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QUALITATIVE ANALYSIS OF BAKED CLAY BRICKS AVAILABLE IN LARKANA REGION, PAKISTAN

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Abstract

Apparently in the beginning non-fired bricks were used for the shelter over the head. As the world progressed fired clay bricks found acceptability for construction. In Pakistan fired clay bricks are used in-plenty for erecting the houses. However, the technology is quite old and the practice is being repeated for several years. More commonly the bricks are porous; water absorbability is quite high and consequently the compressive strength and other properties are much lower than they should have been. In order to get an idea about quality of bricks, a comparative study of the properties of fired clay bricks of Hoofmann kiln versus Sada Bhatta (manually operated kiln) is done. A systematic study was carried out to determine various properties such as water absorption, efflorescence, crushing strength, specific weight, specific gravity of common bricks and specific weight of baked clay. This was particularly deemed imperative because of the fact that the process of burning is not uniform. This is done in two forms; i.e. by burning in the kiln with wooden logs and wooden fuels and in the Sada Bhattas where the fuel is bagasse and rice husks. Obviously it was expected that the compressive strength of bricks in the kiln was somewhat higher than Sada Bhattas. The systematic study consists of compressive strength, modulus of elasticity and Poisson's ratio as major points of investigations.

Streszczenie

Najprawdopodobniej początkowo niewypalonych cegieł używano do budowy prostych schronów. Wraz z postępem cywilizacyjnym w budownictwie zastosowanie znalazły wypalane cegły gliniane. W Pakistanie gliniane cegły wypalane są masowo i wykorzystywane do wznoszenia domów. Technologia ta jest bardzo stara, a praktyka powtarzana przez wiele lat. Powszechnie cegły są porowate; ich nasiąkliwość jest dość wysoka, a tym samym wytrzymałość na ściskanie i inne właściwości są znacznie niższe niż powinny być. Aby ocenić jakość cegieł, przeprowadzono badania porównawcze właściwości cegieł wypalanych w glinianych piecach Hoofmana oraz w Sada Bhatta (piecach obsługiwanych ręcznie). Badania przeprowadzono w celu określenia różnorodnych właściwości, takich jak absorpcja wody, wykwity, wytrzymałość na ściskanie, ciężar względny, ciężar właściwy, ciężar właściwy zwykłych cegieł i ciężarze względny wypalanej gliny. Takie badania uznano za konieczne zwłaszcza ze względu na fakt, że proces spalania nie jest jednorodny. Odbywa się on w dwóch formach, tj. przez spalanie w piecu z drewnianych bali i paliw oraz w drewnianych Sada Bhatta, gdzie paliwem są wytłoki i plewy ryżu. Zgodnie z oczekiwaniami, wytrzymałości na ściskanie cegieł wypalanych w piecach jest nieco wyższa niż tych wykonywanych w Sada Bhatta. Badania właściwości mechanicznych obejmowały wytrzymałość na ściskanie, moduł sprężystości i współczynnik Poissona jako głównych kryteriów oceny.

Keywords: **Clay bricks; Hoofmann Kiln; Bagasse; Rice husk; Porosity; Efflorescence; Compressive strength.**

1. INTRODUCTION

Clay bricks are used in a wide range of buildings from housing to factories, and in the construction of tunnels, waterways, bridges etc. Their properties vary according to the purpose for which they are intended, but clays have provided the basic material of construction for centuries. Brick is the oldest manufactured building material, and much of its history is lost in antiquity. The oldest burnt or fired bricks have been found on the sites of the ancient cities of Babylonia, some of which are estimated to be about 6000 years old. Brick is, after all, virtually indestructible. The industry developed on traditional lines, using hand-making processes for the most part. The first patent for a clay-working machine was granted in the year 1619. Mechanization, however, did not begin to take the place of manual methods until the middle of the nineteenth century. The moulded products were fired in relatively inefficient intermittent or static kilns until about 1858, when Hoffmann introduced a continuous kiln, which enabled all processes connected with the firing to be carried out concurrently and continuously [1].

In Pakistan most of the common houses of middle and lower middle class are constructed with brick masonry for which common bricks from kiln are used. Not only cement mortar is employed but in relatively cheaper houses mud-mortar is also extensively used in the interior plains of the country where the only materials of construction locally available are clay and pit-sand. In the vicinity of Larkana region in Pakistan, there are two types of kilns i.e. Hoffmann kiln and manually operated kiln that is locally known as Sada Bhatta. These bricks are produced on mass scale by different manufacturers in Larkana District. Larkana is one of the fast developing cities in the interior Sindh, Pakistan because of the available facilities for getting higher professional education in the field of Engineering, Medical science, business and job opportunities in the city and developing industrial zone near city. At present, the population of this district is more than 2.0 million [4]. Like the other parts of the country, burnt clay is one of the main materials in the masonry construction. Manufacturing of the bricks is being made commonly by Hoffman kiln as well as by Sada Bhattas. In the vicinity of Larkana several Sada Bhattas are surrounding the city. Samples of water and clay were taken from the common area of each Bhatta, whereas bricks were taken at random from each kiln and bhattas. Details of survey report about the Hoffman kiln and Sada Bhattas are presented in [5]. The brief data of bricks produced from both kinds of kilns are presented in Table. 1. No data regarding their fundamental properties are reported in the literature.

Table 1.
Brief history of Hoofman Kiln and locally available Sada Battha

	S.#	Kiln Name	Kiln Capacity	Clay Source	Water Source	Type of Fuel used	Manufacturing Process
HOOFMANN KILN	1	Mola Bux Brick Work	350000	Near Kiln	Tube well	Coal & Timber	Wet process & manual
	2	Dadan Faqeer Brick Company	400000	Near Kiln	Tube well	Coal & Timber	Wet process & manual
	3	Sun Shine Bricks company	450000	Near Kiln	Tube well	Coal & Timber	Wet process & manual
	4	Lal Khan Batha works	500000	Far from Kiln	Tube well	Coal & Timber	Wet process & manual
	5	Qurban & Co Bricks company	500000	Far from Kiln	Tube well	Coal & Timber	Wet process & manual
	6	Waheed batha works	550000	Far from Kiln	Tube well	Coal & Timber	Wet process & manual
	7	Kashan Manufactures	400000	Near Kiln	Tube well	Coal & Timber	Wet process & manual
	8	Zubair Khan Brick works	300000	Near Kiln	Tube well	Coal & Timber	Wet process & manual
	9	Muhbat Batha works	350000	Near Kiln	Tube well	Coal & Timber	Wet process & manual
	10	Wazeer Bricks company	450000	Near Kiln	Tube well	Coal & Timber	Wet process & manual
SADA BATTHA	1	Ali Hasan Wako Batha	200000	Near Battha	Hand Pump	Rice Bagasse, Timber	Manual
	2	Ghulam Hussain Bricks	300000	Near Battha	Hand Pump	Rice Bagasse, Timber	Manual
	3	Dadan Khan Batha	350000	Near Battha	Tube well	Rice Bagasse, Timber	Manual
	4	Abdul Qudoos Soomro & Co	350000	Near Battha	Tube well	Rice Bagasse, Timber	Manual
	5	Mola Wako Brick work	250000	Near Battha	Hand Pump	Rice Bagasse, Timber	Manual
	6	Ali Nawaz Chandio Batha	450000	Near Battha	Tube well	Rice Bagasse, Timber	Manual
	7	Dedar Ali & Bros Brick works	400000	Near Battha	Tube well	Rice Bagasse, Timber	Manual
	8	Irshad Chandio Batha	450000	Near Battha	Tube well	Rice Bagasse, Timber	Manual
	9	Abdul Hakeem Chandio Batha	450000	Near Battha	Tube well	Rice Bagasse, Timber	Manual
	10	Qamar Zaman Brick works	350000	Near Battha	Hand Pump	Rice Bagasse, Timber	Manual

Therefore specific weight, specific gravity, crushing strength, modulus of elasticity and Poisson's ratio of baked clay bricks made by manually operated Sada Bhattas has been determined experimentally. The rate analysis has also been performed in order to determine their suitability in economic terms as compared with Hoffman Kiln bricks. The results are compared with common bricks to get a clue in respect of their properties. It is important to note that burning temperature plays a very important role as to the properties of bricks. At very high temperature higher or lower than recommended values, bricks might attain the properties where compressive strength is much higher than the standard values. In this regard preliminary experimental studies were carried out, the details of which have already been given elsewhere [2, 3]. The results of present investigations are depicted in the following section.

2. MATERIALS, MANUFACTURING PROCESS & TESTING METHODOLOGY

Clay is the most important raw-material required for manufacturing bricks. Clay is a natural, earthy, fine-grained material which acquires different degrees of distinct plasticity when mixed with a limited amount of water, and becomes hard and stone-like when heated to a suitable temperature [6]. Clay is a very common substance, abundant in nature. Bricks are burnt at temperatures between 1000°C and 1200°C, depending on the clay. Hoffman kilns consist of a rectangular space with a barrel-vaulted roof and a slotted or perforated floor open to flues below. Bricks (40,000 to 100,000 at a time) are stacked in the kiln. Fires are lit in fireboxes along the sides and the hot gases fire up to the curved roof, down through the bricks and from there to the chimney stack. Fires are fuelled by wooden logs, wooden fuels or coal. When the desired temperature has been reached, the temperature is maintained for a specific period and the fires are then allowed to extinguish. The kiln cools down, the fired bricks are removed and another batch of bricks is placed in the kiln for burning.

Sada Bhatta is a manually operated kiln, where some fuel is placed into the body of each brick. The bricks are packed into a pyramid shaped formation. The clamp has a layer of rice husk & bagasse, equivalent to two courses of bricks, packed at the bottom. In this layer fire is set, that ignites the fuel in the base layer of bricks and progressively, each brick packed by rice husk catches fire. The temperature reaches 1000°C at the center of the clamp. The fire in Sada Bhatta continues up to three weeks. As the bricks get burnt after extinguishing of fire, the bricks take much time before they get cooled enough to be sorted.

Figure 1.
Views of two different kilns locally available in Larkana: a) Sada Battha, b) Hoffmann kiln

3. OVERALL DIMENSIONS

Bricks used in experimental study were purchased from 20 different Hoofman kilns and Sada Batthas surrounding Larkana city, Pakistan. Names of manufacturers are listed in Table 1. Bricks from different kilns were taken and tested for dimensions. All the tests were done under the following Indian standards IS 3495: Parts (1-4) [7]. Twenty four bricks of each kiln were taken that were put together and were tested for length, breadth and depth respectively. The most commonly used and manufactured brick size is 222 mm long x 106 mm wide x 73 mm high with a mass between 3 and 3.5 kg, depending on the materials used.

4. ANALYSIS OF SOIL & WATER SAMPLES

4.1. Soil analysis

Table 2 shows the soil analysis report for all the twenty samples extracted from various locations of Hoffman kiln & Sada Bhatta. This table shows that pH value for all the samples is more than 7, implying that the soil is alkaline. Generally the soil is silty clay/loam. This simply means that there are no granular particles but only silt, clay and no silica (pit-sand). There is considerable variation of electric conductivity (EC) which is as low as 0.47 ms/cm and as high as 3.1 ms/cm. Actually EC is an indirect measurement of salinity. The higher values of EC correspond to highly saline soils. While lower values imply the absence of salts. Thus out of twenty samples six are highly saline, ten are medium and the rest are non-saline. This is the point which makes it very clear that salinity affects the overall strength of the baked clay bricks. Variation of exchangeable sodium is also considerably high; the minimum value being only 0.3 (meq/100grams) and the highest value being 3.2 (meq/100grams). This is also sufficiently wide range to show its effects, if any, on the crushing strength of baked clay specimens. Here eleven out of twenty can be regarded as normal; five could be termed as slightly high while only four as high. The presence of gypsum is quite low and in sixteen out of twenty samples, it is zero; maximum value being 2.1. From the test results it is discerned that alkaline soil show better cohesion than those which are acidic [8, 9].

Table 2.
Soil Analysis Report

Type of Kiln	Sample No.	Soil texture	Salinity and sodicity status						
		By feel Method	pH (1:2.5)		EC (1:2.5) ms/cm		Ex.Na meq/100 gm		Gypsum
			Value	Status	Value	Status	Value	Status	Meq/100gm
HOFFMANN KILN	SS-1	Silty Clay Loam	7.7	Sub Alkaline	2.6	Highly Saline	1.2	Slightly High	0
	SS-2	Silty Clay	7.8	Sub Alkaline	1.09	Medium Saline	2.1	High	1.1
	SS-3	Silty Clay	8	Medium Alkaline	0.6	Non saline	0.3	Normal	0
	SS-4	Silty Clay Loam	8	Medium Alkaline	1.41	Medium Saline	1.2	Slightly High	0
	SS-5	Silty Clay Loam	8.1	Medium Alkaline	2.53	Highly Saline	2.6	High	1.6
	SS-6	Silty Clay Loam	8.1	Medium Alkaline	1.12	Medium Saline	0.3	Normal	0
	SS-7	Silty Clay Loam	7.6	Sub Alkaline	1.03	Medium Saline	0.7	Normal	0
	SS-8	Silty Clay Loam	7.6	Sub Alkaline	1.73	Medium Saline	1	Normal	0
	SS-9	Silty Clay	7.6	Sub Alkaline	1.46	Medium Saline	0.6	Normal	0
SADA BATTHA	SS-10	Silty Clay	7.7	Sub Alkaline	0.47	Non saline	0.4	Normal	0
	SS-11	Silty Clay Loam	8.2	Medium Alkaline	1.2	Medium Saline	0.3	Normal	0
	SS-12	Silty Clay	8.4	Medium Alkaline	2.33	Highly Saline	3.1	High	2.1
	SS-13	Silty Clay	8.3	Medium Alkaline	3.1	Highly Saline	3.2	High	2.1
	SS-14	Silty Clay Loam	7.9	Sub Alkaline	2.13	Highly Saline	0.6	Normal	0
	SS-15	Silty Clay Loam	7.9	Sub Alkaline	2.75	Highly Saline	1.9	Slightly High	0
	SS-16	Silty Clay Loam	8	Medium Alkaline	1.19	Medium Saline	0.7	Normal	0
	SS-17	Silty Clay Loam	8.5	Medium Alkaline	0.6	Non saline	0.8	Normal	0
	SS-18	Silty Clay Loam	8.2	Medium Alkaline	1.12	Medium Saline	1.8	Slightly High	0
	SS-19	Silty Clay	8.2	Medium Alkaline	0.84	Non saline	0.8	Normal	0
	SS-20	Silty Clay	7.9	Sub Alkaline	1.12	Medium Saline	1.4	Slightly High	0

4.2. Water analysis

Table 3 shows the test reports of water only in terms of pH value, EC (ms/cm), TSS (PM) for all the twenty samples. It is apparent from this table that pH values for all the samples are more than 7. EC value varies quite a lot i.e. between 0.48 to 7.10 ms/cm clearly indicating that salinity varies widely from location to location. This clearly shows that if presence of salts affected adversely or favorably the crushing strength of baked clay bricks, it would be readily visible. Total PPM of TSS also displays a variation from the value as low as 307.2 and as high as 4544 [8,9]

Table 3.
Water Analysis Report of Hoffmann Kiln & Sada Bhatta

Type of Kiln	S.No.	pH	E.C. ms/cm	TSS Ppm	Remarks
HOFFMANN KILN	WS-1	8	0.48	307.2	Fit
	WS-2	7.3	6.5	4160	Unfit
	WS-3	7.4	5.96	3814.4	Unfit
	WS-4	7.6	2.67	1708.8	Unfit
	WS-5	7.8	0.82	524.8	Fit
	WS-6	7.7	1.47	940.8	Marginally fit
	WS-7	7.7	1.2	768	Fit
	WS-8	8.2	1.03	659.2	Fit
	WS-9	8.2	1.43	915.2	Marginally fit
	WS-10	7.8	1.95	1248	Unfit
SADA BHATTA	WS-11	7.8	7.1	4544	Unfit
	WS-12	8	2.46	1574.4	Unfit
	WS-13	8	5.46	3494.9	Unfit
	WS-14	8	6.27	4012.8	Unfit
	WS-15	7.8	3.98	2547.2	Unfit
	WS-16	7.9	6.1	3990.4	Unfit
	WS-17	7.8	4.05	2592	Unfit
	WS-18	8.2	1.03	659.2	Fit
	WS-19	7.9	4.05	2592	Unfit
	WS-20	8.2	1.43	915.2	Marginally fit

5. PHYSICAL PROPERTIES

5.1. Physical properties of soil

For the purpose of structural characterization and evaluation of cohesive soils as construction materials, it is necessary to determine their consistency properties. Consistency, in general, is the property of material which is manifested by its resistance to flow. Physical properties of soil like specific weight, specific gravity, moisture content, liquid limit, plastic limit, plasticity index, consistency index, wet & dry density of all the samples determined experimentally in the laboratory are presented in Table 4.

5.1.1. Laboratory procedures

5.1.1.1. Specific weight

The specific weight (also known as the unit weight) is the weight per unit volume of a material. It is calculated by taking the weight of brick and dividing by its volume. Following expression was used to determine the specific weight of the brick.

$$\text{Specific weight} = \frac{\text{Weight of brick}}{\text{Volumetric area}}$$

5.1.1.2. Specific gravity

Specific gravity G is defined as the ratio of the weight of a given volume of soil solids at a given temperature to the weight of an equal volume of distilled water at that temperature.

$$G = \frac{\gamma s}{\gamma w}$$

The specific gravity of soil solids was determined by 50 ml density bottle which is the standard method used in the laboratories. In this method the weight W_1 of the dry empty bottle was first taken. An oven dried soil sample was cooled and was put in the bottle and the weight W_2 was taken. The bottle was then filled with distilled water gradually and the entrapped air was removed by shaking the bottle. The weight W_3 of the bottle, soil and water (full up to the top) was taken. Finally the bottle was emptied completely and thoroughly washed and clean water was filled to the top and weight W_4 was taken. Based on these four observations the specific gravity was calculated which is given in Table 4.

5.1.1.3. Moisture content

Moisture content of the soil was determined by oven dried method, in which the moist soil sample was put in a clean and dry container that was placed in a thermostatically controlled oven at temperature of 105°C to 110°C for 24 hours. After drying the container was removed from the oven and was allowed to dry and then the dry weight of soil was found. The moisture content was calculated based on following expression:

$$\text{Moisture content} = \frac{W_1 - W_2}{W_2 - W_3} \times 100$$

where:

W_1 = weight of (Container + wet soil) in grams
W_2 = Weight of (Container + dry soil) in grams
W_3 = Weight of container in grams

5.1.1.4. Liquid limit

To determine the liquid limit, 150 gram of soil passing # 40 sieve was taken. 20% of water was added in the soil and was mixed thoroughly. Soil sample was put in Casagrande apparatus the deepest part of which is about 8-10 mm. Groove of 2 mm at the base was cut and the device was run and the blows were counted till the groove in the soil was close through a distance of 0.5 in. The test was run six times where the number of blows was 10÷20, 20÷40, 40÷60, 60÷80 and 80÷100 respectively. The number of blows vs moisture content was plotted and the liquid limit was determined.

5.1.1.5. Plastic limit

To determine the plastic limit, the soil specimen, passing 425 micron sieve was thoroughly mixed with distilled water until the soil mass became plastic enough to be easily moulded with fingers. A ball was formed with about 8 g of this plastic soil and rolled between the fingers and a glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. When the diameter of 3 mm was reached, the soil was remoulded again into a ball. This process of rolling and remoulding was repeated until the thread started just to crumble at a diameter of 3 mm. The crumbled threads were kept for water content determination. The test was repeated thrice more with fresh samples. The plastic limit was then taken as the average of four water contents.

5.1.1.6. Plasticity index

The range of consistency within which a soil exhibits plastic properties is called plastic range and is indicated by plasticity index. It is calculated by performing the numerical difference between the liquid limit and the plastic limit of a soil as shown in Table 4.

$$P_I = L_L - P_L$$

5.1.1.7. Consistency index

The consistency index is the ratio of the liquid limit minus the natural water content to the plasticity index of the soil. It is calculated by using following expression,

$$C_I = \frac{L_L - W}{P_I}$$

where:

C_I = Consistency index
L_L = Liquid limit
W = Natural water content
P_I = Plasticity index

5.1.1.8. Wet and dry density of soil

A 5 kg sample of air-dried soil passing through the 19 mm IS Sieve was taken. The sample was thoroughly mixed with a suitable amount of water ranging between 12 to 16% below the plastic limit. The soil sample was stored in a sealed container for a period of 16 hrs. The mould of 1000cc capacity with base plate attached was weighed to the nearest 1g (W_1). The mould was then placed on a solid base i.e. concrete floor and the moist soil was compacted into the mould, with the extension attached, in five layers of approximately equal mass, each layer was given 25 blows from the 4.9 kg rammer dropped from a height of 450 mm above the soil. The blows were distributed uniformly over the surface of each layer. The amount of soil used was sufficient to fill the mould, leaving not more than about 6 mm to be struck off when the extension is removed. The extension was removed and the compacted soil was leveled off carefully to the top of the mould by means of the straight edge. The mould and soil was then weighed to the nearest gram (W_2). The compacted soil specimen was removed from the mould and placed onto the mixing tray. The water content (w) of a representative sample of the specimen was determined.

The remaining soil specimen was broken up, rubbed through 19 mm IS Sieve and then mixed with the remaining original sample. Suitable increments of water was added successively and mixed into the sample. The total number of determinations made was five and the moisture contents were such that the optimum moisture content at which the maximum dry density occurred.

Table 4.
Physical properties of soil samples

S. #	Sample No.	Weight of the Brick (N)	Specific Weight (KN/m^3)	Specific Gravity	Moisture Contents	Liquid Limit	Plastic Limit	Plasticity Index	Consistency Index	Density of wet soil	Density of dry soil
1	SS-1	30.02	14.29	2.56	14.55	45.75	25.83	19.92	1.56	1.54	1.34
2	SS-2	29.82	14.03	2.47	15.93	45.25	23.58	21.67	1.35	1.55	1.34
3	SS-3	30.02	13.57	2.52	15.47	43.25	23.60	19.65	1.41	1.55	1.34
4	SS-4	28.05	13.17	2.55	17.40	43.50	23.21	20.29	1.28	1.55	1.32
5	SS-5	29.53	13.18	2.51	16.34	44.75	23.93	20.82	1.36	1.53	1.31
6	SS-6	31.59	14.9	2.57	13.99	45.25	23.13	22.12	1.41	1.53	1.34
7	SS-7	28.45	12.83	2.54	15.41	45.50	24.01	21.49	1.40	1.53	1.32
8	SS-8	29.43	13.38	2.47	11.41	44.75	24.49	20.26	1.64	1.53	1.37
9	SS-9	28.35	13.05	2.52	13.00	44.75	23.85	20.90	1.51	1.52	1.33
10	SS-10	29.82	13.77	2.54	13.27	45.00	23.90	21.10	1.50	1.54	1.35
11	SS-11	24.82	12.4	2.55	15.84	46.25	24.25	22.00	1.38	1.53	1.32
12	SS-12	23.54	12.16	2.56	14.66	45.35	21.85	23.50	1.30	1.52	1.32
13	SS-13	23.74	12.46	2.54	17.93	46.00	25.95	20.05	1.40	1.52	1.29
14	SS-14	23.15	12.31	2.57	15.38	45.05	25.8	19.25	1.54	1.56	1.35
15	SS-15	23.54	12.82	2.60	17.22	45.25	23.25	22.00	1.27	1.55	1.33
16	SS-16	25.31	14.25	2.59	15.55	46.00	23.65	22.35	1.36	1.52	1.32
17	SS-17	23.15	12.66	2.60	15.07	46.00	25.75	25.75	1.20	1.54	1.33
18	SS-18	23.84	12.52	2.59	12.86	44.65	23.45	21.20	1.49	1.53	1.35
19	SS-19	26.78	13.47	2.55	12.63	44.91	23.25	21.65	1.49	1.52	1.35
20	SS-20	22.85	12.11	2.58	14.21	44.75	23.97	20.78	1.46	1.50	1.31

5.2. Water absorption

Burnt clay masonry units undergo an irreversible moisture expansion, which occurs as a result of the absorption of moisture from the atmosphere after firing. This expansion, which is characteristic of all porous brick products, commences once the unit starts absorbing moisture from the atmosphere. Moisture expansion must be considered when designing and constructing a brick structure. Table 5, shows that water absorption tests of Hoffmann kiln is 20.98%, which is 39.85% greater than the standard values. However, in case of Sada Bhatta it is 25.4%, which is totally unsafe when compared with the standard values.

5.3. Efflorescence

Efflorescence is a phenomenon that soluble salts dissolved in water are carried, deposited and gradually accumulated on brick surfaces to form an unsightly scum. The soluble salts may be originated from the raw material of bricks. But in most cases, efflorescence is caused by salts from the external sources such as ground water, contaminated atmosphere, mortar ingredients and other materials in contacts with the bricks. It can be serious, causing unsightly permanent discoloration or even the failure of plaster, paintwork or face finishes. The properties of efflorescence are presented in Table 5. It is satisfying to note that almost all the ten samples coming from the Hoffmann kilns were safe for the value that have been tested. However, in case of Sada Bhattas bricks all the values are unsafe when compared with the standard values.

6. MECHANICAL PROPERTIES

6.1. Compressive strength

A wide range of bricks is available in this country. Bricks vary in compressive strength due to the differing qualities of raw material and the method of burning. The compressive strength of kiln bricks is within the range of 15.31 N/mm^2 and 7.9 N/mm^2. This is also lower than what it should be. The compressive strength of Sada Bhatta brick is even lower and within the range of 8.08 and 5.45 N/mm^2. The average value is 7.2 N/mm^2. This exhibits that this is totally unfit for multistory buildings. Table 5, compare cubical strength of Hoffmann kiln and Sada Bhatta bricks.

Table 5.
Details for the Water Asorption Test, Efflorescence Test, Crushing Strength, Modulus of Elasticity and Poisson's Ratio

Kiln type	S.#	Kiln Name	Water Absorption %			Efflorescence		Crushing Strength	Modulus of elasticity	Poisson ratio	Remarks
			Standard	Current	% Difference	Standard	Current	N/mm^2	kN/mm^2		
HOFFMANN KILN	1	Mola Bux Brick Work	15	22.01	46.71	Slight	Nil	12.3	21.37	0.19	Safe
	2	Dadan Faqeer Brick Company	15	19.41	29.41	Slight	Nil	11.58	19.7	0.21	Safe
	3	Sun Shine Bricks company	15	22.31	48.71	Slight	Slight	9.61	19.05	0.22	Workable
	4	Lal Khan Batha works	15	22.51	50.05	Slight	Moderate	7.9	17.79	0.27	Unsafe
	5	Qurban & Co Bricks company	15	18.52	23.46	Slight	Nil	12.07	21.1	0.19	Safe
	6	Waheed batha works	15	20.22	34.82	Slight	Nil	14.59	22.37	0.18	Safe
	7	Kashan Manufactures	15	21.72	44.83	Slight	Slight	15.31	22.79	0.16	Safe
	8	Zubair Khan Brick works	15	20.05	33.65	Slight	Nil	13.36	21.92	0.18	Safe
	9	Muhbat Batha works	15	22.38	49.19	Slight	Moderate	8.9	18.2	0.26	Workable
	10	Wazeer Bricks company	15	20.66	37.72	Slight	Slight	9.25	18.05	0.24	Workable
		Average	**15**	**20.98**	**39.85**	**-**	**-**	**11.49**	**20.23**	**0.21**	**Safe**
SADA BHATTA	1	Ali Hasan Wako Batha	15	26.04	73.62	Slight	Moderate	5.9	14.49	0.37	Unsafe
	2	Ghulam Hussain Bricks	15	27.33	82.22	Slight	Moderate	5.73	14.23	0.32	Unsafe
	3	Dadan Khan Batha	15	27.22	81.48	Slight	Moderate	6.08	15.01	0.3	Unsafe
	4	Abdul Qudoos Soomro & Co	15	28.44	89.63	Slight	Moderate	5.45	13.99	0.39	Unsafe
	5	Mola Wako Brick work	15	23.95	59.65	Slight	Slight	8	17.21	0.29	Unsafe
	6	Ali Nawaz Chandio Batha	15	23.8	58.7	Slight	Slight	8.08	17.7	0.29	Unsafe
	7	Dedar Ali & Bros Brick works	15	24.49	63.25	Slight	Moderate	7.02	15.59	0.34	Unsafe
	8	Irshad Chandio Batha	15	25.35	68.97	Slight	Moderate	6.14	15	0.31	Unsafe
	9	Abdul Hakeem Chandio Batha	15	21.69	44.61	Slight	Nil	12.66	14.9	0.23	Safe
	10	Qamar Zaman Brick works	15	25.65	71	Slight	Moderate	6.4	14.93	0.33	Unsafe
		Average	15	25.4	69.31	-	-	7.2	17.58	0.34	Unsafe

6.2. Modulus of elasticity

Fundamental structural properties when tested showed a very clear trend in the modulus of elasticity. The modulus of elasticity is well within the range as specified for normal concrete which is 21 kN/m^2. The average value of Modulus of elasticity is 20.23 kN/m^2, which can be regarded as acceptable. It may be mentioned here that modulus of elasticity of Sada Bhatta bricks is much lower than the value of kiln bricks. The lowest value is only 13.99 kN/m^2 and highest value is 17.7 kN/m^2. The average value is 17.58 kN/m^2 shown in Table 5. Obviously this lower value shows that the load bearing walls shall have wider cross-section than the wall built with kiln bricks.

6.2.1. Calculation of modulus of elasticity

The following procedure is adopted during test, which is in accordance with the recommendations of British Code of practice CP-1881-70.

Before the modulus of elasticity test, three brick cubes were tested to determine the cube crushing strength of the brick i.e. denoted by B_m. Then the value of B_m, which is equal to 1/3rd of the average compressive strength was calculated. Demic pads were stuck with the help of araldite on the opposite sides of the cubical specimens and parallel to its axis in such a way that the gauge points were symmetrical about the middle of the specimens. Demic gauge is used to measure the strain at different loading stages. Initially no load reading of the gauge is noted and then the specimen is placed under compression in the universal load testing machine and load is gradually applied up to (B_m+1). The load is maintained here for one minute approximately and demic gauge readings are measured on the either sides of the specimen, the load is then released to measure the strain values again before the second step of loading. The load is then re-applied at the same rate till an average stress of (B_m+2) is reached. Strains are measured once again and load is hold up till the gauge readings are taken safely. The no load readings again noted after releasing the loads. The load was then applied third time at the same rate and demic gauge readings are taken at approximately ten equal increments of stress up to (B_m+1) N/mm^2. The modulus of elasticity is then calculated from;

Modulus of elasticity: (E) = Stress/ Strain

Average of three values was adopted as the modulus of elasticity.

6.3. Poisson's ratio

Poisons ratio is somewhat higher than the range of 0.15. However, it is slightly more than the standard value. However in case of kiln bricks it is in the range of 0.19 to 0.27. The average value is 0.21. Apparently the poison' ratio of Sada Bhatta is also higher than the value depicted for kiln bricks. The Sada Bhatta bricks are very much susceptible to a quicker deterioration than kiln bricks. Table 5 shows the value is so high that it should almost be rejected. However, in the interior of Sindh where the cost of living is unaffordable even for common man. It could be accepted for single storey building.

7. CONCLUSIONS

- The kiln bricks showed relatively better trend with the values of compressive strength, modulus of elasticity and Poisson's ratio.
- The bricks from kiln are better than Sada Bhatta bricks. However, Bhatta bricks could be used only for single storey buildings.
- Water absorption test of Hoofmann kiln is 20.98%, which is 39.85% greater than the standard values. However, in case of Sada Bhatta it is 25.4%, which is totally unsafe when compared with the standard values.
- It was observed that the bricks were not having the same and uniform dimensions, that was due to the improper moulding and placing them in a kiln to be burnt.
- The efflorescence test revels that kilns of both types has little composition of salts.
- During survey it was observed that the Sada Batthas are run by illiterate people who are completely unaware of maintenance of the brick quality.
- Modulus of elasticity of Sada Bhatta is lower than the Hoofmann kiln. Obviously this lower value shows that the load bearing walls shall have wider cross-section than the wall built with kiln bricks.
- The compressive strength of Sada Bhatta brick is even lower and within the range of 8.08 and 5.45 N/mm^2. The average value is 7.2 N/mm^2. This exhibits that this is totally unfit for multistorey buildings.
- Apparently the Poisson' ratio of Sada Bhatta is also higher than the value depicted for kiln bricks. The Sada Bhatta bricks are very much susceptible to a quicker deterioration than kiln bricks. The value is so high that it should almost be rejected. However, in the interior of Sindh where the cost of living is un-affordable even for common man it could be accepted for single storey building.
- pH value for all the samples is more than 7, implying that the soil is alkaline.
- Electric conductivity is as low as 0.47 ms/cm and as high as 3.1 ms/cm.

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