Influence of Oil Well Drilling Waste on the Engineering Characteristics of Clay Bricks

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Abstract: Huge quantities of oil-based mud waste were produced during oil well drilling operations in Egypt. These quantities are environmental hazards and usually disposed in open pits that constructed during drilling operations. These pits, approximately 50 years old, resemble an extreme environmental and health hazards integrated with fire and dangerous sinking risks. Consequently, the main objective of this paper is to explore the influence of oil well drilling waste, basically oil based mud waste, on the engineering characteristics of the manufactured environmentally friendly, sufficient performing red clay building brick. Compositions of the used materials as well as physico-mechanical characteristics of fired briquettes were investigated. The laboratory results demonstrate that the water absorption, bulk density, efflorescence and compressive strength of the fired briquettes are met the acceptable limits of Egyptian Standard No. 204-2005 for clay masonry units used for load and non-load bearing walls construction. The reuse of this waste material in the building industry will contribute to the protection of the environment through great advantages in waste minimization and beneficial income to the community through the utilization process in building industry. [Journal of American Science 2010;6(7):48-54]. (ISSN: 1545-1003).

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1. INTRODUCTION

The conventional process of drilling oil and gas wells uses a rotary drill bit that is lubricated by drilling fluids and muds. As the drill grinds downward through the rock layers, it generates large amounts of drilling fluid waste and ground-up rock known as drilling cuttings.

Drilling fluid systems typically consist of bentonite and a range of additives mixed with water (water based mud; WBM) or hydrocarbon (oil-based mud; OBM). Oil-based muds were developed for situations and commonly used allover the world where WBMs could not provide enough lubrication or other desired characteristics.

The phrase "oil-based mud" was an accurate description of drilling mud containing diesel oil. It is commonly used 10 years ago, but had obvious negative connotations and was, in need, a serious source of pollution in a large number of countries.

Drill cuttings are made up of ground rock coated with a layer of drill fluids. Most drill cuttings are managed through disposal, although some are treated and beneficially reused. Before the cuttings can be reused, it is necessary to ensure that the hydrocarbon content, moisture content, salinity, etc. of the cuttings are suitable for the intended use of the material. However, the treated cuttings can be reused as construction material and used in various ways as fill material, cover material at landfills, aggregate, and filler in concrete, bricks or blocks manufacturing [1 & 2].

On the other hand, drilling fluids play an important role in traditional well drilling. However, the fluids become contaminated by their use. At the end of the drill job, they must be disposed of or processed for recycling.

Pollution problems caused by oil and other contaminates in waste drilling fluids were recognized over 0 years ago in the Gulf of Mexico and since the development of the North Sea oil and gas fields in the 1970s, have become a major political issue in Western Europe.

Bernrdo et al. [3] used oil well-derived drilling waste (muddy and rocky) and electric arc furnace slag as alternative raw materials in clinker production. It was concluded that the manufacturing process of waste–based clinkers was environmentally compatible and related cements were similar in performance to common hydraulic binders.

In Egypt, a large number of oil wells drilling companies are worked and large quantities of pollutants generated. Till now the use of oil well drilling liquid waste in brick industry has received comparatively little attention by researchers and engineers, but there is an increasing interest towards the searching of new industries which are able to give a usable product characterized by environmental compatibility.

The studied waste in this article (oil-based mud) is located in Belayium oil field, Egypt, owned by Petrobel. The field has approximately 100 offshore and 113 onshore wells. A part of regular drilling operations during the construction of these wells and work-over, huge quantities of oil-based mud were produced. These quantities are environmental hazards and usually disposed in open pits that were constructed during drilling operations. These pits, approximately 50 years old, resemble an extreme environmental and health hazards integrated with fire and dangerous sinking risks.

This paper is focused on the evaluation of engineering characteristics of a clay brick used oil well drilling waste as a utilization process of the used slurry pollutant in a beneficial industry.

2. MATERIAL AND METHODS

2.1 Raw Materials

The materials used in this study are Belbeis clay (BLC) and oil-based drilling mud waste (OBMW). The used materials are described briefly as follows.

2.1.1 Belbeis clay sample

The investigated sample was taken from Belbeis quarries area, El-Sharkia Governorate, Egypt. The collected sample is pale grey colour, massive and damped. The sample belongs to deposits of Late Miocene age [4].

2.1.2 Oil-based drilling mud waste

This waste material was supplied by Belayium Petroleum Company (Petrobel), the oldest and largest oil and gas production company in Egypt. The OBMW originally was taken from Belayium oil wells field which is located on the eastern side of the Gulf of Suez, about 180 km south of Suez. Belayium is one of the major production fields in Egypt, The supplied waste sample is slurry, dark brown colour and has an amount of petroleum product.

2.2 Methods and Techniques

The used materials were characterized by X- ray diffraction (XRD) and X-ray fluorescence (XRF) techniques for determining the mineralogical composition and major element oxides, respectively.

For studying the clay sample by XRD, the sample was dried then extremely fine grounded to achieve a good XRD pattern. The ground Belbeis clay sample (BLC) also requires pre-treatments to be analyzed by XRD. This step is to remove undesirable coatings and cementing materials, either to improve the diffraction characteristics of the sample or to promote dispersion during size fractionation. To complete the sample preparation, the clay fraction (< 2µm) was separated, precipitated, and mounted on three glass slides. Three diffractograms were obtained according to Moore and Reynolds's method [5]. The used XRD apparatus was of X'pert Pro type (Netherlands). The analysis was run at 40 kV and 40 mA using Cu Kα radiation in the range 2θ ranged from 3º-38º. The interpretation of the obtained phases was achieved by X'Port high score PDF-2 database software on CD-Release 2006. The semi- quantitative estimation of the clay minerals was calculated on the basis of Johns's method [6]. The chemical analysis was carried out using Philips PW 1400 XRF as well as following the test method described in the American Society for Testing and Materials [7]. The pH value was measured at 20ºC by an electronic pH meter (Jenway 3510, UK) following the test method reported in the ASTM [8].

2.3 Sample Preparation and Briquettes Processing

The natural status of the BLC and OBMW samples used in this study were damped and slurry, respectively. So, the BLC is dried in an electrical dryer for 48 h at 110ºC where the other material is thermally treated at 300ºC for 24 h to release the high content of aromatic hydrocarbons. After the drying process, all the materials were first ground by a traditional jaw crusher then sieved until the fractions passing through 1 mm screen. Designed mixes from the raw materials were homogenized using a cylindrical mixer during 10 min, and then mixed with water to the desired suitable consistency (the forming water used belongs to the soft mud process). The mixtures are then hand molded in a 5 cm side length iron cube. After demolding, the shaped green briquettes left for about 2 weeks in a protected place at room temperature, then dried in a dryer and left inside for 24 h at 110ºC. Finally, the dried briquettes were fried in a controlled electrical furnace at 800º, 850º and 900ºC with a gradually heating rate of 2ºC/min and held for 2 h (soaking time).

2.4 Mixture Formulations

In order to investigate the influence of addition of the oil-based drilling mud waste on the engineering characteristics of the clay building brick for using in construction of load and non-load bearing walls, three mixes were designed on the basis of partial replacement of clay material denoted as M0, M1, M2 and M3. Each mix containing variable content of the waste, 0 % (M0, reference mix), 10 % (M1), 20 % (M2) and 30 mass % (M3) was added to the raw investigated clay (Table 1).

2.5 Laboratory Tests

To evaluate the engineering properties of the fired briquettes of the different mixes, the water absorption, bulk density, efflorescence and dry/wet compressive strength were determined according to ASTMs [9 & 10]. At least 3 fired briquettes were used in each test for all categories and the average values were calculated.

3. RESULTS AND DISCUSSION

3.1 Textural, Mineralogical and Chemical Compositions

The studied BLC sample is a plastic, very fine grained claystone of a well sorted class as mentioned from a pervious study of El-Mahllawy [11]. Table (2) summarizes the mineralogical composition of the used raw materials. The studied clay is composed mainly of quartz with minor contents of plagioclase and calcite as non-clay minerals. In the clay fraction (fraction <2µm) montmorillonite is the major mineral, kaolinite and illite are the moderate and minor clay minerals, respectively. In the ignited OBM waste, the main crystalline phase identified is barite and anhydrite (basically it was gypsum before the thermal treatment process at 300ºC). Also, it is identified peaks of a moderate content of andradite mineral.

The chemical composition of the raw materials used as shown in Table (3) shows that the clay sample matches an average limit of the most common Egyptian clay compositions (composed mainly of SiO_2, Al_2O_3 and Fe_2O_3 rather than a minor content of other oxides). The pH value refers to neutral material. The ignited waste material is composed of SiO_2 as a major oxide, CaO incorporated with BaO as a moderate oxide, minor contents of Al_2O_3 and SO_3, and traces of other major oxides. The pH value indicates a slightly alkaline material. Moreover, a typical formulation for an oil based mud stated by Balson [12] is listed in Table (4).

The chemical composition of the oil-based mud waste is conformed by the XRD as the presence of main mineral sources for the identified major element oxides. Barite ($BaSO_4$) mineral as a weighting material is used in substantial quantities to increase the density of oil mud. Pure barium sulfate is never used and commercial product is preferred which is associated with calcium sulfate, in the form of gypsum, and other minerals may occur along with barite. Lime, in different forms, is essential in the OBM. It neutralizes fatty acids in the fluid mud, stabilizes the emulsion when present in excess, and controls alkalinity. In the oil fields, it also neutralizes acid gases (H_2S and/or CO_2).

3.2 Physical Characteristics

The average values of water absorption, bulk density, and efflorescence for the briquettes made from assorted mix combinations and fired at different temperatures are displayed in Table (5). The influences of the waste addition on the engineering characteristics of the fired briquette as a function of firing temperatures are graphically illustrated in Fig. (1).

The obtained results and the discussion may summarize as follows:

- The water absorption values increase with waste contents, and decrease with firing temperature.
- The bulk density values decrease with the waste content and increase with firing temperature.
- Efflorescence degree for the briquettes fired at 900ºC increases with the waste material content.
- The overall rate of the water absorption, bulk density and efflorescence for all mixes at firing temperatures ranges are within the acceptable limits of the Egyptian Code, ECP, [13].
- The fired briquettes made from mix 0 (no waste added) show a product of better quality than those made from different waste contents with clay.
- The results of water absorption and bulk density are mainly attributed to increasing of glassy phase formation, the main source is clay material, with increasing the firing temperature and clay content causing closing of some open pores within the fired body [14] or decreasing in total-pore space in the structure [15]. The formed glassy phase by the capillary action and surface tension infiltrates the open pores of the structure and cause densification of the ceramic bodies [16].
- The increasing of water absorption and decreasing of bulk density with the waste content means that the OBM waste is mainly remained inert at the tested temperatures.
- The efflorescence values for the briquettes fired at 900ºC of different mixes increase with the waste content indicating to increasing of salts that is moved upwards briquettes surfaces by the capillary action and precipitated after placing in the distilled water.

3.3 Mechanical Characteristics

The average values of the dry and wet compressive strength for the briquettes of different mixes fired at 800º, 850º and 900ºC are listed in Table (6) and graphically illustrated in Fig (2). It is obvious to note that the compressive strength values increase with firing temperature and decrease with waste content. The possible reason for these trends is due to the increase in binding forces, clay material is the main source for the binding materials in the fired briquettes, as well as the formation of more liquid which fill pore spaces remaining and strengthen the briquette body [17].

It was observed that in all mixes, even those with a high waste content (M3), the fired briquettes achieve compressive strength within the acceptable limits prescribed in the Egyptian Code [13] for the clay bricks used either as non-load or load bearing walls.

Table (1): The composition of the raw mixes (mass %)

Mix no.	Mix proportion, %	
	BLC	OBMW
M0 (reference mix)	100	0
M1	90	10
M2	80	20
M3	70	30

Table (2): The mineralogical composition and semi-quantitative minerals of the used materials based on XRD.

Material	Mineralogical composition		Semi-quantitative percentage (SQ, %)	Chemical formula
	Non-clay minerals	Clay minerals		
Belbeis clay	- Calcite - Plagioclase - Quartz	- Montmorillonite - Kaolinite - Illite	- 6.0 - 2.5 - 64.5 - 62.0 - 30.0 - 8.0	- $CaCO_3$ - $(Na,Ca)(Si,Al)_4O_8$ - SiO_2 -$(Na,Ca)_{0,3}(Al,Mg)_2Si_4O_{10}(OH)_2{\bullet}n(H_2O)$ - $Al_2Si_2O_5(OH)_4$ - $(K, H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,(H_2O)]$
Oil-based mud waste	- Barite - Anhydrite - Andradite		- 49.0 - 39 .0 - 12 .0	- $BaSO_4$ - $CaSO_4$ - $Ca_3Fe^{3+}{}_2Si_3O_{12}$

SQ percentage was calculated for the clay minerals in the clay fraction

Table (3): The chemical composition and pH value of the materials used

Material	Oxide content, %									pH	LOI %
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	SO_3		
Bebies clay	50.77	18.27	8.59	1.31	0.72	3.03	1.67	1.13	0.14	14.37	7.0
Ignited oil-base mud waste	60.02	3.83	5.71	Nil	22.1*	0.71	1.64	1.09	4.11	0.79	8.5

LOI: Loss on Ignition (*) sign means also includes BaO content

Table (4): Typical formulation of an oil-based mud

Component	Concentration, kg/m^3
Base oil	375.4
Lime	17.1
$CaCl_2$ salt	75.2
Fresh water	210.2
Weighting material (Barite)	940.3

Table (5): The mean values of water absorption, bulk density and efflorescence of the fired briquettes of the different formulated mixes

Mix code	Water absorption %			Bulk density g/cm^3			Efflorescence %
	800 °C	850 °C	900 °C	800 °C	850 °C	900 °C	
M0	10.81	8.55	7.75	1.70	1.76	1.81	8 Light
M1	12.48	11.14	10.50	1.67	1.72	1.76	12 Moderate
M2	13.65	12.72	11.12	1.66	1.68	1.72	19 Moderate
M3	14.23	13.91	12.46	1.64	1.66	1.69	25 Moderate
Egyptian code: 204 - 2005	Clay brick as non-load bearing walls: < 20 % Clay brick as load bearing walls : < 16 %			--- > 1.6			< 50 % < 50 %

Table (6): The mean of compressive strength of the fired briquettes as function of firing temperatures

Mix code	Dry compressive strength kg/cm^2			Wet compressive strength kg/cm^2		
	800 °C	850 °C	900 °C	800 °C	850 °C	900 °C
M0	165.4	202.8	241.8	142.0	170.1	204.5
M1	155.5	190.3	231.9	131.2	156.1	190.0
M2	139.7	156.4	189.1	109.2	130.3	158.8
M3	114.1	128.3	165.6	90.6	111.9	124.4
Egyptian code: 204 - 2005	Clay brick as non-load bearing walls: --- Clay brick as load bearing walls : ---			Clay brick as non-load bearing walls: 40 Clay brick as load bearing walls : 80		

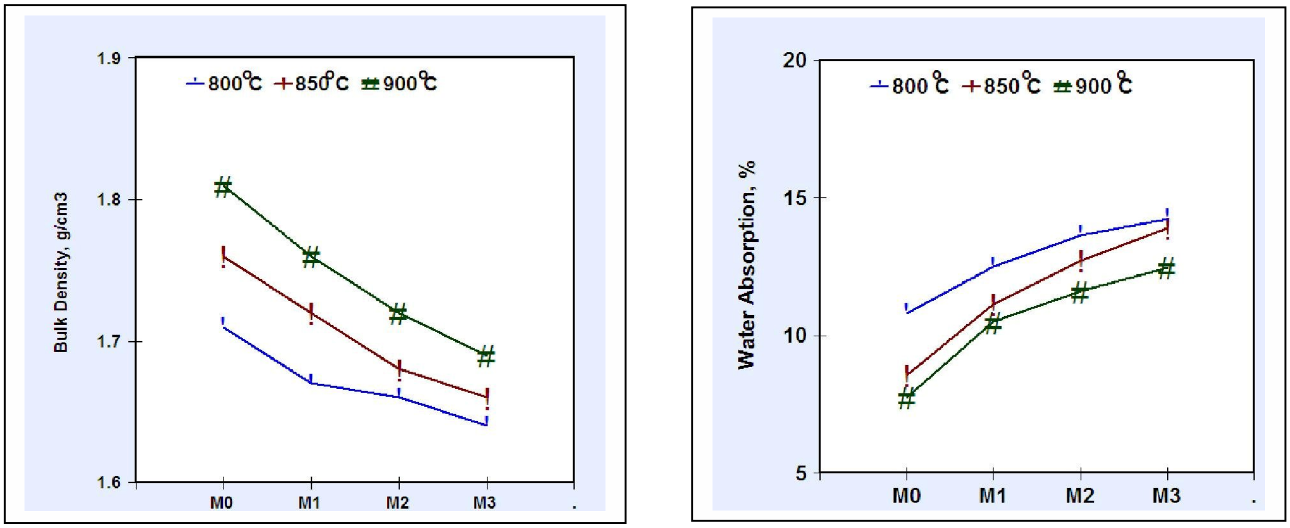

Fig. (1): Water absorption and bulk density as a function of OBM waste content as well as firing temperatures.

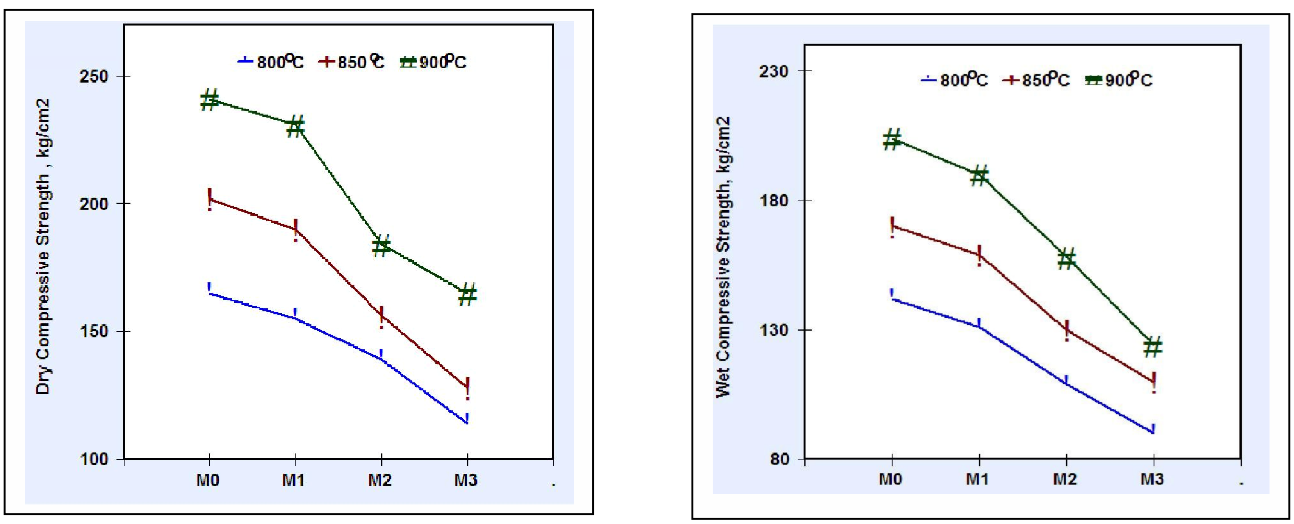

Fig. (2): Dry and wet compressive strength of fired briquettes as a function of OBM content as well as firing temperatures.

4. CONCLUSION AND RECOMMENDATIONS

This paper presented the results of the research study on the influence of the oil-based mud waste as a partial substitution for the Belbeis clay material on the engineering characteristics of fired clay bricks. Based on the experimental investigations reported in this paper, the following conclusions and recommendation are drawn:

1- The clay burnt briquettes containing oil-based mud waste prepared from the different mixes exhibited good engineering characteristics, with regards to water absorption, bulk density, efflorescence and mechanical strength.

2- The incorporation of the used waste with the clay raw material is modified relatively the production process of the red clay building manufacture.

3- The experimental results showed clearly that the oil-based mud waste in the making red clay building brick seems to be an interesting recycling destination for this abundant waste. This is very important because the incorporation of the referred waste in ceramic bodies can be a technological solution to the negative environmental impact caused by oil well drilling sector.

4- The ability to handle the extruded clay bricks from the all formulated mixes in an industrial scale is recommended to be investigated. It is expected to be positive income.

5- In terms of the environmental performance, it is worth mentioning that it is recommended to establish an environmental profile analysis data for the waste material.

6- The fired briquettes fabricated from the four mix combinations can be used as appropriate raw material resource to produce a load and non-load bearing walls suitable for civil constructions.

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