EPS BASED LIGHT WEIGHT CONCRETE DESIGN WITH ENHANCEMENT OF STRENGTH

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Abstract: **We developed a new structural light weight concrete by completely replacing coarse aggregate in concrete by expanded polystyrene (EPS) beads. Expanded polystyrene (EPS) is a lightweight material that has been used in engineering applications since at least the 1950s. Expanded polystyrene waste in a granular form is used as light weight aggregate to produce light weight nonstructural concrete with the unit weight varying from 950 kg/m³ to 1350kg/m³. This paper reports the results of an experimental investigation into the engineering properties, such as compressive strength, modulus of elasticity, drying shrinkage and creep, of polystyrene aggregate concrete varying in density.**

Keywords: **EPS beads, concrete, compression Strength, Replacement.**

I. INTRODUCTION

1.1 INTRODUCTION

The three basic needs of man are food, clothing and shelter. Civil Engineer has relevance with all basic needs of man directly or indirectly. Man has progressed a lot in developing the method of constructing shelter. Initially man used to stay in huts and time passed it developed into house that is load bearing. In this constructed environment, the rising cost of building construction materials is the factor of great concern. The cost of building materials are raising day by day. Nowadays most of the researchers have focus on use of the waste materials in concrete according to their properties. Fly ash, Rice husk, Slag and Sludge from the treatment of industrial and domestic waste water has been found suitable as partial replacement for cement in concrete. The EPS is a material which can be a substitute for coarse aggregate. EPS concrete has better workability because of the smooth surface on one side of the shell.

The aim of this study is to investigate the effect of polystyrene aggregate size on strength and moisture migration characteristics of lightweight concrete. The present study covers the use of expanded polystyrene (EPS) and un-expanded polystyrene (UEPS) beads as lightweight aggregate in concretes that contain fly ash as a supplementary cementations material. Lightweight concrete with wide range of concrete densities (1000-1900 kg/m3) were studied mainly for compressive strength, split tensile strength, moisture migration and absorption.

II. THESIS OBJECTIVE

- To find the characteristics **(workability, compressive, Flexural, Tensile)** of EPS M40 and M50.
- To prepare lightweight concrete by using EPS as course aggregate.
- To increase the speed of construction, enhance green construction environment we can use lightweight concrete.
- The possibility exists for the partial replacement of coarse aggregate with EPS to produce lightweight concrete.
- EPS exhibits more resistance against crushing, impact and abrasion, compared to crushed granite aggregate. EPS can be grouped under lightweight aggregate.
- There is no need to treat the EPS before use as an aggregate except for water absorption. EPS shell is compatible with the cement.

III. CRITIQUE SURVEYED

- A survey of journal articles published between 2010 and 2019 yields studies that vary in scope and level of analysis, yet with consistently good results.

- As our aim is to develop concrete which does not only concern on the strength of concrete, it also having many other aspects to be satisfied like workability, performance, durability and also economy. So for this we need to go for the addition of pozzolanic materials along with super plasticizer with having low water cement ratio. The use of silica fume is many, which is having good pozzolanic activity and is a good material for the production high performance concrete. The application of silica fume in concrete mixture has significantly increased and enhanced the properties of the concrete whether it is in wet stage or in harden condition. Also now a day's one of the great applications in various structural fields is fiber reinforced concrete, which is getting popularity because of its positive effect on various properties of concrete.

1. The Mechanical properties such as compressive strength, tensile strength, toughness, impact, flexural etc are greatly influenced by addition of fibres, optimum dosage of fibres governs these properties and must carry out optimality study on various fibres.

2. The Type of fibres, selection of fibres, properties like length, diameter aspect ratio, its effect on properties of concrete changes with addition of dosage. The prime importance must be given for selection of fibre, its type etc.

3. The various fibre used in concrete significantly improves many properties of concrete. The combination of fibres thus shows advanced improvement and great changes in properties of concrete.

IV. MIX DESIGN

4.1 MIX DESIGN AGGREGATE

Concrete mix design is the process of finding the proportions of concrete mix in terms of ratios of cement, sand and coarse aggregates. For e.g., a concrete mix of proportions means that cement, fine and coarse aggregate are the mix contains one part of cement, two parts of fine aggregate and four parts of coarse aggregate. The concrete mix design proportions are either by volume or by mass. The water-cement ratio is usually expressed in mass Requirements for concrete mix design

The grade designation giving the characteristic strength requirement of concrete.

The type of cement influences the rate of development of compressive strength of concrete.

Maximum nominal size of aggregates to be used in concrete may be as large as possible within the limits prescribed by IS 456:2000.

The cement content is to be limited from shrinkage, cracking and creep.

The workability of concrete for satisfactory placing and compaction is related to the size and shape of section, quantity and spacing of reinforcement and technique used for transportation, placing and compaction.

4.2 Procedure for Concrete Mix Design as per IS 456: 2000

1. Determine the mean target strength ft from the specified characteristic compressive strength at 28-day fck and the level of quality control.

$$ft = fck + 1.65\ S$$

Where S is the standard deviation obtained from the Table of approximate contents given after the design mix.

2. Obtain the water cement ratio for the desired mean target using the empirical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water cement ratio. The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in table and adopts the lower of the two values.

3. Estimate the amount of entrapped air for maximum nominal size of the aggregate from the table.

4. Select the water content, for the required workability and maximum size of aggregates (for aggregates in saturated surface dry condition) from table.

5. Determine the percentage of fine aggregate in total aggregate by absolute volume from table for the concrete using crushed coarse aggregate.

6. Adjust the values of water content and percentage of sand as provided in the table for any difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate the values are given in table.

7. Calculate the cement content form the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.

8. From the quantities of water and cement per unit volume of concrete and the percentage of sand already determined in steps 6 and 7 above, calculate the content of coarse and fine aggregates per unit volume of concrete from the following relations:

$$V = \left[W + \frac{C}{S_c} + \frac{1}{p}\frac{f_a}{S_{fa}}\right] \times \frac{1}{1000}$$

$$V = \left[W + \frac{C}{S_c} + \frac{1}{1-p}\frac{C_a}{S_{ca}}\right] \times \frac{1}{1000}$$

Where V = absolute volume of concrete = gross volume ($1m^3$) minus the volume of entrapped air

Sc = specific gravity of cement

W = Mass of water per cubic meter of concrete, kg

C = mass of cement per cubic meter of concrete, kg

p = ratio of fine aggregate to total aggregate by absolute volume

fa, Ca = total masses of fine and coarse aggregates, per cubic meter of concrete, respectively, kg, and

S_{fa}, S_{ca} = specific gravity of saturated surface dry fine and coarse aggregates, respectively

9. Determine the concrete mix proportions for the first trial mix.

10. Prepare the concrete using the calculated proportions and cast three cubes of 150 mm size and test them wet after 28-days moist curing and check for the strength.

11. Prepare trial mixes with suitable adjustments till the final mix proportions are arrived at.

4.3 Concrete Mix Design Example – M50 Grade Concrete

Grade Designation = M-50

Type of cement = O.P.C-43 grade

Brand of cement = Vikram (Grasim)

Admixture = Sika [Sikament 170 (H)]

Fine Aggregate = Zone-II

Sp. Gravity Cement = 3.15

Fine Aggregate = 2.61

Coarse Aggregate (20mm) = 2.65

Coarse Aggregate (10mm) = 2.66

Minimum Cement (As per contract) =400 kg / m^3

Maximum water cement ratio (As per contract) = 0.45

- **Concrete Mix Design Calculation**

1. Target Mean Strength

Target Mean Strength = 50 + (5 X 1.65)

= 58.25 Mpa

2. Selection of water cement ratio:

Assume water cement ratio = 0.35

3. Calculation of water content:

Approximate water content for 20mm max. Size of aggregate = 180 kg /m^3 (As per Table No. 5 , IS : 10262). As plasticizer is proposed we can reduce water content by 20%.

Now water content = 180 X 0.8 = 144 kg /m^3

4. Calculation of cement content:

Water cement ratio = 0.35
Water content per m^3 of concrete = 144 kg
Cement content = 144/0.35 = 411.4 kg / m^3
Say cement content = 412 kg / m^3 (As per contract Minimum cement content 400 kg / m^3)
Hence O.K.

5. Calculation of Sand & Coarse Aggregate Quantities:

Volume of concrete = 1 m^3
Volume of cement = 412 / (3.15 X 1000) = 0.1308 m^3
Volume of water = 144 / (1 X 1000) = 0.1440 m^3
Volume of Admixture = 4.994 / (1.145 X 1000) = 0.0043 m^3
Total weight of other materials except coarse aggregate = 0.1308 + 0.1440 +0.0043 = 0.2791 m^3
Volume of coarse and fine aggregate = 1 – 0.2791 = 0.7209 m^3
Volume of F.A. = 0.7209 X 0.33 = 0.2379 m^3 (Assuming 33% by volume of total aggregate)
Volume of C.A. = 0.7209 – 0.2379 = 0.4830 m^3
Therefore weight of F.A. = 0.2379 X 2.61 X 1000 = 620.919 kg/ m^3
Say weight of F.A. = 621 kg/ m^3
Therefore weight of C.A. = 0.4830 X 2.655 X 1000 = 1282.365 kg/ m^3
Say weight of C.A. = 1284 kg/ m^3
Considering 20 mm: 10mm = 0.55: 0.45
20mm = 706 kg .
10mm = 578 kg .
Hence Mix details per m^3
Increasing cement, water, admixture by 2.5% for this trial
Cement = 412 X 1.025 = 422 kg
Water = 144 X 1.025 = 147.6 kg
Fine aggregate = 621 kg
Coarse aggregate 20 mm = 706 kg
Coarse aggregate 10 mm = 578 kg
Admixture = 1.2 % by weight of cement = 5.064 kg.

Water: cement: F.A.: C.A. = 0.35: 1: 1.472: 3.043

Table (4.1) M50 Composition.

Water(Kg)	Cement (Kg)	FA	CA	EPS	SF
147.6	422	621	706	0-2%	0-15%

Observations from Concrete Mix Design

A. Mix was cohesive and homogeneous.

B. Slump = 120 mm

C. No. of cube casted = 9 Nos.

7 days average compressive strength = 52.07 MPa.

28 days average compressive strength = 62.52 MPa which is greater than 58.25MPa

Hence the mix accepted.

Percentage strength of concrete at various ages

The strength of concrete increases with age. Table shows the strength of concrete different ages in comparison with the strength at 28 days.

4.4 Concrete Mix Design Example – M40 Grade Concrete

Parameters for mix design M40

The mix design M-40 grade for Pier provided here is for reference purpose only. Actual site conditions vary and thus this should be adjusted as per the location and other factors.

Parameters for mix design M40

Grade Designation = M-40

Type of cement = O.P.C-43 grade

Brand of cement = Vikram (Grasim)

Admixture = Fosroc (Conplast SP 430 G8M)

Fine Aggregate = Zone-II

Sp. Gravity Cement = 3.15

Fine Aggregate = 2.61

Coarse Aggregate (20mm) = 2.65

Coarse Aggregate (10mm) = 2.66

Minimum Cement (As per contract) = 400 kg / m^3

Maximum water cement ratio (As per contract) = 0.45

Mix Calculation: –

1. Target Mean Strength

Target Mean Strength = 40 + (5 X 1.65) = 48.25 Mpa

2. Selection of water cement ratio:-

Assume water cement ratio = 0.4

3. Calculation of cement content: –

Assume cement content 400 kg / m^3

(As per contract Minimum cement content 400 kg / m^3)

4. Calculation of water: –

400 X 0.4 = 160 kg Which is less than 186 kg (As per Table No. 4, IS: 10262)

Hence o.k.

5. Calculation for C.A. & F.A.:

$V = [W + (C/S_c) + (1/p) . (f_a/S_{fa})] \times (1/1000)$

$V = [W + (C/S_c) + \{1/(1-p)\} . (ca/S_{ca})] \times (1/1000)$

Where

V = absolute volume of fresh concrete, which is equal to gross volume (m^3) minus the volume of entrapped air ,

W = mass of water (kg) per m^3 of concrete ,

C = mass of cement (kg) per m^3 of concrete ,

S_c = specific gravity of cement,

(p) = Ratio of fine aggregate to total aggregate by absolute volume,

(fa) , (ca) = total mass of fine aggregate and coarse aggregate (kg) per m^3 of
Concrete respectively, and

Sfa , Sca = specific gravities of saturated surface dry fine aggregate and Coarse aggregate respectively. Assume F.A. by % of volume of total aggregate = 36.5 %

0.98 = [160 + (400 / 3.15) + (1 / 0.365) (Fa / 2.61)] (1 /1000)

FA = 660.2 kg

0.98 = [160 + (400 / 3.15) + (1 / 0.635) (Ca / 2.655)] (1 /1000)

CA = 1168.37 kg.

Considering 20 mm : 10mm = 0.6 : 0.4

20mm = 701 kg.

10mm = 467 kg .

Hence Mix details per m^3

Cement = 400 kg

Water = 160 kg

Fine aggregate = 660 kg

Coarse aggregate 20 mm = 701 kg

Coarse aggregate 10 mm = 467 kg

Admixture = 0.6 % by weight of cement = 2.4 kg.

Recron 3S = 900 gm

Water: cement: F.A.: C.A. = 0.4: 1: 1.65: 2.92

Table (4.2) M40 Composition.

Water(Kg)	Cement (Kg)	FA	CA	EPS	SF
0.4	400	660	700	0-2%	0-15%

V. RESULT AND ANALYSIS

5.1 CEMENT

1. **Fineness Test**
2. **Consistency Test**
3. **Setting time Test**
4. **Soundness Test**
5. **Strength Test**
6. **Specific Gravity Test**

1. Fineness Test:

Type of cement	Finenees Value (mm^2/g)
OPC (33)	225,000

- Sieve Test Result - Not greater 10%

2. Consistency Test:

Percentage of water content for standard consistency = 35-38%

3. Setting time Test:

Initial setting time=30 Minutes

Final setting time=600Minutes.

4. Soundness Test:

For OPC= 10mm.

5. Strength Test:

CEMENT TYPE	COMPRESSIVE STRENGTH (Mpa)			
	1 Day	3 Days	7 Days	28 Days
OPC	—	23	33	43

6. Specific Gravity Test:

For OPC=3.15

5.2 SAND

1. Organic impurities test

Organic impurities (not exceeding to 12%)

2. Silt content test

Silt and clay content in the natural sand =<8%.

3. Sand bulking test (Bulking of Sand)

Sand bulking =5 percent moisture content

5.3 AGGREGATE

1. Crushing test

Strong aggregate =less than 10

Weak aggregates=above of 35

2. Abrasion test

A maximum value for WBM base course =40 percent

3. Impact test

Aggregates to be used for wearing course, the impact value not greater 30 percent.

4. SOUNDNESS TEST

The loss in weight should not exceed 12 percent when tested with sodium sulphate and 18 percent with magnesium sulphate solution.

5.4 CONCRETE

5.4.1 Compressive Strength

For M40 Compressive Strength:

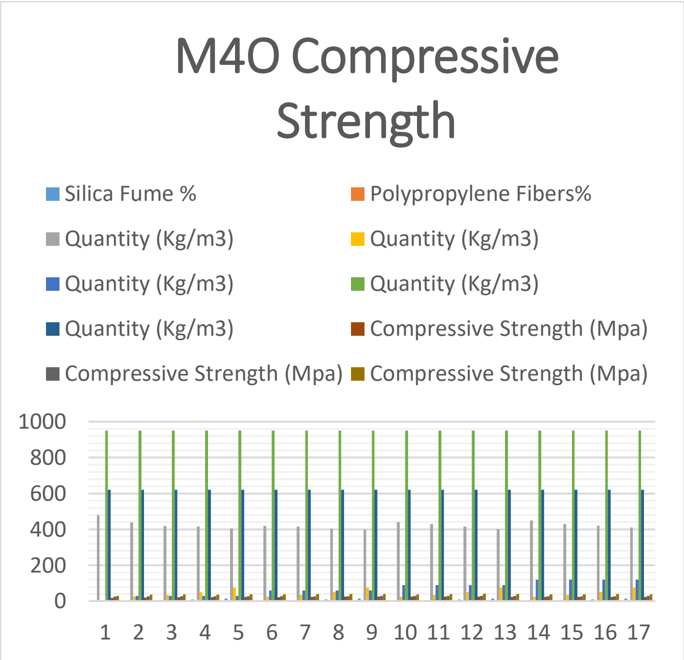
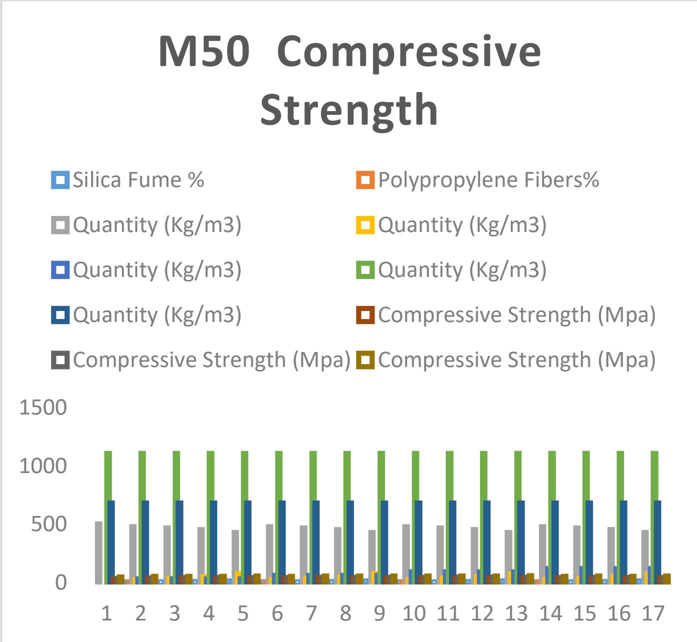


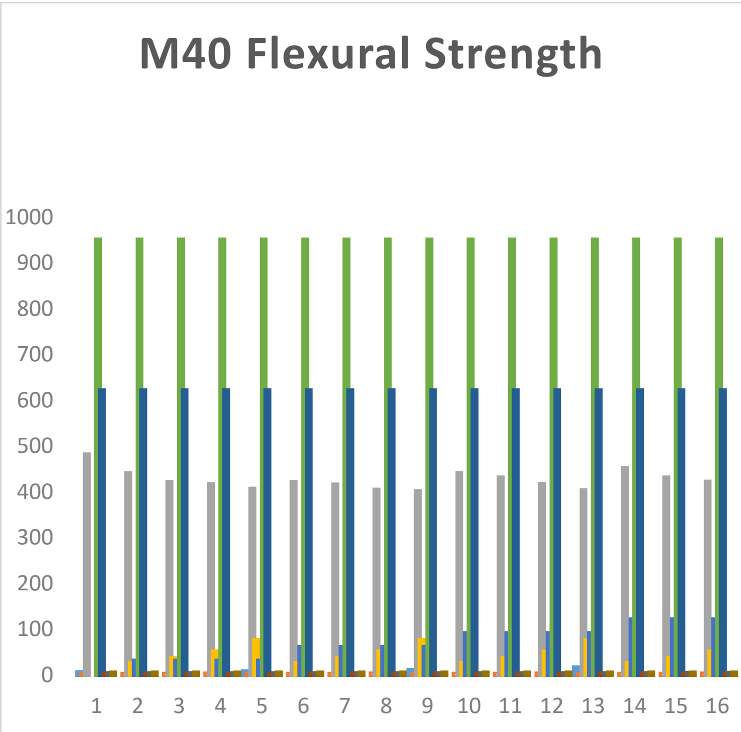
Fig (5.1) M40 Compressive Strength.



Fig(5.2) M50 Compressive Strength.

5.4.2 Flexural Strength:

For M40 Flexural Strength



Fig(5.3) M40 Flexural Strength.

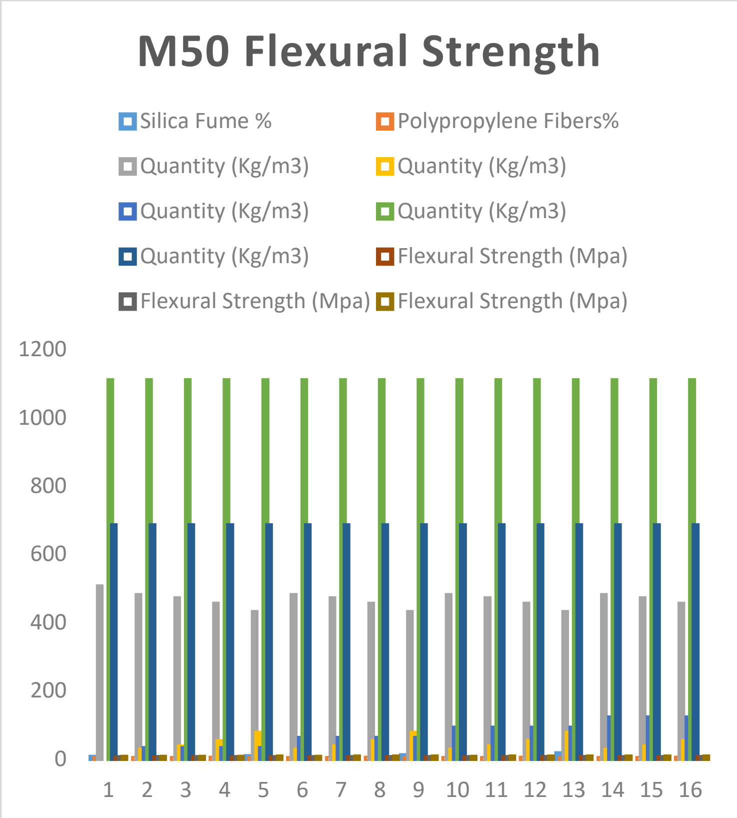
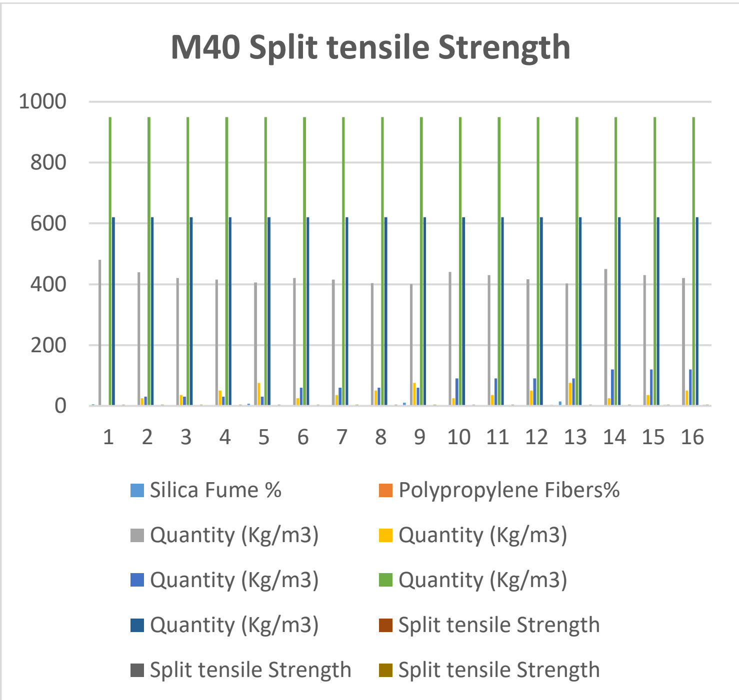


Fig (5.4) M50 Flexural Strength.

5.4.3 Split tensile values

For M40 grade of concrete



Fig(4.5) M40 grade Split tensile Strength.

For M50 grade of concrete

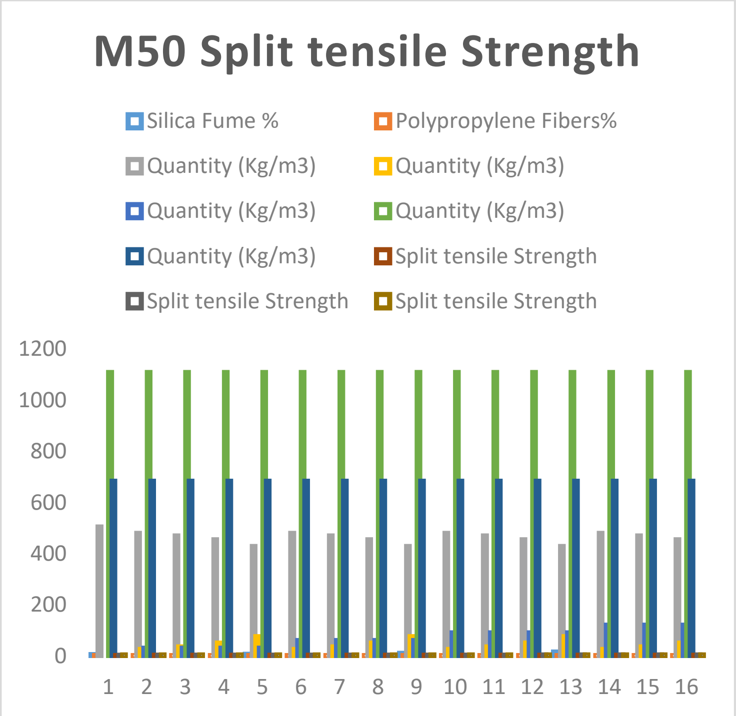


Fig (5.6) M50 grade Split tensile Strength.

VI. CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION:

We developed a new structural lightweight concrete by totally or partially replacing coarse and fine aggregates in high performance concrete by expanded polystyrene (EPS) beads. In this work, the sizes of EPS bead were 1.0, 2.5 and 6.3 mm. Lightweight EPS concretes with a wide range of concrete densities and compressive strengths were successfully developed. Compressive strength, splitting tensile strength, shrinkage, and water absorption were examined. Additionally, fine silica fume (SF) and polypropylene (PP) fibers were added to improve the mechanical and shrinkage properties of EPS concretes. The results show that fine SF greatly increases the bond strength between the EPS beads and cement paste, thus increasing the compressive strength of EPS concrete. With inclusion of PP fibers, drying shrinkage properties are significantly improved. From the test results, the EPS has a future as lightweight aggregate in concrete. It also reduces the total cost of concreting, because of the low cost and its ease of availability is profusion. EPS Concrete can be used in rural areas and places where coconut is profusion and the places where the regular aggregates are not economic. It is concluded that the EPSs are more suitable as low strength-giving lightweight aggregate when used to replace common coarse aggregate in production concrete. EPS is more power to resist crushing, and impact compared to traditional granite aggregate. There is no need to treat the EPS before use as an aggregate except for water absorption.

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