# Strength characteristics of Quaternary Mix Concrete

**P. Bhuvaneshwari, T.Pavaleesh**

***Abstract***: ***By handling the cement, bagasse ash, silica fume and metakaolin as partial replacement of cement of cement a quaternary mix concrete could be achieved. Various percentages of replaced materials were considered for analysis. These three different materials consist of high amount of alumina ion and silica percentage. Use of these materials enhances the microstructure of concrete and helps to attain less permeable concrete. Physical and chemical properties of materials analyzed, and partially replaced with cement in different proportions such as HSC [5B, 10B, 15B, 20B] and HSC [5S, 10S, 15S, 20S] and HSC [5M, 10M]. The cubes of [100mm x 100mm x 100 mm] size were cast and tested. After confirming the characteristic compressive strength from cubes, optimum values (HSC 10B, HSC 15S and HSC 5M) has been taken. These values have been mixed up into three propositions (QBSM1, QBSM2 and QBSM3). Compressive strength results show that optimum percentage was found to be QBSM2 (10% SCBA+ 10% SF + 5% MK).***

## I. INTRODUCTION

### *1.1 General*

Cement (OPC) is a major construction and binding material globally. Earlier studies have been concentrated on bagasse ashes, silica fume and metakaolin to study their cementitious properties and their suitability as cementitious binders. The eligibility of using sugarcane bagasse ash as a mineral admixture in the production of Ultra High strength concrete (UHSC) was studied elobaretly[1]. The properties of concrete with mineral admixture in terms of compressive strength, heat of hydration, drying shrinkage and durability was concentrated [2]. Investigation was carried out for the compressive strength and drying shrinkage properties of self-compacting concretes containing one, two and three types of mineral admixtures for partial replacement of cement. It was found that the drying shrinkage got decreased with the use of fly ash, granulated blast furnace slag, and metakaolin [3].Mechanical and durable properties with different replacement levels of cement with silica fume and metakaolin was concentrated. It was reported that increases in strength and durability performance of blended cement was noted [4]. Similar studies were carried out in earlier research for quantifying the performance of blended cement in different conditions [5,6,7,8].

### *1.2 Research significance*

Nearly tons of $CO_2$ is released from every cement manufacturing industry which is very harmful to environment since it is a major source of greenhouse gases which cause global warming. From the earlier studies it was concluded that SCBA, silica fume and metakaolin could be effectively used for replacing the cement in percentages.

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These paper aims for combining the mineral admixture to form quaternary mix concrete to give high ultimate compressive strength than normal concrete mix of grade M60. The effective combination of mineral admixtures for partial replacement of cement to achieve a quaternary mix was concentrated.

## I. METHODOLOGY

### *2.1 METHODOLOGY*

Mix proportion arrived for M60 concrete was 1:1.14: 2.37 with W/C ratio 0.25[9]. Total 72 specimens of cube (100 mm x 100 mm x 100 mm) were cast for checking the compressive strength. Prior to curing the cubes were tested till failure Compression Testing Machine (CTM) of 3000 kN capacity. For all the combinations the beam specimens (1200 mm x 100 mm x 150 mm) were cast to test for stress-strain characteristics.

**Fig 2 Compressive test on specimens**

**Table 1 Different mix propositions for replacement material**

| S.No | Mix ID | Cement | Mineral admixtures | Fine agg. | Coarse agg | W/B ratio |
|---|---|---|---|---|---|---|
| 1. | HSC 5B | 475 | 21.3 | 550 | 1025 | 0.25 |
| 2. | HSC 10B | 450 | 42.67 | 550 | 1025 | 0.25 |
| 3. | HSC 15B | 425 | 64.01 | 550 | 1025 | 0.25 |
| 4. | HSC 20B | 400 | 85.35 | 550 | 1025 | 0.25 |
| 5. | HSC 5S | 475 | 17.99 | 550 | 1025 | 0.25 |
| 6. | HSC 10S | 450 | 35.85 | 550 | 1025 | 0.25 |
| 7. | HSC 15S | 425 | 53.74 | 550 | 1025 | 0.25 |
| 8. | HSC 20S | 400 | 71.65 | 550 | 1025 | 0.25 |
| 9. | HSC 5M | 475 | 18.31 | 550 | 1025 | 0.25 |
| 10. | HSC 10M | 450 | 36.65 | 550 | 1025 | 0.25 |

## II. MATERIALS USED

### 3. Materials and Methods

Ordinary Portland cement of grade 53, Potable water, M-sand, coarse aggregates. Sugarcane bagasse ash, silica fume and metakaolin were used as constituents of concrete as a partial replacement of cement.

#### *3.1 Cement*

Ordinary Portland cement of grade 53 procured from local suppliers was used for the investigation. The cement being a binder material helps to bind the fine and coarse aggregate together and also filling the voids between aggregates. Cement had a specific gravity of 3.1 with consistency 31% and setting time as 32 minutes [9].

#### *3.2 Fine aggregate*

Locally procured sand has been used as fine aggregate. The fineness modulus was 2.65, confirming to zone-II as per IS: 383-1970. [10]

#### *3.3 Coarse aggregate*

Coarse aggregate of size 20mm were collected from local quarries.The aggregates have been tested as per IS: 2386 (part 1)-1963[11] and surface quality description of the aggregate are classified as per IS: 383-1970 [10].

#### *3.4 Sugarcane bagasse ash*

The sugarcane bagasse ash is a waste material which is being used as a biofuel and also in the production of pulp and building materials**.** The bagasse and ash are as shown in Fig 3(a) and 3(b) respectively.

**Fig 3(a) Bagasse**

**Fig 3(b) Bagasse ash**

The extraction of bagasse ash from bagasse (treatment at 500$^{o}$C) is shown in the above Figures 3(a) and 3(b). Bagasse is burnt around 500$^{o}$C in a controlled process to use its maximum fuel value. EID parry India ltd, located in the city of Nellikuppam (Cuddalore), Tamilnadu. The various chemical composition of bagasse is listed in the following Table 2.

**Table 2 Chemical Composition of Bagasse ash**

| S.NO | Composition | Mass (%) |
|---|---|---|
| 1 | Silicon Dioxide($SiO_2$) | 78.34 |
| 2 | Aluminium ($Al_2$) | 8.55 |
| 3 | Ferrous Oxide($Fe_2O$) | 3.23 |
| 4 | Potassium Oxide($K_2O$) | 3.46 |

#### *3.5 Silica fume*

The amorphous polymorph of silicon dioxide is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production. The shape of the particles is spherical with average diameter of 150 nm. The composition is as shown in Table 3.

**Table 3 Chemical Composition of Silica Fume**

| Chemical composition | Percentage | | |
|---|---|---|---|
| | Portland | Silicious | Calcareous |
| SiO2 | 21.9 | 52 | 35 |
| $Al_2O_3$ | 6.9 | 23 | 18 |
| $Fe_2O_3$ | 3 | 11 | 6 |
| CaO | 63 | 5 | 21 |

#### *3.6 Metakaolin*

The material from calcination of kaolinite. The particle size of metakaolin is less compared to cement particles, but not finer than silica fume.The chemical composition is shown in Table 4.

**Table 4 Chemical Composition of Metakaolin**

| CHEMICAL COMPOSISTION | PERCENTAGE |
|---|---|
| SILICA (SI02) | 54.3 |
| ALUMINA (AL2O3) | 38.3 |
| FERRIC OXIDE (FE2O3) | 42.8 |

## III. EXPERIMENT AND TEST RESULTS

### 4. Results and Discussion

Conventional concrete was partially replaced for cement with sugarcane bagasse ash, silica fume and metakaolin. Strength and durability characteristics of quaternary mix concrete are compared.

#### *4.1 Fresh concrete properties*

#### *4.1.1 Slump Cone Test*

Slump cone test has been carried out to check the workability of concrete mixes. The slump value for different mixes is as shown in the following Table 5.

**Table 5 Slump value for different mix**

| S.NO | Content | Slump value (mm) |
|---|---|---|
| 1 | 0% (CC) | 50 |
| 2 | 5% (HSC 5B,HSC5S,HSB5M) | 85-90 |
| 3 | 10% (HSC 10B,HSC10S,HSB10M) | 95-100 |
| 4 | 15% (HSC 15B,HSC15S) | 120-125 |
| 5 | 20% (HSC 20B,HSC20S) | 128-130 |

From the above result, it was found that increase in percentage of bagasse ash, silica fume and metakaolin increases the workability.

#### *4.2 Hardened concrete properties*

The characteristic compressive strength was checked for the different mixes (HSC5B, HSC10B, HSC15B, HSC20B, HSC5S, HSC10S, HSC15S, HSC20S, HSC5M, HSC10M) by conducting compression test in CTM of 300 kN capacity. The quaternary mix was fixed based on the optimum percentage of all the above mentioned combinations.

#### *4.2.1Compressive strengths*

The compressive strength of different mixes are given in Table 6 and comparison is carried out in Figure 4. Even though the replacement resulted in decrease in target strength, the values were confirming with the characteristic strength.

**Table 6 Compressive strengths of conventional and quaternary mix concrete [10]**

| Type of concrete | % of replacement | Average Compressive strength($N/mm^2$) | | |
|---|---|---|---|---|
| **HSC 5B, 5S, 5M** | 5 | 51.3(B) | 34.17(S) | 50.8(M) |
| **HSC 10B, 10S, 10M** | 10 | 67.8(B) | 34.90(S) | 49.90(M) |
| **HSC 15B, 15S** | 15 | 47.50(B) | 57.02(S) | |
| **HHSC 20B, 20S** | 20 | 39(B) | 50.6(S) | |

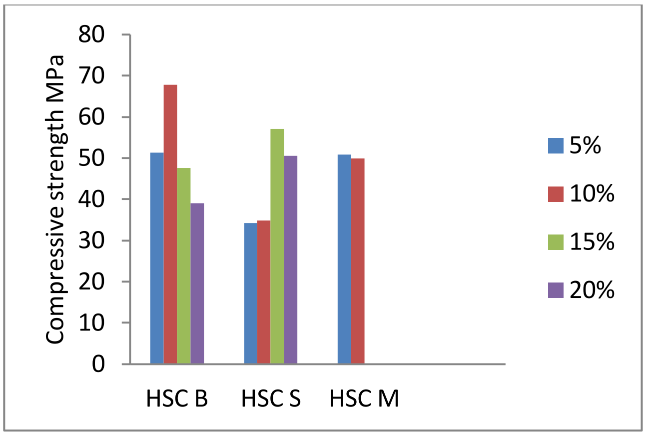


**Fig. 4 Comparison of compressive strength of different mixes**

The comparison shows that the values were higher for mix with 10% SCBA, 15% Silica fume and 5% metakaolin .The similar percentages were fixed for the optimum quaternary mix.

#### 4.2.2 **Compressive Strength for optimum mix**

The optimum composition were arrived with the combinations of mineral admixtures as follows
i) 5% SCBA+ 10% SF + 5% MK (**QBSM1**)
ii) 10% SCBA + 10% SF + 5% MK (**QBSM2**)
iii) 10% SCBA + 15% SF + 5% MK (**QBSM3**).Cube specimens were cast and moist cured for 28 days. Cured specimens were subjected to compressive loading and the compressive strength was calculated. The values are as shown in Table 7.

**Table 7. Compressive strength values for optimum mixes**

| S.No | Mix ID | Failure load (kN) | Compressive strength ($kN/m^2$) |
|---|---|---|---|
| 1. | QBSM 1 | 437 | 43.7 |
| 2. | QBSM 2 | 526 | 52.6 |
| 3. | QBSM 3 | 490 | 49.00 |

Among the three different mixes, QBSM 2 mix was found to give confirming strength. The same mix was adopted to cast specimens for durability studies to check the permeability of the dense concrete mix.

## IV. CONCLUSION

The strength obtained for concrete cubes specimens with partial replacement of sugarcane bagasse ash, silica fume and metakaolin in different percentages were studied. Results were compared and following conclusions are arrived:

- Partial replacement of cement with 10% sugarcane bagasse ash (HSC10B), 15% silica fume (HSC15S)and 5% metakaolin (HSC5M) in plain cement concrete increases its strength under compression.
- The increase of replacement percentage to 15% sugarcane bagasse ash (HSC15B), 20% silica fume (HSC20S) and 10% metakaolin (HSC10M) decreased the compressive strength characteristics.
- . This may be due to the fact that the quantity of pozzolonic silica content in the mix is higher than the amount required to combine with excess lime, during the process of hydration. This may be the reason for leaching out of excess silica thus resulting in decreased strength characteristics.
- Among the specimens cast using the different combinations of optimum percentages of mineral admixtures (QBSM1,QBSM2 and QBSM3), the strength characteristics for QBSM2 was found to be confirming with the control concrete.Apart for achieving the strength the usage of cement was also brought down considerably.

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