**Строительство. Текст 1.**

**Perceptions on Barriers to the Use of**

**Burnt Clay Bricks for Housing Construction**

**Bernard K. Baiden, Kofi Agyekum, and Joseph K. Ofori-Kuragu**

Burnt clay bricks can be readily manufactured in Ghana as all ten regions have significant clay deposits with the Ashanti region having the highest estimated deposit of 37.1 million metric tonnes. In recent times, burnt clay bricks have been regarded as old fashioned and replaced by other perceivedmodern walling units within Kumasi, the metropolitan capital of Ashanti Region, despite its availability, unique advantages (aesthetics, low maintenance cost, etc.), and structural and nonstructural properties.This study involved a questionnaire survey of 85 respondents made up of architects, brick manufacturing firms, and brick house owners or occupants in the Kumasi Metropolis of Ghana and sought to examine their perceptions on barriers to the use of burnt clay bricks for housing construction.The findings revealed that the key factors inhibiting the use of burnt clay bricks for housing construction are low material demand, excessive cost implications, inappropriate use in construction, noncompatibility of burnt clay bricks with other materials, unreliable production, and transportation problems. The findings however provide a platform for stakeholders to

address the barriers to enable the extensive use of clay bricks in housing constructions.

**1. Introduction**

The construction industry is very vital to the socioeconomic

development and, in many countries, the yardstick for the

measurement of national progress is hinged on the degree

of contributions of the construction industry. The building

materials sector is also a major contributor to the construction

industry of every nation becausematerials constitute the

single largest input in construction often accounting for about

half of the total cost of most or any construction products

[1–5]. Furthermore, Adedeji [6] noted that about 60% of the

total house construction cost goes towards the purchase of

construction materials. According to Abanda et al. [7] the

share ofmaterials often used in construction is huge andmost

other factors depend on them.

A report by the United Nations revealed that the building

materials sector was split into three production groups [8]:

modern or conventional building materials which are based

on modern conventional production methods like concrete,

steel, and glass; traditional materials which include those

materials that have been in local production from ancient

times using small-scale rudimentary technologies, for example,

laterite, gravel, thatch, straw, stabilised mud, Azara, and

raphia palm; and innovative materials which are materials

developed through research efforts aimed at providing alternatives

to import-based materials, for example, fibre-based

concrete and ferrocement products [9, 10].

The population of Ghana was estimated to be over 20

million in the year 2000 and projected to be 35 million

by the year 2025. Results from the 2010 population census

indicated that Ghana’s population stood at 24, 233, and 431.

Available data also shows that the housing deficit in Ghana

is in excess of 800,000 housing units. Housing supply growth

varies between 25,000 and 40,000 units per year as against the

annual requirements of 100,000 units [11].

This requires that more housing units would have to be

constructed to satisfy the growth rate of about 1.822%.

**Строительство. Текст 2.**

Studies have shown that despite the modern and innovative

materials in the market, there is still the need to return to

traditional materials [8]. In Nigeria, for instance, Abiola [12]

identified building materials as one of the principal factors

affecting the effective performance of the Nigerian construction

industry. In Ghana, the Building and Road Research

Institute, BRRI [13], reported that despite the commendable

performance and properties of burnt clay bricks, the usage of

sandcrete blocks containing cement, produced from clinker

which is imported, is widespread [13]. According to BRRI

[13], if part of the expenditure currently incurred in the

importation of clinker is invested in the production and

usage of burnt clay bricks, some substantial gains could be

made in solving the nation’s housing deficit. Though several

researchers worldwide have called for the need to revert to

indigenous building materials [8, 13–18], little is being said

about the factors inhibiting the use of such materials in Ghana

[19]. For many years, the government of Ghana has tried

to find suitable ways to solve the housing problem of the

country through various means. One of such means is trying

to encourage the use of indigenous local materials such as

burnt clay bricks and tiles [20].The efforts to construct more

houses have become a priority because the country is said to

have a housing deficit of 1.5 million [20]. The critical factor

in making the extraction of clay an available proposition is

the proximity of a market to absorb the bricks. This study

presents the findings of the perceptions of architects, burnt

clay brick manufacturers, and owners or occupants of burnt

clay brick houses and the reasons behind the apparent low

usage of burnt clay bricks for building construction in the

Kumasi Metropolis.

**2. Brief History of Clay Bricks in Ghana**

Clay bricks are man-made materials that are widely used

in building, civil engineering work, and landscape design

[20].The history of clay bricks in Ghana dates back to the

precolonial era [21] as can be observed from the existence

of some old brick buildings in Accra, Kumasi, Cape Coast,

and Takoradi. One of the legacies of the colonial government

was the scattered pieces of colonial and government flats built

with clay bricks dotted within the countries especially along

the coastal areas [21].

**Строительство. Текст 3.**

**Properties of Bricks**

Generally, a good brick must be hard, well burnt, uniform

throughout, sound in texture and colour, and sharp in shape

and dimension and should not break easily when stuck

against another brick or dropped from a height of about

one meter [22]. In using burnt clay bricks for construction,

certain desirable properties should be achieved. Among

these desirable properties are compressive strength, density,

thermal stability, porosity, sound insulation, fire resistance,

durability, and so forth.

 Compressive strength is a mechanical property used in

clay specifications which has assumed great importance for

several reasons [23, 24]. Compressive strength is easy to

determine whereas other properties are difficult to evaluate

[23, 24]. A higher compressive strength increases other

properties like flexure, resistance to abrasion, and so forth

[23].Compressive strength is the only property of brick which

can be determined accurately [25]. Compressive strength

depends on the raw materials used, the manufacturing

process, and the shape and size of the brick. The crushing

resistance varies from about 3.5N/mm2 for soft facing bricks

to 140N/mm2 for engineering bricks when tested in the dry

state [23]. Generally, compressive strength decreases with

increasing porosity, but strength is also influenced by clay

composition and firing [24].

 Density is described as the ratio between the dry brick

weight and the volume of the clay brick, measuring the

proportion of matter (clay) found in the volume. It is evident

from this description that the higher this value is, the denser

the brick is, and obviously, the better its mechanical and

durability properties are. Typical values for the apparent

density range from 1,200 kg/m3 to 1,900 kg/m3 [26].

 Bricks generally exhibit better thermal insulation property

than other building materials such as concrete. Perforation

can improve the thermal insulation property of

bricks to some extent. The mass and moisture of bricks

help to keep the temperature inside a brick house relatively

constant. The thermal conductivity of bricks measured at

various water content and densities have shown that the

thermal conductivity of denser bricks are higher than less

dense bricks [27]. The increase in thermal conductivity due

to wetting varies from brick to brick and may be as low as

five percent (5%).

**Строительство. Текст 4.**

Porosity can be defined as the ratio between the volume

of void spaces (pores and cracks) and the total volume of

the specimen. Porosity is an important parameter concerning

clay bricks due to its influence on properties such as chemical

reactivity, mechanical strength, durability, and the general

quality of the brick [26]. The amount of water a brick or a

brick structure absorbs varies depending on the properties

of the brick. The dimension and distribution of the pores

are influenced by the quality of the raw clay, the presence

of additives or impurities, the amount of water, and the

firing temperature. Cultrone et al. [28] observed that if the

firing temperature increases, the proportion of large pores

(3–15 𝜇m) increases and the connectivity between pores is

reduced, whereas the amount of small pores diminishes. This

has a strong impact on the durability of the bricks as it has

been shown that large pores are less influenced by soluble

salts and freeze/thaw cycles. Furthermore, several studies by

Cultrone et al. [28] and Elert et al. [29] reported that the

formation of small pores, with a diameter below 1 𝜇m, is

promoted by carbonates in the raw clay (low quality material)

and by a firing temperature between 800 and 1,000∘C. Such

pore sizes negatively influence the quality of the bricks, as

their capacity to absorb and retain water increases. A similar

conclusion was given by Winslow et al. [30] for bricks with a

pore size smaller to 1.5 𝜇m.

 Brick walls also have good insulation properties due to

their dense structure. The sound insulation of brickwork is

generally 45 decibels for 4.5 inch thickness and 50 decibels for

a 9 inch thickness for the frequency range of 200 to 20000Hz

which is specified for buildings [31].

 Brick has excellent fire resistance. 100mmbrickworkwith

12.5mm normal plastering would provide a fire-resistance of

2 hours and 200mm nonplastered brickwork would give a

maximum rating of 6 hours for nonload bearing purposes.

Bricks can support considerable load even when heated to

1000∘C in contrast to a concrete wall which can sustain the

same load only up to 450∘C due to loss of water of hydration

[31].

 The durability of a material is its ability to withstand a

particular recurrent weathering effect without failure [23].

Burnt clay bricks are extremely durable and perhaps are the

most man-made structural building material so far. There

have been numerous ancient brick buildings standing for

centuries as a testimony of the endurance of burnt-clay bricks.

**Строительство. Текст 5.**

 **Sizes of Clay Bricks Used in Ghana**

The extensive use of bigger ……. sandcrete blocks

makes it very difficult for small-size standard bricks to

compete with it [32]. On the other hand, clay bricks cannot be

made in bigger sizes due to danger of cracking on drying and

burning which is an inherent property of clay, unless brick is

made hollow or perforated. For this reason, solid clay bricks

are generally made in standard size which is 20 cm Ч 10 cm Ч

10 cm nominal units. Actual size of brick is slightly less than

this as it includes thickness of mortar joint [32]. Actual size

of finished bricks and required sizes of green bricks for two

nominal sizes are given in Table 1.

**Sustainability Importance of Clay as an**

**Indigenous Material**

Sustainability is defined as meeting the needs of the present

without compromising the ability of future generations to

meet their own needs [33, 34]. Brick masonry has been a

primary technique of the built environment for at least seven

millennia and this makes it one of the oldest construction

technologies still in use [35]. Recently clay bricks have come

under different kinds of fire due to their environmental

impact [35]. Fired clay bricks have certain inherent, sustainable

properties such as durability and high thermal mass.

whereas the kilning process has raised some sustainable

concerns because of energy consumption and greenhouse

gas emissions [35]. New ways have been sought by the

brick industry to address sustainability, altering certain time

honoured practices [35].

Sustainability is an umbrella concept that has come to

encompass efforts to address a multitude of “environmental

sins” [35]. Sustainability issues surrounding brick manufacture

(and construction processes in general) include raw

materials consumption, recycled content, embodied energy,

and greenhouse gas emissions [35]. According to the Brick

Industry Association, BIA, [33], every sustainable building

is unique and designed specifically for its site and the

programming requirements of the user. However, all high performance,

sustainable buildings should consider certain

components of design such as environmentally responsive

site planning, thermal comfort, renewable energy, water

efficiency, safety and security, and acoustic comfort among

others [33]. The versatility and durability of brick facilitate its

use as part of many elements of sustainable design [33].

**Строительство. Текст 6.**

**7. Results and Discussions**

*7.1 Experiences with the Use of Burnt Clay Bricks.* All the

respondents demonstrated in-depth knowledge on the use

of burnt clay bricks in housing. Twelve (12) out of 16 senior

architects interviewed indicated that they had been actively

involved in the use of burnt clay bricks for housing before.

According to these respondents, they had frequently been

involved in the design of burnt clay bricks for clients for about

8 years of their practices.These architects further stated that

though they had been involved in the design of these housings,

clients normally shied away when they recommended

burnt clay bricks to them as alternative building materials.

 The opinions on the experiences of the 60 inhabitants

living in burnt clay brick housings were sought. For the

interviewed inhabitants, about 50 of them opted to build

with burnt clay bricks because of its aesthetic appeal. All the

interviewed inhabitants indicated several reasons for their

choice of burnt clay bricks. All the interviewed inhabitants

indicated several reasons for their choices of burnt clay bricks.

Among the reasons are that burnt clay bricks are aesthetically

appealing, could be used without painting and are unique in

nature.

 The experiences of the senior members interviewed from

the nine burnt clay bricks manufacturing firms were further

sought. According to the respondents, their respective firms

produced burnt clay bricks and these bricks were mainly

purchased for government housing projects. The respondents

further indicated some of their major challenges to include

the outskirt locations of the factories and unavailability of

burnt clay bricks when needed.

 *7.2. Barriers to the Use of Burnt Clay Bricks in the Kumasi*

*Metropolis.* The perceptions of the various respondents on

barriers to the use of burnt clay bricks are presented in Tables

2 to 4. The results in the tables also show the frequencies,

percentage of responses, and ranking of the barriers by the

respondents.

 Table 2 shows that the architects interviewed identified

“excessive cost implications,” “low demand for burnt clay

bricks,” “inappropriate use of burnt clay bricks in construction,”

“noncompatibility with other materials,” and “quality

of output (poor workmanship)” as the five most important

factors that inhibit the use of burnt clay bricks in construction

in the Kumasi Metropolis. However from Table 3, the

perceptions of the burnt clay bricks manufacturers, “unavailability

of burnt clay bricks when needed,” “transportation

problems,” “excessive cost implications,” “low demand for

burnt clay bricks,” and “inappropriate use of burnt clay bricks

in construction” are the five main barriers hindering the

use of burnt brick clays in construction in the metropolis.

**Строительство. Текст 7.**

 It could be seen from the results of this study that all the

three respondent groups had different perceptions on why

the materials are not being used in housing construction. For

the architects, their main challenge was the cost aspect of the

material. To the manufacturers, unavailability of burnt clay

bricks due to seasonal changes together with transportation

problems were issues of major concern. The occupants on

the other hand in most cases were concerned about the poor

quality of outputs arising from poor workmanship.

 Several possible reasons have been identified from the

literature for the persistent discrimination in the use of

indigenous building materials of which burnt clay bricks are

part. These reasons include doubtful durability and life span

of the materials, low aesthetic value, poor social acceptability

by the general public, noncommercial status, and lack of

standards [2, 4, 8]. From the results of the current study, it

could be deduced that “low demand for burnt clay bricks,”

“excessive cost implications,” “inappropriate use of burnt clay

bricks in construction,” and “noncompatibility with other

materials” among others are barriers to the use of burnt clay

bricks in construction in the Kumasi Metropolis.

 From these findings, it can be deduced that these barriers

do exist and the variableness of projects and locations could

have largely influenced the respondents’ choices. However,

 the existence of these barriers should not be viewed as a

reason to abandon burnt clay bricks but could be a worthy

challenge to enhance its acceptance and uptake by the

construction industry.

**8 Conclusions**

Even though burnt clay bricks have the potential for adoption

as alternatives to conventional building materials, this study

has found them to suffer persistent discrimination. In Ghana,

several studies have been conducted by the BRRI into the use

of burnt clay bricks, but the implementation of the results of

the studies has been limited by inadequate patronage of the

product. Furthermore, the use of burnt clay bricks in the construction

of buildings has been inhibited by several barriers.

From the perceptions of the respondents interviewed, “low

demand for burnt clay bricks,” “excessive cost implications,”

“inappropriate use of burnt clay bricks in construction,”

“noncompatibility with other materials,” “unavailability of burnt

clay bricks when needed,” and “transportation difficulties”

are the main barriers to the use of burnt clay bricks in

construction. Though the use of burnt clay bricks presents

significant potential benefits, these are yet to be fully explored

by professionals in the Ghanaian construction industry.

**Строительство. Текст 8.**

**Holistic Diagnosis of Rising Damp and Salt Attack in Two**

**Residential Buildings in Kumasi, Ghana**

**Kofi Agyekum,1 Joshua Ayarkwa,1 and Christian Koranteng2**

Rising damp is one of the most severe phenomena that leads to decay and deterioration of both old and modern types of buildings.This study employed a holistic approach to dampness investigation and sought to examine the problem of rising damp in the walls of two residential apartments in Kumasi, Ghana. The study sought to determine the types of soluble salts and their concentrations in the soils and accumulated percentages in the walls over time and whether there exists any linkage between the salts in the walls and those in the ground. Results from the geotechnical survey of the building sites found that the soils on site 1 consisted of silty sandy gravel with some clay particles and those on site 2 consisted of silty sandy soil with some clay and traces of gravel. The study identified several groups of salts in the walls of the buildings, with the most damaging and dangerous being magnesium sulphate, magnesium chloride, and sodium sulphate salts. Similar salts were identified in the soil samples from the trial pits. The results therefore indicate a linkage between the salts found in the ground and those found in the walls and therefore confirm the presence of rising dampness.

**1. Introduction**

 All buildings are expected to be constructed with materials

which have the tendency to resist the effects of water

throughout their service lives [1]. For buildings to perform

this function, there is the need for correct design and

maintenance throughout their service lives [1].Moisture that

should not be present in buildings is known as dampness

[2]. Buildings are said to have dampness problems when the

materials in the buildings become sufficiently damp, leading

to materials damage or visible mold growth [2].

Ghana, a country with hotter and drier climate, has

experienced dampness for several years [3]. In a study to

identify themost dominant type(s) of dampness in residential

buildings in Ghana, all the surveyed buildings were identified

to have symptoms related to either rising dampness,

condensation, or water penetration (including leakages) [3].

However, the most dominant type of dampness was found

to be rising dampness as it was identified with many of the

buildings surveyed [3]. Hygroscopic salts that led to surface

efflorescence, decayed skirting, dampness below 1.5 m, and

mold growth on walls up to 1m high were among the

symptoms identified with rising dampness in the surveyed

buildings. The study recommended a more detailed investigation

on selected buildings to identify the root cause of the

problem.

 This paper involves a laboratory study to examine the

problem of rising damp and salt attack in the walls of residential

buildings. It sought to determine the types of soluble

salts and their concentrations in the soils and accumulated

percentages in the walls over time and whether there exists

any linkage between the salts in the walls and those in the

ground. Two buildings in different geological settings in

Kumasi, Ghana, were selected as case studies.

**Строительство. Текст 9.**

According to Ahmed and Abdul Rahman [12], the problems

of rising damp and salt attack are closely related since

moisture from rising damp can dissolve existing salts in a

building material. Groundwater may sometimes contain salt

and can find its way through the walls of a building by

capillary action [12].The water rises up the wall, about a metre

or more high, and often deposits a horizontal “tide mark”

[13]. Below this mark, there is discolouration of the wall with

general darkening and patchiness, and there may be mould

growth and loose wall paper. The height to which the absorbed

water rises depends on the water absorption capacity of the

masonry, how wet the soil is and how quickly moisture

can evaporate. The water contains soluble salts (from the

ground or dissolved out of the bricks or mortar) and, as

the water evaporates, the salts crystallise out on the wall

surfaces, often concentrating in the tide mark [13]. There are

three preconditions for rising damp: ground contact; ground

moisture; and porous construction [8, 14].

 In the latter part of the 19th century, the subject of rising

dampness and public health became important to researchers

[15]. The architect Thomas Worthington described rising

damp in his 1892 essay and recommended that a damp proof

course (DPC) should be used to disconnect the whole of the

foundations from the superstructure [15]. In a detailed study

undertaken by the British Research Establishment (BRE),

the moisture contents of a total of ninety-four 100 year old

properties in the Cardiff Bay area were measured [16]. Rising

damp was reported to occur if the moisture content of mortar

samples was above 5% and it was found that 54% of the

properties suffered from rising damp at heights of 0.3mabove

the floor level [15]. In a study by Trotman et al. [17], it was

reported that soluble salts were drawn up into the structures

affected by rising damp and became deposited in the walls.

When the water evaporated and the salt solution became

more concentrated at the surface and crystallised out of

solution, blocked the pores, reduced evaporation, and raised

the height of the level of dampness. In Greece, Maravelaki-

Kalaitzaki et al. [18] revealed that the main reasons for

deterioration of construction materials were attributed to

salt crystallization, water, and movement of salt solutions

through walls by capillarity. Moreno et al. [19] undertook a

detailed study of salt damage on a 16th-17th century church

building by sampling from many heights and locations for

analysis to build up a full picture of salt damage.

**Строительство. Текст 10.**

Salts normally present in buildings are either present in

The masonry at the time of construction or are absorbed from

the atmosphere or ground water during the life of the building

[21, 22]. Salt will crystallize at different heights on walls with

rising damp depending on their solubility [23, 24]. Arnold

[25] synthesized this distribution from a careful analysis and

observation of many damp structures. The distribution of

salts within a wall is also dependent on the actual mixture

of salts present and their origin. On the basis of a thorough

analysis of the north facёade of a former convent in northern

Bavaria and other monuments, Steiger et al. [26] identified

the presence of nitrate, potassium, magnesium, chlorides,

and sodium to be associated with rising dampness.T he zone

of maximum enrichment, around 2-3m from the ground,

reflected the capillary rise height. Sulphates are reported to

be present in many bricks, stones, Portland cement, and

some groundwater and are formed in masonry from sulphur

dioxide and sulphurous acid in the atmosphere [21].

Different types of soluble salts cause damages to masonry

walls. The most common building damaging salts consist of

anions-sulphates, chlorides, and nitrates [27]. Also, sodium

chloride, magnesium chlorides, sodium nitrates, and sulphates

of calcium, sodium, magnesium, and potassium are

damaging [12, 28]. After these salts build up in the plaster and

on brick surfaces over a period, they attract moisture from the

atmosphere [12] and result in plaster peel-off in a belt. The

causes of decay and deterioration of buildings are influenced

by the existence and movement of water and damaging salts

[29–31].

Dealing effectively with the problem of dampness

requires the adoption of an organized system of investigative

procedures to confirm all the sources and ensure that the

recommended remedial works are appropriate [32]. According

to Burkinshaw and Parrett (2004), such a system must

commence with identifying and recognizing symptoms or

signs of dampness. The selection of an effective remedy for

any form of dampness must start with a correct diagnosis of

the cause [32]. There are four major stages to any dampness

investigation (Figure 1) [2, 11, 33]. These are visual inspection,

investigations using moisture meters (nondestructive tests), a

more detailed investigation (destructive tests) and homing in

on the problem (laboratory assessment study) [2, 11, 33].

The visual investigation stage requires the surveyor to

inspect the defect closely and act as a preliminary assessment

for further investigation and confirmation of the defect

assessed [2]. In this stage, the identification of a dampness

problem is dependent on symptoms such as staining of water,

cracking, rotten timber, decay, and blisters, and the diagnosis

requires knowledge of the behaviour of relevant building

materials, construction knowledge, and knowledge of the use

(past, present, and future) of the building.