

MECHANICAL PROPERTIES OF CLAY BRICKS AND MORTAR OF ANCIENT ABHAYAGIRIYA THUPA

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INTRODUCTION

Abhayagiri vihara complex is situated 85 m above mean sea level in the old town of *Anuradhapura* in the North Central Province of Sri Lanka. In extent, it is about 200 hectares sited at the northern end of the town of *Anuradhapura* as demarcated by the Urban council. The most impressive monument in the *Abhayagiriya vihara* complex is the *Abhayagiri thupa*, which dominates the northern end of the city of *Anuradhapura* by its colossal proportions and rugged but majestic appearance. History does not record, by whom this *thupa* was built, but traditionally it is believed to have been built by King *Vattagamini* in the first century B.C. (Hettiarachchi, 2009).

Age of the *Abhayagiriya thupa* is nearly 2100 years. Although, the sediments were deposited on the surface of the *thupa* and plants were grown on its surface, the construction materials of *Abhayagiriya thupa* is still in the good condition. This paper analyses the physical properties of construction materials of ancient *Abhayagiriya thupa*.

METHODOLOGY

Bricks were taken from various levels of the *thupa*. Each brick was cut into small samples with the size $20 \times 20 \times 50 \times 10^{-9} \text{ m}^3$. The samples were cut by hand to avoid discrepancies caused by machining. The machine cut is not suitable for the tests to be carried out. A Universal testing machine was used to obtain the fracture toughness and modulus of rupture values.

Bricks

The main building block of the *Abhayagiriya thupa* is burnt clay brick. Different size of clay bricks were found in *thupa*.

Size of the bricks

Length and the breadth of the bricks are nearly same in all over the *thupa*. The length is about 4.2×10^{-1} m and Breadth is about 2.1×10^{-1} m.

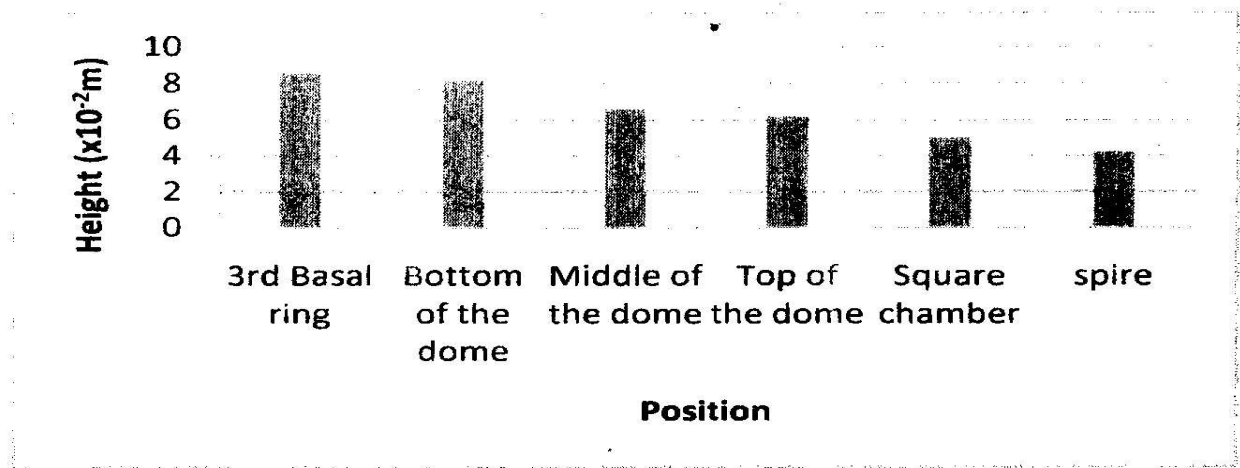


Figure 1- Height variation of ancient *Abhayagiriya* bricks

However the height of the bricks varies from position to position as shown in the figure 01. The height of the brick decreases with the height level of the *thupa*.

Table 1: Mechanical properties of bricks

Brick	Density (kg m ⁻³)	Average Fracture Toughness (kPa m ^{-1/2})	Modulus of Rupture (N m ⁻²)	Water Absorption	Porosity
Ancient <i>Abhayagiriya</i>	1938.8	237	1.543×10^6	14.1%	27.3%
New reconstruction	1942.6	114.3	1.349×10^6	16.2%	31.4%

Particle size analysis

Table 2 : Particle size analysis

Test sieves size (mm)	Percentage
>4.00	5%
2.00-4.00	13%
0.71- 2.00	33%
0.50 – 0.71	3%
<0.50	46%

Table 2 depicts the particle size of about 50% of the ancient bricks are <0.50 mm in size.

Mortar

The mortar is spread between bricks in very thin layers, unlike the thick layers used in modern brickwork. Some mechanical properties of mortar are given in the table 3. It can be seen that the density and the porosity of mortar decreases with the height level of the *thupa*.

Table 3: Density and porosity of bricks

Position	Density (kg m ⁻³)	Porosity
Spire	1602.2	13.6%
Square Chamber	2149.2	19.9%
Dome	2222.3	24.1%

Brickwork

Because of the flatness of the *Abhayagiri* brick, and the flexibility of the mortar, the fracture does not spread to other bricks. Hence, the vertical force by a brick is transferred directly to the next brick. The tensile forces do not concentrate at a single place due to the uniformity of the surface of the brick achieved by filling the cavities. Unlike the modern day construction ancient brickwork can expand without any failure since mortar was not applied at the vertical joints.



Figure 2 - Brick work at ancient *Abhayagiriya thupa*

CONCLUSION

Ancient construction materials of *Abhayagiriya thupa* is of much higher in quality than the modern reconstruction materials. The bricks that were used to construct the *thupa* have high fracture toughness and modulus of rupture values even if they used large bricks. The use of a very thin layer of flexible mortar made the brickwork stronger.

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