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Fresh Properties of Concrete having Banana Leaf Ash and Banana Fibres

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ABSTRACT. *This paper focuses on the investigation of fresh properties of concrete with the influence of banana leaf ash and banana fibre. In this study, cement was partially replaced by 10% banana leaf ash content in weight; whereas; banana fibre was incorporated in concrete mixes at 1%, 1.5% and 2.5% by weight of cement. 1 % content of superplasticizer based on polycarboxylic ether was used. A single concrete mix ratio was developed to achieve a strength of 30 MPa and slump, density, and compacting factor tests were conducted for examining the fresh concrete properties. The results exhibited that the incorporation of banana leaf ash developed fresh concrete properties, while banana fibre decreased the fresh characteristics of concrete. The incorporation of 2.5% fibre resulted in a 55% decrease of slump as compared to the reference concrete whereas 1% and 1.5% banana fibre in concrete showed a reduction of 8.2% and 16.11% as compared to reference concrete. With the significant amount of research being carried out in the domain of natural fibres and natural ashes it is important to evaluate the fresh properties of such concrete for their easy application in civil engineering.*

Keywords: Banana leaf ash, Banana fibre, Compaction factor, Slump test

1. INTRODUCTION

Concrete is a very durable material, and it has been used for decades. The properties of concrete make it a good option for its application in different fields of civil engineering ranging from pavement application to canal lining application. However, concrete also has flaws that lead to a reduction in the performance of concrete. Some of these flaws are directly related to fresh concrete properties. Lower workability results in compaction problems which ultimately result in strength reduction. Moreover, higher workability results in lower concrete strength due to the higher water-cement ratio. More amount of water results in more shrinkage cracks which propagate with time.

Increasing the mechanical properties of concrete can reduce the cracking probability. One way of doing this is using different organic materials in it which can also result into reduced thickness hence reducing the overall cost of the pavement. Natural fibers are being used for enhancing the compressive strength of concrete by partially replacing the cement, this results in reduction of cement content, hence saving the cost. On the other hand, fibers can enhance the mechanical properties along with capability of stopping the initiation of cracks. It is the need of the time to use these materials due to their easy availability and cheap nature. Banana fiber is an abundantly available fiber in Pakistan. Research has been conducted on the use of banana fiber and banana leaf ash in concrete separately. However, it is important to find the combined effect of both materials on fresh concrete properties to ensure its maximum application in civil engineering.

With the recent development in sustainable concrete technology, the usage of waste materials in concrete has gained much of attention. In the construction industry, the usage of agricultural waste such as rice husk ash, banana leaf ash, and bagasse ash is gaining attention as discussed by many researchers [1]. The problems related to cement production such as the consumption of non-renewable energy can be solved by using of agricultural waste ashes from biomass power plants. These ashes are cementitious in nature and can be used as an alternative to cement [2]. Some of the by-products of agricultural industries like rice husk ash, corncob, sugarcane bagasse ash, and banana leaf ash can be effectively used as supplementary cementitious materials due to the pozzolanic nature of these ashes. 10 per cent Banana leaf ash when substituted with cement resulted in higher compressive strength [3]. The filler effect of banana ash leaf concrete and the pozzolanic effect of BLA along with lower water absorption capacity makes it suitable for increasing the compressive strength of concrete. Furthermore, the compressive testing of samples containing BLA as a partial replacement showed that the results were better than the reference plain cement concrete samples [4].

Natural fibre incorporation in concrete has been a practice for decades in rural areas. Using Jute fibre in concrete enhances the effectiveness and economy of concrete [5]. Coir fibre concrete, as compared to plain concrete, gives a higher value of compressive strength and split tensile strength [6]. Banana fibre, used in concrete, improves the mechanical properties of concrete [7]. Using banana fibre in concrete is a sustainable way to increase the mechanical properties of concrete [8]. Natural fibres are usually obtained from trees and plants, and these fibres are environment-friendly. These fibres, when used in concrete, increase the flexural and tensile strength of concrete [9]. Using natural fibres in concrete reduces the workability of concrete. As banana fibre is a lignocellulose natural fibre, this fibre, when added to concrete increases water absorption hence decreasing the workability [10]. Banana fibres have better mechanical strength as compared to Sisal, Talipot, Palmyrah and Coconut fibre [11]. Banana fibre has a lesser water absorption capacity as compared to Sisal and Jute fibre [11]. Plant fibre concrete has a reduced workability due to the fibres introduced in concrete [15]. Waste banana leaf ash when incorporated in concrete reduces the workability of the concrete [16]. Ali [17] studied the behaviour of natural fibres for canal lining application and found that the use of fibres reduces the workability of the mix. This paper reports the preparation of concrete having banana fibre and banana leaf ash. Moreover, the fresh properties, mainly including slump test, compaction factor test and fresh density of concrete are discussed. Concrete having banana fibre and banana leaf ash is prepared along with the reference concrete using the mix design 1:1.3:2.3. Banana leaf ash is used as 10% replacement of cement while banana fibre was used in three different proportions i.e., 1%, 1.5% and 2.5% by weight of cement. 1 % content of superplasticizer based on polycarboxylic ether was used in this concrete. The fresh properties which include the slump cone test, compaction factor test for workability and fresh concrete density test are determined. Till now no combination of banana fibre and banana leaf ash has been used. Banana leaf ash has the property to enhance the compressive strength and banana fibre has the property to increase the tensile and flexural strength of concrete.

2. EXPERIMENTAL PROGRAM

2.1 Raw Materials

For the preparation of the modified concrete, the raw materials used are banana fibre and banana leaf ash. Both of these materials and their production has been explained briefly. Raw materials that have been used in research are treated in order to enhance their performance in concrete.

2.1.1 Banana Leaf Ash

Banana leaf ash was produced by heating the leaves of the banana tree up to 900 degrees Celsius in a furnace and then grinding the burnt leaves in a ball mill. This fine powder is composed of Silicon Oxide, Calcium Oxide. The existence of Silicon oxide is very important as it reacts with calcium hydroxide to form calcium silicate hydrate. Calcium hydroxide is released during the hydration process of cement.

2.1.2 Banana Fibre

The used banana fibre is locally available in abundance that is produced from the stems of the banana tree. Banana fibre contains 62 to 66 per cent of cellulose which results in the degradation of fibres over time, which is why it is important to treat the fibres before using it in concrete. For the treatment of fibre, calcium carbonate was used, and the fibre was soaked in this chemical. After the treatment, the fibre was cut into a length of 50 mm and the fibres were separated to avoid balling effect in concrete.

Fig-1: Raw Banana Fiber and Treated Banana Fiber

Figure 1 shows the raw banana fibre and treated banana fibre. The usage of banana fibre in concrete is justified by its elastic modulus that is around 20 GPa and its elongation percentage that is around 6.6 percent of its original length.

2.2 Mix Design

The mix design ratio of 1:1.3:2.3 (cement: sand: aggregate) is used for the preparation of both plain cement concrete and concrete having banana fibre and banana leaf ash, with a w/c ratio of 0.48. The mix design used in this research is based on the trials to obtain a compressive strength of 30MPa. In the case of concrete having banana fibre and banana leaf ash, the variation is only the addition of fibres 1 percent, 1.5 percent, and 2.5 percent by mass of cement. The fibre added in concrete are same in length 50 mm for banana fibre, but their content varies in concrete.

Table-1: Concrete Nomenclature and percentage of banana fibre and banana leaf ash

Concrete Sample	Banana fibre (%)	Banana Leaf Ash (%)
PC	-	-
C1	1	10
C2	1.5	10
C3	2.5	10

Table 1 shows the composition and the nomenclature of concrete batches that were prepared for the testing. PC refers to plain cement concrete, C1, C2 and C3 refer to concrete having 10% banana leaf ash (as partial replacement of cement) and banana fibre with 1% banana fibre, 1.5% banana fibre, and 2.5% banana fibre respectively.

2.3 Concrete Preparation

A concrete mixer is used to prepare both PC and concrete having banana fibre and banana leaf ash. For the production of PC, the raw ingredients along with water are poured into the mixer, and the mixer is rotated for about 3 minutes. After that, the slump test is conducted to check the workability of the concrete before pouring it into the moulds. For the preparation of concrete having banana fibre and banana leaf ash, one-third part of the material is poured into the mixer in layers, and the process is repeated to complete the material for a specific number of moulds or specimens. For the preparation of concrete having banana fibre and banana leaf ash, the mixer is rotated for about three minutes to mix the material along with calculated fibre proportions in its dry state for the proper material mix-up. Then, one-third of the water is added to a mixer, and the mixer is rotated for about three minutes to prepare the required number of specimens. The remaining water is added to the mixer, and the mixer is then again rotated for about 3 minutes. Before pouring the concrete mix into the mould, a workability test is performed. All the concrete, having banana fibre and banana leaf ash, mixes are observed to be workable at that time and are evenly dispersed.

2.4 Testing

Testing of the fresh concrete includes slump cone test, compaction factor test and fresh density test. These tests have been explained in detail with the standards of the tests along with the method of performing the tests.

2.4.1 Slump Test

The method for testing the slump values is ASTM C-143. In this method, a metallic mould is used having the shape of a conical frustum, and it is open on both sides with the top diameter being 100 mm and the bottom diameter of 200 mm with a height of 305 mm. The cone is placed on a non-absorbent surface mainly a steel rectangular plate is used. The cone is filled in three layers with each layer compacted using the rod with 25 blows. Once the concrete in the cone is compacted, the cone is lifted using the handles on the cone. Afterwards the cone is placed upside down parallel to the concrete heap and then the tamping rod is placed on the top of the cone with the other side being above the concrete heap. The distance between the concrete top and the tamping rod is measured using a scale.

2.4.2 Compaction Factor Test

The compaction factor test apparatus consists of two hoppers and a cylinder. The upper hopper is on the top with lower hopper being directly below it and below this hopper is the cylinder. Concrete is filled in the top hopper with its lower opening being closed. Once the upper hopper is filled, it is opened to allow the concrete to fall into the lower hopper. Once the lower hopper is opening the concrete falls into the cylinder. Now, the weight of concrete is measured by excluding the cylinder weight from the total weight. Now the cylinder is again filled with concrete and compacted using a rod in three layers with a specific number of blows. The compacted concrete cylinder is measured and the mold weight is excluded. Using the values of weight of partially filled cylinder weight and the fully filled cylinder weight the compaction factor is calculated.

2.4.3 Fresh Density Test

For the determination of fresh density of concrete ASTM C-138 standard is used. As per this standard, the fresh concrete is filled in a cylinder of known volume and then it is compacted. The weight of empty cylinder is also measured before filling the cylinder. Now, the empty cylinder weight is subtracted from the total weight of cylinder having concrete and then this weight is divided from the volume of the cylinder. This gives the density of fresh concrete.

3. RESULTS AND ANALYSIS

3.1 Slump

The variation of slump and density of various concrete mixtures is presented in table 2. The slump of fresh concrete reduced gradually with the increment of banana fibre concentration. The maximum slump observed was 85 mm for PC. On the other hand, the slump values for C1, C2, C3 were 78 mm, 71.3 mm and 38.1 mm.

Table-2: Concrete slump values for each batch of concrete

Concrete sample	Slump Value (mm)	Remarks
PC	85	Acceptable
C1	78	Acceptable
C2	71.3	Acceptable
C3	38.1	Not Acceptable

Significant deviation in the slump value of plain concrete is due to the interlocking effect of the fibres that reduce the slump of the concrete. However, using solely fibres in concrete decreases the slump value to almost zero. With the addition of fibres, the slump of concrete reduces [12].

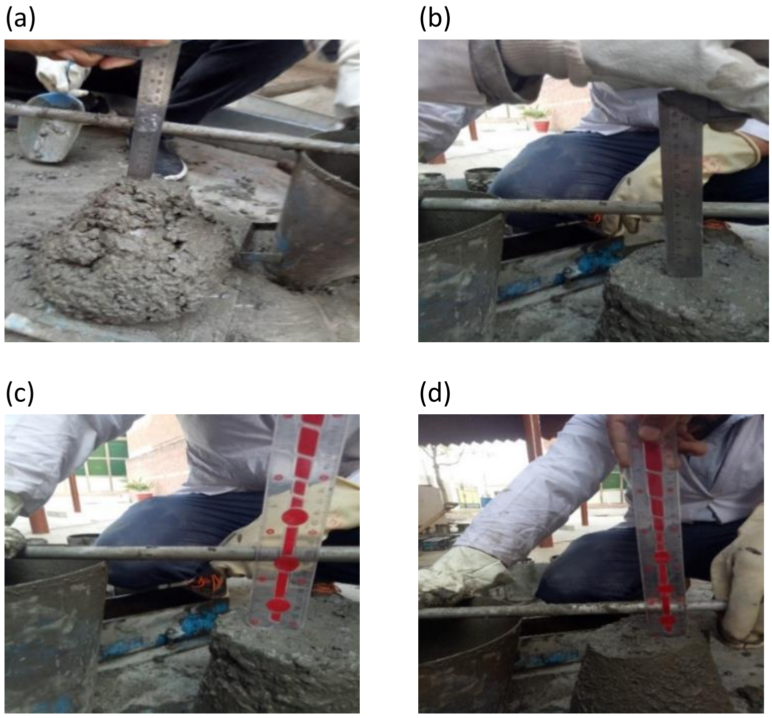

Fig-2: Slump of concretes (a) PC (b) C1 (c) C2 (d) C3

Contrarily, using banana leaf ash increases the slump value of the concrete. The improved workability is due to the smooth texture, particle shape and the fineness of the banana leaf ash. As shown in table 1 that the highest value of slump is 85 mm and the lowest value of slump is 38.1 mm. The slump values of C1, C2 and C3 decreased 8.2%, 16.11% and 55% as compared to reference concrete. This minimum slump observed is for C3 due to the banana fibres. However, the difference between the slump values of PC and C1 and C2 is not that much.

3.2 Compaction Factor

The compaction factor test is usually conducted for determining the workability of the concrete. Compaction factor test was performed on the PC, C1, C2, C3 were performed. It was seen that the compaction factor value for PC was 0.91, for C1 the compaction factor value was 0.86, for C2 the compaction factor value was 0.84, and for C3 the compaction factor value was 0.77.

Table-3: Compaction factor values and workability of concrete batches

Concrete sample	Compaction Factor Value	Workability
PC	0.91	Plastic
C1	0.86	Stiff Plastic
C2	0.84	Stiff Plastic
C3	0.77	Stiff

As it can be seen in table 3 that the workability as per the compaction factor test shows significant decrease in the compaction factor value of C3 as compared to the PC compaction factor value. Stiff plastic workability of C1 and C2 are in accordance with the slump required for rigid pavement construction. With the addition of fibres in concrete the compaction factor of concrete reduces [13]. With the addition of banana fibre, the concrete becomes less workable and the value of compaction factor reduces [14]. This is validated from the compaction factor test as it can be seen in table 3 that the workability is plastic in case of PC and with the increased proportion of banana fibre the workability is moving towards stiffer nature.

3.3 Fresh Density

A decrease in the density of fresh concrete was observed with the increase in content of banana fibre. The observed densities of PC, C1, C2, and C3 are 2310 kg/m3, 2294 kg/m3, 2286 kg/m3, 2278 kg/m3 respectively. Hence, C1, C2, and C3 have reduced by 0.69%, 1.03%, and 1.4% as compared to the reference concrete. Among all the batches, C3 shows the lowest density as maximum amount of fibre in included in this batch as compared to other batches.

Table-4: Fresh density of concretes

Concrete sample	Density (Kg/m^3)
PC	2310
C1	2294
C2	2286
C3	2278

Table 4 shows the fresh densities of the concretes. It can be seen that with the increase in the fibre content the density of the concrete is decreasing this is due to the lower density of concrete. However, the reduction is not much because of the fine particles of banana leaf ash. The reduction in the densities is in accordance with the literature as per which the densities decrease with the addition of natural fibres and natural ash [18].

4. CONCLUSION

Concrete having 1%, 1.5% and 2.5% banana fibres and 10% banana leaf ash, partially replaced with cement, was prepared and the fresh densities, including slump, compaction factor and fresh density, were determined. Based on the results obtained after the tests conducted on the fresh concrete following conclusion are drawn.

- Addition of fibres in concrete decreases the slump of the concrete. The lowest slump observed was of concrete having 2.5% banana fire. The slump values of C1, C2 and C3 decreased 8.2%, 16.11% and 55% as compared to reference concrete.
- The lowest compaction factor recorded is 0.77 inhibited by fresh concrete having 2.5% banana fibre. The increase in the banana fibre reduces the compaction factor.
- With the increase in the content of fibre in concrete the density due to the low density of banana fibre. The maximum decrease in density was at 2.5% fibre content which was 1.4% lesser than the reference concrete.

Considering the test results, C1 is has benefits over other concretes having banana fibre and banana leaf ash because of its acceptable slump and compaction factor value. For the practical application C1 and C2 are recommended mainly for their usage in rigid pavements. However, for their practical usage the mechanical properties of these concretes need to be evaluated.

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