An investigation of mechanical properties of concrete by addition of sugarcane bagasse ash and steel fiber

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Abstract. Concrete is a powerful industrial substance into construction industry due to the durability and its strength properties. Construction industries have drained natural resources as well as build the poisonous material in the atmosphere by the utilization of raw materials. The substitute items have been found to conserve the natural resources and atmosphere to some degree. Utilization of this atmospheric waste material into the construction industry without much treatment may be a good alternative for natural aggregates. Accordingly, in this paper M30 grade of concrete mix (As per IS 10262:2009) is replaced with natural / industrial wastes like sugarcane bagasse ash and steel fiber. For casting the concrete cube, the replacement dosage of Sugarcane bagasse ash and steel fibre varied from 0% to 20% in the level of 5% and 0% to 1.5% in a level of 0.5% respectively by cement weight. Concrete cube having above ingredient of the mixes was cured for 7, 28 and 90 days. The impact of the mixture of sugarcane bagasse ash and steel fibre on different mechanical properties like compressive/ flexural/ split tensile strength was examined. It was observed that addition of 10 % of sugarcane bagasse ash and 1% of steel fibre into cement is a promising combination that provides optimum mechanical properties.

Keywords. Mechanical properties, Waste utilization, Steel fiber, Sugarcane bagasse ash, Cement-based composites, etc.

1. Introduction
Concrete is like the composite material utilized throughout building construction. The concrete is made through binding the cement, water, sand, and aggregate to fluid [1]. Portland Cement Concrete is the most commonly used concrete. Cement, which damages the environment at a very fast pace, is one of the main components of concrete. Concrete is a greatly favoured building material, and cement is an inevitable part of the construction sector as the primary component of concrete. Production of cement is however, related to higher consumption of energy and greenhouse gases emissions [2].
Cement is a fine gray powder type substance that is produced through combusting clay and lime mixture, and when mixed with water, sets hard. There are several procedures involved in the production of cement, such as the milling, crushing and mix proportions of alumina, iron, lime, gypsum, and silica. Cement is the binding agent and that is a substrate which helps to bind together various materials [3]. This characteristic makes it an outstanding part of concrete. Cement processing produces high concentrations of CO₂. After the transport industry and the electricity production sector, cement is the world's third largest manufacturer of manmade CO₂ [4]. About 0.97 tonnes of carbon dioxide is expected
to be released into the atmosphere to produce one ton cement. Carbon dioxide is blamed in large part for global warming [5]. This encourages one to research the different cement alternatives for making a specific climate friendly. Utilization of industrial goods or waste materials could be the substitute for cement devoid of reduction in a required concrete strength [6].

Sugarcane bagasse ash (SCBA) is a by-product of the sugar industry, generated during sugar cane juice processing. Such fibers substance is being used as fuel for power production within sugar industry and the waste of the whole operation is referred as the sugarcane bagasse ash [7]. Bagasse ash should not be used specifically in concrete, as in other secondary cement products. The removal of unwanted elements involves some prior care, in particular heat treatment within controlled conditions [8]. Ganesan et al.[9] tested the effect of SCBA as cement substitute in concrete mechanical/physical performance, and it was found that bagasse ash could utilized as optimum substitute of 20 percent. Singh et al. [10] investigated a hydration properties of SCBA mixed Portland cement, and has concluded that 10 percent cement substitution was ideal for improved results. The effect of incineration temperature, incineration time and ultra-fine grinding length on the chemical-physical characteristic of SCBA was investigated [11]. Sumrereng Ruzkon et al. [7] explored the prospect of using SCBA in High Strength Concrete as a cement alternative, changing substitution from 10 percent to 30 percent. An ideal substitution proportion was proposed as 10 percent and up to 30 percent substitution is suitable for concrete construction.

Management of baggase is one of the great importance from an environmental point of view. The combustion of this bagasse is one of the most common practices, resulting in the production of an additional residue, the sugarcane bagasse ash (SCBA). Chemical and mineralogical composition of SCBA makes it a potential supplementary material in Portland cement blends and also in geopolymic binders. Fineness, crystallinity, and the presence of unburned particles are crucial for the development of pozzolanic reactivity and for having good mechanical performance. Durability of SCBA-based mortar and concrete is appropriate, and in many cases 15% replacement of cement can be carried out without significant performance loss. Also, SCBA and sugarcane straw ash are good candidates for preparing geopolymeric binary systems. A reduction of CO₂ emissions has been proposed with the use of these residues.

Agricultural residues are primarily used as biomass fuel. The bottom ash is the final waste, which are aroused wide research interest. It has been found that several different kinds of biomass ash can be used as supplementary cementitious materials [26], previous researchers found that incorporating biomass ash into building materials could maintain or even improve the mechanical performance of the cementitious materials. Additionally, the incorporation of biomass ash into cementitious materials can help to reduce the greenhouse gases produced in cement production, lower the costs of construction materials, alleviate waste disposal pressure, and prevent soil and air pollution. [26]

Traditional brittle concrete has poor tensile strength/strain capacity/strain. An incorporation of fibers has been shown dramatically increment in resistance to tensile stress, altering concrete's brittle behaviour [12]. Due to the enhanced tensile properties, fibers can be used to minimize concrete pavement thickness and joint spacing. Addition of steel fibers additionally enhances a resistance to fatigue and impact, tends to result in high pavement stability and smooth-riding surface [13], [14]. While considering the steel fibers into surplus of 1.5 percent of concrete volume because of balling of fibers, changes into properties can be negligible, minimizing the efficacy of fibers in the concrete. In most current applications, the quantity of fibers is reduced to about 1 percent of the amount of concrete. Steel fiber is the building material for airport and highway pavements because of increased performance when considering the hardness, strain hardening, and crack control [15][16].

So, the current research paper focused on the casting the mixed concrete cube by replacement of the cement from industrial and environmental waste by varying the compositions for understanding a different characteristics of mix concrete such as compressive, flexural, and split tensile strength.

2. Materials and Methods

2.1. Cement constituents
All of concrete mix proportions were done with the Pozolona Portland cement of makers Ultratech, confirming to IS 8112:2013 [17], as the binder. Laboratory testing were used to know the specific gravity, and time for initial/ final setting. Normal consistency was found to be 22% on the Vicat's apparatus. (as per IS code 8112-1976). Cement specific gravity was observed as 3.15 [18]. Fineness of cement was found to be 5.0% (IS code 4031 - 1996 {Part -I}). Soundness of cement was 2 mm found by the Le-Chatelier apparatus (IS code 4031 - 1996 {Part -III}, and IS 5514-1996). Compressive strength of cement was found to be 27.52N/mm² and 36.28 N/mm² for 3 and 7 days respectively (IS code 12269-1987). Physical properties of Pozolona Portland cement is shown in Table 1.

### Table 1. Characteristics of Ordinary Portland cement.

| Physical Properties          | Values of OPC used |
|------------------------------|--------------------|
| Normal Consistency           | 22 %               |
| Setting Time (Initial)       | 50 minutes         |
| Setting Time (Final)         | 365 minutes        |
| Specific gravity             | 3.15               |
| Fineness of cement           | 5.0%               |
| Soundness of cement          | 2 mm               |
| Compressive strength (N/mm²) at 3 days | 27.52N/mm² |
| Compressive strength (N/mm²) at 7 days | 36.28 N/mm² |

2.2. Coarse aggregate

Crushed angular and graded aggregate were purchased from Kanhan village of Nagpur district of Maharashtra state. To render the concrete, a coarse aggregate having fixed 20 mm size of was utilized. To evaluate a fineness modulus, sieve analysis was performed. Using a pycnometer test, the specific gravity was obtained [19]. Table 2 shows the characteristics of coarse aggregate.

### Table 2. Characteristics of coarse aggregate.

| Characteristics   | Values         |
|-------------------|----------------|
| Specific gravity  | 2.855          |
| Fineness modules  | 7.098          |
| Water Absorption: | 0.97 %         |
| Air content       | 2% of Volume of concrete |

2.3. Fine aggregate

Zone 2 graded sand with the fineness modulus of 2.493 and specific gravity of 2.605 was utilized. The fineness modulus is obtained by the Sieve analysis [20]. Table 3 shows the characteristics of fine aggregate.

### Table 3. Characteristics of fine aggregate.

| Characteristics   | Values         |
|-------------------|----------------|
| Specific gravity  | 2.605          |
| Fineness modules  | 2.493          |
| Water Absorption: | 1.23 %         |

2.4. Sugarcane bagasse ash

SCBA utilized into the work was procured from Vainganga Sugar and Power Ltd, Devhara village of Bhandara district of Maharashtra, India. Sugarcane bagasse ash improves the concrete characteristics
like compressive strength and water tightness [21]. The main parameter responsible for this improvement was higher silica content. Chemical Composition of Sugarcane bagasse ash was found by performing XRF Scan Test at Indian Bureau Mines Modern Mineral Processing Laboratory & Pilot Plant. Table 4 presents a chemical composition of a Sugarcane bagasse ash. The results describe that the main composition of silicon di-oxide is present to about 75% in sugar cane bagasse ash. The other main oxides presents are aluminum oxide, iron oxides and CaO of about 3% and loss of ignition was found to be 3% of composition. The similar oxide has been found with that of cement. As we compare our Sample composition with available literature sample found suitable for replacement.

Table 4. Chemical composition of the Sugarcane bagasse ash.

| Present Oxides | Percentage Content | Present Oxides | Percentage Content | Present Oxides | Percentage Content |
|----------------|--------------------|----------------|--------------------|----------------|--------------------|
| SiO₂           | 76.667 %           | TiO₂           | 0.123 %            | MnO₂           | 0.130 %            |
| Na₂O           | 0.162 %            | BaO            | 0.015 %            | LOI            | 3.15 %             |
| MgO            | 2.905 %            | CuO            | 0.021 %            | CaO            | 3.496 %            |
| Al₂O₃          | 1.097 %            | Rb₂O           | 0.011 %            | K₂O            | 7.521 %            |
| P₂O₅           | 3.115 %            | ZrO₂           | 0.101 %            | Fe₂O₃          | 1.315 %            |
| SO₃            | 0.118 %            | Cr₂O₃          | 0.008 %            |                |                    |
| Cl             | 0.026 %            |                |                    |                |                    |

2.5. Concrete mix preparation

For traditional concrete, concrete mix is constructed as per IS 10262:2009 standard. The dosage of this aggregate applied while concrete processing is take as 0.92 percent of cement content weight [19]. The concrete grade M30 has applied and w/c ratio was originally chosen for construction combination of 0.16. The sum of the ingredients collected during a design mix and a percentage of a mix [22]. Table 5 shows proportion of mix for 1 m³ of concrete.

Table 5. Proportion of mix for 1 m³ of concrete.

| Characteristics | Values |
|-----------------|--------|
| Cement mass (kg/m³) | 380    |
| Fine aggregate mass (kg/m³) | 711    |
| Water mass (kg/m³) | 186    |
| W/C ratio | 0.42   |
| C.A aggregate mass (kg/m³) | 1283   |

2.6. Casting of specimen

For experimentation, a total of 108 concrete samples have been cast with dimensions 150x150x150 mm for compressive strength. According to Indian Standard guidelines for M30 grades, the mixing design of concrete was carried out. The amounts of SCBA for 0, 5, 10, 15, and 20 percent substitution by weight is determined on the basis of the ingredient quantities of the blends, and the ratio of water cement varies from 0.44-0.63. In the cement mixer, the concrete materials were thoroughly combined until a consistent consistency was obtained.

Machine oil was smeared on the interior surface of a CI mould prior to casting [23]. After 24 hours, the specimens were removed from the mould and then cured under water for 7, 28, and 90 days. Few experiments were also carried out in the Indian Bureau of Mines, Nagpur, outer to concrete laboratory, such as XRF scan tests. In compliance with the applicable Indian Quality requirements, these tests were also performed. The mixing proportions for the M30 concrete grade are as seen into Table 6.
Table 6. Proportions of mix for M30 Grade of concrete.

| Mix   | Cement Kg/m³ | Coarse Aggregate Kg/m³ | Sugarcane Bagasse ash Kg/m³ | Natural Sand Kg/m³ | W/C  |
|-------|---------------|-------------------------|-----------------------------|-------------------|------|
| Mix 1 | 454           | 823                     | 0.00                        | 425               | 0.45 |
| Mix 2 | 432           | 888                     | 19.33                       | 454               | 0.45 |
| Mix 3 | 409.2         | 888                     | 32.5                        | 458               | 0.45 |
| Mix 4 | 387           | 858                     | 48.3                        | 454               | 0.45 |
| Mix 5 | 364           | 890                     | 64.3                        | 454               | 0.45 |

3. Testing on casted specimen

3.1. Compressive strength
Compression test was carried out subsequent to curing of 7, 28 and 90 days on concrete specimens of 150x150x150 mm for all mixes at 140 kg/cm²/min rate of loading [24]. Compression test was performed on analog based compression testing machine. The findings recorded were an average of three samples and testing was done on a compression measuring system with a capacity of 3000 kN.

3.2. Flexural strength
Flexural strength test was done on flexural strength test machine. Flexural strength testing was done after curing of 7, 28 and 90 days on concrete specimens of 100x100x500mm for all mixes. Figure 1 shows a test specimen on flexural strength testing machine. The findings recorded were an average of three samples.

![Testing of a specimen on flexural strength testing machine](image)

3.3. Split tensile strength
Split tensile strength testing was done on analog based compression test machine. Split tensile strength test was done subsequent to curing of 7, 28 and 90 days on concrete specimens of 150x300 mm for all mixes [25]. Figure 2 shows the test specimen on analog based compression testing machine. The findings recorded were an average of three samples.

![Testing of a specimen on flexural strength testing machine](image)
Figure 2. Testing of a specimen on analog based compression testing machine

4. Results & discussions

4.1. Result of Compressive strength
To check the compressive strength effect of sugarcane bagasse ash, primarily sample having steel fiber 0% have checked with incremental sugarcane bagasse ash percentage. Sugarcane bagasse ash percentage varied from 0% to 20% in the level of 5%. In next check, the percentage of steel fiber varied cumulatively 0.5%, 1%, and 1.5% with incremental sugarcane bagasse ash percentage. Figure 3 shows the result of the compressive strength after the curing of 7, 28 and 90 days on concrete specimens of 150x150x150 mm.

Figure 3. Effect on compressive strength of sugarcane bagasse ash on steel fiber with curing time.
Compressive strength was found highest i.e. 45.657 MPA at a combination of steel fiber 1.5% and sugarcane bagasse ash 15%. Compressive strength is higher at higher combinations of steel fiber % and
sugarcane baggase ash %. Variations in compressive strength for curing time of 28 days are found just similar.

To check the compressive strength effect of steel fiber, primarily sample having sugarcane baggase ash 0% have checked with incremental sugarcane baggase ash percentage. Steel fiber percentage varied from 0% to 1.5% in the level of 0.5%. In next check, the percentage of sugarcane baggase ash varied cumulatively 5%, 10%, 15%, and 20% with incremental steel fiber percentage. Figure 4 shows the result of the compressive strength after the curing of 7, 28 and 90 days on concrete specimens of 150x150x150 mm.

![Figure 4. Effect on compressive strength of steel fiber on sugarcane baggase ash with curing time.](image)

Compressive strength was found highest i.e. 45.657 MPA at a combination of steel fiber 1.5% compared to other steel fiber percentage with all percentage of sugarcane baggase ash. Significant change in the compressive strength is found with the curing time.

4.2. Result of Flexural strength

The same method of varying the percentage was adopted from compressive testing for the flexural strength testing. To check the flexural strength effect of sugarcane baggase ash, primarily sample having steel fiber 0% have checked with incremental sugarcane baggase ash percentage. Sugarcane baggase ash percentage varied from 0% to 20% in the level of 5%. In next check, the percentage of steel fiber varied cumulatively 0.5%, 1%, and 1.5% with incremental sugarcane baggase ash percentage. Figure 5 shows the result of the flexural strength testing after the curing of 7, 28 and 90 days on concrete specimens of 100x100x500 mm.
Figure 5. Effect on flexural strength of sugarcane baggase ash on steel fiber with curing time.

Flexural strength was found highest i.e. 9.548MPA at a combination of sugarcane baggase ash 10% and steel fiber 1.5% for 90 days curing. Flexural strength was found lowest i.e. 9.548MPA at a combination of sugarcane baggase ash 5% and steel fiber 0%. Similar trend of increment was found with the combinations of sugarcane baggase ash and steel fiber.

The same method of varying the percentage was adopted from compressive testing for the flexural strength testing. To check the flexural strength effect of steel fiber, primarily sample having sugarcane baggase ash 0% have checked with incremental sugarcane baggase ash percentage. Steel fiber percentage varied from 0% to 1.5% in the level of 0.5%. In next check, the percentage of sugarcane baggase ash varied cumulatively 5%, 10%, 15%, and 20% with incremental steel fiber percentage.

Figure 6 shows the result of the flexural strength testing after the curing of 7, 28 and 90 days on concrete specimens of 100x100x500 mm.

Figure 6. Effect on flexural strength of steel fiber on sugarcane baggase ash with curing time.
Flexural strength was found highest i.e. 9.454 MPA at a combination of steel fiber 1.5% and sugarcane baggase ash 20% for 90 days curing. Flexural strength was found lowest i.e. 3.733 MPA at a combination of sugarcane baggase ash 5% and steel fiber 0%. Composites having 1.5% steel fiber have higher flexural strength as compared to other combinations.

4.3. Result of Split tensile strength

The same method of varying the percentage was adopted from compressive testing and flexural strength testing for the Split tensile strength. To check the Split tensile strength effect of sugarcane baggase ash, primarily sample having steel fiber 0% have checked with incremental sugarcane baggase ash percentage. Sugarcane baggase ash percentage varied from 0% to 20% in the level of 5%. In next check, the percentage of steel fiber varied cumulatively 0.5%, 1%, and 1.5% with incremental sugarcane baggase ash percentage. Figure 7 shows the result of the Split tensile strength testing after the curing of 7, 28 and 90 days on concrete cylinder of specimens of 150mm in diameter & 300 mm in length.

Split tensile strength was found highest i.e. 7.668 MPA at a combination of sugarcane baggase ash 10 % and steel fiber 1.5% for 90 days curing. Split tensile strength was found lowest i.e. 1.537MPA at a combination of sugarcane baggase ash 20% and steel fiber 0%. Composites having 10% sugarcane baggase ash have higher split tensile strength as compared to other combinations.

The same method of varying the percentage was adopted from compressive testing and flexural strength testing for the Split tensile strength. To check the Split tensile strength effect of steel fiber, primarily sample having sugarcane baggase ash 0% have checked with incremental sugarcane baggase ash percentage. Steel fiber percentage varied from 0% to 1.5% in the level of 0.5%. In next check, the percentage of sugarcane baggase ash varied cumulatively 5%, 10%, 15%, and 20% with incremental steel fiber percentage. Figure 8 shows the result of the Split tensile strength testing after the curing of 7, 28 and 90 days on concrete specimens of cylindrical size 150mm in diameter & 300 mm in length.
Split tensile strength was found highest i.e. 7.668 MPA at a combination of steel fiber 1.5% and sugarcane bagasse ash 10 % for 90 days curing. Split tensile strength was found lowest i.e. 1.537 MPA at a combination of steel fiber 0% and sugarcane bagasse ash 15%. Composites having 1.5% steel fiber have higher split tensile strength as compared to other combinations.

5. Conclusions

The result on the properties of partial substitution of sugarcane bagasse ash and steel fiber as a substitute was examined. In a present analysis, the characteristics observed from different samples composed of diverse compounds contribute to the below mentioned conclusions:

- Utilization of Sugarcane bagasse ash reduce the waste disposal pressure, and prevent not only soil pollution but air pollution also.
- Incorporation of Sugarcane bagasse ash improves the flexural strength, split tensile strength and decreases a rate of water absorption.
- For any structure, concrete with a partial substitution of 10 percent sugarcane bagasse ash with the inclusion of an optimum percentage of steel fiber can be recognized as a heavy section member.
- The retarding effect of SCBA with increase in curing time is found in split tensile strength at 20% SCBA.
- Increase in sugarcane bagasse ash with steel fiber content result into the increase in compressive / flexural / split tensile strength.
- Sugarcane bagasse ash is much lighter than fly ash and slag in weight. Therefore, it can be considered as the significant substitute for higher strength.
- The study also proved that reducing the cement consumption and steel in the concrete will also help in conserving the environment by reducing the air pollution in the surrounding produced from steel factories and sugar industries.

6. References

[1] BKH Obla, D Ph M 2008 Engineering, Specifying Fly Ash for Use in Concrete, Concr In FOCUS, Spring 60–66
[2] Jokar Z, Mokhtar A 2018 Policy making in the cement industry for CO2 mitigation on the pathway of sustainable development- A system dynamics approach J Clean Prod 201, 142–155

[3] Harris L N, Philip J Ross 1989 Taguchi techniques for quality engineering McGraw-hill book company Quality and Reliability Engineering International, 5(3), 249–249

[4] TE Limited 1987 Manual for Life Cycle Aspects of Concrete in Buildings and Structures, Taywood, Engineering

[5] S Masoud, K Soudki 2006 Evaluation of corrosion activity in FRP repaired RC beams, Cem Concr Compos 28 969–977

[6] Dhande H K, S D Shelare, P B Khope 2020 Developing a mixed solar drier for improved postharvest handling of food grains Agricultural Engineering International: CIGR Journal, 22(4) 17-24

[7] S Rukzon, P Chindaprasirt 2012 Utilization of bagasse ash in high-strength concrete, Mater Des 34 45–50

[8] A Bahurudeen, M Santhanam 2015 Influence of different processing methods on the pozzolanic performance of sugarcane bagasse ash Cem Concr Compos 56 32–45

[9] K Ganesan, K Rajagopal, K Thangavel 2007 Evaluation of bagasse ash as supplementary cementitious material, Cem Concr Compos 29 515–524

[10] NB Singh, VD Singh, S Rai 2000 Hydration of bagasse ash-blended portland cement, Cem Concr Res 30 1485–1488

[11] GC Cordeiro, RDT Filho, EMR Fairbairn 2010 Ultrafine sugar cane bagasse ash : high potential pozzolanic material for tropical countries Cinza ultrafina do bagaço de Cana-de-açúcar : material, IBRACON Struct Mater 3 50–67

[12] Batson G 1976 Steel fiber reinforced concrete Mater Sci Eng 25 (C) 53–58

[13] Neocleous, K, H Angelakopoulos, K Pilakoutas, and M Guadagnin 2011 Fibre-reinforced roller compacted concrete transport pavements Proc Inst Civ Eng Transp 164 (2) 97–109

[14] Nataraja M C, T S Nagaraj, and S B Basavaraja 2005 Reproportioning of steel fibre reinforced concrete mixes and their impact resistance Cem Concr Res 35 (12) 2350–2359

[15] Naaman A E, and H W Reinhardt 2003 High performance fiber reinforced cement composites HPFRCC-4: International RILEM workshop Mater Struct/Materiauxet Constr 36 (264) 710–712

[16] Teja Prathipati, S R R, C B K Rao, and N R Dakshina Murthy 2020 Mechanical behavior of hybrid fiber reinforced high strength concrete with graded fibers Int J Eng 33 (8) 1465–1471

[17] IS: 8112-2013, Ordinary Portland Cement, 43 Grade - Specification,Bureau of Indian Standards, New Delhi, India, Indian Stand [18] IS 516 - 1959 (Reaffirmed 2004) 2004 Bureau of Indian Standards, Method of Tests for Strength of Concrete, New Delhi, India [19] Akshay Dhawan, Nakul Gupta, Rajesh Goyal, KK Saxena 2020 Evaluation of mechanical properties of concrete manufactured with fly ash, bagasse ash and banana fibre, Materials Today: Proceedings

[20] Chusilp N 2009 Utilization of bagasse ash as a pozzolanic material in concrete, Construction and Building Materials, 200911

[21] Jawalekar S B, and S D Shelare 2020 Development and performance analysis of low cost combined harvester for rabicrops Agricultural Engineering International: CIGR Journal, 22(1) 197-201

[22] Liu Y 2003 Comparison of guarded and unguarded linear polarization CCD devices with weight loss measurements, Cement and Concrete Research, 200307

[23] Shelare SD, Kumar R, Khope PB 2021 Formulation of a Mathematical Model for Quantity of Deshelled Nut in Charoli Nut Deshelling Machine In: Prakash K, Krolczyk G, Singh S, Pramanik A (eds) Advances in Metrology and Measurement of Engineering Surfaces Lecture Notes in Mechanical Engineering Springer, Singapore

[24] High Tech Concrete: Where Technology and Engineering Meet, 2018 Springer Science and Business Media LLC

[25] Sustainable Construction and Building Materials, 2019 Springer Science and Business Media LLC

[26] Qing Xu, Tao Ji, San-Ji Gao, Zhengxian Yang and Nengsen Wu 2019 Characteristics and Applications of Sugar Cane Bagasse Ash Waste in Cementitious Materials, Materials (Basel) 12(1) 39 (Published online 2018 Dec 22)