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Utilization of Fly Ash in Concrete and Beam House Processes

A thesis submitted for fulfillment of the requirements for the degree of

PhD in Chemical Engineering

by

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ABSTRACT

This study has primarily been done with the purpose of investigating the possibility of using fly ash that is produced from petroleum coke burning in Garry Power Station Plant, north of Khartoum.

The analysis of the collected samples showed that the fly ash is composed of oxides which furnish the ash with an alkaline nature. For that reason, the idea of using the ash in leather industry as a hair removal has been considered in this research.

After several trials, Garry fly ash was found that it could be used successfully for replacement of sodium sulfide in the main soaking, beside using it to replace the hydrated lime in the unhairing and reliming processes. All the skins processed were physically and chemically tested. The results obtained were good compared with the control sample and the standard specifications. The test values obtained for samples '1' through '8' compared with the control sample and the standard values were as follows:

For the average tensile strength test the values were 181.3, 287.78, 168.9, 219.78, 270.43, 275.28, 246.5, 215.84 kg/cm² and the control value was 175.73 kg/cm² and they were complying with the standard value which is 200 kg/cm².

For the average elongation test the values were 92.5, 84.1, 70, 70, 83, 73.5, 92.5, 59.5% and the control value was 69% and they were complying with the standard value which is not less than 60%.

For load at crack test the values were 2.15, 4.15, 4.6, 4.1, 4.1, 4.6, 3.45, 5.9 kg and the control value was 4.0 kg.

For load at burst test the values were 8.15, 11.75, 8.9, 7.6, 10.25, 9.95, 10.1, 14 kg and the control value was 8.9 kg.

Reduction in the biological oxygen demand (B.O.D) and the chemical oxygen demand (C.O.D) levels were observed more clearly in experiment No. 7, where fly ash was used in place of sodium sulphide in soaking and calcium hydroxide in liming and reliming.

Further experiments were carried out to investigate the use of Garry fly ash as a partial replacement of cement in concrete making with percentages of 10% and 30%. All the values of the compressive strength were less than the standard strength of concrete without using fly ash, and therefore, that ash is considered not suitable to be used and rejected. The obtained negative results found to be due to the presence of a considerable amount of unburnt carbon.

More experiments were carried using samples of fly ash that were brought from India. Cement replacement with the same percentages using (10% and 30%) were made, and this imported fly ash has achieved almost the same results as the control at 10% replacement to cement, as it contains very small amount of unburnt carbon.

المستخلص

لقد تم إجراء هذه الدراسة بشكل أساسي بغرض دراسة إمكانية الاستفادة من استخدام الرماد المتطاير الناتج عن حرق الفحم في محطة قري لتوليد الطاقة الكهربائية شمال الخرطوم.

وقد أظهرت التحاليل على العينات التي تم جمعها احتواء الرماد على كمية من الأكاسيد التي اعطته الطابع القلوي. ومن هنا نبعت فكرة استخدام الرماد في صناعة الجلود كمزيل للشعر ودراستها في هذا البحث.

وبعد اجراء العديد من المحاولات وجد ان الرماد المتطاير من محطة قري الحرارية يمكن استخدامه بنجاح كبديل للصوديوم سلفايد في البلل الرئيس بجانب استخدامه كبديل للجير المطفا في إزالة الشعر والتجبير.

وأجريت التحاليل الفيزيائية والكيميائية لكل الجلود التي تم تصنيعها وقد اظهرت نتائج جيدة بالمقارنة مع العينة الحاكمة والمعيارية. وقد كانت نتائج الاختبارات للعينات من '1' حتى '8' مقارنة مع العينة الحاكمة والمعيارية على التوالي كالآتي:

- اختبار قوة الشد 181.3، 287.78، 168.9، 219.78، 270.43، 275.28،
215.8، 246.5 كجم/سم² وقيمة اختبار العينة الحاكمة 175.73 كجم/سم² مقارنة مع القيمة القياسية 200 كجم/سم²

- اختبار الاستطالة 92.5، 84.1، 70، 70، 83، 73.5، 92.5، 69.5 % وقيمة العينة الحاكمة 69% مقارنة مع القيمة القياسية 60%

- اختبار الحمل عند الشق 2.15، 4.15، 4.6، 4.1، 4.1، 4.6، 3.43، 5.9 كجمقيمة العينة الحاكمة 4.0 كجم .

- اختبار الحمل عند الاختراق 8.15، 11.75، 8.9، 7.6، 10.25، 9.95، 10.1، 14 كجم قيمة العينة الحاكمة 8.9 كجم .

إن تحليل السوائل المرتجعه في مراحل النقع والغسيل وإزالة الشعر والتجبير وإعادة التجبير للتجربة الأكثر نجاحاً والتي تحمل الرقم 7 ، مقارنة مع السوائل المرتجعه في العينة المرجعية قد أوضحت إنخفاضاً مقدراً في معدل تلوث هذه المحاليل إحيائياً وكيميائياً.

كما تم إجراء تجارب إضافية لدراسة استخدام الرماد المتطاير من محطة قري كبديل جزئي للأسمنت في تركيب الخرسانة بنسبة 10% ونسبة 30% . وقد كانت نتيجة اختبار الضغط لكل من التجريبتين اقل منالمقاييس المعيارية بالنسبة للخرسانة بدون استخدام الرماد المتطاير ، وبناء على ذلك فالرماد بحالته الراهنه غير ملائم للاستخدام. ويعزى ذلك لوجود كميات كبيرة من الكربون غير المحترق.

كما اجريت تجارب أخرى لعينات من رماد متطاير تم استجلابه من الهند ، حيث تماستبدال الاسمنت في الخرسانة بذات النسب التي استخدمت في الرماد السوداني (10% ونسبة 30%) وقد أعطت نتائج جيدة جداً" و مماثله لنتائج العينه المرجعيه في حالة استبدال الأسمنت بنسبة 10% ويعزى ذلك لإنخفاض نسبة الكربون غير المحترق.

1. INTRODUCTION

1.1 Historical Background:

1.1.1 Fly Ash:

The total world's population is 7.33 billion (by the United States census bureau's world population clock). The population depends on thermal power plants for the generation of electrical power. The total of 41% of the electrical power is produced from thermal power plants by the combustion of coal and petroleum coke. The global consumption of coal was 7.25 billion tones in 2010 and it is expected to increase to 9.05 billion tones by the year 2030. The percentage of production of electricity from the thermal power plants by burning coal is shown in the figure below.

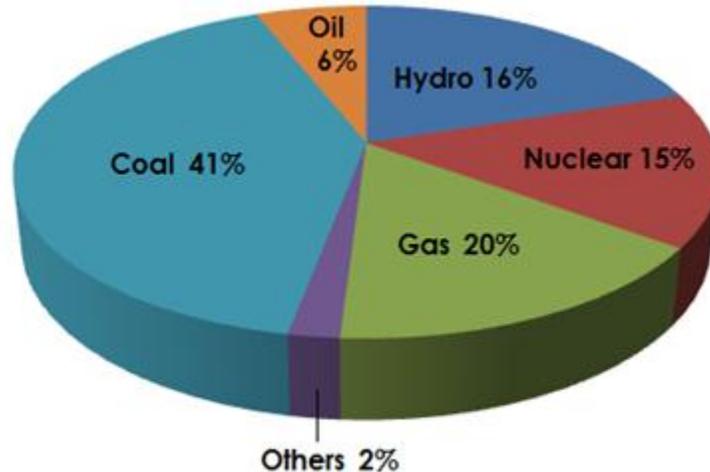


Figure 1.1: Total World Electricity generation by fuel from International Energy Agency (Kumar 2012)

The waste products from the thermal plants for the generation of electrical power resulted in the production of tones of fly ash, bottom ash and boiler slag which

causes environmental pollution. Fly ash is one of the by- products that is generated from coal burning process. The history of fly ash has started more than 2000 years ago, long before the modern power plants began producing coal ash.

The Romans used volcanic ash knowing the power of pozzolan. The term pozzolan was derived from the name of an Italian city “Pozzuoli”, which is the birth place of ash concrete technologies. In recognition, that volcanic ashes were capable of forming effective cement with lime, Romans widely exploited this pozzolanic property.

Fly ash particles are generally spherical in shape and range in size from $2\mu\text{m}$ up to $10\mu\text{m}$. They consist mostly of silicon oxide (SiO_2), aluminum oxide (AlO_3), ferric oxide (Fe_2O_3), calcium oxide (CaO) and carbon. The properties of fly ash vary from one sample to the next, depending on the source of the coal; degree of coal preparation, cleaning and pulverization; design, type and operation of the power plant boiler unit; conditions during combustion; additives used to assist combustion or improve precipitation performance; efficiency of emission control devices; storage and handling of the byproducts (Susanne 1992).

Uses of Fly Ash •

- A partial replacement of cement in concrete and mortar applications.
- Raw material for manufacturing of building materials like bricks.
- Agricultural uses to improve soil texture, increase soil water holding capacity and increase soil pH (for acidic soil).
- Fly ash is composed of oxides compounds that act as pigment. Fly ash meets the chemical and physical requirements of ASTM C618 and range in color from nearly white to dark gray or black (‘Fly Ash’).

Generally fly ash is utilized in many sectors such as construction materials, road making, and cement. Applications of fly ash depend on the quality of FA used.

1.1.2 Leather Industry:

Sudan is situated in the northeastern part of Africa. Sudan is endowed with a very large livestock population. The animal herd of Sudan is estimated at about 103 million heads, being the largest in Africa and the Middle East. It consists of about 30 million cattle, 37 million sheep, 33 million goats and 3.0 million camels (Ministry of Animal Resources, 2016). (Rodriguez 2010).

Table 1.1 Availability of Hides and Skins in Sudan in 2016 (Ministry of Industry)

Category	No. of Pieces (in millions)
Cattle Hides	3
Camels Hides	0.5
Sheep Skins	13
Goat Skins	12

The tanning industry started in Sudan since pre-historic time, when the hides and skins were treated in rural tanneries. Those rural tanneries are present up to now in different parts of Sudan especially in the western part of Sudan.

The mechanized tanneries started in 1945 with a private tannery known as Osman Salih tannery located in Omdurman. Now the number of the mechanized tanneries is 27 (Ministry of Industry), most of them are in Khartoum state. These tanneries consume a lot of alkaline materials, e.g. Calcium Hydroxide and Sodium bicarbonate, Sodium formate in the soaking, unhairing, tanning and retanning processes and it worth mentioning, all these chemicals are imported.

1.2 Problem Statement:

Electrical power generation plants results in increasing environmental problems associated with gaseous emissions and disposed ash residue. In Garry Power

Station Plant, massive quantities of fly ash are being generated (1542 cubic meters per month). This large quantity of fly ash has created enormous problems. Accumulation of fly ash leads to its disposal over a vast areas of land, with resultant degradation of the soil and danger to both human health and environment. Fly ash particles, small enough to escape emission control devise, so it creates great pollution in the nearer area as well as pollution of the soil, water and air.

1.3 Objectives:

1.3.1 Overall Objectives:

- Utilization of fly ash from Garry station to produce useful material instead of dumping it as a waste.
- Protection of the environment.

1.3.2 Specific Objectives:

- Utilization of Garry fly ash as soaking, liming and reliming agent.
- Utilization of Garry fly ash as a replacement of Portland cement in concrete making.
- Mitigation of beam house pollution load.
- Import substitution.
- Reduction of leather processing cost.

1.4 Research Methodology

The methodology followed to fulfill this research includes a comprehensive literature review to be aware of the most recent and distinguished technologies and the current researches all over the world, using Internet and journals as well as books. Also, analysis of the samples of fly ash from Garry station is done to identify its properties to compare it with standards. The research takes account of

feasibility and economical impact of using fly ash in industry or other fields. Results obtained are compared with results obtained for samples taken from other sources.

1.5 Thesis Layout

This thesis is organized in five chapters including this introduction. In Chapter Two, a literature review is included that covers many areas, which are related with the objectives of the thesis.

Chapter Three discusses the materials and the methods used to carry the experiments on the fly ash. In Chapter Four, the results obtained are presented and deeply discussed. Finally, Chapter Five includes the comments on the results and conclusions, as well as recommendations for possible future work.

A list of all references used during the research is presented, as well as some useful appendices placed at the end of the thesis.

