

Quality assessment of clay bricks using a ratio to standard brick quality index

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Abstract

The quality of five clay brick samples (S1–S5) was assessed using a multi-parameter Brick Quality Index (BQI) based on the ratio-to-standard method. Density, compressive strength, porosity and water absorption were considered, using ideal reference values for comparison. The calculated BQI values showed that S2 had the highest quality (0.868), followed by S5 and S1, while S4 had the lowest quality (0.732). The study demonstrates that the ratio-to-standard BQI method provides a simple and effective way to compare the overall quality of clay bricks.

Keywords: Clay bricks; Brick Quality Index; BQI; Ratio-to-standard method; Density; Compressive strength; Porosity; Water absorption.

1. Introduction

Clay bricks remain widely used in masonry because of their availability, durability, fire resistance, thermal mass, and relatively simple production process. Their engineering performance is strongly influenced by the mineralogical composition of the raw clay, particle-size distribution, moulding pressure, drying conditions, firing temperature, firing duration, and cooling regime. Variations in these factors can produce bricks with noticeably different [1,4,10] physical and mechanical properties, even when the units are manufactured in the same geographical area.

Brick quality is commonly determined using properties such as density, compressive strength, porosity, and water absorption. Compressive strength reflects the ability of a brick to withstand applied loads, while density provides an indirect indication of consolidation, firing, and internal structure. Porosity represents the fraction of voids within the fired body, and water absorption indicates the amount of water that can enter accessible pores. Water-related properties are especially important because moisture movement can contribute to salt crystallization, staining, [5,6,8,11] biological growth, and deterioration during repeated wetting and drying.

These properties are interrelated, but the relationships are not always simple. Higher porosity often leads to greater water absorption and lower strength, although pore size, connectivity, mineralogy, and firing-induced vitrification can modify these trends. Experimental research has shown that bricks from different sources may display distinct relationships between compressive strength, porosity, and moisture uptake.

Conventional quality assessment normally compare each property with an individual standard [5,6,8,10] limit. This approach is essential for determining compliance, but it does not always provide a clear overall ranking. One brick may have high strength but excessive absorption, whereas another may have moderate strength and superior resistance to water penetration [11,13]. Selecting the better product therefore requires simultaneous consideration of several criteria.

A composite quality index can address this difficulty by converting measured parameters into dimensionless values and combining them into one representative score. Among the available normalization procedures, the ratio-to-standard method is particularly suitable for routine assessment because it is easy to interpret. A measured value is divided by an ideal reference value when a larger result is preferable, while the inverse ratio is used when a smaller result is preferable [11,13].

The present study applies this principle to five clay brick samples. Density, compressive strength, porosity, and water absorption were selected because they represent compactness, load-bearing capacity, internal void structure, and moisture susceptibility.

2. Material and methods

2.1. Sample preparation

Loose dust and adhering particles were removed from the brick surfaces using a dry brush. The specimens were inspected for visible cracks, broken edges, distortion, and other defects. Their dimensions were measured using a calibrated measuring device.

For dry-mass measurements, the specimens were oven-dried to constant mass and allowed to cool before weighing. Compression specimens were prepared according to the applicable brick-testing standard, including surface grinding or capping where required to obtain sufficiently plane and parallel loading faces.

Table 1: Sample notations & locations

S.No.	Sample Notation	Sample Locations
1	S1	Thevangudi
2	S2	Vattathur
3	S3	Orathur
4	S4	Vatharayanthethu
5	S5	Theethampalayam

**Fig.1. Flow chart**



Fig.2. Different clay brick specimens

2.2. Materials

The properties of fired clay bricks originate from the interaction between raw-material composition and manufacturing conditions. Clay mineralogy controls plasticity, drying behaviour, shrinkage, and thermal transformations. Non-clay components such as quartz, carbonates, iron oxides, soluble salts, and organic matter also influence firing colour, pore development, dimensional stability, and strength.

During firing, dehydration, dihydroxylation, oxidation, mineral transformation, and partial vitrification progressively alter the clay body. Inadequate firing can leave the product weak and highly absorbent, whereas appropriate firing promotes particle bonding and densification. Excessive firing may cause deformation, bloating, cracking, or undesirable energy consumption. Brick quality therefore depends on achieving a suitable balance between densification and controlled pore development [3,10].

Five clay brick samples were selected for the investigation and designated as S1,S2,S3,S4 &S5. The samples were evaluated based on density, compressive strength porosity and water absorption [5,6].

3. Parameters studied

The following properties were evaluated:

- Bulk density, representing mass per unit external volume.
- Compressive strength, representing resistance to crushing under axial load.
- Apparent porosity, representing the proportion of accessible voids.
- Water absorption, representing moisture uptake under the selected immersion condition.

3.1. Density

Bulk density expresses the mass of a brick relative to its external volume. In conventional clay bricks, greater density often indicates better compaction and stronger bonding developed during firing. Dense products may consequently exhibit improved strength and reduced water penetration.



Fig.3. Density test in clay brick

The bulk density of each brick was determined from its dry mass and volume

$$\rho = \frac{M}{V} \quad (\text{g/cm}^3)$$

Where M is the dry mass and V is the volume of the brick specimen

3.2. Compressive strength

Compressive strength is one of the principal measures of masonry-unit performance. It is affected by raw-material composition, pore volume, microcracks, degree of vitrification, specimen geometry, loading orientation, surface preparation, and test procedure. Bricks containing fewer structural defects generally transfer compressive loads more effectively [6,8]. The compressive strength was determined by applying a gradually increasing compressive load until failure [5,8].

$$CS = \frac{P}{A} \quad \text{N/mm}^2$$

Where P is the maximum load and A is the load cross-sectional area (IS1077 and 1S3495 part1)



Fig.4. Compressive strength test in clay brick

3.3. Water absorption

Water absorption measures the increase in mass resulting from immersion under specified conditions. It is widely used as an indirect indicator of accessible pore volume and potential moisture susceptibility. Excessive absorption can affect mortar-brick interaction, promote moisture transport, and increase vulnerability to salt deposition and repeated wetting and drying [5,8].

Water absorption was calculated from the dry and saturated masses *S1077 and S 3495 Part 2)*

$$WA \% = \frac{M_s - M_d}{M_d} \times 100$$

Where M_s is the saturated mass and M_d is the dry mass



Fig.5. Water absorption test in clay brick

3.4. Apparent porosity

Porosity refers to the volume of voids relative to the total bulk volume of a material. The pores in fired bricks may be open, closed, connected, or isolated. Open and interconnected pores permit liquid and vapor movement, whereas closed pores contribute to total porosity without necessarily causing high water absorption.

The amount and distribution of porosity are controlled by particle packing, gas release, organic-matter combustion, carbonate decomposition, shrinkage, vitrification, and cooling. Increased porosity commonly reduces the effective load-bearing area and creates points of stress concentration. It may therefore reduce compressive strength. However, equal total porosity

does not always produce equal strength because pore geometry and microcracking also matter [5,6].



Fig.6. Apparent porosity test in clay brick

It is the percentage of the volume of open pores in a bricks than can be filled with water.

In some important indicator of the internal pores structure and durability of fire clay bricks

$$PA = \frac{M_s - M_d}{M_s - M_i} \times 100$$

Where PA is the apparent porosity

M_d is the oven dry mass of bricks

M_s – is the saturated mass of brick

M_i – is the mass of saturated brick immersed in water

Ratio to standard BIS method for the present comparative study the following ideal reference values were selected [5].

Table 2: Ideal Performance Parameters of Clay Brick Specimens

Parameter	Ideal value	Type
Density	2.00 g/cm ³	Beneficial
Compressive strength	15.00 N/mm ²	Beneficial
Porosity	15%	Non beneficial
Water absorption	10%	Non beneficial

3.5. Brick Quality Index

To provide an integrated assessment of the overall quality of the fired clay bricks, a Brick Quality Index (BQI) was calculated by considering four important physical and mechanical parameters, namely density, compressive strength, apparent porosity, and water absorption. The index-based approach enables the different properties to be expressed on a common normalized

scale and facilitates comparison among the investigated brick compositions and firing conditions.

The selected parameters were classified into beneficial and non-beneficial parameters according to their desired influence on brick quality. Density and compressive strength were treated as beneficial parameters, whereas apparent porosity and water absorption were considered non-beneficial parameters. For the beneficial parameters, a higher normalized value indicates better performance. In contrast, for the non-beneficial parameters, a lower measured value represents better performance.

Beneficial parameters

For density and compressive strength, light values are considered desirable D

$$Q_D = \frac{\text{desirable D}}{D_0}$$

$$Q_{cs} = \frac{CS}{CS_0}$$

Where D_0 and CS_0 are the ideal density and compressive strength values

Non-beneficial parameters

For porosity and water absorption lower values are desirable

$$Q_p = \frac{P_0}{P}$$

$$Q_{WA} = \frac{WA_0}{WA}$$

Where P_0 and WA_0 are the ideal porosity and water absorption values

Overall BQI

With equal weighting

$$BQI = \frac{QD + QCS + QP + QWA}{4}$$

Equal weighting was adopted so that density, compressive strength, porosity, and water absorption contributed equally to the overall index. Consequently, the BQI provides a single comparative indicator incorporating both mechanical performance and pore-related characteristics of the bricks.

The normalized BQI

$$BQI(N) = BQI \times 100$$

The ideal reference values used here are study specific.

4. Result and discussion

Physical and mechanical parameters have been used in process investigation of fire clay bricks [5]

The ratio to standard method indicates that S2 has the highest overall BQI of 0.868 (86.8%). This result is consistent with it relatively high density and compressive strength and its comparatively low porosity. S2 has a density of 1.95 g/cm³ and compressive strength of 14.02N/mm² which has the highest values among the fire samples [3,5,6].

S5 ranks second with a BQI of 0.84 (84.93%). Although its compressive strength is slightly lower than the of S2, S5 has the lowest water absorption (11.87%). Giving the highest water absorption quality ratio provides a BQI of 0.807(80.7%) and therefore occupies the fixed position its performance relatively balances across the parameters.

Table 3: Physical and mechanical properties of clay bricks along with their specimen identifications S1, S2, S3, S4 and S5

Specimens	Bulk density g/ cm ³	Water absorption %	Porosity %	Compressive strength N/mm ²
S1	1.89	13.81	21.74	13.04
S2	1.95	12.89	19.01	14.03
S3	1.75	14.88	23.15	12.60
S4	1.72	15.67	25.04	12.44
S5	1.90	11.88	20.60	13.16

S3 and S4 show lower BQI values of 0.759 and 0.732 respectively. S4 has the highest porosity (25.06%) and water absorption (15.67%) and the lower density (1.72g/mm³) and compressive strength (12.43 N/mm²) There combined characteristics result in the lower BQI among the investigated samples.

Table 4: Ratio to standard BQI calculation

S.No.	Sample identifications	Density ratio (QD)	CS ratio (CS)	Porosity ratio (QP)	Water absorption (QWA)
1	S1	0.945	0.869	0.690	0.724
2	S2	0.975	0.935	0.789	0.776
3	S3	0.875	0.840	0.648	0.672
4	S4	0.860	0.829	0.599	0.638
5	S5	0.950	0.877	0.728	0.842

For convenient interpretation, the BQI was further expressed as a percentage using the normalized Brick Quality Index:

4.1. Ranking procedure

The samples were ranked in descending order of BQI. The sample with the largest index was assigned the first rank. The BQI is a relative and reference-dependent indicator; it is not automatically equivalent to a statutory brick class.

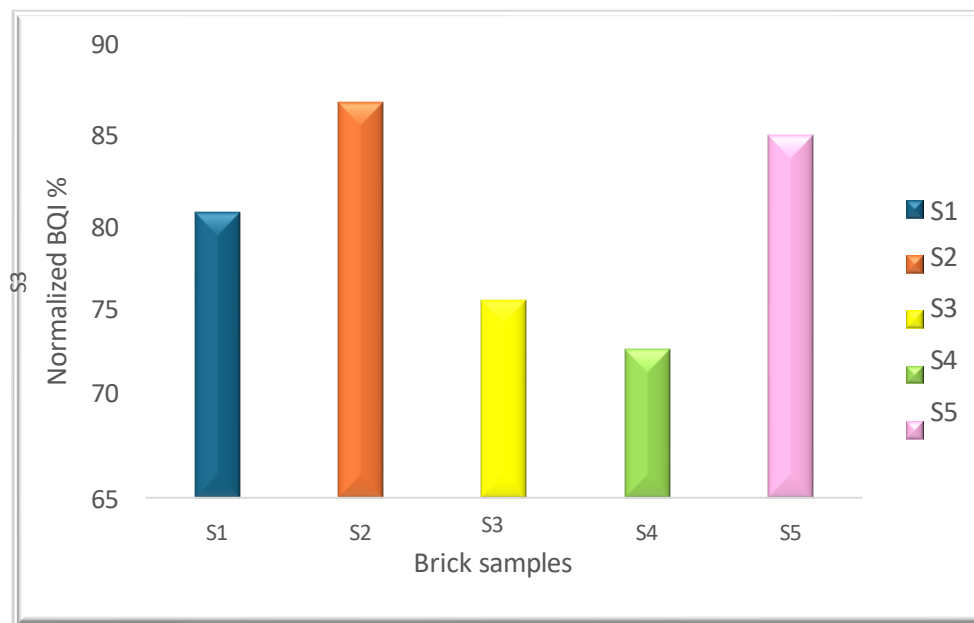


Fig 3. Normalized BQI% of brick specimen

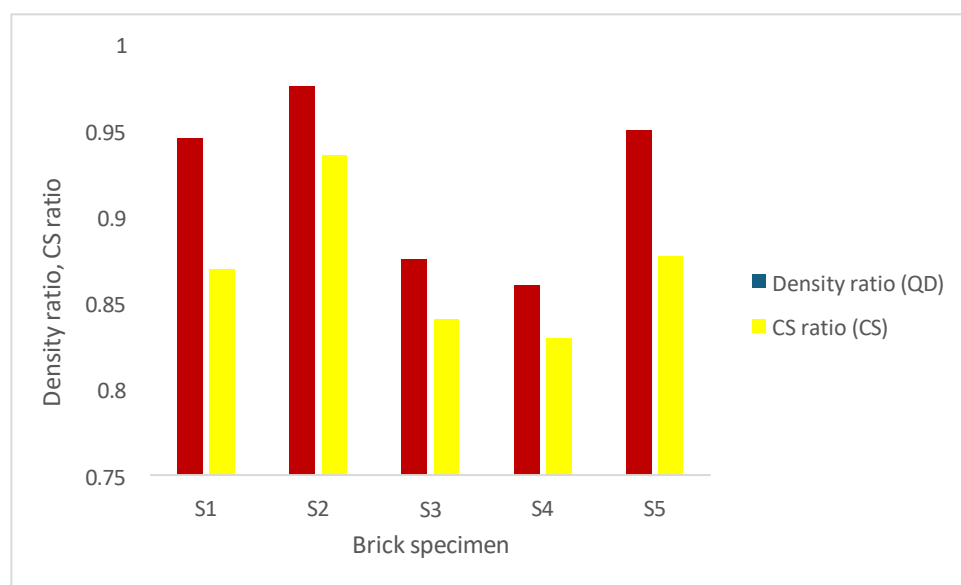


Fig 4. Density and Compressive strength ratio of brick specimen

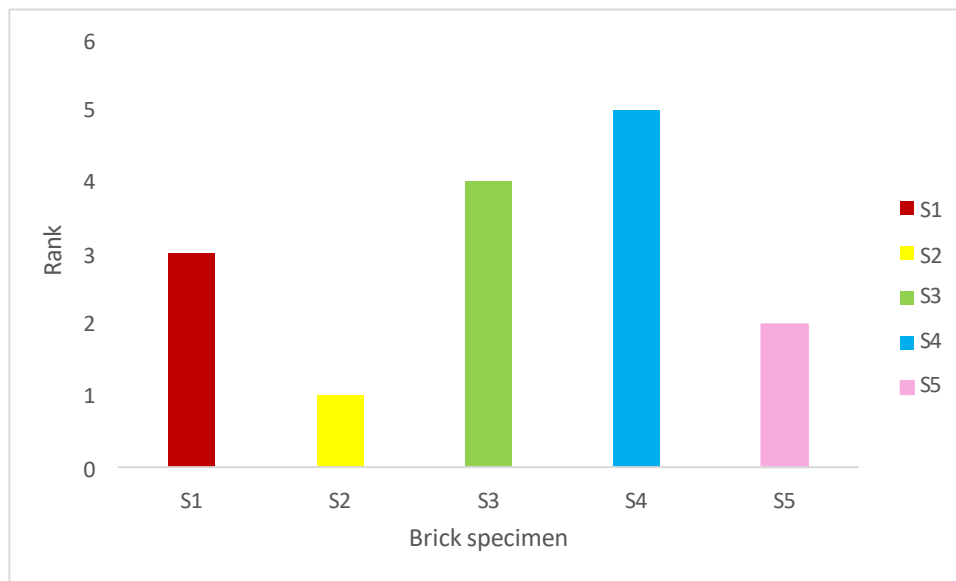


Fig 5. Rank of brick specimen

The observed relationship between porosity, water absorption, density and mechanical strength is consistent with clay brick studies.

Increased pore formation can increase water absorption while reducing density and mechanical performance.

The obtained compressive strength of the present samples falls with the class designations covered by (IS7077).

Classification of brick samples for interpretation the following comparative scale was used [5,8].

Table 5: Classification of Clay Brick Quality Based on Normalized BQI (%)

Normalized BQI%	Classification
80 – 100	Excellent
60 – 79	Very good
40 – 59	Good
20 -39	Fair
< 20	Poor

Table 6: BQI, Normalized BQI and Quality Classification of Clay Brick Samples

Samples	BQI	Normalized BQI%	Classification
S1	0.807	80.69	Excellent
S2	0.868	86.76	Excellent
S3	0.759	75.87	Very good
S4	0.732	73.16	Very good
S5	0.849	84.93	Excellent

Table 7: Pearson correlation classification between density and selected physical and mechanical properties of clay bricks.

Sl.No.	Relationship	Pearson correlation (r)	Interpretation
1	Density Vs Compressive strength	+ 0.908	Strong positive correlation
2	Density Vs Water absorption	- 0.877	Strong negative correlation
3	Density Vs Porosity	-0.956	Very strong negative correlation

As density increases, compressive strength generally increases (a strong positive correlation) This suggests that denser and more compact brick structure tend to exhibit higher mechanical strength. Higher density, bricks generally show lower water absorption, (a strong negative correlation) suggest lower excessive pore and a more compact.

As density increases, porosity decreases (a very strong negative correlation) this is physically reasonable because greater compactness generally corresponds to a smaller volume of internal values.

4.2. Interpretation of the integrated index

The principal benefit of the BQI is that it condenses different properties, units, and preferred directions into a single score. A laboratory manager, producer, or purchaser can therefore compare several brick products more quickly than by examining four separate result columns. The index also makes the assessment logic explicit. Beneficial properties increase the score when their measured values approach the reference, while non-beneficial properties increase the score

when they are reduced toward the reference. This direction-sensitive normalization is more meaningful than directly averaging raw values expressed in incompatible units [1,13,14,15].

The BQI must nevertheless be read together with the original data. Two bricks can obtain similar index values through different property combinations. One may have excellent strength and moderate absorption, while another may have moderate strength and excellent absorption. Their suitability may differ depending on whether the intended application prioritizes structural capacity, exposure resistance, thermal performance, or low suction.

5. Conclusion

A ratio-to-standard Brick Quality Index was used to combine density, compressive strength, porosity, and water absorption into a single measure of clay-brick quality. The following conclusions were reached:

1. The method successfully converted properties with different units and preferred directions into comparable dimensionless ratios.
2. The ratio to standard BQI method was successfully used to assess the overall quality of fire clay brick samples
3. S2 shows the highest BQI of 86.76%
4. S5 and S1 shows BQI values of 84.93% and 80.69% respectively.
5. S3 and S4 showed comparatively lower BQI values.
6. The BQI difference between S2 and S4 was 13.6%, equivalent to approximately 18.6% of the S4 score, demonstrating useful discrimination among the products.
7. The quality ranking was $S2 > S5 > S1 > S3 > S4$.

A high BQI represents a favourable balance of the assessed properties but does not prove superiority in every individual test. The ratio-to-standard method is simple, transparent, and suitable for screening, production monitoring, and comparative material selection. The BQI should not replace mandatory compliance testing. Every parameter should first satisfy the relevant product specification before the index is used for ranking. The BQI method provides a simple and effective approach for overall brick quality assessment.

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