Summary

The present study aimed at assessment of a raw clay as raw material for clay bricks manufacture. The raw clay quarry under investigation belongs to "Egypt Company for production and selling of clay bricks “Misr Brick . Misr Brick is considered the largest company for clay bricks manufacture in Egypt. It aimed also at raising the performance of the industrial process in the company by reuse of some wastes, such as waste fired bricks rejects and sawdust as batch additives with comparing the results with those of using sand. It is noteworthy to mention that waste fired bricks rejects were accumulated over the last twenty years in huge amounts spread over large floor area in the company. It forms then a great environmental- and economical problem to the company.

The first step to achieve the aimed goals was to make a literature survey about the different technical aspects of such industry and about using different additives to the clay batch. Afterwards, representative samples of the raw clay and sand were brought from the company. They were crushed in a jaw crusher to reduce the grain size down to 2-1 inch. Crushed materials were thoroughly mixed and quartered by coning and quartering method to obtain representative samples .

Investigatory studies were carried out on the raw clay used in " Misr Brick " , in order to evaluate its various properties .Such studies were:

- X-Ray diffraction analysis (XRD).
- Differential thermal analysis (DTA).
- Particle size distribution (PSD).
- Chemical composition by X-ray Fluorescence (XRF).

- Determination of clay Plasticityby using Pfefferkorn apparatus .
- Drying behavior of shaped brick samples (Bigot curve)

Sample of the fired bricks rejects was brought from Misr Brick. It was crushed and ground to be divided into two categories :

Category A: (fine) passing through a 0.6 – 0.3 mm sieve.
Category B: (Coarse) passing through a 2-1.6 mm sieve.

The sawdust was brought from the lot at wood-work refuse dump. Wood chips and strands were removed from the sawdust and it was sieve analyzed .

Clay batches were prepared from the raw clay and the different types of additives ; sand, fine grog, coarse grog and saw dust in various proportions.. Sand additives vary from 9.5% (originally present in the raw clay) to 40% by weight of the clay batch , bricks rejects (fine - coarse) vary from 0-30% by the weight of the clay batch and sawdust has replaced 5 wt% and 10 wt % of the 40 % sand in the clay batch. Effect of such additives on the properties of the clay batch e.g plasticity, sensitivity for drying of the extruded brick sample (bigot curve) and properties of the fired bricks were determined.

From Studies on the raw clay it was found that , the raw clay consists of non clay minerals (≈ 9.5 %) and clay minerals (≈ 90.5%). The non clay minerals are mainly quartz, feldspar , goethite and dolomite . The clay minerals are montmorillonite , illite and kaolinite; the ratio of the percentages of the clay minerals related to each other is 39.1%, 25.6% , 35.3 % respectively. It means that, montmorillonite and illite represent the predominate clay minerals in the raw clay .

From the chemical analysis data, it was found that the batch is considered a low grade clay referring to its low content of Al_2O_3 and its considerable content of the impurity oxides: Fe_2O_3 , Na_2O , K_2O …. Etc. The impurity oxides act as fluxing agents to the refractory oxides , causing the formation of liquid phase on firing at relatively low temperature (800-1000^oC). Such liquid phase stimulates the densification of the brick .

Thermal behavior of the raw clay was revealed from the differential thermal analyses data (DTA)as follows :

a- Evolution of residual hygroscopic and interlayer water of montmorillonite and illite clay minerals (130 ^oC) endothermic peak .
b- Dehydration of goethite (274 ^oC).
c- Dehydroxylation of lattice water of montmorillonite, illite and kaolinite clay minerals (504 ^oC).
d- Quartz transformation $\alpha \rightarrow \beta$ from (573 ^oC).
e- Between 850 and 900 ^oC an endothermic peak corresponding to dissociation of dolomite and calcium carbonate.

During cooling, the most important change is the $\beta \rightarrow \alpha$ quartz transformation (573 ^oC) which is exothermic in nature

From the analysis of the particle size distribution of the raw clay sample, it was found that it consists of 9.46 % sand , 51.05 % silt and 39.49 clay. The results were also plotted on folks clay-silt-sand ternary diagram showing that the raw clay under investigation is far from the balanced particle size distribution of sandy mud required for clay bricks manufacture. The raw clay

sample has large fraction of fines (90.54%) as silt and clay with low fraction of sand particles (9.46%).

The plasticity of the raw clay tested by Pfeffekorn apparatus was found to attain 48% which is considered high value. It means in other words that each 100 grams of the dry raw clay needs 48 grams of water to be shaped by extrusion. High values of plasticity means high degrees of shrinkage of the brick during drying with higher possibility for drying cracks and drying problems. It is aimed always to decrease the plasticity of the clay body as possible e.g by addition of opening non plastic material such as sand, grog …etc as has been evaluated through the present studies.

From the plotted Bigot curve relating the % shrinkage of a raw clay brick sample during drying and its loss of water as % of its original weight , it was found that the raw clay batch can be considered as highly sensitive to drying. It means that the slope of Bigot curve is large reflecting high shrinkage extents with loss of water on drying. Shrinkage attains about 14% of the original brick length on loss of about 15% of the brick original weight as water. This represents the first stage of drying (the shrinkage period). Afterwards, drying proceeds without shrinkage (second stage of drying),till the brick looses its whole water content , about 34 % of its original weight.

Effect of additives on the raw clay batches can be summarized as follows :

The plasticity of raw clay batch decreases remarkably with sand addition . It decearses by about 37% of its original value to reach about 31 % on addition of 40 % sand.

The plasticity of the raw clay decreases also with addition of ground brick rejects (grog), both fine and coarse. It decreases from 48% to 33% on addition

of 30% fine grog and decraeses to 37% on addition of 30% coarse grog. The fine grog addition has more considerable effect on decreasing the plasticity of the raw clay than coarse grog addtioin. That can be referred to the larger voids spaces in case of coarse grog with subsequent larger water uptake.

By replacing part of the 40% sand in the clay batch by sawdust (5 % and 10% by weight), the plasticity of the batch increases. With 5 % saw dust and 35% sand the plasticity attains 37 % and with 10% sawdust and 30% sand the plasticity of the clay batch increases to reach 42%. Such increase of plasticity on saw dust addition can be referred to the nature of sawdust and its ability to absorb water. Saw dust is characterized however by its fibrous structure which can lead to increase of the dry strength of the brick sample. Saw dust has also the advantage of combustion in the firing kiln leaving pores and lighter more heat insulating brick beside its liberated heat of combustion which would lead to energy saving in the kiln. It this situation, it can be recommended to use 5% saw dust and 35% sand as additive to the raw clay which will give good benefits of both sand and sawdust.

The drying sensitivity of the raw clay brick samples was imporved by sand addition. With 40% added sand, shrinkage of the brick sample attains 14% of the raw clay brick sample, at the end of the first stage of drying about 7 % of its original brick length with loss of about 10 % of its original weight as water in comparison to shrinkage extent.

With 5% saw dust and 35% sand the drying sensitivity of the brick samples was not markedly effected. Shrinkage attains about 7 % of the original brick length at the end of the first drying stage with loss of about 15 % of the

brick original weight as water. On the other hand addition of 10% saw dust and 30% sand was accompanied by increase of the shrinkage extent at the end of the first drying stage; it attains about 8.5 % of the original brick length. Shrinkage proceeds till the brick looses about 21 % of its original weight as water.

Drying sensitivity of the clay brick samples was improved ,also ,by addition of both fine and coarse ground fired brick rejects to the raw clay. With addition of 30% fine grog, shrinkage of brick samples attains about 8.5 % of the original brick length at the end of the first drying stage with loss of about 10 % of its original weight as water. With addition of 30% coarse grog the shrinkage attains about 9.5 % of the original brick length at the end of the first drying stage with evaporation of about 11 % of its original weight as water.

From the investigations carried out on the fired brick samples made of clay batches with and without additives it was found that :

- Increase of the content of additive in the clay batch (sand ,waste fired brick (grog) and saw dust) leads to decrease of the total drying shrinkage ,the bulk Density, the loss on weight on firing and the crushing strength, whereas it leads to a increase of the apparent porosity and water absorption of the brick samples . Addition of saw dust was more effective than other additives.

- Increase of the firing temperature leads to increase of the loss on weight, total linear shrinkage, bulk density and crushing strength of the

fired brick sample whereas its apparent porosity and water absorption decrease as the firing temperature increases.

According to tests results clay batch containing up to 40% Sand and clay batch containing up to 30% fine grog and clay batch containing 5% Sawdust and 35% sand can be recommended for clay bricks manufacture. The reuse of waste-brick material (grog) and sawdust in the production provides an economical contribution and also helps to protect the environment.