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# Study of Properties of Bendable Concrete for M25 Grade

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***Abstract- Engineered Cementitious Composite has new variety of fiber reinforced concrete featured as Bendable concrete (BC). It is a simply molded mortar-based composite, reinforced with precisely selected small sized fibers, sometimes polymer fibers. Unlike regular concrete bendable concrete has a strain capability within the range of 3 to 7 percent when compared to 0.01% for ordinary Portland cement (OPC). It also acts more like a ductile metal than a normal OPC concrete which acts like a brittle glass. That's why it leads to wide applications. In this research there have been 1 standard concrete batch mix of total 36 samples and 3 partially concrete batch mix of108 sample were created. Every batch contains 36 samples of concrete cubes of 150x150x150mm size, 36 samples of beams of 100x100x500mm size and 36 samples of cylinders of 150x300mm size. Additionally for the check of durability 9samples (cubes, beams and cylinders) were created. These samples were tested with different partially replaced samples for comparison purpose.***

## I. INTRODUCTION

The growth of fiber reinforced concrete material has experienced a number of stages. There are various kinds of concrete available, produced by changing the proportions of the key elements.

The research will cover the enhancement of physical property of bendable concrete (BC) via AR Glass fiber (Alkali Resistant).The objectives of the work is to prepare different mix proportions by replacing cement with fly ash and by incorporating different volume of fibers. To compare the strength parameters of Bendable concrete samples with the parameters of conventional concrete. To compare the results of flexural behavior of the Bendable concrete with conventional concrete and comparison of bending phenomenon.

## II. FORMULATION OF WORK

Various researches have been conducted to study the effect of variation of glass, carbon, synthetics, and natural fibers but there is alkali resistant Glass fiber whose effect has not been experimentally studied. In the present study, three composition of Alkali resistant glass fiber with cement i.e. (1.5 percent, 2 percent, and 2.5 percent) will be used and their effect on Compressive Strength, Flexural Strength and Split Tensile Strength will be observed and compared to Standard Concrete.

| Batch Mix | Cement (%) | Fly Ash (%) | AR Glass Fiber (%) | Sand (%) | Coarse Aggregates (%) |
|---|---|---|---|---|---|
| 1 | 70 | 30 | -- | 100 | 100 |
| 2 | 68.5 | 30 | 1.5 | 100 | 0 |
| 3 | 68 | 30 | 2.0 | 100 | 0 |
| 4 | 67.5 | 30 | 2.5 | 100 | 0 |

Methodology of this research topic is to discover different properties of concrete formed by replacement of cement with Alkali Resistant Glass Fiber (ARGF) at variable percentages of 1.5%, 2.0% and 2.5%. Properties of Green concrete and hardened concrete would be verified for its compressive strength, flexural strength, split tensile strength and durability. Cement would be tested for its consistency and initial and final setting time.

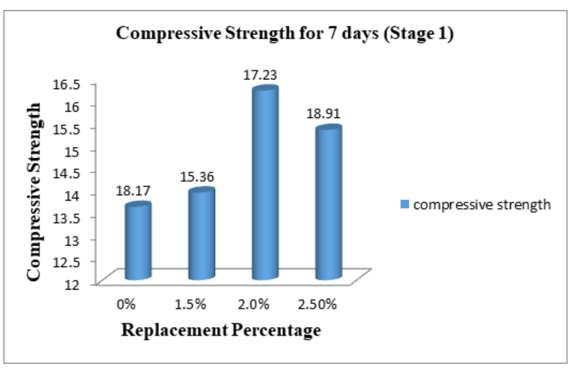
## III. RESULTS & DISCUSSION

The results obtained are shown below in tabular & graphical form.

Compressive Strength of M-25 Grade Concrete
Compressive strength test is performed on 3 cubes of each batch mix for 7 days, 14 days & 28 days. There are 4 batch mixes and each one having 3 cubes. Of these 12 cubes, 3 cubes are tested for 7 days, 14 days & 28 days each. An average of 3 values as tabulated in subhead results, are considered for discussions.

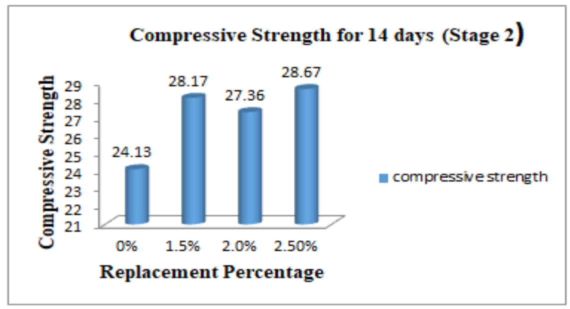
7 day compressive strength of concrete

| S. No. | COMBINATION | CUBES | MAXIMUM LOAD(KN) | COMPRESSIVE STRENGTH (N/mm²) | AVERAGE COMPRESSIVE STRENGTH (N/mm²) |
|---|---|---|---|---|---|
| Mix -01 | C+S+NCA | Cube-1 | 310 | 13.77 | 13.64 |
| | | Cube-2 | 324 | 13.92 | |
| | | Cube-3 | 295 | 13.25 | |
| Mix -02 | C (68.5%) + FA (30%) +S (100%) + ARGF (1.5%) | Cube-1 | 325 | 13.93 | 13.96 |
| | | Cube-2 | 335 | 14.02 | |
| | | Cube-3 | 329 | 13.95 | |
| Mix -03 | C (68%) + FA (30%) +S (100%) + ARGF (2.0%) | Cube-1 | 350 | 15.52 | 16.24 |
| | | Cube-2 | 375.50 | 16.78 | |
| | | Cube-3 | 365 | 16.42 | |
| Mix -04 | C (67.5%) + FA (30%) +S (100%) + ARGF (2.5%) | Cube-1 | 340.40 | 15.13 | 15.36 |
| | | Cube-2 | 348.70 | 15.5 | |
| | | Cube-3 | 347.90 | 15.46 | |



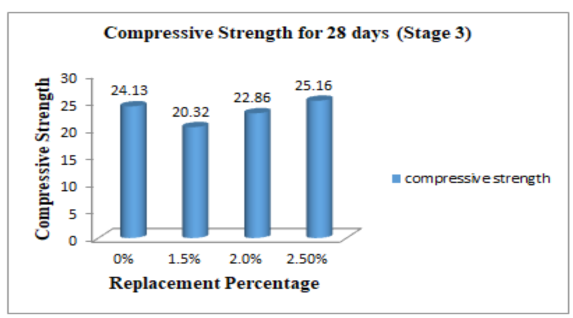

14 day compressive strength of concrete

| S. No. | COMBINATION | CUBES | MAXIMUM LOAD (KN) | COMPRESSIVE STRENGTH (N/mm²) | AVERAGE COMPRESSIVE STRENGTH (N/mm²) |
|---|---|---|---|---|---|
| Mix -01 | C+S+NCA | Cube-1 | 395 | 17.55 | 18.50 |
| | | Cube-2 | 405 | 18.15 | |
| | | Cube-3 | 420.50 | 19.20 | |
| Mix -02 | C (68.5%) + FA (30%) +S (100%) + ARGF (1.5%) | Cube-1 | 481.80 | 21.41 | 20.06 |
| | | Cube-2 | 445.50 | 19.20 | |
| | | Cube-3 | 448.50 | 19.58 | |
| Mix -03 | C (68%) + FA (30%) +S (100%) + ARGF (2.0%) | Cube-1 | 509.80 | 22.66 | 22.30 |
| | | Cube-2 | 508.50 | 22.30 | |
| | | Cube-3 | 499.50 | 21.85 | |
| Mix -04 | C (67.5%) + FA (30%) +S (100%) + ARGF (2.5%) | Cube-1 | 537.60 | 23.89 | 23.20 |
| | | Cube-2 | 532.50 | 22.74 | |
| | | Cube-3 | 530.20 | 22.56 | |



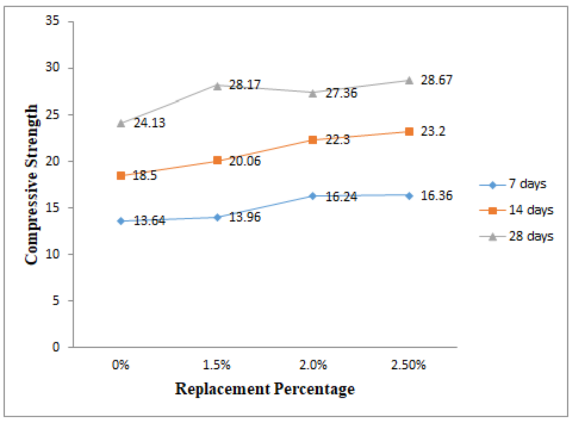

28 day compressive strength of concrete

| S.NO. | COMBINATION | CUBES | MAXIMUM LOAD (KN) | COMPRESSIVE STRENGTH (N/mm²) | AVERAGE COMPRESSIVE STRENGTH (N/mm²) |
|---|---|---|---|---|---|
| Mix -01 | C+S+NCA | Cube-1 | 518.60 | 23.05 | 24.13 |
| | | Cube-2 | 560.80 | 24.93 | |
| | | Cube-3 | 549.50 | 24.42 | |
| Mix -02 | C (68.5%) + FA (30%) +S (100%) + ARGF (1.5%) | Cube-1 | 555.00 | 24.67 | 28.17 |
| | | Cube-2 | 562.50 | 24.96 | |
| | | Cube-3 | 570.50 | 25.20 | |
| Mix -03 | C (68%) + FA (30%) +S (100%) + ARGF (2.0%) | Cube-1 | 573.30 | 25.48 | 27.36 |
| | | Cube-2 | 635.40 | 28.24 | |
| | | Cube-3 | 638.00 | 28.36 | |
| Mix -04 | C (67.5%) + FA (30%) +S (100%) + ARGF (2.5%) | Cube-1 | 629.00 | 27.96 | 28.67 |
| | | Cube-2 | 662.00 | 29.42 | |
| | | Cube-3 | 644.20 | 28.63 | |



As shown in the graph: 1 (7 days strength), when cement is partially replaced 2.5% by ARGF, compressive strength is increased by 19.9 % When graph: 2 (14 days strength) is analyzed, 2.5% replacement of ARGF gives 25.49 % more strength when compared with conventional concrete. 28 days strength in graph: 3 show an increment of 26.85% of strength of 2.5% replacement of ARGF as compared with conventional concrete.

Compressive Strength in N/mm2 at various age (Days)

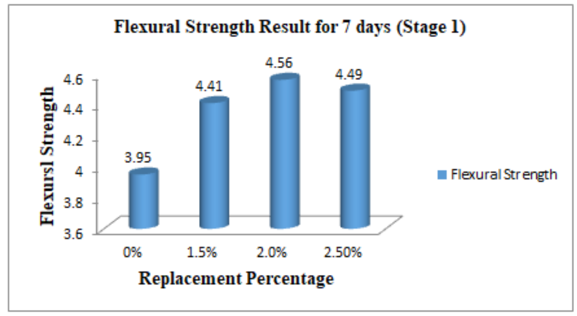



Flexural Strength of M-25 Grade Concrete

Flexural strength test is performed on 3 beams of each batch mix for 7 days, 14 days & 28 days. There are 3 batch mixes and each one having 3 beams. Of these 9 beams, 3 beams are tested for 7 days, 14 days & 28 days each. An average of 3 values as tabulated in subhead results, are considered for discussions.

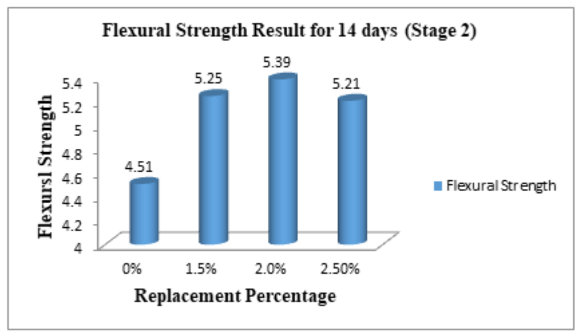
7 day flexural strength of concrete

| S. No. | COMBINATION | BEAMS | MAXIMUM LOAD (KN) | FLEXURAL STRENGTH ($N/mm^2$) | AVERAGE FLEXURAL STRENGTH ($N/mm^2$) |
|---|---|---|---|---|---|
| Mix -01 | C+S+NCA | Beam- 1 | 9.40 | 3.76 | 3.95 |
| | | Beam -2 | 10.00 | 4.00 | |
| | | Beam- 3 | 10.20 | 4.08 | |
| Mix -02 | C (68.5%) + FA (30%) +S (100%) + ARGF (1.5%) | Beam -1 | 10.60 | 4.24 | 4.41 |
| | | Beam -2 | 11.20 | 4.48 | |
| | | Beam- 3 | 11.25 | 4.50 | |
| Mix -03 | C (68%) + FA (30%) +S (100%) + ARGF (2.0%) | Beam -1 | 11.30 | 4.52 | 4.56 |
| | | Beam -2 | 11.35 | 4.54 | |
| | | Beam- 3 | 11.55 | 4.62 | |
| Mix -04 | C (67.5%) + FA (30%) +S (100%) + ARGF (2.5%) | Beam -1 | 11.30 | 4.52 | 4.49 |
| | | Beam -2 | 11.00 | 4.40 | |
| | | Beam- 3 | 11.40 | 4.56 | |



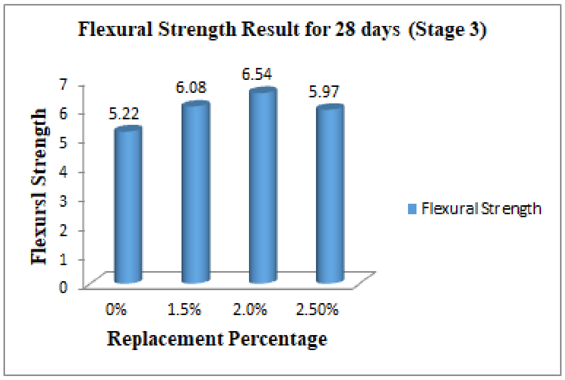

14 day flexural strength of concrete

| S.NO. | COMBINATION | BEAMS | MAXIMUM LOAD (KN) | FLEXURAL STRENGTH ($N/mm^2$) | AVERAGE FLEXURAL STRENGTH ($N/mm^2$) |
|---|---|---|---|---|---|
| Mix -01 | C+S+NCA | Beam-1 | 10.80 | 4.32 | 4.51 |
| | | Beam -2 | 11.45 | 4.58 | |
| | | Beam- 3 | 11.60 | 4.64 | |
| Mix -02 | C (68.5%) + FA (30%) +S (100%) + ARGF (1.5%) | Beam -1 | 12.70 | 5.04 | 5.25 |
| | | Beam -2 | 13.20 | 5.28 | |
| | | Beam- 3 | 13.60 | 5.44 | |
| Mix -03 | C (68%) + FA (30%) +S (100%) + ARGF (2.0%) | Beam -1 | 13.20 | 5.28 | 5.39 |
| | | Beam -2 | 13.50 | 5.40 | |
| | | Beam- 3 | 13.75 | 5.50 | |
| Mix -04 | C (67.5%) + FA (30%) +S (100%) + ARGF (2.5%) | Beam -1 | 13.10 | 5.24 | 5.21 |
| | | Beam -2 | 12.85 | 5.14 | |
| | | Beam- 3 | 13.15 | 5.26 | |



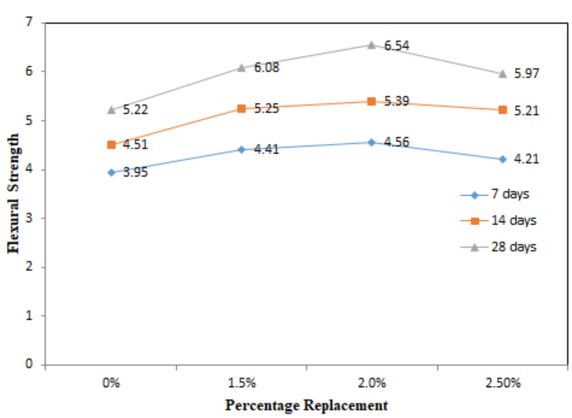

28 day flexural strength of concrete

| S. NO. | COMBINATION | BEAMS | MAXIMUM LOAD(KN) | FLEXURAL STRENGTH ($N/mm^2$) | AVERAGE FLEXURAL STRENGTH ($N/mm^2$) |
|---|---|---|---|---|---|
| Mix -01 | C+S+NCA | Beam-1 | 12.40 | 4.96 | 5.22 |
| | | Beam -2 | 13.30 | 5.33 | |
| | | Beam- 3 | 13.45 | 5.38 | |
| Mix -02 | C (68.5%) + FA (30%) +S (100%) + ARGF (1.5%) | Beam -1 | 14.85 | 5.94 | 6.08 |
| | | Beam -2 | 15.25 | 6.10 | |
| | | Beam- 3 | 15.55 | 6.22 | |
| Mix -03 | C (68%) + FA (30%) +S (100%) + ARGF (2.0%) | Beam -1 | 15.50 | 6.20 | 6.54 |
| | | Beam -2 | 16.65 | 6.66 | |
| | | Beam- 3 | 16.90 | 6.76 | |
| Mix -04 | C (67.5%) + FA (30%) +S (100%) + ARGF (2.5%) | Beam -1 | 15.10 | 6.01 | 5.97 |
| | | Beam -2 | 14.80 | 5.92 | |
| | | Beam- 3 | 15.00 | 6.00 | |




As shown in the graph: 5 (7 days strength), when cement is partially replaced 2.5% by ARGF, flexural strength is increased by 20%. Afterwards when % of ARGF is increased the strength starts decreasing When graph: 6 (14 days strength) is analyzed, 2.5% replacement of ARGF gives 25.39% more flexural strength when compared with normal concrete. Here also, when % of ARGF is increased, strength starts decreasing. 28 days strength in graph: 7 show an increment of 22.10% of strength of 2.5% replacement of ARGF as compared with conventional concrete. Again strength is decreased when % of ARGF is increased. As discussed here, it can be said that an increment in compressive strength of 2.0% replacement of ARGF nearly 25% is achieved as compared with conventional concrete mix.

Flexural Strength for Various days

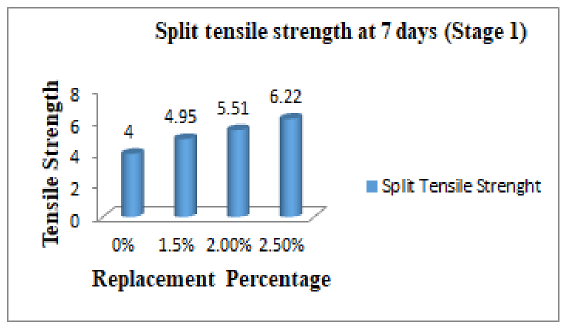



Split tensile Strength of M-25 Grade Concrete

Split Tensile Strength is performed on 3 cylinders of each batch mix for 7 days, 14 days & 28 days. There are 3 batch mixes and each one having 3 cylinders. Of these 9 cylinders, 3 cylinders are tested for 7 days, 14 days & 28 days each. An average of 3 values as tabulated in subhead results, are considered for discussions.

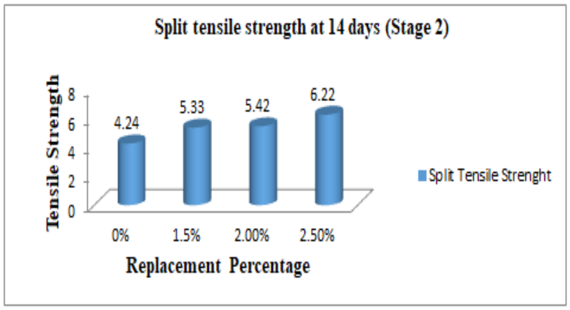
Split Tensile Strength Result for 7 days

| S.No. | COMBINATION | CYLINDERS | MAXIMUM LOAD (KN) | SPLIT TENSILE STRENGTH (N/mm²) | SPLIT TENSILE STRENGTH (N/mm²) |
|---|---|---|---|---|---|
| Mix -01 | C+S+NCA | Cylinder-1 | 250 | 3.53 | 4.00 |
| | | Cylinder -2 | 290 | 4.10 | |
| | | Cylinder -3 | 310 | 4.38 | |
| Mix -02 | C (68.5%) + FA (30%) +S (100%) + ARGF (1.5%) | Cylinder -1 | 380 | 5.37 | 4.95 |
| | | Cylinder -2 | 320 | 4.52 | |
| | | Cylinder -3 | 350 | 4.95 | |
| Mix -03 | C (68%) + FA (30%) +S (100%) + ARGF (2.0%) | Cylinder -1 | 420 | 5.94 | 5.51 |
| | | Cylinder -2 | 350 | 4.95 | |
| | | Cylinder -3 | 400 | 5.65 | |
| Mix -04 | C (67.5%) + FA (30%) +S (100%) + ARGF (2.5%) | Cylinder -1 | 470 | 6.65 | 6.22 |
| | | Cylinder -2 | 420 | 5.94 | |
| | | Cylinder -3 | 430 | 6.08 | |



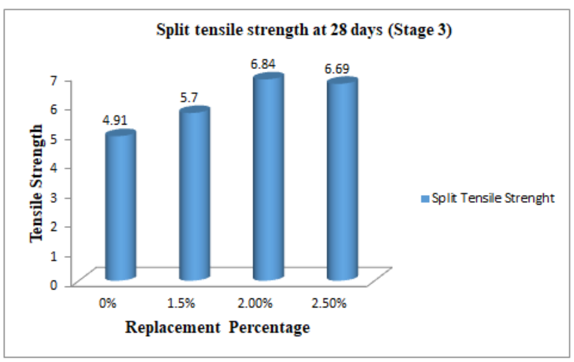

Split Tensile Strength Result for 14 days

| S. NO. | COMBINATION | CYLINDERS | MAX. LOAD (KN) | SPLIT TENSILE STRENGTH (N/mm²) | AVERAGE SPLIT TENSILE STRENGTH (N/mm²) |
|---|---|---|---|---|---|
| Mix -01 | C+S+NCA | Cylinder-1 | 320 | 4.52 | 4.24 |
| | | Cylinder -2 | 280 | 3.96 | |
| | | Cylinder -3 | 300 | 4.24 | |
| Mix -02 | C (68.5%) + FA (30%) +S (100%) + ARGF (1.5%) | Cylinder -1 | 370 | 5.23 | 5.33 |
| | | Cylinder -2 | 350 | 4.95 | |
| | | Cylinder -3 | 320 | 4.52 | |
| Mix -03 | C (68%) + FA (30%) +S (100%) + ARGF (2.0%) | Cylinder -1 | 410 | 5.80 | 5.42 |
| | | Cylinder -2 | 340 | 4.81 | |
| | | Cylinder -3 | 400 | 5.66 | |
| Mix -04 | C (67.5%) + FA (30%) +S (100%) + ARGF (2.5%) | Cylinder -1 | 460 | 6.51 | 6.36 |
| | | Cylinder -2 | 440 | 6.22 | |
| | | Cylinder -3 | 450 | 6.36 | |




Split Tensile Strength Result for 28 days

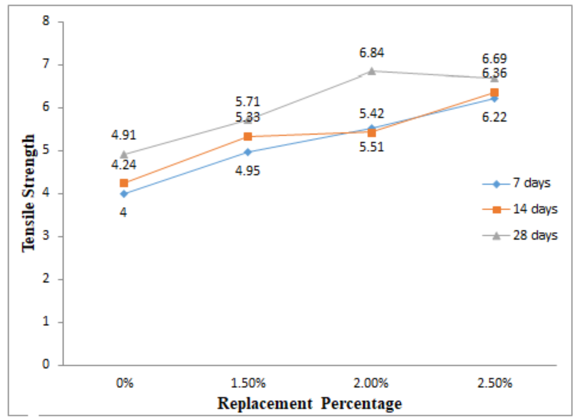
| S.NO. | COMBINATION | CYLINDERS | MAXIMUM LOAD (KN) | SPLIT TENSILE STRENGTH (N/mm²) | AVERAGE SPLIT TENSILE STRENGTH (N/mm²) |
|---|---|---|---|---|---|
| Mix -01 | C+S+NCA | Cylinder-1 | 360 | 4.01 | 4.91 |
| | | Cylinder -2 | 370 | 5.09 | |
| | | Cylinder -3 | 400 | 5.65 | |
| Mix -02 | C (68.5%) + FA (30%) +S (100%) + ARGF (1.5%) | Cylinder -1 | 410 | 5.23 | 5.70 |
| | | Cylinder -2 | 390 | 5.80 | |
| | | Cylinder -3 | 430 | 6.08 | |
| Mix -03 | C (68%) + FA (30%) +S (100%) + ARGF (2.0%) | Cylinder -1 | 410 | 5.80 | 6.84 |
| | | Cylinder -2 | 510 | 7.22 | |
| | | Cylinder -3 | 530 | 7.50 | |
| Mix -04 | C (67.5%) + FA (30%) +S (100%) + ARGF (2.5%) | Cylinder -1 | 480 | 6.79 | 6.69 |
| | | Cylinder -2 | 440 | 6.22 | |
| | | Cylinder -3 | 500 | 7.07 | |




As shown in the graph: 9 (7 days strength), when cement is partially replaced 1.5% by ARGF i.e., Split Tensile strength is increased by 38%. Afterwards when % of ARGF is increased the strength starts decreasing When graph: 10 (14 days strength) is analyzed, 2% replacement of ARGF gives 42.39% more Split Tensile strength when compared with normal concrete. Here also, when % of ARGF is increased, strength starts decreasing. 28 days strength in graph: 11 show an increment of 45.58% of strength of 2.5% replacement of ARGF as compared with conventional concrete. Again strength is decreased when % of ARGF is increased.

As discussed here, it can be said that an increment in compressive strength of 2.5 % replacement of ARGF nearly 45% is achieved as compared with conventional concrete mix.

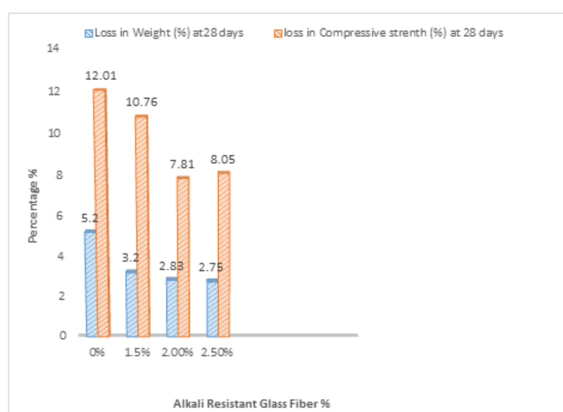
Split Tensile Strength for various days




Durability Test of M-25 Grade Concrete

Effect of Acid Attack on Weight and Compressive Strength of Cubes are as follows:

| S.No. | ARGF % | Loss in Weight (%) At 28 Days | Loss in Compressive strength (%) At 28 days |
|---|---|---|---|
| 1. | 0 | 5.2 | 12.01 |
| 2. | 1.5 | 3.2 | 10.76 |
| 3. | 2.0 | 2.83 | 7.81 |
| 4. | 2.5 | 2.75 | 8.05 |



## IV. CONCLUSION & FUTURE SCOPE

It is clear from the discussion that there is drastic increment in Flexural strength and Compressive Strength of concrete at 2.0 % partial replacement of cement with fiber. But durability and split tensile strength is little bit reduced at 2.0 % of partial replacement of cement with fiber. Hence, concrete made by partial replacement of cement with fiber at 2.0 % is more effective.

The Future Scope of this Research work is vast. Many alterations can be done to get varied and desired results. Some of them are stated below:-

1. Different fibers can be used for varied and desired results such as PVA (Polyvinyl Alcohol), Steel Fibers.

2. Use of Admixture to increase the process of hydration can also be studied.

3. The self-healing property of ECC can be studied at the various ages of the concrete.

4. The study on ECC can be done for higher grade concrete such as M55 to M70.

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