A Comparative Study of the Physical Properties of Perforated Clay Bricks Available in the Iraqi Local Market

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Abstract. Bricks are the most frequently used building units in residential and commercial construction in Iraq. This paper presents a comparative study of the physical properties of perforated clay bricks manufactured by five different factories: three of brick samples are local, with the other two being imported. Thirty specimens were tested for each factory for a total number of 150 bricks. Brick samples were randomly selected from the local market and then tested according to Iraqi specifications 24/1988 and 25/1988. The tests results showed that water absorption was lower in the local samples (13.7% minimum) than the imported ones (22.2% maximum), while efflorescence rates for both local and imported samples ranged from light to medium. The compressive strength of one local (about 29 MPa) and both imported samples (about 12 MPa) met the specifications, while the other local samples demonstrated lower compressive strength than the specifications. Overall, based on the adopted specifications, only one local sample was classified as class A, with the other samples did not meet requirements.

1. Introduction

One of the most important materials in construction is brick. Shakir and Mohamed [1] have noted the need for more sustainable methods of manufacturing brick in the future, including preventing the consumption of natural resources such as clay, sand and shale in the production process by promoting the use of industrial waste such as billet scale, quarry dust, fly ash, and bottom ash as the main constituents of bricks. They also recommend seeking alternative fuels and promoting the use of renewable energy for brick plants that still follow traditional methods of brick manufacture.

Tang [2] concluded that increasing the waste glass content decreased the water absorption and increased the compressive strength of bricks; he also stated that the use of waste glass to manufacture bricks helped reduce the cost of bricks production. Similarly, Al-khafaji [3] concluded that increasing marble dust content enhanced the properties of clay brick specimens based on tests including chemical, physical, and mechanical examination of bricks. Tests in such cases may be chosen based on their importance and their relationship to the proposed use of bricks, in accordance with Iraqi standard 24/1988 [4].

A recent practical study aimed to investigate the methods used to control the quality of bricks manufactured in Iraq [5]. Two case studies were adopted: the first considered conventional brick produced by a manufacturing factory while the second considered a new arrangement for bricks. In the first case, a specific brick factory that had developed a pure water system for producing clay bricks was adopted. The results of efflorescence tests showed an obvious reduction in the percentages of soluble salts, with the level of efflorescence decreased from medium to low. In the second case, the research and development department of the General Construction Industries Company suggested a new design for perforated bricks with holes were centred along the brick length. A model of the new design was
manufactured in Alqadisyia brick factory and several future studies were planned to investigate the feasibility and efficiency of this design. A comparison of the physical properties of Iraqi and Iranian samples of perforated bricks from different factories was performed by Jabbar et al [6]. The test results revealed that the Iraqi bricks were generally better than the Iranian ones in terms of variation in dimensions and water absorption; in contrast, Iranian bricks had better appearances, less concavity and convexity, higher compressive strength, and lower efflorescence. When evaluating all the characteristics examined in accordance with the requirements of Iraqi specification, the Iraqi bricks performed better than the Iranian ones, yet all the specimens examined were classified as class B or class C, with none in class A. The brick industry has significantly and continuously evolved; the number of brick factories in 2000 was only 164, offering a production capacity of 270,700,000 bricks. By 2012, this number had risen to 549, with a production capacity of 921,800,000 bricks. This growth reflects the urgent and continuous demand for bricks caused by increases in population and the need for new dwelling units [7].

The physical and mechanical properties, colours, and overall appearance of brick are affected by the firing process [8]. At present, one of the most commonly used brick types in Iraq is the burnt red perforated brick manufactured locally by a brick factory in Al-Sulaymaniyah province. The soil used to make this type of brick is Al-Sulaymaniyah original red soil without any natural or chemical dyes. The key characteristic of Sulaymaniyah bricks is insulation adequacy against heat, sound, and humidity. According to factory classifications, these bricks are classified into bearing bricks, used to construct bearing walls, and non-bearing bricks, used for constructing partitions and other non-load-bearing structural members.

The objective of the current work is to assess the physical properties of samples of local and imported perforated clay bricks available in the Iraqi local market to provide a clear overview of the suitability of available brick for specific local requirements in both research and construction.

2. Experimental programme
Sampling and testing procedures were performed on the brick specimens in accordance with Iraqi standard specifications (24/1988) [4]. Table 1 shows the sources of brick samples tested in this work.

| Samples Source | Source of brick          | Symbol |
|----------------|--------------------------|--------|
| Local          | Iraq, Sulaymaniyah       | B1     |
|                | Iraq, Baghdad            | B2     |
|                | Iraq, Baghdad            | B3     |
| Imported       | Iran                     | B4     |
|                | Iran                     | B5     |

2.1. Physical properties of bricks

2.1.1. Overall appearance and dimensions. Testing on overall appearance and dimensions was carried out according to Iraqi standard specification 24/1988 [4]. A sample of 24 bricks was taken; for ease and practicality, the dimensions were measured after the whole sample was divided into three groups of eight bricks. Each group was measured individually to the nearest 1 mm and the total dimensions of all
the 24 bricks calculated as shown in figure 1. Table 2 lists the results of the dimension and appearance tests.

![Width measurement](image1.png) ![Length measurement](image2.png) ![Thickness measurement](image3.png)

**Figure 1.** Brick positions used to measure dimensions.

Iraqi standard specification 25/1988 [9] sets the dimensions of perforated bricks as 240 x 115 x 75 mm and states that the percentage of holes in each brick should not exceed 25% of the entire brick. The specification also lists tolerances in dimensions as ±3% for length and width, ±4% for thickness, and 5 mm for surface uniformity.

The results of the general appearance tests for Iraqi brick samples B1, B2, and B3 had several common characteristics, such as uniform brick shape, right-angled corners that were straight and good, and fragments of less than 10% of the overall brick size, which did not affect the other characteristics of the bricks. Bricks from local sample B1 and imported samples B4 and B5 were the most regular and uniform in appearance. With regard to colour and goodness of firing, all brick samples had homogenous colourations that indicated uniformity in burning; most samples were yellow, while the B1 samples were red due to the unique nature of the soil from which they were made. All the brick samples used were free of gravel, stone and limestone conglomerates. As shown in table 2, all the tested specimens were of uniform shape in compliance with Iraqi standard specification 25/1988 [9]. With respect to variation in dimensions, the Iraqi specification gives the maximum limits of variation in length and width as ±3% and limits thickness variation to ±4%. Based on the results in table 2, brick samples B1, B2 and B3 were within these limits. The B1 samples were the best in terms of minimal deviation in length, width and thickness. For the imported brick samples, the dimension tests showed that the examined specimens were outside of the requirements of the Iraqi specifications (25/1988) [9]. The main reason for this is that imported brick samples were produced according to the requirements and specifications of the producing country (Iran). Table 2 also shows that all the local and imported brick samples had fairly even surfaces without any unacceptable deviations, meeting both concavity and convexity criteria.

**Table 2.** Test results for general appearance and dimensions measurement.

| Property               | B1   | B2   | B3   | B4   | B5   |
|------------------------|------|------|------|------|------|
| **General Appearance** |      |      |      |      |      |
| Concavity              | 0    | 0    | 0    | 0    | 0    |
| Convexity              | 0    | 0    | 0    | 0    | 0    |
| Cracks                 | Minor| Minor| Minor| Minor| Minor|
| Fragmentation rate     | 5%   | 6%   | 6%   | 5%   | 5%   |
| Colour                 | Red  | Yellow| Yellow| Yellow| Yellow|
| Burning homogeneity    | Homogeneous| Homogeneous| Homogeneous| Homogeneous| Homogeneous|
2.1.2. Water Absorption Test. Iraqi standard specification 24/1988 [4] was adopted in terms of measuring and calculating the absorption of water by all brick samples. The method adopted included drying out the brick sample surface in the oven, with ventilation, at 110 °C for 36 hours until the brick mass held constant. Thereafter, the samples were immersed in cold water for about 24 hours. For each sample, Table 3 lists the average water absorption rates for ten bricks as well as the highest absorption rate for a single brick. Iraqi specification 25/1988 [9] sets the maximum standard average absorption rates for ten bricks of classes A, B, and C as 20%, 24%, and 26%, respectively, and the maximum absorption rate for one brick as 22%, 26%, and 28%, respectively. As shown in table 3 and figure 2, the results of the absorption tests for the B1 samples were the best among these samples, and thus, according to the Iraqi specification, the B1 samples fell within class A, implying that these bricks offer the least water absorption; all other brick samples fell within class B.

Porosity is the presence of fine pores that may or may not be distinguishable by the naked eye; they might be connected with each other or closed, and may be within the brick body or on its outer surface. An increase in the porosity tends to lead to a decrease in density, a decrease in strength, and an increase in water absorption; it may also indicate an increase in brick thermal insulation [10]. The porosity of bricks depends upon several factors, including the degree of pressure during manufacture, the amount of water evaporated from inside the brick paste, and the degree of burning, as porosity decreases on increases in the firing temperature [10]. Water absorption characteristics affect brick durability significantly, and high porosity masonry walls are not suitable for healthy housing. Iraqi specification 25/1988 [9] thus sets upper limits for water absorption rates for bricks [10]. Water is also a major factor in the movement of salts that cause efflorescence and react negatively with bonding materials. The absorption of water may lead to damage in finishing materials, and absorbed water is a powerful source of damage to brick during freezing. The phenomenon of water absorption thus has a strong relationship with the durability of any ensuing structures [11].

The nature of the soil used in the manufacturing bricks also has a major impact in determining absorption rates. Iraqi soil usually consists of a group of Montmorillonites, rich in calcium, which usually presents in the form of a high percentage of carbonates and a small percentage of sulphates. This leads to a high percentage of loss in weight during burning as carbonates convert into oxides, producing bricks of poor quality due to high porosity, which leads to high absorption and low compressive resistance [6]. The results may thus indicate that the soil used in manufacturing of the B1 sample (from the north of Iraq) has better engineering characteristics than the soils used by the other brick factories.

| Impurities Rate of adequate bricks | None | None | None | None | None |
|---|---|---|---|---|---|
| Dimensions | None | None | None | None | None |
| Length (mm) | 240.5 | 246 | 244 | 230 | 230 |
| Width (mm) | 114.8 | 112 | 112 | 110 | 110 |
| Thickness (mm) | 74.5 | 74 | 74 | 70 | 70 |
| Variation in length | +2.1 | +2.5 | +1.7 | -4.2 | -4.2 |
| Variation in width | -2.2 | -2.6 | -2.6 | -4.3 | -4.3 |
| Variation in thickness | -0.7 | -1.3 | -1.3 | -6.7 | -6.7 |
Table 3. Water absorption tests for local and imported bricks.

| Brick Symbol | Absorption (%) | Maximum limit of individual brick |
|--------------|----------------|-----------------------------------|
| B1           | 13.7           | 14.6                              |
| B2           | 21.5           | 22.5                              |
| B3           | 20.3           | 24.2                              |
| B4           | 22.2           | 25.3                              |
| B5           | 22.1           | 25.2                              |

Figure 2. Results of absorption tests on brick samples.

2.1.3. Compressive Strength Test. The results of the compressive strength test are shown in table 4 and figure 4. The results show the average strength for ten bricks and the lowest strength for an individual brick for the samples taken from five sources. Figure 3 shows the samples during the test. Iraqi specification 25/1988 [9] sets the minimum compressive strength limit for brick classes A, B, and C for the average of ten bricks as 18, 13, and 9 MPa, respectively, and the compressive strength for an individual brick for these classes as 16, 11, and 7 MPa, respectively. Based on these limits, table 4 and figure 4 reveal that the B1 sample is the best performing, falling within class A of Iraqi specification 25/1988 [9]. The Iraqi bricks B2 and B3 do not conform to the Iraqi standard limits, while the imported bricks B4 and B5 fell under class C. This indicates that the soil of Sulaymaniyah province used in the manufacturing of the B1 sample is the most suitable for producing bricks.

Raw materials have an important influence on a brick’s strength, shape and durability. The most likely reason for B2 and B3 not matching the specifications is thus the raw materials used to create them: the clay used to make these bricks is not adequate. In particular, the presence of lime in large quantities as small blocks in clay may negatively affect the required engineering characteristics in any bricks produced from such clay, as the fired brick could later break up into small parts in the presence of water. Any clay used must be clean and contain key mineral compounds, though the presence of such compounds varies from quarry to another depending on the geological composition of quarry soil, which also leads to differences between various types of clay bricks.

Another factor that affects brick characteristics is the burning process. The temperature should exceed 800 °C to ensure melting to allow clay to be converted into a dense glassy material to achieve the required cohesion between molecules and hence the required hardness [10]. The low quality of bricks
B2 and B3 may thus be attributed to several factors, including the design of the furnace, the soft brick loading method, the quality of the clay used, and the method of ignition used to generate the heat needed for each operation. The mechanism used to burn clay bricks is very important in producing building bricks that conform to specifications, and the use of modern machines and concepts can increase the probability of producing good quality bricks.

**Table 4.** Compressive strength results for local and imported bricks.

| Brick Symbol | Average of 10 bricks | Minimum Limit of Individual brick |
|--------------|----------------------|----------------------------------|
| B1           | 29.1                 | 21.2                             |
| B2           | 7.7                  | 6.2                              |
| B3           | 7.2                  | 3.3                              |
| B4           | 12.7                 | 10.8                             |
| B5           | 12.1                 | 8                                |

**Figure 3.** Brick layout during compression testing.

**Figure 4.** Results of compressive strength tests on brick samples.

2.1.4. **Efflorescence Test.**
Table 5 and Figure 5 show the results of the efflorescence tests on local and imported bricks in each sample. Iraqi specification 25/1988 [9] specifies the maximum degree for efflorescence for ten bricks for class A as light, and for class B as a medium; it does not determine a specific degree for class C. The results of the efflorescence tests illustrate that local brick samples B1 and B3 fall within class A, as the percentage of efflorescence is less than 10%, while the B2 samples fall within class B. For the imported brick samples, the B4 samples are of class B, while the B5 samples are of class A. The B1 sample, manufactured in Sulaymaniyah province, has the lowest efflorescence. Figure 6 shows the traces of efflorescence of the B1 samples and the quantity of the salts seen, and one of the reasons for this may be the low solubility of salts in the soil in that province.

Soluble salts are an important factor in the occurrence of efflorescence, known locally as "shoora". Water containing dissolved salts moves towards a brick’s outer surfaces and then evaporates, leaving crystals of salt on the surface or just underneath it. This gradually leads to the presence of white and yellow spots on masonry walls that disturb the finishing layer. Dissolved sulphate salts can also have...
harmful effects on cement mortar, as sulphate salts in the presence of water develop the ability to interact with certain cement compounds to produce new compounds of larger sizes, resulting in the fragmentation of the bonding material. This is why a maximum amount of salts is specified in Iraqi specification 25/1988 [9].

![Figure 5. Results of efflorescence testing of brick samples.](image)

![Figure 6. Efflorescence test for B1 sample.](image)

**Table 5.** Efflorescence results for local and imported brick samples.

| Brick Symbol | Maximum Percent of Efflorescence (%) | Degree of efflorescence |
|--------------|-------------------------------------|-------------------------|
| B1           | 1.6                                 | Light                   |
| B2           | 20.2                                | Medium                  |
| B3           | 6.6                                 | Light                   |
| B4           | 13.3                                | Medium                  |
| B5           | 5.7                                 | Light                   |

3. Overall evaluation

Table 6 shows the overall evaluation of the three local and two imported brick samples based on the requirements of Iraqi specification 25/1988 [9]. Overall, the best brick sample is B1, which is classified within class A. Local bricks B2 and B3 are not in accordance with the requirements of the specification because the values of their compressive strengths are lower than the minimum allowed even for class C. In contrast, the imported brick samples, B4 and B5, are classified as class C, although the results of their variation in dimensions do not conform to the permissible limits of specification 25/1988 [9], presumably because Iranian specifications are different from those in Iraqi.

**Table 6.** Overall evaluation of tested local and imported brick samples.

| Brick Symbol | Dimensions | Test Name | Efflorescence | Brick Class Iraqi Specification (25/1988) [9] |
|--------------|------------|-----------|---------------|---------------------------------------------|
| B1           | Conform    | Class A   | Class A       | Light                                       |
| B2           | Conform    | Class B   | Not conform   | Medium                                      |
| B3           | Conform    | Class B   | Not conform   | Light                                       |
| B4           | Not conform| Class B   | Class C       | Medium                                      |
| B5           | Not conform| Class B   | Class C       | Light                                       |


4. Conclusions and recommendations
In this research, several engineering tests were carried out on 150 clay perforated bricks taken from three local brick factories (B1, B2 and B3) and two foreign ones (B4, B5). Based on the test results, the following conclusions can be drawn:
1- The results of the general appearance test showed that bricks from sample B1 and the two imported samples (B4, B5) were more regular in terms of shape, angles, sides, and colour homogeneity than those in samples B2, and B3.
2- With regard to deviation in dimensions from the standards, brick sample B1 had the least deviation, followed by B3 and B2. In contrast, both samples of imported bricks (B4 and B5) did not match the permissible rates of variation in dimensions, with disparity exceeding ±3% for length and width and ±4% for thickness.
3- The water absorption tests revealed that local bricks have lower rates (13.7% minimum for sample B1) of absorption than imported bricks (22.2% maximum for sample B4).
4- The results of the compressive strength tests showed that sample B1 had the highest strength, followed by the imported bricks (B4, B5). Local bricks B2 and B3 did not conform to the minimum compressive strength outlined in the relevant Iraqi specification.
5- Efflorescence test results confirmed that sample B1 had the lightest percentage of efflorescence (less than 1.6%). The B3 sample had a higher rate of salts (6.6%) while remaining within the light range, while the rate of salts for the B2 sample was more than 10% and less than 50%, giving a medium result. For the imported bricks, the rate of efflorescence for sample B5 was light, while that for sample B4 was medium.
6- The overall evaluation for bricks based on the tests performed is that local brick B1 is the best, falling within class A.
7- According to the findings reached, good and clean raw materials that contain the essential minerals required for making clay bricks must be sourced. Additionally, adequate burning furnaces and modern mechanisation are highly recommended strategies in the production of acceptable perforated clay bricks. It is recommended that further investigation of bricks from more companies be undertaken to develop a better picture of the brick types available in the Iraqi local market, however.

References

[1] Shakir A A and Mohamed A A 2013 "Manufacturing of Bricks in the Past, in the Present and in the Future: A state of the Art Review" International Journal of Advances in Applied Sciences (IJAAS) Vol 2 No 3 p 145-156
[2] Tang C W 2018 "Properties of Fired Bricks Incorporating TFT-LCD Waste Glass Powder with Reservoir Sediments" J. Sustainability Vol 10, 2503 p 1-18
[3] Al-Khafaji B T 2017 "Study of the Properties of Clay Brick Made with the Addition of Certain Additives" Journal of Babylon University Engineering Science Vol 25 No 5 p 1539-1551
[4] Iraqi Standard Specification IQS 24 1988 "Methods of Sampling and Testing Clay Building Bricks" p 1-8
[5] Hassan S A 2013 "Controlling the Quality of Brick Properties in Laboratories (Al-Qadisiyah Brick Laboratory-Case of Study)" Journal of Engineering and Development Vol 17 No 4 p 1-10
[6] Jabbar D N, Abd M K, Hassan A A 2013 "A Comparison Study for Physical Properties between Iraqi and Iranian Perforated Bricks" Al-Qadisiyah Journal of Engineering Sciences Vol 6 No 3 p 70-89
[7] Al-Janabi A J T 2014 "The Brick Industry in Iraq (2000-2012) (Analytical Study)" Literature Journal, University of Baghdad, Faculty of Education, Ibn Rushd Humanitarian Sciences Issue 110 p 433-456

[8] Kadir A A and Mohagerani A 2013"Physical and Mechanical Properties of Fired Clay Bricks Incorporated with Cigarette Butts: Comparison between Slow and Fast Heating Rates" J. Applied Mechanics and Materials Vol 421 p201-204

[9] Iraqi Standard Specification IQS 25 1988 "Clay Building Bricks" p 1-3

[10] Sersam J B and Abdulali S 2006 "Construction Materials" Dar Al Yazourdi Amman, Jordan Chapter 2 p25-58

[11] Sako Z and Levon A 1983 "Building Construction" University of Baghdad, Faculty of Engineering, Department of Civil Engineering Chapter 6 p 169-245