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# STRENGTH PERFORMANCE STUDIES ON CEMENT CONCRETE MODIFIED WITH LIGHT WEIGHT PELLETIZED BAGASSE ASH AGGREGATE

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***ABSTRACT:- This study investigates the usage of artificial aggregates made with bagasse ash, which is a by-product of bagasse cogeneration power industries where pulped sugar cane is used as a burning element and the final residue can be obtained in the form of fine powder. An attempt is made to produce light weight pelletized bagasse ash aggregates by pelletization technique. The usage of Bagasse ash aggregate in concrete as a partial replacement of natural aggregate has been examined. The concrete so produced is light weight in nature and the development of such concrete with light weight pelletized bagasse ash aggregates is to minimize the conventional aggregate which results in decreasing the self weight of the concrete along with to increase the efficiency of concrete as a structural material. In this Investigation M25 grade concrete with replacement of natural coarse aggregates by (0%, 20%, 50%, 75%, and 100%) bagasse ash aggregate is studied. The effect on strength properties such as compressive strength of cubes, spilt tensile strength of cylinders, flexural strength of beams, modulus of elasticity and in-plane shear strength through mode-II fracture test are studied.***

***Key Words: Bagasse ash pellets, light weight aggregate, mode-II fracture***

## 1. INTRODUCTION

Concrete is a composite material made from cement, water, coarse aggregate and fine aggregate. Coarse aggregate is more essential in concrete which is used as a fixer material in higher ratio. Generally the concrete prepared with natural aggregates has more density and it increases dead weight acting on the structures which becomes critical when structures are built in weak soils. Researchers carried out an extensive work on this area. In the Present study, coarse aggregates from waste material like bagasse ash is used with lime and little quantity of cement as binder. An attempt has been made to produce artificial coarse aggregate which is also light weight in nature. The Bagasse ash is a by-product from Thermal furnace. One of the essential requirements for green building is to use eco friendly building materials such as industrial waste by- product like bagasse ash which will also lead to a range of economic and environmental benefits.

### 1.1 Light Weight Aggregate

Light weight aggregates can be divided into following categories

- Naturally occurring materials such as pumice, foamed lava, volcanic tuff and porous lime stone.
- Naturally occurring materials which require further processing such as expanded clay, shale and slate, vermiculite etc.,
- Industrial by-products such as sintered pulverized fuel ash, foamed or blast furnace slag, fly ash, bagasse ash, rise husk ash etc., which are produced either by expansion or agglomeration.

### 1.2 Light Weight Concrete

One of the disadvantages of conventional concrete is its high self weight. Density of normal concrete is in the order of 2200 to 2600Kg/m$^3$. This heavy self weight will make it to some extent an uneconomical structural material. Attempts have been made and light weight aggregate concrete has been introduced whose density varies from 300 to 1850Kg/m$^3$.

 

## 2. LITERATURE REVIEW

In their work **V.Bhaskar Desai and A. Sathyam [1]** studied about the different percentages of constituent materials in pelletized aggregates and their different properties and they compared with those of natural aggregates.

**Shanmugasundaram S et.al [2]** from their experiments conducted on fly ash aggregate concrete it was concluded that the strength characteristics of fly ash aggregate concrete with different cement fly ash proportions were studied at different ages. The fly ash aggregates were very effective in improving the strength and durability of concrete.

**Owens, P.L. et.al.[3]** stated that Light weight aggregate concrete has been used for structural purposes since the 20th century. The Light weight aggregate concrete is a material with low unit weight and often made with spherical aggregates. The density of structural Light weight aggregate concrete typically ranges from 1400 to 2000 kg/m³ when compared with that of about 2400 kg/m³ for normal weight aggregate concrete.

In their work **Hari Krishnan and Ramamurthy, 2006 [4]** used Pelletization process to manufacture light weight concrete aggregates. Some of the parameters need to be considered in their work for the efficiency of the production of pellets are speed of revolution of pelletizer disc, moisture content, and angle of pelletizer disc and duration of Pelletization.

In their work **Lakshmi Kumar Minapu, et.al. [5]** studied about light weight aggregate as a partial replacement to natural coarse aggregate and concluded that the compressive strength is promising. The density of concrete is found to decrease with the increase in percentage replacement of natural aggregate by pumice aggregate.

From the literature study conducted above , it appears that very little work is reported in the literature about the study of various strength properties of bagasse ash aggregate concrete where in that direction by natural aggregates is replaced in different proportions. Hence the present study has been undertaken.

## 3. OBJECTIVE

1. Study of examining the light weight pelletized bagasse ash aggregates is considered as a partial replacement in place of conventional coarse aggregate.

2. To Find a solution to reduce the dead load of the concrete structure by replacing coarse aggregate in concrete with light weight pelletized bagasse ash aggregate.

## 4. MATERIALS USED

The following materials are used for preparing the concrete mix. Properties of constituent materials are mentioned in table 1.

1) **Cement** **:** Ordinary Portland cement of (Ultratech) 53 grade is used.
2) **Fine aggregate (Sand)** **:** Locally available river sand from Chitravathi river near Battalapally which passing through 4.75mm IS sieve is used which conforms to grading zone-II of IS: 383-1970**[6**].
3) **Conventional Coarse aggregate:** Crushed granite aggregate conforming to IS: 383-1970**[6]** of 20mm maximum size has been obtained from the local sources.
4) **Artificial coarse aggregate** (i.e., Light weight pelletized Bagasse ash aggregates)

Bagasse ash aggregates = Bagasse ash + Lime + Cement + Water (by cold bonded Pelletization)

**Bagasse ash**: Bagasse ash is a by-product of thermal power industries where pulped sugar cane is used as a burning element. This ash is very light weight material and contains very small size particles. This bagasse ash is obtained from Mayura Sugars Pvt. Ltd. (Sreekalahasthi).

**Lime**: locally available lime is used as another binder.

**Pelletizing Process**: The desired grain size distribution of an artificial light weight aggregate is done by means of agglomeration process. The Pelletization process is to manufacture light weight coarse aggregate. Some of the parameters need to be considered for efficiency of production of pellets are speed of revolution of pelletized disc, moisture content, angle of pelletizer disc and duration of Pelletization. Moisture content and angle of drum parameter influences the size growth of pellets. The dosage of binding agent is more important for making bagasse ash pellets. Initially some percentage of water is added to the binder and remaining water is sprayed during the rotation period because while rotating without water in the drum bagasse ash and binder (lime & cement) tend to form lumps and does not increase the particle size. The pellets are formed approximately in duration of 6 to 7minutes. The bagasse ash pellets are dried under sunlight for 1 or 2 days and hardened by normal water curing method for 28 days. The setup of the machine for manufacturing bagasse ash aggregates is drum pelletizer of 1 HP fabricated by MINERAL Process Equipment Pvt. Ltd.. Bagasse ash aggregates are formed in rounded shape. The percentage proportion adopted for formation of pellets is 47:47:6 i.e., bagasse ash: lime: cement and 20 to 25% of water by total weight.

**5)** **Water:** locally available potable water which is free from acids, organic substances has been used in this work for mixing and curing.

**Table 1: Properties of constituent materials in M25 grade concrete.**

| S. No | Name of the material | | Properties of the material | |
|---|---|---|---|---|
| 1 | OPC – 53 GRADE | | Specific gravity | 3.15 |
| | | | Initial setting time | 50 minutes |
| | | | Final setting time | 460 minutes |
| | | | Fineness | 5.5% |
| | | | Normal consistency | 30% |
| 2 | Fine aggregate passing through 4.75 mm sieve. | | Specific gravity | 2.46 |
| | | | Fineness modulus | 2.64 |
| 3 | Coarse aggregate passing through 20mm sieve | Natural aggregate | Specific gravity | 2.66 |
| | | | Fineness modulus | 6.99 |
| | | | Bulk density compacted | 1620Kg/m$^3$ |
| | | Bagasse ash aggregates | Specific gravity | 1.45 |
| | | | Fineness modulus | 6.89 |
| | | | Bulk density | 870kg/m$^3$ |
| | | | Water absorption | 23% |
| | | | Shape | Round |

## 5. EXPERIMENTAL PROCEDURES

An experimental study has been conducted on concrete with various percentage replacements (0, 25, 50, 75,100) of conventional coarse aggregate by weight. i.e., granite by light weight aggregate i.e., by bagasse ash aggregates. The experimental investigation has been carried out by casting following specimens after 28 days of curing for each proportion.

1) 3 numbers of cubes (150*150*150mm) for compressive test
2) 3 numbers of cylinders (Ø150*300mm) for split tensile test
3) 3 numbers of beams (100*100*500mm) for flexure test
4) 3 numbers of Impact discs (Ø150*75mm) for Impact test
5) 3 numbers in-plane shear cubes (with notches of 0.3,0.4,0.5,0.6 a/w ratio) (150*150*150mm) for in-plane shear strength through mode-II fracture test

### 5.1 Casting of specimens

**Mix design**

The $M_{25}$ concrete mix is designed using ISI method i.e., IS 10262-2009**[7]** and IS 456-2000**[8]** which gives a mix proportion of 1:1.592:2.61 with constant water cement ratio of 0.45. Five different mixes have been studied which are designated as follows,

**Table 2: Designation details of specimen**

| S.No | Name of the Mix | % volume of natural coarse aggregate and bagasse ash aggregate | | No. of specimen cast and tested | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Natural aggregate | Bagasse ash aggregates | Cubes | Cylinders | Beams | In-plane shear cubes | Impact discs |
| 1 | D0 | 100 | 0 | 3 | 3 | 3 | 12 | 3 |
| 2 | D1 | 75 | 25 | 3 | 3 | 3 | 12 | 3 |
| 3 | D2 | 50 | 50 | 3 | 3 | 3 | 12 | 3 |
| 4 | D3 | 25 | 75 | 3 | 3 | 3 | 12 | 3 |
| 5 | D4 | 0 | 100 | 3 | 3 | 3 | 12 | 3 |
| | | **Total specimens** | | **15** | **15** | **15** | **60** | **15** |

**Mixing, Casting and curing of specimens**

To proceed with experimental program initially steel moulds were cleanly brushed with mechanical oil on all inner faces to facilitate easy removal of specimens afterwards. For in plane shear cubes notch plates are fixed to the mould with binding wire to proved the notches after placing the concrete. After applying the mechanical oil to the steel mould, First fine aggregate and cement were added and mixed thoroughly and then the conventional coarse aggregate with partially replaced pre soaked bagasse ash aggregates were mixed with them. All of these were mixed thoroughly in a mixer. Each time 3no of cubes, 3no.of beams, 3no.of cylinders, 3no.of in-plane shear cubes and 3no.of impact discs are casted. For all test specimens, moulds were kept on the platform and the concrete was poured into the mould in three layers. Each layer was compacted thoroughly with tamping rod and then the specimens were placed on vibration table for 6-7sec to avoid honey combing. In the case of in-plane shear cubes the steel plates forming notches were removed after 3 hours of casting carefully and neatly finished. However specimens were de-moulded after 24hrs of casting and were kept immersed in a clean water tank for curing. After 28 days of curing the specimens were taken out of water and were allowed to dry under shade for few hours and then they were white washed on both sides for clear visibility of cracks during testing. Beam specimens were tested under simply supported condition and under two point loading. All the other specimens were tested under standard way of loading.

## 6. TESTING

### 6.1 Compressive strength for Cubes

The cubical specimen was placed vertically between the plates of the compressive testing machine. The load was applied gradually without shock and continuously at the rate of 140 kg/ $cm^2$/ sec till the specimen fails and ultimate loads were recorded. These ultimate load divided by the area of the specimen gives the compressive strength of each cube. The test results are furnished in table 3 are graphically presented in figure 1.

**Table 3: Cube Compressive Strength Results.**

| CUBE COMPRESSIVE STRENGTH | | | | | | |
|---|---|---|---|---|---|---|
| S. No | Name of the mix | Percentage volume replacement of coarse aggregate (%) | | Ultimate load(KN) | Cube Compressive Strength in ($N/mm^2$) | Percentage decrease of Compressive Strength (%) |
| | | Natural aggregate | Bagasse ash aggregate | | | |
| 1 | D0 | 100 | 0 | 777.33 | 34.55 | 0.0 |
| 2 | D1 | 75 | 25 | 711.67 | 31.63 | 8.4 |
| 3 | D2 | 50 | 50 | 464.3 | 20.64 | 40.3 |
| 4 | D3 | 25 | 75 | 390.7 | 17.36 | 49.7 |
| 5 | D4 | 0 | 100 | 221.0 | 9.82 | 71.6 |

### 6.2 Split Tensile strength for Cylinders

In this test the cylindrical specimens were kept horizontally so that its axis was parallel to the compressive plates of the 3000KN digital compression testing machine. Narrow strips of the packing material i.e., plywood was placed between the plates and the cylinder to receive compressive load. The load was applied uniformly until the cylinder fails. Split tensile strength results of cylinder are tabulated in table 4 and values are graphically presented in figure 2.

**Table 4: Cylinder Tensile Strength Results.**

| SPLIT TENSILE STRENGTH | | | | | | |
|---|---|---|---|---|---|---|
| S. No | Name of the mix | Percentage volume replacement of coarse aggregate (%) | | Ultimate load(KN) | Cylinder split tensile strength in (N/mm2) | Percentage decrease of Split tensile Strength (%) |
| | | Natural aggregate | Bagasse ash aggregate | | | |
| 1 | D0 | 100 | 0 | 289.7 | 4.10 | 0.00 |
| 2 | D1 | 75 | 25 | 275.7 | 3.90 | 4.83 |
| 3 | D2 | 50 | 50 | 183.7 | 2.60 | 36.59 |
| 4 | D3 | 25 | 75 | 158.3 | 2.24 | 45.34 |
| 5 | D4 | 0 | 100 | 149 | 2.11 | 48.56 |

**6.3 Flexural Strength for Beams**

Flexural strength is one measure of the tensile strength of the concrete. It is a measure of an unreinforced concrete beam to resist failure in bending. The flexural strength test was done by standard test method of two-point loading. In this study, three beams of size 100x100x500 mm were used to find the flexural strength. The flexural strength results are tabulated in table 5 and the values are presented in figure 3 in graphical form

**Table 5: Beam Flexural Strength Results.**

| BEAM FLEXURAL STRENGTH | | | | | | |
|---|---|---|---|---|---|---|
| S. No | Name of the mix | Percentage volume replacement of coarse aggregate (%) | | Ultimate load(KN) | Beam Flexural Strength in ($N/mm^2$) | Percentage decrease of Flexural Strength (%) |
| | | Natural aggregate | Bagasse ash aggregate | | | |
| 1 | D0 | 100 | 0 | 11.625 | 4.6499 | 0.00 |
| 2 | D1 | 75 | 25 | 11.309 | 4.5234 | 2.72 |
| 3 | D2 | 50 | 50 | 10.254 | 4.1016 | 11.79 |
| 4 | D3 | 25 | 75 | 91.993 | 3.6797 | 20.86 |
| 5 | D4 | 0 | 100 | 7.722 | 3.0892 | 33.57 |

**6.4 Impact Strength for Impact Discs**

In this study impact strength of concrete is indicating with the number of impact blows. Impact testing machine consists of iron casing to hold the specimen, steel round ball and hammer with a weight of 2.5 kg . With the use of hammer the blows are given to concrete specimen until the specimen fails. The number of blow is counted in this experiment. The impact test values are tabulated in table 6 and the values are graphically presented in figure 4.

**Table 6: Impact Discs test Results.**

| IMPACT TEST | | | | | |
|---|---|---|---|---|---|
| S. No | Name of the mix | Percentage volume replacement of coarse aggregate (%) | | Number of Impact blows | Percentage increase or decrease in number of blows |
| | | Natural aggregate | Bagasse ash aggregate | | |
| 1 | D0 | 100 | 0 | 663 | 0 |
| 2 | D1 | 75 | 25 | 574 | 13.42 |
| 3 | D2 | 50 | 50 | 472 | 28.81 |
| 4 | D3 | 25 | 75 | 421 | 36.50 |
| 5 | D4 | 0 | 100 | 324 | 51.13 |

**6.5 Mode II fracture test:** For testing DCN specimens of size 150x150x150mm, notches were introduced at one third portion centrally during casting. The Mode II fracture test on the DCN cubes was conducted on 3000KN digital compression testing machine. Test results are shown in table 7 and presented graphically vide in figure 5. Uniformly distributed load was applied over the central one third part between the notches and steel supports of square cross section were provided at bottom along the outer edges of the notches, so that the central portion could get punched/ sheared through along the notches on the application of loading. The test setup and loading pattern is presented in plate 1.

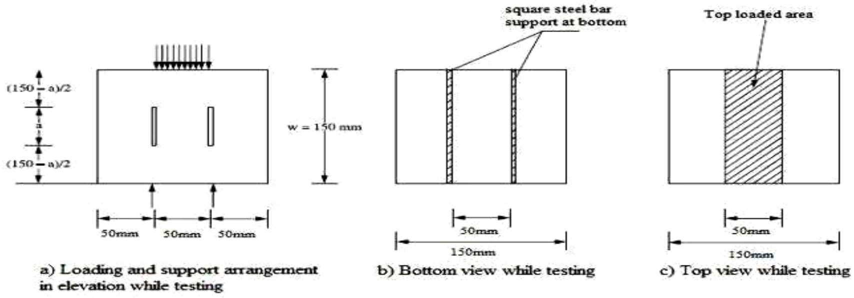


**Plate1. Loading Diagram of DCN specimens**

**Table 7: Ultimate loads in Mode -II fracture test Results**

| **Ultimate loads in Mode -II fracture test** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| S. No | Name of the mix | % Volume replacement of Bagasse ash pellets | a/w=0.3 | | a/w=0.4 | | a/w=0.5 | | a/w=0.6 | |
| | | | Ultimate Load in KN | %increase or decrease of ultimate load | Ultimate Load in KN | %increase or decrease of ultimate load | Ultimate Load in KN | %increase or decrease of ultimate load | Ultimate Load in KN | %increase or decrease of ultimate load |
| 1 | D0 | 0 | 140 | 0.000 | 127 | 0.000 | 116 | 0.000 | 102 | 0.000 |
| 2 | D1 | 25 | 103 | 26.190 | 102 | 19.948 | 97 | 16.427 | 84 | 17.647 |
| 3 | D2 | 50 | 89 | 36.190 | 86 | 32.546 | 84 | 27.378 | 76 | 25.490 |
| 4 | D3 | 75 | 82 | 41.667 | 76 | 40.157 | 69 | 40.634 | 61 | 39.869 |
| 5 | D4 | 100 | 78 | 44.286 | 72 | 43.307 | 67 | 42.315 | 53 | 48.039 |

**In-Plane shear strength:** The in plane strength of modified concrete was calculated using the formula

In plane shear strength = P/2*d(d-a) N/mm2
Where P= Ultimate load in mode-II shear
d= size of the cube = 150mm
a= depth of notch in mm

The values of In-plane shear strength of modified concrete for various a/w ratios in mode-II shear are presented in Table 8 and values are presented graphically in figure 6 and figure 7.

**Table 8: In Plane Shear Stress and Percentage Increase or Decrease of In Plane Shear Results**

| **In plane shear stress and percentage increase or decrease of in plane shear** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| S. No | Name of the mix | % Volume replacement of Bagasse ash pellets | a/w=0.3 | | a/w=0.4 | | a/w=0.5 | | a/w=0.6 | |
| | | | In plane shear stress in $N/mm^2$ | % decrease of In plane shear stress | In plane shear stress in $N/mm^2$ | % decrease of In plane shear stress | In plane shear stress in $N/mm^2$ | % decrease of In plane shear stress | In plane shear stress in $N/mm^2$ | % decrease of In plane shear stress |
| 1 | D0 | 0 | 4.444 | 0.000 | 4.704 | 0.000 | 5.141 | 0.000 | 5.667 | 0.000 |
| 2 | D1 | 25 | 3.280 | 26.190 | 3.765 | 19.948 | 4.296 | 16.427 | 4.667 | 17.647 |
| 3 | D2 | 50 | 2.836 | 36.190 | 3.173 | 32.546 | 3.733 | 27.378 | 4.222 | 25.490 |
| 4 | D3 | 75 | 2.593 | 41.667 | 2.815 | 40.157 | 3.052 | 40.634 | 3.407 | 39.869 |
| 5 | D4 | 100 | 2.476 | 44.286 | 2.667 | 43.307 | 2.965 | 42.315 | 2.944 | 48.039 |

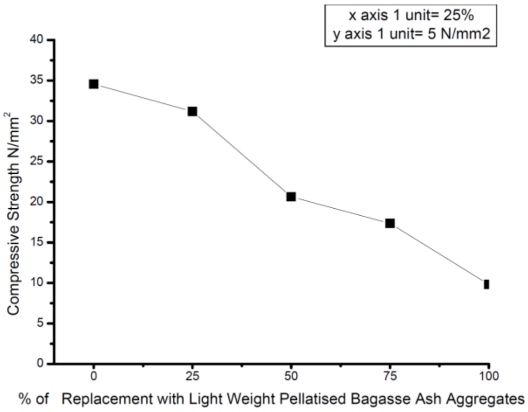


**Figure 1. Compressive strength of cube**

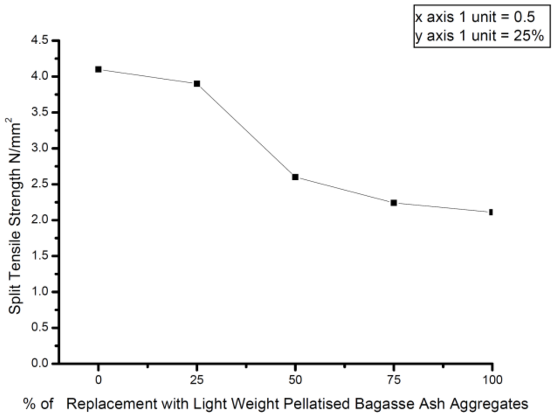


**Figure 2. Spilt tensile strength of cylinder**

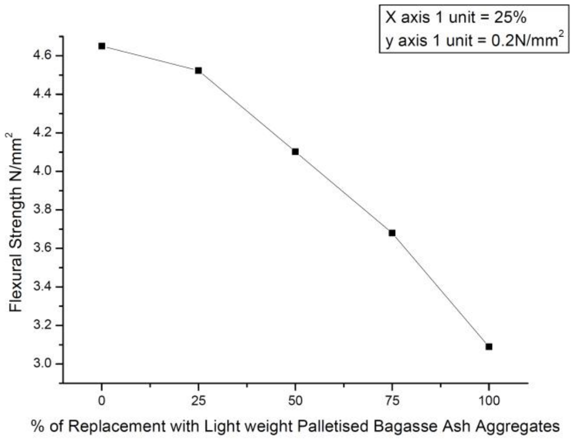


**Figure 3. Flexural strength of beam**

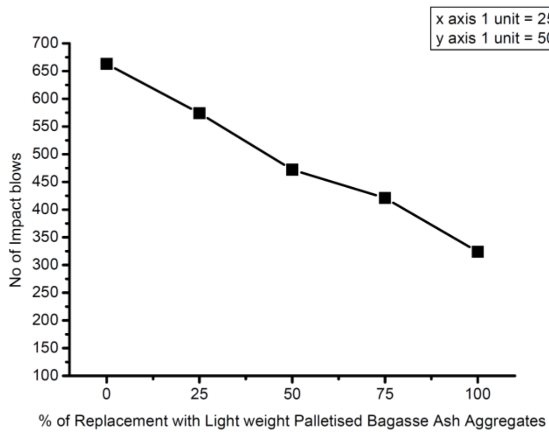


**Figure 4. No.of Impact blows for impact discs**

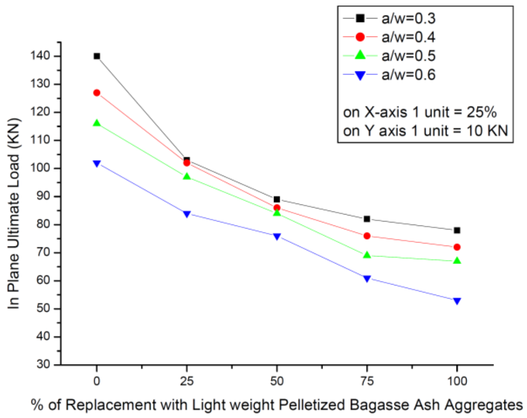


**Figure 5. Superimposed loads for different a/w ratios**

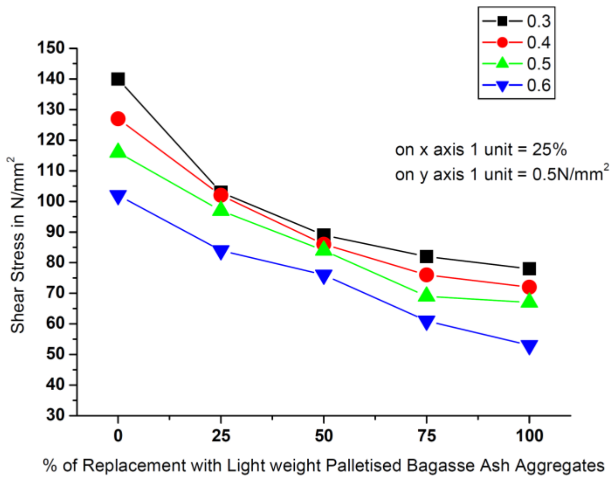


**Figure 6. Inplane shear stress for different a/w ratios**

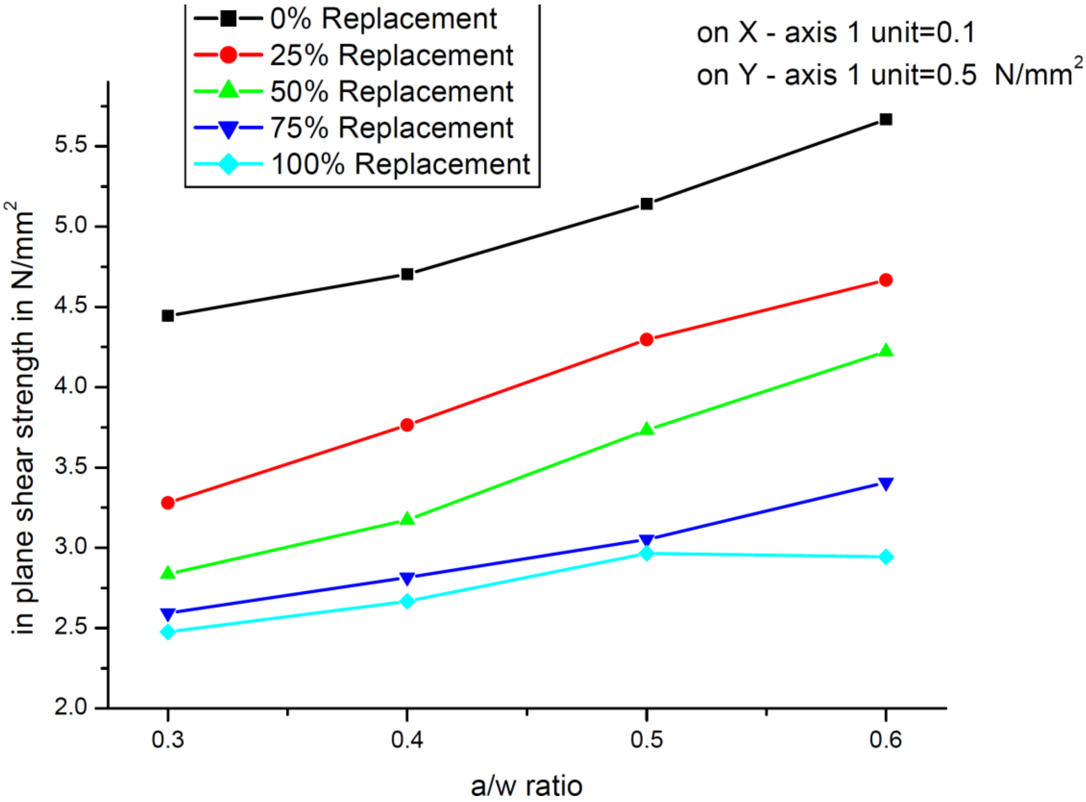


**Figure 7. In-plane Shear strength**

## 7. Discussion on test results

### 7.1 Influence of bagasse ash aggregates on compressive strength of cube

The cube compressive strength versus percentage replacement of natural aggregate with bagasse ash aggregate for 28 days curing period are shown in figure 1. It is observed that with the replacement of bagasse ash aggregate the cube compressive strength decreases continuously up to 100%. The target mean strength of $M_{25}$ concrete i.e., 31.6 N/mm$^2$ has been achieved even when the natural aggregate is replaced with 25% bagasse ash aggregate as tabulated in table 3 i.e., 31.63 N/mm$^2$. From figure 1 it is observed that as the percentage of bagasse ash aggregates increases from 0 to 100 % the cube compressive strength decreases from 34.55 to 9.82 N/mm$^2$.

### 7.2 Influence of bagasse ash aggregates on split tensile strength of cylinder

The cylinder split tensile strength versus percentage replacement of natural aggregate with bagasse ash aggregate for 28 days curing period are shown in figure 2. It can be noticed that the split tensile strength of cylinder decreases from 0% to 100% replacement of bagasse ash aggregates. From table 4 it is observed that as the percentage of bagasse ash aggregates increases from 0 to 100 % the cylinder split strength decreases from 4.10 to 2.11 N/mm$^2$. However even with 25% replacement the strength decrease is only 4.83%. Hence the 25% replacement is the acceptable replacement.

### 7.3 Influence of bagasse ash aggregates on flexural strength of beam

The beam flexural strength versus percentage replacement of natural aggregate with bagasse ash aggregate for 28 days curing period are shown in figure 3. It can be noticed that the flexural strength of beam decreased continuously from 0% to 100% replacement of bagasse ash aggregates. From table 5 it is observed that as the percentage of bagasse ash aggregates increases from 0 to 100 % the beam flexural strength decreases from 4.65 to 3.09 N/mm$^2$. At 25 % replacement flexural strength decreases is 2.72% only and so it is the suggestible percentage of replacement.

### 7.4 Influence of bagasse ash aggregates on impact strength of discs

The number of impact blows versus percentage replacement of natural aggregate with bagasse ash aggregate for 28 days curing period are shown in figure 4. It can be noticed that the number of impact blows for specimens decreased continuously from 0% to 100% replacement of bagasse ash aggregates. From table 6 it is observed that as the percentage of bagasse ash aggregates increases from 0 to 100 % the number of impact blowa decreases from 663 to 324.

### 7.5 Influence of bagasse ash aggregates on in plane shear strength

All the DCN(double central notched) specimens with different a/w ratios i.e 0.3, 0.4, 0.5 and 0.6 and with different percentages of bagasse ash aggregates were tested with load in Mode-II (in plane shear). The variations of ultimate loads and percentage increase or decrease in ultimate loads verses percentage replacement of normal coarse aggregate with bagasse ash aggregate are presented in table 7 and 8 which are presented for different a/w ratios after 28 days of curing. The values are decreased from 0% to 100% replacement of bagasse ash aggregate as shown in figure 5,6 and 7. Even the in plane shear strengths with 25% replacement show nominal decrease. Hence 25% replacement may be an acceptable replacement.

## 8. CONCLUSIONS

- From the experimental investigation, it is observed that the production of structural light weight aggregate concrete from light weight pelletized bagasse ash aggregate is possible.
- Bagasse ash aggregates are lighter and porous in nature; having bulk density is lesser than that for conventional aggregate and hence it is light weight aggregate.
- Light weight pelletized bagasse ash aggregates are spherical in shape and hence it improves the workability of concrete with lesser water content when compared to conventional concrete.
- From this study, it is concluded that compressive strength, split tensile strength, flexural strength, impact strength, in plane shear stress decreased continuously with the increasing bagasse ash aggregate content in concrete.
- Most of strength parameters studied in this investigations show that with 25% of replacement the decrease in strength properties is nominal and this percentage gives acceptable results (decreasing self weight with improving the structural property). Hence 25% replacement is the acceptable replacement.
- Since bagasse ash aggregates shows results comparable with natural coarse aggregate, as the natural aggregate is in the depletion, bagasse ash aggregates can be considered as replacement material for coarse aggregate.

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