# Performance Evaluation of Self-Compacting Concrete Using Bagasse Ash and Granine as Partial Replacement of Cement and Sand

S. Iqbal[1], M. Irshad,[2] S. Room[3], K. Mahmood[4], Q. Iqbal[5]

[1,3] University of Technology, Nowshera, Pakistan,
[2]CECOS University of IT and Emerging Sciences, Peshawar, Pakistan,
[4,5] Sarhad University of Science and IT, Peshawar, Pakistan

[1] shahid.iqbalmce@gmail.com

***Abstract-*** Concrete is a broadly used man-made construction material, consuming cement and natural aggregates. World is facing key environmental problems as industries produce large amount of wastes and some of them like cement industry, emit harmful gases such as carbon dioxide. Waste Bagasse ash (BA) is produced in sugar industry while waste marble and granite are generated during their crushing and cutting. As there are no proper disposal and control facilities available for these industrial wastes and end in land fill, these waste materials may be utilized in concrete as cement and aggregate substituents. Key objective of this study was to evaluate the effects of BA and granite sand (GS) as a partial substitute of cement and natural sand in self-compacting concrete (SCC). Reference mix was finalized for SCC using waste marble powder as filler material. 10 %, 15 %, and 20 % cement by mass was replaced by BA and GS as a substitute for natural sand at 10 %, 20 % and 30 % by mass. Workability, density and air content were tested for fresh concrete. Also, mechanical properties i.e. compressive, splitting tensile, flexural strength and modulus of elasticity were tested. Results indicated declining trend in the workability of concrete when BA and GA were incorporated into SCC while the mechanical properties improved. Thus, SCC with better mechanical properties can be produced by utilizing industrial waste materials as fractional substitutes of cement and sand which in turns will reduce negative impact on environment and utilization of natural materials in concrete production.

***Keywords-*** Self-compacting concrete (SCC); bagasse ash; granite sand; mechanical properties.

## I. Introduction

Self-compacting concrete (SCC) is highly workability concrete that can flow under its own weight, fill the formwork and encapsulate the reinforcement without any mechanical consolidation. It doesn't require vibration for compaction and can flow through narrow spaces without segregation and excessive bleeding [1]. Due to various competing features, SCC is widely used. Self-flow advantages of SCC over normal concrete are that it requires lesser effort for placing and compaction thereby lowering the value of required labor and construction time, thus eliminates the requirement of vibrator. SCC is usually produced by mixing binding materials like cement, filler materials (fly ash, micro silica, blast furnace slag etc.), coarse aggregates (CA), fine aggregates (FA), water and admixtures (superplastisizer). Cement production consumes energy and produces about 7 % of greenhouse gases, to counter this problem and utilize industrial leftovers, researchers have introduced production of green concrete by replacing cement with industrial by-products in concrete for eco-friendly and economic value purposes [2]. Rapid increase and advancement in urbanization and industrialization is facilitating the mankind but it has disadvantages in the form of pollution and solid waste production. Solid waste management and load on sanitary landfills is the main problem of Pakistan, at most of the disposal location proper solid waste management facilities are lacking and most of the sanitary landfills are non-engineered [3]. Aggregates occupy 60-70 % of the concrete volume; hence the concrete has the capacity to consume industrial by-products as fillers and replacement material in high quantity [4]. Some of the industrial by-products in Pakistan are BA, granite and marble waste. Marble and granite building material industries results in huge amount of waste during cutting and grinding process of marble and granite stones [5] while in sugar industry, bagasse is obtained by squeezing out extract from sugarcane which is then burnt for heat generation to run boilers [6]. There are approximately 70 sugar mills in Pakistan, the average generation of bagasse per year is about 14 million tons [7]. Ash of burnt bagasse in uncontrolled condition is called as BA which is non-reactive [8]. It is reported that Self-compacting Concrete (SCC) maintains ideal level of workability and shows better resistance to elevated temperature when cement is replaced by BA [9]. The characteristic of pozzolanic reaction in bagasse ash was observed when up to 10 % of cement was replaced by bagasse ash in production of cement mortar [10]. Showing pozzolanic behavior, replacement of up to 15 % of cement by bagasse ash showed equivalent mechanical properties to that of the reference concrete [11]. It has been reported that incorporation of BA in concrete shows decrease in workability because of its particles having more surface area and high porosity in comparison to cement [12]. Decrease in air content was observed by substituting untreated BA as fractional replacement with cement up to 10 % in mortar beyond which increase was observed in air content of the concrete mix, while optimum dosage in case of compressive strength was 20 % [13]. Portland fly ash cement Concrete containing BA show improved workability and durability with reduced cost [14]. Replacement of Portland cement by bagasse in the range of 0-60 % in pavement concrete exhibits good mechanical and durability properties [15]. Both the stone dust and BA (Burnt at 500 ºC) in size less than 0.074 mm was used as a 10 % cement replacement in concrete by BA and stone dust respectively, increase in compressive as well as in flexural strength have been reported [16]. Researchers used processed (burnt up to 400 ºC for one hour) and unprocessed BA as fractional substitution of cement in concrete, in which processed BA showed better mechanical properties than unprocessed BA while 25 % substitution was recorded optimum content [17]. It has been reported that strength and flow characteristics of SCC can be enhanced by adding BA in concrete while strength at 15% BA showed maximum increase [18, 19]. Another study reported that using BA as a fractional substitute of cement enhances mechanical properties of lightweight concrete, ordinary concrete and SCC[20].

The workability as well as mechanical properties of SCC improves when up to 40 % of natural sand is replaced by granite cutting waste [21]. Marble dust consists of calcium carbonate (CaCO3) and silica (SiO2) due to which it helps in formation of secondary strength hydrates improving mechanical characteristics of concrete [22]. Marble waste in terms of binder showed more positive effect on conventional concrete as compared to SCC whereas, it improves flow properties of SCC significantly [23]. Marble dust and lime stone used as filler in higher quantities slightly affect the fresh properties of SCC but its mechanical and transportation properties can be improved [24]. It is reported that compressive strength of cement mortar improved with 10 % substitution of cement by marble dust without effecting the setting time and expansion of cement [25]. Concrete containing waste granite dust cement replacement shows better durability properties [26]. In another study, when natural sand is replaced by waste granite powder and cement was replaced by glass powder, the resulting concrete showed better durability properties [27]. A study showed that up to 15 % granite powder replacement of FA increases compressive and flexural strength, beyond which both workability and strength decreases [28]. GS used as FA up to 25% replacement of natural sand showed almost similar workability as of control mix while density decreased and compressive strength increased at 30 % addition of GS [29, 30]. Similarly another study showed that at 10% substitution of FA by GS almost comparable slump and highest compressive and splitting tensile strength was obtained compared to control mix while at 20 % replacement almost similar strength to that of control mix was noted [31]. Addition of granite stone dust as FA in concrete causes decrease in workability, rise in compressive, splitting tensile and flexural strength [32]. Therefore, industrial wastes like marble powder, BA and GS may be used as fillers in combination with cement replacement and FA replacement for the manufacturing of SCC. Thus, maximizing the use of waste materials in SCC production resulting in reduced environmental impact and scarcity of natural resources.

## II. OBJECTIVES

Following are the objectives of this study:

- To replace cement by bagasse ash and fine aggregate by granite sand for production of self-compacting concrete and investigate the effect of this partial replacement on fresh properties of resulting SCC mix i.e. flow characteristics, fresh state concrete density and concrete air content.
- To investigate the effect of varying proportion of cement and fine aggregate replacement by bagasse ash and granite sand on the mechanical properties of the produced self-compacting concrete which include compressive strength, splitting tensile strength, flexural strength and modulus of elasticity.

## III. MATERIALS AND METHODS

### *3.1. Materials*

#### *3.1.1. Ordinary Portland Cement*

In this investigation type-I grade 53 ordinary Portland cement (OPC) as per ASTM C150 [33] was used. Chemical composition of cement is represented in Table I.

#### *3.1.2. Water and Superplasticizer*

For concrete mixing and curing, potable water as per guidelines ASTM C192/C192M [34] was used in this investigation while for enhancement of workability, sika viscocreate (3110) high range water reducer having density of 1.085 kg/m3 at 25 ºC was used.

#### *3.1.3. Bagasse Ash*

BA procured from local source, Khazana Sugar mill Peshawar was used as partial replacement of cement.

It was burnt under control temperature up to 700 ºC for one hour in the laboratory of Pakistan Council of Scientific and Industrial Research (PCSIR). It was grinded in the same laboratory to the average particle size of OPC. Chemical composition of BA determined in the laboratory are stated in Table I.

*3.1.4. Marble Powder*

To fulfill the demand of filler materials in SCC, Marble powder (MP) was use. It was collected from locally available marble dressing factory situated in Peshawar after which it was sieved in the laboratory to collect marble powder having maximum particle size of 0.125 mm. Chemical composition of MP is given in Table I.

Table I. Chemical composition of cement, BA and MP

| Chemical constituents | Cement (%) | Bagasse ash (%) | Marble powder (%) |
|---|---|---|---|
| SiO2 | 20.7 | 79.71 | 0.63 |
| CaO | 63.5 | 3.57 | 54.6 |
| Al2O3 | 5.64 | 4.26 | 0.42 |
| Fe2O3 | 3.67 | 2.63 | 0.21 |
| MgO | 0.05 | 0.85 | 0.53 |
| SO3 | 2.84 | 0.11 | 0.02 |
| K2O | 1.05 | 0.84 | 0.04 |
| Na2O | 0.34 | 0.95 | 0.05 |
| LOI | 2.21 | 7.08 | 43.5 |

*3.1.5. Aggregates*

For mix preparation FA and CA were collected from locally available sources while GS was obtained from nearby crushing plant of granite. FA of fineness modulus 2.76 and GS less than 4.75 mm in size was used while CA up to 16 mm in size was used. Physical properties of natural FA, GS, and CA are given in Table-II.

Table II. Physical properties of aggregates

| Materials | Size Range (mm) | Specific Gravity | Water Absorption (%) |
|---|---|---|---|
| FA | 0 - 4.75 | 2.87 | 0.82 |
| GS | 0 - 4.75 | 2.78 | 0.84 |
| CA | 4.75 - 16 | 2.66 | 0.81 |

*3.2. Methodology*

For making SCC mixture, after successive trials 28 days targeted compressive strength of 25 MPa and 650 mm slump flow value were achieved. After finalization of reference concrete mix for SCC, cement was partly substituted by BA at the levels of 10 %, 15 % and 20 % by weight of cement, similarly the FA was partially substituted by GS at 10 %, 20 % and 30 % by weight. Marble stone powder was used as filler material for all the mixes with equal proportions. Fresh and mechanical characteristics of concrete were investigated. Fresh SCC properties included workability, concrete density and air content. Workability was assessed through slump flow, V-funnel, L-box and J-Ring tests. Whereas for finding air content and density of SCC concrete ASTM C138/C138M [35] procedure was adopted. Mechanical properties included modulus of elasticity, compressive, splitting tensile, flexural strength tests. All types of concrete mixes were prepared and moist cured in a tank full of water. For compressive strength test total 90 cylinders (75 mm×150 mm), three for every mix type were prepared and tested according to ASTM C39/C39M guidelines [36] after 14, 28 and 56 days. For splitting tensile strength test total 60 cylinders (75 mm×150 mm), three for each mix type were prepared and tested as per ASTM C496/C496M guidelines [37] at 28 and 56 days of curing. Similarly for modulus of elasticity test total 30 cylinders (75 mm×150 mm), three for every mix type were prepared and tested according to ASTM C469/C469M [38] at 56 days of curing only. For flexural test 60 prisms, three for each mix type having dimensions of 100 mm x100 mm x350 mm were casted and tested in accordance with ASTM C78/C78M [39] at 28 and 56 days of curing.

## IV. RESULT AND DISCUSSION

*4.1 Concrete Mix design*

Mix proportions of all types of concrete mixes used in this research work are summarized in Table III.

Table III. Composition of concrete mixes.

| Mix Label | Cement (kg/m³) | BA (kg/m³) | FA (kg/m³) | GS (kg/m³) | CA (kg/m³) | MP (kg/m³) | Water (kg/m³) | $V_w/V_p$ | S.P (kg/m³) |
|---|---|---|---|---|---|---|---|---|---|
| B0G0 | 460 | 0 | 905.5 | 0 | 755.25 | 110 | 179.40 | 0.94 | 4.6 |
| B10G10 | 414 | 46 | 814.95 | 90.55 | 755.25 | 110 | 179.40 | 0.94 | 4.6 |
| B10G20 | 414 | 46 | 724.4 | 181.1 | 755.25 | 110 | 179.40 | 0.94 | 4.6 |
| B10G30 | 414 | 46 | 633.85 | 271.65 | 755.25 | 110 | 179.40 | 0.94 | 4.6 |
| B15G10 | 391 | 69 | 814.95 | 90.55 | 755.25 | 110 | 179.40 | 0.94 | 4.6 |
| B15G20 | 391 | 69 | 724.4 | 181.1 | 755.25 | 110 | 179.40 | 0.94 | 4.6 |
| B15G30 | 391 | 69 | 633.85 | 271.65 | 755.25 | 110 | 179.40 | 0.94 | 4.6 |
| B20G10 | 368 | 92 | 814.95 | 90.55 | 755.25 | 110 | 179.40 | 0.94 | 4.6 |
| B20G20 | 368 | 92 | 724.4 | 181.1 | 755.25 | 110 | 179.40 | 0.94 | 4.6 |
| B20G30 | 368 | 92 | 633.85 | 271.65 | 755.25 | 110 | 179.40 | 0.94 | 4.6 |

Table IV. Fresh SCC properties

| Mix Label | Slump Flow (mm) | V-Funnel (sec) | L-Box Value | J-Ring Flow (mm) | Density (kg/m3) | Air content (%) |
|---|---|---|---|---|---|---|
| B0G0 | 730 | 7 | 1.0 | 722 | 2352.23 | 2.58 |
| B10G10 | 720 | 8 | 0.90 | 710 | 2347.39 | 2.78 |
| B10G20 | 698 | 8 | 0.86 | 686 | 2346.21 | 2.83 |
| B10G30 | 679 | 10 | 0.82 | 669 | 2344.67 | 2.90 |
| B15G10 | 702 | 8 | 0.87 | 692 | 2341.98 | 3.01 |
| B15G20 | 688 | 9 | 0.85 | 679 | 2338.32 | 3.16 |
| B15G30 | 678 | 10 | 0.82 | 668 | 2335.82 | 3.26 |
| B20G10 | 674 | 10 | 0.82 | 665 | 2339.82 | 3.10 |
| B20G20 | 668 | 10 | 0.81 | 657 | 2338.12 | 3.17 |
| B20G30 | 659 | 11 | 0.80 | 650 | 2336.73 | 3.23 |

Table V. SCC Hardened Properties Tests Results

| Mix Label | Compressive Strength ( MPa ) | | | Split Tensile Strength ( MPa ) | | Flexural Strength ( MPa ) | | MOE ( MPa ) |
|---|---|---|---|---|---|---|---|---|
| | *14-days* | *28-days* | *56-days* | *28-days* | *56-days* | *28-days* | *56-days* | *56-days* |
| B0G0 | 29.75 | 33.76 | 34.96 | 3.33 | 3.44 | 4.58 | 4.69 | 27984.69 |
| B10G10 | 33.12 | 36.82 | 38.13 | 3.59 | 3.69 | 4.86 | 4.97 | 29227.84 |
| B10G20 | 31.75 | 35.05 | 36.30 | 3.4 | 3.52 | 4.7 | 4.81 | 28617.93 |
| B10G30 | 30.37 | 33.58 | 34.77 | 3.38 | 3.48 | 4.57 | 4.67 | 27909.15 |
| B15G10 | 34.59 | 38.00 | 39.42 | 3.6 | 3.69 | 4.96 | 5.08 | 29818.08 |
| B15G20 | 32.86 | 35.87 | 37.19 | 3.51 | 3.62 | 4.7 | 4.84 | 28665.76 |
| B15G30 | 31.08 | 34.01 | 35.25 | 3.39 | 3.47 | 4.61 | 4.72 | 28204.11 |
| B20G10 | 32.87 | 35.99 | 37.50 | 3.52 | 3.64 | 4.78 | 4.92 | 28785.41 |
| B20G20 | 31.17 | 33.90 | 35.32 | 3.36 | 3.47 | 4.6 | 4.72 | 28328.81 |
| B20G30 | 29.43 | 32.07 | 33.38 | 3.22 | 3.36 | 4.43 | 4.55 | 27245.01 |

### *4.2 Fresh Properties of SCC*

For investigation of SCC fresh properties Slump flow, V-funnel value, L-box ratio, J-ring flow, fresh density and air content were determined as listed in Table IV. Results of fresh concrete properties obtained in the laboratory have been found within the ranges as per EFNARC. Values of slump flow decreased with incorporation of both BA and GS as replacement of cement and sand at all percentages. It may be because of the fact that BA particles are highly porous and has high surface area as compared to cement due to which it absorbs high water. Whereas the GS particles are rough

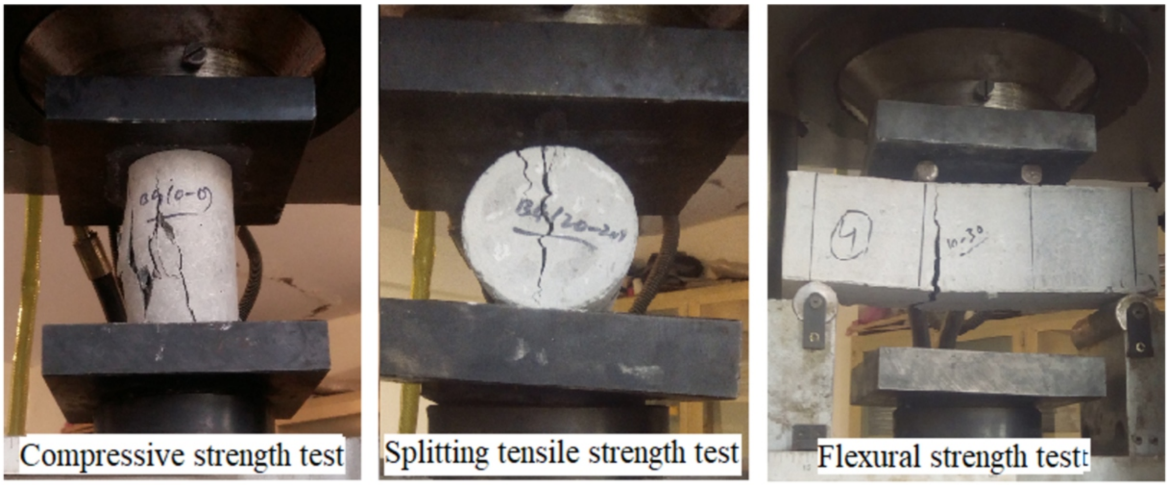


Fig. 1 Concrete strength tests arrangement.

and has sharp edges due to which it provides hindrance to the concrete flow. It has been observed that at ultimate replacement of both BA and GS in this study the slump flow decreased by 9.72 % as of control mix. Control mix has the maximum density as compared to all other mixes; decrease in density is due to the lesser relative density of BA and GS than cement and natural sand respectively.

*4.3 Hardened Properties of SCC*

The testing arrangement for compressive strength, splitting tensile strength and flexural strength tests are shown in Fig. 1. Compressive Strength.

SCC compression tests of all concrete mixes have been carried out at 14, 28 and 56 days of moist curing and outcomes are presented in Table V.

Compressive strength variations for 56 days are shown for all SCC mixtures in Fig. 2. Results depicts that concrete strength is increased with incorporation of both BA and GS, maximum rise in compressive strength was observed at 15 % BA as fractional replacement of cement in addition to 10 % GS as replacement of virgin sand and increase in compressive strength of 15 % was observed at 14 days of testing while 11.83% and 12% increase was observed on 28 and 56 days respectively as of control mix. This increase is expected because of water to binder ratio reduction and due to the formation of secondary calcium silicates hydrates as BA is a pazzolanic material.

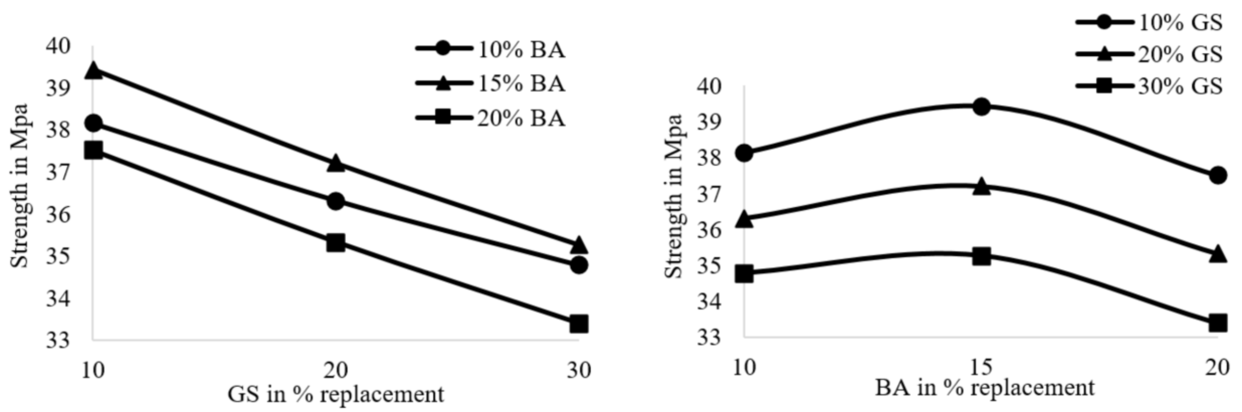


Fig. 2 Compressive strength variations at 56 days.

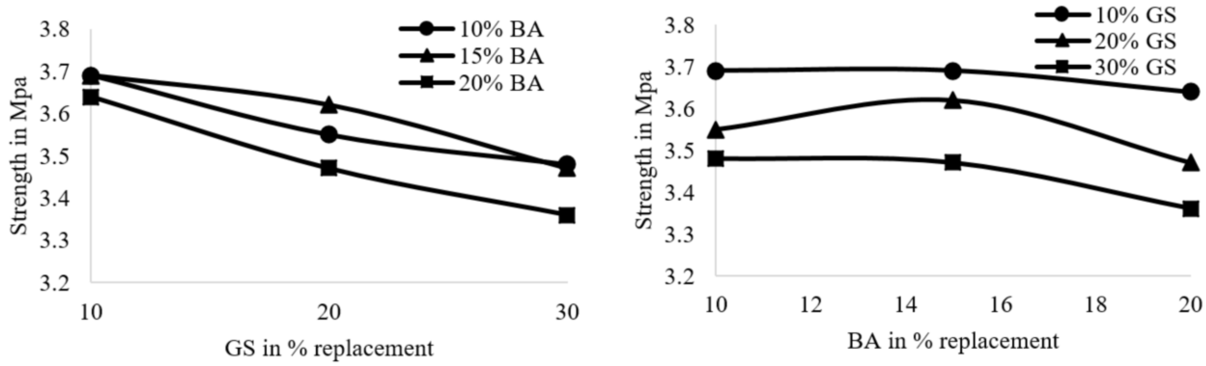


Fig. 3 Splitting tensile strength variation at 56 days.

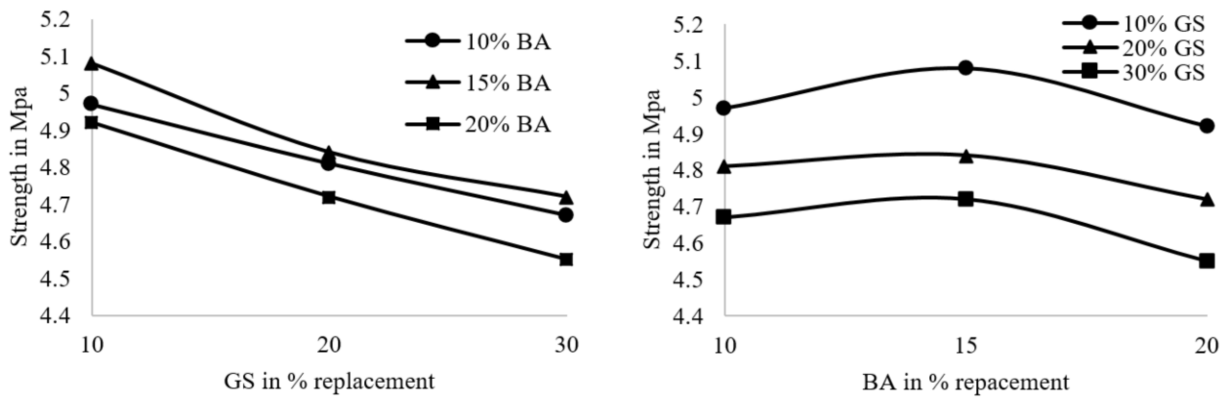


Fig. 4 Flexural strength variation at 56 days.

Lowest compressive strength values were obtained for concrete containing BA and GS as 20 % cement replacement and 30 % FA replacement respectively with compressive strength 1.08 % at 14 days, 5.13 % at 28 days and 4.62 % at 56 days lower than the reference mix.

*4.3.1 Splitting Tensile Strength*

Three cylinder-shaped samples having 75 mm diameter and 150 mm height have been tested for 28-days and 56-days of water curing. Split tension test results and its percentage variation are shown in Table V. Split tension strength variations at 56-days of testing are graphically represented in Fig. 3. Likewise, compression test results, maximum rise in split tension test at 28-days of testing was achieved at 15 % BA as cement fractional replacement and 10 % GS as fractional virgin sand replacement, while after 56-days almost similar rise in split tension strength was observed at both 15 % and 10 % BA as a cement substitute along with 10 % GS as a FA substitute by weight.

Enhancement in split tension strength occurs up to cement and FA replacement levels of 20 % by BA and GS respectively as compared to that of reference concrete mix. Using BA and GS above 20 % decreased the splitting tensile strength compared to reference mix. Results show that after 28-days of concrete curing there is no significant rise in the split tension strength of all concrete mixes.

*4.3.2 Flexural Strength*

Three prism samples for each type of concrete mix have been tested at the concrete age of 28-days and 56-days. Flexure strength test results and various percentage differences are shown in Table-V.

Flexure strength variations for 56-days are given for all SCC mixture in Fig. 4. Substituting BA as a cement and GS as a FA has shown enhancement in the flexure strength of all types of concrete mixes except B20G30. The optimum replacement B15G10 showed 7.96 % and 7.98 % increase in flexural strength at 28-days and 56-days of testing to that of control mix. With high amount of incorporation the flexural strength starts decreasing and at B20G20 the strength again becomes approximately equivalent to the strength of reference concrete mix.

The lowest flexure strength was noted for concrete mix B20G30 which is 3.32 % and 3.03 % lesser than the reference concrete mix strength at 28-days and 56-days respectively.

*4.3.3 Modulus of Elasticity*

This test was performed on specimens having different percentages of BA as fractional substitute of cement and GS as a fractional FA substitute. The tests were performed after 56-days of casting and results are presented in Table V.

Test results indicate that there is no major difference in the concrete modulus of elasticity when cement and sand is replaced by BA and GS. However, maximum value was observed for B15G10 with 6.34 % increase as compared to control concrete mix.

## V. Conclusions

From this research study using BA as fractional cement replacement and GS for natural sand in SCC, following are the key conclusions drawn from the experimental investigation:

1. Workability of SCC decreases when BA is added as fractional cement replacement and GS for natural sand, while there is no major impact on fresh concrete density and air content. Reduction in workability is expected to be because of GS coarse texture and higher porosity of BA.
2. Mechanical properties of concrete including compression, split tension strength and flexure strength improves with BA and GS incorporation into SCC as cement and sand replacement. The optimum content for the maximum increase was 15 % cement replacement by BA and 10 % FA replacement by GS.
3. There is no major impact in the modulus of elasticity of SCC when BA and GS replace cement and sand.
4. The waste materials like marble powder, BA and GS may effectively be used for the production of SCC exhibiting good workability and better mechanical properties. Thus, reducing negative environmental impact by utilizing waste products and reducing the production of harmful gases. Additionally, it reduces the scarcity of natural aggregates used in the production of SCC.

## References

[1] ACI Committee report 237R-07, Self-Consolidating Concrete. American Concrete Institute, 2007.

[2] M. S.-E. Imbabi, C. Carrigan and S. McKenna, "Trends and Developments in Green Cement and Concrete Technology," International Journal of Sustainable Built Environment, vol. 1, no. 2, pp. 194-216, 2012.

[3] A. Mahar, R. N. Malik, A. Qadir, T. Ahmed, Z. Khan and M. A. Khan, "Review and Analysis of Current Solid Waste Management Situation in Urban Areas of Pakistan," in Proceedings of the International Conference on Sustainable Solid Waste Management, 2007.

[4] M. S. Nadesan and P. Dinakar, "Mix design and Properties of Fly Ash Waste Lightweight Aggregates in Structural Lightweight Concrete," Case Studies in Construction Materials, vol. 7, pp. 336-347, 2017.

[5] H. Y. Aruntaş, G. Gürü, M. Dayı and İ. Tekin, "Utilization of Waste Marble Dust as an Additive in Cement Production," Materials & Design., vol. 31, no. 8, pp. 4039-4042, 2010.

[6] J. Payá, J. Monzo, M. V. Borrachero, L. D. Pinzón and L. M. Ordonez, "Sugar-cane Bagasse Ash (SCBA): Studies on its Properties for Reusing in Concrete Production," Journal of Chemical Technology and Biotechnology, vol. 77, no. 3, pp. 321-325, 2002.

[7] N. Amin, "Use of Bagasse Ash in Concrete and its Impact on the Strength and Chloride Resistivity," Journal of Materials in Civil Engineering., vol. 23, no. 5, pp. 717-720, 2010.

[8] N. Singh, D. D. V. Singh and S. Rai, "Hydration of Bagasse Ash-Blended Portland Cement," Cement and Concrete Research, vol. 30, no. 9, pp. 1485-1488, 2000.

[9] L.C.D.A. Mello, M.A.S.D. Anjos, M.V.V.A.D. Sa, N.S.L.D. Souza and E.C.D. Darias, "Effect of high temperatures on self-compacting concrete with high levels of sugar cane bagasse ash and metakoalin" Construction and Building Materials, vol. 248, 118715, 2020.

[10] S. Praveenkumar, G. Sankarasubramaniam and S. Sindhu, "Strength, permeability and microstructure characterization of pulverized bagasse ash in cement mortar" Construction and Building Materials, vol. 238, 117691, 2020.

[11] R.A. Berenguer, A.P.B. Capraro, M.H.F.D. Medeiros, A.M.P. Carneiro and R.A.D. Oliveira, "Sugar cane bagasse ash as a partial substitute of Portland cement: Effect on mechanical properties and emission of carbondioxide" Journal of Environmental Chemical Engineering, vol. 8(2), 103655, 2020.

[12] D.-H. Le, Y.-N. Sheen and M. N.-T. Lam, "Fresh and Hardened Properties of Self-Compacting Concrete With Sugarcane Bagasse Ash–Slag Blended Cement," Construction and Building Materials, vol. 185, pp. 138-147, 2018.

[13] M. A. Maldonado-García, U. I. Hernández-Toledo, P. Montes-García and P. L. Valdez-Tamez, "The Influence of Untreated Sugarcane Bagasse Ash on the Microstructural and Mechanical Properties of Mortars," Materiales de Construcción, vol. 68, no. 329, p. 148, 2018.

[14] P. Chindaprasirt, W. Kroehong, N. Damrongwiriyanupap, W. Suriyu and C. Jaturapitakkul, "Mechanical properties, chloride resistance and microstructure of Portland fly ash cement concrete containing high volume bagasse ash" Journal of Building

Engineering, vol. 31, 101415, 2020.

[15] P. Chindaprasirt, P. Sujumnongtokul and P. Posi, "Durability and mechanical properties of pavement cement concrete containing bagasse ash" Materialstoday: Proceedings, vol. 7(4), pp. 1612-1626,2019.

[16] H. A. Manon, A. M. Kuddus and I. S. Hasan, "Properties of Concrete Modified With Sugarcane Bagasse Ash and Stone Dust," in Proceedings of the 3rd International Conference on Civil Engineering for Sustainable Development, KUET, Khulna, Bangladesh, 2016.

[17] J. P, A. Ramachandramurthy and R. Murugesan, "Evaluation of Mechanical Properties of Sugar Cane Bagasse Ash concrete," Construction and Building Materials, vol. 176, pp. 608-617, 2018.

[18] H. S. and P. N. K. Whardani, "The Behavior of self-Compacting Concrete (SCC) with Bagasse Ash," in American Institute of Physics Conference Series, 2017.

[19] J. P. Moretti, S. Nunes and A. Sales, "Self-compacting Concrete Incorporating Sugarcane Bagasse Ash.," Construction and Building Materials, vol. 172, pp. 635-649, 2018.

[20] S. A. Zareei, F. Ameri and N. Bahrami, "Microstructure, Strength, and Durability of Eco-Friendly Concretes Containing Sugarcane Bagasse Ash," Construction and Building Materials, vol. 184, pp. 258-268, 2018.

[21] A. Jain, R. Gupta and S. Chaudhary, "Performance of self-compacting conrete comprising granite cutting waste as fine aggregate" Construction and Building Materials, vol. 221, pp. 539-552, 2019.

[22] H. S. Arel, "Recyclability of Waste Marble in Concrete Production," Journal of Cleaner Production, vol. 131, pp. 179-188, 2016.

[23] G. C. Ulubeyli and R. Artir, "Properties of Hardened Concrete Produced by Waste Marble Powder," Procedia-Social and Behavioral Sciences, vol. 195, pp. 2181-2190, 2015.

[24] M. Gesoğlu, E. Güneyisi, M. E. Kocabağ, V. Bayram and K. Mermerdaş, "Fresh and Hardened Characteristics of Self Compacting Concretes Made with Combined Use of Marble Powder, Limestone Filler, and Fly Ash," Construction and Building Materials, vol. 37, pp. 160-170, 2012.

[25] K. Vardhan, S. Goyal, R. Siddique and M. Singh, "Mechanical Properties and Microstructural Analysis of Cement Mortar Incorporating Marble Powder as Partial Replacement of Cement," Construction and Building Materials, vol. 96, pp. 615-621, 2015.

[26] S. Ghorbani, I. Taji, J.D. Brito, M. Negahban, S. Ghorbani, M. Tawakkolizadeh and A. Davoodi, "Mechanical and durability behaviour of concrete with granite waste dust as partial cement replacement under adverse exposure conditions" Construction and Building Materials, vol. 194, pp. 143-152, 2019.

[27] K. L. Jain, G. Sancheti and L.K. Gupta, "Durability performance of waste granite and glass powder added concrete" Construction and Building Materials, vol. 252, 119075, 2020.

[28] M. Vijayalakshmi, A. S. S. Sekar and G. P. Ganapathy, "Strength and Durability Properties of Concrete Made with Granite Industry Waste," Construction and Building Materials, vol. 46, pp. 1-7, 2013.

[29] Raghavendra R, Sharada. S. A, G. Ravindra. M.V, "Compressive Strength of High Performance Concrete Using Granite Powder as Fine aggregate," International Journal of Research in Engineering and Technology, vol. 4, pp. 47-49, 2015.

[30] S. Singh, S. Khan, R. Khandelwal, A. Chugh and R. Nagar, "Performance of Sustainable Concrete Containing Granite Cutting Waste," Journal of Cleaner Production, vol. 119, pp. 86-98, 2016.

[31] S. Ghannam, H. Najm, and R. Vasconez , "Experimental Study of Concrete Made with Granite and Iron Powders as Partial Replacement of Sand," Sustainable Materials and Technologies, vol. 9, pp. 1-9, 2016.

[32] S. Singh, R. Nagar and V. Agrawal, "A Review on Properties of Sustainable Concrete using Granite Dust as Replacement for River Sand," Journal of cleaner production, vol. 126, pp. 74-87, 2016.

[33] ASTM C150, "Standard Specification for Portland Cement," ASTM international, 2004.

[34] ASTM C192/C192 M, "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory.," ASTM International, 2018.

[35] ASTM C138/C138M, "Standard Test Method for Density (Unit weight), Yield and Air Content (Gravimetric) of Concrete," ASTM international, 2016.

[36] ASTM C39/C39M, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens," ASTM international, 2018.

[37] ASTM C496/C496M, "Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens," ASTM international, 2017.

[38] ASTM C469/C469M, "Standard Test Method for Static Modulus of Elasticity and Poison's Ration of Concrete in Compression," ASTM international, 2014.

[39] ASTM C78/C78M, "Standard Test Method for Flexural Strength of Concrete (Using Simple Beam With Third-Point Loading)," ASTM international, 2018.