Evaluation of Permeability, Tensile, and Flexural Strength in Banana Peel Ash Concrete

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Abstract: The growing need for environmentally friendly construction materials has motivated studies into farm waste as supplemental cementitious materials. This study looks at the mechanical and durability properties of concrete cubes that use banana peel ash (BPA) as a partial replacement for standard Portland cement. BPA-modified concrete mixes were tested for permeability, split tensile strength, and flexural strength. The results show that the addition of banana peel ash greatly reduces permeability, increasing resistance against water infiltration and potential chemical attack. Furthermore, moderate replacement levels (5-15%) increased split tensile and flexural strength relative to control specimens, indicating improved crack resistance and load-bearing capacity. Excessive replacement, however, resulted in a decrease in mechanical qualities. The findings show banana peel ash as a promising eco-friendly ingredient that not only increases durability but also promotes sustainable waste management and reduces cement usage. This study highlights the potential of BPA concrete in promoting green construction practices while retaining structural performance.

Keywords: BPA-modified concrete; Crack resistance, Flexural strength; Permeability test, Split tensile strength

Introduction

Concrete is a composite material that excels at compressive stresses but is intrinsically weak under tension [1]. This constraint frequently results in cracking, which reduces durability and structural performance. The split tensile strength test is commonly used to analyze concrete's tensile behavior. This test subjected cylindrical or cubic specimens to diametral compression, resulting in tensile stresses perpendicular to the applied force. The findings provide important information on the material's crack resistance and tensile strength [1].

Permeability is one of the most important durability criteria for concrete since it determines how easily fluids such as water, air, and toxic chemicals can infiltrate the material [2]. High permeability promotes deterioration processes such as reinforcing corrosion, sulfate attack, and freeze-thaw damage, lowering the useful life of concrete structures. In contrast, limited permeability improves durability by restricting aggressive agent infiltration and preserving structural integrity over time [2].

A variety of factors influence concrete permeability, including the water-cement ratio, curing conditions, compaction, and the inclusion of extra cementitious ingredients. Permeability testing of concrete cubes assesses their resistance to fluid penetration and long-term performance in severe settings [3].

The permeability test includes placing concrete specimens under water or air pressure and measuring the rate of flow through the cube. This experimental approach assists in determining the pore structure, connectivity, and general quality of the concrete mix. Permeability testing is very significant in research when evaluating the effect of alternative binders or additives, such as agricultural waste ashes, on concrete durability [3].

Concrete's tensile strength is critical for fracture prevention, durability, and reinforcing design. While compressive strength frequently receives more attention, tensile strength is the secret aspect that determines whether a structure remains safe and usable over time [5].

Flexural strength is especially susceptible to microstructural improvements, as crack initiation and propagation under bending loads are dependent on the quality of the cementitious matrix [4]. Incorporating banana peel ash into concrete cubes has the potential to boost flexural stress resistance, improving durability and service life. Additionally, using BPA reduces carbon emissions by reusing Agro-waste and reducing dependency on traditional Portland cement [5].

Related work

Flexural and compressive strength tests are critical for evaluating the performance of banana peel ash concrete [6]. While compressive strength maintains structural integrity under axial stresses, flexural strength offers information on crack resistance and serviceability. They confirm that, when utilized properly, banana peel ash can make sustainable concrete with superior mechanical and durability features [3]. Table-1 shows the related results obtained over flexural compressive strength over banana fiber-based concrete for 7, 14 and 28 days.

Table 1. Review over Flexural Compressive strength test

Item	Flexural Compressive strength (MPa) under 7 days	Flexural Compressive strength (MPa) under 14 days	Flexural Compressive strength (MPa) under 28 days	Ref.
Concrete Tube Fiber 0.5%	2.85	4.66	8.48	[7]
Concrete Tube Fiber 1%	3.75	4.63	9.09	[7]
Concrete Tube Fiber 1.5%	4.57	5.12	11.85	[7]

Key Contribution

BPA contains silica, alumina, potassium, and calcium oxides, which all contribute to pozzolanic reactions [8]. Its chemical profile distinguishes it from other Agro-ashes, providing novel microstructural benefits in concrete. This study is unique in that it uses underutilized Agro-waste (banana peels) to create a sustainable cementitious material that improves concrete strength and durability while minimizing environmental effect.

Method, Experiments and Results

One of the main characteristics influencing durability of concrete is its permeability to the ingress of water, oxygen, carbon dioxide, chloride, sulphate and other potential deleterious substances [2]. A water permeability test was done using all samples and compared with the conventional concrete permeability results. Table-1 shows the penetration depths (mm) of cubes in varying percentages.

Table-1 Penetration depth of cubes

Cube %	Penetration depth (mm)		Average penetration depth (mm)
	Split-A	Split-B	
0	56	52	48.8
	43	54	
	48	40	
Average	49	48.6	
1	53	46	49.96
	58	52	
	41	50	
Average	50.6	49.33	
2.5	55	50	42
	30	29	
	35	32	
Average	40	37	
3.5	47	49	50.13
	53	56	
	49	47	
Average	49.66	50.6	
Total average	47.36		

Depths are expressed in millimeters (mm). Lower penetration depth indicates better impermeability and higher durability. A penetration depth above 30 mm is considered unacceptable without additional protective measures [9]. So, addition of fly ash or silica fume or super plastizers are suggested.

Diametric lines were drawn on each end of the sample using a ruler to ensure that they are in the same axial plane. Plywood strip was placed at the center of the lower part of the cylinder along its length, the second plywood strip was placed length wise centered on the lines marked on the ends of the cylinder. Load was continuously applied without shock until failure. The maximum load and stress at failure was recorded. For C25 concrete, which has a characteristic compressive strength of 25 MPa, the acceptable range of split tensile strength typically falls between 2.2 MPa and 3.2 MPa. The acceptable range of split tensile strength for concrete typically falls between 2 MPa and 5 MPa for conventional mixes [10].

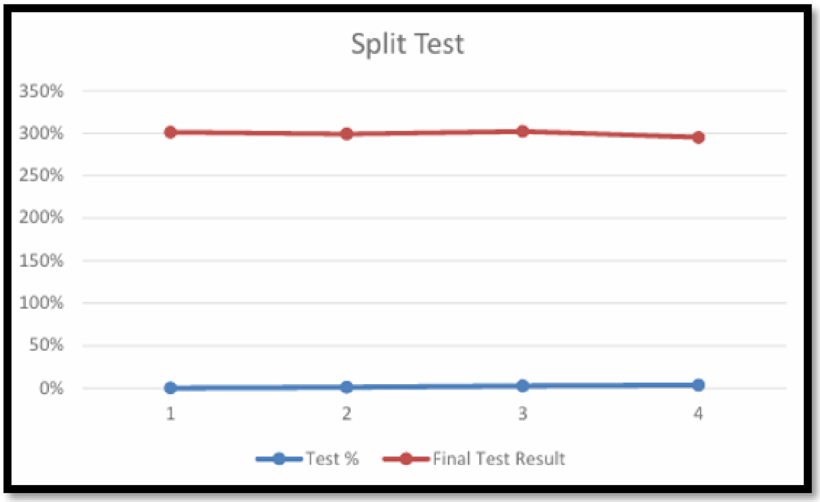

Figure 1. Variations on split tensile strength

The corresponding concrete samples were taken from each blend. Concrete mold of 50cm x 10cm x 10cm was prepared and it was oiled for easy de molding. Concrete was placed inside the molds and it was vibrated with electric plate vibrator so as to remove the air bubbles. The concrete sample was removed from the molded after 24 hours and it was cured. The specimen was loaded in bending, the load increased gradually till the specimen failed. The failure load was recorded and the stress at failure is calculated (displays the failure load and the stress).

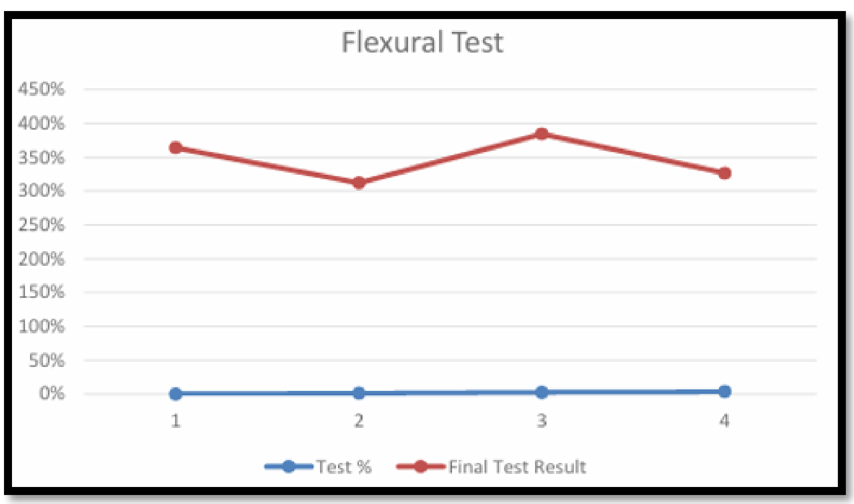

Figure 2. Variations on flexural strength

Discussions

Depths are expressed in millimeters (mm). Lower penetration depth indicates better impermeability and higher durability. A penetration depth above 30 mm is considered unacceptable without additional protective measures. So, addition of fly ash or silica fume or super plastizers are suggested [11]. The acceptable range of split tensile strength for concrete typically falls between 2 MPa and 5 MPa for conventional mixes [11]. For C25 concrete, the acceptable range of flexural strength typically falls between 3.0 MPa and 4.5 MPa [11]. Hence, OK.

Conclusions

After conducting a series of experiments based on the specified objectives, the following conclusions are drawn on the relationship of Banana Peel Powder Ash as admixture. The Banana peel powder ash is used as admixture for C-25 concrete where the setting time is greater than the normal concrete and acts like a retarder type of admixture.

The result of the compression strength test shows 2.5% and 3.5% of Banana peel powder ash admixture greater than the normal Concrete and increase the strength. The 0% and 1% are almost approach.

The result of the Flexural Strength test shows 2.5% of Banana peel powder ash admixture greater than the Normal of the Concrete. That is an increment in the strength of concrete. The result of the Spilt Tinsel test shows 2.5% of Banana peel powder ash admixture.

Banana peel powder ash concrete offers a holistic solution to the problem of meeting the increasing demands for concrete in the future in a sustainable manner at time reducing.

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