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# Study on Alternative Materials (Expanded Polystyrene and Glass Powder) for Construction

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**ABSTRACT-** Expanded Polystyrene (EPS) that was used in the research work was in the form of 'EPS Beads' which were spherical in shape and size varied in between 6 mm to 8 mm in diameter. Beads were made up of pre-extended Polystyrene balls. It is non-hydroscopic and does not promptly absorb moisture from the atmosphere. Expanded polystyrene exhibits number of outstanding properties such as light weight, high strength, structural stability, economy, insulation, aging resistance, recyclability etc. Glass is completely recyclable since it is not damaged by everyday use. An experimental program was planned in which one lean concrete mix which did not include any percentage of crushed glass powder and Expanded Polystyrene beads. The other combination of Mixes was prepared with different combinations of crushed glass powder and Expanded Polystyrene beads were. Cylindrical specimens, Cubes and beams were casted to obtain different physical properties. Concrete mixes with 0%, 10%, 20%, and 30% of crushed glass powder as to replace some part of fine aggregate and 0%, 1.5%, 2.5%, and 3.5% of Expanded Polystyrene beads as to replace some part of natural coarse aggregates. Suitable quantities of super-plasticizer and materials are added to improve the workability and stability. The cylindrical specimens, cubes and beams will be tested after the recommended curing period of 7 days and 28 days respectively.

**KEYWORDS –** Expanded polystyrene, Glass powder, Compressive Strength, Cubes, Aggregate

## I. INTRODUCTION

The word concrete denotes to a combination of aggregates, typically sand, and each gravel or crushed stone, seized together by a binder of cementitious paste. The paste is normally made up of Portland cement and admixtures [1]. Concrete's flexibility, durability, sustainability, and low-cost have made it the world's most extensively used construction material. It is one of the most essential and valuable materials for structure work. When all the elements (cement, aggregate, water) are mixed in the required proportions, the cement and water start a reaction with each other to fix themselves into a hardened mass [2]. This hardened rock-like mass is identified as concrete. Most concretes used are lime based concretes such as Portland cement concrete or concretes made with other hydraulic cements [3]. However, asphalt concrete, which is normally used for road surfaces, is also a kind of concrete, where the cement material is bitumen, and polymer concretes are occasionally used where the strengthening material is a polymer [4]. By combining dry Portland cement and water with aggregate, the mixture creates a liquid slurry that can easily be poured and shaped. A chemical reaction between the cement, water, and other ingredients forms a matrix of hard, durable materials that have many uses, like stone [5]. In many cases, additives are added to the wet mix or the finished material in order to improve their physical properties. Reinforcing materials are incorporated into concrete to provide tensile strength, resulting in reinforced concrete [6].

## II. STRUCTURAL LIGHTWEIGHT CONCRETE

Construction materials such as lightweight structural concrete are important. If a concrete is lightweight and sufficiently strong, and it is used in conjunction with steel reinforcement [7], then it will more cost effectively than a conservative concrete. Because of this, concrete that is both strong and light will have undisputed economic advantages [8]. Structures constructed of lightweight aggregate concrete can be defined by ACI 213 R as those that meet the following requirements: 28-d compressive strength of 17 MPa, equilibrium density between 1120 kg/m3 and 1920 kg/m3, and containing just lightweight aggregate or a combination of lightweight aggregate and normal density aggregate [9].

### A. *Expanded Polystyrene Beads*

Polystyrene (PS) is defined as a synthetic aromatic hydrocarbon polymer that is made from the monomer styrene [10]. It can be foamed or solid. Polystyrene used for general purpose is clear, brittle and hard. It is a low cost organic compound per unit weight. It is a poor obstruction to oxygen and water vapour and has a very less melting point [11]. It is the most commonly used plastics, with production scale of millions of tonnes per year. Polystyrene is naturally transparent, but can be made colored with coloring agents [12]. It is a thermoplastic polymer and is in a solid (glassy) state when kept at room temperature but starts to flows if heated above about 100 °C. On cooling it becomes rigid again [13]. This temperature change behavior is used for swelling (as in Styrofoam) and for moulding and vacuum forming, as it has capability of moulding with fine detail [14]. Expanded Polystyrene (EPS) that was used in the research work was in the form of 'EPS Beads' which were spherical in shape and size varied in between 6 mm to 8 mm in diameter. Beads were made up of pre-extended Polystyrene balls [15]. It is non-hydroscopic and does not promptly absorb moisture from the atmosphere. Expanded polystyrene exhibits no of outstanding [16] properties such as light weight, high strength and structural stability, economy, insulation, aging resistance, recyclability etc.Figure 1 shows the EPS beads.

Figure 1: EPS beads

### B. *Crushed Glass Powder*

The reprocessing of discarded glass into useable items is known as glass recycling. Glass trash should be isolated by chemical structure, and relying on [7] the final use as well as local process technology, it may also need to be segregated by colour. Because glass keeps its colour after reprocessing, many recyclers segregate distinct hues of glass [17]. Crystalline glass, green glass, and brown or amber glass are by far the most frequent varieties being used as household products. Glass is completely recyclable since it is not damaged by everyday use [18].

### C. *Objectives of the Study*

The objectives of the study are given below

- To Study the effect on the compressive strength of concrete on partially replacement of coarse aggregate with Expanded polystyrene beads and fine aggregate with glass powder.
- To Study the effect on tensile strength of concrete on partially replacement of coarse aggregate with Expanded polystyrene beads and fine aggregate with glass powder.
- To study the density of lightweight concrete made by partially replacement of coarse aggregate with Expanded polystyrene beads and fine aggregate with glass powder.
- To study the flexural strength of lightweight concrete made by partially replacement of coarse aggregate with Expanded polystyrene beads and fine aggregate with glass powder.

## III. METHODOLOGY

The experimental study was divided into the following stages

- Casting and Curing.
- Compressive Strength of Concrete.
- Split Tensile Strength of Concrete.
- Flexural tensile strength of Concrete.

### D. *Casting and Curing*

A suitable control mix was prepared and subsequently mixes containing replaced Coarse aggregates with expanded polystyrene and crushed glass powder in part for fine aggregates [6]. For each trial 6 standard cubes were used to investigate 7 days and 28 days strength [6]. For each batch of concrete mix, the quantities of various ingredients i.e. cement, expanded polystyrene, fine aggregate, coarse aggregate, glass powder, water, super plasticizer were kept ready in required proportions.

Afterwards the required proportions of cement, aggregates, expanded polystyrene and glass powder were mixed thoroughly [19]. Water in the prescribed amount was then added and then the mix was filled in layers in the cubes. Compaction of each layer was accomplished either manually or by a vibrator and the layer was then given a smooth finish. After that, the specimens were allowed to harden for 24 hours [7]. These were extracted from the moulds and identification marks were made to designate them before they were immersed in the curing tank containing clean water [8]. After curing of 7 and 28 days the specimens were removed from the tank and were tested to obtain the compressive, split tensile strength results.

### E. *Compressive Strength of Concrete*

Cube specimens of size 150mm x 150 mm x 150mm were taken out form the curing tank at the ages of 7 and 28 days and tested immediately on removal from the water (while they were still in the wet condition). Surface water was wiped off, the specimens were tested [8]. The position of the cube when tested was straight angle to that as cast. The load was applied gradually without shock till the failure of the specimen occurred and thus the compressive strength was found [8]. The quantities of cement, coarse aggregate (20 mm), fine aggregate, expanded polystyrene, glass powder and water for each batch i.e., for different percentage of expanded polystyrene and glass powder replacement was weighed separately [9]. The coarse aggregates were mixed with expanded polystyrene to get uniform distribution throughout the batch .The fine aggregates were mixed with glass powder to get uniform distribution throughout batch [9]. Water in proportions was added to the mix. Firstly, 50to70% of water was added to the mix and then mixed thoroughly for 3 to 4 minutes in the mixer. Then the concrete was filled into the cube mould then was vibrated to ensure proper compaction [9]. The surface of the concrete was finished level with the top of the mould using a trowel. The finished specimens were left to hardened in air for 24 hours [9]. The specimens were removed from the moulds after 24 hours of casting and were placed in the water tank, filled with potable water in the laboratory.

### *F. Splitting Tensile Strength*

The splitting tensile strength of the concrete specimens was determined at 7 and 28 days following IS 5816-1999. The specimens were molded at the same time as the compressive strength specimens [8]. Cylinders were molded with a diameter of 150 mm and a length of 300 mm [9]. The measured split tensile strength of the specimen shall be calculated to the nearest value 0.05 N/mm2 using the formula.

$(2 P)/\pi dl=fct$
Where
P = Maximum of applied load in N
d = diameter of the specimen

### *G. Flexural Tensile Strength*

Flexural strength is a material boundary communicated as the pressure in a substance instantly before it gives in a flexure test [9]. It is also called the modulus of rupture, bend strength, or transverse rupture strength. One of most normal tests is the cross over bending test, wherein an example with a roundabout or rectangular cross-segment is bowed till break or yielding using a three-point flexural test method [9]. The flexural strength of the example shows the greatest pressure supported inside it at the place of yield [9].
It is determined by the amount of stress. Beams with dimensions of 10 cm x 10 cm x 50 cm are chosen for beam testing. Fill the mould with concrete in three layers of about similar thickness to create the test specimen. Tamp each layer 035 times with the tamping bar as directed. Tamping should be equally spread over the full cross-section of the beam mould and throughout the depth of each layer.
The load will be applied at a rate of loading of 0400 kg/min for the 015.0 cm examples and at a rate of 0180 kg/min for the 010.0 cm examples. Test examples are eliminated from the molds following 024 hours and are submerged in water for curing. The top surface of the beam should be smoother and surprisingly this is accomplished by spreading cement paste on every one of the essences of the examples. The test example will be put in the machine accurately focused with the longitudinal axis of the example at right points to the rollers. For molded examples, the mould filling heading will be normal to the direction of loading. Figure 2 shows the sample of flexural strength
For a rectangular sample, the resulting stress under an axial force is given by the following formula:
The Flexural Strength or modulus of rupture (fb) is given by
fb = pl/bd2
(When a >020.0cm for 015.0cm specimen or >013.0cm for 010cm specimen)
Or
fb = 03pa/ibd2
(When a <020.0cm but >017.0 for 015.0cm specimen or <013.3 cm but >011.0cm for 010.0cm specimen.)
Where,
a = the distance between the line of fracture and the nearer support, measured on the center line of the tensile side of the specimen.
b = width of specimen (cm).
d = failure point depth (cm).
l = supported length (cm).
p = max. Load (kg).
Usually, L (length of the support span) is much bigger than id, so the fraction is bigger than one.

Figure 2: Sample of flexural strength

## IV. RESULTS

The objectives of the present work is to develop cement concrete with good strength and workability by using both crushed glass waste as partial replacement of fine aggregates and expanded polystyrene (EPS) as a partial replacement of natural coarse aggregates together in different combinations. To fulfill this objective, the study is carried and discussed as under:
The M30 grades of concrete was prepared and examined at fresh and hardened stage respectively. Then different mixes were prepared containing different proportion of replacement and mixes were made 0%, 10%, 20%, and 30% of crushed glass powder as to replace some part of fine aggregate and 0%, 1.5%, 2.5%, and 3.5% of Expanded Polystyrene beads aggregate as to replace some part of natural coarse aggregates. Suitable quantities of super-plasticizer and materials are added to improve the workability and stability. The cube specimens and cylindrical specimens were tested after the recommended curing time of curing period of 7 days and 28 days respectively.

- Slump Test.
- Compressive strength of solidified concrete cube specimens.
- Split tensile strength of solidified cylinder specimens.
- Flexural Strength of solidified specimen

The Values of slump for different mixes are shown in Table 1. and Fig. 3 shows the graph variation of slump.

Table 1: Test Result of Slump Variation in Samples

| Mix Designation | Replacement of fine aggregate by glass | Replacement of coarse Aggregate by EPC | Height of frustum cone (mm) | Height of sample (mm) | Slump (mm) |
|---|---|---|---|---|---|
| MY0 | 0% | 0% | 300 | 271 | 29 |
| MY1 | 0% | 1.5% | 300 | 269 | 31 |
| MY2 | 0% | 2.5% | 300 | 268 | 32 |
| MY3 | 0% | 3.5% | 300 | 266 | 34 |
| MY4 | 110% | 10% | 1300 | 1265 | 135 |
| MY5 | 110% | 111.5% | 1300 | 1262 | 138 |
| MY6 | 110% | 12.5% | 1300 | 1258 | 142 |
| MY7 | 110% | 13.5% | 1300 | 1255 | 145 |
| MY8 | 120% | 10% | 1300 | 1252 | 148 |
| MY9 | 120% | 11.5% | 1300 | 1249 | 151 |
| MY10 | 120% | 12.5% | 1300 | 1246 | 154 |
| MY11 | 120% | 13.5% | 1300 | 1244 | 156 |
| MY12 | 130% | 10% | 1300 | 1243 | 157 |
| MY13 | 130% | 11.5% | 1300 | 1239 | 161 |
| MY14 | 130% | 12.5% | 1300 | 1238 | 162 |

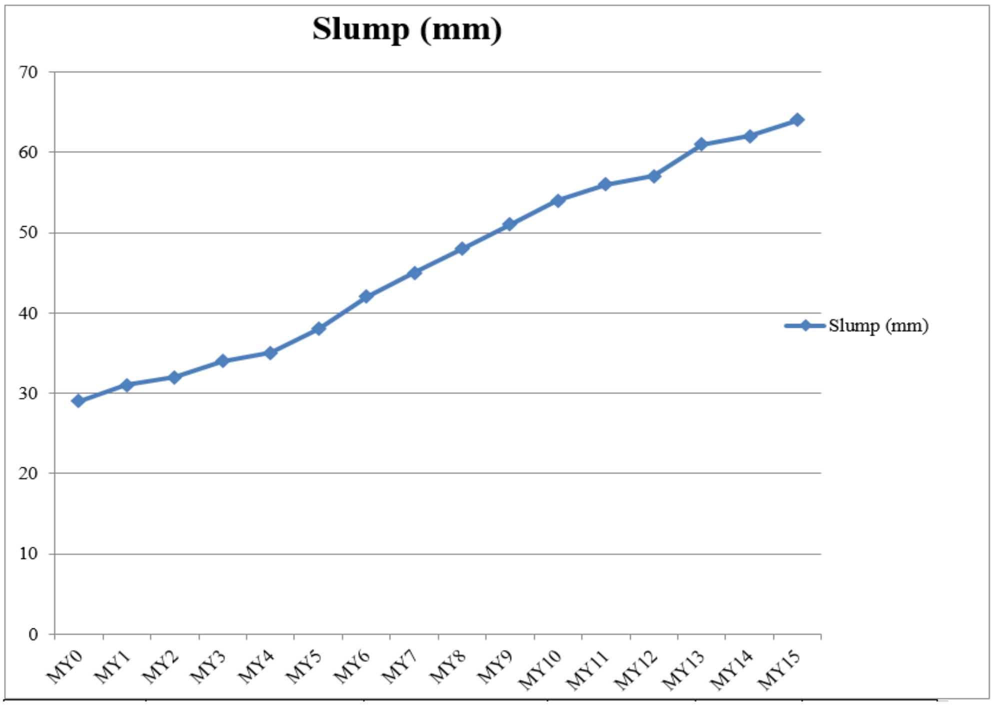


Figure 3: Graph showing slump variation in samples

Values of CS after 7 days for M30 shown in Table 2. and Fig. 4 shows the graphical representation.

Table 2: Compressive Strength of M30 Concrete after 7 days

| Mix designation | Replacement of fine aggregate by CGW | Replacement of coarse Aggregate by EPS | Compressive strength after 07 days (N/mm$^2$) |
|---|---|---|---|
| MY0 | 0% | 00% | 27.13 |
| MY1 | 0% | 01.5% | 29.28 |
| MY2 | 0% | 02.5% | 24.10 |
| MY3 | 0% | 03.5% | 24.69 |
| MY4 | 010% | 00% | 028.62 |
| MY5 | 010% | 01.5% | 028.40 |
| MY6 | 010% | 02.5% | 029.05 |
| MY7 | 010% | 03.5% | 027.31 |
| MY8 | 020% | 00% | 031.65 |
| MY9 | 020% | 01.5% | 031.85 |
| MY10 | 020% | 02.5% | 030.72 |
| MY11 | 020% | 03.5% | 030.22 |
| MY12 | 030% | 00% | 028.25 |
| MY13 | 030% | 01.5% | 027.46 |
| MY14 | 030% | 02.5% | 026.41 |
| MY15 | 030% | 03.5% | 025.62 |

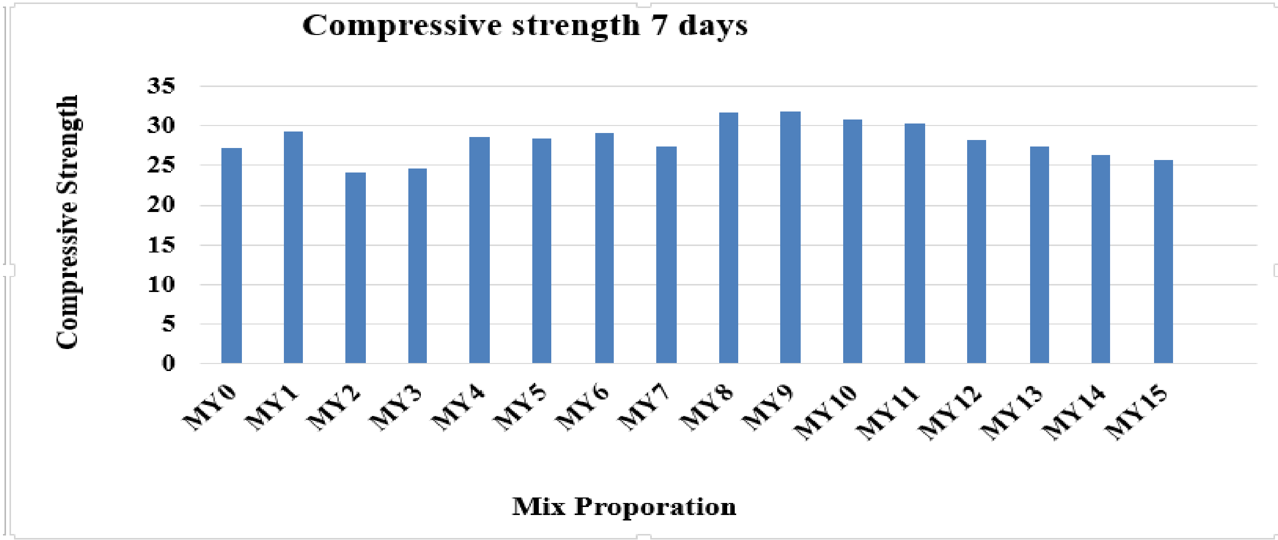


Figure 4: Compressive strength of M30 concrete for 7 days

Values of CS after 28 days for M30 shown in Table 3. and Fig. 5 shows the graphical representation.

Table 3: Compressive strength of M30 concrete after 28 days

| Mix designation | Replacement of fine aggregate by CGW | Replacement of coarse Aggregate by EPS | Compressive strength after 028 days (N/mm$^2$) |
|---|---|---|---|
| MY0 | 0% | 0% | 37.85 |
| MY1 | 0% | 1.5% | 41.52 |
| MY2 | 0% | 2.5% | 34.47 |
| MY3 | 0% | 3.5% | 34.27 |
| MY4 | 110% | 10% | 138.16 |
| MY5 | 110% | 11.5% | 139.16 |
| MY6 | 110% | 12.5% | 139.56 |
| MY7 | 110% | 13.5% | 137.52 |

| | | | |
|---|---|---|---|
| MY8 | 120% | 10% | 142.24 |
| MY9 | 120% | 11.5% | 142.85 |
| MY10 | 120% | 12.5% | 141.78 |
| MY11 | 120% | 13.5% | 140.64 |
| MY12 | 130% | 10% | 139.81 |
| MY13 | 130% | 11.5% | 136.63 |
| MY14 | 130% | 12.5% | 136.13 |
| MY15 | 130% | 13.5% | 135.69 |

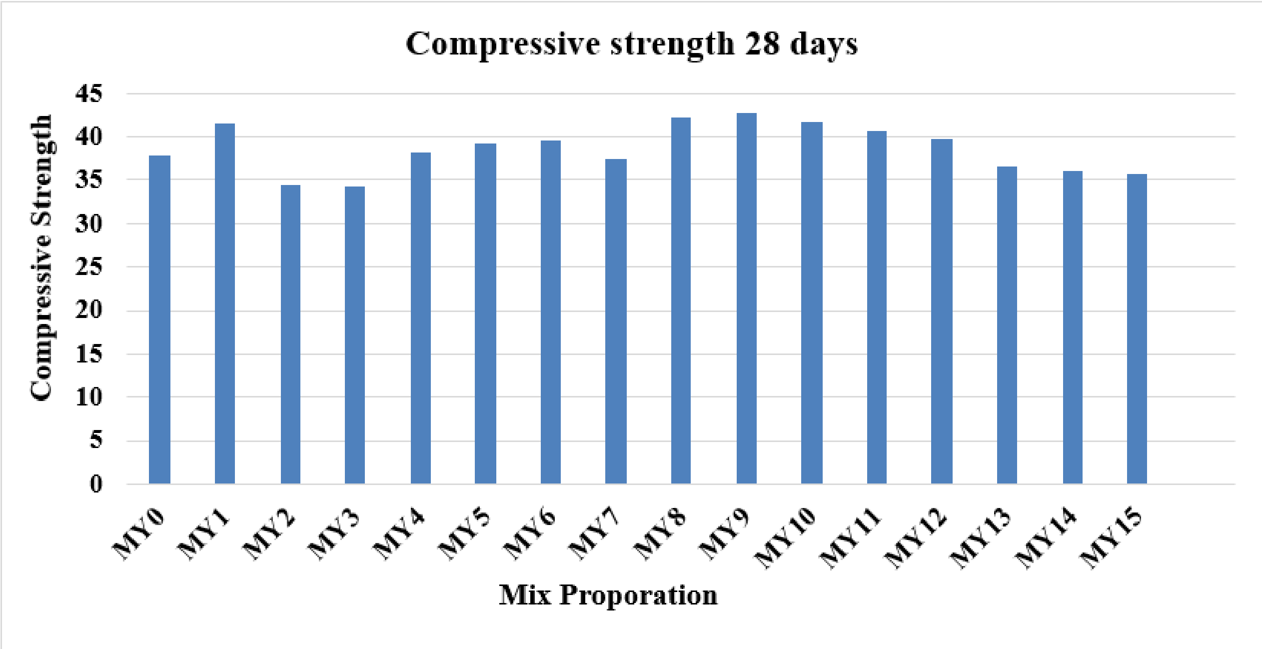


Figure 5: Compressive strength of M30 concrete for 28 days

Values of Split tensile after 7days for M30 shown in Table 4. and Fig.6 shows the graphical representation.

Table 4: Split tensile strength of M30 concrete after 7 days

| Mix designation | Replacement of fine aggregate by CGW | Replacement of coarse Aggregate by EPS | Split tensile strength after 07 days ($N/mm^2$) |
|---|---|---|---|
| MY0 | 0% | 0% | 1.49 |
| MY1 | 0% | 1.5% | 1.44 |
| MY2 | 0% | 2.5% | 1.42 |
| MY3 | 0% | 3.5% | 1.39 |
| MY4 | 110% | 10% | 11.52 |
| MY5 | 110% | 11.5% | 11.47 |
| MY6 | 110% | 12.5% | 11.38 |
| MY7 | 110% | 13.5% | 11.32 |
| MY8 | 120% | 10% | 11.55 |

| | | | |
|---|---|---|---|
| MY9 | 120% | 11.5% | 11.61 |
| MY10 | 120% | 12.5% | 11.52 |
| MY11 | 120% | 13.5% | 11.48 |
| MY12 | 130% | 10% | 11.43 |
| MY13 | 130% | 11.5% | 11.37 |
| MY14 | 130% | 12.5% | 11.31 |
| MY15 | 130% | 13.5% | 11.29 |

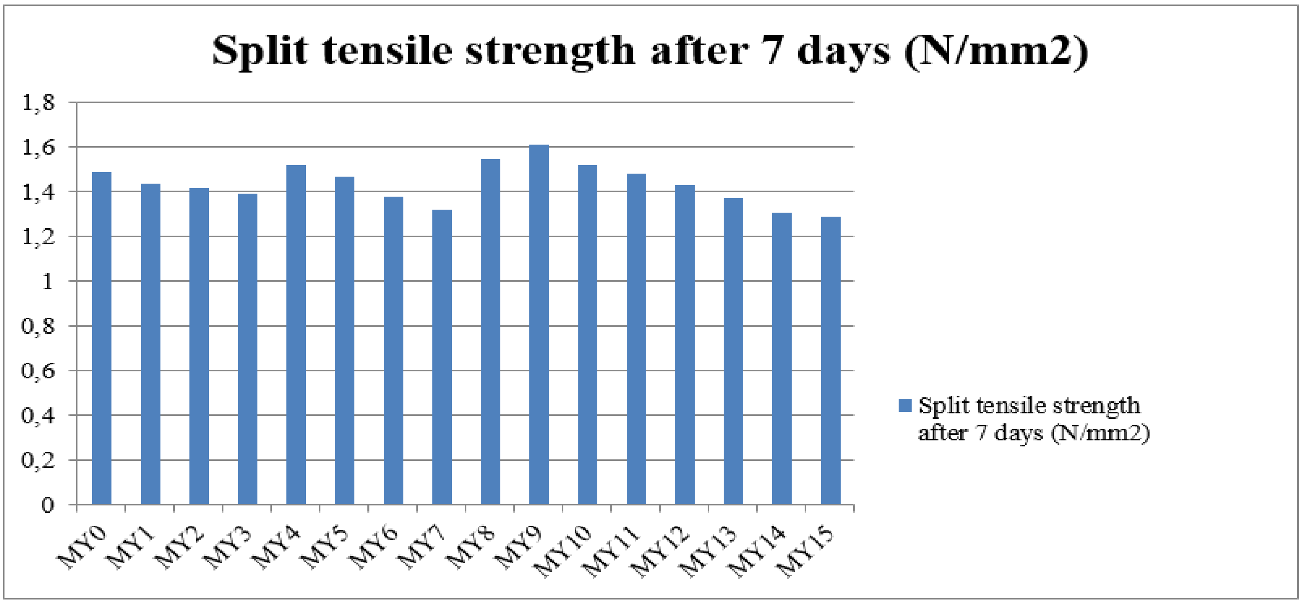


Figure 6: Split tensile strength after 7 days

Values of Split tensile after 28 days for M30 shown in Table 5. and Fig.7 shows the graphical representation.

Table 5: Split tensile strength of M30 concrete after 28 days

| Mix designation | Replacement of fine aggregate by CGW | Replacement of coarse Aggregate by EPS | Split tensile strength after 028 days (N/mm$^2$) |
|---|---|---|---|
| MY0 | 0% | 0% | 2.42 |
| MY1 | 0% | 1.5% | 2.36 |
| MY2 | 0% | 2.5% | 2.12 |
| MY3 | 0% | 3.5% | 2.04 |
| MY4 | 110% | 10% | 12.34 |
| MY5 | 110% | 11.5% | 12.29 |
| MY6 | 110% | 12.5% | 12.14 |
| MY7 | 110% | 13.5% | 12.10 |
| MY8 | 120% | 10% | 12.40 |
| MY9 | 120% | 11.5% | 12.48 |
| MY10 | 120% | 12.5% | 12.33 |
| MY11 | 120% | 13.5% | 12.26 |
| MY12 | 130% | 10% | 12.20 |
| MY13 | 130% | 11.5% | 12.15 |
| MY14 | 130% | 12.5% | 12.09 |
| MY15 | 130% | 13.5% | 12.07 |

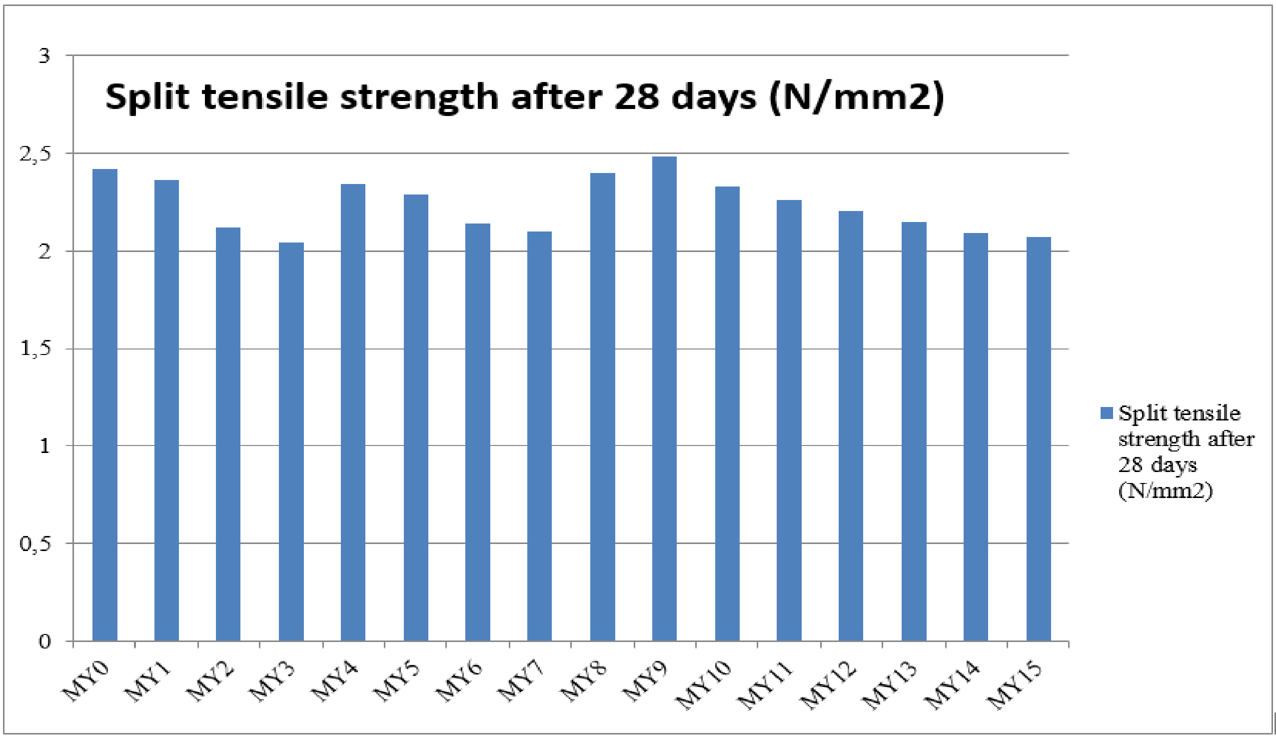


Figure 7: Split tensile strength after 28 days

Table 6: Flexural Strength of M30 Concrete after 7 days.

| Mix designation | Replacement of fine aggregate by CGW | Replacement of coarse Aggregate by EPS | FLEXURAL strength after 07 days ($N/mm^2$) |
|---|---|---|---|
| MY0 | 0% | 0% | 3.67 |
| MY1 | 0% | 1.5% | 3.68 |
| MY2 | 0% | 2.5% | 3.71 |
| MY3 | 0% | 3.5% | 3.76 |
| MY4 | 110% | 10% | 13.79 |
| MY5 | 110% | 11.5% | 13.82 |
| MY6 | 110% | 12.5% | 13.85 |
| MY7 | 110% | 13.5% | 13.87 |
| MY8 | 120% | 10% | 13.99 |
| MY9 | 120% | 11.5% | 14.01 |
| MY10 | 120% | 12.5% | 14.13 |
| MY11 | 120% | 13.5% | 14.03 |
| MY12 | 130% | 10% | 13.98 |
| MY13 | 130% | 11.5% | 13.91 |
| MY14 | 130% | 12.5% | 13.95 |
| MY15 | 130% | 13.5% | 13.90 |

Values of Flexural strength after 7 days for M30 shown in Table 6. and Fig.8 shows the graphical representation

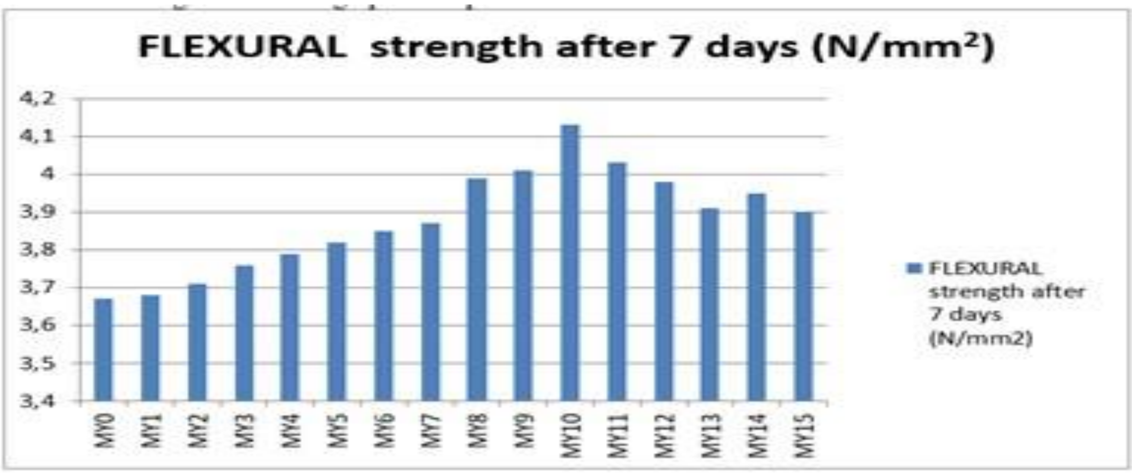


Figure 8: Flexural strength after 7 days

Table 7: Flexural strength of M30 concrete after 28 days

| Mix designation | Replacement of fine aggregate by CGW | Replacement of coarse Aggregate by EPS | FLEXURAL strength after 07 days ($N/mm^2$) |
|---|---|---|---|
| MY0 | 0% | 0% | 3.67 |
| MY1 | 0% | 1.5% | 3.68 |
| MY2 | 0% | 2.5% | 3.71 |
| MY3 | 0% | 3.5% | 3.76 |
| MY4 | 110% | 10% | 13.79 |
| MY5 | 110% | 11.5% | 13.82 |
| MY6 | 110% | 12.5% | 13.85 |
| MY7 | 110% | 13.5% | 13.87 |
| MY8 | 120% | 10% | 13.99 |
| MY9 | 120% | 11.5% | 14.01 |
| MY10 | 120% | 12.5% | 14.13 |
| MY11 | 120% | 13.5% | 14.03 |
| MY12 | 130% | 10% | 13.98 |
| MY13 | 130% | 11.5% | 13.91 |
| MY14 | 130% | 12.5% | 13.95 |
| MY15 | 130% | 13.5% | 13.90 |

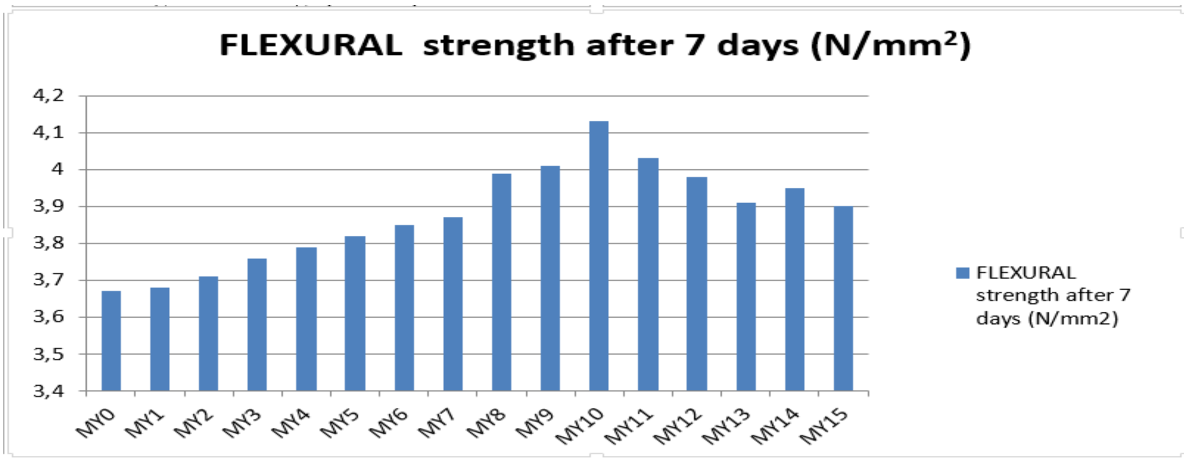


Figure 9: Flexural strength after 28 days

Values of Flexural strength after 28 days for M30 shown in Table 7. and Fig.9 shows the graphical representation

## V. CONCLUSION

The strength characteristics of concrete mixtures have been computed in the present work by replacement of fine aggregate by 0%, 10%, 20% and 30% with glass powder and Coarse aggregate 0%, 1.5, 2.5%, & 3.5% with the EPS beads. On the basis of present study, following conclusions are drawn.

- The maximum compressive strength M30 grade for 7 days of all the mixed combinations is found to be 31.85 N/mm2 when coarse aggregate was replaced with 1.5% and fine aggregate with 20%.
- The maximum compressive strength M30 grade for 28 days of all the mixed combinations is found to be 42.85 N/mm2 when coarse aggregate was replaced with 1.5% and fine aggregate with 20%.
- The maximum split tensile strength M30 grade for 7 days of all the mixed combinations is found to be 1.61 N/mm2 when coarse aggregate was replaced with 1.5% and fine aggregate with 20% respectively.
- The maximum split tensile strength M30 grade for 28 days of all the mixed combinations is found to be 2.48 N/mm2 when coarse aggregate was replaced with 1.5% and fine aggregate with 20% respectively
- The workability of concrete increase with the increase in the variation in the replacement of coarse and fine aggregate with glass powder and EPS beads respectively.
- It was observed that with the increase in the variation in the replacement there was great reduction in weight of concrete and maximum was attain at when Coarse aggregate was replaced with 2.5 % and fine aggregate with 20% respectively and was attained 1.92% less than normal weight of concrete.
- The maximum flexural strength M30 grade for 7 and 28 days of all the mixed combinations is found to be 4.13 N/mm2& 5.18 N/mm2respectivelly swhen coarse aggregate was replaced with 2.5% and fine aggregate with 20%.

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## CONFLICTS OF INTEREST

I Mariya Younis declare that I have involvement in no other organisations and I have no conflicts of interest.

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