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Partial Replacement of Cement with Cinchona Bark Biomass Ash in the Production of Concrete Blocks

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ABSTRACT: Biomass ash generated by EPZ companies in Kenya is a big environmental concern. The research focused on investigation of suitability of the cinchona bark biomass ashes partial replacement of cement in concrete. The biomass was analysed for chemical composition to determine the pozzolanic properties and compared with those of Ordinary Portland and Pozzolana cements. Cement replacement with cinchona biomass ash varied between 0 and 100%. The characterisation of partially and fully replaced cements was evaluated before application on concrete works. Concrete blocks were produced by mixing the partially replaced cement and crushed rock sand (CRS) or CRS blended with 10mm nominal size coarse aggregates. Two brands of cement were selected for this study. For each brand, two cement classes, Cem 32.5 and 42.5 were investigated. The ratio of cement to CRS in concrete mix were as follows: 1:2, 1:3, 1:4, 1:6 and 1:8. The initial coarse aggregate (<10mm) content in the CRS averaged 12%. The coarse aggregate content was adjusted to 25% in the mix design. The performance of Concrete blocks for 12% coarse aggregate was compared to that of 25%. 12% coarse aggregates resulted in stronger blocks. Pigments were incorporated to produce coloured blocks. Compressed solid blocks of size 140mm x150mm x290mm were produced by compression. The blocks were tested for physical and mechanical properties after curing. Within a range of 50 to 70 % cement replacement with CBBA, load bearing concrete blocks with compressive strength of 7.0mPa was produced on application of CRS. Infill concrete blocks with compressive strength of 3.0mPa was produced with cement replacement of 80%. Production of concrete blocks with more than 90% cement replacement resulted in compressive strength less than 2.0mPa. 100% cement replacement give blocks that will disintegrate when immersed in water an indication of very little binding. The percentage of water for standard consistency was slightly lower for cem 42.5 than with 32.5 with a value of 37.5 % for 0% of ash content and an average value of 111% at 100% ash content.

I. INTRODUCTION

Concrete blocks are masonry units used in the construction of walls. They are precast products which are formed or cast in moulds, extruded and cured in water or steam before use. The concrete blocks are: solid, cellular or hollow. The cost of conventional construction materials continues to rise due to depletion and increased demand creating a need for research and innovation for cheaper and environmental friendly materials. The present and future demands for construction industry are materials which are light, durable, economic and environmentally sustainable. The building and construction industry play a critical role in economic and social development. Provision of a built environment contributes to our economic competitiveness and the quality of life for the citizens. Conventional concrete has low strength to weight ratio which results in longer construction period and more workers during the construction process. According to Kenya National Housing Survey report 2012/2013, over 50 per cent of Kenyans live below the poverty line. The median income levels for employed people in this country are between Ksh 20,000 and Ksh 25,000 (Statistical Abstract, 2013)

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II. LITERATURE REVIEW

As reported by B. SomeSwara Roa et. al, due to low pozzolanic action the Rice Husk Ash (RHA) and Sugar Cane Bagasse Ash (SCBA) concrete achieve significant improvement in its mechanical properties at a late age. According to Obilade, LO., the compressive strength of concrete reduced as the percentage RHA replacement for cement increased and the optimum addition of RHA as partial replacement for cement is in the range of 0-20%. Satish H. Sathawane et.al, reported that Compressive strength of concrete increases with increase in the percentage of fly ash and Rice Husk up to replacement 22.5% FA and 7.5% RHA of cement in concrete for different mix proportions. The workability of concrete had been found to decrease with increase of RHA. Due to low specific gravity of RHA, the mass per unit volume of concrete reduced. Production of concrete waste blocks mixed with concrete waste could be profitable disposal alternative in future as reported by M.S. Rosman, N.F. Abas, M.A. Othuman Mydin, "Concrete Waste as a Cement Replacement Material in Concrete blocks for Optimization of Thermal and Mechanical properties" SHS Web of conferences 11, 01013 (2014). They are reported that thermal data showed that the mixture containing 15% of concrete waste had the lowest temperature in regard to the average difference with the surrounding area by 3.06°C and that the density and compressive strength indicated best performance with the control mix.

III. MATERIALS AND METHODS

3.0 Materials and Methodology

3.1 Cinchona Bark

Cinchona bark produces several alkaloids with the most important one being quinine. Some alkaloids are soluble in water while others are soluble in wine. The medicinally active bark is stripped from the tree, dried and sometimes powdered and includes other alkaloids that are closely related to quinine but react differently in the treatment of malaria. The plants are cultivated in the native south America and other tropical regions.

3.2 Extraction of Quinine

In early days infusion were prepared with lime or wine by boiling. Today other methods that allow for safer and pure extracts are available.

3.3 Production of Bio energy

The biomass waste residue that remains after extraction of quinine is used for production of bio energy. The biomass is used as bio fuel in the boiler by direct combustion. As the demand for bio energy increases ash residue volume increases.



Figure 1: Cinchona harvested bark (EPZ botanical extracts company)

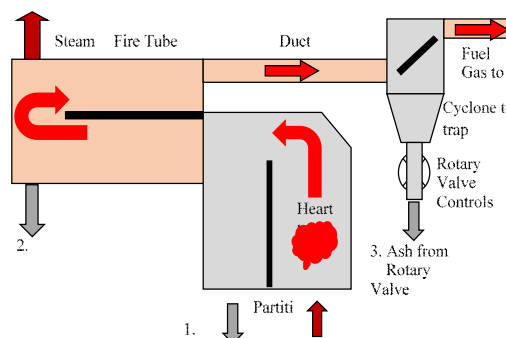


Figure 2: Cinchona Biomass ash (CBA) generation

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3.4 Biomass Ash

Boiler fuel varies according to the materials available but generally a mixture of wood chips and residue cinchona bark after extraction of the alkaloids. The residual cinchona contains 80% of the powdered bark, 15% of lime (Calcium hydroxide), 5% caustic soda (sodium hydroxide) on dry weight basis. The volume of ash produced daily varies according to the factory activities and type of fuel used. On a normal production, there will be 1-1.5m³ of ash per day. The ash is currently collected in drums. Forty (40) tonnes of Cinchona bark are consumed by the factory per month. The capacity for the factory is one hundred and twenty (120) tons per month giving a daily production of 3-4.5m³ of ash daily.

3.5 Crushed rock Sand(CRS)

Crushed sand samples were sampled from three crushing plants in Nairobi. The particle size distribution varied slightly for different plants.

3.6 Cement

Two cement manufacturing companies were selected for this research work. From each company pozzolanic and OPC cement were procured from Juja and Thika town.



Figure 3: Crushed Rock Sand (CRS)



Figure 4: Cinchona Biomass ash (CBA)

3.7 Research Design

The ACI method for normal concrete mixtures was employed in the computation of the proportions on the concrete mixture. According to Frasson Jr. et al, 2012, a design methodology for concrete block units, the coarse aggregates most employed in concrete block production are those that pass 9.5mm sieve. To ensure adequate cohesion of the mix, fine aggregates mix must have a fineness modulus of 2.20 to 2.80 and the proportion of coarse aggregates should be within a range of 20 to 40% of the total aggregates. The pozzolanic materials were tested for chemical, physical and mechanical properties. The chemical tests covered oxides of interest as required for cementitious binders. Cement was mixed with CRS to produce concrete which was cast into cubes for mechanical properties testing after curing. Specimens were cast with CEM I and CEM 11 cements from two Cement manufacturing companies.

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IV. RESULTS AND DISCUSSION

4.1 Chemical Analysis of Cement and Cinchona ash

The results for the chemical analysis of the ash and the cement are shown in figure 1. The concentration of Al_2O_3 in ash is 2.60% as compared 7.90% in the Cement. The ash contains 0% of SiO_2 whereas cement contains 41.8% of the same oxide. The CaO concentration of 88.9% in ash exceeds that of the cement

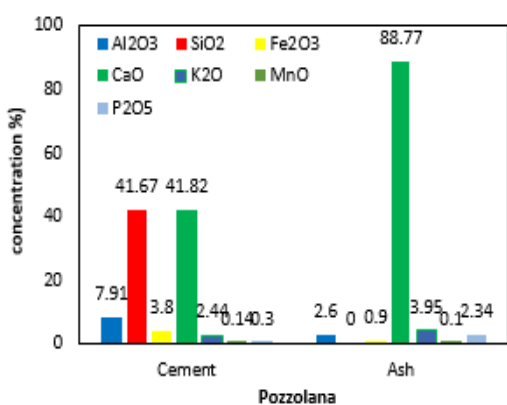


Figure 5: Chemical composition of Pozzolana

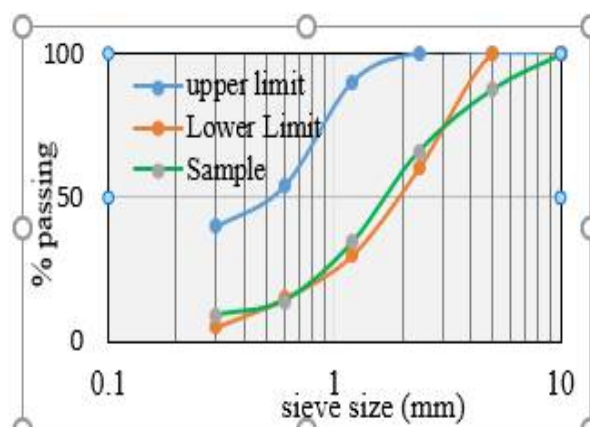


Figure 6: Particle size distribution of crushed rock sand.

4.2 Standard Consistency

The water demand for cement paste of standard consistency was established for control and partially replaced cement.

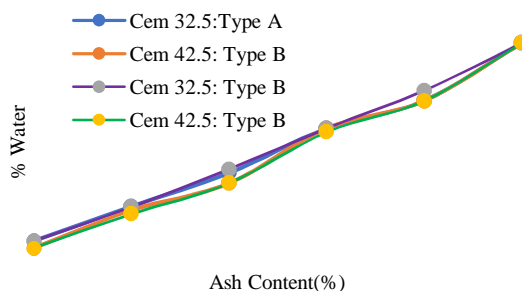


Figure 7: Variation of water (%) for standard consistency with ash content

The percentage of water for standard consistency increases with increase in ash content. At 100% ash content, water content for a standard consistency is 111% for the four types of cements. 36% water content is required for a standard consistency with cem 32.5 at 0% ash content while the value increases to 39% for cem 42.5. The variation of the percentage of water for various cement replacement is minimal for different types of cements.

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4.3 Specific Gravity

Cement was replaced with cinchona ash at different proportions and the specific gravity of each mix determined using the Lechatelier method

Table 9: Specific Gravity of Cem 32.5 and 42.5

	Company A		Company B	
	Cem 32.5	Cem 42.5	Cem 32.5	Cem 42.5
Specific Gravity	2.79	3.08	3.05	3.06

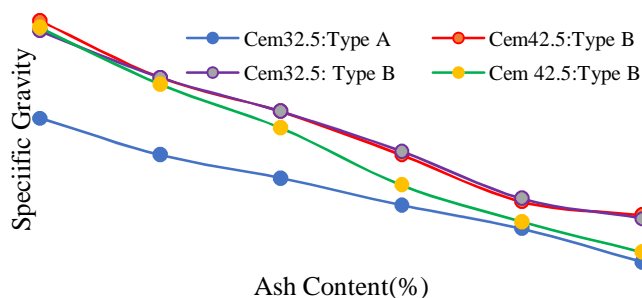


Figure 8: Variation of specific gravity with ash content

Cem 42.5 had the highest specific gravity values of 3.08 and 3.06 for company A and B respectively. Cem 32.5 from company B had a specific gravity value of 3.05 which was very close to values given by cem 42.5. However, it was noted that the specific gravity of cem 32.5 from company A was very low in comparison with the rest having a value of 2.79. From figure4 there was a general trend where specific gravity reduced with an increase of the ash content. On average cement from company B (Cem 32.5 and 42.5) had the same values of specific gravity while cem 32.5 from company A had the lowest values for the various ash content.

4.4 Initial and Final Setting Time

The initial and final setting time for the pozzolana and OPC cements from the two companies was determined. Each class of cement was replaced with cinchona biomass ash at an interval of 20% and initial and final setting time determined for each replacement.

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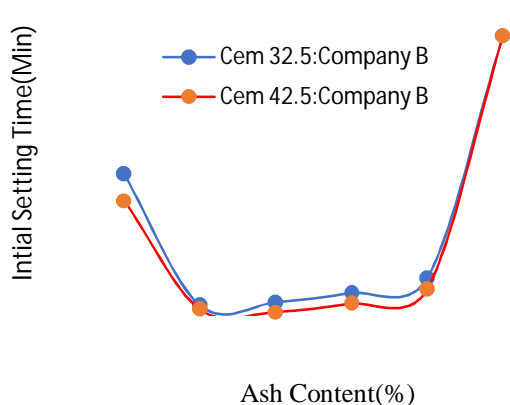


Figure 9: Variation of initial Setting Time with ash content

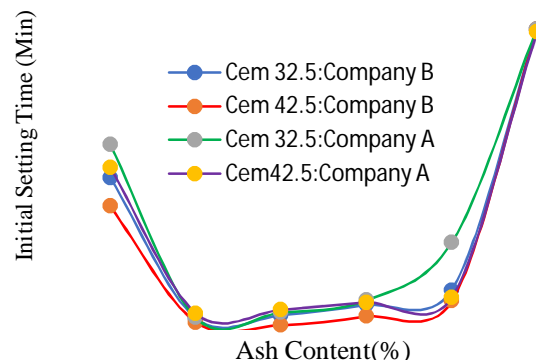


Figure 10: Variation of initial Setting Time with ash content

Replacement of 20% cement with ash reduces the initial setting time to between 10 and 24 minutes for the four types of cements under investigation. Cem 42.5 from company B had the lowest initial setting time of 3 hours while cem 32.5

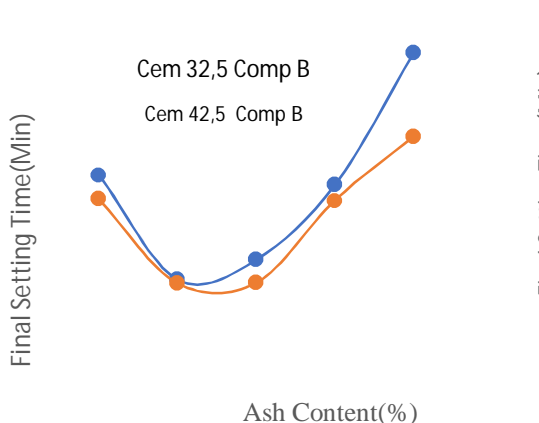


Figure 11: Variation of Final setting time with Ash content (Comp. B)

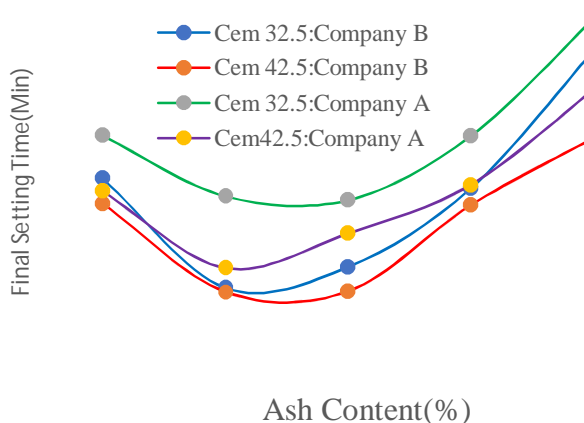


Figure 12: Final Setting Time, 32.5 and 42.5 (Comp. A and B)

from the same company had an initial setting time of 3 hours 40min. Pure ash had the longest initial setting time of 7.5 hours on average. Cem 32.5 from company A had the longest initial setting time of 4.6 hours.

Cem 42.5 has less final setting time than Cem 32.5. Replacement of cement with Cinchona biomass ash reduces the final setting time geometrically up to between 20 and 30% but replacement beyond this level increases the final setting time. Cem 32.5 from company A has longer final setting time than cem 32.5 from company B. Cem 42.5 from company B has the least setting time for the cement brand under consideration.

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4.6 Compressive strength and density

Concrete cubes were tested for compressive strength and density after 7 and 28 days curing

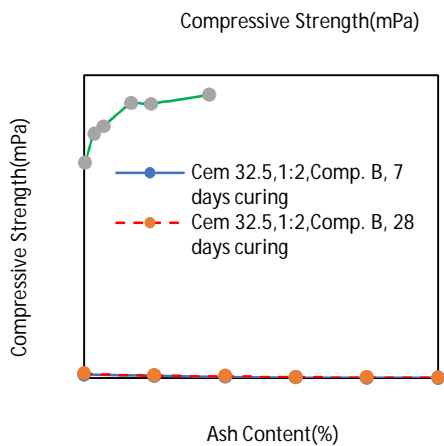


Figure 13: Variation of compressive strength, density, ash content with mix ratio 1:2, Cem 32.5

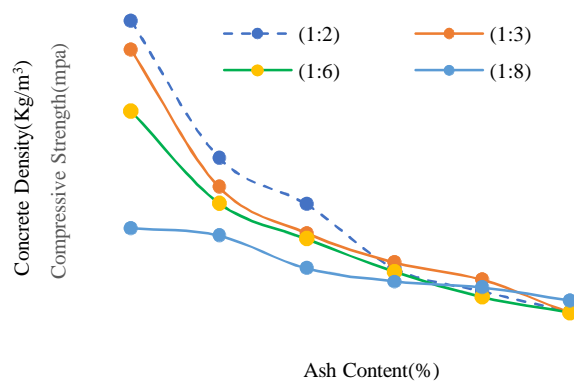


Figure 14: Variation of compressive strength with ash content Cem 32.5 (Comp. B)

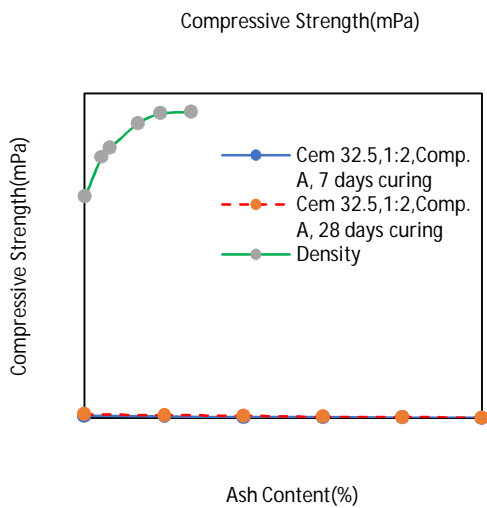


Fig. 15: Variation of Compressive strength and density with ash content, mix ratio 1:2, cem 32.5 (Comp. A)

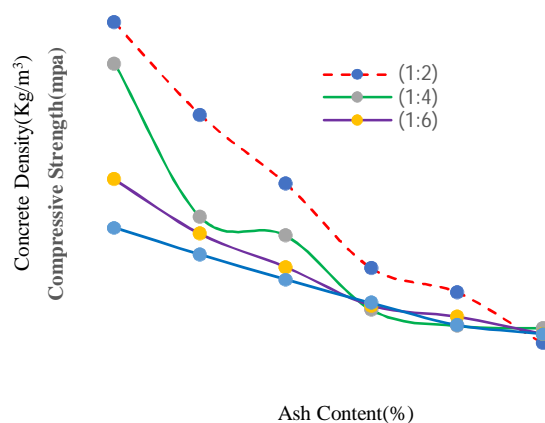


Fig. 16: Compressive strength with ash content, for diferent mix ratios, cem 32.5(Comp.A)

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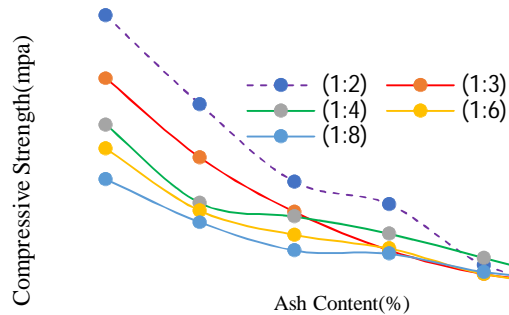


Figure 17: Variation of compressive strength with ash content on Cem 42.5 (Company A) at 28 days

The compressive strength of the concrete mix with material proportion of 1:3 (0% ash content) based on cem 42.5 from Company A was 37.5mPa at 28 days. The general trend where the 7 days strength is lower than the 28 days strength was observed. The compressive strength of the blocks increased with an increase in density. At a compressive strength of 5mPa the block density was 2000Kg/m³ which falls below that of normal solid concrete block. This means there is economy in weight and design with cinchona ash blocks as opposed to the normal solid concrete blocks. The compressive strength of the mix ratios 1:2, 1:3, 1:4, 1:6 and 1:8 are 48.5, 37.8, 28.9, 24.6 and 19.1 mPa respectively for 0% ash content with cem 42.5 from company A. For each mix ratio, the compressive strength decreases with an increase of the ash content.

4.5 Water Absorption

The concrete blocks were tested for water absorption and the results are as shown in figure 9 below

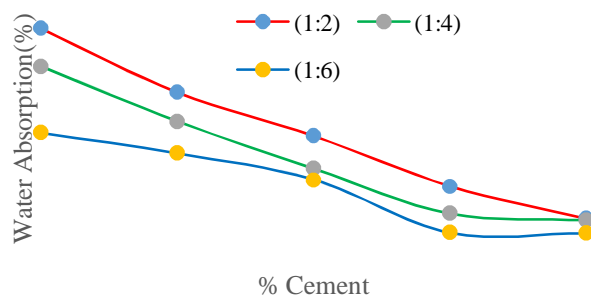


Figure 18: Variation of water absorption with cement content

Water absorption reduced with an increase of cement content. Water absorption also reduced with the increase of the ratio of cement to CRS.

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Fig.19:Curing of Cinchona Ash concrete Blocks



Fig 20: Efflorescence on 100% Cinchona ash Mortar cube.

V. CONCLUSION

From the investigations of the research, it was concluded that concrete blocks produced with CBBA are strong and durable. More specifically it was concluded that:

- Within a range of 50 to 70 % cement replacement with CBBA, load bearing concrete blocks with compressive strength of 7.0mPa can be produced on application of CRS. Infill concrete blocks with compressive strength of 3.0mPa can be produced with cement replacement of 80%. Production of concrete blocks with more than 90% cement replacement results in compressive strength less than 2.0mPa. 100% cement replacement give blocks that will disintegrate when immersed in water an indication of very little binding.
- Concrete blocks of different colours can be produced by incorporating colour pigments in the concrete mixes.
- CRS which has an average value of 12.0% CA gives concrete blocks with higher compressive strength than those with 25% CA as required in the mix design for concrete blocks.
- An increase of cement replacement with CBBA increases water demand for consistent paste. The percentage of water for standard consistency was slightly lower for cem 42.5 than with 32.5 with a value of 37.5 % for 0% of ash content and an average value of 111% at 100% ash content.
- The effect of ash content on initial and final setting time is in the form of a trough with setting time values reducing initially and later increasing as the ash content increases. The setting time for cem 42.5 is generally lower than cem 32.5. The initial setting time of 100% ash content averages final setting time for 100% ash content takes more than one week.
- The water absorption of concrete blocks increases with an increase of the ash content. Water absorption also increases with an increase of ratio of cement to CRS
- The specific gravity reduces with an increase of ash content. The ash has lower density than the cement thereby reducing the specific gravity of cement when mixed.
- The CBBA blocks have higher modulus of elasticity than the machine cut stones from Ndarugu.

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