

Behaviour of Concrete Subjected to Elevated Temperature by Partially Replacing Cement with Bagasse Ash

Dr.Y.M. Manjunath¹, Dinakar. K²

Professor, Department of Civil Engineering, The National Institute of Engineering, Mysuru, Karnataka, India¹

P.G. Student, Department of Civil Engineering, The National Institute of Engineering, Mysuru, Karnataka, India²

ABSTRACT: The present work aims at studying the mechanical properties of concrete using bagasse ash as replacement for cement subjected to elevated temperatures. The concrete is made by partial replacement of cement with 0%, 5%, 10%, 15%, 20%, 25% and 30% of Sugar Cane Bagasse Ash (SCBA). The grade of concrete used is M25. Concrete specimens (cubes and cylinders) are casted and they are exposed to different elevated temperatures (200°C, 400°C, 600°C and 800°C) for a duration of 2 hours using electrical furnace and then tested. The mechanical properties such as compressive strength, split tensile strength and Modulus of elasticity of concrete are determined. The experimental investigation reveals that SCBA can be effectively used by about 10% to 15% as a replacement of cement to get the better strength of concrete. The compressive strength of concrete specimens found to be maximum when exposed to a temperature of 2000C for all percentage replacement of SCBA.

KEYWORDS: Bagasse Ash, Compressive Strength, Split Tensile Strength, Modulus of Elasticity and Workability.

I. INTRODUCTION

An ever-evolving world requires innovative construction methods. One of the most widely used materials for construction is concrete. It is estimated that the present consumption of concrete in the world is of the order of 10 billion tones (12 billion Tons) every year. Concrete is second only to water as the most consumed substance on earth, with nearly three tones of the material used annually for each person on the planet. Cement is the critical ingredient in concrete, locking together the sand and gravel constituents in an inert matrix; it is the “glue” which holds together much of modern society’s infrastructure. Production of one ton of cement uses approximately 1.5 tons of raw materials, 0.3 tons of air and 6 gigajoules of fuel; and releases 0.94 tons of carbon dioxide. The main environmental issues associated with cement production are emissions to air and energy use. Waste water discharge is usually limited to surface run off and cooling water only and causes no substantial contribution to water pollution. Quarrying activities associated with the cement industry impact land use and biodiversity. The energy consumed by the cement industry is estimated at about 2% of the global primary energy consumption; 5% of global man-made carbon dioxide emissions originate from cement production. With the ever increasing demand and consumption of cement and in the backdrop of waste management, scientists and researchers all over the world are always in quest for developing alternate binders that are environment friendly and contribute towards sustainable management. Researchers all over the world today are focusing on ways of utilizing either industrial or agricultural waste, as a source of raw material for industry. Fly ash is considered as most prolific cementitious materials compared to other industrial and agricultural by products because of its chemical composition, particle size & its availability. But other potential byproduct of agricultural waste such as sugarcane bagasse ash needs to be investigated.

Bagasseash is an agricultural/industrial waste and it is by-product of sugarcane milling process in sugar factories. The sugarcane is a major crop growing in Mysore and Mandya district. There are around 8 sugar mill factories in and

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

around Mysore and Mandya district which are extracting sugarcane juice from around 30 lakh metric tons sugarcane yearly to produce sugar. Sugarcane bagasse (SCB) which is a voluminous by-product in the sugar mills obtained when juice is extracted from the sugarcane. For each 1 ton of sugarcane crushed, a sugar factory yields about 300 kg of bagasse. Since bagasse is a by-product of the sugar cane industry, the quantity of production in each country is in line with the quantity of sugarcane produced. It is, however, generally used as a fuel to fire furnaces in the same sugar mill that yields about 3-5% bagasse ash containing high amounts of un-burnt matter, silicon, aluminum, iron and calcium oxides. The bagasse ash, therefore, becomes an industrial waste or agricultural waste and poses disposal problems. For obtaining amorphous and reactive sugarcane bagasse ash (BA), several trials were conducted to define optimum burning time and temperatures. BA used in this study was obtained by burning BA at 600°C-800°C under controlled conditions and its physical, chemical, and mineralogical characterization was done to evaluate the possibility of its use as binder partially replacing cement in the concrete applications. Bagasse ash is locally available cementitious material in and around Mysore and Mandya district compared to other supplementary cementitious material so that bagasse ash can be used as alternative material for cement.

Concrete is one of the most widely used in the construction of high rise buildings and special purpose. Buildings in case of unexpected fire, the concrete changes its both physical and chemical properties after fire. Hence, it is most important to understand the behavior of concrete subjected to elevated temperature (200°C, 400°C, 600°C and 800°C) for 2 hours duration. High temperature can cause the development of cracks. These cracks like any other cracks propagation may eventually cause loss of strength, structural integrity and shorting of service life. This significant effect was mainly due to unfavorable $\text{Ca}(\text{OH})_2$ and it can be eliminated by using the SCBA, Silica Fume and Fly Ash as the mineral admixture.

II. MATERIAL CHARACTERIZATION

A. MATERIAL USED:

The materials used in present investigation are as follows:

1. **Cement:** In the present investigation ordinary Portland cement of grade 53 (Birla) has been used. The cement is tested according to IS specification IS: 12269-1987[7] to determine its various properties.
2. **Bagasse Ash:** The sugarcane bagasse consists of approximately 50% of cellulose, 25% of hemicellulose and 25% of lignin. Each ton of sugarcane generates approximately 26% of bagasse (at moisture content of 50%) and 0.62% of residual ash. The residue after combustion presents a chemical composition dominated by silicon dioxide (SiO_2). In spite of being a material of hard degradation and that presents few nutrients, the ash is used on the farms as a fertilizer in the sugarcane harvests. In this sugarcane bagasse ash was collected during the cleaning operation of a boiler operating in the Pandavapura Sugar Factory, located in the city of Mandya, Karnataka.
3. **Fine Aggregate:** In the present work nearly available Manufactured sand conforming to zone-II of IS 383-1970[8] has been used as fine aggregate. The aggregate was tested for its physical requirements such as Specific gravity, Fineness modulus etc... and in accordance with IS 2386-1963[9].
4. **Coarse Aggregate:** The crushed aggregates used were 20mm and 10mm nominal maximum size and are tested as per Indian standards and results are shown in table-3.
5. **Water:** Portable water has been used in the concrete mix design. pH value as per IS 456-2000[11] less than 7.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

B. MATERIAL PROPERTIES:

Table 1: Physical Properties of Cement

Sl No.	Test	Result
1	Specific Gravity	3.10
2	Fineness (%)	3.0
3	Normal consistency (%)	30
4	Initial setting time(min)	175
5	Final setting time(min)	295

Table 2: Physical Properties of Fine Aggregate

Sl No.	Test	Result
1	Specific Gravity	2.54
2	Bulk Density (kg/m ³)	1507.74
3	Fineness modulus	2.54
4	Water absorption (%)	1.63

Table 3: Physical Properties of Coarse Aggregate

Sl No.	Test	Results
1	Specific gravity	2.64
2	Bulk Density (kg/m ³)	1460.5
3	Fineness modulus	2.17
4	Water absorption (%)	0.8

Table 4: Physical Properties of SCBA

Sl No.	Test	Results
1	Specific gravity	2.02
2	Normal Consistency (%)	36
3	Initial Setting Time (min)	164
4	Final Setting Time (min)	385
5	Bulk Density (kg/m ³)	
	a) Loose	360
	b) Compact	433

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

Table 5: Chemical Properties of SCBA

Sl No.	Chemical Compound	%
1	Silica (Sio ₂)	80.34%
2	Aluminum (Al ₂ O ₃)	0.20%
3	Ferric Oxide (Fe ₂ O ₃)	3.44%
4	Calcium (Cao)	5.89%
5	Magnesium (Mgo)	2.20%
6	Loss on Ignition	2.34%

III. EXPERIMENTAL STUDY

The main objective of this experimental investigation is to study the mechanical properties of the concrete exposed to elevated temperatures and cooled to room temperature. In this study sugarcane bagasse ash partially replaced for 0%, 5%, 10%, 15%, 20%, 25% and 30% by weight of cement in concrete and exposed to different elevated temperature (i.e. 200°C, 400°C, 600°C and 800°C) for a duration exposure of 2hrs. In this experimental work, a total of 105 number of cubes (150mmX150mmX150mm) for Compressive strength, 105 number of cylinders (150mm diameter and 300mm height) for Split tensile strength and 28 number of cylinders (150mm diameter and 300mm height) were casted for Modulus of Elasticity. Specimens were cured for 28 days. After curing each 3 specimens are tested for its strength at room temperature and sustained elevated temperature of (200°C, 400°C, 600°C and 800°C) for 2hr duration. An Electric furnace has been used to conduct the experiments. It is having a capacity of reaching a maximum temperature of 1000°C. The oven having a dimension of 2.1 m x1.1 m x1 m. Electric Power was used to raise the temperature inside the oven. After increasing the temperature to the required target level, it was sustained for duration of 2 hours.



Fig. 1. Electrical Furnace

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

IV. MIX PROPORTION

In the present experimental study a mix design is carried out as per IS: 10262-2009[6] for M25 grade of concrete. The resultant mix proportions of all the mixes are tabulated in Table 6.

Table 6: Mix Proportion for M25 Concrete

Mix Designation	Cement Kg/m ³	Bagasse Ash Kg/m ³	Fine Aggregate Kg/m ³	Coarse Aggregate Kg/m ³	Water liter	w/c ratio
M0 – 0 % BA	330	0	701.98	1169.26	175	0.53
M1 – 5 % BA	313.5	16.5	698.16	1164.02	175	0.53
M2 – 10 % BA	297	33	695.33	1159.34	175	0.53
M3 – 15 % BA	280.5	49.5	692.51	1154.63	175	0.53
M4 – 20 % BA	264	66	689.68	1149.91	175	0.53
M5 – 25 % BA	247.5	82.5	687.0	1145.52	175	0.53
M6 – 30 % BA	231	99	684.22	1140.80	175	0.53

V. RESULTS AND DISCUSSION

From the above experimental study the following results and discussion can be drawn;

1. Workability

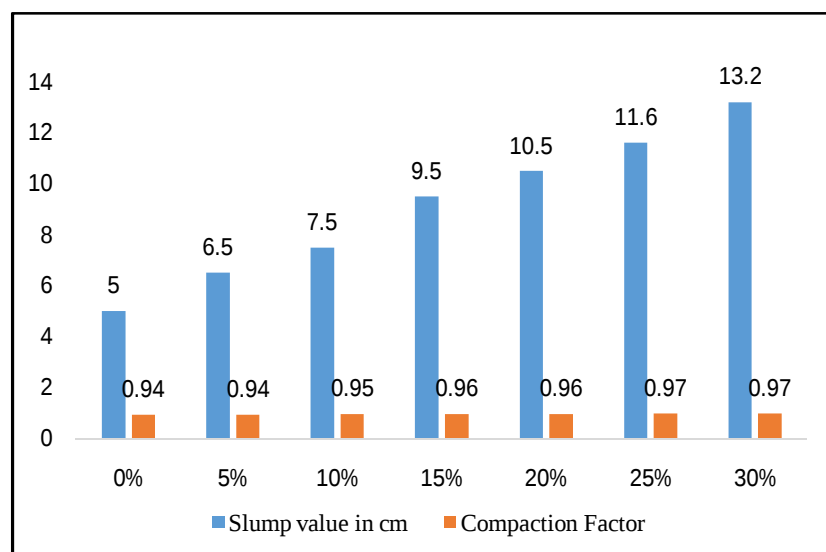


Fig. 2. Workability

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

A high quality concrete is one which has acceptable workability (around 6.5cm height) in the fresh condition and develops sufficient strength. Basically, the bigger the measured height of slump, the better the workability will be, indicating that the concrete flows easily but at the same time is free from segregation. Maximum strength of concrete is related to the workability and can only be obtained if the concrete has adequate degree of workability because of self-compacting ability. From the above Fig.2, it shows that 15% replacement of SCBA had high slump values and acceptable workability. Also, the partial replacement of SCBA increases workability of fresh concrete; therefore use of super plasticizer is not essential.

2. Compressive Strength

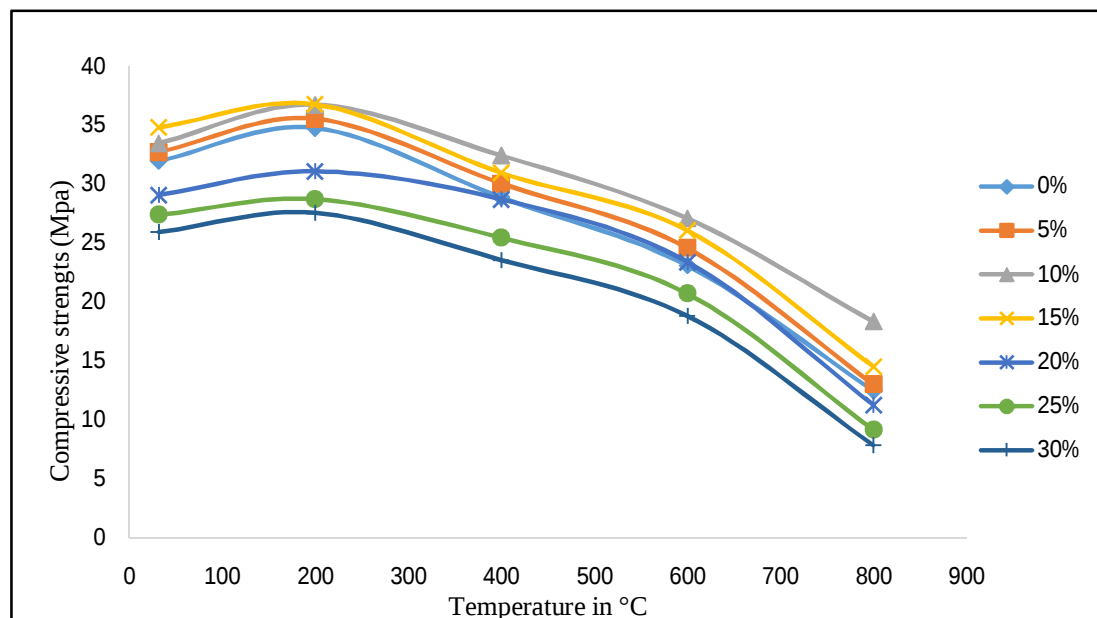


Fig. 3. Variation of Compressive strength with rise in temperature

From the above Fig.3, it is evident that with rise in temperature the maximum compressive strength is gained at 200°C than at room temperature for all percentage replacement of cement by SCBA. On heating the concrete specimen for 400°C and 600°C the loss of strength is found to be gradual and when the specimens are subjected to a temperature of 800°C for 2 hour duration, the strength decreases drastically. Also the specimens are found to be in milky white color and having more cracks on their surface. But, when it comes to a particular percentage replacement of cement with SCBA, the concrete retained its strength about 10% to 15%.

3. Split Tensile Strength

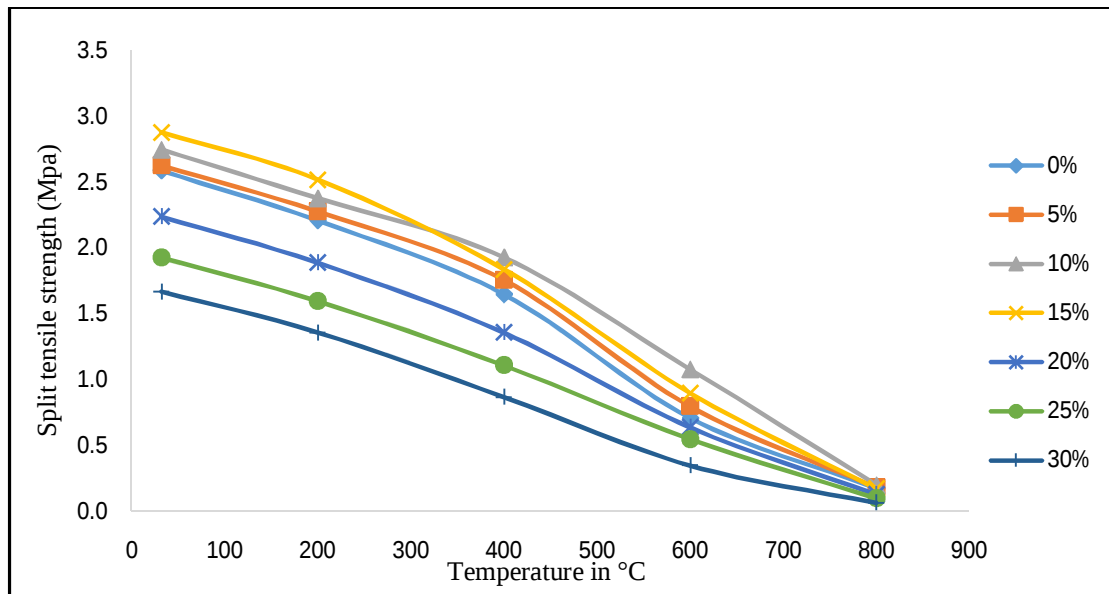


Fig. 4. Variation of Split tensile strength with rise in temperature

From the above Fig.4, it is observed that with rise in temperature, the split tensile strength is found to be maximum at room temperature for all percentage replacement of cement by SCBA. On heating the concrete specimen for 200°C, 400°C and 600°C the loss of strength is found to be gradual and when the specimens are subjected to a temperature of 800°C for 2 hour duration, the strength decreases drastically. But, when it comes to a particular percentage the SCBA concrete retained its strength about 10% to 15%. Hence, the SCBA concrete behaves as a refractory material.



Fig. 5. Change in colour found in specimens subjected of 800°C

4. Modulus of Elasticity

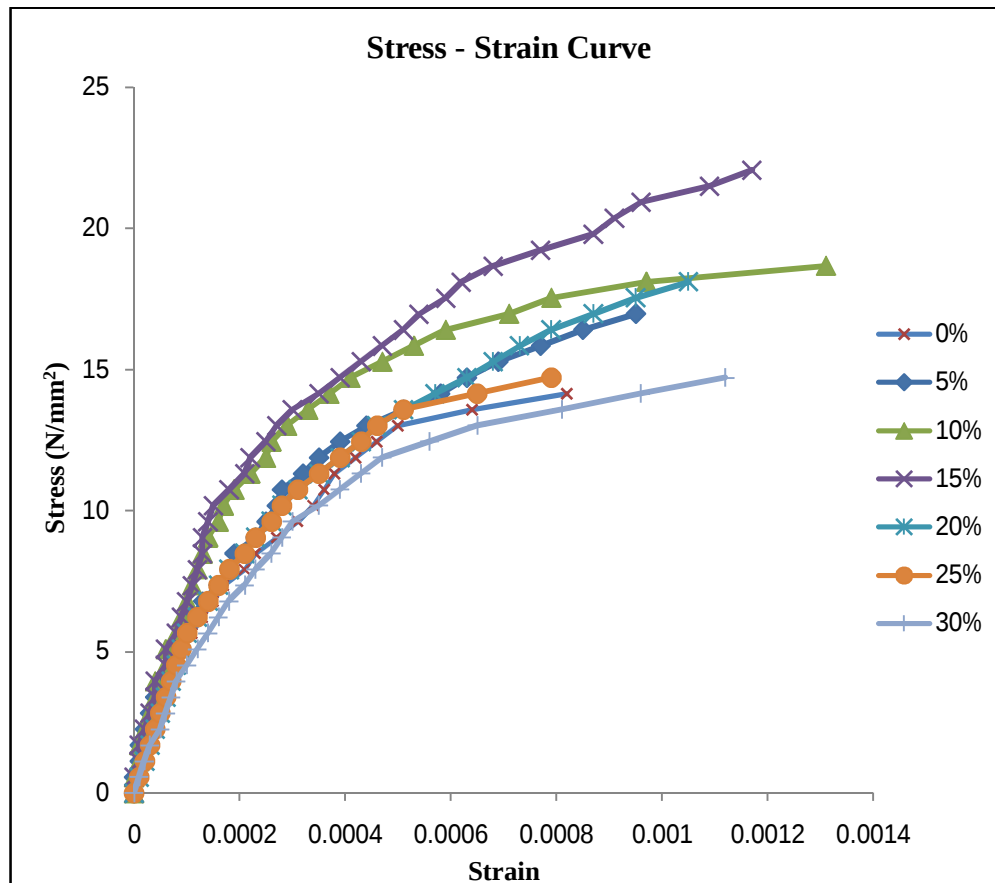


Fig. 6. Stress – Strain Relationship for different percentage of SCBA

From the above Fig.6, it is observed that at room temperature with the replacement of cement with bagasse ash up to 15% the modulus of elasticity has increased. Beyond 15%, replacement of cement with bagasse ash the modulus of elasticity has decreased gradually.

The modulus of elasticity has increased by 5.11%, 9.58% and 12.71 % for replacement of 5%, 10% and 15% and decreased by 1.89%, 8.20% and 12.03%, for replacement of 20%, 25% and 30% respectively.

VI. CONCLUSION

From the above experimental study the following conclusions can be drawn;

- The results shows that the SCBA concrete up to 15% cement replacement have significantly higher compressive strength, Split tensile strength and Modulus of elasticity at all the temperatures when compared to the normal concrete.
- It is found that the cement could be advantageously replaced with SCBA up to a maximum limit of about 10% to 15%.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

- Maximum increase of Compressive strength were observed, when concrete exposed to 200°C for a duration of 2hrs, at all percentage replacement of cement with SCBA.
- At room temperature, maximum increase of Compressive strength, Split tensile strength and Modulus of elasticity is obtained for 15% replacement of cement with bagasse ash.
- With the increase in the temperature, at all the percentage replacements of cement with bagasse ash, split tensile strength of concrete has found to be decreased.
- For all percentage of SCBA the rate of decrease in strength is gradual when concrete specimens were exposed to a temperature of about 600°C.
- Concrete exposed to 800°C the specimens were found to be in milky white colour and having more cracks on their surface.
- Partial replacement of cement by SCBA increases workability of fresh concrete; therefore use of super plasticizer is not essential.
- From the study, it can be concluded that concrete produced with bagasse ash as replacement to cement can resist elevated temperature better when compared to normal concrete.
- It can be concluded from the above result that 15% replacement of cement by bagasse ash is the best percentage to produce the efficient concrete and it can reduce the cost of construction.

REFERENCES

- [1] Abdolkarim Abbasi and Amin Zargar, "Using Bagasse Ash in Concrete as Pozzolan", Middle-East Journal of Scientific Research 13 (6): 716-719, 2013.
- [2] Amrita Kumari, Prof. Sheo Kumar, "Experimental Study on Partial Replacement of Cement by Sugarcane Bagasse Ash", IJIRSET, Vol. 4, Issue 7, July 2015.
- [3] Cordeiro G.C.Toledo Filho RD, Tavares LM and Fairbairn EMR. "Effect of Calcination Temperature on the pozzolanic activity of Sugarcane Bagasse Ash", Construction and Building Materials 23 (2009). 3301-3303.
- [4] Dharanidharan S, Rajkumar L, Karthick B, "An Experimental Study on Mechanical properties of concrete Using Sugarcane Bagasse Ash", International Journal Of Engineering Science and Research Technology, ISSN: 2277-9655, March 2015.
- [5] Ganesan K, Rajagopal K, and Thangavel K, "Evaluation of bagasse ash as supplementary cementitious material" Cement and Concrete Composites, 29 (2007) 515 – 524.
- [6] IS 10262: 2009, "Indian Standard, recommended guidelines for concrete mix designs", Bureau of Indian Standard, New Delhi.
- [7] IS 12269: 1987, "Specification for 53grade ordinary Portland cement", Bureau of Indian Standard, New Delhi.
- [8] IS 383: 1970 "Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete", Bureau of Indian Standards, New Delhi.
- [9] IS 2386: 1963, "Methods of test for aggregates for concrete", Bureau of Indian Standards, New Delhi.
- [10] IS 516: 1959, "Methods of Tests for strength of concrete", Bureau of Indian Standards, New Delhi.
- [11] IS 456: 2000, "Code of practice for plain and reinforced concrete" (fourth revision), Bureau of Indian Standard, New Delhi.
- [12] Jayaminkumar A. Patel, Dr. D. B. Raijiwala, "Experimental study on compressive strength of concrete by partially replacement of cement with sugar cane bagasse ash", IJERA, ISSN: 2248-9622, Vol. 5, Issue 4, (Part -7) April 2015, pp.117-120.
- [13] Lakshmi Priya K and R. Ragupathy, "Effect of Sugarcane Bagasse Ash on Strength properties of Concrete", IJRET, Vol: 05 Issue: 04, April 2016.
- [14] Lavanya M.R, Sugumaran.B and Pradeep.T, "An Experimental study on the compressive strength of concrete by partial replacement of cement with sugarcane bagasse ash", IJEI, Volume 1, Issue 11 December 2012, PP: 01-04.
- [15] Mrs.U.R.Kawade, Mr.V.R.Rathi, Miss Vaishali D. Girge, "Effect of use of Bagasse Ash on Strength of Concrete", ISSN: 2319-8753 Vol. 2, Issue 7, July 2013.
- [16] Nuntachai Chusilp, Chai Jaturapitakkul, Kraiwood" Utilization of bagasse ash as apozzolan material in concrete" Construction and Building Materials 23 (2009) 3352–3358.
- [17] Rattapon Somna, Chi Jaturapitakkul, Pokpong Rattanachu and Wichian Chalee, " Effect of ground bagasse ash on mechanical and durability properties of recycled aggregate concrete", Materials and Design 36 (2012) 597-603.
- [18] Srinivasan R, K.Sathiya, "Experimental Study on Bagasse Ash in Concrete", International Journal for Service Learning in Engineering, Vol. 5, No. 2, PP: 60-66, 2010.
- [19] Varun Teja K, P. Purna Chandra Sai, Sk. Umami Salma, "Behaviour of Ternary Blended Concrete with SCBA & SF When Exposed to Elevated Temperature's and Cooled with Different Regimes", IJIRSET, Vol. 4, Issue 11, November 2015.