Mechanical Properties and Chloride Penetration Resistance Studies on Fiber Reinforced Semi-Light Weight Concrete (FRsLWC)

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INTRODUCTION

- Fiber Reinforced Concrete (FRC) is a type of concrete that is made by adding various types of fibers, such as steel, glass, or synthetic fibers, to the concrete mixture. The fibers improve the concrete's toughness and ductility, resulting in increased resistance to cracking and tensile stress.
- Light Weight Concrete - Mixture made with a lightweight coarse aggregate and sometimes a portion or entire fine aggregates may be lightweight instead of normal aggregates.
- Types of Light Weight Concrete:
  - Lightweight Aggregate Concrete
  - Aerated Concrete
  - No Fines Concrete

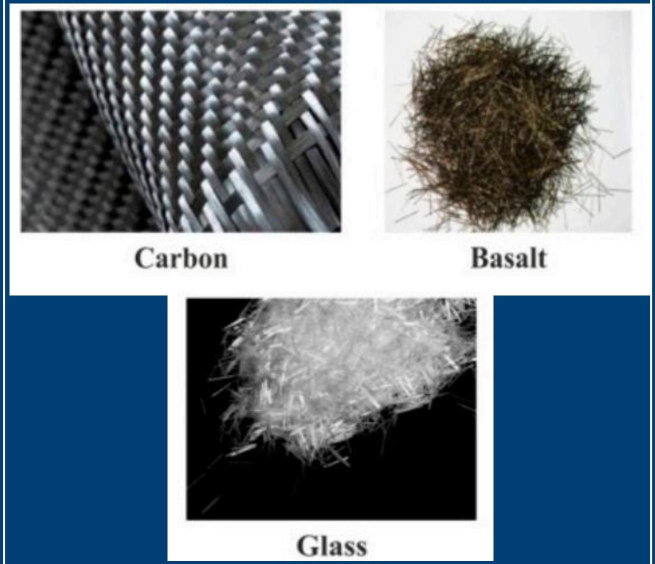

Figure 1 - Artificial Fiber

Figure 2 - Natural Fiber

- Light Weight Aggregate Concrete is a type of lightweight concrete that is made using lightweight pellets as the aggregate such as shale, wood ash, or recycled glass, into uniform pellets that can be used as a substitute for traditional coarse aggregate in concrete mixes.

- Properties of Pellet Lightweight Concrete :
  - Lower density
  - Good strength and durability
  - More workable
  - Cost Efficient

- Production of Pellets can be done by:
  - Cold bonded Process
  - Sintering Process

Figure 3 shows formation of Pellets using Pelletizing Disc

GAP IDENTIFICATION

- Properties of Lightweight aggregates directly affects the mechanical properties of concrete.
- Improved workability because of shape and texture of light weight aggregates which caused the reduction in dosage of Superplasticizers.
- Aspect ratio and structure of fiber influence the mechanical properties of concrete.
- Lightweight concrete exhibits very brittle behavior with respect to normal weight concrete having the same compressive strength. The addition of fibers with an increase in the volume fraction corrects the brittle behavior of lightweight concrete.
- Sintering process is costlier than cold bonded technique for the preparation of pellets.
- There is limited study in Fiber reinforced semi-light weight concrete (FRsLWC) so our study will be focused on developing FRsLWC which will be able to provide desired results.

OBJECTIVE

- To study the Fresh and Hardened State Properties of Proposed Concrete.
- To determine the durability properties such as Water absorption, Sorptivity, UPV and Electrical resistivity.
- To evaluate Chloride Penetration Resistance for the above concrete mix using Rapid Chloride Permeability Test.
- To study Cost Benefits of Fiber Reinforced Semi-Light Weight Concrete in comparison with Conventional Concrete.

METHODOLOGY FLOW CHART

Preparation of Fiber Reinforced Semi-Light Weight Concrete (FRsLWC)

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Material testing and Characterization

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Preparation of cold bonded aggregates using Calcite powder, Fly Ash and Cement

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Preparation of fibers using disposed PET bottles

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Trial mix as per ACI 211.2

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Optimization of Fiber content by varying it from 0 to 1% by weight of cement (0.25% increment) by conducting Compression, Split and Flexure tests

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Durability studies on finalized FRsLWC mix

MIX DESIGN PROCEDURE (ACI 211.2)

Step-1: Choice of slump.

Step-2: Choice of nominal maximum size of lightweight aggregate.

Step-3: Estimation of mixing water and air content.

Step-4: Selection of approximate w/c.

Step-5: Calculation of cement content.

Step-6: Estimation of lightweight coarse aggregate content.

Step-7: Estimation of fine aggregate content.

IDENTIFICATION OF POTENTIAL SUSTAINABLE MATERIAL

- Calcite Powder
  - Calcite powder is a by-product of high calcium wood ash obtained from the barks of Tamarindus indica having a greyish white appearance.
  - Calcite or Calcium carbonate is the major composition of wood ash and hence named as Calcite powder.
  - In the nearby rice mills the tamarind barks are used to generate heat energy to dry the fresh paddy grains before milling.
  - Residual wood ash which was collected was found disposed in the open environment near the rice mills.

- PET Fiber
  - Polyethylene terephthalate (PET) bottles were collected from the college campus.
  - Collected bottles were washed and dried, and further processed into thin strips of PET fibers.

MANUFACTURING OF PELLETS

- Mechanical parameters of the Disc Pelletizer
  - Inclination angle of Disc – 54˚
  - rpm of the drum – 20
  - Pelletization time duration – 20 minutes

- Material composition of pellets
  - Calcite powder (60%)
  - Class-F Fly Ash (20%)
  - Cement (OPC 53) (20%)

- Stone chips (2% by weight of fine material)

- Quantity of pellets = 300 kg




PREPARATION OF PET FIBERS

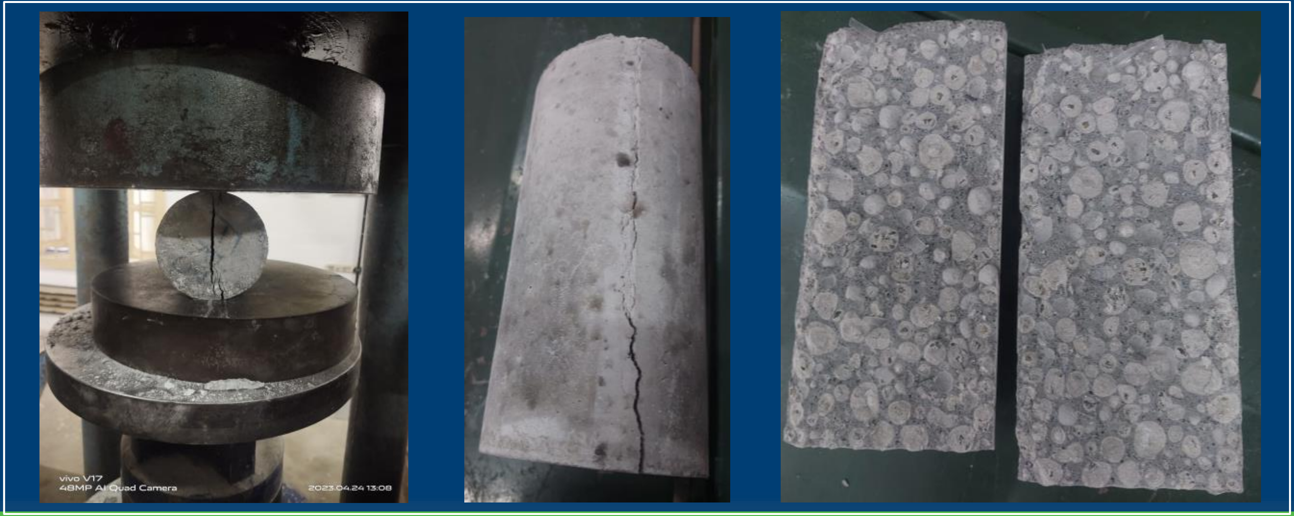
- A Customized tool was made to cut thin and uniform width of PET fibers as shown in the figure.
- The strips were further cut for the desired length.
- Dimension of fiber
  - Width – 5 mm
  - Length – 25 mm

FINALIZED MIX DESIGN

DESIGN MIX PROPORTIONS					
Mix ID	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)		Water (litre/m^3)
			Cold bonded aggregate (10 - 20 mm)	Cold bonded aggregate (4.75 – 10 mm)	
C1	433.33	665.66	399.5	399.5	208

MIX ID	CR	FR1	FR2	FR3	FR4
Fiber content (% by weight of cement)	0	0.25	0.5	0.75	1
TEST SPECIMENS CASTED					
Compressive strength (7, 28 days)	6	6	6	6	6
Split tensile Strength (28 days)	3	3	3	3	3
Flexural strength test (28 days)	3	3	3	3	3
Shear strength (L specimen) (28 days)	3	3	3	3	3
Ultra sonic pulse velocity test (28 days), Electrical Resistivity (7, 14, 21, 28 days)	3	3	3	3	3
Sorptivity (28 days)	3	3	3	3	3
Water absorption (28 days)	3	3	3	3	3
RCPT (28 days)	3	3	3	3	3

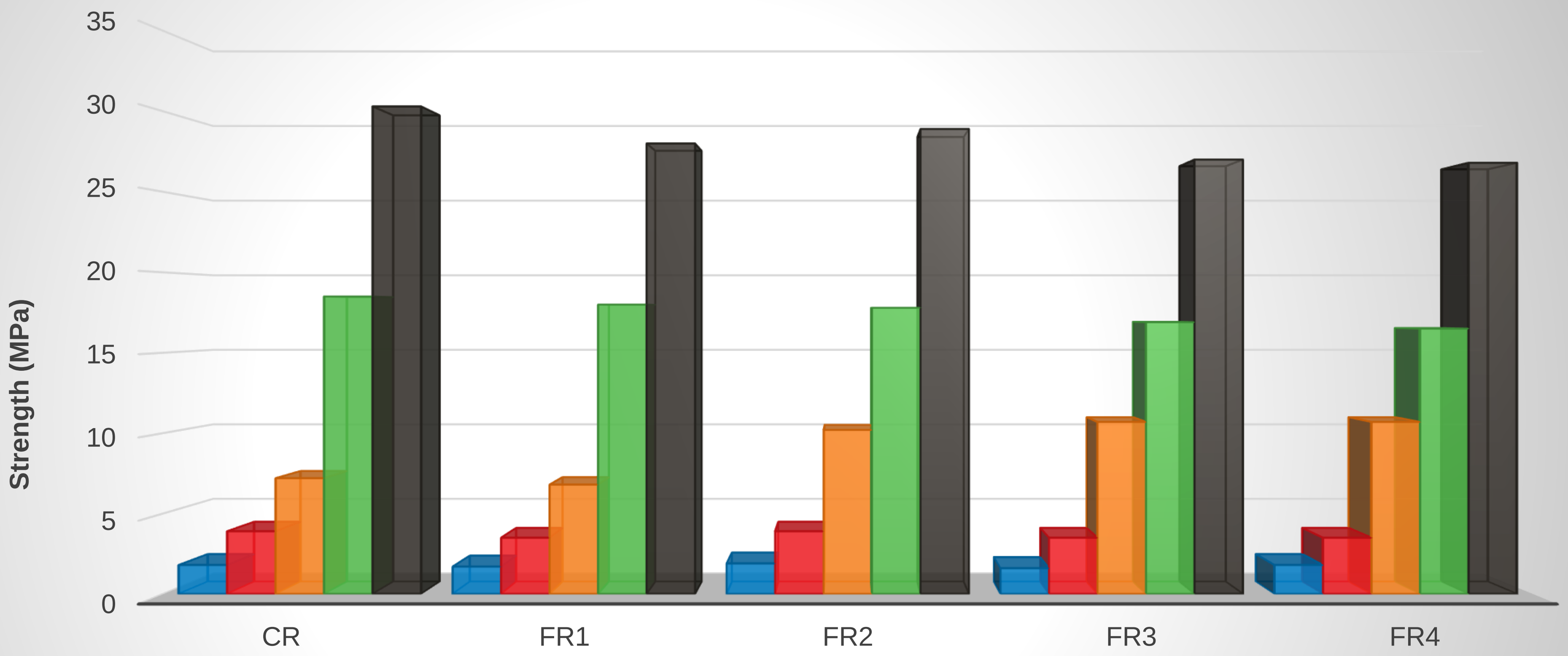
OBSERVATIONS



RESULTS

Description	CR	FR1	FR2	FR3	FR4
Density (kg/m^3)	2121	1996	2015	2021	2025
Slump Value in mm	160	160	140	120	90
Compressive strength in MPa (28 days)	30.3	28	28.9	27	26.8
Split Tensile strength in MPa (28 days)	1.8	1.7	1.9	1.6	1.8
Flexural strength in MPa (28 days)	3.9	3.5	3.9	3.5	3.5
Shear strength in MPa(28 days)	7.2	6.8	10.2	10.7	10.7
Modulus of Elasticity (28 days)	21.03	16.78	15.69	14.11	12.67
Electrical Resistivity in kΩ-cm (28 days)	12.82	12.73	11.34	11.09	11.52
Sorptivity in mm/√sec (28 days)	0.004	0.0069	0.0063	0.0072	0.007
Water absorption in % (28 days)	5.5	5.8	7.3	7.2	7.2
RCPT in Coulombs (28 days)	2312	2289	2794	2669	3080
Ultra sonic pulse velocity test in km/sec (28 days)	3.81	3.89	3.74	3.82	3.78

Comparison of Split, Flexure, and Shear Strength



	CR	FR1	FR2	FR3	FR4
Split Tensile Strength (MPa)	1.8	1.7	1.9	1.6	1.8
Flexural Strength (MPa)	3.9	3.5	3.9	3.5	3.5
Shear Strength (MPa)	7.2	6.8	10.2	10.7	10.7
7-Days Compressive strength	18.5	18	17.8	16.9	16.5
28-Days Compressive strength	30.3	28	28.9	27	26.8

COST ANALYSIS OF MATERIALS

Material	Type	Brand	Product / Source	Rate/Kg
Cementitious	Portland Pozzolana Cement	Ultra Tech	PPC	8
Aggregates	Coarse Aggregate (20 and 10 mm) comprising of mainly Calcite powder and Fly ash	NA	Mettur thermal power plant and Rice mill	0.5
	Fine Aggregate - Manufactured Sand	NA	Local vendors	0.4
Fibers	PET fibers	NA	From college wasteyard	-
Mix cost of FRsLWC (INR)				4132.4
Cost of conventional concrete (INR)				4400

CONCLUSIONS

- The optimum percentages of pellets in the mix are 50% of 10 – 20 mm size aggregates and 50% of 4.75 – 10 mm size aggregates.
- Based on the results, the FR2 mix containing 0.5% PET fiber was found to be the most optimal.
- The compressive strength of the mix decreased slightly to significantly with the addition of PET fibers due to poor bonding characteristics. However, the split tensile strength and flexural strength showed a marginal increase of 3-5%, and the use of PET fibers prevented brittle failure of the concrete.
- The shear strength of the mix significantly improved with the addition of PET fibers.
- Modulus of Elasticity decreases with increase in fiber content. CR is stiffer than FR samples.
- The water absorption rate was low, indicating that the material was less porous and had good resistance to water penetration.
- The values of Rapid Chloride Penetration Test (RCPT), Sorptivity, and Ultrasonic Pulse Velocity (UPV) increased slightly with an increase in fiber content.
- The Electrical Resistivity of the mix decreased slightly to significantly when PET fibers were added due to the weak conductance of the PET fibers.

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Thank You