# Strength and Durability Studies on Lightweight Fiber Reinforced Concrete by Incorporating with Palm Oil Shells

**Ala Muralidhar, J. Durga Chaitanya Kumar**

***Abstract:*** ***In this present research agricultural byproducts obtained at the industry of palm oil is used a coarse aggregate in the concrete. The palm oil shells (OPS) are the waste from the palm oil industry. For this study 30% (0,10,20 and 30) of coarse aggregate are replaced with OPS. for this study M30 grade concrete is designed by adding 0.2% electro-chemical resistances (ECR) glass fiber to the volume of the concrete and to be reduced the greenhouse gases from the cement industry replacing the cement with ground granulated blast furnace slag (GGBS) up to 30% (0,10,20 and 30)) are used. For this concrete strength (compressive strength, split tensile strength, and modulus of rupture), and durability of Sulphate attack, Acid attack and Chloride attack are done. All the results are compared with normal concrete.***

***Index Terms*****: Acid Attack, chloride Attack, Electro-chemical resistances (ECR) glass fiber, ground granulated blast furnace slag (GGBS), palm oil shells (OPS), Sulphate Attack.***

## I. INTRODUCTION

Most extremely utilized materials in the construction in various modes of all civil engineering works is "CONCRETE". This includes infrastructure, low- and high-rise building. Palm oil shells (OPS) which are a forming agriculture solid waste, available bulk quantities in tropical countries like Malaysia. OPS is used as coarse aggregate and also used as structural lightweight concrete. The opacity of OPS is based on the various nuts from different species of palm trees ranging from 0.50-8.00 mm [1] The main aim of this work is to bring to a successful end to accomplish a lightweight concrete by replacing OPS with agricultural waste in the place of coarse aggregate. Also, the GGBS is used as a partial replacement in cement substitution. The mix design is done by taking into a count of the strength required, density and workability obligatory for the specific use of lightweight concrete. Durability and strength are serviceability factors for concrete structure. Great significant facts are these structures are still in good condition validating the durability of concrete. The current work focuses on exploring the quality of M30 grade concrete blended with GGBS by replacing cement with 0%, 10%, 20%, and 30%. The cubes, cylinders, prisms, and beam are trailed under compressive strength, split tensile strength, and modulus of rupture. Durability studies Sulphate attack, Acid attack, and Chloride attacks.

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### *A. Lightweight concrete*

Lightweight concrete, resemble normal weight concrete, is a mixture of water, Portland cement or ordinary Portland cement (OPC), and aggregate. Lightweight aggregate concrete uses a variety of aggregate causing to descend density than normal weight concrete. The density of lightweight concrete typically ranges from 1400 to 2000 Kg/m$^3$ for normal-weight concrete. The lightweight concrete density of approximately 1850 Kg/m$^3$. The bulk density of OPS is about 500 to 600 Kg/m$^3$ [ 2]. M1 mix is a plane normal concrete mix. M2 indicates concrete mix with palm oils shells and 10% GGBS are used. M3 indicates concrete mix with 20% of palm oil shells and 20% GGBS are used. M4 indicates concrete mix with 30% palm oil shell and 30% GGBS are used [5]. Demould density all mixes as shown in Table.1.

**Table: 1 Demould Density**

| Mix ID | Demould Density (Kg/m$^3$) |
|---|---|
| M1 | 2417 |
| M2 | 2373 |
| M3 | 2337 |
| M4 | 2222 |

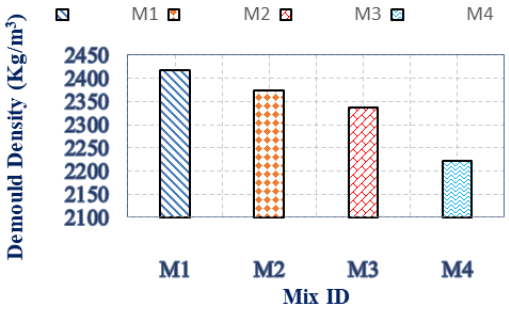


**Fig. 1: Demould Density**

It is observed that from the fig. 1 density of concrete is reducing with the rise of OPS percentages. But all three mixes are given the density are in the range of light weight concrete. The minimum density is 22.2 Mpa for M4.

## II. MATERIAL PROPERTIES

### *A. Cement:*

In this present research work, ordinary Portland cement of 53 grade is owed. The cement tests are conducted as per Indian standard IS 12296-1987 [9]. The Physical Properties of cement are shown in the table.2

**Table: 2 Physical Properties of cement**

| Properties | Results |
|---|---|
| Specific gravity | 3.14 |
| Initial setting time | 30 minutes |
| Final setting time | 600 minutes |

*B. Coarse aggregate*

The range between 20 mm and 4.75 mm are considered as a coarse aggregate. The aggregate of a particular shape, surface texture, bulk density, absorption, and hardness are required as a coarse aggregate. In this Investigation maximum size of aggregates are used as 20mm. The physical properties of coarse aggregate are shown in the following Table.3

**Table: 3 Physical properties of coarse aggregate**

| Properties | Results |
|---|---|
| Specific gravity | 2.24 |
| Water absorption | 0.69 |
| Aggregate crushing value (%) | 28.70 |
| Aggregate impact valve (%) | 24.00 |
| Abrasion value (%) | 27.02 |
| Fineness modulus | 7.94 |
| Size (mm) | 20 |

*C. Fine aggregate*

In this work river sand is used as a fine aggregate which is passing through IS 4.75 mm sieve. The physical properties of fine aggregate are shown in the Table.4

**Table: 4 Physical properties of fine aggregate**

| Properties | Results |
|---|---|
| Specific gravity | 2.62 |
| Water absorption (%) | 0.8 |
| Size (mm | 4.75 |
| Zone | II |

*D. Palm oil shell (OPS)*

Palm oil shell (OPS) are obtained in different forms i.e., curved, flaky, elongation, roughly parabolic, and other irregular shapes. The apparent surface of shell will be clearly smooth for the concave and convex face [3]. The palm oil shell (OPS) color ranges on dark grey to black. Before the palm oil shell (OPS) is used as coarse aggregate which is obtained from the sieve analysis. The aggregates that are passed through the 12.5 mm and retained on the 4.75 mm sieve was used, the palm oil shells ranging in between 0.50-8.00 mm. The specific gravity of palm oil shell is 1.14-1.37 [5]. The physical properties of palm oil shell (OPS) as shown in table.5

**Table: 5 Physical properties of palm oil shells**

| Properties | Results |
|---|---|
| Specific gravity | 1.20 |
| Abrasion value (%) | 4 |
| Impact value (%) | 27.77 |
| Water absorption (%) | 20 |
| Shell thickness, mm | 0.5-3.0 |
| size, mm | 8 |

**Fig. 2**: Palm oil shells

*E. Glass fibers*

Glass fiber is a high strength of concrete. Glass fiber considered best in terms of chemical resistance. It Corrosion resistance of glass fiber. Long-term acid resistances and short-term alkali resistances is offered by ECR glass fiber. The chemical composition of ECR glass fiber as shown table.6

**Fig. 3:** ECR Glass Fibers

**Table: 6** Chemical composition of ECR glass fibers

| Oxide | % |
|---|---|
| $Sio_2$ | 54-62 |
| $Al_2O_3$ | 12-16 |
| Cao | 17-25 |
| MgO | 0-4 |
| ZnO | 2-5 |
| $Na_2O+K_2O$ | 0-2 |
| $TiO_3$ | 0-4 |
| $Fe_2O_3$ | 0-0.8 |

*F. Ground granulated blast-furnace slag (GGBS)*

Ground granulated blast-furnace slag (GGBS) is granular material formed. When molten iron blast furnace is rapidly quenched by immersing it into the water. It is a regular product with very limited crystal formation and is highly cementitious in nature. It is obtained by cooling the cast iron blast furnace slag immediately in water or steam, to produce a granular vitreous product that is dried and crushed into a fine powder [ 4].

It is an excellent blinder to produce high-performance cement and concrete. The physical properties of GGBS as shown in table.7.

**Table: 7 Physical properties of GGBS**

| Properties | Results |
|---|---|
| Specific gravity | 2.8 |
| Colour | White |
| Sieve | 4.75 |


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**Fig. 4: Ground granulated blast-furnace slag (GGBS)**

*G. Water*

Portable water is used in mixing purpose and curing conditions. Measurement of water is done accurately only when weigh batching method is adopted.

*H. Admixture*

Aramix 450 is a high performance hyperplasticiser intended for application is increased ultimate compressive strength and pumpable concrete, high performance concrete.

Specific gravity 1.10 and appearances are light yellow coloured liquid. By using this durability and early strength of concrete increases.

## III. MIX PROPORTIONS

A concrete mixture of M30 grade done as per standard specification IS 10262-1982 to achieve the target mean strength 38.25 N/mm2. The material which is used in the mixes were ordinary Portland cement (OPC), river sand, coarse aggregate, palm oil shell (OPS), GGBS, superplasticizer, ECR glass fiber, and potable water. The other four concrete mixtures were made by replacing up to 0% to 30% palm oil shells with dissimilar combination percentage of coarse aggregate. All mixes are water/cement ratio 0.45. The detail mix proportion along with their recognition is designed according to the replacement of palm oil shells and GGBS. As the percentage of palm oil shells and GGBS are increases but W/C ratio constant. Total quantity of materials as shown in table.8

**Table: 8 Total Quantity of materials**

| Mix Proportion (Kg/m$^3$) | | | | |
|---|---|---|---|---|
| Materials | M1 | M2 | M3 | M4 |
| Cement | 396 | 356.4 | 316.8 | 277.2 |
| GGBS | - | 39.6 | 79.2 | 118.8 |
| C.A | 1166.51 | 1112.38 | 988.38 | 863.46 |
| Palm shells | - | 54.130 | 108.21 | 162.06 |
| F. A | 665.25 | 665.52 | 665.25 | 665.25 |
| Water | 178 | 178 | 178 | 178 |
| Admixture | 0.4% | 0.4% | 0.4% | 0.4% |
| Glass Fiber | 0.2% | 0.2% | 0.2% | 0.2% |

## IV. EXPERIMENTAL INVESTIGATION & RESULTS

The experimental are carried out for 4-mixes for strength and durability studies. For conducting experiments standard size of moulds are use. Cube dimension is 15cm×15cm×15cm, cylinder section dimension is 15cm×30cm, prism dimension is 50cm×10cm×10cm. The moulds are smeared with a lubricant before placing the concrete. After 24 hours of casting specimen are kept for normal water curing.

## V. STRENGTH STUDIES

*I. Compressive strength*

The primary property that is considered to determine the standard of concrete is "Compressive strength". The compressive strength of four types of concrete cube sample under the curing of the environmental condition. The compressive strength is M30 grade of concrete. The strength of concrete including ordinary Portland cement along GGBS, coarse aggregate, fine aggregate and palm oil shells of concrete at the age of 7days, 28days, 56 days trail are conducted. The compressive strength of concrete [16] is with different percentage of cement and GGBS, coarse aggregate and palm oil shells. The compressive strength of concrete was tested using 150mm×150mm×150mm cube specimen. Specimen should cast and to measure the compressive strength for each trial condition and average values were considered. The test results are as shown in the table.9

**Table: 9 Compressive strength**

| Compressive Strength, (N/mm2) | | | |
|---|---|---|---|
| Mix ID | 7Days | 28Days | 56Days |
| M1 | 31.11 | 44.5 | 61.5 |
| M2 | 11.11 | 31.55 | 39.11 |
| M3 | 27.55 | 34.55 | 41.77 |
| M4 | 18.66 | 23.11 | 30.22 |

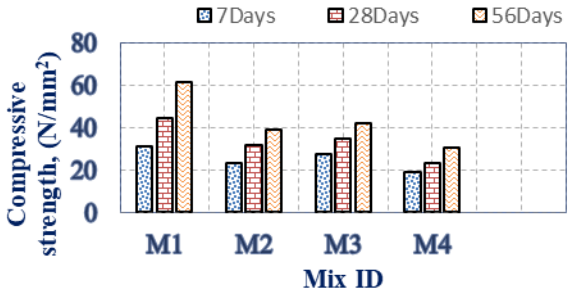


**Fig. 5: Compressive Strength for 7,28 and 56 Days**

It is observed that the compressive strength of concrete is increasing with curing age and the mix. The compressive strength is more for M3 in all curing periods.

**Fig. 6: Compressive Strength Machine**

*J. Split tensile strength*

The point at which tensile strength of a concrete fails is "Split tensile strength". The cylinder specimen is placed on the tensile testing machine having a maximum capacity of 2000 KN. In this current investigation, the trail is made on a cylinder dividing through its central plane parallel to the end by applying a compressive load to the opposite end. Ultimate load at which specimen fails is noted down from dial gauge reading [6]. Total mix results as shown in table.10

**Table: 10 Split tensile strength test results**

| Split Tensile Strength, (N/mm2) | | | |
|---|---|---|---|
| Mix ID | 7Days | 28Days | 56Days |
| M1 | 3.910 | 4.880 | 6.210 |
| M2 | 2.230 | 2.547 | 3.397 |
| M3 | 2.264 | 2.760 | 3.680 |
| M4 | 1.981 | 2.264 | 2.547 |

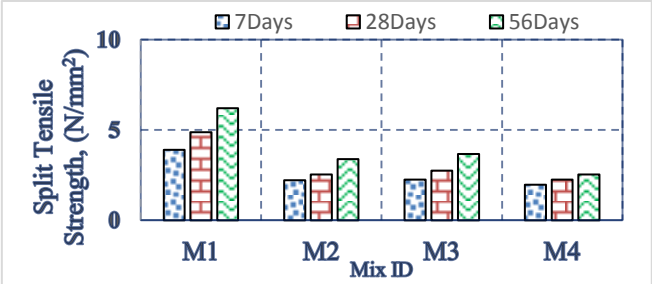


**Fig. 7: Split Tensile Strength for 7, 28 and 56 Days**

As like the compressive strength, the split tensile strength also increasing with curing period. M3 concrete given good tensile strength.

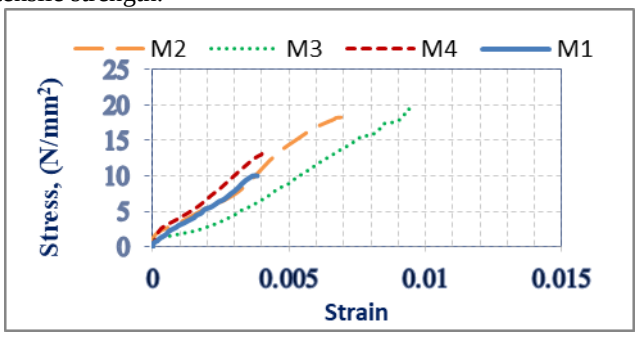


**Fig. 8:** Stress-Strain Curve for 28 Days**.**

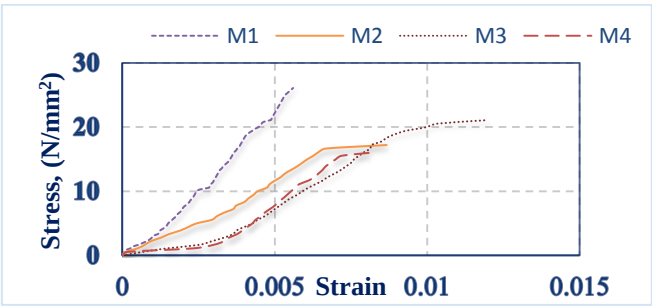


**Fig. 9: Stress-Strain Curve for 56 Days**

The young modulus is calculated for all mixes. The stress vs strain graphs are plotted and shown in fig:8 and 9 for 28 and 56 days of curing.

*K. Young's Modulus:*

It is ratio between stress to strain with in the limit proportionality. In this results stress by strain in the graphs as shown in results.

**Table: 11 Young Modulus results**

| Young Modulus(E), Mpa | | |
|---|---|---|
| Mix ID | 28Days | 56Days |
| M1 | 4288.69 | 4659.26 |
| M2 | 2647.00 | 1987.25 |
| M3 | 2074.17 | 1757.90 |
| M4 | 3249.63 | 1939.67 |

It is to observed that from the table:11. The young modulus is high for the M4-Mix.

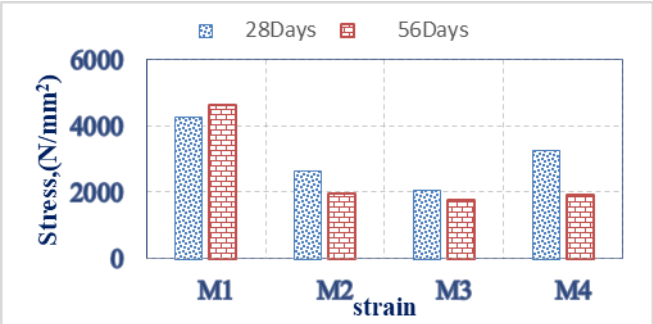


**Fig. 10: Young Modulus graph for 28days and 56days.**

*L. Modulus of rupture*

The prismatic specimen is placed on a flexural testing machine of having a maximum loading 15000kgs. The test specimen a two-point loading. Ultimate load at which the prismatic specimen fails is noted down from dial gauge reading. Modulus of rupture results as shown in table.12

**Table: 12 Modulus of rupture test results**

| Modulus of Rupture, (N/mm2) | | | |
|---|---|---|---|
| Mix ID | 7Days | 28Days | 56Days |
| M1 | 600 | 900 | 1300 |
| M2 | 200 | 400 | 650 |
| M3 | 400 | 450 | 700 |
| M4 | 400 | 300 | 450 |

**Fig. 11: Flexural Strength Test**


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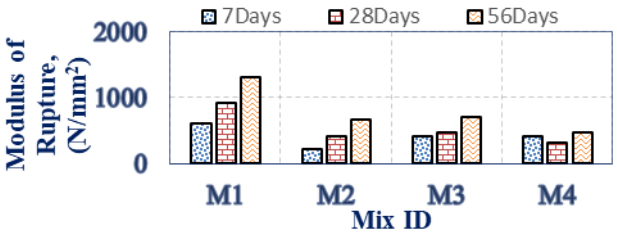


**Fig. 12: Modulus of Rupture for 7 and 28 Days.**

It is observed from fig:12. The modulus of rupture is more than for M3-Mix.

## VI. DURABILITY STUDIES

In this project is studied in durability studies are Acid attack, Sulphate attack, Chloride attack. For all the mixes from M1 to M4 durability studies are carried out for Acid attack, Sulphate attack, and Chloride attack. All the mixes are first cured in normal water for 28 days and then removed from the water and surface cleaned with running water, after surface dry it is weighed in balance and after kept for chemical curing. After 56 days curing (28 days water + 28 days chemical curing). The cubes are cleaned and checked for weight loss and strength loss. For 28 days of chemical curing the PH is maintained constantly.

### 1) Acid attack

Concrete cube specimen has resisted attacking and the output has been carried out by measuring the loss of weight of the sample continuously which was submerged in 5% of the acid solution. Resulting this palm oil shell has concrete cube its weight in acid solution. Curing for the immersion of concrete cube in acid solution was done to 28days and 56days. In 5% of $H_2$ $SO_4$ solution specimen as immersed and the constant PH value was maintained in solution [7].

**Table: 13**

| Mix | Weight before chemical curing | Weight after chemical curing | Weight Loss (%) | Strength | | |
|---|---|---|---|---|---|---|
| | | | | Before curing | After curing | Loss (%) |
| M1 | 8.890 | 7.880 | 1.01 | 61.5 | 22.22 | 63.9 |
| M2 | 8.490 | 7.770 | 0.72 | 39.11 | 16.00 | 59.09 |
| M3 | 8.640 | 7.620 | 1.02 | 30.22 | 17.77 | 54.25 |
| M4 | 8.760 | 7.590 | 1.17 | 41.77 | 19.11 | 41.2 |

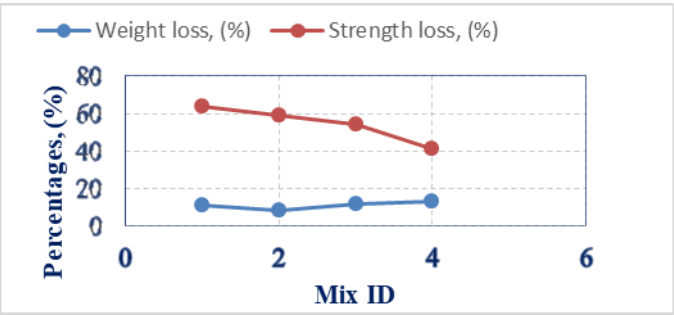


**Fig. 13: Weight and strength loss**

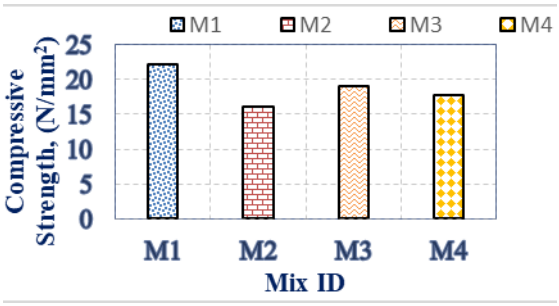


**Fig. 14: Compressive Strength 28days**

M3 mix gives better resistances to acid attack. when other mix are compared.

### *2) Sulphate attack*

Immersing concrete in magnesium sulphate solution and chemical resistance throughout the chemical attack. After curing gap of 28days, the specimen is removed and collected from the tank. PH value was maintained constant throughout by immersing the specimen in 5% of $MgSo_4$ solution.

**Table: 14**

| Mix | Weight before chemical curing | Weight after chemical curing | Weight Loss (%) | Strength | | |
|---|---|---|---|---|---|---|
| | | | | Before curing | After Curing | Loss (%) |
| M1 | 8.875 | 8.810 | 0.74 | 61.5 | 31.11 | 49.42 |
| M2 | 8.760 | 8.610 | 1.72 | 39.11 | 31.55 | 19.34 |
| M3 | 8.340 | 8.320 | 0.24 | 41.77 | 26.22 | 37.23 |
| M4 | 8.210 | 8.200 | 0.13 | 30.22 | 23.11 | 23.53 |

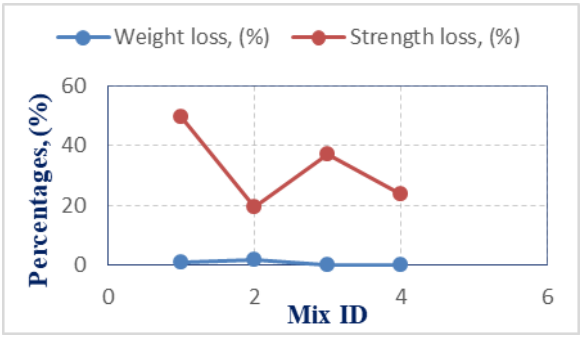


**Fig. 15: Weight and strength loss**

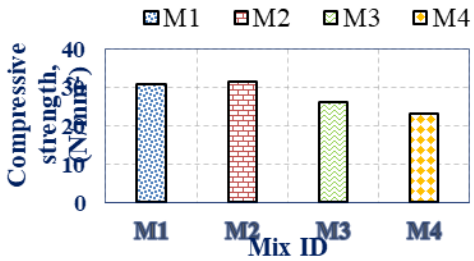


**Fig. 16: Compressive strength 28days**

In this fig 16, sulphate resistances are well performed by M2, when compared to other mix.

### *3) Chloride attack*

Sodium chloride is salt is known as a salt. Which molar mass of 22.99 and 35.45 gram/mole. It is most of reasonable for salinity of sea. 100grams of NaCl contains 40 gram of sodium and 60grams of chloride. Sodium chloride results as shown in table.15

**Table: 15 Compressive test results**

| Mix | Weight before chemical curing | Weight after chemical curing | Weight loss | Strength | | |
|---|---|---|---|---|---|---|
| | | | | Before curing | After curing | Loss (%) |
| M1 | 8.885 | 8.836 | 0.049 | 61.5 | 50.5 | 17.89 |
| M2 | 8.750 | 8.740 | 0.005 | 39.11 | 38.0 | 2.84 |
| M3 | 8.170 | 8.160 | 0.01 | 43.5 | 44.4 | 1.34 |
| M4 | 8.120 | 8.109 | 0.011 | 30.22 | 30 | 0.73 |

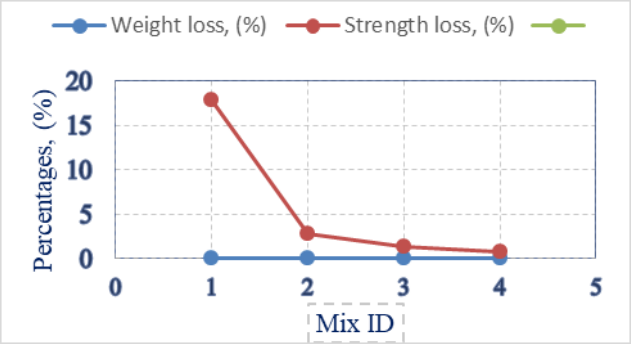


**Fig. 17: Weight and Strength loss**

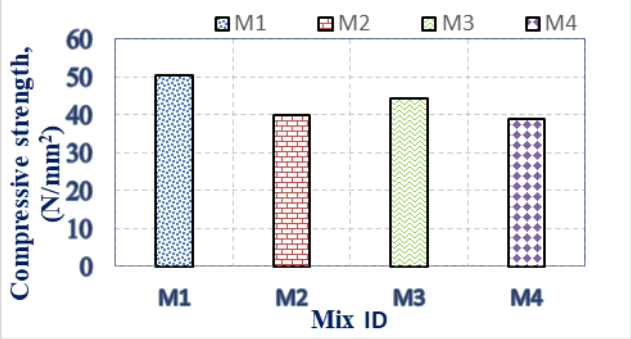


**Fig. 18: Compressive Strength 28days.**

In this fig 18, chloride attack resistances are shown best through M3 mix when compared to other mix.

## VII. RESEARCH SIGNIFICANCE

In this present research work main aim of replacing aggregates with palm oil shell is to reduce the dead load of the structure and reduce the environmental pollution from the OPS land fill and fuel for the turbains. And also reducing greenhouses gases releasing from the cement industries with GGBS in this research.

## VIII. CONCLUSION AND RECOMMENDATIONS

- It is concluded from the strength and durability studies of the light weight fiber reinforced concrete the OPS replacement up to 30% is recommend and the up to 20% replacement the compressive strength of concrete given good results and for 30% replacement is in the range of normal light weight concrete.
- For 28 days compressive strength for normal concrete is 44.5 Mpa and 30% replacement of concrete is 34.5 Mpa. Even through 10 Mpa difference, M3 concrete is given nearest target strength 38.5 Mpa.
- The split tensile strength and modulus of rupture are gradually increasing for M1 to M4 and after that decreasing for M4 mix.
- The young modulus is shown in M4 mix is$3.2\times10^5$ Mpa. Which is more in all the OPS replacement mixes due to ECR-Glass fiber.
- For all durability studies the compressive strength after chemical during strength is decreased. M3 mix is shown good results.

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