Utilization of Oil Palm Shell in Light Weight Reinforced Concrete

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Abstract

Utilizing alternative material resources which are obtained as by products from various manufacturing industries are considered for research for better and reliable outcome so as to adapt these in future. This thesis, presents the optimization of partial replacement of coarse aggregate by oil palm shell which can act as light weight concrete in grade of M30 which are evaluated for its fresh and hardened properties say compressive strength, split tensile strength, flexural strength, fresh and 28-day air dried density where coarse aggregate will be replaced with oil palm shell in five different proportions (i.e., 10%, 20%, 30%, 40% and 50%) as per IS 10262 -2019 and IS 456 -2000.

In addition, the durability studies say Rapid Chloride permeability as per ASTM C 1202-25, acid attack for M30 grade of concrete as per ASTM C 1202-27 were studied and compared with the control identities. It was observed that oil palm shell replacing 10% of coarse aggregate is determined to be the optimum percentage of replacement in M30 Grade of concrete post scrutinizing.

Furthermore, Finite element analytical studies using ANSYS Explicit Dynamics were carried out to evaluate the load displacement property and flexural property of M30 Grade reinforced concrete beams.

***Keywords**: Oil Palm Shell, Light weight concrete, Finite element analysis, Displacement, Deformation*

1. INTRODUCTION

1.1 Cement

Cement is manufactured from the oxides of silicon, calcium, iron, aluminium which were finely grounded and thus agitated in fusion in a kiln at 1450°c. During the tenure, the liberation of carbon dioxide gases are determined to be one of the major green-house gases in the atmosphere causing environmental pollution and global warming. It was estimated that nearly 1 tonne of cement manufacture produces 1 tonne of carbon dioxide gases in the atmosphere. According to the recent survey report, 8% of carbon dioxide gases are being emitted from the cement manufacturing unit. Besides, our planet will face the wrath of nature due to the rapid collapse of environmental and ecological cycle in a period of time and the impact will be devastating. In order to conserve, utilization of natural resources in a large scale should be reduced and an alternative solution to be identified. Recent research studies reveal that Limestone calcined clay cement evolved in such a way to curb this impact for the betterment of the environment.

1.2 Sand

Sand is one of the vital ingredients in producing concrete. About 35% of the volume of sand accounts for manufacturing conventional concrete containing higher percentage composition of inorganic materials, chlorides, sulphates and clay which will affect the rheological properties of concrete in terms of reduced strength and durability.

1.3 Manufactured sand

Manufactured sand is different from river sand and sea sand due to its mineralogical and physical properties. Due to the fact that, river beds get exploited, manufactured sand will drive the need to act as alternative source material in terms of alternate aggregate which are being procured from quarries, wastes obtained from different sectors. Crusher dust seem to have good resource and hence manufacturedsand is produced from rock quarries. Manufactured sand yields strength at 30% to 45% in production rate depending upon its parent rock, equipment used for crushing and the stipulations adopted.

In view towards cost comparison, manufactured sand is cheaper than river sand the requirement in mortar applications pertaining to different ratios are 20% lesser than that of actual quantity requirement

1.4 Oil Palm Shell

Oil palm shell replacement as coarse aggregate, attains the strength greater than 17MPa, which is a mandatory requirement for structural light weight concrete as per ASTM standards. The bulk density of oil palm shell stands in the range of 500-600kg/m³. It was observed that partial replacement oil palm shell concrete's densityvaries in the range of 1700 to 2185kg/m³, hence it can be used as an alternative material for the replacement of coarse aggregate to produce structural light weight concrete.

1.5 Objectives of the Study

The objective of this study is to determine the mechanical and durability performance in terms of compressive, split tensile and flexural strength of oil palm shell light weight concrete for the grade of M30 at various replacement levels say 10%, 20%, 30%, 40% and 50% respectively thereby comparing the result outcomes to conclude the most effective or viable part considered for replacement level in concrete mix proportioning. The outcomes on the mechanical performance shall be validated through Finite Element Analysis by developing a model in Analysis Systems and computing stress strain for different percentage levels of replacement of which the elastic moduli, stress strain, load versus displacement relationships shall be assessed. In addition to that determining the extent of durability corresponding to different strategies will be performed

2. MATERIALS

2.1 Cement

Ordinary Portland cement of Grade 53 confirming to the Bureau of Indian StandardsIS 12269:2013 are considered for evaluation.

2.2 Aggregate

For a good quality of concrete, aggregates are to be hard, clean, free from chemicals which are being absorbed or free from clay coating alongwith other fine materials which will render the concrete to deteriorate. Basically, aggregates accounts for 75% of the total volume in concrete which will be further divided into two categories say fine aggregate (manufactured sand) and coarse aggregate.
Fine aggregate (M-Sand) has a Specific gravity of 3.1, similarly specific gravity of coarse aggregate is 2.89.

Fig. 1 Manufactured sand

2.3 Oil Palm Shell

Oil palm shell had been classified as low-cost construction material – type of agricultural waste which can be adopted in terms of replacement of coarse aggregates for producing concrete at mass levels.

Fig. 2 Oil Palm Shell

Table 1. Physical Properties of OPS aggregate

S. No	Description	OPS
1	Maximum size (mm)	12.4
2	Specific gravity (SSD)	1.17
3	Water absorption (24hr) [%]	23.2
4	Aggregate absorption value (%)	4.6
5	Los Angeles value (%)	4.6
6	Compacted bulk density (kg/cu.m)	590
7	Fineness modulus (F.M)	6.23
8	Flakiness index (%)	65
9	Elongation index (%)	12.14
10	Aggregate impact value (%)	7.9

2.4 Admixture Conplast SP 430

Conplast SP 430 is a chloride free, super plasticising admixture based on selected sulphonated naphthalene polymers. Conplast SP 430 provides excellent acceleration of strength gain at early ages and major increases in strength at all ages by significantly reducing water demand in a concrete mix. It is particularly suitable for precast concrete and other high early strength requirements.

2.5 Water

Fresh potable water, free from acid and organic impurities are used for blending theconcrete mix.

2.6 Mix design for M30 grade of concrete

Mix design was formulated given in Table 2, in accordance with IS10262:2019 in terms of weight basis for each component involved say cement, fine and coarse aggregates, oil palm shell considering 0%, 10%, 20%, 30%, 40% and 50% replacement, water and admixture.

Table 2. Mix Design for M30 Grade of Concrete

S.No	Mix ID	% of OPS	Cement	FA	CA	OPS	Water	Conplast SP 430
1	C.M	0	425	670	1280	0	168	2.2
2	M1	10	425	670	1150	130	168	2.3
3	M2	20	425	670	1020	260	168	2.2
4	M3	30	425	670	890	390	168	2.2
5	M4	40	425	670	770	510	168	2.2
6	M5	50	425	670	640	640	168	2.2

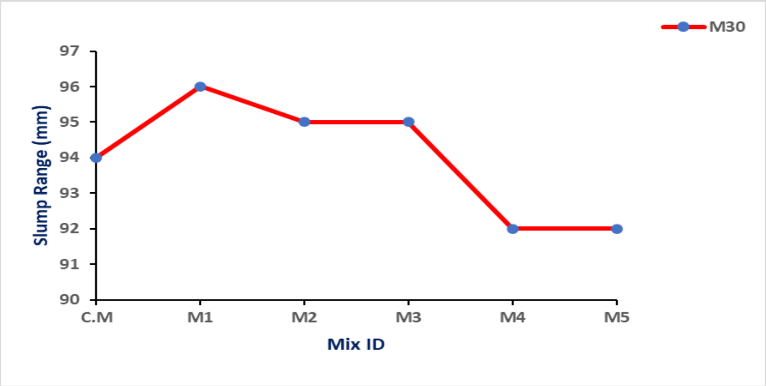


Fig. 4 Graph showing slump values for different grade of concrete

3. EXPERIMENTAL INVESTIGATION

3.1 Compressive Strength

Concrete samples which have successfully completed its curing regime are allowed to undergo compressive strength test. The surface of the concrete samples is made dry and allowed to note down the density (kg). Then, the sample (150mm x 150mm x 150mm) is placed in the compressive strength testing machine having a capacity of 2 tonne. Loading is applied gradually of which the specimen is ought to undergo compressive forces and at one point the specimen will attain fracture.

$$\text{Compressive Strength} = P/A \text{ (MPa)}$$

Where,

P is Load in N, A is Area of Specimen mm^2

Fig. 5 Compressive Strength Testing Machine

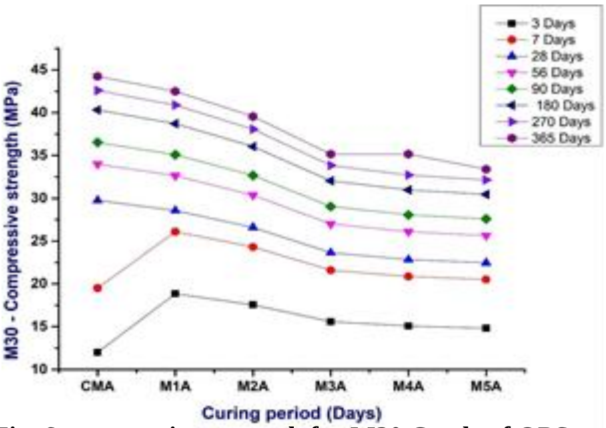


Fig. 6 compressive strength for M30 Grade of OPS concrete

3.2 Split tensile Strength

Split tensile strength concept where the cylindrical specimens after its curing regime are taken out, dried and weighed for density note and placed in compression testing machine. Care should be taken that the upper andlower base plates are fixed prior to loading the specimen. Loading shall be applied gradually and fracture point is to be noted. Based on that, split tensile strength shall be computed using the formula

$$\text{Split tensile strength} = 2P/\pi DL \text{ (MPa)}$$

Where

P corresponds to the fracture load
D and L corresponds to the diameter and the length of the specimen

Fig. 7 Sample of cylindrical specimen

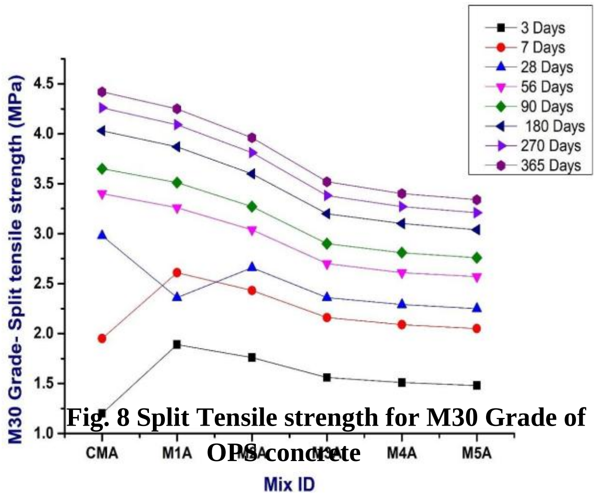


Fig. 8 Split Tensile strength for M30 Grade of OPS concrete

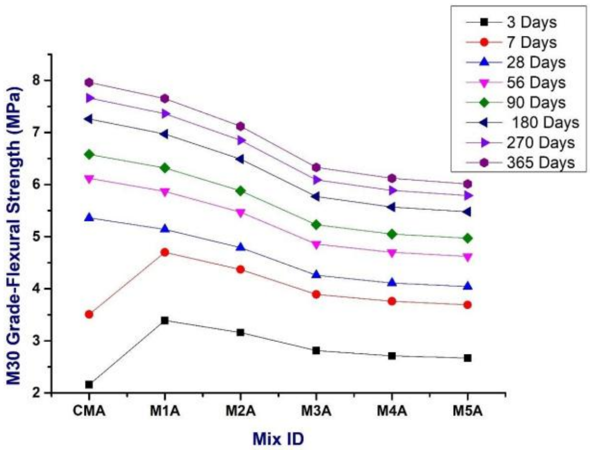
3.3 Flexural Strength

Flexural strength shall be described as modulus of rupture. It is a property in which the determination of stress is known in a composite material prior to yield at the time of rupture.Three-point loading had been considered for evaluation. Prism specimens are placed on the testing machine and loading is applied. First crack will attain at the bottom surface of the specimen. Based on the fractured load, flexuralstrength of the specimen shall be computed by the formula

Flexural strength of the specimen: $3FL/2bd^2$ (MPa)

Where
F corresponds to the fracture load
L is the length of the support span
b and d are the width and thickness of the specimen

Fig. 9 Flexural crack occurrence in prism specimen



3.4 Load versus Deflection for M30 grade of OPS concrete

In order to assess the load deflection pattern for the proposed M30 grade of concrete with

10% replacement of oil palm shell, a beam was designed and executed as per the detailing requirements given in Fig. 11. The cross section of the beam is of 0.2 m x 0.2 m with a span length of 1.2 m. Fe 500D grade of steel with a clear spacing of 25 mm is adopted. Three-point method of loading is considered with 100 mm offset from the base of the support. Linear voltage displacement transducers were used for measuring deflection including one at the mid span and the other beneath the loading points. The test was carried out using universal testing machine. The loading point is fixed at the center of the specimen.

The set beams are preloaded with 0.5 kN so as to allow intimation of the linear voltage displacement transducers. The flexural deformation and development of cracks were observed.

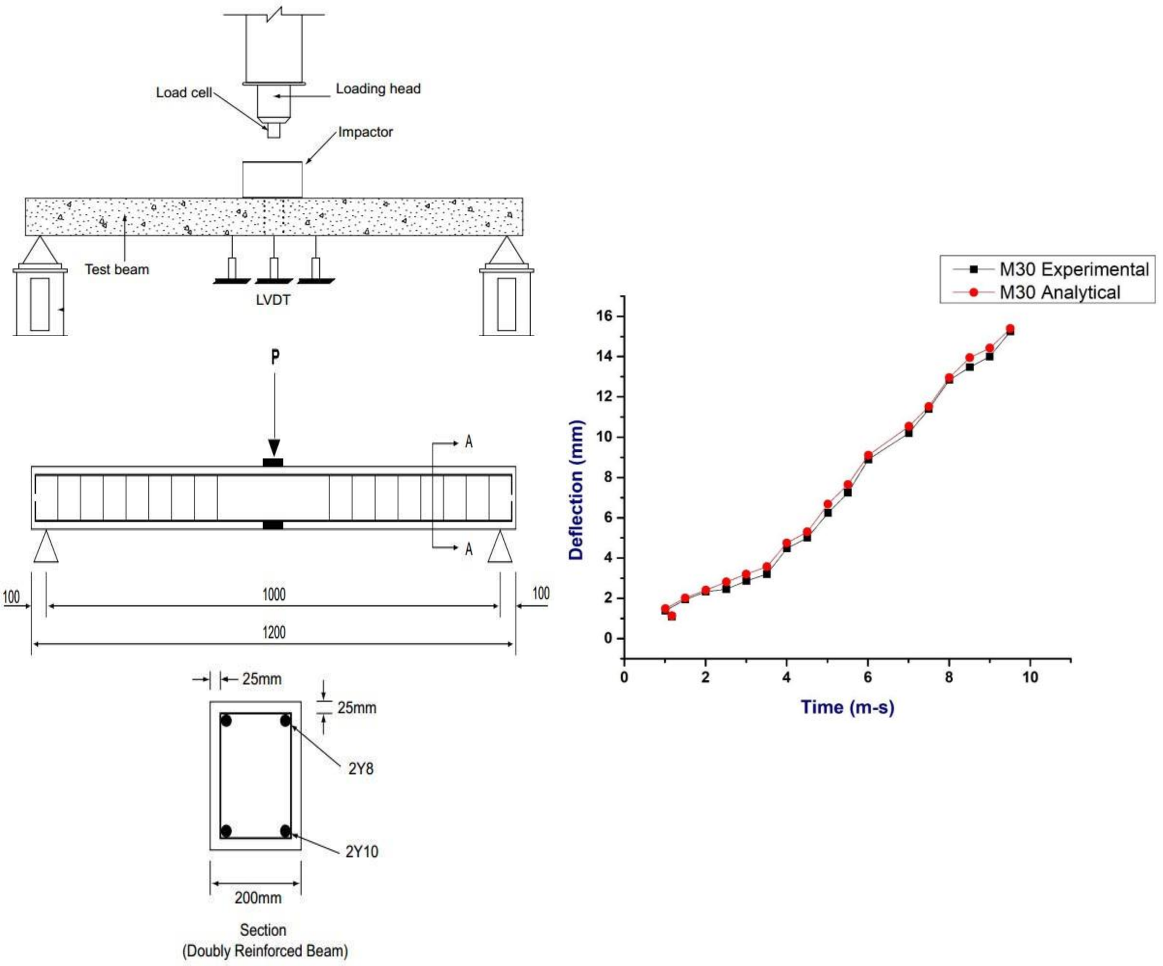


Fig. 11 Experimental Test setup of the doubly reinforced beams & Load deflection Curve for M30 grade Control concrete

3.5 Rapid Chloride Permeability Test

Rapid Chloride Permeability Test method (RCPT) was carried out as per ASTM C1202. The samples of oil palm shell concrete including conventional and replacement for M30 was considered for chloride permeable evaluation. Sample dimensions say 100 mm diameter x 50 mm thick are carved into slices from the mid part of the 100 mm diameter x 200 mm height cylindrical specimen. A direct current voltage of 60.0 ± 0.1 V was applied across the two faces of the sample and the current passing through the concrete specimens was observed at 30 min intervalsin a period of 6 hours. The total charge passed in Coulombs was determined and the cadre of evaluation was made according to chloride permeability range. The tests were performed at the age of 28 days respectively and the results procured at each age for M30 grade of oil palm shell concrete were tabulated.

The formula given below, can also be used to calculate the average current flowing through single cell.

$$Q900 (I_0+2I_{30}+2I_{60}+2I_{90}+2I_{120}+2I_{300}+2I_{330}+I_{360})$$

where,

Q: current flowing through one cell (coulombs)

I_0:current reading in amperes immediately after the voltage is applied

I_t :current reading in amperes at ‘t’ minutes after voltage is applied

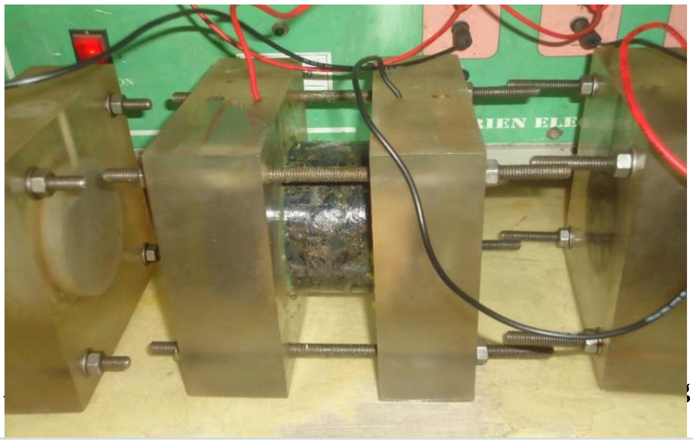


Fig. 12 **RCPT**

Fig. 13 Graph showing in charge passed for M30 grade OPS concrete at 28 Days

3.6 Acid attack Test

Generally, Concrete is rigorously susceptible to acid attack. If it tends to remain alkaline in nature in the presence of calcium silicate and water, the reaction converts those to calcium silicate hydrate with calcium hydroxide. This will attack a part of cement paste producing calcium salts which is highly soluble as a byproduct. This can be easily eliminated from the cement paste by weakening its structure in terms of mass form. Aggressive and destructive attacks will occur when concrete is exposed to sulfuric acid which will elevate degradation due to sulfate attack as a product.

$$H_2SO_4 + Ca\,(OH)_2 \Rightarrow Ca\,(SO)_4 + 2H_2O$$

Fig. 14 Concrete sample exposed to acid (H_2SO_4) attack

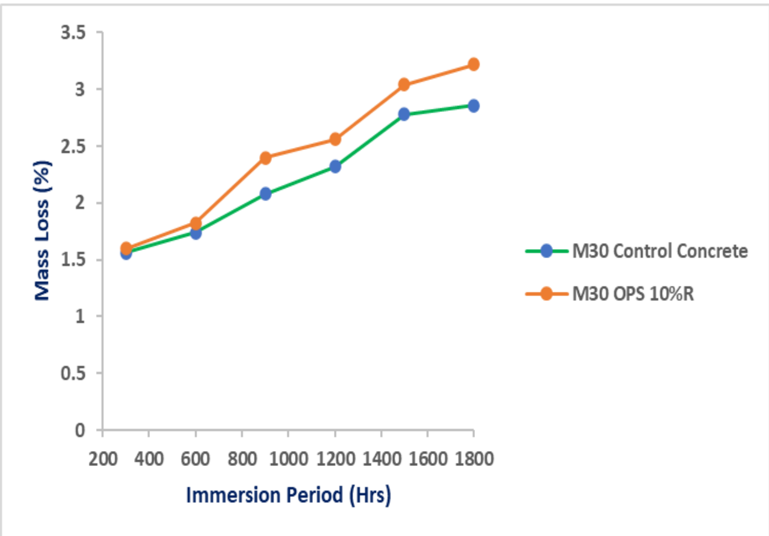


Fig. 15 Graph showing percentage loss in mass of M30 grade of control concrete and 10% Replacement of Oil Palm Shell in Concrete after Exposed to Acid Attack

4. NUMERICAL ANALYSIS

ANSYS is determined as an analytical software involving the concept of Finite Element Analysis (FEA)

It is a computerized method to predict and evaluate how an object reacts to real forces, thermal, vibration, fluid flow and additional or other physical effects.

It also explores whether an object at real time designed by any user will collapse the way it had been designed subjected to real time forces

4.1 Governing equation in Explicit Dynamics

This equation is based on Implicit Time Integration:

$$Mx + Cx + Kx = F\ (t)$$

Where m and c are mass and damping matrix, k corresponds to stiffness matrix, and F(t) corresponds to force vector.

4.2 Modelling and Post Processing conventional M30 Grade OPS concrete with 10% Replacement

Meshing for the entire solid model was created and the entire model was divided into fragments on par with the size of the mesh. Support and Impact were created at the ends and centre of the model and boundary conditions were applied to the support and impactor where the movement at both the direction was restrained and the impactor is allowed to precede in negative y axis at marginal loading rate.

Outcomes were chosen and ANSYS solver was allowed to run to derive the response of the model represented in terms of failure.

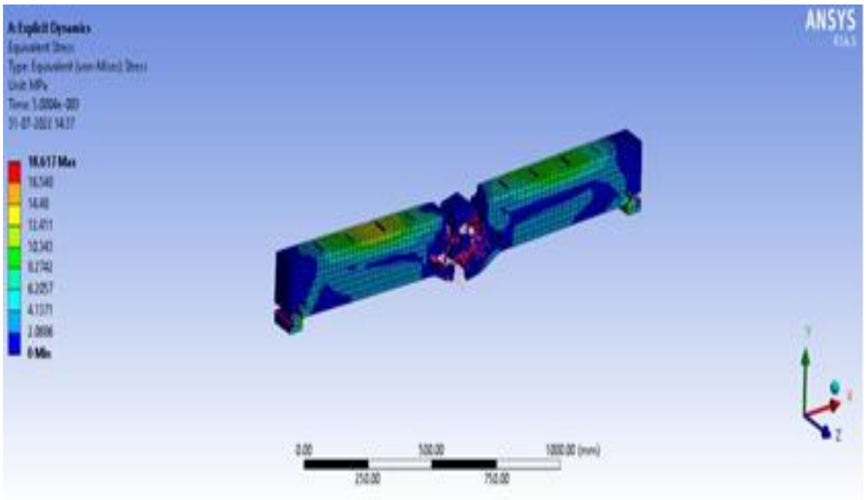


Fig. 16 M30 with 10% OPS Concrete – Von Mises Stress

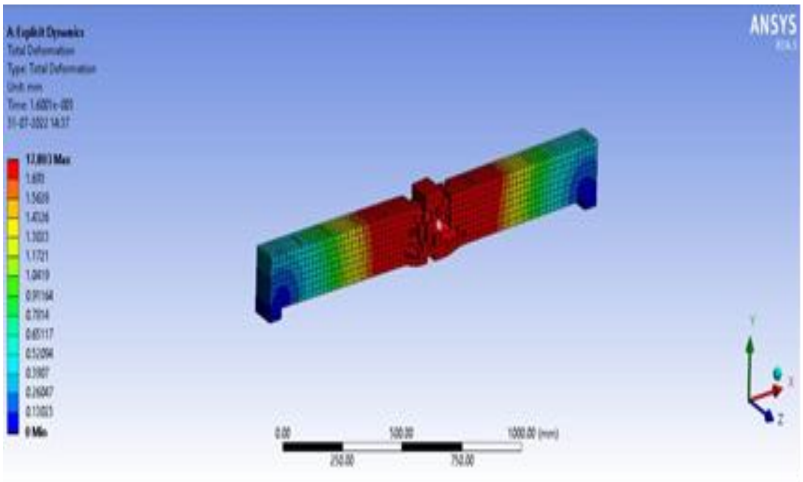


Fig. 17 M30 with 10% OPS Concrete – Total Deformation

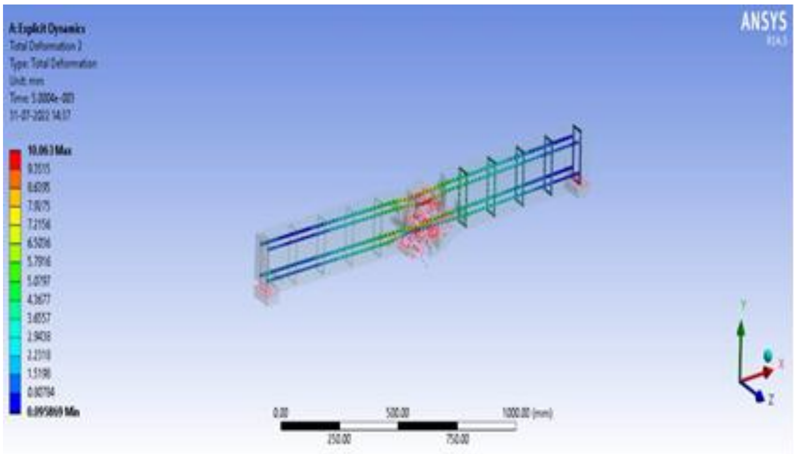


Fig. 18 M30 with 10% OPS Concrete – Total Deformation in reinforcement

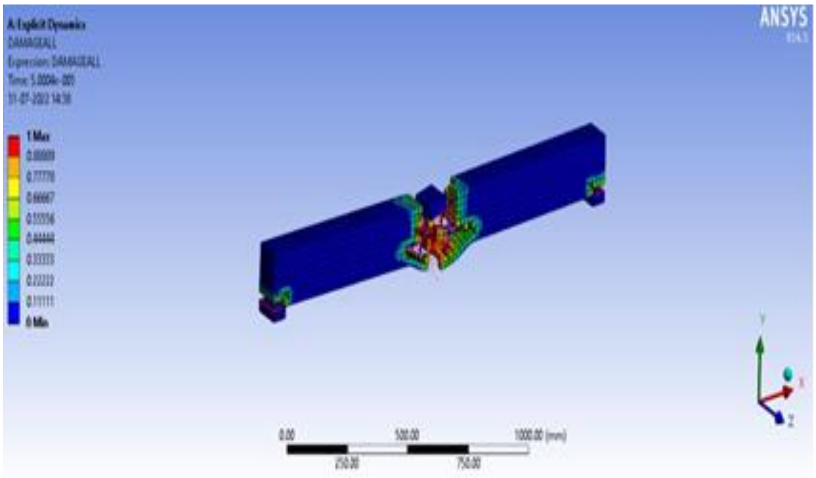


Fig. 19 M30 with 10% OPS Concrete – Fracture

5. EXPERIMENTAL AND ANALYTICAL TEST RESULTS

5.1 Compressive strength

The compressive strength for conventional M30 grade of concrete had a marginal increase ranging from 12 MPa to 44.24 MPa (3 day and 365 day) whereas while replacing the coarse aggregate by oil palm shell in terms of 10% the compressive strength was increased to 18.85 MPa at 3 day, 28.57 MPa at 28 days, 42.49 MPa at 365 days tenure. When adding the oil palm shell by 20%, 30%, 40%, 50%, the compressive strength drastically reduced ranging fromlower most 14.82 MPa to 33.40 MPa when compared with 10% replacement of OPS

5.2 Split tensile strength

The split tensile strength for conventional M30 grade of concrete had a marginal increase ranging from 1.2 MPa to 4.42 MPa (3 day and 365 day) whereas while replacing the coarse aggregate by oil palm shell in terms of 10%, the split tensile strength was increased to 1.89 MPa at 3 day, 2.86 MPa at 28 days, 4.25 MPa at 365 days tenure. When adding the oil palm shell by 20%, 30%, 40%, 50%, the split tensile strength drastically reduced ranging from lower most 1.48 MPa to 3.34 MPa, when compared with 10% replacement of OPS.

5.3 Flexural strength

The flexural strength for conventional M30 grade of concrete had a marginal increase ranging from 2.16 MPa to 7.96 MPa (3 day and 365 day) whereas while replacing the coarse aggregate by oil palm shell in terms of 10%, the flexural strength was increased to 3.39 MPa at 3 day, 5.14 MPa at 28 days, 7.65 MPa at 365 days tenure. When adding the oil palm shell by 20%, 30%, 40%, 50%, the flexural strength drastically reduced ranging from lower most 2.67 MPa to 6.01 MPa when compared with 10% replacement of OPS.

5.4 Rapid Chloride Permeability Test

It was observed that, in accordance with ASTM C1202 rating, chloride penetration was higher for conventional concrete with replacement levels containing oil palm shell at at 28 days, the charge passing ranges from 4282 to 4688 at different stages and at M30 grade of concrete revealing higher chloride penetration.

5.5 Acid attack

Concrete specimens subjected to acid attack (sulfuric acid) will reveal no sign of mass loss while immersion at early stage. Specimens usually exhibit linear increase in mass loss post 300 to 500 hours of immersion in the solution. The chemical reaction between calcium hydroxide and sulfuric acid, produce ettringite which initiate crack formation on the concrete and as a result, fine aggregate particles tend to fall off from its position. Control concrete exhibit 1.34% to 3.34% of mass loss when immersed in sulfuric acid between 300 to 1800 hour tenure. With respect to concrete with 10% OPS which determined as the optimum percentage of replacement has 1.4% to 3.68% of mass loss.

6. CONCLUSION

- It is observed that the compressive, split tensile, flexural strength of M30 grade of concrete can be improved by partial replacement of coarse aggregate by OPS (10%)
- It is noted that, the target strength was nearly achieved by partial replacement of coarse aggregate by OPS (10%) pertaining to 365 days long term compressive, split tensile, flexural strength. However, OPS in terms to 20%, 30%, 40%, 50% provides acceptable outcome criteria that can be adaptable for minor works
- It is concluded that M30 control concrete has a maximum deformation of 15.39 mm and 13.58 mm in reinforcement. When comparing with analytical studies, M30 deformed to 17.8 mm and 10.06 mm in reinforcement. Overall, it reveals that there is marginal increase in deformation whencompared with control concrete
- From the above experimental results, it is proved that, Oil palm shell can be used as an alternative material for coarse aggregate
- The present experimental programme revealed that the properties of the concrete will enhance the utilization of OPS contained from the place of river sand in concrete
- When the percentage replacement of oil palm shell goes beyond 10%, the strength is considerably reduced

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