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Developing an Economized Normal Strength Concrete by Incorporating Bagasse Ash as Partial Replacement of Cement

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Abstract: Pakistan produces approximately 52 Million tons of Sugar cane annually and most of it is used for production of Sugar. The industrial waste of Sugar cane, known as bagasse, is used throughout the world as fuel for power generation in the same mills from where it is obtained. The burning gives ash containing high proportion of matters that are unburned silica and alumina as main components, which have the characteristics to react with free lime made available as the by-product of cement hydration. This research study is carried out to evaluate the feasibility of use of bagasse ash, in production of concrete, as a partial cement replacement. The most important variables of this research study are the proportion of bagasse ash and dosage of superplastisizer. The parameters which remained constant are the quantity of cementitious material equal to 430 Kg/m3 and water to binding material ratio equal to 0.55. Test results revealed that the mixes associated with bagasse ash, showed slightly lower compressive strength than Control Mix (CM). However, it showed better resistance against water absorption as compared to CM. The concrete produced using bagasse ash as partial replacement of cement has exhibited excellent properties as construction material. Government of Pakistan has allowed sugar mills to generate electricity through bagasse, this will produce large amount of bagasse ash as industrial waste. The successful bagasse ash use as a partial cement substitute would minimize the construction cost and will also significantly help to lessen the greenhouse gases.

Keywords: *Bagasse ash, construction, greenhouse gases, replacement, superplastisizer*

1. Introduction:

In the near past sufficient construction has taken place in the areas damaged/destroyed by earthquake and much more is looked forward as backdrop of recent construction announcement of multi hydel power projects in Pakistan; Moreover, development and construction phase is undergoing in Afghanistan nowadays and will continue in future which is expected for a long time as well. The requirement of materials of construction in the region has increased manifold. It is truly understood that the overall cost of any project is directly proportional to the cost of cement used. Hence, economy in the existing conditions is considered as an important issue of all the activities of engineering.

The process of making of cement serves as a major supplier to greenhouse gases. The global manufacturing process of cement makes up almost seven per cent of the total carbon dioxide (CO2) produced in the world and it is considered to remain steady in the coming ten years as well (Pera et al., 2001) as per the data provided by the manufacturers of cement. Moreover, as the cement production consumes a lot of energy; one ton of production of cement utilizes about 1.6 MWh energy and discharges almost equal weight of carbon dioxide into the atmosphere (Neville, 2000).

The use of complementary cementing materials, like ground granulated blast furnace slag, fly ash and many other mineral admixtures, in concrete is in practice all over the world. The original reasons of using these materials are usually economy and the advantages offered in terms of durability. They are cheaper than cement, some time they may exist as natural deposits requiring no or little, processing, at other time they exist as by product or waste from industrial processes (Neville,2000). One of the types of industrial waste, used as a substituent of cement in concrete, is agricultural waste. In this context rice husk ash utilization is a frequent practice. Manufacturing processes, service industries and municipal solid wastes are the sources of production of numerous waste materials. Concerns related with disposal of the generated wastes have tremendously increased with the increasing awareness about the environment. Solid waste management is one of the major environmental concerns in the world. Waste utilization has become an attractive alternative to disposal because of the scarcity of space for land filling and due to its ever increasing cost. The use of waste products in concrete not only makes it economical, but also helps in reducing disposal problems. Reuse of bulky wastes is considered the best environmental alternative for solving the problem of disposal. One such waste is plastic, which could be used in various applications. According to the World Commission on Environment and Development: sustainability means "Meeting the needs of the present without compromising the ability of the future generations to meet their own needs". Sustainability is an idea for concern for the well being of our planet with continued growth and human development

[McDonough 1992]. For example, if we run out of limestone, as it is predicted to happen in some places, then we cannot produce portland cement and, therefore, we cannot produce concrete; and, all the employers associated with the concrete industry go out -of-business, along with their employees [Naik and Moriconi, 2005].

Concrete is a blend of cement, sand, coarse aggregate and water. The key factor that adds value to concrete is that it can be designed to withstand harshest environments significant role. Today global warming and environmental devastati on have become manifest harms in recent years, concern about environmental issues and a changeover from the mass-waste, mass consumption, mass-production society of the past to a zero-emanat ion society is now viewed as significant. Normally glass does not harm the environment in any way because it does not give off pollutants, but it can harm humans as well as animals, if not dealt carefully and it is less friendly to environment because it is non-biodegradable. Thus, the development of new technologies has been required. The term glass contains several chemical diversities including soda-lime silicate glass, alkali-silicate glass and boro-silicate glass. To date, these types of glasses glass powder have been widely used in cement and aggregate mixture as pozzolana for civil works. The introduction of waste glass in cement will increase the alkali content in the cement. It also helps in bricks and ceramic manufacture and it preserves raw materials, decreases energy consumption and volume of waste sent to landfill. As useful recycled materials, glasses and glass powder are mainly used in fields related to civil engineering, for example, in cement, as pozzolana (supplementary cementitious materials), and coarse aggregate. Their recycling ratio is close to 100% and it is also used in concrete without adverse effects in concrete durability. Therefore, it is considered ideal for recycling. Recently, Glasses and its powder has been used as a construction material to decrease environmental problems. The coarse and fine glass aggregates could cause ASR (alkali-silica reaction) in concrete, but the glass powder could suppress their ASR tendency, an effect similar to supplementary cementations materials (SCMs). Therefore, glass is used as a replacement of supplementary cementitious materials.

2. Experimental investigation:

2.1 Materials:

The materials along with specifications, which were used for this experimental program, are mentioned below:

2.1.1 Cement:

Throughout the experimental work, OPC conforming to ASTM C150 Type I, Lucky cement factory, was utilized. The ingredient composition of the glass powder is given in Table 2.1.

Table 2.1. Ingredient Composition of Glass Powder

S.No	Chemical Properties of Glass Powder	% by mass
1	SiO_2	67.33
2	AL_2O_3	2.62
3	Fe_2O_3	1.42
4	CaO	12.45
5	MgO	2.74
6	Na_2O	12.05
7	K_2O	0.638

2.1.2 Fine Aggregate:

Dry Lawrancepur sand graded between 5 mm (No.30) sieve and 150 μm (No.100) was used for mixing all samples. The sieve analysis was determined accordingly as per ASTM C136 - 04. The specific gravity and the percentage of water absorption were determined accordingly as per ASTM C128 - 04.

Results of the sieve analysis of fine aggregate as compared with the requirement of ASTM C33 - 04 are shown in Table 2.2 and particle size distribution in Fig. 2.1. The physical properties of fine aggregate are given in Table 2.3.

Table 2.3 Physical Proper ties of Fine Aggregate

Unit Weight (Kg/m^3)	Bulk Specific Gravity (SSD)	Absorption
1798	2.73	0.21

Table 2.2. Grading of Fine Aggregate

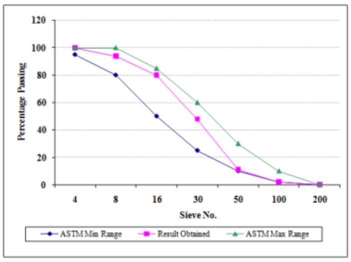

Fig.2.1 Particle size distribution of Fine Aggregate

Table 2.5. Physical Properties of Coarse Aggregate

ASTM Sieve No.	**Sieve Size (mm)**	**Weight Retained (gm)**	**% Reta-ined**	**Cum-ulative % Retai-ned**	**Percentage Passing**	
					Act-ual	**ASTM C33**
No. 4	5	4	0	0	100	95-100
No. 8	2.36	44	6	6	94	80-100
No. 16	1.18	109	14	20	80	50-85
No. 30	0.6	245	32	52	48	25-60
No. 50	0.3	282	37	89	11	10-30
No.100	0.15	64	9	98	2	2-10
No.200	0.125	12	2	100	0	0

Unit Weight (Kg/m^3)	Bulk Specific Gravity (SSD)	Absorption	Fineness Modulus
1697	2.74	2.27	2.65

2.1.3 Coarse Aggregate:

Crushed stone (Margala crush) having maximum size of 20 mm was used as coarse aggregate. The sieve analysis was determined accordingly as per ASTM C136 - 04. The specific gravity and the percentage of water absorption were determined accordingly as per ASTM C 127.

The results of sieve analysis as compared with the requirement of ASTM C33 - 04 are shown in Table 3.4 and particle size distribution in Fig. 2.2.The physical properties of coarse aggregate are given in Table 2.4.

Table 2.4. Grading of Coarse Aggregate

Sieve Size (mm)	Weight Retained (gm)	Percent Retained	Cumulative percent retained	Percent Passing	
				Actual	ASTM C33
19	223	6	6	94	90-100
12.5	1113	32	38	62	60-85
9.5	669	20	58	42	20-55
4.5	1532	42	100	0	0-10

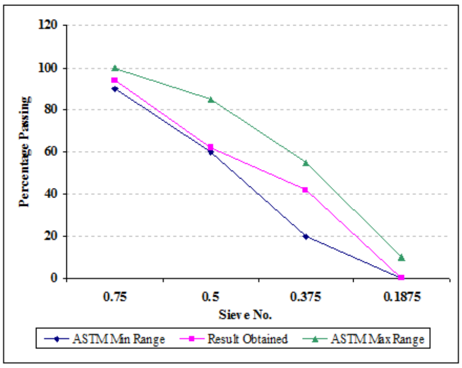

Figure 2.2.Particle size distribution of Coarse Aggregate

2.1.4 Superplasticizer:

The superplasticizer used for the entire research work, was "Ultra Super Plast 437". The dosage of superplasticizer was varied according to the variation in the mix proportions of bagasse ash to get the slump in the range of 25 mm to 50 mm.

2.1.5 Glass Powder:

Initially an effort was made to get the ground glass from the chemical stores but due to no utilization of glass powder for any commercial purpose in Pakistan and lack of milling facility it could not be procured or made available. However the ground glass (glass dust) was collected from the point where the glass top sheets for tables or glass doors edges were grinded with the help of hand held grinders for giving them smooth edges, curves or different shapes. An exclusive room and clean collection point was ensured in order to eliminate addition of any impurities.

2.1.6 Mixing Water:

Ordinary tap water from Peshawar was used for the entire experimental work.

2.2 Specimen designation:

The various mixes which were used in this research are abbreviated in two different forms, namely CM and 5GC. Specimen which were cast without addition of bagasse ash are designated as Control Mix (CM); whereas 5G represents amount of cement, in percentage, that has been substituted with Glass powder and C represents cement. The specific designation, 5GC, indicates that 5 percent cement has been replaced with Glass Powder in the mix.

2.3 Mix proportions:

For the entire experimental work, six concrete mix with ratio of 1:2:4 (one part of cement, two parts of sand and four parts of coarse aggregate/crush stone) were prepared. These include one mix with cement without addition of bagasse ash, and rest of the four mixes with different ratios of glass powder. Each mix had the same water to cementitious material ratio of 0.55 and slump in the range of 25 mm to 50 mm was maintained by adjusting the superplasticizer dosage. The overall cementitious material contents of 430 Kg/m3 were kept constant. The experimental matrix for the mix design is given in Table 2.8.

Table 2.8. Casting of Concrete Cylinders for Different Mixes

S.No.	Mix	Number of Cylinders			Total
		7 days	28 days	56 days	
1	CM	3	3	3	9
2	5BC	3	3	3	9
3	10BC	3	3	3	9
4	15BC	3	3	3	9
5	20BC	3	3	3	9
	Total	15	15	15	**45**

2.4 Testing program:

Each mix was tested for properties of fresh concrete and compressive strength.

2.4.1 Density of Fresh Concrete:

For each mix, the fresh concrete density was found out by the use of Compacting Factor Apparatus accordingly.

2.4.2 Compressive Strength Test:

Compressive strength of each mix design was determined according to ASTM specifications C 109M - 02 and C 796. Standard 300 mm x 150 mm cylinders were prepared. In accordance to the provisions of ASTM C 192M - 02, specimens were moist cured till the date of testing. Testing was carried out at the age of 7, 28 and 56-days. Cylinders were caped with plaster of paris before testing for compressive strength according to ASTM C39.

3. Test results and discussion:

3.1 Properties of fresh concrete:

The properties of fresh concrete are presented in Table 4.1. The maximum fresh density achieved by the CM was 2292 Kg/m3. The density started decreasing with the introduction of Glass Powder as replacement of cement, and as the glass powder contents increased the density became less and less because the specific gravity governs the density. Since the specific gravity of glass powder is less than cement , therefore the density of the Control Mix is the highest.

Table 3.1. Properties of Fresh Concrete

Mix	**Cement (Kg/m^3)** [C]	**GP (Kg/m^3)** [P]	**[W/(C+P)]**	**Percentage of Super plasticizer**	**Fresh Concrete Density (Kg/m^3)**	**Slump (mm)**
CM	430.0	0.0	0.55	0.0000	2292	25
5BC	408.5	21.5	0.55	0.0025	2270	32
10BC	387.0	43.0	0.55	0.0050	2257	33
15BC	365.5	64.5	0.55	0.0075	2223	38
20BC	344.0	86.0	0.55	0.0100	2209	40

3.2 Compressive strength of cylinders:

The compressive strengths of CM for 7, 28 and 56 days are summarized in Table 3.2 and graphically shown in Fig. 3.1. The results show that, the compressive strength of the CM is lower at all stages of testing than the mixes with glass powder. However, the comparative compressive strength analyses indicate that the difference in compressive strengths increases with the increase in time. The difference of compressive strength between CM and Glass Powder (5GC) is found to be increasing with increase in time. It shows that, as the age increases, pozzolanic activity in specimens, containing less glass powder, is relatively slower than those containing more glass powder.

Table 3.2. Compressive Strenght Test Results

Mix	**Compressive Sregth of Cylinders*(Psi)**		
	7 Days	**28 Days**	**56 Days**
CM	2800	3742	4318
5GC	2804	3758	4347
10GC	2810	3764	4370
15GC	2830	3786	4394
20 GC	2940	3914	4486

*The compressive strength results are average of three cylinders

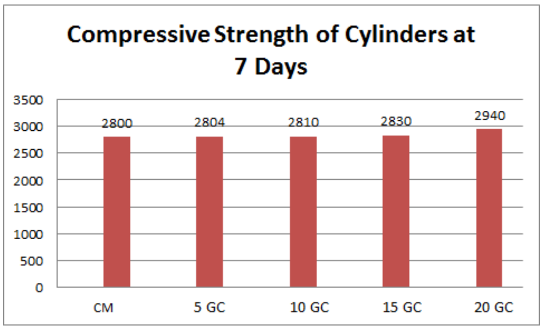

Figure 3.1 Compressive Strength of Cylinder at 7 Days

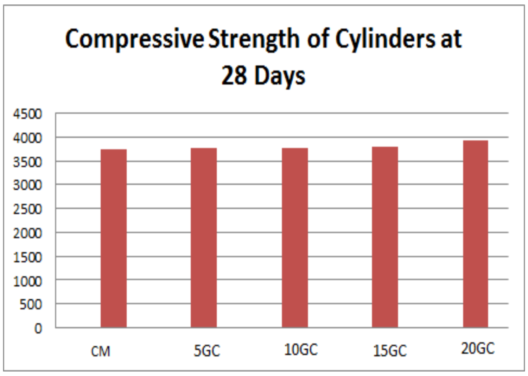

Figure 3.2 Compressive Strength of Cylinders at 28 Days

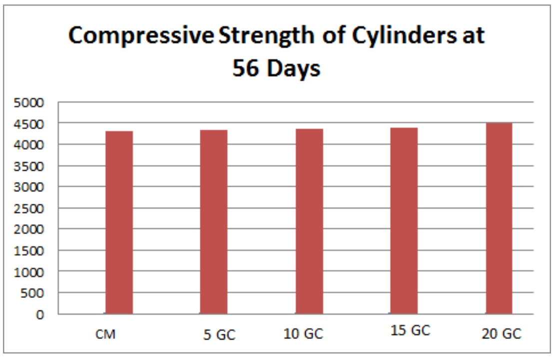

Figure 3.3 Compressive Strength of Cylinders at 56 Days

4. Conclusions and recommendation:

4.1 Conclusions:

Based on the experimental findings, following conclusions can be drawn:

- The properties of glass powder are found to meet the requirements of ASTM class N Pozzolans, as per ASTM C618-04. The bagasse ash, therefore, qualifies itself as a member of pozzolan family.
- The possibility of using bagasse ash as partial replacement of cement is feasible.
- The optimum percentage of bagasse ash that satisfied ASTM C618-04 was found to be 20BC.
- Low cost concrete can be produced by incorporating percentage of bagasse ash as a partial cement replacement, along with the main ingredients of concrete and superplasticizer for compensating the loss of workability, provided

that the water to cementitious material ratio is kept constant.

- Water absorption decreased with increase in the amount of bagasse ash as cement replacement. Therefore, it enhances the durability of concrete.
- The production of bagasse ash as industrial waste is quite high and likely to further increase in Pakistan. Financially and technically bagasse ash has a lot of potential to be used as pozzolan in construction industry. Furthermore, its usage as construction material will also resolve the problem of its disposal and will also help in keeping the environment free from pollution.
- Use of bagasse ash as partial replacement of cement is a cost effective option without compromising the strength parameters.

4.2 Suggestions for future research:

During the course of this study following areas are identified for future research:

- Silica contents in any agro-waste product depends on the silica available in soil and capacity of plant to fix it, therefore, bagasse ash of different areas could be used for the research and their comparison may be drawn.
- High volume replacement of bagasse ash, as replacement of cement in concrete can be studied.
- Research can be undertaken on some more agro-waste products, like wheat, corn, bamboo and sorghum, either as an individual pozzolan or with the blend of two or more.
- Feasibility of bagasse ash use in cement mortar for brick masonry and plaster need to be evaluated.
- Pozzolanic reactivity of bagasse ash with addition of lime needs to be evaluated.

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