INVESTIGATION ON THE IMPACT OF PALM OIL FUEL ASH ON THE STRENGTH CHARACTERISTICS OF CONCRETE

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ABSTRACT

Cement which is highly responsible for hydration enthalpy and also the cost of cement which makes it uneconomical. The only way to deal with this kind of challenge is by introducing different products to replace certain amount of cement. An environmental friendly waste product produced from agricultural industries known as POFA (Palm-oil- fuel-ash) can be replaced with certain percentage of cement replacement in concrete and still attains similar strength such as conventional concrete.The present research is to focus the changes on mechanical, strength properties of concrete by using (POFA) palm-oil-fuel-ash. It is very much efficient in reducing cement expenses and also enhances the strength when engineered in technical aspects. When this agro waste palm oil ash is added, very less quantity of CO2 emission takes place with reduction in liberation of heat from concrete.With the incorporation of palm oil fuel ash in various incremental order of (0, 10, 20, 30, 40) % replacement by cement in concrete, certain amount of change in behavior in concrete strength parameters namely compression strength, split tensile strength, and flexure strength is noted. The concrete is which is used for the research, shows that 10%replacement of cement by palm oil ash (POFA) gave high strength compared to conventional concrete. All the results generated are compared against control mix whichgave an impression of improvement in (mechanical, strength) parameters of concrete in a positive way which helps balance the

environment and also achieve sustainability of the concrete.

Keywords: Palm Oil Fuel Ash; Mechanical Properties; Cementitious Replacement; Strength Parameters; CO2 emission; Concrete Sustainability.

INTRODUCTION

1. 1. GENERAL

The CO2 which is produced during the emissions through the generation of Ordinary Portland Cement (OPC) green house gases mainly effected our environment. On the other hand unused industrial by products are polluting surrounding water and air. These emissions have a great impact entire ecological system. The estimated manufacturing of cement around the world is approximately in tons is (4.1 billions). Every ton of cement manufacturing process produces an approximate quantity of 900 kilograms of carbon emission and eventually this CO2 will be due to its habit pollutes the air of atmosphere by penetrating in to the environment. It was estimated that production of the cement in 2019 was incredibly increasing in billions of tons in quantity. Recent facts strongly communicate that many industrial waste products or by products are dumped in open field which leads deterioration of land and nearby streams of ground water. Most of the unutilized products are mainly rice husk ash (RHA), fly ash (FA), palm oil ash fuel(POFA), palm oil (clinker powder) (POCP), oil palm shell (OPS), palm oil clinker (POC), steel slag, incinerated bottom ash aggregates (IBAA) could be utilized as substitutes in concrete.The POFA with Geo-polymer has very limited research and due to abundant availability of POFA in south East Asia, the research on pozzolonic materials should be widely spread. The strengthening of structural elements by incorporating palm oil ash (POFA) as bond for replacement in epoxy has seen satisfying results with flexure performance of the member compared to control specimen, which will be seen economic point of view. Waste materials as a replacement for binders and conventional aggregates is very much in demand as the growing waste land is affecting the environmental cosystem. Metakaolin, Palm ash fuel oil (POFA), ground granulated blast furnace slag must have Plant ash is the powdery residue that remains after plants are burned; chemically the ash is alkaline (pH >

10) and composed primarily of calcium carbonate and, secondarily, most often, of potassium chloride (interestingly, alkaline derives from the Arabic word meaning plant ashes). Incineration of any or all parts of a palm tree produces a fine ash that has subsistence and commercial utility. The ash plays a role in religion, is a salt substitute, serves as a soil amendment, has certain industrial applications and is used in traditional medicine.

Fig. 1: Palm oil Ash

Fig 2: Palm oil shell and Palm oil fibres

Difference B/W Fly Ash and POFA

Fly ash is the finely divided residue that results from the combustion of pulverized coal and is transported from the combustion chamber by exhaust gases. Whereas POFA is obtained by incineration of palm tree shell.

Fig 3 : Fly Ash formation

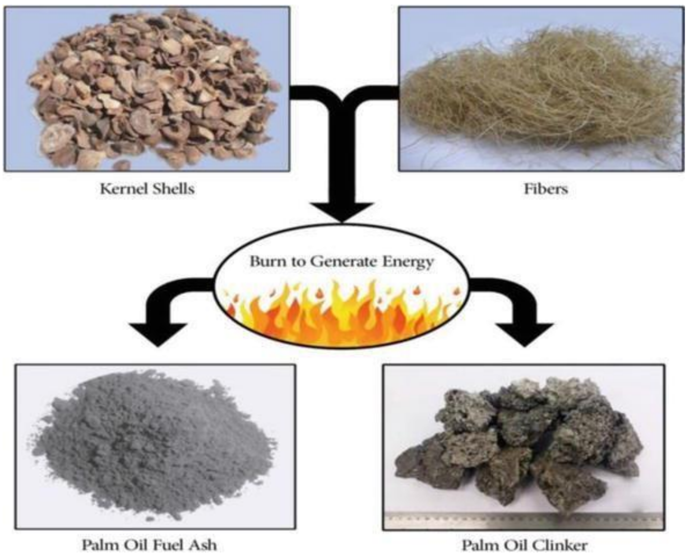

Fig 4: Palm oil ash formation

Characteristics of Palm oil ash

Palm oil has an especially high concentration of saturated fat, specifically the 16-carbon saturated fatty acid.

Chemical composition of POFA

Oxides (%)	POFA
Phosporus pentoxide (P_2O_5)	8.458
Sulphuric anhydride (SO_3)	5.03
Mangenese dioxide (MnO_2)	0.225
$SiO_2 + Al_2O_3 + Fe_2O_3$	59.519

SOURCE OF POFA

POFA is an engineering by-product generated from the waste of the PO industry POFA is the residual of the PO fruitiness clusters after oil removal in PO mills. In practice, three typical POFA materials are available in Malaysia and other Southeast Asian countries. Such materials are generated from three different palm oil mills, namely CAPOFA, KTPOFA, and ALPOFA. In the reservoirs used to produce POFA and electricity for palm oil mills. These residues are abundant and readily available within the plant areas. Approximately 5% of EFB in terms of solid waste weight can be produced economic profit and irritation to the environs causes severe problems because of the failure to utilize this ash and it is disposed of in open areas without any control.

steam boiler, the palm kernel and husk shell are also combusted to produce POFA, containing a large amount of silica oxide content that satisfies the pozzolanic property criterion and can be potentially used as cement replacement. In general, cultivation waste ashes encompass high silica amounts, leading to pozzolanic materials.

An empty fruit bunch (EFB) is an appropriate raw material burnt in as a POFA. Given the continuously increasing making of PO, higher volumes of POFA will be made in PO mills. Therefore, the dump of PO wastes in open areas deprived of any

APPLICATIONS IN CONSTRUCTION

Ground POFA as a partial replacement of OPC resulted in increased water demand for concrete's preferred workability. However, the concrete strength with 20% ground-

LITERATURE REVIEW

Mohammad hosseini and Tahir

Stated that industrialization and mechanization inventions result in massive amounts of municipal solid wastes being produced each year in the modern way of life. Many non-biodegradable wastes, including plastics, will persist in the environment for hundreds or perhaps thousands of years. As a result, the idea of sustainability encourages the use of waste products as raw resources substitutes in the building and construction sectors. This results in a greener environment, environmentally building, and economic development. The Oil-palm tree emerged as one of the most valuable agricultural commodities in the world, with an average life expectancy of twenty-five years. palm- oil is the most generated vegetable oil on a worldwide scale, with over 60 million tons generated and a market share of more than 37% by weight in 2012.

Salih, et al.

Stated that one prospective substitute for cement is alkali activated materials, which appear to have comparable mechanical characteristics to PC, despite the fact that these substances are still in their infancy. Up to now, various forms of alumino-silicate materials including metakaolin , FA , and ground granulated blast furnace (GGBFS) were utilized in the form of alkali activated cement. PFA, a type of agricultural waste that is abundant in Malaysia, is another type of alkali activated cement that is categorized as a pozzolanic material . Recently, PFA has been combined with various alumino-silicate substances including GGBFS, rice husk ash, and FA to form GP concrete.

Bashar, et al.

Stated that PFA is a significant industrial pozzolanic byproduct in Southeast Asia. The accessibility and abundance of PFA provided an excellent foundation for researchers to investigate this pozzolanic substance as an original source for the development of more

environmentally friendly and sustainable materials such as GP concrete. Because of the pozzolanic reactions of these supplementary cement-based materials, they have been utilized to increase the strength and durability of concrete. PFA is a by-product of the burning of palm-oil waste, including Oil-palm-shells, empty fruit bunches, and fibres, at temp between 850 and 1000 °C for the purpose of generating power in palm-oil mills.

Muthusamy and Azzimah

Studied the usage of PFA in small weight concrete and existed that 20% subspace substitution gave the extreme pressure power, despite up to 50% could remain to be utilized for architectural implementation. The conclusions of these previous surveys accentuated the reduction of PFA when utilized in HSC, which could be basically owing to the grossness of particle volume, the great substance of un-burned carbon, and higher missing on combustion of un-treated-PFA. Some other scientists also utilized the fundamental quantity of treated-PFA in the manufacture of concrete and mortar. The usage of up to 82% in subspace substitution with GGBFS in alkaline operationalized

3.1.1. PROPERTIES OF MATERIALS

1. CEMENT

Cement is a substance used for binding and hardening other material. Ordinary Portland cement OPC 53 grade is used. Cement Chemical composition and properties are shown.

Specific gravity	3.10
Fineness test	3%
Consistency	33%
Initial setting time	30min

2. PALM OIL FUEL ASH (POFA)

It is a waste product of the palm oil industry, the raw POFA obtained from NBL palm industry of oil manufacturing. POFA was sieved for removal of the large particles. Then with the help of Los Angeles machine was used to obtain fine particles.

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Composition %	OPC	Palm oil fuel ash(POFA)
SiO_2	9.81	50.3
Al_2O_3	2.76	4.74
Fe_2O_3	4.38	8.08
CaO	64.0	5.19
MgO	0.92	3.22
SO_3	2.30	1.40
K_2O	0.74	11.8
Na_2O	0.44	0.10
$SiO_2 + Al_2O_3 + Fe_2O_3$	-	56.77
Loi	1.10	8

Table: Chemical composition of OPC and POFA

5. WATER

From the nearby tap fresh water was procured. The Ph value was also considered, as it plays a crucial role when added to concrete. Ph value according to IS 456-2000 can be less than are equal to 6.0 ,water used for mixing and curing should be contained against injurious amounts of harmful chemicals and other acidic substances and other organic debris that can lead to deterioration of concrete or steel.

PREPARATION OF POFA

Palm oil fuel wastes were obtained from a local palm oil mill of palm kernel shells, empty fruit bunches and fruit fibres in dry state. The Palm oil waste was burnt at a temperature of

700°C using a controlled blast furnace for about 4 hours. The burning was done at the fabrication workshop. The burnt ash was grinded using mortar and pestle and was sieved using 0.09mm sieve. Chemical analysis of the processed POFA was carried out at the Chemistry laboratory.

PHYSICAL ANALYSIS WITH POFA

1. Fine aggregate and coarse aggregate

The physical properties of the fine aggregates, coarse aggregate and POFA were examined. All these were used in designing the mixing ratio for the concrete work which will lead to the production of concrete with target strength. The tests were carried

2. Particle size distribution

The particle size distribution is the analysis of soil samples which involves the determination of the percentage by mass of particles within the different size ranges. The particle size distribution of coarse and fine aggregates used was determined by the method of sieving. 1000g and 3000g of oven dried samples of fine and coarse aggregates respectively were passed through series of standard test sieves having successively smaller mesh sizes. The mass of sample retained in each sieve was determined and the cumulative percentage by mass passing each sieve was calculated. This was used in analyzing uniformity and gradation of samples.

- $D_{\text{ground POFA}} = 0.35$ µm
- $D_{OPC} = 0.2$ µm
- $D_{\text{unground POFA}} = 0.07$ µm
- $C_u = (D_{OPC}/D_{\text{ground POFA}}) = 2.86$
- $C_c = (D_{\text{unground POFA}})^2/(D_{\text{ground POFA}} \times D_{OPC}) = 0.35$
- C_u (uniformity coefficient) is more than 2, and C_c (coefficient of gradation) is limited to 0.30

FINENESS

POFA fineness is found to develop the concrete strength attributable to its density, and homogeneity. Reportedly, the concrete comprising 10% and 20% treated POFA increased the concrete strength. These results probably because of the contribution of POFA that behaves as a micro-filler used to seal the voids among the particles, leading to an increase in the concrete microstructure.

HEAT OF HYDRATION

POFA is employed in high volumes to decrease the heat of hydration (HoH) of concret. The sum of pozzolanic SCMs has improved with the rapid developments in concrete technology. It is reported that the concrete encompassing 100% OPC and 50%, 60%, and 70% POFA at the early-age. However, over time, concrete, including POFA revealed a reduction in the entire heat increase and overdue the highest temperature incidence. This indicates that the increase in ground POFA content reduced the rise in the peak temperature of concrete.

DRYING SHRINKAGE

The findings of the drying shrinkage (DS) test of water- and air-cured samples are presented in Reportedly, the increase of unground POFA content reduced the DS slightly after 28 days. The concrete DS with 10%-POFA is similar to that of control samples. The investigation reported that the mortar with 10% to 40% POFA exhibited the uppermost DS; 20% and 30% POFA gave similar DS development in control samples.

POROSITY

Reportedly, the increase in POFA content may be caused by a high porosity due to the permeable nature of POFA. The mercury-intrusionporosimetry (MIP) test is utilized to investigate the porosity of concrete. Porosity increases with the water content, which could have adverse effects on fresh material properties

3.3.7 Chemical Analysis of RHA

The total sum of the percentages of SiO2, Al2O3 and Fe2O3 in the processed POFA was 77.60%. This satisfied the minimum percentage requirement of 70% according to ASTM C618 (1978) for any pozzolanic materials. The silica will enable the concrete to have good strength and durability while the alumina will make the concrete to be corrosion resistant as well as impacting quick setting quality to the concrete. In addition to assisting in color, hardness and strength, iron oxide also helps in the fusion of raw materials during cement production.

1. SPLIT TENSILE STRENGTH

The split tensile test is an indirect way of evaluating the tensile test of concrete. In this test, a standard cylindrical specimen is laid horizontally, and the force is applied on the cylinder radially on the surface which causes the formation of a vertical crack in the specimen along its diameter. The experimental setup for this test is shown in. Tensile stress increases with the increase in radial compressive force and specimens deteriorate along the direction of the applied force. This test is relatively simple and needs only a standard cylindrical test specimen and a loading assembly.

The spilt tensile test on cylinders of 150x300mm has been carried out; the experimental setup can be seen.

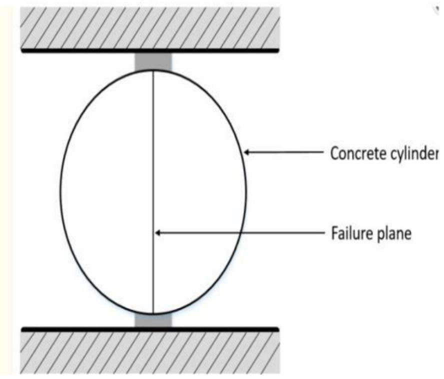


Fig7: Split Tensile strength

Assuming concrete specimen behaves as an elastic body, a uniform lateral tensile stress acting along the vertical plane can be calculated from the following formula:

$$fct = \frac{2p}{\pi D l}$$

where f_{ct} is the split tensile strength, P is the compressive load at failure, L is the lengthof the cylinder, and D is the diameter of the cylinder. The splitting cylinder test gives values about 1.05-1.15 times those obtained from direct tension test

Fig 8: Specimen Testing

2. FLEXURAL STRENGTH

Flexure strength of concrete is determined by prisms of dimensions 100mm, 100mm,and 500mm of size with curing period of 7days, 28 days.

Flexural test or modulus of rupture is another form of the indirect tension test. In this method, two loadings are applied on the beam equidistant from the centre for producing the pure bending moment until the outermost fiber of the beam specimen in tension reaches the maximum tensile stress. The upper half portion of the beam, i.e., the portion above the neutral axis, is subjected to compression while the portion below the neutral axis is subjected to tension. Also, it is assumed that there is a linear triangular variation of the stress along the section, but the actual distribution of the stresses should be parabolic instead of linear variation.

EXPERIMENTAL RESULTS

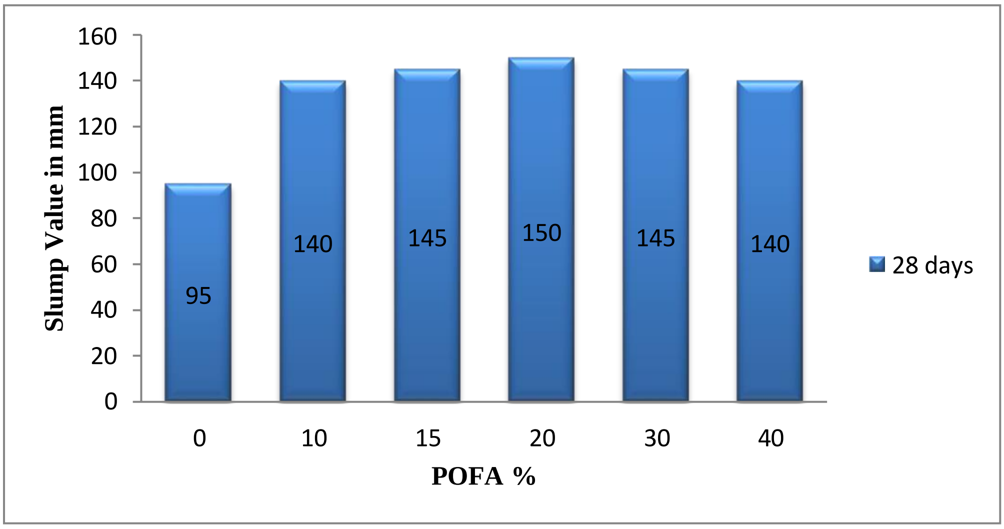
The following Results were obtained after performing the Tests:

1. SLUMP TEST

This method is commonly used methods to find concrete workability. The apparatus is set on a flat surface either on ground or table and the cone is filled by placing concrete mix in three layers one by one and is compacted after each layer for 25 times with the tamping rod. The mould removed slowly by rotating in the vertical direction so as to allow the concrete to get stability and this allows the concrete inside the mould to subside. The testing slump is shear slump as per IS-7320(1974) and investigative findings can be seen.

Palm oil fuel ash %	**Slump value (mm)**
0	95
10	140
15	145
20	150
30	145
40	140

Table1 : Slump cone values

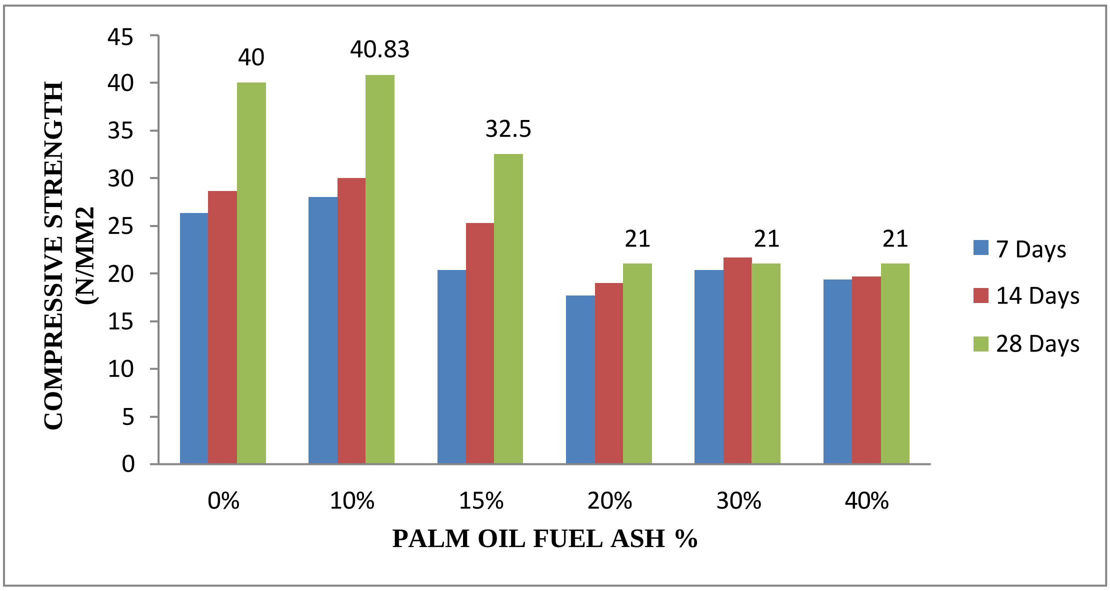


Graph1: Column chart for slump value (mm) versus % Replacement of palm oil ash (POFA)

2. COMPRESSIVE STRENGTH

Compressive strength of concrete specimens was determined by casting of cube having dimensions standards according to Indian standard which is 150x150x150(mm). After casting POFA concrete they were left under curing condition for 7 days, 14 days and 28 days. Cube specimens were placed in the test machine in such a way that the specimen is placed centrally on bottom plate of the test machine, and movable part is adjusted so that it touches the top surface of cube.

Application of load was without any shock and was gradual; the load application was continued until the specimen was failed. The load at which the specimen was failed is noted and this process was done for every % mix. For good results a minimum of 3 cubes were casted for every % mix and the average load value was taken as compressive strength. This test was done on 7 days, 14 days and 28 days and results are shown.

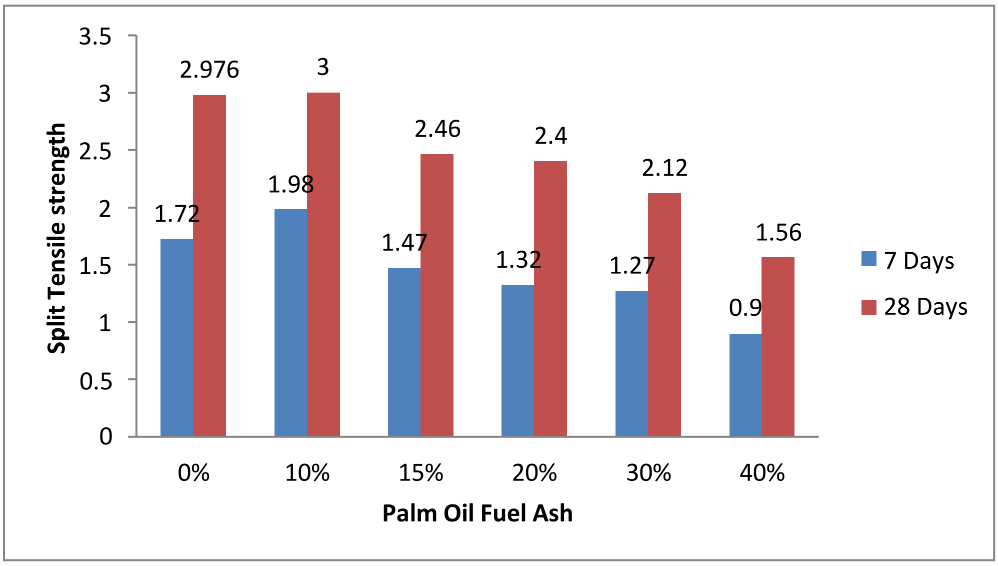


Graph 2: Column chart for % (POFA-Palm oil ash) versus compressive strength

Note: from the above graph it is observed maximum value compressive strength 10% replacement.

3. SPLIT TENSILE TEST

There was no direct method for knowing the tensile strength of concrete, for determining the tensile strength of POFA cylinder were cast of height 300mm and 150 mm diameter. The test specimens were placed under compression test machine with specimen longitudinal axis parallel to horizontal direction. The load was applied gradually until cylinder splits in two parts. Number of specimens tested for accurate results was 3, failure load was taken as split tensile strength after testing all the 3 specimen as average for every mix percentage replacement of palm oil ash. The test was performed as per is 5816:1999 and results shown in the Figure 8 are for 7days and 28 days strength.

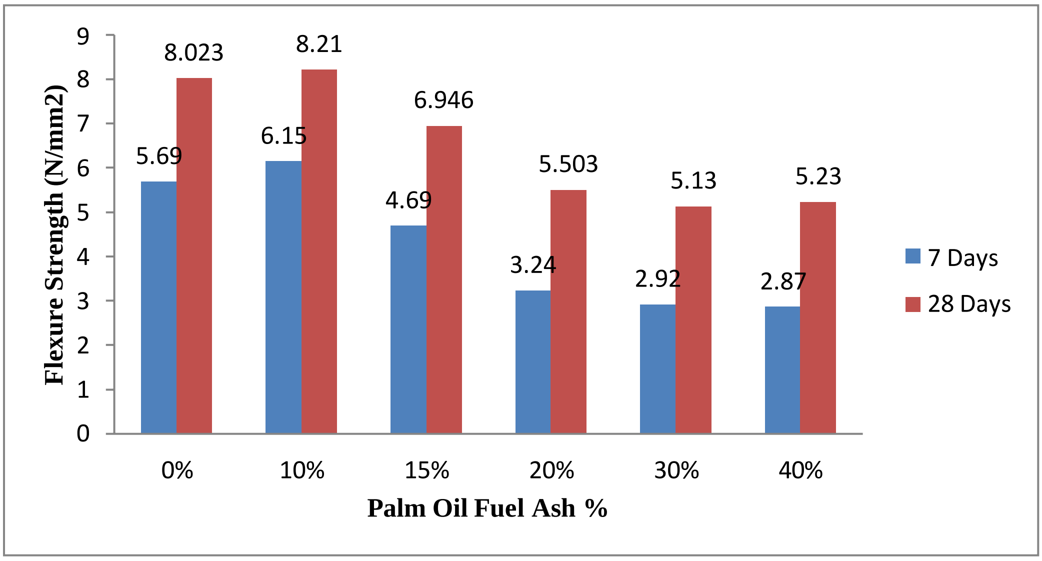


Graph 3: Column chart for % (POFA-Palm oil ash) versus splitting tensile strength

Note: The following results shows that maximum value for spilt tensile test is **10%** replacement of palm oil fuel ash

4. FLEXURAL / BENDING TEST

The test performed for flexure/ bending strength of concrete was performed with prisms with dimensions 100 x 100 x 500 mm for 7days and 28 days strength. This test was performed as per IS 516:1959 code. In this the test two supports of testing machine on which prisms were placed and the load application known as two point loads was applied. The test setup for flexural strength was shown in Figure . The load where failure of the specimen occurred was noted.



Graph 4: Column chart for Palm oil fuel ash % versus flexural strength

Note: The above results shows that maximum value of flexure strength is for **10%** replacement of POFA-Palm oil fuel ash.

CONCLUSIONS

The Experimental Analysis in this study done on Palm oil ash replaced in concrete where cementitious replacement has been done is completed and following conclusion can be made:

1. The study shows that a significant change in strength parameters of concrete when palm oil fuel ash is being added which leads to overall cost reduction of concrete compared to conventional one and making it less harmful by reducing the emission of CO2 and the heat of hydration.
2. Compressive strength is increased maximum at 10% addition of POFA mix proportion.
3. A maximum of 10% Palm oil fuel ash (POFA) replacement was ideal for attaining the peak compressive strength of concrete \compared with 0% replacement which is control mix.
4. The Split tensile test also showed higher strength at 10% POFA replacement.
5. The Flexure/Bending test showed maximum strength at 10 % replacement ofPOFA in M30 concrete.
6. Usage of POFA increases the

utilization of waste products which is suitable for environmental aspects and increases the reduction in agro-waste.

The Rate of Absorption of water and Workability increased with higher % of POFA palm oil fuel ash.

REFERENCES

1. Hockstad L, Hanel L. Inventory of US greenhouse gas emissions and sinks. Environmental System Science Data Infrastructure for a Virtual Ecosystem.
2. Benhelal E, Zahedi G, Shamsaei E, Bahadori A. Global strategies and potentials to curb CO2 emissions in cement industry. Journal of cleaner production.
3. Alengaram UJ, Mohottige NH, Wu C, Jumaat MZ, Poh YS, Wang Z. Response of oil palm shell concrete slabs subjected to quasi-static and blast loads. Construction and Building Materials
4. Bashar II, Alengaram UJ, Jumaat MZ, Islam A, Santhi H, Sharmin A. Engineering properties and fracture behaviour of high volume palm oil fuel ash based fibre reinforced geopolymer concrete. Construction and Building Materials.
5. Hosen MA, Jumaat MZ, Alengaram UJ, Sulong NR, Alsubari B. Sustainable palm oil fuel ash mortar used as partial adhesive replacement in flexurally strengthened RC beams. Construction and Building Materials.
6. Kabir SA, Alengaram UJ, Jumaat MZ, Yusoff S, Sharmin A, Bashar II. Performance evaluation and some durability characteristics of environmental friendly palm oil clinker based geopolymer concrete. Journal of cleaner production.
7. Hamada HM, Jokhio GA, Yahaya FM, Humada AM, Gul Y. The present state of the use of palm oil fuel ash (POFA) in concrete. Construction and Building Materials. 2018 Jun 30; 175:26-40.
8. Isaia GC, GASTALDInI AL, Moraes R. Physical and pozzolanic action of mineral additions on the mechanical strength of high-performance concrete. Cement and concrete composites.