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Characterization of Chicken Feathers Ash as a Potential Soil Stabilizing Material

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Abstract:

As a byproduct of the poultry meat processing industries, huge quantities of chicken feathers are produced. The methods utilized to dispose of chicken feathers from these industries and abattoirs are expensive and not sustainable. The study aims to examine the chemical composition and cementitious properties of a chicken feather, and its fractions in ash form (as a Powder and Flake). The morphological, structural, and chemical properties of the prepared chicken feather ash powder and flakes are analyzed through XRF, XRD, and SEM. This experiment is carried out to compare the changes in chicken feathers when it turns to ash powder and the flake structure after the incineration process. The incinerator to convert waste chicken feathers to ash powder and flakes is designed with a carbon filter to reduce the environmental impact. Results indicate that feather ash powder contains lime content in the form of CaO i.e. 39% which can act as a good stabilizing material in soil compared to the chicken feather ash flakes that contain a high amount of wollastonite that comprises small traces of iron, manganese, and magnesium substituting calcium. Also, the optimum temperature of 600°C is derived to convert the chicken feathers into ash form with a high level of calcium carbonate and silica. The study concludes that the chicken feather ash powder is recommended as a soil stabilizing material over the flake due to the higher amount of pozzolanic material in the Chicken Feather Ash Powder (CFAP) than the Chicken Feather Ash Flake (CFAF). Thus, chicken feather waste can be turned to be potential soil stabilizing material by converting it into ash form.

Keywords: *Chicken Feather Ash, Incineration, Soil Stabilization, Sustainability*

1 Introduction:

According to a National Chicken Council report, chicken is one of the most popular meats consumed around the world. India is one of the global highest producers of chicken meat. The demand for chicken has grown significantly over time, and consumption has risen significantly due to increasing average income and urban population. In 2021, it is found that over four million metric tons of chicken meat were consumed in India. Apart from the meat, chickens' feathers make up to 10% of their total weight, which indicates that every year, 8–9 million tons of waste chicken feathers (CFs) are generated worldwide. [7,10,12]. The keratin and numerous cysteine bonds in CFs make them difficult to break down [3]. Traditionally, Poultry litter (including feathers, poultry excreta, spilled feed, and other materials used as bedding in poultry operations) is spread on soils as an organic fertilizer. However, excess application of this material results in an overabundance of nutrients that eutrophicates water bodies spreads diseases, produces phytotoxic chemicals, pollutes the environment, and emits greenhouse gases. [1]. In developing countries, these CFs produced are commonly disposed of by open dumping which causes deposition and clogging of roadside drains and other open pits. Thus posing a serious challenge in solid waste management and a high threat to people's health. In most cases, only a small portion of (CFs) are converted into useful byproducts like fertilizer and feather meal, while the rest is disposed of in a landfill. The utilization of feathers as a meal will affect the digestive system due to the presence of pepsin and leachate produced through the landfilling of feathers will result in groundwater contamination. Therefore, there is a need for adequate waste management facilities and treatment of the CFs for their disposal. Adversely Presence of high p and k in the chicken litter ash which includes chicken manure may affect the pozzolanic activity with the soil and it can be controlled by segregating the chicken feathers and turns to ash which can be used as a soil stabilizing agent. Around the world, CFs are disposed of by two major methods i.e., Incineration and landfill disposal. Disposal of waste in landfills is a concept that has been practiced for many decades but bio-accumulation of heavy metals in feathers may lead to soil and groundwater contamination. Moreover, one of the effective methods for destroying potentially infectious pathogens and controlling leachate production is incineration process. Thus, using waste chicken feather ash as binding material will minimize environmental pollution. Municipal Solid Waste (MSW) can be incinerated to dispose of a significant volume of waste and generate energy at the same time, with a reduction in mass and volume to 70% and 90%, respectively. [8,11,13]. But incinerating at high temperatures will affect its physicochemical composition and becomes useless as trash. So, CFS must incinerate at optimum temperature for high retention of cementitious properties.

According to Luyckx et al (2020), poultry litter in ash form contains elements such as Ca, Si, Mg, Fe, and Al which can be effectively used as a building material. However, the conversion of poultry litter into ash may increase the fertility when added to soil than the increase in strength properties due to the presence of high p and k components [6]. Studies suggest that replacing a percentage of chicken feather ash (CFA) in cement production with other organic ash compounds (stimulating pozzolanic activity) reduces the percentage of greenhouse gases released into the atmosphere [2, 4, 5]. Hence, an attempt has been made to characterize the CFA (in powder and flakes forms) including morphological, mineralogical, and chemical composition, and examine the presence of cementitious properties. Based on the results and literature analysis the feasibility of using chicken feather ash as a potential stabilizing agent is discussed.

2 Experimental Methods:

As the Namakkal district in Tamil Nadu is one of the major poultry hubs in the country, the chicken feathers are collected from various farms and the poultry meat processing industry. The collected feathers are rinsed several times with warm water and soap to remove impurities air-dried for 24 hours. The cleaned feathers are burned at a different temperature through an incinerator which is designed to a capacity of 150 grams. Through various trials, it is found that the cementitious properties are retained at a high percentage at an optimum temperature of 600°c. At this stage, the chicken feathers are incinerated at 600°c. At different time intervals (i.e. 30 and 10 minutes) to convert into two forms i.e. ash powder and ash flakes. As a preventive measure, the filter to reduce the emission of sulfur dioxide is fixed in the furnace to control the air pollution and Loss of ignition is calculated. The collected ash powder and flakes are kept inside the desiccator and allowed to cool for 30 mins. The ash powder is pulverized and sieved to fine material. Now, CFA in both powder and flake forms is taken to a laboratory for further analysis. The entire process of is depicted in (Fig.1).

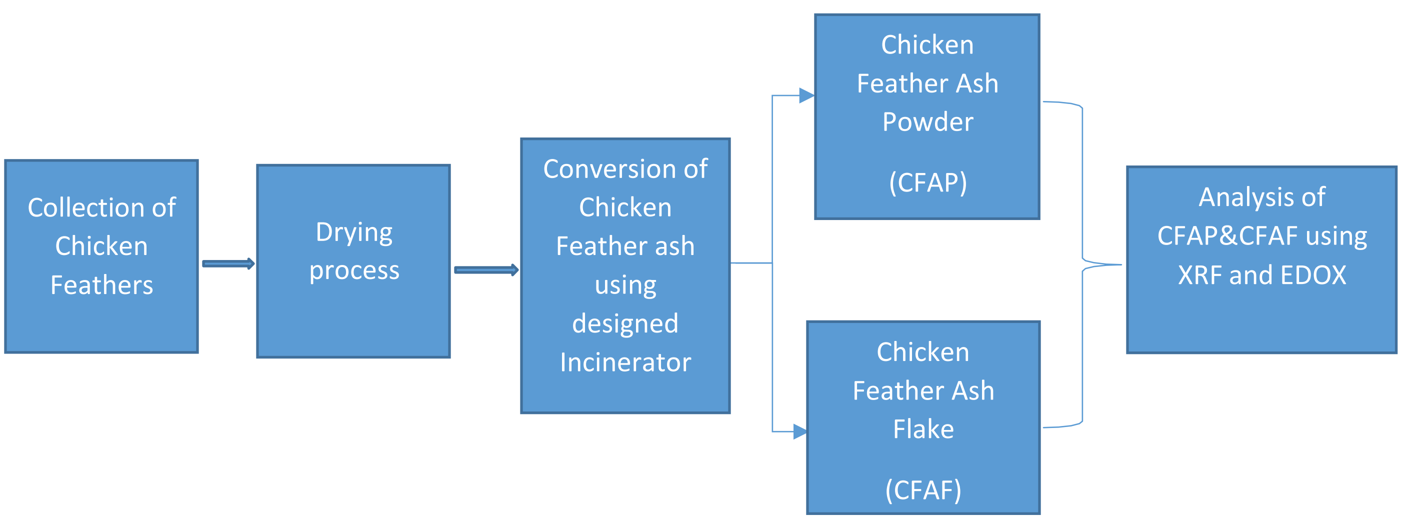

Fig. 1. Methodological process of conversion of chicken feather to Ash.

2.1 Characterization of Samples:

More than 90% of a chicken feather's composition is beta keratin, an insoluble, fibrous structural protein that is extensively cross-linked by disulfide bonds. This study is conducted to assess the Chicken feather compositions and the cementitious properties of feather ash (Flake and powder). The chemical, mineralogical and morphological composition of CFs are analyzed as follows.

2.1.1 X-ray diffraction (XRD):

Samples are dried for 24 h in an oven at a temperature of 110 °C and then sieved through N60. The samples were stored in an air-tight bag. XRD analysis is conducted using XRD-diffractometer (Model: D8 advance). The samples were inspected by 2 at a rate of 1.5°/min in the 10-60° angstrom range. The qualitative analysis is found to have distinct peaks in the spectrum.

2.1.2 Scanning Electron Microscopy (SEM).

The morphological analysis is carried out by scanning electron microscopy (Model No: EVO / 18 Research, Brand Name: Carl Zeiss). The materials for SEM analysis are prepared similarly to XRD analysis. The results of the SEM investigation are used to identify the surface features, and size of the components. Energy dispersive spectroscopy (EDS) is carried out with SEM analysis to determine the characteristics and nature of the elements present in the sample.

2.1.3 X-Ray Fluorescence (XRF).

The chemical compositions of the ashes are determined by X-ray fluorescence. Chicken feather ash is dried for 24 h in an oven at a temperature of 110 °C and then sieved through a 60N sieve. XRF analysis is conducted at the NCES consisting of Bruker model S8 Tiger and S4 Pioneer sequential wavelength-dispersive x-ray spectrometers and sample preparation units.

3 Result and Discussion

Initially, SEM and EDS tests are performed on the chicken feather ash (powder and flake) to determine the cementitious properties and their Morphological structure. The chemical composition of the CFA in powder and flake forms is shown in Table 1.

Table 1: Chemical composition of Chicken Feather Ash: Flake and Powder

Element	CFAF%	CFAP%
$CaCO_3$	-8.50	61.73
SiO_2	42.18	26.2
MAD-10 Feldspar	21.37	1.61
Wollastonite	44.95	4.18
Magnesium Oxide	-	1.45
Albite	-	1.38
Iron disulpide	-	1.02

3.1 SEM and EDS

3.1.2 SEM and EDS Analysis on Chicken Feather Ash Flake

SEM analysis on chicken Flake is conducted to examine bonding structure, fabric arrangement, surface individuality, and particle orientation. EDOX is to determine the chemical composition of the chicken feather flake. The results show that the chemical composition of the flake structure contains more wollastonite i.e., 44%. Wollastonite is a calcium inosilicate mineral with minor levels of iron, magnesium, and manganese that act as calcium replacements. It also contains silicon dioxide i.e nearly 42% and 21% of Feldspar as shown in Table 1. The chemical formula SiO2 (silicon dioxide), commonly referred to as silica, is an oxide of silicon that is most frequently found in nature as quartz mineral and organic waste materials. Silica makes up most of the sand in various places of the world. The morphological image of the CFAF indicates the presence of pores structure. (See Fig.2.)

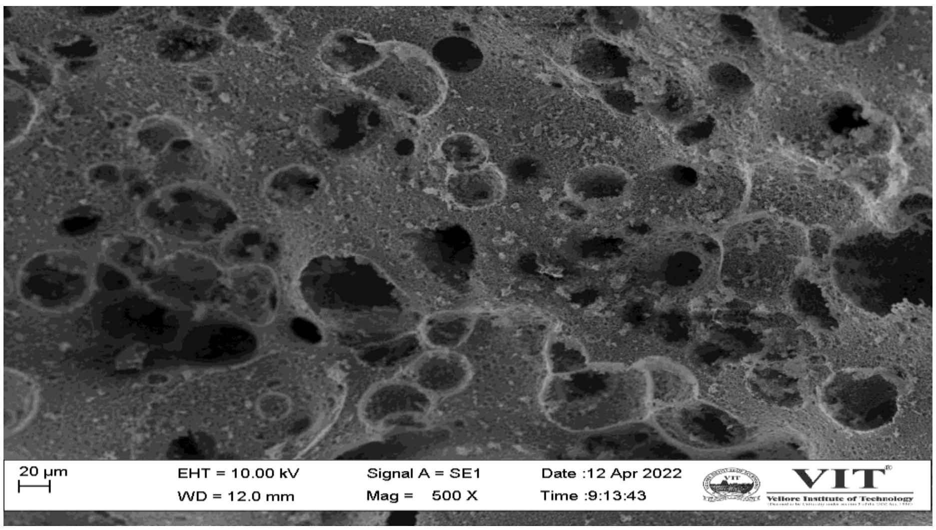

Fig.2.Morphology of Chicken Feather Flake.

3.1.2 SEM and EDS Analysis on Chicken Feather Ash Powder

The internal structure and arrangement are inferred by examining the morphology of the chicken feather ash powder. It clearly shows that the chemical composition of the powder structure contains more calcium carbonate i.e. of 61% a microfibrous material that has been extensively used in the reinforcement of cementitious material. The major constituent of feather ash is calcium carbonate which can be used as a stabilizing agent due to its cementitious properties. It also contains nearly 26% of silicon dioxide 4% of wollastonite 1% of Magnesium Oxide and Albite and of Feldspar as shown in Table 1. The morphological image of the Chicken feather ash powder clearly indicates that the presence of porous structure in the chicken feather ash powder is similar to CFAF but the structure is quite uniform as compared to chicken feather flake (see Fig.3).

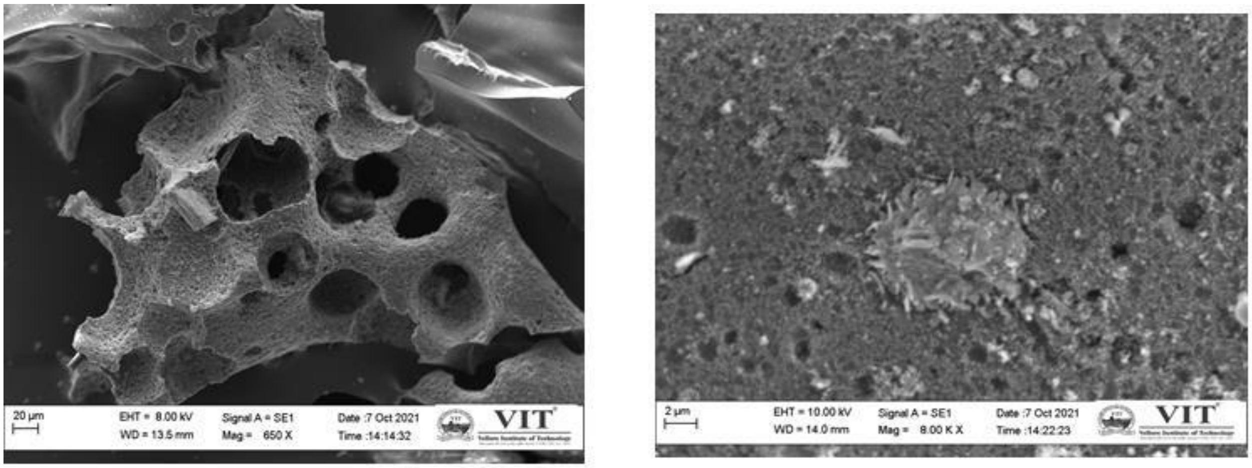

Fig.3.Morphology of Chicken Feather ash.

3.2 Chemical and Mineralogical Composition of Chicken Feather Ash Powder:

The results through SEM and EDS analysis for CFAP and CFAF indicates the presence of a porous structure and a high percentage of calcium carbonate is present in the chicken feather ash powder specifying the existence of cementitious properties which can be used to improve the engineering properties of soil and partial replacement in cement. The major constituent in CFAP is calcium oxide and in CFAF is calcium wollastonite. Chicken Feathers converted into ash powder at different temperature also indicates the presence of silicon and aluminum. Since calcium carbonate is the major constituent of CFAP, it can improve pozzolanic reaction in addition to soil with water thus improving their engineering properties. It is found that the percentage of calcium carbonate varies with the process of incineration at different temperatures. Hence, the optimum temperature of 600°C is established for incineration of CFs into CFAP with a higher proportion of calcium carbonate through various trial processes. The XRF analysis has been carried out and results are presented in Table 2.

Table 2: Chemical composition of chicken feather ash XRF.

Sample (%)	**CF Ash 600***
SiO_2	10.20
TiO_2	0.36
Al_2O_3	3.01
MnO	0.12
Fe_2O_3	4.55
CaO	39.20
MgO	8.63
Na_2O	3.79
K_2O	3.87
P_2O_5	9.78
SO_3	12.30
Cl	2.69
ZnO	0.93
LOI	0.80

It indicates that the major components of CFAP are CaO > 39%, P_2O_5 > 9%, SiO_2 > 10%, K2O > 3%, MgO > 8%, SO_3 >12% and Al_2O_3 > 3%. When added to water, it reacts with calcium oxide (CaO) and forms Calcium hydroxide

(Ca (OH) $_2$) the calcium oxide compound is subsequently treated with carbon dioxide to create the calcium carbonate.

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