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# Effect of Age and Environment on Strength of Old Baked Clay Bricks of Indus Valley Civilization

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## ABSTRACT

This paper presents results of experimental investigations conducted on old baked clay bricks of Indus Valley civilization of tenth century. The object of this study is to evaluate the effect of age and environmental conditions on the strength of the baked clay bricks which are about 1000 years old. The brick samples were collected from six different archeological sites at the banks of old route of River Indus in district Sanghar, Sindh, Pakistan. These specimens were tested for apparent density, compressive strength, tensile strength, modulus of rupture and the weathering effects on them during the course of time. ASTM (American Society for Testing and Materials) standard for baked clay bricks, based on compressive strength, suggests that the bricks of four sites can withstand severe weathering while the bricks of two sites are resistant to moderate weathering. These results were compared to the values of the corresponding data of bricks, of same period, obtained from the historical monuments of the world as reported in the literature. The comparison showed that the values of physical properties of old baked clay bricks of Indus valley civilization of tenth century are in agreement with that of old baked clay bricks of contemporary era. The results of this study could also be helpful for preservation of old archeological sites of Indus valley civilization.

**Key Words:** Baked Clay, Compressive Strength, Old Bricks, Indus Valley Civilization, Apparent Density, Effect of Age.

## 1. INTRODUCTION

Brick has remained a fundamental material of building construction in the history of civilizations. The historical buildings and monuments constructed throughout the evolution of civilizations are mainly made of brick and stone masonry. Brick masonry is one of the ancient and most reliable methods of construction used by people throughout the ages. It is still commonly used in modern buildings [1]. The study of old baked clay bricks reveals that physical,

chemical and mechanical properties of these bricks show scattered values. The values of apparent density, and compressive strength of old baked clay bricks vary from 1500-1800 kg/m<sup>3</sup> and 1.5-50 MPa, respectively [1].

Brick is an artificial metamorphic rock [2] and is prone to weathering and disintegration due to atmospheric and environmental effects with time, and results in less compressive strength if not baked and compacted properly

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[3-9]. To preserve masonry historical buildings and monuments [10-17], much care is needed nowadays because of high content of ChloroFlouro Carbon in atmosphere which can deteriorate baked clay bricks in short time [18]. The moisture content and the salts present in the bricks and the surroundings where these bricks are buried is also a governing factor for weathering of these bricks [19-20].

In Pakistan, there are a number of masonry buildings and archeological sites which represent its cultural heritage and national identity. Therefore, it is necessary to save these monuments of brick masonry to preserve them in their original shape and condition against such environmental and weathering effects. Thus, it is important to study the effect of age and environment on the bricks through its service life. In order to get insight of the environmental and weathering effect on old baked clay bricks, such bricks were collected from six ruined sites of Indus valley in District Sanghar, Sindh, Pakistan, on the banks of river Indus. These sites were destroyed by an earthquake that occurred in 975 AD [21]. The object of this study is to determine physical properties of old baked clay bricks such as apparent density, compressive strength, tensile strength, modulus of rupture and effect of weathering on these bricks with time.

## **2. MATERIALS AND METHOD**

To study structural behaviour and resistance to weathering of historical baked clay bricks of Indus valley, the baked clay bricks were collected from six different ruined sites of district Sanghar, Sindh, Pakistan (Figs. 1-3). These sites are on the banks of old route of river Indus. Of these four were human settlements while other two were grave yards situated near these sites. These sites lie within a circle of 2 km radius. The description and Global Position of these sites is given in Table 1.

### **2.1 Test Specimens**

To determine compressive strength, tensile strength, modulus of rupture, apparent density and water absorption ratio, three brick specimens were collected from each site and tests were conducted to determine above structural properties. Each of the following

specimen was cut from each brick: (i) 50mm Cubes, (ii) briquettes having neck section equal to 25x25mm (iii) small beam section 50x50x225mm.



*FIG. 1. BAKED CLAY BRICK COLLECTED FROM JARKUS*



*FIG. 2. BAKED CLAY BRICK COLLECTED FROM DAIM PIR*



*FIG. 3. BAKED CLAY BRICK COLLECTED FROM BARA HAZARI*

### 2.1.1 Tensile Strength

Tensile strength of old baked clay bricks was determined by cutting one briquette from each baked clay brick. The size of briquettes was 76x44mm and having neck section equal to 25mm (Fig. 4). These briquettes were tested in briquettes testing machine (Fig. 5).

### 2.1.2 Compressive Strength

Cubes of 50mm size were cut from each baked clay brick and tested for compression in UTM (Universal Testing Machine) (Figs. 6-7).

### 2.1.3 Modulus of Rupture and Apparent Density

Small beam specimens having size of 50x50x225mm were sawed from each brick to determine modulus of rupture and apparent density. These plain beam specimens were tested in flexure by applying point load at mid-span of the beam.

### 2.1.4 Water Absorption Ratio

The brick specimens were oven dried at 110°C for 24 hours and were immersed in water at room temperature. After 24 hours, the beam specimens were taken out of water and

after wiping off the surface of bricks with a cloth, weight was taken within five minutes.

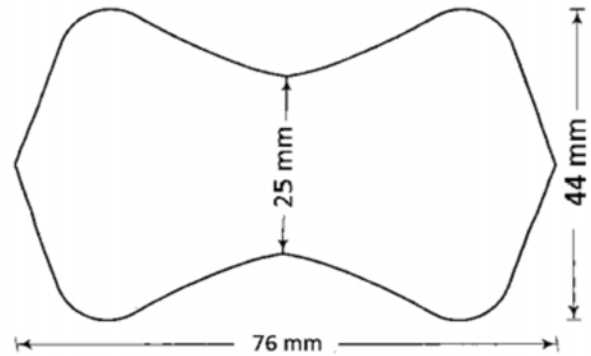


FIG. 4. PLAN OF BRIQUETTE FOR TENSION TEST OF OLD BAKED CLAY BRICKS

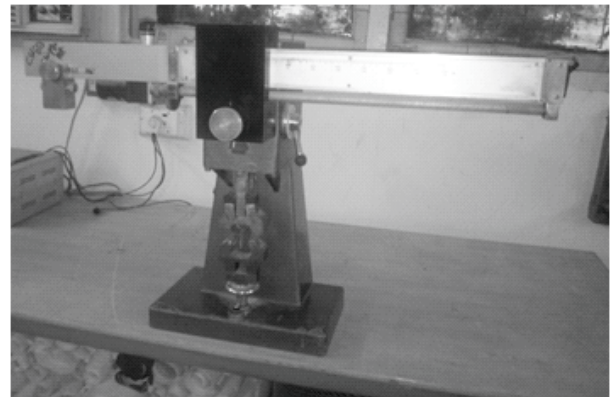


FIG. 5. BRIQUETTE TESTING MACHINE

TABLE 1. DESCRIPTION OF SITES AND THEIR GLOBAL POSITION

No.	Local Name of Site	Type of Site	Area of Site (acres)	River Bank	Global Position (deg)
1.	Lanjari	Town	16	Right	25 51 37 N 68 29 45 S
2.	Jarkus	Town	11	Right	25 51 03 N 68 30 16 S
3.	Daim Pir	Grave yard	5	Right	25 50 20 N 68 30 36 S
4.	Bara Hazari	Big town	42	Left	25 50 35 N 68 31 46 N
5.	Jadam Pir	Grave yard	3	Left	25 50 05 N 68 30 51 S
6.	Ghohat	Town	36	Right	25 49 59 N 68 30 22 S

Note: deg represents degrees, N shows latitude and S represents longitude.

### 3. RESULTS AND DISCUSSION

These bricks were investigated for apparent density, compressive strength, tensile strength, and modulus of rupture, water absorption and the effect of weathering. The results are given in Table 2.

The results of compressive strength of old baked clay bricks of Indus valley civilization of tenth century were



FIG. 6. TESTING OF CUBE CUT FROM BAKED CLAY BRICK IN UNIVERSAL TESTING MACHINE

compared with that of bricks of contemporary era. The comparison shows that the values of compressive strength of four sites are more than the reported value of compressive strength, and values of two sites (i.e. Lanjari and Jarkus) are less than that of reported [22].

The values of apparent density of baked clay bricks of Indus valley civilization when compared to the reported values of the same era, show that the values of three sites (Lanjari, Jarkus and Bara Hazari) of Indus valley are in agreement with the reported values while the values of other three sites (Daim Pir, Jadam Pir and Ghoghat) are more than the reported ones [23-24].

The values of tensile strength of old baked clay bricks of Indus valley civilization of tenth century were compared with the corresponding values of modern baked clay bricks



FIG. 7. CUBE CUT FROM BAKED CLAY BRICK OF BARA HAZARI AND TESTED IN UNIVERSAL TESTING MACHINE

TABLE 2. PHYSICAL PROPERTIES OF OLD BAKED CLAY BRICKS

Site	Apparent Density (kg/m <sup>3</sup> )	Compressive Strength (N/mm <sup>2</sup> )	Tensile Strength (N/mm <sup>2</sup> )	Modulus of Rupture (N/mm <sup>2</sup> )	Absorbed Water (%)	Effect of Weathering
Lanjari	1455-1680	9	0.8	4.3	17	Moderately Affected
Jarkus	1500-1660	12	1.6	3.8	22	Very Slightly Affected
Daim Pir	1700-1820	14	1.6	4.5	19	Not Affected
Bara Hazari	1400-1830	19	2.2	5.9	20	
Jadam Pir	1750-1800	16	1.8	4.4	16	
Ghoghat	1640-1750	16	1.6	4.2	20	

[25]. The comparison shows that the tensile strength values of the old baked clay bricks taken from two sites (Bara Hazari and Jadam Pir) are higher than the corresponding values of modern bricks. Whereas, the tensile strength values of the four sites (Lanjari, Jarkus, Daim Pir and Ghoghat) are less than the corresponding values of the modern bricks.

The values of modulus of rupture of the baked clay bricks of Indus valley civilization of tenth century are more than the corresponding values of baked clay bricks of present age, as reported by Ansari [25] and they are found to be weather resistant [26].

#### **4. CONCLUSION**

Old baked clay bricks of Indus valley civilization of tenth century were tested for determination of their physical properties. These properties were compared to the corresponding values of the baked clay bricks of same era. The results of compressive strength, modulus of rupture and apparent density are in agreement with the corresponding values of old bricks of same era. This study shows that bricks collected from the banks of river Indus in district Sanghar are found to be weather resistant according to ASTM standards.

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