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EXPERIMENTAL INVESTIGATION ON MECHANICAL PROPERTIES OF CONCRETE WITH PALM EMPTY BUNCH ASH (PEBA) AS A CEMENT REPLACEMENT

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ABSTRACT

Due to rapid developments in infrastructure, the usage of concrete is very high now-a-days. This has led to an exponential increase in the production of Cement. This excessive production and usage of Cement leads to large scale generation of CO2, all the while increasing the overall cost of construction. One possible solution to this issue, might be to replace the amount of Cement used in the production of a Concrete mix. The materials used to replace cement may be Industrial by-products or Agricultural waste materials. The purpose of this project, is to utilize palm empty bunch ash (PEBA) a waste product, generated during the extraction of Palm Oil from Palm Fruit Bunches. The palm empty bunch ash contains high silica content, which helps the concrete mix, to improve its strength by the formation of the C-S-H Gel. PEBA is also comparatively richer in terms of Alkalis, which help in the improvement of workability, without compromising strength. Improper disposal of PEBA in lands near the industry has resulted in Land, Air and Water pollution. It also affects the human health by impairing the functioning of respiratory system and also eye irritations. Usage of this strength *improving industrial waste, not only curbs the pollution caused due to the improper disposal of the PEBA, but it also contributes to reducing the carbon footprint of Concrete by reducing the total amount of Cement used. The strength properties of the concrete mix can be determined by compressive strength, split tensile and flexural strength tests. The workability of concrete has been measured by slump cone test. The replacement levels are 0%, 5%, 10%, 15%, 20%, 25% and 30%. In which the concrete attains good strength at 5%, 10%, 15% and the maximum replacement level is 15%.*

Keyword head: Palm Empty Bunch Ash (PEBA), Industrial by-product, Workability, Cement Replacement

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1. INTRODUCTION

One of the largest used composite material on this planet is Concrete, with Cement being the largest energy consuming material in the mix. The worldwide consumption of concrete was estimated to be about 8.8 billion tons per year. Cement takes up one of the largest portions of the cost of any given project. It also generates a large amount of CO_2 during its production. Due to increase in infrastructure developments, the demand for concrete would increase in the future. On the other hand, the climate change due to global warming has become a major concern. The global warming is caused by the emission of greenhouse gases, such as carbon dioxide (CO_2), to the atmosphere by human activities. Among the greenhouse gases, CO_2 contributes nearly 65% by volume and hence is a major driving factor in this process. “The cement industry is held responsible for some of the CO_2 emissions, because the production of one ton of Portland cement generates approximately one ton of CO_2 into the atmosphere” (Davidovits, 1994).

About four tons of concrete is produced per person per year worldwide and about 1.7 tons per person in the United States. The term concrete refers to a mixture of aggregates, usually sand, and either gravel or crushed stone, held together by a binder of cementitious paste. The paste is typically made up of Portland cement and water and may also contain supplementary cementing materials (SCMs), such as fly ash, ground granulated blast furnace slag (GGBS), metakaoline, and some chemical admixture.

In this project we are introducing palm empty ash (PEBA) as the supplementary cementing material. A number of research works have been carried out to investigate the potential of PEBA for use in normal, high strength, high performance, and aerated concretes. Due to uncontrolled dumping of palm empty ash (PEBA) not only occupies valuable land but also creates environmental pollution and health hazard. These problems can be reduced to large extent by using PEBA in concrete. When coming to palm crop in several states, like Maharashtra, Tamil nadu, Kerala and Andhra Pradesh cultivate huge amount of palm crop with respective areas. Normally Godhavari and Krishna districts are the highest production of palm oil in Andhra Pradesh. The oil palm mill is commercially located in several places; due to this investigation the local area industry is selected. The name of palm oil industry is Ruchi Oil Palm Industries Private Limited, Ampapuram village, Bapulapdu Mandal, Krishna District, Andhra Pradesh

2. LITERATURE REVIEW

The development of alternative source of binders to manufacture concrete a3nd the use of palm empty ash (PEBA) in concrete. The available published literature on POFA concrete technology is also briefly reviewed in the following discussions.

BlessenSkariahThomasa et all (2017) the paper presents an overview of some of the published results on the successful utilization of palm oil fuel ash as a supplementary cementitious material and the properties of such concrete at fresh and hardened stages. [1]The summary and discussions provided in this paper should provide new information and knowledge on the applications of greener and sustainable palm oil fuel ash concrete. Sooraj V.M et al (2016)this paper will discuss the strength properties of POFA concrete in different replacement level and also compares with control mixture.[2] Strength properties such as Compressive strength, Flexural Strength and Split Tensile Strength were studied, and compared with that of concrete containing 100% OPC as control. P. Premalatha et al (2016) the investigation on palm ash shows the properties of palm ash concrete is similar to the properties of normal concrete. [3]Therefore cement is replaced partially by palm ash in various percentages such as 10%, 20% and 30%. The concrete specimens were casted. The durability of concrete cubes is also determined. The results shows palm ash concrete give high strength, highly durable, economical and also ecofriendly. Khairunisa Muthusamya et al (2015**)** this paper addresses [4] the compressive strength of this oil palm shell lightweight aggregate concrete upon usage of different ash replacement level, water cement ratio, superplasticiser, sand and cement content were conducted using two types of mixes.

3. MATERIALS AND PROPERTIES

3.1. Palm Empty Bunch Ash (PEBA)

Palm empty bunch ash is one of the solid waste materials and it is an industrial by product. This is obtained by burning the palm oil fruit empty bunch and fibre husk wastes at boilers with a temperature of 850°C to 1000°C during after the extraction process of palm oil from palm fruit bunch. The fig.1 shows the PEBA.

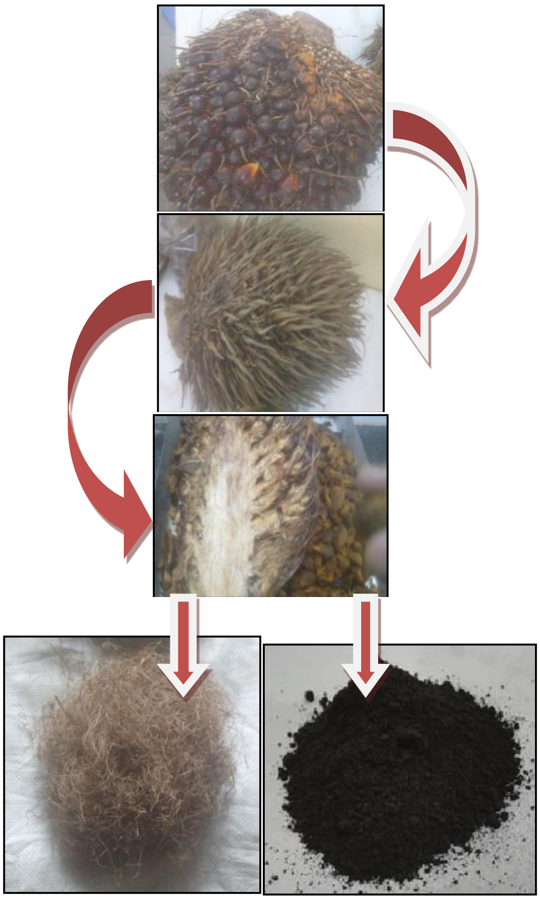


Fig.1. Making of palm empty bunch ash

- By cleaning and separating the empty bunch we get fibre.
- By burning the fibre @ 850 °C – 1000 °C we get PEBA.

3.2. Cement

The cement used 53 Grade ordinary Portland cement conforming to IS 12269.The specific gravity of cement is 3.15. It is highly durable and produces high compressive strengths in mortars and concretes.

Table No.1 Physical Properties

S. No.	Property	Cement	PEBA
1.	Specific gravity	3.15	2.12
2.	Density(kg/m3)	1440	966

3.	Sieve size(µm)	90	325
4.	Mean particle size(µm)	13.2	15

Table No.2 Chemical Properties

S. No	Property	Cement (%)	PEBA (%)
1.	CaO**%**	58	7.5
2.	SiO_2%	25.5	63.8
3.	Al_2O_3%	5.6	5.1
4.	Fe_2O_3%	6.0	3.7
5.	MgO%	3.4	0.58
6.	Alkalis(K_2O, Na_2O) %	0.5	8.9 & 0.9
7.	SO_3%	2.4	2.79
8.	Loss of Ignition%	0.9	2.19

3.3. Fine Aggregates

When the aggregate is sieved through 4.75mm sieve, the aggregate passed is called fine aggregate. Fine aggregate is commonly known as sand should comply with coarse, medium, or fine grading requirements. The fine aggregate was saturated surface dry condition to ensure the water cement ratio is not affected. In this study, sand was used and sieve analysis was done prior to using it to determine the fine aggregate passing 600 µm sieve.

Table No.3 Physical Properties

Properties	value
Specific gravity	2.89
Bulk density(kg/m^3)	1820
Fineness modulus	2.59
Water absorption	0.58%
Zone	II

3.4. Coarse Aggregates

When the aggregate is sieved through 4.75mm sieve the aggregate retained is called coarse aggregate. The coarse aggregate was air dried to obtain saturated surface dry condition to ensure that water cement ratio was not affected. In this study 20mm and 12.5mm sizes are used accordance to BS 882, 1992

Table No.4 Physical Properties

Property	20mm	12.5mm
Specific gravity	2.98	3.03
Bulk density(kg/m^3)	1694	1732
Fineness modulus	5.86	4.51
Water absorption	1.26%	1.03%

3.5. Coarse Aggregates

In the production of concrete, water plays very important role. The water used should not contain any substance that might affect the hydration of cement and affect the durability of concrete. Generally, supplied tap water will be used throughout the study in mixing, curing and other purposes.

Table.5 Physical properties of portable water

Property	Value
P^H	7.45 for tap water
Maximum density(3.98 ° C)	1 g/m^3
Density 25° C	0.99701 g/m^3
Vapor pressure 25° C	23.75 torr
Viscosity	0.8903 centipoises
Surface tension 25° C	71.97 dynes/ cm

4. MIX DESIGN AND EXPERIMENTAL INVESTIGATIONS

4.1. M$_{30}$ Grade Mix Design

In this investigation mix design is considered as per IS: 10262-2009 and IS: 456-2000. The grade of concrete adopted is M$_{30}$ with a water cement ratio of 0.4. There are seven mixture proportions were made. First was control mix (without palm empty bunch ash), and the other mixes contained palm empty bunch ash. The Cement was replaced with palm empty bunch ash by weight. The cement is replaced range from 5% to 30%. The mix proportions are given in Table -6. The controls mix without palm oil fuel ash was proportioned as per Indian standard Specifications IS: 10262-1982, to obtain a 28-days cube compressive strength of 30 MPa. The ingredients of concrete were thoroughly mixed till uniform consistency was obtained. The complete mix is listed in the form of figures as shown in fig.2

Fig 2: Casting of specimens

Table: 6 Quantities of materials required for 1 m^3 with 20% extra volume

MIX ID	NC	PFC_1	PFC_2	PFC_3	PFC_4	PFC_5	PFC_6
Replacement Level	0%	5%	10%	15%	20%	25%	30%

Cement (kg/m^3)	478.94	455	431	407	383.16	359.21	335.26
C.A (12.5mm) (kg/m^3)	500	494.99	492.19	489.38	486.58	483.78	480.98
C.A (20mm) (kg/m^3)	750	740.04	735.82	731.38	727.45	723.26	719.01
PEBA (kg/m^3)	-	23.94	47.89	71.84	95.79	119.74	143.7
F.A (kg/m^3)	675	672.52	668.71	664.9	661.10	657.3	653.5
Water (lit/m^3)	201	200.52	200.47	200.42	200.37	200.32	200.27

4.2. Casting and Curing of Specimens

The 150 mm size concrete cubes, concrete prism of size 100 mm x 100 mm x 500 mm and cylinders of 150 × 300 mm size were used as test specimens to determine the compressive strength and flexural strength and Splitting Tensile Strength respectively. After casting, all the test specimens were finished with a steel trowel. Remove the moulds and moist cure specimens at 23+/-2 ^{o} C till the time of testing.

Fig.3 specimens at curing tank

4.3. Compressive strength test

Compressive strength of concrete cube test provides an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. The loading rate as per ASTM* standard can be computed based on the following equation:

$$\text{Characteristic compressive strength (Fck)} = \frac{\text{Load}}{\text{Aera}} \ (N/mm^2) \qquad \text{.........1}$$

4.4. Split Tensile Strength Test

The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. The loading rate as per ASTM standard can be computed based on the following equation:

$$Tsp = \frac{2P}{\pi\ DL}\ (N/mm^2) \qquad \text{............2}$$

Where,

P = applied load in KN
D = diameter of the specimen in mm
L = length of the specimen in mm

4.5. Flexural Strength Test

Flexural test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending. Flexural test on concrete based on the Indian standards. The results of flexural test on concrete expressed as a modulus of rupture in Mpa. The loading rate as per ASTM standard can be computed based on the following equation:

$$MR = \frac{PL}{BD2}(\ N/mm^2) \qquad \text{........3}$$

Where,
P: peak load KN
D: average specimen depth in mm
L: span length in mm
B: average specimen width in mm

4.6. Slump Cone Test

Concrete slump test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Concrete slump test is carried out from batch to batch to check the uniform quality of concrete during construction.

Fig.4 slump cone test

The following table.7 should comprise the slump value with respect to mix type.

Table.7 Slump value

Mix ID	Slump (mm)	Type of Slump	Degree of Workability
NC at 0%	55	True	Low
PFC at 10%	65	True	Medium

For normal concrete the degree of workability is low, it means suitable for foundation works, road constructions with required compaction. Where as in palm oil fruit empty bunch ash concrete (PFC) the degree of workability is medium, it means suitable for super structural elements like beams, columns and slabs. When reinforcement is light we have to use hand compaction, if reinforcement is heavy use plate or pin type vibration.

5. MIX DESIGN AND EXPERIMENTAL INVESTIGATIONS

5.1. Compressive Strength Test:

Compressive strength of concrete cube test provides an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. The specimen should be kept for 7 or 28 days. Then slowly apply the load axially at the rate of 140kg/cm ^{2} per minute till the cube get break. The maximum load at which the specimen breaks is taken as a compressive load. The following fig.5 & fig.6 shows the testing and crack formation of the cube specimens.

Fig.5 testing of cube

Fig.6 failure cube after testing

Table No.8 test results of Compressive strength

MIX ID	Replacement %	Average Compressive Strength (N/mm^2)	
		7 days	28days
NC	0	25.62	35.70
PFC_1	5	23.37	39.29
PFC_2	10	24.3	40.41
PFC_3	15	23.47	35.97
PFC_4	20	21.42	30.77
PFC_5	25	20.26	26.88
PFC_6	30	18.93	24.71

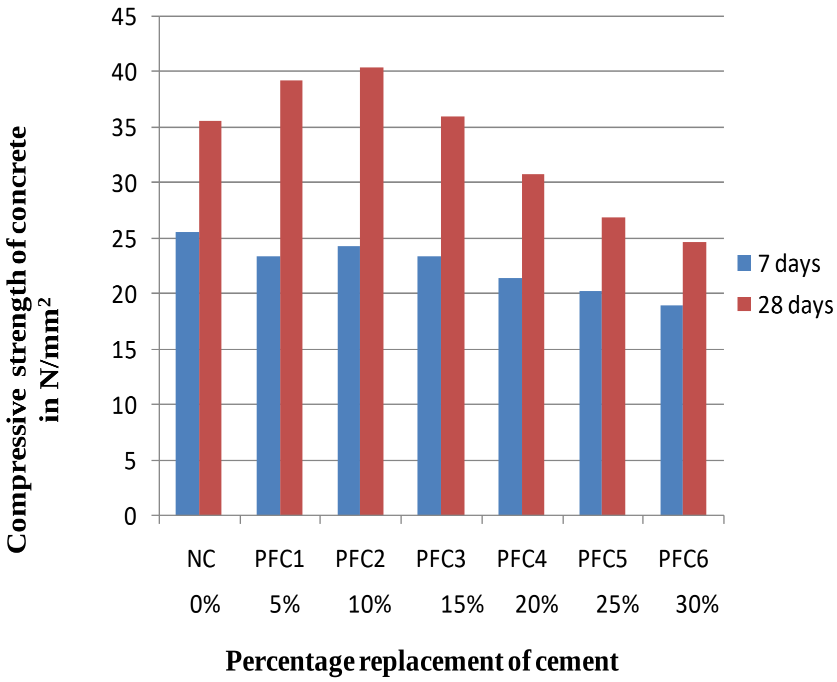


Fig.7 Compressive strength Vs percentage replacement.

5.2. Split Tensile Strength Test:

The split tensile test is done as per code recommendations and the cylinders are casted with M_{30} Grade of concrete of 0.4 w/c ratios. After casting cylinders put them undisturbed area of water at a temperature of 27 ° C ± 2 and Keep the specimen submerged under fresh water at 27 ° C, then the cylinders should keep in water as per code recommendations is 7 & 28 days. After curing the specimen should be in dry condition before conducting the testing. The following fig.8& fig.9 shows the testing and crack formation of the cylinder specimens. The test results should be listed in table-9 as follow,

Fig.8 Testing of Cylinders **Fig.9 Cylinder failure after testing**

Table .9 Split tensile strength test results

MIX ID	%Replacement	Average Strength in N/mm^2	
		7 days	28 days
NC	0	2.38	2.98
PFC_1	5	2.26	2.83
PFC_2	10	2.15	2.56
PFC_3	15	2.20	2.40
PFC_4	20	2.09	2.35
PFC_5	25	1.80	2.15
PFC_6	30	1.57	1.95

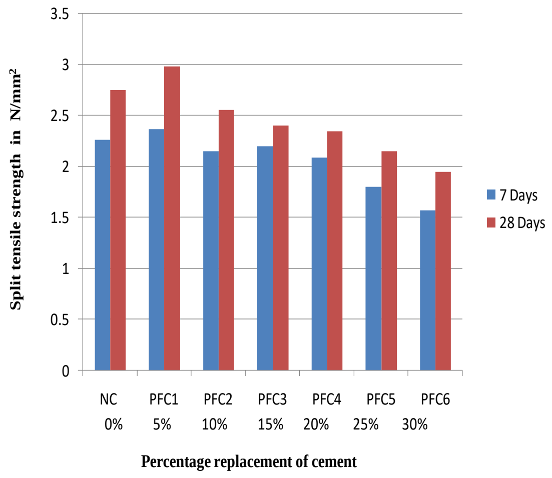


Fig.10 split tensile strength of concrete Vs percentage replacement

5.3. Flexural Strength Test

The test is conducted after casting prisms put them undisturbed area for 24 hours at a temperature of 27 ° C ± 2 and Keep the specimen submerged under fresh water at 27 ° C, then the cubes should keep in water as per code recommendations is 7 & 28 days. After curing the specimen should be in dry condition before conducting the testing. Finally we have to conduct the flexural Strength test for prisms, the test results should be listed in table-10 as follows,

Fig.11 testing of prisms

Fig.12 prism failure after testing

Table No.10 flexural strength test results

Mix ID	% Replacement	Average load in KN		Flexural strength N/mm^2	
		7 days	28 days	7 days	28 days
NC	0	10.3	16	5.15	8

PFC_1	5	12.5	18.8	6.25	9.4
PFC_2	10	15.6	20.7	7.8	11.35
PFC_3	15	17.8	22.5	8.9	11.25
PFC_4	20	13.21	17	6.6	8.5
PFC_5	25	10	15	5	7.5
PFC_6	30	8.6	11.2	4.3	5.6

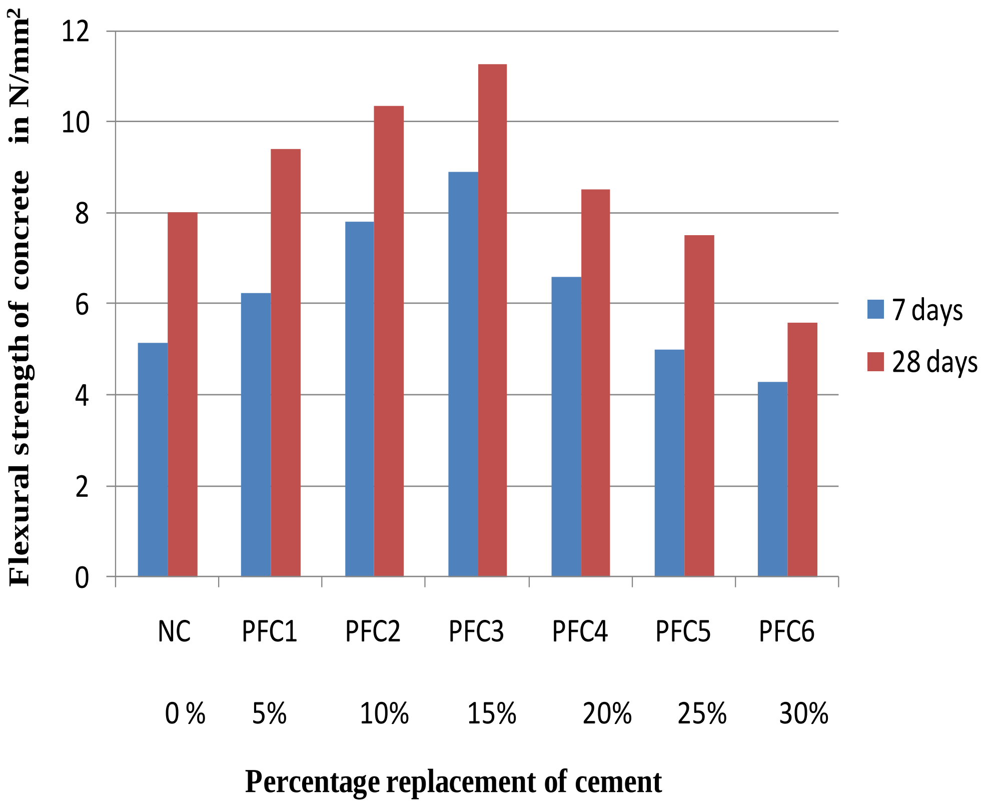


Fig.13 Flexural strength of concrete Vs percentage replacement of cement.

5.4. Surface Structure Analysis and Micro Structure Analysis using Scanning Electronic Microscope (SEM)

i. The surface structures of various concrete mixes were analysed by using SEM with VEGA3 TESCAN.

ii. The inherent properties of regular concrete and PEBA concrete having different percentage replacement levels were analysed.

iii. The optimum percentage could be taken into consideration for complete surface structure and micro structure analysis.

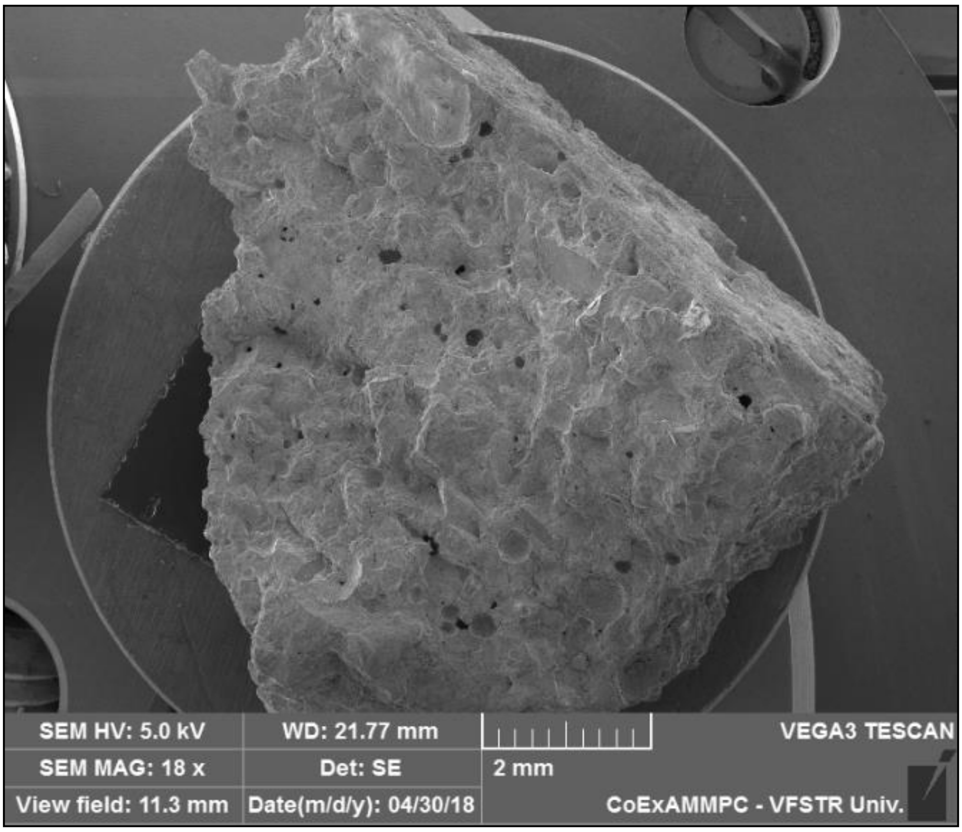
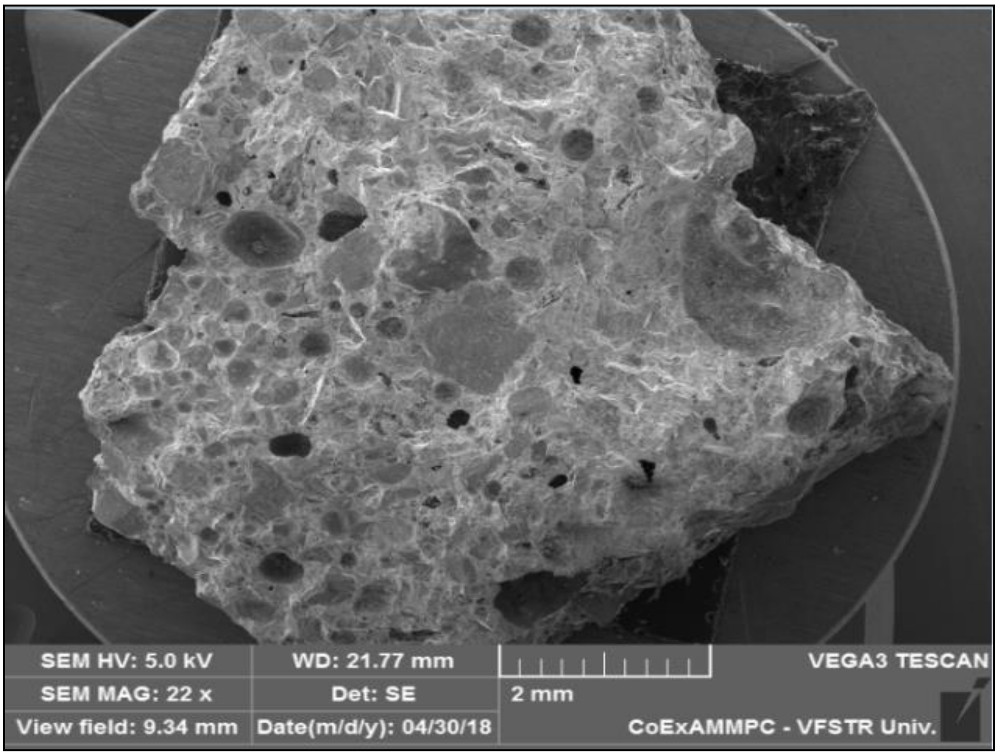


Fig.18 Surface S



tructure of Normal Concrete

Fig.19 Surface structure of palm oil fuel ash (PEBA) concrete

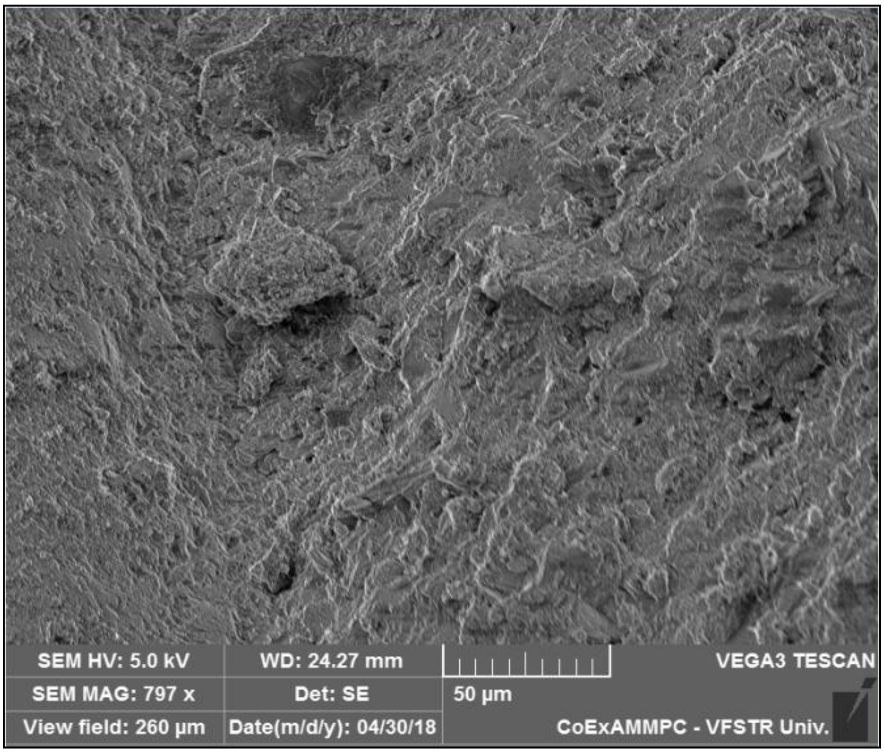


Fig.20 Micro Structure of Normal Concrete Sample-1

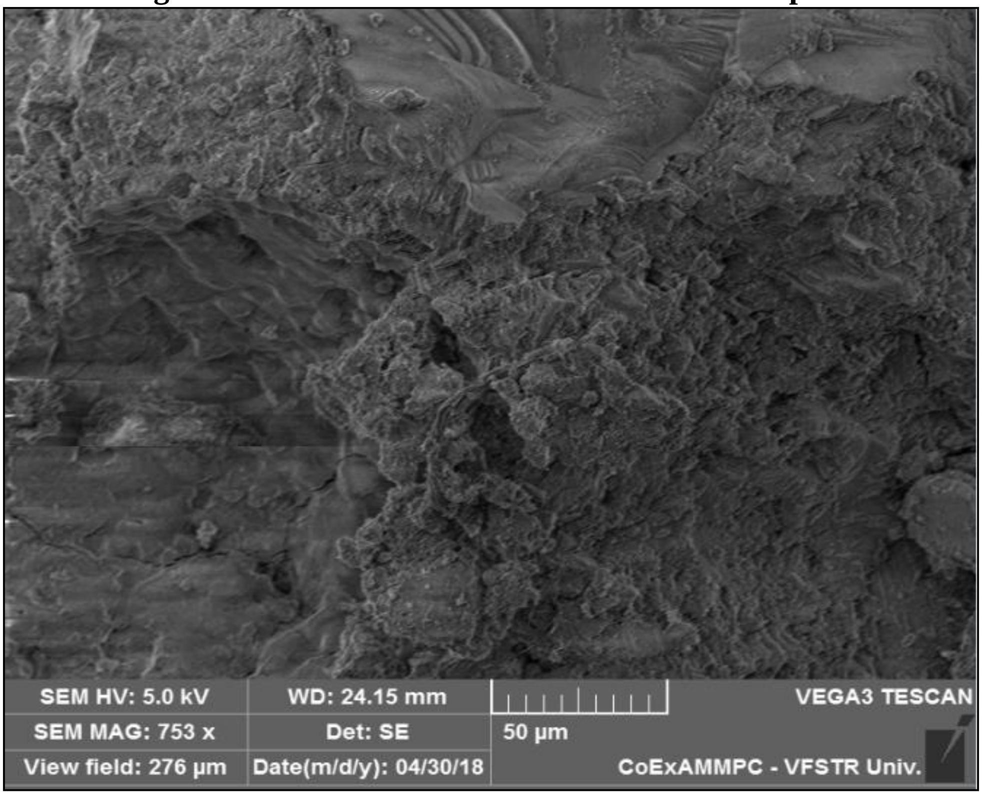


Fig.21 Micro Structure and bonding details of Normal Concrete Sample-2

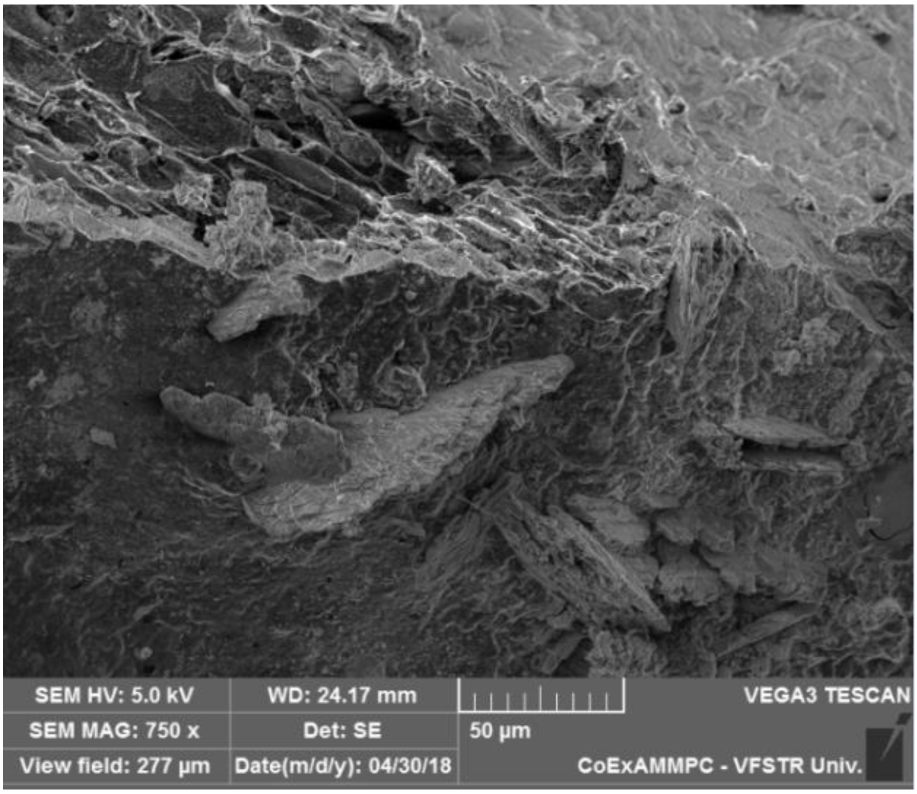


Fig.22 Micro Structure of PEBA Concrete Sample-1

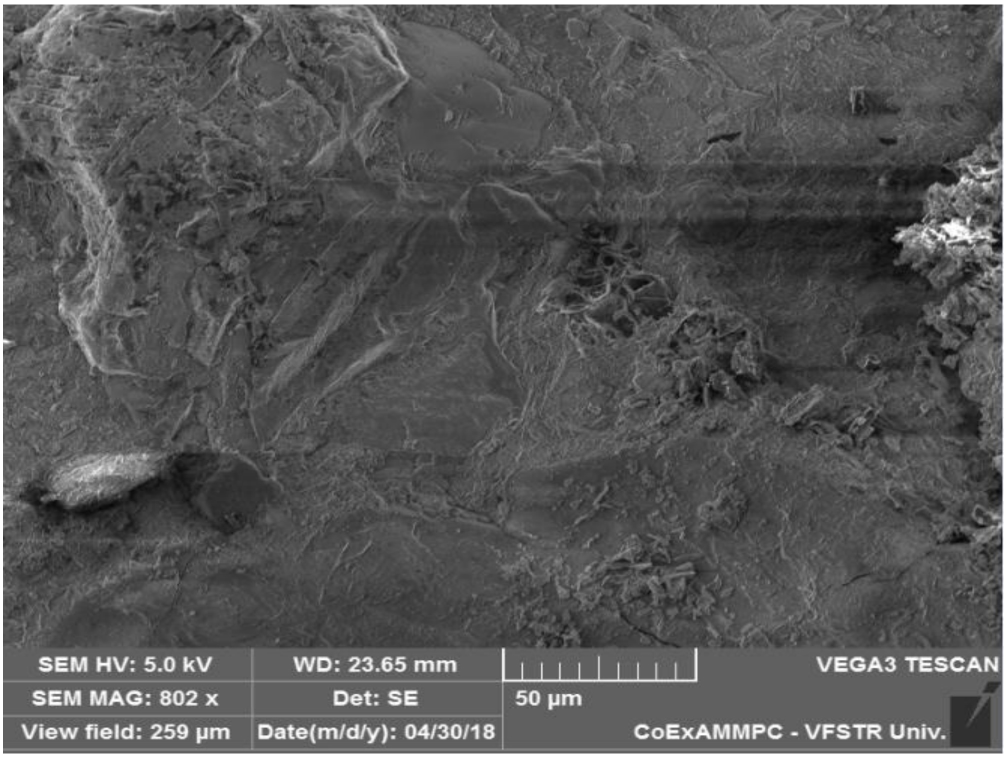


Fig.23 Micro Structure of PEBA Concrete Sample-2

Observations:

- The micro structure of the material should have found with digitally and the variations of the micro filling ability can also be examined physically by practice.

- In this investigation compare the two concrete mixes on the basis of micro-structure by using SEM. The mixes are normal concrete, PEBA (palm empty bunch ash) concrete.

The surface structure and micro structure of the two concretes are unique.

5.4. Abstract Estimate of Cement and PEBA (Palm Empty Bunch Ash)

In previous chapters shows the detailed discussion about material properties, quantities required, tests and test results, in this chapter gives the cost estimation of cement and PEBA per one cubic meter. The abstract estimate of cement and PEBA is done on the basis of present market schedule of rates. The following **table-11** should be given the complete abstract as listed below;

Table No.11 abstract estimate of cement & PEBA

% Replace		0	5	10	15
Quantity of material (kg/m^3)	**Cement**	478.94	478.94	478.94	478.94
	PEBA	0	23.94	47.89	71.84
No. of bags ($1m^3$)	**Cement**	9.578	9.1	8.621	8.142
	PEBA	-	0.798	1.594	2.394
Cost of each bag	**Cement**	310			
	PEBA	0			
Total cost (Rs/m^3)	**Cement**	2969.43	2829	2672.5	2524
	PEBA	0			
Cost of control (Rs/m^3)		0	148.43	296.92	445.41

Observations:

i. Type of cement = OPC 53 grade KCP Cement.

ii. Rate of materials (50 kg/bag)

- Cement = Rs 310 /- (As per schedule of rates)
- PEBA = Rs 0 /- (As per my project company given to me with free of cost, but they use to sell with some cost as per company requirements)

6. CONCLUSIONS

The following are conclusions could be achieved from the investigation:

i. Workability* of concrete and the micro filling ability is also good.

ii. The PEBA concrete is eco-friendly* and controls the environmental pollution by improper disposal.

iii. The maximum compressive strength of PEBA concrete is 40.41N/mm^2 the optimum replacement level of cement by PEBA is 10%.

iv. The maximum split tensile strength of PEBA concrete is 2.83 N/mm^2 the optimum replacement level of cement by PEBA is 5%.

THE AVERAGE FLEXURAL STRENGTH OF PEBA CONCRETE IS 11.25 N/MM^2 THE OPTIMUM REPLACEMENT LEVEL OF CEMENT BY PEBA IS 15%.

v. **AFTER OPTIMUM PERCENTAGE LEVEL THE STRENGTH WILL DECREASE WITH INCREASING OF PEBA CONTENT.**

vi. The SEM results shows that PEBA concrete performs better than normal concrete by compare with the surface and micro structure analysis, the maximum voids takes place in normal concrete than PEBA concrete.

vii. It's proved; the maximum usage of cement is minimized by replacing cement by PEBA and also cost will be decreased with increasing of PEBA. The maximum replacement level is 15% and Cost of control (Rs/m^3) is 445.408, % save in cost is 14.99 % respectively.

From the above results PEBA concrete performs well at 5%, 10%, and 15%. So the optimum percentage level of PEBA by cement is 15 %. After that the strength may decreases with increasing PEBA. For the future development this investigation may help to control the environmental pollution* and make the work feasible to the normal constructions, finally the PEBA concrete is eco-friendly in nature.

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