

Study on the valorization of used waste oils as fuel for the firing of clay bricks in an artisanal kiln

ABSTRACT

The present study aims to contribute to solving the environmental problem by recovering waste from the recycling of used oil to improve the firing of clay bricks. The waste from the recycling of used oil is collected and mixed with wood charcoal. This mixture is used as fuel in the artisanal kiln to fire the bricks. The temperature rises in the kiln, the cooling time and the quality of baked Clay Bricks are analyzed. The maximum temperature observed inside the kiln is 900°C in 36 hours of kiln operation when wood charcoal is used as fuel with a firing time of five (5) days and 1020°C in 80 hours when wood charcoal and “Chinese coal” (waste from recycling of used oil) are used as fuel with a firing time of ten (10) days. This explains the longer cooling time than with wood charcoal alone as fuel. The firing of the bricks is perfect with both fuels, whereas with wood charcoal alone as fuel, 15% of the bricks are unbaked. The bricks also have a very clean appearance. They have an average shrinkage of 1% which is lower than the normative value of 3%, the average compressive strength is 16.5MPa which is higher than the normative value of 12.5MPa and the water absorption is 40% which is lower than the normative value of 60%. This combination of fuels reduces the use of wood charcoal, which in turn reduces deforestation and prevents air pollution and soil degradation through the dumping of waste oil in the environment.

Keywords: Artisanal kiln, used oil, charcoal, combustion, recycling used oil waste

1. INTRODUCTION

The degree of household and similar waste production is one of the indications of development of an individual or society. A less fortunate person produces less household waste than a wealthy person. A developed town generates more waste than a less developed town. The diversity of waste follows the same pattern. The management of this diverse waste is one of the environmental problems that developing countries must find sustainable solutions. This involves improving collection processes, treatment, recycling and burial in order to reduce waste volume and make cities cleaner [1].

A great growth in various income-generating activities is observed nowadays in Lome City as many African capitals. This phenomenon is leading to a rapid increase in the acquisition of motorized means of transport, resulting in a large discharge of used oil. Used oils such as engine lubrication oil, hydraulic fluids, and gear oils used in worksite vehicles, cars, motors, bikes, or lawnmowers can pollute the environment if they are not recycled or disposed of properly [2].

The increasing incorporation of waste materials in the manufacture of clay bricks has gained significant proportions for reasons of sustainability [3], environmental protection [4] and the need for easy supply of essential products [5]. The depletion of fossil fuels [6] is also leading to their conservation and efficient use [7].

Fired clay bricks are generally used as wall construction material in buildings. They are often fired in a kiln at a temperature of 1000°C [8]. Thus, a huge amount of fuel is needed to fire the clay bricks. The most common fuel used in firing clay bricks in kilns is coal [9]. However, the cost of coal is high and the use of coal as fuel contributes to deforestation. Therefore, the use of coal as a fuel increases the cost of bricks and building construction on the one hand and deforestation on the other. In order to reduce the cost of fired clay bricks and to slow down deforestation, alternative, low-cost fuels should be explored [10]. The study of Nawab Ali Lakho et al. [11] focused on the effect of alternate fuels on compressive strength, water absorption and density of fired clay bricks. They found that compressive strength of bricks fired using rapeseed husk and combination of sugarcane-bagasse, rice husk and used clothes fuels was decreased to 11% and 7%, respectively, compared to those fired with coal. However, the values of water absorption and density of bricks fired with rapeseed husk fuels were almost same as exhibited by those baked with coal. This study shows also that a saving of 25%, and 18% could be achieved when the bricks were fired using rapeseed husk and combination of sugarcane-bagasse, rice husk and used clothes fuels, respectively, compared to those fired with coal. An experimental study of the firing of red brick using liquefied petroleum gas fuel was performed in a fixed kiln by [12]. Improvement alternatives to the traditional firing techniques were analyzed, including the design of a thermally efficient kiln and the use of gas burners to reduce the pollution generated by using trash or other industrial or agricultural wastes as fuels. The results show an increase in the thermal efficiency, based on the use of 600 liters of fuel to fire a load of 17500 bricks.

This work aims to solve the problem of environmental pollution caused by the discharge of waste from the recycling of used oil. This waste is valorized by using it to improve the combustion of charcoal used to fire bricks in an artisanal kiln. For this purpose, the physical and mineralogical properties of the waste from the recycling of used oils are determined. This waste is used as a fuel and mixed with charcoal to fire bricks in an artisanal kiln. The temperature evolution in the kiln and the firing quality of the bricks were examined.

2. MATERIAL AND METHODS

2.1 Materials

The execution of this research required a number of materials of various kinds and a perfect methodology.

These included:

- waste from the recycling of used oil obtained from the recycling unit
- charcoal;
- the artisanal kiln built at the « Centre de la Construction et du Logement (CCL) » of Lome city (Togo);
- the temperature measurement equipment;
- clay bricks,
- the equipment for determining the mechanical characteristics of the fired bricks.

2.2 APPROACH: FIRING TESTS

2.2.1 Fuels

Motor oils are used to lubricate internal combustion engines. They are mineral oils made up of petroleum derivatives and technical additives.

Particularly polluting for the soil and water, "black oil" is a hazardous waste. After their use in the engines of private or industrial vehicles, used oils must be reprocessed. Their volume represents more than 220,000 tons per year, depending on the country. They are composed

of heavy metals, organic acids, hydrocarbons and toxic elements that require specific reprocessing by approved companies [13]. The literature indicates that one liter of used oil can pollute an area of 1,000 m² of water and thus reduce the oxygenation of underwater, fauna and flora for several years [14].

Motor oils can be recycled, i.e. re-refined using various processes. Two solutions exist for recycling these waste oils:

- energy recovery by incineration to produce energy,
- regeneration to produce a new lube [15].

Thus, the oil is first separated from the impurities, then the water and finally the additives. The water can be reprocessed. The oil is converted into diesel fuel. The remaining residue contains the additives, mainly graphite, i.e. carbon, plus some oil derivatives.

The waste used in the CCL is referred to as “Chinese Coal” (Fig. 1.). This study focuses on the recovery of this coal. It consists of carbon (C) and petroleum derivatives.

Similarly, the composition of the waste oil also takes into account (i) graphite: i.e., a natural, black, friable carbon mineral with the chemical formula (C), (ii) petroleum derivatives. The petroleum derivatives from which motor oils are made are derived from the refining of crude oil under atmospheric pressure.

The atmospheric residue undergoes vacuum distillation to give short-chain hydrocarbons containing a carbon number if possible in the range of C8 to C10.

In motor oils, the petroleum derivatives encountered are hydrocarbons which are organic compounds containing carbon (C) and hydrogen (H). The number of carbon atoms ranges from 8 to 10 (C8 to C10) [16].

The waste from the recycling of used oil is collected and mixed with wood charcoal (Fig. 2.). The efficiency of a fuel is characterized by its Calorific Value. The Calorific Value (CV) of a fuel is equal to the energy released by the complete combustion of 1 kg of fuel. It is expressed in KJ/Kg.



Fig. 1. Chinese Coal



Fig. 2. Wood charcoal

2.2.2 Artisanal kiln

The experimental kiln (Fig. 3) is an open artisanal kiln with a natural updraft, whose structure is made up of:

- a hearth, in which the fuel burns to produce the heat necessary for firing the clay bricks.
- a hearth in contact with the combustion chamber, which retains the heat and in which the clay bricks are located;
- a flue through which the hot gases escape, the chimney.

Above the hearth, there is the floor or hearth plate, on which the clay bricks are stacked. It is pierced by holes called flues which allow the flames from the hearth to pass upwards.

This kiln is made of baked bricks obtained from clay from Kouvé, a town located about 65 km North-East of Lome (Togo).

The schematic of the artisanal kiln is shown in fig. 4.



Fig. 3. Artisanal kiln

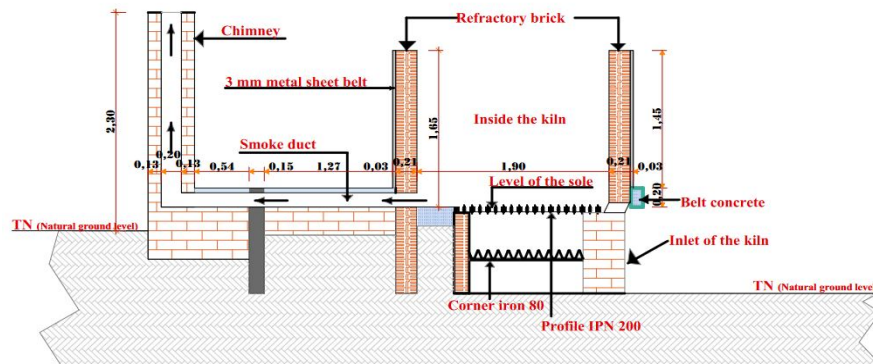


Fig. 4. Schematic of the artisanal kiln

2.2.3 Baked clay bricks

Fig. 5 and Fig. 6 show respectively, clay preparation and bricks production, and natural drying of clay bricks. The clay bricks to be fired have dimensions of 6 cm x 9 cm x 20 cm obtained from Kouve. The production is done according to the NF P 12-121-1 or NFEN 771-1:2011 standard [17].



Fig. 5. Clay preparation and brick production



Fig. 6. Natural drying of bricks

2.2.4 Temperature measuring device

For temperature measurements, a digital thermocouple thermometer shown in fig. 7. is used as well as J thermocouples with a temperature range of -210 to 1200°C.



Fig. 7. Digital thermocouple thermometer: PROSTER PST095

2.2.5 Firing process

The clay brick firing process is carried out using wood charcoal as fuel and then a combination of wood charcoal and Chinese coal. The dry bricks are placed in the kiln in a very precise way, so as to allow the horizontal and vertical passage of hot air.

For the first experiment, the clay bricks were fired with wood charcoal alone as fuel, the quantity of bricks fired being two thousand (2000). With the help of a dosing box, 280kg of wood charcoal are loaded into the kiln alternately with the clay bricks. The firing operation lasts seven (7) days: the maximum temperature of 900°C is reached after 36 hours, i.e. two (2) days of kiln operation. Complete cooling of the kiln is observed after three (3) days when the temperature inside the kiln is equal to 32°C i.e., the ambient temperature. After removal of the fired clay bricks from the kiln, it was found that 15% of them were unburnt.

For a complete firing, the combustion equation is as follows;
 $C + O_2 \rightarrow CO_2\uparrow + Q$ (1)

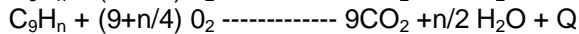
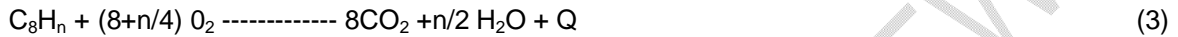
The carbon input is mainly from the charcoal.

Concerning the second experiment, the cooking takes place by combining the two fuels namely Chinese charcoal and ordinary charcoal. 120 kg of charcoal and 405 kg of Chinese charcoal are used for the same quantity of bricks to be fired, i.e. two thousand (2000). The firing process takes ten (10) days. The maximum temperature of 1020°C is reached after three (3) days and cooling lasts seven (7) days.

The following equations explain the combustion phenomenon. For charcoal we have to consider equation (1) and for Chinese charcoal we have:



But since waste oils contain C8, C9 and C10 hydrocarbons the combustion equations to consider are:



where n is the number of carbon atoms and Q represents the amount of heat released as a result of waste fuel combustion.

2.2.6. Quality of fired clay bricks

This is done through the analysis of the values of the significant characteristics, namely shrinkage, water absorption, compressive strength, obtained on the fired bricks [18].

2.2.6.1. Shrinkage test

As well as during drying, fired clay bricks are subject to shrinkage during firing. It is due to the transformation of the clay particles. To carry out the shrinkage test, a ruler is used to measure to within 1mm each of the dimensions on the four corresponding edges and the flatness of the faces on the basis of the procedure contained in standards NF P 31-305, NF P 31-306 and NF P 13-305.

2.2.6.2. Water absorption test

The water absorption test by capillarity is a control test established by the French standard NF P 13-305 for clay bricks. The procedure is as described in this standard.

The experimental equipment consists of a container in which seven (7) test specimens are immersed. The container must be at a temperature of 20°C ± 2°C and 65% ± 5% of relative humidity. However, the experiment was conducted at an ambient temperature of 30°C and 75% of relative humidity. Four kiln trays model 68/14D.35 of PROLABO with a capacity of 393 litres was used. The water absorption coefficient of each clay brick is conventionally expressed by the formula:

$$C = \frac{100 \cdot m}{S\sqrt{t}} \quad (4)$$

in which :

m is mass of water absorbed by the product, expressed in g;

S: surface area of immersed face, expressed in cm²,

t: time, in minutes, elapsed since the start of immersion.

2.2.6.3. Compressive strength test

The purpose of determining the compressive strength of fired bricks is to check whether the firing has been perfect to the extent that products capable of withstanding stress and weathering have been obtained.

As experimental equipment, apart from the test specimens, there is the PERRIER type 368 hydraulic press with a measurement range of 60kN to 1500kN, and a pressure of 40MPa

with a piston stroke of 0 to 30 millimeters to carry out the compression test, commonly known as the crushing test. The procedure is the one described in the French standard NF P 13-305 on clay bricks intended to remain exposed.

3. Results and discussion

3.1 Characteristics of fired clay bricks

The tables 1 and 2 show respectively, the technical data on the performance of fired clay bricks when wood charcoal, and the combination of wood charcoal and Chinese coal are used as fuel.

From the results obtained from the characteristics as shown in the tables above, it is found that the firing was perfect, the bricks have a stress well above the normative limits and therefore have a good mechanical strength.

Table 1. Fired clay brick behaviour with wood charcoal fuel


Order No.	Product	Characteristics	Before firing	After firing	Withdrawal
	Brick				
		Thickness (cm)	6.00	5.80	0.20
		Width (cm)	9.20	9.00	0.20
		Length (cm)	20.1	19.80	0.30
		Weight (kg)	1.92	1.91	0.01
		Compressive strength (MPa)	3.07	10.30	

Table 2. Behaviour of fired clay bricks with wood charcoal and Chinese coal as fuel


Order No.	Product	Characteristics	Before firing	After firing	Withdrawal
	Brick				
		Thickness (cm)	6.00	5.75	0.25
		Width (cm)	9.20	9.10	0.10
		Length (cm)	20.10	19.9	0.20
		Weight (kg)	1.92	1.89	0.03
		Compressive strength (MPa)	3.07	16.50	

Table 3. Characteristics of fired clay bricks

Order No.	Description	Characteristics	Values Experimental	Normative values
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		*Withdrawal		
		- length	1.00 %	< 3.00 %
		- Width	1.00 %	< 3.00 %
		- Thickness	2.50 mm	< 3.00 mm
1	Fired	Water absorption	C = 40.00	C ≤ 60.00
	clay	Compressive strength	16.50 MPa	≥ 12.50 MPa
	brick			

The firing process was conducted in such a way as to obtain fired clay bricks with functional and also satisfactory technical characteristics. Furthermore, the usual normative firing temperatures for these baked clay bricks are between 850°C and 900°C, but with wood charcoal as fuel the maximum temperature is 900°C and with the combination of wood charcoal and Chinese coal the maximum temperature of 1020°C is recorded. The total firing time varies from 12 to 48 hours depending on the clay brick and the type of kiln used. In the case of this study, it ranges from 120 hours for charcoal fuel to 240 hours for charcoal and Chinese coal fuel.

Table 3 shows the average values of the tests carried out on the fired clay bricks at the firing temperature of 1020°C. It is noted that the water absorption coefficient obtained is within the limits set by the standard for fired clay bricks NF P 13-305. Similar result is observed for the average compressive strength values.

From the results obtained from the characteristics as shown in the tables 1 to 3, it is found that the firing was perfect, the bricks have a stress well above the normative limits and therefore have a good mechanical strength.

3.2 Efficiency of Fuels

The efficiency of the fuel depends on its calorific value [19]. The calorific value of carbon is 15MJ/Kg. Wood charcoal contains a lot of carbon. The calorific value of waste oil is 90% of that of fuel oil, which is 43MJ/Kg.

Studies carried out at the CCL in Cacavelli have shown that Chinese charcoal is made up of P1= 78% carbon and P2 =22% of waste oil.

Taking P1 as the percentage of carbon, P2 as the percentage of waste oil, and taking PC1 as the calorific value of coal and PC2 as the calorific value of waste oil with PC1= 15MJ/Kg, PC2 is evaluated as:

$$PC2 = 0.9 \times 43 \text{ MJ/Kg or } PC2 = 38.7 \text{ MJ/Kg}$$

Then the calorific value of Chinese coal is expressed as :

$$PC = P1 \times PC1 + P2 \times PC2 \text{ i.e. } PC = 0.22 \times 38.7 + 0.78 \times 15 = 20.21 \text{ MJ/Kg}$$

Hence, PC is approximately equal to 20.21 MJ/kg. This result shows that the calorific value of Chinese charcoal is higher than that of charcoal due to the presence of petroleum derivatives, whereas charcoal consists of carbon only.

3.3 Temperature distribution

Fig. 8 and Fig. 9 present respectively, the evolution of the average internal and external temperature of the kiln and the chimney during operation with wood charcoal as fuel and combination of wood charcoal and Chinese coal as fuel. The maximum temperature of 900°C is reached in 36 hours and total cooling to 32°C after 120 hours with charcoal as fuel. Brick firing is observed with 15% incineration.

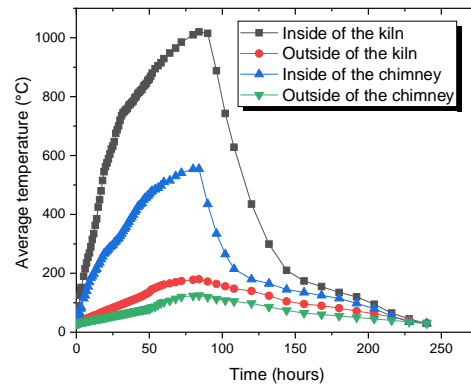


Fig. 8. Evolution of the average temperature during the operation of the loaded kiln using wood charcoal as fuel

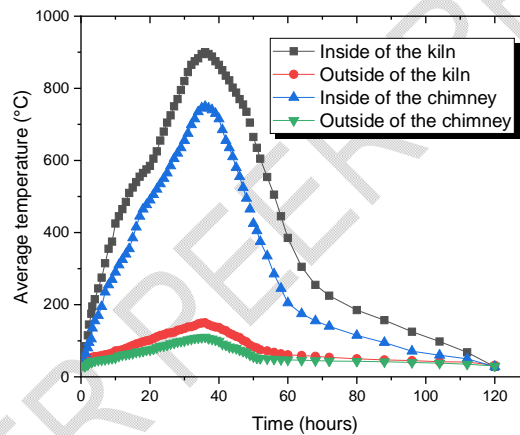


Fig. 9. Evolution of the average temperature during operation of the loaded kiln using the combination of charcoal and "Chinese coal" as fuel.

The maximum temperature of 1020°C is reached in 84 hours and total cooling to 32°C after 240 hours with wood charcoal and Chinese coal as fuel. Perfect firing of the clay bricks is observed. The standards provide for a firing temperature range between 850°C and 1450°C depending on the type of kiln and the clay brick [20]. The profiles during heating and cooling correspond perfectly to those proposed by GLINKOV [20].

4. CONCLUSION

In this study the effect of firing, using wood charcoal and the combination of wood charcoal and waste from used oils as fuel for the firing of clay bricks in an artisanal kiln was investigated. The main findings drawn from the experimental tests can be listed as following:

- the maximum temperature observed inside the kiln is 900°C in 36 hours of kiln operation when wood charcoal is used as fuel with firing time of five (5) days;

- for the use of the combination of wood charcoal and “Chinese coal”, the pick of internal temperature of the kiln is around 1020°C in 80 hours of kiln operation with a firing time of ten (10) days
- the cooling time of the kiln is longer when the combination of wood charcoal and waste from recycling of used oil (“Chinese coal”) is used as fuel for firing the clay bricks;
- The firing of the clay bricks is better with the use of the combination of wood charcoal and Chinese coal as fuels
- When the fuel employed is the combination of wood charcoal and the waste from the recycling of used oil, the baked clay bricks have a better clean appearance.
- The baked clay bricks resulting from the firing with the combination of wood charcoal and “Chinese coal” as fuel, have an average shrinkage of 1% which is lower than the normative value of 3% the average compressive strength is 16.5MPa which is higher than the normative value of 12.5MPa and the water absorption is 40% which is lower than the normative value of 60%.
- the valorization of waste from recycling used oil contribute to the reduction of the use of wood charcoal, which in turn reduces deforestation and prevents air pollution and soil degradation.

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