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Review

Utilization of wood ash in concrete manufacturing

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ABSTRACT

Solid waste management is the prime concern globally due to ever increasing quantities of waste materials and industrial by-products. Scarcity of land-filling space and because of its ever increasing cost, recycling and utilization of industrial by-products and waste materials has the only option. There are several types of such materials. The utilization of such materials in concrete not only makes it economical, but also helps in reducing disposal concerns. One such material is wood ash (WA). Wood ash (WA) is the residue generated due to combustion of wood and wood products (chips, saw dust, bark, etc.). It is the inorganic and organic residue remaining after the combustion of wood or unbleached wood fiber.

This paper details about the physical, chemical, elemental and mineralogical composition of wood ash. It highlights the influence of wood ash on the slump, water absorption, compressive strength, splitting tensile strength, flexural strength, freezing and thawing resistance, and shrinkage of concrete. It also deals with the leaching behavior of wood ash.

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1. Introduction

Wood ash (WA) is the residue generated due to combustion of wood and wood products (chips, saw dust, bark, etc.). It is the inorganic and organic residue remaining after the combustion of wood or unbleached wood fiber. Hardwoods usually produce more ash than softwoods and the bark and leaves generally produce more ash than the inner woody parts of the tree. On the average, the burning of wood results in about 6–10% ashes. Wood ash composition can be highly variable depending on geographical location and industrial processes.

1.1. Applications of wood ash

Approximately, 70% of the wood ash generated is landfilled; 20% is applied on land as a soil supplement, and remaining 10% has been used for miscellaneous applications (Etiegni, 1990; Campbell, 1990; Etiegni and Campbell, 1991; NCASI, 1993) including construction materials, metal recovery, and pollution control.

1.1.1. Land application

Wood ash applications should be limited to a level that maintains the soil pH within the optimum range for the intended crop growth. The liming ability of wood ash is generally estimated by using a laboratory measured parameter called the calcium carbonate equivalent (CCE). The CCE indicates how well the wood ash will raise the soil pH compared to lime (calcium carbonate). As with the nutrient composition of wood ash, the CCE of different wood ash may vary considerably, however, most are within the range of 25–60%.

Etiegni and Campbell (1991) reported the use of wood ash as an agricultural soil supplement and liming material. For that investigation, two types of plants (winter wheat and poplar) were grown in a greenhouse on six different Idaho (United States) soils amended with varying amounts of wood ash. The results indicated a substantial increase in the wheat biomass and in the diameter and height of the poplar at ash concentrations of up to 2% (16 tons/acre). Based on the results obtained, the author indicated that wood ash could be used as a low-grade fertilizer containing potassium and as a liming agent. Meyers and Kopecky (1998) reported that use of wood ash resulted in a higher yield compared to those obtained with limed and fertilized control treatments. No adverse effects were noted at wood ash application rates of up to 20 tons/acre.

Nguyen and Pascal (1997) measured tree growth responses using two sources of wood ash as a forest soil amendment. The addition of wood ash affected all the measured growth responses (height, diameter, and total leaf area) within the tested range. However, 2% (i.e., 16 tons/acre) application rate was found to be optimum. Bramryd and Frashman (1995) reported a decrease in acidity and aluminum concentration when wood ash was applied to the soil having 35-year old pine trees in Sweden. Except Cu, no significant increase in heavy metal concentrations was found due to the addition of wood ash.

Naylor and Schmidt (1986) evaluated wood as a fertilizer and liming material. Wood ash was mixed with two acidic soils at rates of 0, 0.4, 1.8 and 2.4 tons/acre to assess changes in extractable nutrients and soil pH. Concentrations of extractable P, K, and Ca increased with increasing ash application rate. The same trend was also noticed for soil pH. The neutralizing capability of the ash was found to be half of that achieved by using agricultural limestone.

1.1.2. Pollution control

Wood ash has been used as a replacement of lime or cement kiln dust in the solidification of hazardous wastes (NCASI, 1993). It has also been used for odor as well as pH control of hazardous and non-hazardous wastes. Wood ash has been added to compost as a color and odor control. Wood ash has been found to capture several water borne contaminants (NCASI, 1993).

1.1.3. Construction materials

Not much work has been reported relating to the applications of wood ash as a construction material, particularly in cement-based materials. Due to high carbon content in wood ash, its use is limited to low- and medium-strength concrete materials. In Europe, wood ash has also been used as a feedstock in the manufacture of Portland cement (Etiegni, 1990). Naik (1999) reported that wood ash has a substantial potential for use as a pozzolanic mineral admixture and an activator in cement-based materials. He further indicated that wood ash has significant potential for use in numerous other materials including controlled low strength materials (CLSMs), low- and medium-strength concrete, masonry products, roller-compacted concrete pavements (RCCPs), materials for road base, and blended cements.

2. Properties of wood ash

Physical and chemical properties of wood ash are important in determining their beneficial uses, and vary significantly depending on many factors. These properties are influenced by species of tree, tree growing regions and conditions, method and manner of combustion including temperature, other fuel used with wood fuel, and method of wood ash collection (NCASI, 1993; Etiegni, 1990; Etiegni and Campbell, 1991).

2.1. Physical properties

Etiegni and Campbell (1991) studied the effect of combustion temperature on yield and chemical properties of wood ash. The results showed that wood ash yield decreased by 45% when combustion temperature were increased from about 550 to 1100 °C. The average particle size of the wood ash was found to be 230 μm. The pH of wood ash was found to vary between 9 and 13.5.

Naik (1999) determined the physical and chemical properties of wood ashes derived from different mills. The average moisture content values for the wood ash studied were about 13% for fly ash and 22% for bottom ash. The average amount of fly ash passing sieve #200 (75 μm) was 50%. The average amount of fly ash retained on sieve no. 325 (45 μm) was about 31% for wood fly ash. Test results for unit weight or bulk density (ASTM C 29) exhibited average density values of 490 kg/m^3 for fly ash and 827 kg/m^3 for bottom ash. Wood fly ash had an average specific gravity value of 2.48. Specific gravity for bottom ash showed an average of 1.65. The average saturated surface dry (SSD) moisture content values were 10.3% for fly ash and 7.5% for bottom ash. The average cement activity index at the age of 28 days for fly ash was about 66% of the control. The average water requirement for fly ash exhibited a value of 116%. Autoclave expansion tests for fly ash exhibited a low average expansion value of 0.2%.

Naik et al. (2003) evaluated the wood ashes from five different sources for possible use in making controlled low-strength materials (CLSMs). They used wood ashes from five different sources in Wisconsin (USA) and were designated as W1–W5. Physical properties of all the five sources of wood ash are presented in Table 1. Fineness of the wood ash (% retained on 45 μm sieve) varied from 23 to 90%. Specific gravity of wood ash sources ranged from 2.26 to 2.60.

Udoeyo et al. (2006) reported the physical properties of waste wood ash (WWA), used as additive in concrete. The WWA had a specific gravity of 2.43, a moisture content of 1.81%, and a pH value of 10.48. The average loss on ignition of the ash was found to be 10.46.