Strength and Durability of OPC-Fly Ash-Sugarcane Bagasse Ash Blended Concrete

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Abstract— **Concrete is an important and commonly used man made construction material, which can be considered to have better strength and durability characteristics. Nowadays, ternary blended concrete is achieving popularity by overcoming the disadvantages of binary blended concrete. The present work deals with study of fresh properties, strength, and durability of ternary blended concrete with Fly Ash and Sugarcane Bagasse Ash (SCBA). Concrete mix is designed for strength of 30MPa. The study is limited to ternary blended concrete with 30% replacement of cement with Fly Ash and remaining cement is replaced with 5%, 10%, 15%, 20%, 25 %and 30% of SCBA in different mixes. The tests on hardened concrete were destructive in nature which includes compressive test, flexural strength, modulus of elasticity, split tensile strength and impact resistance test. Durability tests are carried for which the specimens were exposed to the respective chemical condition for a time period of 56 and 90 days. Durability study includes sulphate resistance, and bulk diffusion. From the above tests conducted, the cement replaced by 30% fly ash and 10% SCBA showed better results. From the results, it can be concluded that the SCBA is a valuable pozzolanic material and it can be potentially be used as a partial replacement for cement. Up to 10% SCBA in concrete can be considered as the optimum replacement level with the addition of 30% fly ash by weight of cement.**

Keywords— Sugarcane Bagasse Ash;FlyAsh;strength;durability

I. INTRODUCTION

The infrastructure need of our country is increasing day by day and with concrete as a main constituent of construction material and the safety of systems is to be ensured. Cement is a prime ingredient for concrete based construction but its over usage leads to environmental pollution. Therefore, the cement demand needs to be reduced to decrease environmental pollution from cement industry. Moreover the unit cost of concrete can also be reduced by partial replacement of cement with some industrial by product. In the past, many researchers used different popular industrial by-products such as fly ash, ground granulated blast-furnace slag, silica fume, and natural pozzolans, such as calcined shale, calcined clay or metakaolin in conjunction with portland or blended cement to improve the properties of ordinary concrete. 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. Today researches all over the world are focusing on ways of utilizing agricultural wastes as a source of raw materials for the construction industry. Sugar-cane bagasse is one such fibrous waste-product of the sugar refining industry, along with ethanol vapor. Bagasse ash mainly contains aluminium ion and silica. Nowadays, ternary blended concrete is achieving popularity by overcoming the disadvantages of binary blended concrete. The present work deals with study of fresh properties, strength, and durability of ternary blended concrete with Fly Ash and Sugarcane Bagasse Ash (SCBA). The objective of the present study is to design a control mix blended with 30% fly ash as cement replacement and also to arrive at an optimum dosage of SCBA in fly ash blended concrete by studying the fresh properties, hardened properties and durability properties for different percentage of SCBA 5, 10, 15,20,25 and 30% by weight of cement.

II. EXPERIMENTAL PROGRAMME

A. Materials

Detailed tests were conducted in the laboratory to evaluate the required properties of the individual materials. Properties of the constituent materials were tested as per the methods prescribed by the relevant IS codes.

***Cement*:** Ordinary Portland cement (OPC) confirming to IS 12269 (53 Grade) was used for the experimental work. Laboratory tests were conducted on cement to determine specific gravity, fineness, standard consistency, initial setting time, final setting time and compressive strength. The results are presented in Table 1.

TABLE I PROPERTIES OF CEMENT

Sl No.	Particulars	Values
1	Grade	OPC 53 grade
2	Specific Gravity	3.13
3	Fineness	4%
4	Standard Consistency	30.5%
5	Initial Setting Time	90 mins
6	Final Setting Time	270 mins

Fly Ash: Low-calcium, Class F, dry fly ash with specific gravity 2.08, obtained from the silos of Tuticorin Thermal Power Plant in Tamil Nadu is to be used as binder. 70% of flyash was passing through the 45µm sieve. Wet sieve analysis was conducted as per IS 3812(part1):2003[11].

Sugarcane Bagasse Ash**:** SCBA was collected during the cleaning operation of a boiler operating in the Sakthi Sugar Factory, located in the city of Sathyamangalam, Tamilnadu. Specific gravity of SCBA was determined as 2.16.The fineness was determined as 18%.

Fine aggregate**:** Manufactured sand having fineness modulus 3.06 and specific gravity 2.50 was used as fine aggregate. Tests are conformed to IS: 383-1970[12].

Coarse aggregate**:** Crushed stone aggregate of size between 20mm and 4.75mm and specific gravity 2.80 and fineness modulus 7.09 was used as coarse aggregate. Tests are conformed to IS: 383-1970[12].

Water**:** Clean drinking water available in the college water supply system was used for mixing and preparing alkaline liquid.

Superplasticizer: The superplasticizer used was Ceraplast-300.

MIX PROPORTION

Mix proportion was arrived through various trial mixes. The grade of concrete prepared for the experimental study was M30. The proportion used in the investigation, after necessary adjustments made on the trial mixes, is shown in Table 2.The mix designation is shown in Table 3.

TABLE 2. MIX PROPORTION

Grade of concrete	**Mix Proportion**			
M30	C	FA	CA	w/c
	1	1.786	3.21	0.43

TABLE 3. MIX DESIGNATION

Mix Designation	**Cement(%)**	**Fly Ash (%)**	**SCBA (%)**
C	100	0	0
FB0	70	30	0
FB5	65	30	5
FB10	60	30	10
FB15	55	30	15
FB20	50	30	20
FB25	45	30	25
FB30	40	30	30

C. Methods

Workability: The workability was assessed by determining the compacting factor as per the **IS 1199:1959** [13] specification.

Compressive strength**:** In the present study, compression tests were carried out on 100mm cube specimens at ages of 3, 7, 28, 56 and 90 day as per **IS:516-1959** [14]**.** The reported strength values are average of three test results.

Flexural Strength Test**:** Flexural strength test was conducted as per **IS: 516-1959**.The standard beam specimens of size 500 x 100 x 100 mm were used for this investigation. Two-point loading was applied and breaking load was noted at 28th day.

Split Tensile Strength Test: The split tensile test is a well known indirect test used for determining the tensile strength of concrete. Test was carried out on concrete cylinder of size 150mm×300mm as per IS 5816:1999 specification.

Modulus of Elasticity: The modulus of elasticity was determined by subjecting cylinder specimen having 150 mm diameter and 300 mm height to uniaxial compression as per IS 516:1959 specification.

Impact Resistance:Impact resistance is one of the important attributes of concrete. According to this test, impact resistance is characterized by a measure of the number of blows in a repeated impact test to achieve a prescribed level of distress.

Sulphate Resistance Test**:** The test was conducted based on ASTM C 452-02[15] test method. After 56 days and 90 days of 20000ppm magnesium sulphate exposure, 100mm cube specimens were tested for compressive strength.

Bulk diffusion test: The test proposes to assess the chloride attack on concrete specimen by measuring the depth of chloride penetration into the concrete specimen. In this test, cylinder of 100 mm diameter and 200mm length was used as test specimen. After 7 days of water curing, the concrete specimens were exposed to 1.8 Molar NaCl solution for 56 days and 90 days. After 56 days and 90 days of exposure the specimens were split by applying splitting tensile force. To the split face, 0.1 Molar Silver Nitrate ($AgNO_3$) solution was sprayed to observe the colour changes ie, up to the penetrated depth of chloride ion, a white precipitation will form and thus the depth of chloride ions can be found out.

II. RESULTS AND DISCUSSIONS

This session provides a summary of the experimental results and endeavours to draw some conclusions. The test result covers the workability, mechanical properties and durability properties geopolymer concrete with and without steel fibres.

Workability: The results showed that the workability was decreasing wiyh increasing percentage of SCBA. Inorder to get workability concrete with SCBA needs higher water content than a concrete without SCBA.The probable reason may be higher specific surface area of SCBA and its lower density resulting in a higher porosity which requires higher water demand.

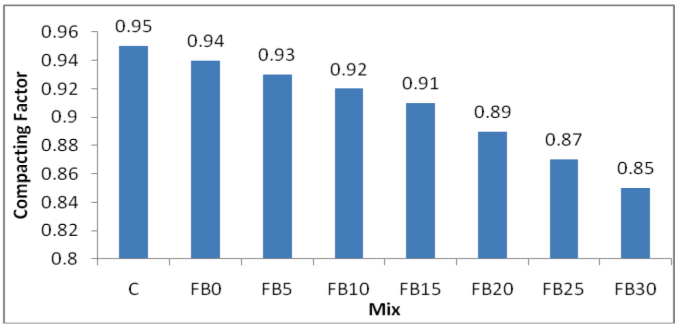

Fig. 1 Compacting factor variation

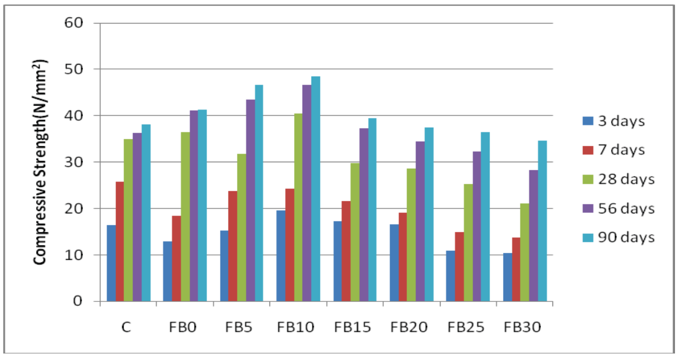

Fig. 2 Compressive strength variation for different mixes

Compressive Strength test: For each mix, three cube specimens of size 150mm×150mm×150mm were tested for compressive strength. Cubes were tested after 3, 7, 28, 56 and 90 days of water curing. The control mix showed greater early age strength (3 days and 7 days) compared to the mix with 30% replacement of fly ash only, but its long term strength was higher than the control mix. When fly ash is added to concrete, fly ash plays the dual role of fine aggregate and cementitious component. In the earliest stages of curing, it acts as an inert fine aggregate, but in the presence of moisture, the silica and alumina of the fly ash gradually react with the calcium hydroxide released in the hydration of Portland cement. As the fly ash combines with the calcium hydroxide, it slowly converts it to calcium silicate and calcium aluminate binders. This chemical reaction occurs much more slowly than the hydration of Portland cement. Because the reaction proceeds slowly, the full potential strength of fly ash concrete may not be attained at early ages. The ternary mixes up to 15% replacement level showed strength comparable to the control mix at early ages. The mixes up to 20% replacement level showed higher early age strength compared to FB0.Among the ternary mixes FB10 showed better strength compared to control mix and FB0 at all ages. The higher replacement of cement by SCBA reduces cement content of mixture which in turn results in reduction of hydration reaction. Also the higher content of SCBA resulted in a higher water requirement, making water unavailable for hydration of cement and reducing hydration and compressive strength development. The increase in compressive strength of FB10 is 13.46% than the control mix and 9.89% than FB0 after 28 days. The increase in compressive strength in the presence of 10% SCBA may be both due to physical and chemical processes. It may lead to the segmentation of large capillary pores. It may introduce a large number of nucleation sites in the system for rapid precipitation of hydration products.

Flexural strength Test: The maximum flexural strength is obtained for ternary mix with 10% SCBA replacement. The mixes up to 25% replacement level showed a greater flexural strength than the control mix. It may due to large pozzolanic reaction and improved interfacial bond between paste and aggregates.Fig 3 shows the variation of flexural strength for different mixes.

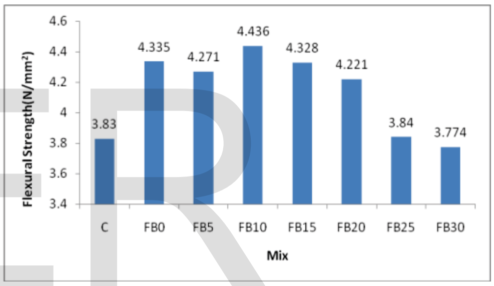

Fig.3 Variation of flexural strength for different mixes

Split Tensile Strength Test:Fig. 4shows the result of split tensile strength of all mixes after 28 days of water curing. The maximum tensile strength is obtained for FB10 mix with 10% replacement of SCBA and the result is comparable to FB0 mix. The mixes up to 25% replacement level showed greater strength than the control mix. The greater strength may due to grain and pore refinement of concrete resulted from very high fineness of particles and pozzolanic reaction of ashes

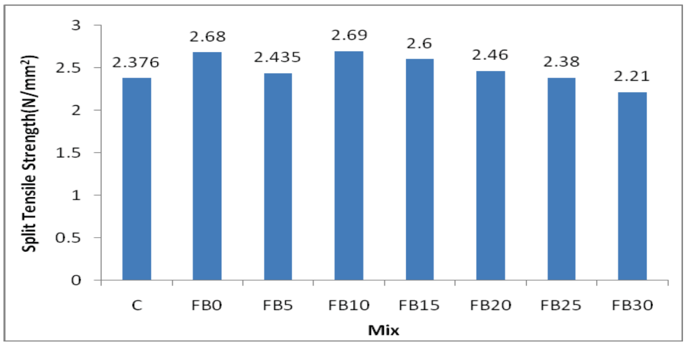

Fig.4 Variation of Split tensile strength for different mixes

Modulus of elasticityThe Young's modulus values are obtained from stress-strain diagram obtained by carrying out the test on 150mm × 300mm cylinders. Fig 5 shows the

Modulus of elasticity after 28 days of water curing. The maximum strength for Modulus of elasticity was obtained for FB10 mix and minimum Modulus of elasticity for FB30 mix. From the figure, as the percentage of SCBA increases, modulus of elasticity reduced.

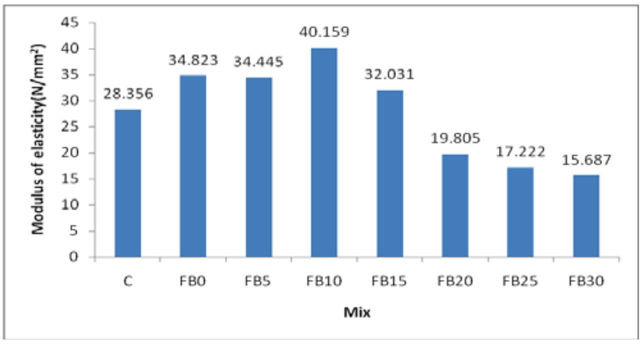

Fig.5 Variation of Modulus of Elasticity for different mixes

Impact Resistance:Dynamic energy absorption or strength is called as impact resistance and is one of the major attributes of concrete. Here the repeated impact test or drop weight test was conducted to determine the number of blows to achieve a prescribed level of distress of the specimen. To determine the impact resistance of concrete the first crack and ultimate failure of specimens were determined. The resistance offered by the concrete was found out using this test. Fig 6 shows the variation of impact resistance for different mixes.

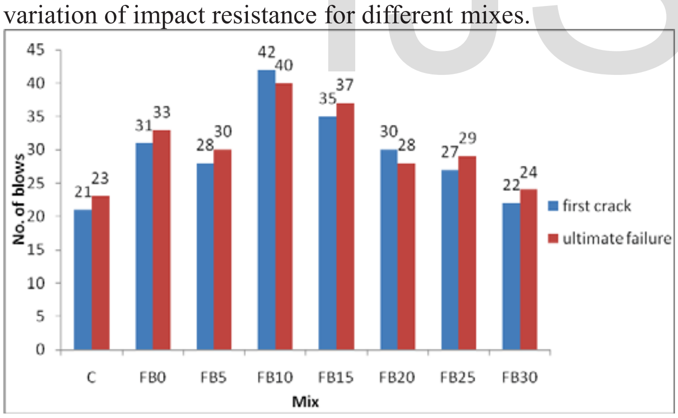

Fig.6 Variation of Impact Resistance for different mixes

Sulphate Resistance Test: Calcium, Magnesium, Aluminium, and Ammonium of the sulphate salt affects the type and the severity of the attack. Therefore, use of supplementary cementitious materials together with cement results in the improvement of sulphate resistance of concrete.

The concrete cubes were found visually intact after immersion of cubes in 20,000 ppm (52gm $MgSO_47H_2O$ in one litre solution) sulphate solution for 56 and 90 days after 7 days of water curing. After exposure to sulphate solution, white patches were found on the surface of concrete specimens. This white precipitation layer was significant in control specimens (with cement as the only binder).Fig 7 shows the compressive strength variation of mixes after 56 days of water curing and 56 days of sulphate exposure.Fig 8 shows the compressive strength variation of mixes after 90 days of water curing and 90 days of sulphate exposure.

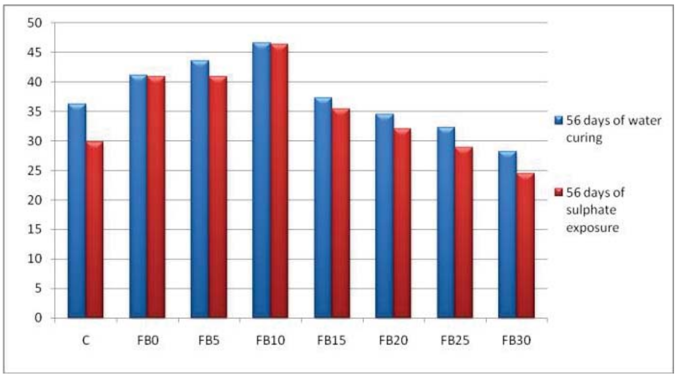

Fig.7 Compressive strength variation of mixes after 56 days of water curing and 56 days of sulphate exposure

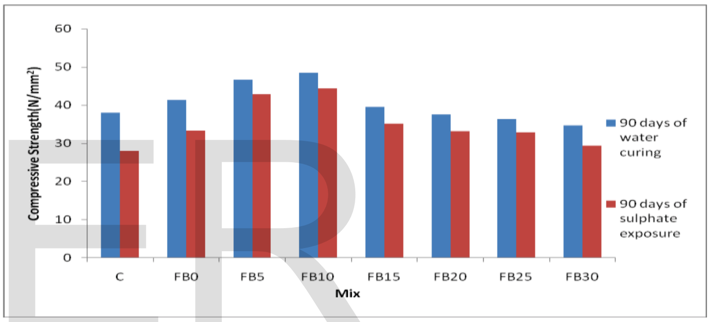

Fig .8 Compressive strength variation of mixes after 90 days of water curing and 90 days of sulphate exposure

From this study it is observed that when the concrete specimen is immersed in 20000 ppm solution the cube compressive strength of all the mixes get reduced as the duration of sulphate exposure increases. The reduction in strength may be due to the reaction of sulphates with free lime and calcium aluminate compounds in concrete to form gypsum and ettringite that can cause internal disruption of concrete by volume increase of paste. From the results it is clear that compared to all other mixes the strength loss is maximum for the control mix. The rate of strength loss was found to be minimum for FB10 mix for 56 day and 90 day sulphate exposure.

Sulphuric acid attack test:The strength loss of cubes in 3% sulphuric acid solution was determined by the cube compressive strength.7 day water cured cube specimens of size 150mm×150mm×150mm, after being exposed to sulphuric acid solution for 56 and 90 day were tested for various mixes. Fig 9 shows the compressive strength variation after 56 days of water curing and 56 days of acid exposure and Fig 10 shows the compressive strength variation after 90 days of water curing and 90 days of acid exposure.

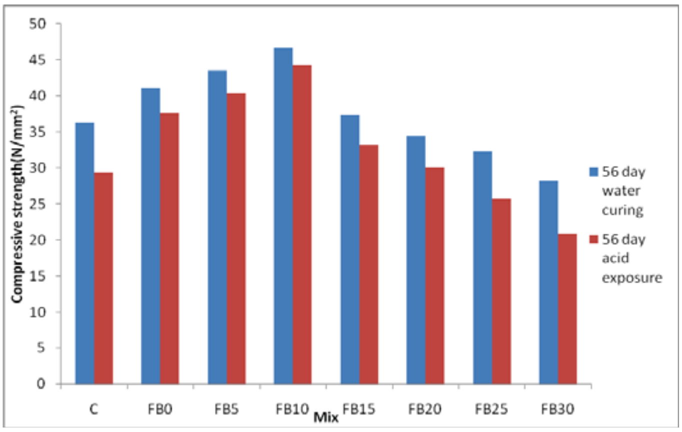

Fig.9 Compressive strength variation of mixes after 56 days of water curing and 56 days of acid exposure

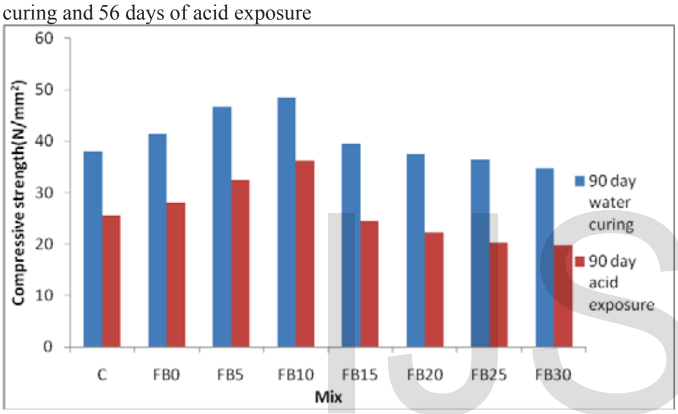

Fig.10 Compressive strength variation of mixes after 90 days of water curing and 90 days of acid exposure

Bulk diffusion test: The test was carried out to determine the depth of penetration of chloride ions by spraying 0.1M $AgNO_3$ solution to the split face of the cylinder exposed to 1.8 M NaCl solution, a white precipitation will form up to the penetrated depth of chloride ion. After 7 days of water curing the concrete specimens were exposed to NaCl solution for 56 days and 90 days. The depth of penetration of chloride ions is measured in millimetre. Fig 11 shows the variation of depth of penetration of chloride ions for various mixes.

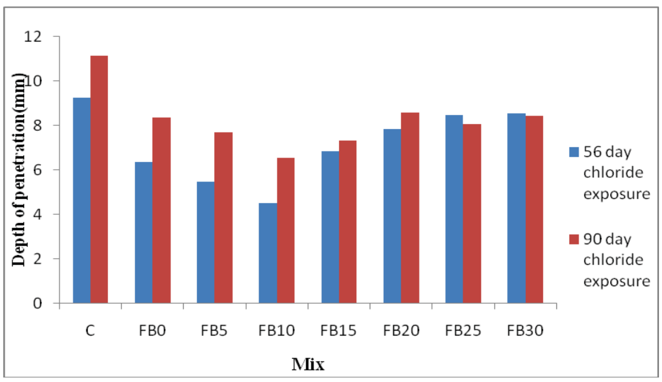

Fig 11 Variation of depth of penetration of chloride ions for various mixes.

IV. CONCLUSIONS

From the above experimental works following conclusions could be drawn:

- Addition of SCBA is found to decrease the workability.The mix having fly ash content have workability comparable with the control mix.
- The mechanical properties such as compressive strength, flexural strength, modulus of elasticity, split tensile strength, impact resistance gets improved due to the addition of 10% SCBA with optimum dosage of 30% fly ash.
- Ternary mixes up to 15% replacement level showed higher early age strength comparable to control mix which is greater than FB0.
- Replacement of SCBA up to 20% showed higher early age strength than FB0.
- FB10 showed higher strength compared to FB0 and control mix at all ages.
- The resistance to sulphate attack, chloride attack gets improved in FB10.

References

- Abdol, K. A., and A. Zargar (2013) Using Bagasse Ash in Concrete as Pozzolan, *Middle-East Journal of Scientific Research*, 6,716-719.
- Deepa, A. S., A. K. Verma, K. B. Prakash (2012) The Need of Ternary Blended Concrete, *Indian Journal of Applied Research*, 2, 80-81.
- Guruvaiya, G., S. R. Mercy and V. Sheela (2013) A Study On Optimizing The Strength Of Concrete Using Green Materials, *International Journal of Engineering Research & Technology*,2,70-73.
- Hailu, B. and A. Dinku (2012) Application of Sugarcane Bagasse Ash as a Partial Replacement material, *School of Civil and Environmental Engineering and Technology, Addis Ababa University*.
- Hemanth, V and H. B. Balakrishna (2013) Flexural Behaviour of Reinforced Concrete Beams with Partial Replacements of Slag Sand with River Sand and Fly Ash with Cement, *International Journal of Emerging Trends in Engineering and Development*,5,75-85.
- Kawade, U. R.,V. R. Rathi and D. Vaishali (2013) Effect of Use of Bagasse Ash on the Strength of Concrete, *International Journal of Innovative Research in Science,Engineering and Technology*,2,2997-3000.

- Lavanya, M. R., B. Sugumaran and T. Pradeep (2012) An Experimental Study on the Compressive Strength of Concrete by Partial Replacement of Cement with Sugarcane Bagasse Ash, *International Journal of Engineering Inventions*, 1,01-04.
- Nutachai, C., C. Jaturapitakkul and K. Kiattikomol (2009) Utilization of Bagasse Ash as a Pozzolanic Material, *Construction and building materials,*23,3352-3358.
- Parande, A. K., S. Karthick, T. Ravi Kumar and M. S. Karthikeyan (2011) Utilization of Agroresidual Waste in Effective Blending in Portland cement, *International Scholarly Research Network.*
- Saifullah , I., M. Nasir, S.M.K. Uddin, M.A. Hossain and M.H. Rashid (2011) Experimental and Analytical Investigation of Flexural Behavior of Reinforced Concrete Beam, *International Journal of Engineering & Technology,***11,**146-153.
- Sarath, C.K. (2011) Contribution of Fly Ash to the Properties of Mortar and Concrete,International Journal of Earth Sciences and Engineering,**04,**1017-1023
- Semsi, Y and H. S. Arel (2012) Effect of Fly Ash Fineness on the mechanical Properties of Concrete*, Indian Academy of Sciences*,**37**,389-403
- Srinivasan, R. and K. Sathiya (2010) Experimental Study on Bagasse Ash in Concrete, International *Journal for Service Learning in Engineering***, 5, 60**-66