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Use of High Lignin Ash in Bio Concrete by Partial Replacement of Cement

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ABSTRACT:

Corn stover cellulose and hemicellulose has been utilized as a substrate for ethanol production using Saccharomyces cerevisiae. Lignocellulosic materials through a process of pre-treatment, hydrolysis and fermentation produces ethanol from a corn stover. With the cellulosic ethanol process, left over material which has lignin and some cellulose in it can be burn out to get the ash. Adding this high lignin ash to the cement, makes concrete strong and durable. Corn stover has the potential for use as a supplementary cementitious material (SCM) for concrete. On the pozzolanic reactivity of corn stover ash (CSA), the effects of distilled water and diluted acid pre- and post-treatments were investigated. The possible application of high lignin residue (HLR), a bioethanol by product, in the synthesis of SCM was also looked at. When utilised as a 20% replacement for cement in the system, pre-treatment CSA and high lignin residue ash (HLRA) improved the early reactivity of cement paste, however unpretreated CSA was discovered to significantly stifle the hydration reaction. From samples containing HLRA, the maximum compressive strength was attained.

Keywords: corn stover, compressive strength ethanol, high lignin residue.

INTRODUCTION:

As a significant and crucial step towards reducing contemporary society's reliance on fossil fuels, the introduction of biofuels into the transportation sector, bioethanol has already been implemented as a petrol substitute in some nations. [1-3]. From the perspective of sustainability, bioethanol should be created from secondary biomass derived mostly from lignocellulosic waste, with the benefits of both utilising the waste through resource recovery and avoiding the use of biomass that would otherwise be used as food for human consumption [4]. Around the world, there exist large amounts of lignocellulosic waste, particularly corn stover [2-5]. Corn is not only the largest agricultural commodity in the world (1.06 £ 109 t/y of corn, 7.49 £ 108 t/y of wheat and 7.41 £ 108 t/y of rice) [6], Nevertheless, the stover component of corn's by-product is also important. Consequently, the manufacture of bioethanol from corn stover may be a crucial technique for the manufacturing of ethanol as a petrol substitute. As a typical lignocellulosic feedstock, maize stover contains lignin, cellulose, and hemicellulose. Together, these three components form a complex polymer structure that prevents reaction media or enzymes from coming into intimate contact with cellulose, making maize stover difficult to convert into bioethanol [7]. Pre-treatment, which tries to disassemble the crystalline and polymeric structures before the hydrolysis, fermentation, and final purification steps, is therefore crucial. Many studies have been done recently on the pre-treatment of maize stover, including physical, chemical, biological, and other procedures. While the later steps are technologically quite well understood [8-9]. Physical pre-treatment commonly entails milling, extrusion, and microwave irradiation; physicochemical pre-treatment refers to steam explosion, liquid hot water explosion, ammonia fibre explosion, and supercritical CO2 explosion; chemical pre-treatment frequently uses acid and alkaline materials, and occasionally organic solvent or ionic liquid as reaction media; biological pre-treatment uses microorganisms like various types of fungi [10]. Although acid and hydrothermal technologies can also be used as hydrolysis processes, enzymatic hydrolysis now dominates the hydrolysis of carbohydrates. These technologies share the same goal of increasing ethanol production, but their approaches, operating parameters, and yields fundamentally differ. Even within the same technology, operational circumstances, as well as sugar and ethanol yields, might change significantly. Microorganisms enjoy various fungus species. Furthermore, full-scale technologies are still in short supply and in the early stages of development [10,11].

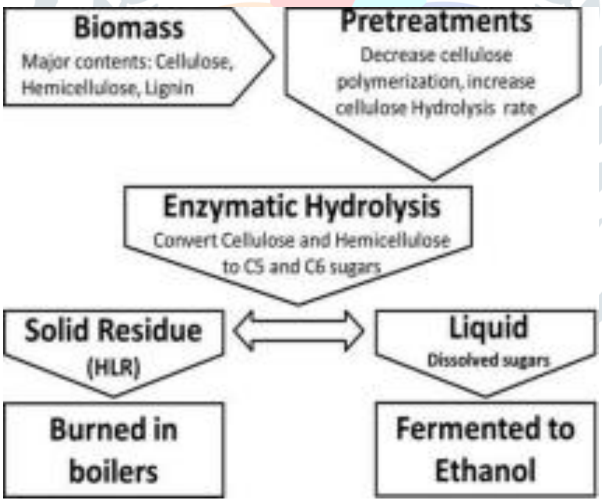

Figure 1: Bioethanol production process

MATERIALS REQUIRED:

1. **For the extraction of high lignin ash, the materials and apparatus required are -** Corn stover, Sodium Hydroxide solution, Sulphuric acid, Glass beakers, Glass rod, Oven, Filter papers, Funnel, 250ml Conical flask.
2. **For Concrete, materials required are -** Cement, Aggregates (Fine and Coarse), High lignin Ash, Water.

METHODOLOGY:

a) Method of extraction of High lignin ash from corn stover are -

1. Sample Preparation

The corn stover is collected from and taken to a standard laboratory for analysis. The corn stover is cleaned, chopped and oven-dried at 60 °C for 48 hours at moisture content of 10 % dry basis. The oven dried corn stover is then milled between 10 - 25mm to 0.1 - 0.5mm particle. The milled corn stover is sieved to produce a uniform particle size between 0.180 – 0.250mm and kept in a sealed plastic jar at room temperature until required for treatment.

2. Alkaline Pre-treatment of Corn Stover

Corn stover pre-treatment helps to increase accessibility to plant cell wall polysaccharides for carbohydrate-active enzymes to produce sugars for bioethanol fuels. Thus, 98grams of the milled corn stover was mixed with 800ml of distilled water containing 2grams of anhydrous NaOH crystals. This resulted in a solid to liquid weight ratio of 1:8. The mixture is autoclaved at 121oC for 25 min filtered, the residue washed and oven dried at 65 ^{0}C.

3. Hydrolysis:

The alkaline pre-treated corn stover is hydrolysed with dilute sulphuric acid (H_2SO_4) and hydrochloric acid (HCl) at different concentrations of H_2SO_4 (i.e. 1, 2 and 4% H_2SO_4 in distilled water respectively). In order to break down the cellulose and hemicelluloses into simple sugar, 20mg of the pre-treated corn stover sample was maintained at solid to liquid ratio of 1:10, in 250 ml round bottom flask, and refluxed. Samples (60ml each), were retained after 2, 4, and 6 hours of hydrolysis for subsequent fermentation experiments. After hydrolysis the liquid fraction of the hydrolysate samples was cooled, filtered, collected, and adjusted to pH 5 by adding concentrated sulphuric acid and 2N Sodium hydroxide, and the solutions prepared for fermentation.

4. Ash production

The biomass samples were heated to a predetermined temperature and held for a predetermined amount of time using a programmable electric muffle furnace. Each batch of corn stover ash (CSA) was generated by burning 200 g of dry corn stover. The biomass was held during burning in a stainless-steel cage with two wire mesh shelves. Below the cage, a stainless-steel pan was set up to catch any ash that managed to get through the mesh. By putting 100 gr of high lignin residue (HLR) on a stainless-steel pan and heating it in a furnace, high lignin residue ash (HLRA) was created. Samples were heated to 500 ^{0}C for two hours (500/2) or 650 ^{0}C for one hour (650/1). Finally, the ash was pulverised in a laboratory ball mill for an hour at 85 revolutions per minute (rpm). Ash samples are named as follows: kind of ash, pre-treatment, washing intervals, burning temperature, and holding period.

b) High lignin ash added to concrete -

High lignin ash (biofuel by-product) is added to concrete replacing partially with cement in different percentages that is 10%,20% and 30% of high lignin and 90%, 80% and 70% of cement to the concrete. The finished concrete is tested.

TEST CONDUCTED:

1. Specific gravity
2. Slump Test
3. Normal consistency test of cement
4. Setting time test of cement
5. Compressive strength of concrete

RESULTS:

1) SPECIFIC GRAVITY TEST:

For High Lignin Ash Residue (HLRA) -

The specific gravity test was conducted for high lignin residue and the results are tabulated in table 1.

Table 1: Specific gravity test for HLRA

S.no	Particulars	
1	Weight of the empty density bottle W1(gms)	45
2	Weight of the bottle + water W2 (gms)	155
3	Weight of the bottle + kerosene W3(gms)	136
4	Weight of the bottle +kerosene+ash W4(gms)	166
5	Weight of the ash W5(gms)	50

Results:

Specific gravity of kerosene is = 0.827

Specific gravity of ash = 2.06

For Cement

The specific gravity of cement was conducted to compare with the specific gravity of HLRA. Table 2 shows the results of specific gravity of cement.

Table 2: Results of specific gravity of cement

S.no	Particulars	
1	Weight of the empty density bottle W1(gms)	28
2	Weight of the bottle + water W2 (gms)	83
3	Weight of the bottle + kerosene W3(gms)	71
4	Weight of bottle+kerosene+cement(w4)gms	60

5	Weight of the cement W5(gms)	50

Results:

Specific gravity of kerosene is = 0.78

Specific gravity of cement = 3.12

2) SLUMP TEST:

The consistency of the concrete was conducted using slump test. 30% of HLRA and 70% of cement was used in this test. The results is given in table 3:

Table 3: Results of Slump cone test

Water content	Slump (mm)
0.5	0 (true)
0.6	0 (true)
0.7	40 (shear)
0.8	150 (collapse)

3) NORMAL CONSISTENCY TEST:

For Cement

The test is conducted to find out the amount of water to be added in the cement to get paste of normal consistency. The observations and results are given below:

Table 4: Results of Normal consistency test

S.no	No of trials	1	2	3	4
1	Percentage of water	26	28	30	32
2	Initial Reading(mm)	40	40	40	40
3	Final Reading(mm)	38	38	31	7
4	Height Penetrated(mm)	2	2	9	33

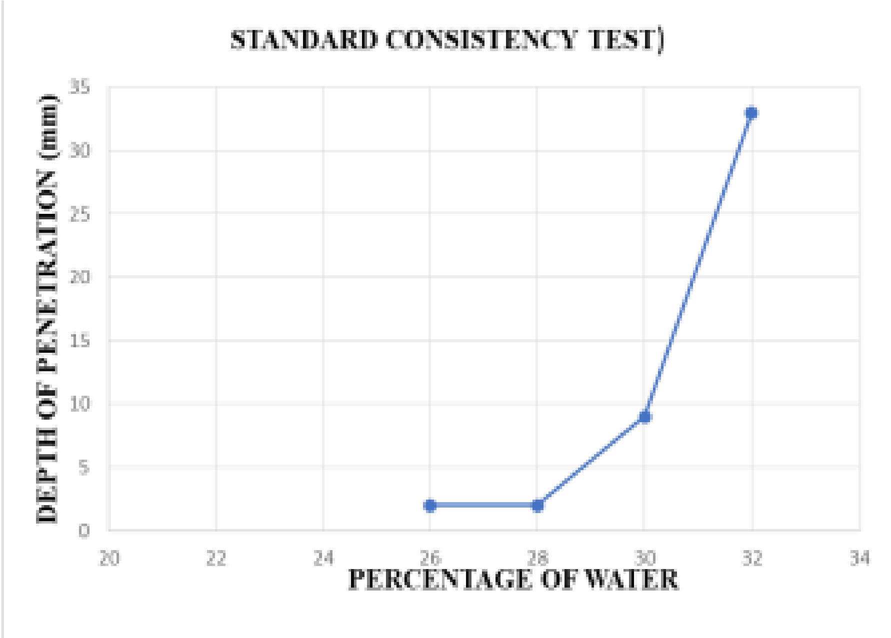

Figure2: Graph plotted between depth of penetration and water content for cement

Result:

The normal consistency of cement P=32%

For HLRA

The test was conducted to determine the water content for setting time test for HLRA. The results are given in table 5.

Table 5: Water content for setting time test for HLRA

S.no	**No of trials**	**1**	**2**
1	Percentage of water	26	28
2	Initial Reading(mm)	40	40
3	Final Reading(mm)	31	33
4	Height Penetrated(mm)	9	7

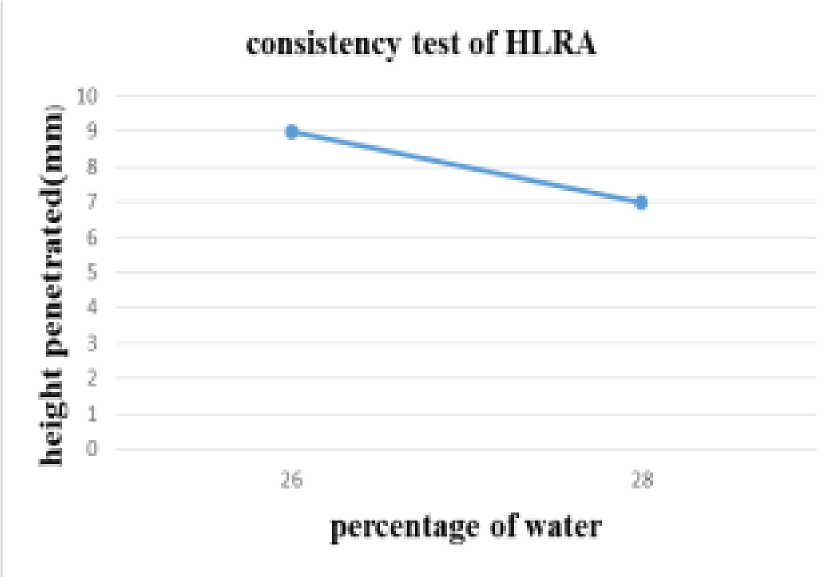

Figure 3: Graph plotted between depth of penetration and water content for HLRA

Result:

The normal consistency of ash P= 28%

4) SETTING TIME TEST For HLRA

This test was conducted to determine the initial setting time by taking HLRA 90gm of HLRA and 210 gm of cement was taken. The results are tabulated in table 6:

Table 6: Results of HLRA setting time

S.no	No of trials	1	2	3	4	5
1	Time in minutes	10	10	10	10	8
2	Initial Reading	48	48	48	48	48
3	Final Reading	6	8	11	13	16
4	Height Penetrated(mm)	42	40	37	35	32

Result:

The initial setting time of HLRA = 48 minutes

For Cement

This test is conducted to determine and compare the initial setting time of cement with HLRA. The results are given in table 7

Table 7: Initial setting time for cement

S.no	No of trials	1	2	3	4	5
1	Time in minutes	5	5	5	5	10
2	Initial Reading	48	48	48	48	48
3	Final Reading	8	10	10	12	16
4	Height Penetrated(mm)	40	38	38	36	32

Result:

The initial setting time of cement is = 30 minutes

5) COMPRESSIVE STRENGTH TEST:

In this test the cement was partially replaced with HLRA in different percentages and the strength of the concrete was checked and compared. The results are tabulated in table 8.

Table 8: Characteristic strength of concrete in different proportions of high lignin ash

Ash content	Load (KN)	Compressive strength(N/mm^2)
0% ash content	395	17.55
10%ash content	401	17.82
20%ash content	406	18.04
30%ash content	413	18.35

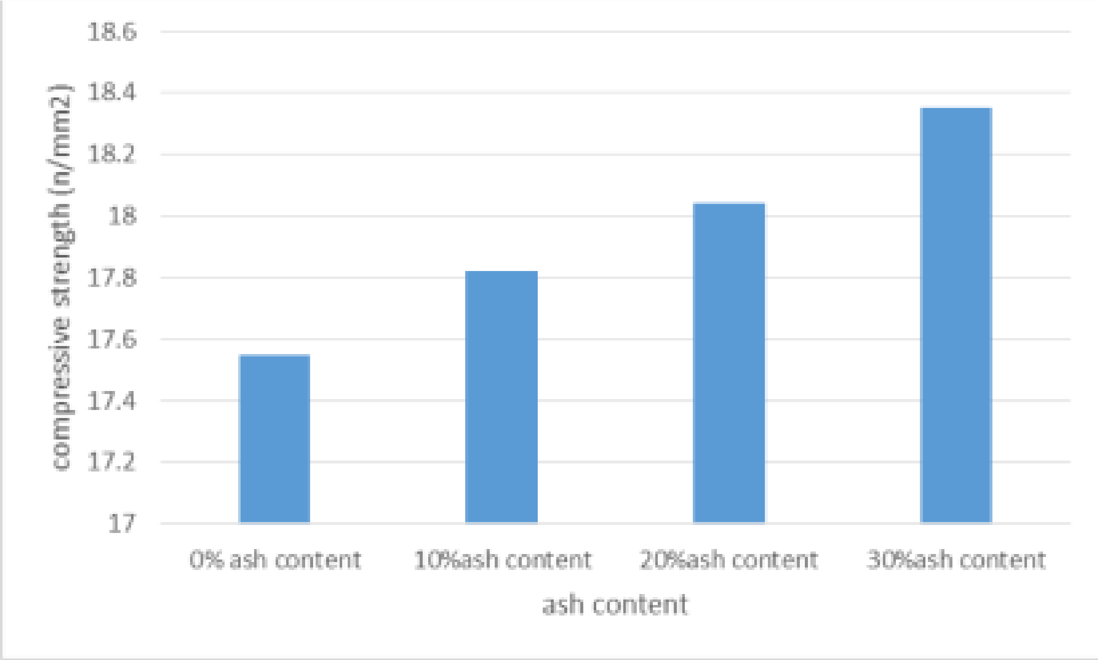

Figure 3: Compressive strength comparison graph

CONCLUSION:

1. It is concluded that the by-product of Ethanol produces a material that can be used in concrete as a partial replacement of cement.
2. The study was conducted with an aim to replace the cement partially with high lignin ash and focus on the properties of the concrete blocks.
3. Cement plays an important role in the compressive strength and behaviour. When high-lignin ash by-product is added to cement, the ash reacts chemically with the cement to make it stronger. Specimens with cement and ash exhibit larger compressive strength.
4. Using high lignin ash material can reduce the amount of cement and thus reduces the carbon footprint.
5. The manufacturing, processing, and construction techniques are still not developed enough to facilitate its uses and this requires extensive amount of research. This type of concrete can be developed as a material which is suitable for concrete pavement, concrete benches and temporary shelters.
6. Hence this type of concrete consumes less energy and becomes more economical.

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