Volume 2, Issue 2 (2014) 363-365 ISSN 2347 - 3258
International Journal of Advance Research and Innovation

Recent Scientific tests on Ancient Building Materials of Mansar-Ramtek (M.S.)

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Article Info
Article history:
Received 2 January 2014
Received in revised form
10 January 2014
Accepted 20 March 2014
Available online 15 June 2014

Keywords
Efflorescence
Conservation
Civilization
Heritage

Abstract
The Indian civilization, among worlds, oldest and richest, has a strong tradition of Science and Technology. This paper presents results of various engineering tests conducted on some building materials collected from Ramtek(M.S.). The tests on Bricks were conducted as per IS 1070:1992 & IS 3495(Part 1 to 4): 1992.. The test results are interpreted in the context of technical specifications of Indian Standard Institution.

1. Introduction

Conservation of architectural heritage is a difficult task due to the complex geometry of building and the large variability of the construction materials. The tasks of inspection and diagnosis of ancient buildings require obtaining a certain number of parameters, which provide information about the properties of the materials, the structural behavior, or possible defects. Mechanical characterization is a fundamental task for the structural works and safety assessment.

We performed various test on bricks and on binding material for brick as per the IS 1077: 1992 and IS 3495 (Part 1 to 4): 1992. Test on bricks is done in our college labs whereas the tests on binding material are carried out from V. National Institute of Technology, Nagpur.

2. Case-Study Mansar

Mansar, a small town on national highway no. 7, 40 km N-E of Nagpur in Ramtek tehsil of Nagpur district in Maharashtra. The site is being excavated under the aegis of Bodhisatva nagarjuna smarak sanstha and anusandhan kendra, Nagpur since 1998, under licence from archaeological survey of India.

The oldest stupa were constructed during late Maurya and early Sunga period (300 BC to 200AD). Palace was constructed in satvahana period (200BC to 250 AD) and temple is also built during Vakataka period (275 – 500 AD). Due to the ivasion by different kings, the ancient stupa, palace and temple neglected and underwent dilapidation.

2.1 Stupa

Ancient stupa in Mansar are solid structures built mostly by burnt clay bricks, having size of the bricks is 46x22x7 cm. located at a diameter of area 8.0 m due to undulating ground, the ground is rammed with earth up to a height of 1.55m and wall having extend 38 courses was raised.

2.2 Palace

The palace was fortified by a massive 1.30m wide brick fortification wall on all four sides is 5 m. the brick used are of size 44 x 21 x 7 and 44 x 22 x 7 cm. internally the area un composed by the fortification wall is 124.0 m (E-W) x 110 (N-S).

The area between the fortification wall and adhistan of the place is nearly uniformly 30 m in width. All around the adhistan wall, on four sides a uniform open country yard measuring 9.30m in width has been left out. Front wall of verandah is 0.70m. on eastern side central room is 3.50 m x 2.35m, flanked on both sides by larger rooms, measuring 5.70 x 2.35m; followed by two rooms of the size 10 x 2.35 on each side to the back of this row of room is anotherlong 5.80m wide hall, running throughout. On the outer side of this hall there is 5.50m wide space in between this hall and the main fortification wall where a no. of rooms of different size but having uniform width of 2.75m were exposed. These row of room open in common corridor measuring 2.20m in width. Doors of all the rooms are nearly of uniform size. (i.e. 1.10m in width).

To the west of this palace a satvahana period 42 Pillared mandapa has been earthen. Each brick pillar measuring 1.30 x 1.30m the distance between two pillar is 2.20m. This mandapa is 23 m in length north-south and 19.50m in width east-west. The width of the passage is 3.20m. The mandapa is enclosed by a 29 x 29m, enclosures wall which is 1.20m in width pillar bricks are of the 42x26x8 cm and in vakataka period wall brick measuring 46x24x8 cm.

3. Materials Used In Construction

The main building block of the palace, temple and stupa are burnt clay brick. Bricks have been laid with a very thin mortar and outside surface of the palace, temple and stupa has been protected by element of thin lime plaster.

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Materials used during Maurya-Sunga, Satvahana and Vakataka period were subjected to great quality control.

3.1 Bricks

It is logical to assume that the earliest bricks used in the construction were un burnt sun dried mud bricks. These were later replaced with high quality burnt bricks.

3.1.1 Mechanical Properties Of Bricks

Ancient brick from various structures were tested for their mechanical properties.

3.1.2 Various Tests On Bricks

1. Compressive Strength test.
2. Efflorescence test.
3. Water absorption test.

3.2 Mortar

The mortar used in the brickwork of ancient structure is a clay-slurry type. The binding material of the last period is very thick where gritty; kankar mixed mortar has been used. During Satvahana period binding material used is of lime based mortar used in thin layer, unlike thick layer used in modern brickworks.

3.2.1 Various Tests On Mortar

1. X-RAY DIFFRACTION (XRD) TEST:
2. SCABBUBG ELECTROM MICROSCOPY (SEM) TEST:

3.3 Plaster

Almost entire structure was lime plastered rather normal stucco.

4. Burnt Clay Bricks

4.1 Compression Strength

Testing Procedure

Immerse the specimen in water at room temperature for 24 hours. Remove the specimen from water and drain out any surplus water. No mortar shall be filled in perforation and no mortar capping shall be provided.

Place the perforated faces of the brick between two 3-ply plywood sheets each of the testing machine. Apply the load axially at uniform rate of 14 N/mm^2 (140kgf/cm^2) per minute till the failure occurs and note the maximum load at failure. The load at failure shall be maximum load at which the specimen fails to procedure any further increase in the indicator on the resting machine.

Formula

$$\text{Compression strength} = \frac{\text{Maximum load at failure in N (kgf)}}{\text{Average net area of the two faces under compression in } mm^2 \ (cm^2)}$$

Table: 1. Compressive strength analysis

Sr. no.	Brick name	Size (mm)	Load (Kg)	Compression strength (N/mm^2)	Average compression strength
1.	B 1	220x220	23000	4.66	4.63 (N/mm^2)
2.	B 2	215x230	22000	4.36	
3.	B 3	210x230	24000	4.84	

This is less than 15% class designation as per IS 1077:1992 is 5

Result: The average of result is found to be 4.63 N/mm^2

4.2 Water Absorption

Determination of Water Absorption

Testing Procedure

Dry the specimen in a ventilated oven at a temperature of 105 to 115 degree Celsius till it attains substantially constant mass. Cool the specimen to room temperature and obtain its weight (M1). Specimen warm to touch shall not be used for this purpose.

Immerse completely dried specimen in clean water at a room temperature of 27 + -2 degree Celsius for 24 hours. Remove the specimen and wipe out any traces of water with a damp cloth and weigh the specimen. Complete the weighing 3 minutes after the specimen has been removed from water (M2).

Formula

$$\text{Water absorption} = \frac{M2 - M1}{M1} \times 100$$

Table: 2. Water absorption analysis

Sr. no.	Brick name	M1 (Kg)	M2 (Kg)	Water absorption	Average water absorption
1.	B 4	6900	7865	13.98%	14.61%
2.	B 5	4825	5560	15.23%	

Result

Water absorption, present by mass, after 24-hour immersion in cold water is given by the following formula:

Average water absorption of ancient brick is found to be 14.61%.

As per IS 3495 (Part 2): 1992 permissible value is 20% by weight up to 12.5 and 15% by weight for higher classes.

4.3 Efflorenscence

Determination of Efflorscence

(as per IS 1077:1992, reaffirmed 2007)

Testing Procedure

Place the end of the bricks in the dish, the depth of immersion in water 25 mm. Place the whole arrangement in a warm (for example, 20 to 30 degree Celsius) well ventilated room until al the water in the dish is absorbed by the specimen and the surplus water evaporates. Cover the dish containing the brick with suitable glass cylinder so that excessive evaporation from the dish may not occur. When the water has been absorbed and bricks appear to be dry, place a similar quantity of water in the dish and allow it to evaporate as before. Examine the bricks for efflorescence after the second evaporation and report the results.

5. Result

The liability to efflorescence shall be reported as 'nil', 'slight', 'heavy' or 'serious' in accordance with the following definitions:

i. **Nil: -** When there is no perceptible of efflorescence.
ii. **Slight: -** When not more than 10 percent of the exposed area of the brick is covered with a thin deposit of salts.
iii. **Moderate: -** When there is heavies deposits than under 'slight' and covering up to 50 percent of the exposed of the brick surface but unaccompanied by powdering or flaking of the surface.
iv. **Heavy: -** When there is a heavy deposit of salts covering 50 percent or more of the exposed area of the brick surface but unaccompanied by powdering of flaking of the surface.
v. Serious: - When there is a heavy deposit of salts accompanied by powdering and or flaking of the exposed surfaces.

Table: 3. Effloresces analysis

Sr. no.	Brick name	Result
1.	B 6	Nil
2.	B 7	Nil

Nil: There Is No Perceptible Of Efflorescence

The bricks when tested in accordance with the procedure laid down in IS 3495 (Part3): 1992 the rating of efflorescence shall not be more than "moderate" up to class 12.5 and "slight" for higher classes.

Acknowledgement

Author is thankful to Mr. AK Sharma, Archaeological Advisor (Chhatisgarh, India) for providing valuable information during the project work.

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