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Bagasse ash utilization as viscosity modifying agent to produce an economical self compacting concrete

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Abstract: In this research for viscosity modifying agent in place of an expensive admixture, the usage of bagasse ash is assessed. Super Plasticizer values are kept constant and Bagasse ash is added in different proportions and a study is carried out on its hardened and fresh properties. Results indicated to the possibility of utilizing bagasse ash to develop an economical SCC. Different mixes of concrete (including Control Concrete and Blended mixes) displayed the slump flow values in the range of 313 mm to 675 mm, L-box ratio from 0.9 to 0.8 and flow time from 1.4 seconds to no flow were obtained for the fresh state of concrete. Two mixes out of five met the requirements recommended by the European guide lines for making self-compacting concrete (EFNARC). Self-compacting blended mixes of bagasse ash at 28 and 56 days showed comparable results with control concrete with a cost reduction of 43.23%. The outcomes of this research will positively affect the commercial construction scenario of Pakistan and bring economical and environmental safety benefits as bagasse ash is locally available free of cost, which is wasted in millions of tons every year without any usage in construction.

Keywords: *Admixtures, Bagasse Ash, Construction, Economical, Self-Compacting Concrete (SCC)*

1. Introduction:

With the passage of time as the technology of structural engineering is getting advanced, accordingly advancement is coming in modern design of reinforced concrete. Desired strength, durability and homogeneity is achieved by compaction of normal concrete which is the major portion of the structure. It doesn't matter how well it is produced how well its quality is if it is not compacted to an adequate amount its desired ultimate strength will not achieve. Untrained labor is used for compaction of concrete and the monitoring of compaction is also hectic. Hence the endorsed techniques do indicate the quality of concrete which is being poorly compacted on site.

Furthermore vibrations can cause white 'finger syndrome' and noise pollution is created at the site of construction. Previous researches have shown that even a desired degree of compaction cannot achieve homogenous and uniform concrete (Wallevik and Nilsson, 1998). For a much extended period the option of removing the compaction from concrete was in the mind of the structural engineers.

"Self-Compacting Concrete (SCC) doesn't require any inner or outer vibration for the compaction". According to European Project Group (2005), SCC can be well-defined as "the concrete which under its self-weight has the ability to flow and compact, it fills the formwork without the necesity of any surplus compaction and maintains uniformity even in condense reinforcemnent forms".

SCC was first proposed in 1986 by Okamura at Kochi University of Technology, Japan (Barbhuiya and Nimityongskul, 2005). Basic principle of SCC was introduced by these pioneers. During casting of concrete it offers the best solution for maintaining quality of concrete. Compaction, time saving, reduced labour cost and conserving energy are the advantages. The need for remedial measures can be reduced by improving the quality of surface finish.

SSC has very eye-catching properties in the fresh state and also hardened state that is why its practice is spreading in the entire world. SCC use will provide to us a very industrialized production. Manual compaction of normal concrete will be replaced by it and it will give health and safety to construction sites due to its self-automated placing technology but this concrete requires more intensive care and handling then ordinary concrete.

2. Experimental Investigation:

2.1 Materials:

The materials along with specifications, which were used for this experimental program, are summarized below.

2.1.1 Cement:

Cement utilized was Ordinary Portland Cement (OPC) Askari Cement , Type I ASTM C150-04.

2.1.2 Fine aggregate:

Natural sand (quarry site at Nizampur, Khairabad) was used for mixing all samples. The sieve analysis was carried out under ASTM C136-01. The specific gravity and the percentage absorption was calculated under ASTM C128-01.

2.1.3 Coarse aggregate:

Crushed limestone (quarry site at Bassay, Peshawar) having upper bound of 20 mm was used as coarse aggregate. Two different nominal sizes were mixed, namely, 10 mm and 20 mm. The mixing ratio of 10 mm to 20 mm aggregates was 1:1 by weight. The sieve analysis was carried out under ASTM C136-01. The specific gravity and the percentage absorption were determined under ASTM C127-01.

2.1.4 Superplasticizers:

A conventional high range water reducing admixture, named Ultra Super Plast 310 (two % by weight of binder for control concrete and blended mixes) was used to accomplish greater workability and placeability..

The superplasticizer for viscosity is commercially branded as Sika Viscocrete 1 and was used for making the control concrete.

2.1.5 Bagasse Ash:

Bagasse is a waste material of sugarcane industry and the ash produced by burning it is termed as bagasse ash. For this study, bagasse ash was obtained from Premier Sugar Mill, Mardan. Los Angles Abrasion machine was used for the grinding purpose. Bagasse ash was ground by giving total 2500 revolutions. The resulting ash was then sieved through sieve no. 100. Retained ash was discarded and ash passing through this sieve was again ground for total 500 revolutions. The ash was further sieved through sieve no. 200 and the passing ash was used for experimental purpose. The ash was tightly packed in the polythene bag and was stored in dry place before use. The quantity of ash required for the mix samples as calculated in the mix design was recovered from this process. Bagasse ash was used as "5, 10, 15 and 20" percent by weight of cement. Each percentage was further combined with the 2% quantity of superplasticizer for flowability.

2.2 Specimen Designation:

Abreviations were used to designate specimens, namely SCC-CM and SCC-5B e.t.c. In case of SCC-CM, SCC stands for Self Compacting Concrete and CM refers to the Control Mix made by combining VMA with it.

Likewise, in SCC-5B, 5B refers to the percent dosage of the Bagasse ash by weight of binder content. The Specific codes listed above characterizes mix having 5 percent of Bagasse ash. A photograph of sample is shown in Fig 2.1

Table 2.1: Design of Concrete Mixes

Mix Design	W/C ratio	Water kg/m^3	Cement kg/m^3	Bagasse ash kg/m^3	Fine aggregate kg/m^3	Coarse aggregate kg/m^3	Ultra Super Plast 310 (% by Weight of binder)	Viscocrete (% by Weight of binder)
SCC-CM	0.45	225	500	-	875	750	2	2
SCC-5B	0.43	225	550	25	963	750	2	-
SCC-10B	0.41	225	550	50	963	750	2	-
SCC-15B	0.39	225	550	75	963	750	2	-
SCC-20B	0.37	225	550	100	963	750	2	-

Figure 1: Designation of Samples

2.3 Mix Proportions:

A Number of 5 mixes were casted including one control concrete mix and 4 mixes with varying quantities of bagasse ash. Mix design Matrix for experiment is given in Table 2.1.

2.4 Preparation and casting of specimens:

From each concrete mix, nine 150 mm x 300 mm cylinders were casted.

These cylinders were casted without vibration and were used for finding 7, 28 and 56 days strength. All the moulded specimen were kept in covering of plastic sheets after casting for 24 ± 8 hours. After 1 day the specimen were removed from cylinder moulds and were shifted to moist curing tubs for 25°C until required for testing.

2.5 Testing of specimens:

One must keep in mind that there are no strict and standard methods for testing SCC. The test procedures stated here are descriptive. They are core methods, which are derived specially for SCC by EFNARC 2002 guidelines.

Following points should be taken in care whileperforming these tests:-

- There hasn’t been a single test that can measure all the three properties of SCC namely fillability, passability and segregation resistance which are compulsory for SCC.
- The site performance and results have no relation.
- For SCC No clear guidance can be imparted because data isn’t very precise.
- Advise of identical tests is recommended.
- For an upper bound of 20mm aggregate size these tests are advised.

2.5.1 Slump Flow Test:

Procedure is derived from EFNARC guidelines. A good idea of Fillabilty can be stated by this test. Note that this test can not be compared with the actual behavior of concrete on site,however it can be used to find the consistency of ready mixed concrete supply on site very effectively.

To carryout the test we need 6L of concrete aproximately. Moisten the smooth floor surface on which concrete is to be placed. Then moisten the inner surface of slump cone. Decisively Held the slump cone. Fill the cone with concrete. Remove any surplus concrete from base of the slump cone and don’t do tamping. Concrete is allowed to flow out freely by raising the cone vertically. Meaure the diameter of the concrete spreaded in perpendicular directions. Calcultae the average of two diameters in units of mm.

2.5.2 Deducing Results:

As per EFNARC guidelines (EFNARC,2005) slump flow from 650 mm to 800 mm is recommended. The fillabilty of SCC increases under its own weight when slump flow values are increased. For SCC lower bound for SCC slump flow value is 650mm. Concrete mixes might segregate with slump flow value of 700mm and higher and the concrete mix is inevitably to have lesser flow when slump value is 500mm or lesser.

2.5.3 L - Box Test:

Procedure is derived from EFNARC guidelines. For SCC filling and passing ability can be found by this test. One can visually detect if there is an instability in the mix.Geometry of this apparatus is that its shape is L – type, a rectangular box with a movable gate at the other end and having strips of steel fitted. Fill the vertical section with concrete with lower gate closed. Then lift the gate and allow the concrete to flow through the horizontal section . Measure the height of the concrete at the end of the plan section when the flow stops. This height is expressed as aatio of that remaining height in the vertical section. When at rest it represents the slope of concrete.

The test is carried out with 14 L of concrete approximately. Set the L- box on a level and smooth surface. Check whether the sliding gate is in a condition to be opened and closed on will and smoothly. Moisten the inside surface of the assembly. Fill the vertical section of concrete (completely) and leave it for 1 minute to settle. Lift the sliding gate and allow the concrete to flow out in the plan section. Measure the heights H2 and H1 when the flow is stopped. Measure the blocking ratio(H2/H1). Within 5 minutes complete the entire test.

2.5.4 Deducing Results:

If the H2/H1 = 1 then concrete will flow freely and stay horizontal when static. Hence, for good flow of concrete the value of blocking ratio must be near to one. The EFNARC guide (EFNARC 2005) gives a range of 0.8 to 1.0 for this ratio. Furthermore, one can visually analyse the aggregate blocking behind the reinforcement bars.

2.5.5 V-Funnel Test At T_{5min} :

Procedure is derived from EFNARC guidelines. Measuring flowability and segregation resistance of SCC is the purpose of this test. The test was developed in Japan. This test is invented to measure flow but flow has no effect on its properties. It is effected by other concrete properties.. The test procedure is described as follows.

The test can be carried out by approximately 12 L of concrete. Moisten the inside surfaces of assembly and set it gently on the floor. Place a bucket beneath the assembly and close the trap door. Fill the assembly (completely) and don’t do any temping . Open the trap after 10 seconds when the assembly is filled. Let the concrete to flow under its own weight. Record the time of discharge via stop watch immediately after opening the trap outlet. Perform the entire test within 5 minutes. After measuring the flow time refill the funnel immediately to measure the flow at T5minutes with trap door closed. Without any temping fill the whole apparatus. The trap door is opened 5 minutes after the second fill of the funnel and the concrete is allowed to flow out under gravity. Record the time of discharge via stop watch with trap door opened, it will give the flow time at $T_{5minutes}$.

2.5.6 Deducing Results:

If flow is of higher magnitude flow time will be smaller. Recommended flow time is 10 secs for SCC. As per EFNARC guide (EFNARC 2005), the minimum and maximum time of flow are 6 and 12 seconds respectively and the recommended time for V-funnel at T 5minutes is 3 seconds (maximum).

3. Results and Discussion:

3.1 Self compacting concrete fresh state properties:

To determine fresh SCC charcteristics, various test such as slump flow test, L-box test, V-funnel test (6-12 Sec) and V- funnel T5minutes were performed. The results of these tests are given and the results are discussed as follows:

3.1.1 L - Box test results:

Result values varied from 0.9 to 0.7 for first 3 mixes (SCC-CM, SCC-5B,SCC-10B) and passed with convenience in between the steel bars (SCC-15B,SCC20B) . The last two mixes were very viscous and got stucked in the assembly. The results are given in Table 3.1 and Figure 3.1 shows the behavior of the Slump flow with bagasse ash variation.

Table 3.1. L-Box test results

Mix	**L – box H_2/H_1(0.8–1)**
SCC-CM	0.9
SCC-5B	0.8
SCC-10B	0.7
SCC-15B	0
SCC-20B	0

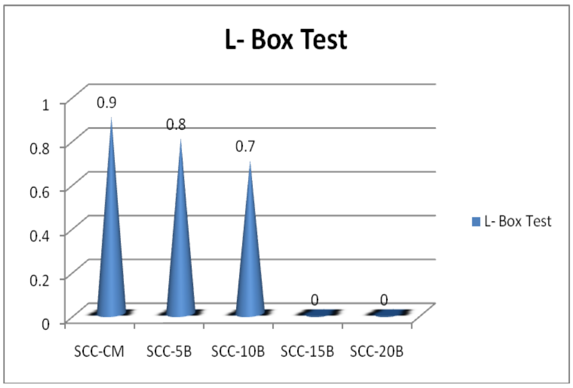

Fig.3.1. L – box flow values vs Blended mix of bagasse ash

3.1.2 Slump flow test results:

Slump flow crossed both the lower bound and upper bound of SCC and was found to be between 313 mm to 675 mm . Only Control mix and SCC-5B qualified to be with in the permissible limits of SCC. From the results it is clear that keeping the superplastcizer value constant, the values of slump flow kept on decreasing as the bagasse ash was added with each of the blended mixes.

Table 3.2. Slump Flow Test Results

Mix	**Average slump (650–800 mm)**
SCC-CM	675
SCC-5B	612
SCC-10B	474
SCC-15B	425
SCC-20B	313

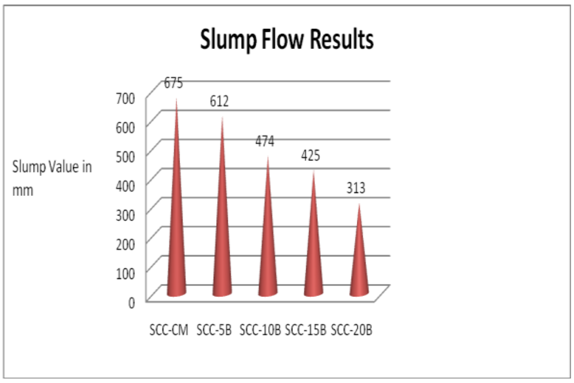

Fig. 3.2. Slump flow vs Blended mixes of bagasse ash

3.1.3 V - Funnel at T5minutes test results:

SCC-CM qualified the limits of this test. SCC-5B and SCC-10B showed close values with the EFNARC guidelines. SCC-15B and SCC 20B were not in the permissible limits of EFNARC. Table 3.3 shows the results for this test. Figure 3.3 shows the graphical analysis of the values.

Table 3.3 V - Funnel at T5minutes Test Results

Mix	**V - Funnel at $T_{5\ min.}$ (0– +3 sec)**
SCC-CM	0.5
SCC-5B	1.4
SCC-10B	6
SCC-15B	Stucked
SCC-20B	Stucked

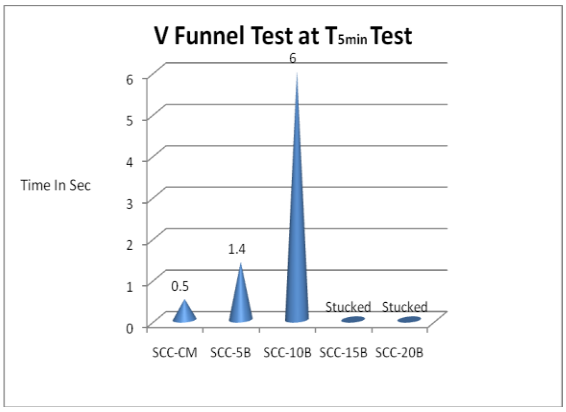

Fig. 3.3. V Funnel time 5 min vs Blended mix of bagasse ash

3.1.4 V - Funnel test results:

SCC-CM and SCC-5B showed values close to EFNARC range. SCC-10B, SCC-15B and SCC-20B were not in the permissible limits of SCC. Results indicate that quantity of baggase ash added to each blended mix increased the viscosity of concrete. Table 3.4 Shows the results for this test. Figure 3.4 shows the graphical analysis of the values.

Table 3.4 V - Funnel Test Results

Mix	**V - funnel(6–12 sec)**
SCC-CM	5.3
SCC-5B	7
SCC-10B	14
SCC-15B	18
SCC-20B	Stucked

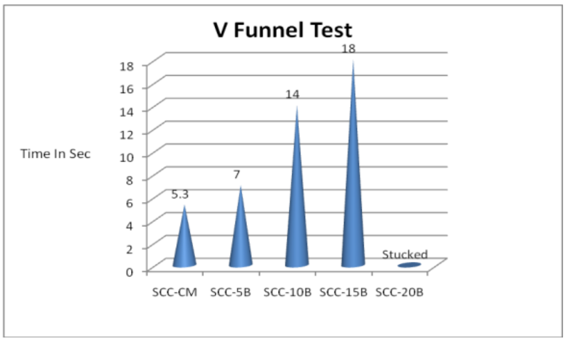

Fig. 3.4. V Funnel time-vs Blended mixes of bagasse ash

3.2 Compressive strength of SCC:

The results for compressive strength for 7,28 and 56 days are displayed in Table 3.5 . The graphs are displayed in (Fig. 3.5 to Fig. 3.6).

Highest compressive strength of 30 MPa after 56 days was developed by SCC-15B. Two mixes SCC-10B and SCC-15B displayed incremented strengths in contrast to control concrete. More quantity of bagasse ash causes a reaction between calcium hydroxide generated from the hydration of OPC, which leads to the formation of additional C-S-H gel and results in higher density and strength. 20B2SP mix had shown the decrease in strength, although it had a higher quantity of bagasse ash. Neglecting the fact that whether or not the mixes are with in SCC limits, higher compressive strengths were attained after 7 28 and 56 days both in control concrete and blended mixes(keeping 2% SuperPlasticizer dosage).

Table 3.5. Compressice strength (7, 28 and 56 Days)

Specimen	Compressive Strength of Cylinders					
	7 days		28 days		56 days	
	Psi	Mpa	Psi	Mpa	Psi	Mpa
SCC-CM	2933	20	3480	24	3793	26
SCC-5B	2823	19	3237	22	3512	24
SCC-10B	3121	22	3561	25	3878	27
SCC-15B	3389	23	3991	28	4302	30
SCC-20B	2679	18	3438	24	3713	26

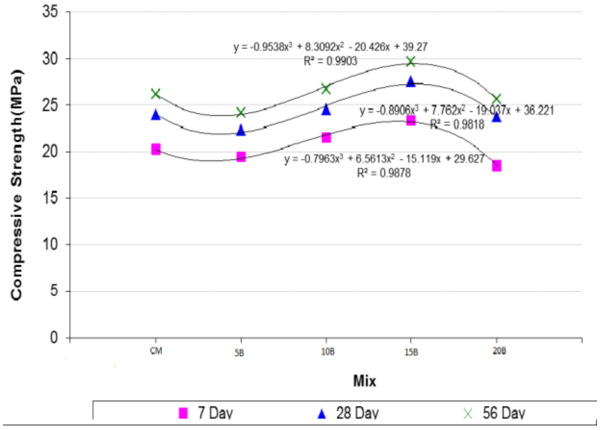

Fig. 3.5. Trend Line for Compressive strengths (Mpa)

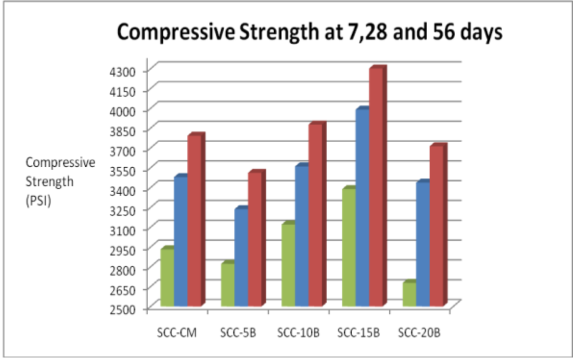

Fig.3.6. Compressive strength Comparison by Bar Charts(Psi)

3.3 Hardened density of SCC:

Control concrete achieved maximum density of 2382 kg/m3 with 2 percent of superplasticizer for flowability. Densities are given in Table 3.6 .The results in graphs are given in Figure 3.7. Density reached its peak value for SCC-15B but after this point a fall in the graph was observed due to decrease in powder content.SCC-15B achieved the maximum density which contained 2 percent of dosage of superplasticizer.

The fall in the graph when 15% B.A value was exceeded, disclosed that bagasse ash filled the pores entirely leaving no gaps when 15% B.A was used. This is due to the fact that the density is a function of specific gravity of bagasse ash when other parameters such as cement and water contents are kept constant. B.A replaced the cement after filling all the pores in concrete ,hence the density decreased because its specific gravity is lower then the value of cement.

Table 3.6. Density at 1 day of Cylinders

Specimen	For 7 days (kg/m³)	For 28 days (kg/m³)	For 56 days (kg/m³)	Average (kg/m³)
SCC-CM	2377.9	2388	2383	2382
SCC-5B	2410.7	2435	2432	2425
SCC-10B	2450.2	2480.2	2481.1	2470
SCC-15B	2523	2520.9	2527.9	2523
SCC-20B	2483.8	2474.7	2479.8	2494

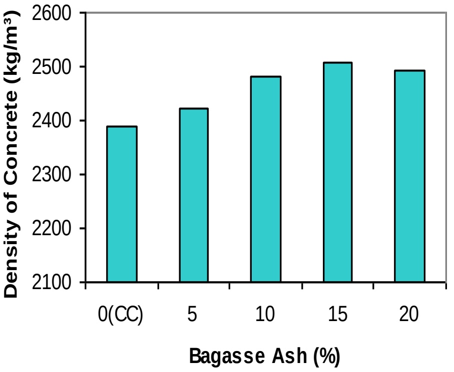

Fig. 3.7. Density of hardened concrete at 1 day vs Blended mixes of bagasse ash

3.4 Cost analysis:

Table. 3.7 give the calculation. (As of February 2013) cost of materials was obtained from the market. Those mixes were selected which exhibit good strength results and were close to the limits of EFNARC guidelines .SCC-CM and SCC-15B were selected for cost analysis.

Table. 3.7. Cost Analysis

Material	Rate per kg (rupees)	Control Concrete (SCC-CM)		SCC with bagasse ash (SCC-15B)	
		Quantity (kg)	amount (rupees)	Quantity (kg)	amount (rupees)
Cement	9	43	387	43	387
Coarse aggregate	0.198	75	14.85	75	14.85
Sand	0.105	65	6.825	65	6.825
Superplasticizer (Ultra Super Plast 310)	50	0.86	43	0.86	43
Superplasticizer (Viscocrete)	400	0.86	344	-	-
Bagasse ash	Free of cost	-	-	6.42	-
Total	-	-	795.675	-	451.675
Percent reduction in cost = 43.23					

4. Conclusions and Recommendation:

4.1 Conclusions:

Analyzing the experimental results obtained from the fresh and hardened concrete tests carried out in this study. Conclusions are stated below:

- It is feasible to develop an economical SCC via B.A. By adding some percentage of B.A with the constituents of concrete and superplasticizer, economical SCC can be made. Water to binder ratio has to be decreased while using bagasse ash as a viscosity enhancing material.
- By increasing different percentages of bagasse ash with the same content of cement, SCC achieved the slump flow values from 313 mm to 675mm, L - box values from 0 to 1, V - funnel vales from 0 to 18 seconds and V - funnel at T5minutes values from 0 to 6 seconds.The Best mix was Control Concrete and blended mix with 5% bagasse ash which showed results in the range of EFNARC. SCC-15B and SCC-20B were out of EFNARC limits.It is advised that before casting, a check shall be made on SCC fresh properties.

- The compressive strength of SCC using bagasse ash was even more than the control concrete. Reason is the better densification of the concrete mix.
- Compared with SCC-CM the mix containing 15 percent of bagasse ash and 2 percent of superplasticizer dosage proved to be the best SCC. The compressive strength achieved by these mixes was 30 MPa.
- As far the cost analysis is concerned, 43.23 percent reduction in cost was observed between SCC-CM and SCC-15B.
- To keep the environment of Pakistan clean B.A should be consumed in SCC.

4.2 Sugesstions and recommendations:

Pakistan's industrial, agricultural and mining sector produces enormous quantity of waste / by-product (such as pulverized fly ash, slag, bagasse ash, rice husk ash, bentonite, dolomite, limestone e.t.c), which possesses pozzolanic properties. The suitability regarding usage of these materials in SCC needs to be investigated.

Higher powder contents can be achieved by using bagasse ash more than 20 percent in the concrete mix. With the derived mix design upto 20 percent of B.A has been studied in this research. Fresh and hardened Properties of concrete may be examined by including higher percentage of bagasse ash in a different mix design.

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