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Study on Flexural and Shear Behaviour of Ternary Blended Steel Fibre Reinforced Concrete Beams

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***Abstract*— Cement which is one of the ingredients of concrete plays a great role, but it is most expensive. Therefore requirements for economical and more environmental-friendly cementing materials have extended interest in other cementing material that can be used as a partial replacement of the normal Portland cement. Considerable efforts are being taken worldwide to utilize natural waste and byproduct as supplementary cementing materials to improve the properties of cement concrete. Rice Husk Ash (RHA) and Sugarcane Bagasse Ash (SBA) are such materials. RHA is byproduct of paddy industry. RHA is a highly reactive pozzolanic material produced by controlled burning of rice husk. Sugarcane bagasse is a fibrous waste product of the sugar refining industry, along with ethanol vapour. SBA mainly contains aluminium ion and silica.**

In the present study, a preliminary investigation was carried out to study the mechanical properties of Ternary Blended Cement (TBC) concrete of M30 grade obtained by partially replacement of Ordinary Portland Cement (OPC) by SBA and RHA in varying proportion from which optimum percentage was obtained. Based on the result obtained from the preliminary study, investigations were carried out to find the mechanical properties of Ternary Blended Steel Fibre Reinforced Concrete (TbSFRC) adding steel fibre at various percentages as 0%, 0.25%, 0.5%, 0.75% and 1% by the volume fraction on M30 grade concrete. Also detailed investigation has been conducted to study the flexural and shear behavior of TbSFRC beams in terms of ultimate load, first crack load, energy absorption and ductility characteristics.

Keywords—Ternary blended concrete, Bagasse ash, Rice husk ash, Steel fibre, Ternary blended steel fibre reinforced concrete

I. INTRODUCTION

Concrete is one of the most commonly used construction material in the world. Every year concrete consumes 12.6 billion tons of natural raw materials. This huge consumption rate of natural raw materials creates several ecological problems. More economical and environmental-friendly supplementary cementing materials have extended interest in partial cement replacement materials. Ground granulated blast furnace slag (GGBS), pulverized fly ash, silica fume, metakaolin, etc have been successfully used for this purpose. Bagasse ash is a by-product from sugar industries, which is burnt to generate power required for different activities in the factory. The burning of bagasse leaves bagasse ash (BA) as a waste. Bagasse ash has pozzolanic property and it can be used as a cement replacement material. With the country's plan to boost the sugar production to over 3 million tons by the end of 2015, the disposal of the bagasse ash will be of a serious concern.

Rice Husk Ash (RHA) is an agricultural waste product, and how to dispose of it is a problem to waste mangers. While Concrete today has assumed the position of the most widely used building material globally. The most expensive concrete material is the binder (cement) and if such all important expensive material is partially replaced with more natural, local and affordable material like RHA will not only take care of waste management but will also reduce the problem of high cost of concrete and housing. There is an increasing importance to preserve the environment in the present day world. RHA from the parboiling plants is posing serious environmental threat and ways are being thought of to dispose them. This material is actually a super pozzolan since it is rich in Silica and has about 85% to 90% Silica content. When blended with Portland cement in appropriate amounts it will enhance the strength and durability of the concrete.

Replacement of Portland cement by sugarcane bagsse ash and rice husk ash on weight basis seems to be very suitable for Indian construction industry due to abundant availability of bagasse ash and metakaolin at cheap cost.

The main objectives of the study are:

- To develop M30 grade concrete mix
- To find the effect of bagsse ash and rice husk ash in concrete and to fix the optimum percentage in concrete replacing the cement.
- To study the effect of steel fibre on the flexural and shear behavior of Ternary blended concrete
- To compare the load deflection behaviour, first crack load, crack pattern and failure mode, ductility index, energy absorption, and ultimate load of TbSFRC beams with control beams.

II. PRELIMINARY INVESTIGATION

The aim of preliminary investigation was to obtain the optimum percentage of bagasse ash and rice hisk ash. For the same purpose the material properties of the constituent materials were first determined. Then the fresh and hardened properties of Ternary Blended concrete were determined and optimum percentage of bagasse ash and rice husk ash was determined.

A. Mix design

M30 mix was designed as per IS 102262: 2009 and the mix proportion was obtained as 1:1.419:2.421. Water-cement ratio was 0.4. Eight mixes were made namely TBC0, TBC1, TBC2, TBC3, TBC4, TBC5, TBC6, TBC7 and TBC8 to determine mechanical properties and properties of fresh concrete. TBC0 is considered as control mix and other seven mixes TBC1, TBC2, TBC3, TBC4, TBC5, TBC6, TBC7 and TBC8 contained bagasse ash and rice husk ash at different percentages. Mix designation and mix proportion are given in the Table 1 and Table 2.

TABLE 1: MIX DESIGNATION FOR DIFFERENT MIXES

Sl.No.	Mix designation	SCBA (%)	RHA (%)	OPC (%)
1	TBC0	0	0	100
2	TBC1	0	30	70
3	TBC2	5	25	70
4	TBC3	10	20	70
5	TBC4	15	15	70
6	TBC5	20	10	70
7	TBC6	25	5	70
8	TBC7	30	0	70

TABLE 2: MIX PROPORTION

Mix designation	Cement (kg/m³)	Bagasse ash (kg/m³)	Rice husk ash (kg/m³)	Fine aggregate (kg/m³)	Coarse aggregate (kg/m³)	Water (kg/m³)	Water cement ratio
TBC0	29.91	0	0	42.4	72.4	11.9	0.4
TBC1	20.9	0	9	42.4	72.4	11.9	0.4
TBC2	20.9	1.5	7.5	42.4	72.4	11.9	0.4
TBC3	20.9	3	4	42.4	72.4	11.9	0.4
TBC4	20.9	4.5	4.5	42.4	72.4	11.9	0.4
TBC5	20.9	4	3	42.4	72.4	11.9	0.4
TBC6	20.9	7.5	1.5	42.4	72.4	11.9	0.4
TBC7	20.9	8.9	0	42.4	72.4	11.9	0.4

Based on the test results of hardened properties of shown in Table 3, TBC5 mix of 20% bagasse ash and 10% rice husk ash was selected as optimum mix which was used for the further investigation.

TABLE 3: SUMMARY ON HARDENED PROPERTIES OF TBC MIX

Mix designation	Cube compressive strength (N/mm²)	Flexural strength (N/mm²)	Splitting tensile strength (N/mm²)
TBC0	39.56	3.43	3.25
TBC1	20.44	2.09	2.05
TBC2	23.11	2.56	2.26
TBC3	24.44	2.70	2.48
TBC4	29.33	2.91	2.69
TBC5	34.67	3.41	3.11
TBC6	31.56	3.20	3.04
TBC7	30.22	2.67	2.83

III. EXPERIMENTAL INVESTIGATION

The main aim of the experimental investigation was to study the ductility and energy absorption capacity of Ternary Blended Steel Fibre Reinforced concrete beams. The influence of steel fibre on first crack load, load deflection behaviour, cracking pattern, ultimate load were studied. In the present study the effect of steel fibre with a volume fraction of 0.5% in the flexural and shear behaviour of TBC beams were studied.

A. Mix proportion of Ternary Blended Steel Fibre Reinforced Concrete (TbSFRC)

Ternary Blended Steel Fibre Reinforced Concrete (TbSFRC) was obtained by adding crimped steel fibres having diameter 0.5mm, length 25mm and aspect ratio 50 with a volume fraction of 0.5% added to the TBC mix after finding the optimum percentage of combined bagasse ash and rice husk ash. Table 4 shows the mix details and Table 5 shows the mix proportion of TbSFRC mix.

B. Specimen details

The specimens are standard cubes of 150mm side, cylinders of diameter 150mm and 300mm height, beams of size 500x100x100mm and large beams of size 1200x100x150mm. Details of number of specimens are given in the Table 6

TABLE 4: MIX DESIGNATION OF TbSFRC MIX

Sl.No.	Mix designation	Volume fraction (%)	Steel fibre (%)
1	TbSFRC	0.5	0
2	TbSFRC1	0.5	0.25
3	TbSFRC2	0.5	0.5
4	TbSFRC3	0.5	0.75
5	TbSFRC4	0.5	1

TABLE 5: MIX PROPORTION OF TbSFRC MIX

Mix designation	TbSFRC	TbSFRC1	TbSFRC2	TbSFRC3	TbSFRC4
Cement (kg/m³)	42.1	29.5	29.5	29.5	29.5
Bagasse ash (kg/m³)	0	8.4	8.4	8.4	8.4
Rice husk ash (kg/m³)	0	4.2	4.2	4.2	4.2
Fine aggregate (kg/m³)	59.7	59.7	59.7	59.7	59.7
Coarse aggregate (kg/m³)	101.9	101.9	101.9	101.9	101.9
Water (kg/m³)	16.8	16.8	16.8	16.8	16.8
Water cement ratio	0.4	0.4	0.4	0.4	0.4
Volume fraction (%)	0.5	0.5	0.5	0.5	0.5
Steel fibre (kg/m³)	0	0.889	1.788	2.676	3.566

TABLE 6: SPECIMEN DETAILS

Sl. No.	Specimen	Property	Size	Numbers
1	Cube	Compressive strength	150x150x150mm	72
2	Cylinder	Split tensile strength	300mm height and 150mm diameter	24
3	Beam	Flexural strength	500x100x100mm	24
4	Large beam	Flexural and shear behaviour	1200x100x150mm	20
Total number of specimens				140

C. Preparation and casting of specimens

For each mix of TBC and TbSFRC mix, six concrete cubes of size 150x150x150mm were casted for compressive strength test, and for TBC mix three cylinders of 150mm diameter and 300mm height for splitting tensile strength test and three beams of size 500x100x100mm for flexural strength test were casted.

To study the flexural crack pattern and shear crack pattern, total of 20 reinforced concrete beams of 1200x100x150mm were casted. For each type, four reinforced concrete beams were casted. The beam details are shown in Table 7. The reinforcement details of the beams for flexural and shear are shown in Fig. 1 and Fig. 2 respectively.

Concrete was mixed in a concrete mixer in the laboratory. All the specimens were vibrated with a mechanical vibrator and were stored at temperature of about 23^{0}C in the cast in room. They were demoulded after 24 hours and were cured in a water curing tank. After 28 days, the large beams were white washed for easy detection of cracks.

TABLE 7: BEAM DETAILS

Sl.No.	Steel Fibre (%)	Flexural behaviour	Shear behaviour
1	0	F0TbSFRC	S0TbSFRC
2	0.25	F1TbSFRC	S1TbSFRC
3	0.5	F2TbSFRC	S2TbSFRC
4	0.75	F3TbSFRC	S3TbSFRC
5	1	F4TbSFRC	S4TbSFRC

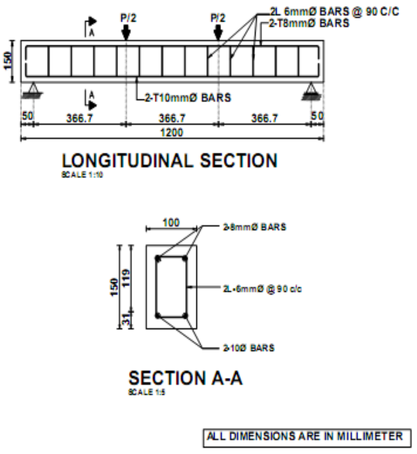

Fig.1 Reinforcement details (flexural)

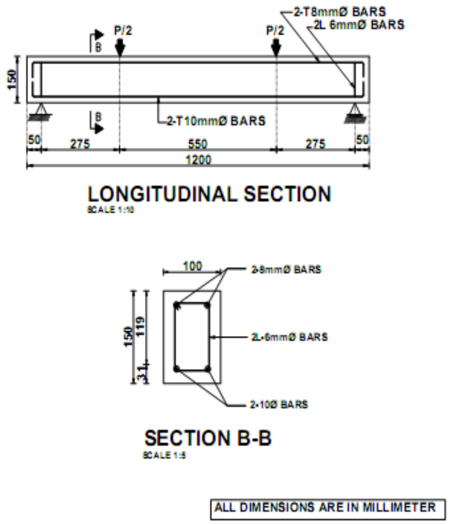

Fig. 2 Reinforcement details (shear)

D. Tests on specimens

Testing of concrete specimens plays an important role in controlling and confirming the quality of concrete. Thus the experimental investigation carried out was divided into three main headings. They are as follows:

1. Study on workability
   - Slump test
   - Compacting factor test
2. Study on strength
   - Compressive strength test
   - Splitting tensile strength test
   - Flexural strength test
3. Study on flexural and shear behaviour of RC beam

E. Test setup for studying flexural and shear behaviour

A two point flexural bending system is adopted for the tests. Specimens were tested in a loading frame of 2000kN (200t) capacity with an effective span of 1100mm. Load cell of 200kN capacity with a least count of 1kN is used to measure the applied load. Fig. 3 shows the test setup. The load was increased in stages till the failure of the specimen and at each stage of lading the following observations was made.

1. First crack load
2. Displacement at mid span
3. Ultimate load
4. Crack pattern and failure mode

Fig. 3: Test setup for RC beam

IV. RESULTS AND DISCUSSION

Fresh properties and compressive strength of TbSFRC mix were tested. The detailed investigation on the effect of steel fibre on the flexural and shear behaviour was carried out.

A. Test on fresh properties of TbSFRC specimens

Studies conducted on fresh properties are given in Table 8. From the results obtained it can be concluded the workability decreases with percentage increase of steel fibre.

B. Cube compressive strength of TbSFRC mix

From test results, it was observed that compressive strength generally increased with increase in steel fibre percentage in fibre content. Maximum compressive strength was found for TbSFRC3. The test results are shown in Table 9.

TABLE 8: TEST RESULTS ON FRESH PROPERTIES OF TbSFRC MIX

Sl.No.	% of Steel Fibre	Mixes	Workability	
			Slump (mm)	*Compacting factor*
1	0	TbSFRC	32.9	0.85
2	0.25	TbSFRC1	29	0.83
3	0.5	TbSFRC2	28	0.81
4	0.75	TbSFRC3	26	0.78
5	1	TbSFRC4	25	0.75

TABLE 9: TEST RESULTS ON COMPRESSIVE STRENGTH ON TbSFRC MIX

Sl. No	Mixes	Compressive strength (N/mm^2)	
		7days	*28 days*
1	TbSFRC	26.15	33.42
2	TbSFRC1	27.38	36.32
3	TbSFRC2	31.38	38.02
4	TbSFRC3	32.90	40.05
5	TbSFRC4	29.80	38.27

C. Test results on Beams

1) First crack load and ultimate load

The test results show that the steel fibre addition increased the first crack load and ultimate load of TbSFRc beams. The first crack load and ultimate load increased with the increase of steel fibre percentage and the maximum was obtained for1% of steel fibre content. The test results for flexural beam specimens are tabulated in Table 10 and that for shear beam specimens are shown in Table 11.

TABLE 10: TEST RESULTS FOR FIRST CRACK AND ULTIMATE LOAD OF FLEXURAL BEAM SPECIMENS

Sl. No	Beam Designation	First Crack Load (kN)	Ultimate Load (KN)	Deflection at Ultimate load (mm)
1	F0TbSFRC	12	46	9.8
2	F1TbSFRC	15	49	10.2
3	F2TbSFRC	16	52	10.5
4	F3TbSFRC	20	54	10.9
5	F4TbSFRC	21	55	11.2

TABLE 11: TEST RESULTS FOR FIRST CRACK AND ULTIMATE LOAD OF SHEAR BEAM SPECIMENS

Sl. No	Beam Designation	First Crack Load (kN)	Ultimate Load (kN)	Deflection at Ultimate Load (mm)
1	SSSFRC	10	32	3.8
2	S1SSFRC	12	33	3.9
3	S2SSFRC	15	36	4.1
4	S3SSFRC	17	40	4.5
5	S4SSFRC	19	42	4.9

2) Load deflection behaviour

Mid span deflection was noted at every 2kN load increment. Defection of all specimens was observed to increase considerably after the first crack was observed. Deformations corresponding to each increment of load for all specimens were noted. The load deflection graph for all the flexural specimen is shown in Fig. 4 and shear specimens is shown in Fig. 5.

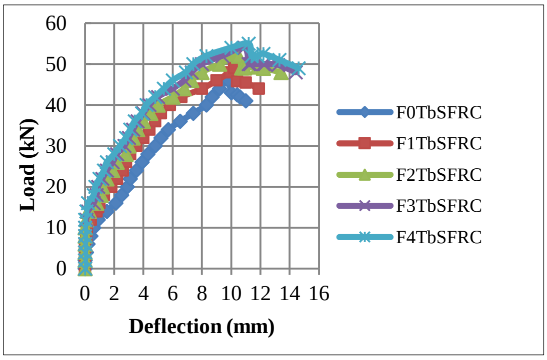

Fig. 4: Influence of fibre on the flexural behaviour of beam under loading

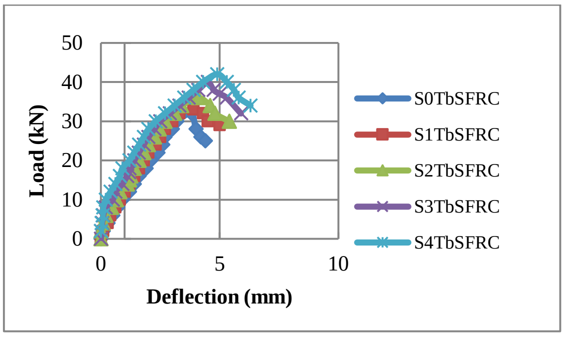

Fig. 5: Influence of fibre on the shear behaviour of beam under loading

3) Crack pattern and failure mode

The typical crack pattern of the flexural beam specimen is shown in Fig. 6 and shear beam specimen are shown in Fig.7

Fig.6 Typical crack pattern of flexural beam specimen

Fig.7 Typical crack pattern of shear beam specimen

4) Energy absorption capacity

In general energy absorption capacity of a given material could be obtained from area under the load deflection plot of the specimen. Concrete will be effective in resisting the load until the formation of the first crack. At this stage concrete is relieved of its tensile stress and steel becomes effective at the cracked section. Energy absorbed at ultimate load can be obtained by calculating the area under load deflection curve up to the ultimate load. Energy absorption capacity of all flexural specimens is shown in Table 12 and shear beam specimen is shown in Table 13.

TABLE 12: ENERGY ABSORPTION CAPACITY FOR ALL FLEXURAL BEAM SPECIMENS

Sl. No	Beam Designation	Energy absorption (kNm)
1	F0TbSFRC	0.277
2	F1TbSFRC	0.344
3	F2TbSFRC	0.390
4	F3TbSFRC	0.432
5	F4TbSFRC	0.463

TABLE 13: ENERGY ABSORPTION CAPACITY FOR ALL SHEAR BEAM SPECIMENS

Sl. No	Beam Designation	Energy absorption (kNm)
1	S0TbSFRC	0.069
2	S1TbSFRC	0.078
3	S2TbSFRC	0.093
4	S3TbSFRC	0.115
5	S4TbSFRC	0.139

From the results obtained it can be seen that energy absorption capacity was maximum for 1% steel fibre content.

5) Ductility index

Ductility is an important parameter in the design of structures subjected to large deformation. Ductility is the property of the material by which it undergoes large deformation without any reduction in load carrying capacity. Generally ductility of members subjected to flexure can be obtained from ductility factor. Table 14 shows the ductility index for flexural specimens and Fig. 8 shows a graphical representation of ductility index for all flexural specimens.

TABLE 14: DUCTILITY INDEX FOR FLEXURAL SPECIMENS

Sl. No	Beam Designation	Ductility index
1	F0TbSFRC	1.27
2	F1TbSFRC	1.63
3	F2TbSFRC	1.83
4	F3TbSFRC	2.00
5	F4TbSFRC	2.14

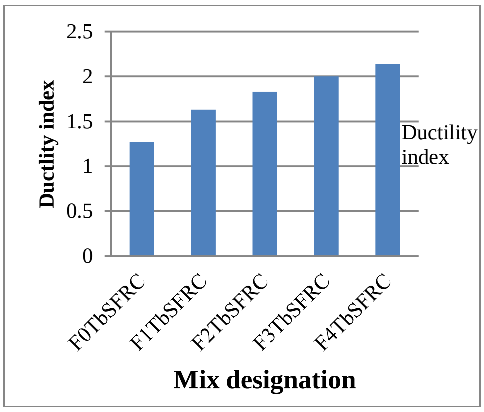

Fig. 8 Ductility index for all flexural specimens

V. CONCLUSION

The major conclusions of my thesis work are presented below:

- Ternary Blended concrete with 20% bagasse ash and 10% rice husk ash showed satisfactory flexural strength when compared with the control mix and thus it was selected as the optimum mix.
- The addition of steel fibres in Ternary Blended concrete further enhances the compressive strength of concrete. There is a further increase in the compressive strength by 16.55% with the addition of steel fibre. The percentage of steel fibre for this being 0.75%.
- Workability of concrete mixes containing steel fibre is low due to problems in mixing and compacting. Therefore the inclusion of fibre percentage should be limited and should not be more than 0.75%.
- Addition of steel fibre in TBC mix improved all the hardened properties of the mix.
- The load deflection characteristics of the Ternary Blended steel fibre reinforced concrete beam specimens were better than control mix.
- Addition of steel fibre improved the energy absorption capacity and ductility of TbSFRC beams.
- Three dimensionally distributed steel fibres helped in arresting the cracks and also reduced the spacing and width of the cracks.
- The steel fibre volume fraction of 0.5% significantly improves the overall performance of Ternary Blended Steel fibre reinforced concrete beams.
- The Ternary Blended Steel Fibre Reinforced concrete beam exihibit greater reduction in crack width at all load levels when compared to the control beam.

REFERENCES

[1] A.A. Boateng and D.A. Skeete (1990), Incineration of Rice Hull for use as a Cementitious Material: The Guyana Experience, Cement and Concrete Research, Vol. 20, pp. 795-802.
[2] AbdolkarimAbbasi and Amin Zargar, (2013), Using bagasse ash in concrete as as pozzolan, Middle -East Journal of scientific research, 13(6): 716-719.
[3] Aigbodion, V.S., S.B.Hassan, T.Ause and G.B.Nyior (2010), Potential utilization of solid waste (Bagasse Ash), Journal of Minerals and Materials Characterization and Engineering, 9(1): 67-77.
[4] Ajay Goyal, A.M. Anwar, Hattori kunio, and OGATA Hidehiko (2007), Properties of Sugarcane Bagasse Ash and its potential as Cement – pozzolana Binder. Ain Shams University – Faculty of Engineering – Department of Structural Engineering.
[5] Amin,N (2011), Use of Bagasse ash in cement and its impact on the mechanical behaviour and chloride resistivity of mortor, Advances in cement Research,23(2): 75-80.
[6] Arpana (2004), Rice Husk Ash-Admixture to concrete, 2nd National conference on Advances in concrete Technology, February 26-27,pp. 93-98.
[7] Bentur A and Mindess S (1990), Fibre Reinforced Cementitious composities, Elsevier Science Publishers Ltd, London.
[8] Bui DD, Hu J, and Stroeven P (2005), Particle size effect on the strength of rice husk ashblended gap-graded Portland cement concrete, Cement and Concrete Composites, 27 pp 357-66.
[9] Dwarakanath H.V and Nagaraj T.S (1991), Comparative study of predictions of flexural strength of steel fibre concrete, ACI Materials Journal, Nos.73-76.
[10] E.M., B.B.Americano, G.C.Cardeiro, T.P.Paula, R.D.Toledo and M.M.Silvoso (2010), Cement replacement by sugarcane bagasse ash: CO2 emissions reduction and potential for carbon credits, Environ 91(9): 1864-71.
[11] Ganesan, K., K.Raja gopal and K.Thangavel (2007), Evaluation of bagasse ash as supplementary cementitious material, Cement and Concrete Composites, 29: 515-524.
[12] Pajak M. and T. Ponikiewski (2013), Flexural behavior of self-compacting concrete reinfoeced with different types of steel fibers, Construction and Building Materials, 47, 397-408.
[13] Paya J et. Al (2002), Sugarcane Bagasse Ash studies on its properties for reusing in concrete production, Journal of Chemical technology and Biotechnology.
[14] Rama Rao G.V, and Seshagiri Rao M.V (2004), High Performance Concrete Mix Design using Husk Ash As Mineral Admixture, proceedings of natural conference on materials and structures, Warangal, pp. 65-70.
[15] Rama Samy and Dr. Viswa. S (2009), Durable To Properties Of Rice Husk Ash Concrete, ICI journal Indian concrete institute pp. 41-50.
[16] Rukzon.S and Chindaprasirt.P (2008), Strength and carbonation model of rice husk ash cement mortar with different fineness, Journal of materials in Civl Engineering , ISSN 0899-1561.
[17] R. Srinivasan and K.Sathiya (2010), Experimental study on Bagasse ash in Concrete, International Journal of Service Learning In Enginerring.
[18] Shukla.A, Singh. C.K and Sharma A. K (2011), Study of properties of concrete by partial replacement of ordinary Portland cement by rice husk ash.
[19] Sumrerng Rukzon and Prinya Chindaprasirt (2012), Utilization of Bagasse ash in High Strength Concrete, Journal of Materials and Design.
[20] Vandewalle L (2000), Cracking behavior of concrete beams reinforced with combination of ordinary reinforcement and steel fibres, ACI Materials and Structures, Nos. 227-232.