectively.Awal andHussin [17].

Table 1: Physical properties of the materials.

Sample	Specific Gravity	Retained On A 45μm Sieve	Median Particle Size, $d50$ (μm)
PCC	3.14	13.5	14.7
POFA	1.89	94.4	183
Ground POFA	2.52	1.7	10.7

(Ref.: Hindawi Advances in Materials Science and Engineering)

Table 2: Chemical compositions of the ground POFA and Portland cement.

Sample	SiO2	Al2O3	Fe2O3	CaO	MgO	K2O	Na2O	SO3	LOI
Cement	20.9	4.8	3.8	65.4	1.2	0.4	0.2	2.7	1.0
Ground POFA	55.4	9.1	5.5	12.4	4.6	-	-	2.3	7.9

(Ref.: Hindawi Advances in Materials Science and Engineering)

2.2. Mix Proportion of Concrete

In this experiment materials used to design the mix M30 grade of concrete are cement, sand, coarse aggregate water and mineral admixture. To investigate the effects of W/B ratios on properties of concrete containing ground POFA. The concrete was designed to have binder contents of 449 kg/m3, corresponding to the W/B ratio of 0.45, respectively. The mixture proportions of the control types of concrete (30CT) and the types of concrete containing ground POFA (30P12, 30P24, 30P36) are summarized in Table 1. The compressive strengths of the 30CT control types of concrete (types of concrete using OPC as a binder) were designed to be 30MPa at 28 days, respectively. The cement replacements with ground POFA in the concrete mixtures were at rates of 12, 24, and 36% by weight of binder (ground POFA + OPC). The effects of W/B ratio and ground POFA on the properties of the concrete were investigated and compared to the control concrete.

Table 1: Mixture proportions(kg/m$^{3)}$ of the types of concrete.

Sample	Cement	Ground POFA	Fine aggregate	Corse aggregate	Water
30CT	449	0	733	998	214
30POFA12	395	54	733	998	214
30POFA24	341	108	733	998	214
30POFA36	287.36	161.64	733	998	214

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1.3. Tests for the Compressive Strengths of Concrete

For the determination of compressive strength of concrete cubes of size 150 mm × 150 mm ×150 mm have been casted under controlled conditions were tested after 7 and 28days of curing period. For removing moisture from the specimens, they were taken out of the curing tanks and kept for half an hour at room temperature the prepared specimens were then tested in the Automatic Compression Testing Machine (ACTM) of 2000 kN capacity. The procedure for finding the compressive strength of concrete in explained in IS 516: 1959. Load was continuously applied on the cube at the rate of 5.1 kN per second until the specimen fails.

III. RESULTS AND DISCUSSION

Chart 1 shows the compressive strengths of the control concrete and the POFA concrete with OPC replacements of 12, 24, and 36% by weight of binder. The development of the compressive strengths of the POFA concrete was compared to that of the 30CT type of concrete, from which the effects of the 0.45 W/B ratios on the compressive strengths and durability properties of the concrete were investigated. The 30CT types of concrete gained compressive strength of 18.58MPa at 7 days, respectively. At 28days, the 30CT concrete developed strengths up to 27.11, At the same W/B ratio, the POFA concrete produced higher compressive strengths than those of the control concrete up to 28days. At 7 days, the 30P12 concrete had compressive strength of 19.22MPa and increased to 29.35MPa at 28 days. The compressive strengths of the 30P24 concrete were 17.15 and 25.09MPa at 7 and 28days, respectively. At ages of 7 and 28days, the 30P36 concrete had compressivestrengths of 15.64 and 21.21MPa,respectively. The results indicated that the use of ground POFA to replace OPC at rates of 12 to 36% by weight of binder

slightly decreased the compressive strength of the concrete. The 30P12 concrete had a compressive strength of 29.35Mpa of the 30CTconcrete at 28 days, the increase in compressive strength was observed when ground POFA was used instead of OPC in concrete at the rate of POFA-12%. In POFA concrete, the reduction in compressive strength was due to the lower amount of OPC, which caused the compressive strength obtained from the pozzolanic reaction of the ground POFA to be inadequate to compensate for the loss in strength caused by the hydration of the cement. Using ground POFA to replace OPC however, can reduce the amount of OPC in concrete mixtures and at the same W/B ratio, the compressive strength is slight significantly different from control concrete.

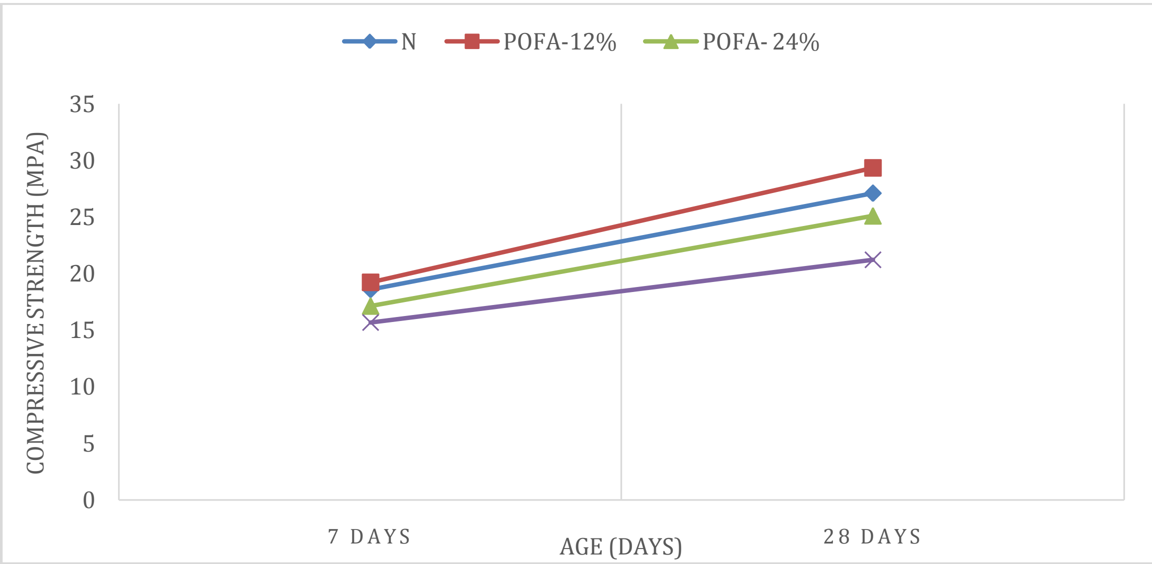

Chart 1: Compressive Strength of The Concrete At Different Ages

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Table 1: Compressive strengths of the types of concrete at 7 and 28days

mix	Compressive strength (MPa)	
	7 days	28 days
30CT	18.58	27.11
30POFA-12	19.22	29.35
30POFA-24	17.15	21.09
30POFA-36	15.64	21.21

IV. CONCLUSION

- The present state of research into the use of POFA in the concrete industry. POFA is a green agriculture waste material that is relatively inexpensive to obtain. The review summarises the many applications of POFA as construction materials, emphasises some key findings and conclusions related to concrete hardened state qualities, analyses POFA in present applications, and makes some research recommendations. Conclusions are formed and listed below based on the review:
- When waste materials are burned in palm oil mills to generate energy, palm oil fuel ash (POFA) is produced as a by-product. Ground POFA (GPOFA), Ultrafine POFA (UPOFA), and Nano POFA are examples of finer POFA variations that can be obtained through grinding methods.
- The POFA is a pozzolanic material that has a high SiO2 content. Calcium-Silicate-Hydroxide (C-S-H) gels are produced when calcium is added, which gives cement mortar its strength and durability.
- In study investigated proportion 12% of cement replacement by POFA to be optimum for the compressive strength of concrete. After percentage of POFA increase the compressive strength of concrete slightly decrease.
- At its initial size, POFA's microstructure is weak and porous. POFA's performance is greatly enhanced by reducing the particle size to micro and nano. When POFA is finely ground, it reacts well with the other constituent materials, which leads to stronger concrete.
- A high amount of POFA used as a cement replacement will result in decreased workability due to its high unburned carbon content. In this case, a super plasticizer is required.
- The compressive strength of concrete is optimally enhanced when cement replacement is 10% to 20% by POFA.
- As a result of using Nano POFA, concrete has been reported to have stronger strengths than normal concrete.

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