

# MASONRY WALLS ANALYSIS FROM SHISH MAHAL IN LAHORE-PAKISTAN

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## ABSTRACT

Lahore Fort is situated in the north-west corner of the Walled City of Lahore. Shish Mahal within the Lahore Fort was built in 1631-1632 by the then Mughal Emperor Shah Jahan. The restoration works were done recently for the ceiling of Shish Mahal including the fixing of the roof, glass work and re-plaster. The side rooms and main courtyard were also restored. Nothing, however was properly proposed and implemented for masonry walls of Shish Mahal on which it is standing. Patches of bricks and plaster have deteriorated from walls due to effect of weather conditions.

The main part of Lahore Fort was made of burnt bricks with lime mortar which has deterioration over time due to various reasons. The brick work in Lahore Fort and its special monument Shish Mahal are badly distressed. This research has been done to underscore the reasons behind decay of masonry walls of Shish Mahal and propose some remedial solutions for them.

**Keywords:** Dampness, Deterioration, Erosion, Mortar, Masonry Walls, Shish Mahal, Lahore.

## INTRODUCTION

The present condition of Shish Mahal, the surrounding rooms, corridors, courtyard and pavilions are in good condition due to continuous repairs throughout the years. Major and minor cracks are visible in the side rooms, but the condition of masonry walls is in decay.

Major steps were taken by Archaeological Survey of India for the restoration and preservation of damaged structure of the Shish Mahal in 1904-05. The remedial works were successfully done for saving the ceiling of Shish Mahal with all its mirror work (Khan, 1997). The ceiling of main verandah of Shish Mahal has been repaired many times,

that is in 1904, 1905, 1922, 1963-64 and more recently in 2012. The false ceiling has also remained under observation of the Department of Archaeology (Rauf, 2006).

In 1991-92 serious cracks were observed in the ceiling and on the recommendations of experts the conservation of ceiling of Shish Mahal was carried out from 2003-2005 (Dawn, 2006). Most of the restoration was done for the ceiling of Shish Mahal, including roof, glass work, plaster of side rooms, *Naulakha* pavilion and its main courtyard.

The masonry walls of Shish Mahal remained unnoticed till recently. Shish Mahal has two basements which are visible from outside towards north-west sides. The current poor condition of its walls can easily be seen in Figure 1 and Figure 2. The patches of bricks have been deteriorated from walls and plaster and mortar is removed due to various reasons, but mainly because of weather conditions.

The condition of the walls is better inside the basements but the exterior walls are in poor condition due to direct impact of the weather. Vegetation, bird holes and dampness can be seen in the walls. This condition is getting serious day by day and the dampness increases during rainy season.

## MATERIALS AND METHODS

The methodology formulated for this study is based on site surveys of Shish Mahal in Lahore Fort. The study focused on the condition of masonry walls and materials used in Shish Mahal. Site visits were conducted to study and examine the causes of decay of masonry walls. A number of photographs of deteriorated walls were taken. This was an explorative study based on literature review, site survey and interviews with the concerned authorities responsible for its restoration. Analytical study of the literature was undertaken to develop the chronology of conservation and restoration elements. The field surveys were conducted to collect information, to further explore the condition of the structure

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and to document the present condition of the Shish Mahal and the level of deterioration.

During the site visit to Shish Mahal following damages to the masonry walls were observed: bricks deteriorated from walls (Figures 1, 2), removed plaster, effect of water/rains causing dampness (Figure 3), erosion of mortar (Figure 4), plantation and holes in walls (Figure 5). The reasons for this deterioration were weather conditions, poor maintenance, bad repairs, poor drainage and general neglect.

### CAUSES OF DETERIORATION OF MASONRY WALLS OF SHISH MAHAL

Deterioration of the Shish Mahal is not only because of poor construction or neglect, but other reasons like water



*Figure-1:* Deteriorated bricks.



*Figure-2:* Deteriorated patches of bricks.



*Figure-3:* Dampness on brick wall.



*Figure-4:* Erosion of mortar from brick wall.



*Figure-5:* Fungal stain and plantation.

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penetration through small holes, openings in the bricks, mortar joints and dampness also cause the foundation to become vulnerable to deterioration.

The brick deteriorates due to harmful vegetation which accumulates on brick surface through structural movements and such movements may be because of settlement of the foundation through decades. The decay is also because of environmental pollution, encroachments, additions and alteration, drainage, water supply, poor maintenance, lack of monitoring and management, lack of awareness, causes related to nature of ground, causes related to material and techniques used in original construction, poor conservation in an unplanned manner, frost, soluble salts, efflorescence, vegetation, neglect and ignorance. The causes of deterioration of load bearing masonry walls are detailed here:

#### **Natural Causes**

Natural causes having prolonged action are:

- Gravity: extra dead loads added to the structure during Sikh and British period (Koch, 1991)
- Age: with the passage of time every structure has to decay, heavy rain falls and floods add to this process of decay
- Humidity: it causes dampness in masonry structures, climatic effects like extreme thermal variations and severe wind storms add to the humidity factors
- Fire caused by lightning, as Shish Mahal was badly affected by lightning in 1904 (Cumming, 1939)
- Earthquakes: The masonry structures have been the most vulnerable during earthquakes. Masonry has adequate compressive strength and is designed for vertical loads. Masonry structure behaves well as long as vertical loads are concerned, but is not strong against lateral inertial loads during earthquake. As a result shear and flexural stresses develop in the masonry walls (Arya, et. al, 2014). The strength of masonry in this condition depends upon the bond between masonry and mortar, which is quite poor in the case of Shish Mahal. This masonry joint is also poor when lime mortar is used. Shear failure in the form of diagonal cracks are observed due to this. In many places in Lahore Fort, cracks have developed in masonry due to earthquake forces.

Throughout history, all above mentioned factors have had destructive effects on the Lahore Fort and thereby on Shish Mahal (Government of Pakistan, 1986).

#### **Dampness**

Unwanted water or moisture was found to be present in the building structures. The dampness created serious damages in structures which were close to water bodies. Dampness not only damaged the building structure but also its finishes and contents. The main cause of dampness was water which entered through different routes. Water generally entered through walls exposed to prevailing rain or moist wind (Figure 3).

Due to gravity water penetrated through capillaries or cracked bricks and mortar joints. In Shish Mahal the dampness on the walls was due to direct exposure to weather conditions. This dampness was due to direct rains and defective drainage system.

#### **Erosion of mortar from masonry joints**

The function of mortar is to bind the bricks; it provides adhesion between the bricks. Mortar has eroded from the masonry walls of Shish Mahal (Figure 4).

The bricks have also been deteriorated due to erosion of mortar. The reason for this erosion is water penetration leading to the concentration of moisture, dampness, plants growing on the walls and presence of salt crystallization.

#### **Fungal stain and plantation**

Fungus has occurred due to presence of water or high moisture content in masonry walls. Plantation is seen on masonry walls of Shish Mahal (Figure 5). Fungus flourishes in damp environmental conditions having high humidity and lack of ventilation (Lourenco, et. al., 2006). Fungus also flourishes in water disposal areas of walls of Shish Mahal. The plantation is also due to seeds present in the fecal dropping of birds, specially pigeons. The mortar joints and holes in walls provide shelter and a suitable ground for any seeds to grow. The roots go deep into the walls causing deterioration, cracks and water penetration.

#### **Defective plaster rendering**

Defective plaster rendering was observed at many places in the Fort as well as on the walls of Shish Mahal. Due to hot climate these defects of rendering were caused by evaporation, air pollution, condensation, thermal stresses, dehydration and biological attacks arising from penetration of rain. The other causes may be growth of plants, presence of animals, insects and traffic vibration. The plaster rendering has cracked due to shrinkage or movement in substrate itself. Figure 6 shows defective plaster rendering of Shish Mahal.

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### Improper materials for restoration works

The use of improper materials has always been another cause of deterioration of historical buildings. The material used for restoration should be according to the materials used originally by the Mughals. There should be proper workmanship behind preparation of construction materials. Due to financial problems and shortage of time hasty restoration works were seen at Shish Mahal.

### Poor Conservation

Proper planned restoration has never been done for the walls of Shish Mahal. Repairs have been done from time to time but not in an effective manner. Restoration is not something which can be done by any technician or lover of antiquity, but should be undertaken only by experienced and qualified experts. This always demands supervision by competent authorities and is the work of skilled craftsmen. Poor conservation was one of the main reasons for deterioration of masonry walls. The use of wrong material and incompetence of staff has made the situation worse (Figure7).

### Neglect

General neglect was another cause of deterioration of the bricks of masonry walls of Shish Mahal. A number of issues like economic, political, social and lack of awareness were the underlying causes of neglect (Figure 8). Neglect might be due to an individual, a community, an agency or the state itself.

There may be conscious or unconscious reasons for neglect. In the third world countries economic priorities are major factors that determine conservation policies. Unawareness results in weakening of structures and allows other causes of decay to take over like dust, dirt, growth of vegetation and dampness.

### Poor drainage

The drainage system is an important element of any structure. Proper drainage system saves the structure from dampness and other side effects due to accumulation of water. Poor drainage is another main cause of deterioration of bricks at Shish Mahal. In the rainy season water collects along the walls of the Shish Mahal which results in the growth of unwanted plantation. Another thing noticed is the garbage collection along the walls of the Fort, due to which water is collected and causes dampness (Figure 9).



Figure-6: Defective plaster rendering of Shish Mahal



Figure-7: Poor conservation of Shish Mahal



Figure-8: Neglect of wall of Shish Mahal



Figure-9: Garbage along water disposal



Figure-10: Destruction due to pigeons

### Pigeons

Pigeons also create problems in building structures especially in city centers. They occupy loose roof coverings and block gutter pipes with feathers, causing water penetration and consequent decay. Pigeons are also responsible for bringing seed through germination and eventually causing unwanted plantation (Figure 10).

### PROPOSED MEASURES AND RECOMMENDATIONS FOR MASONRY WALLS OF SHISH MAHAL

The essence of this research shows that adequate conservation with appropriate materials originally used by the Mughals is very important. Conservation, restoration and repair works must be done by skilled staffs including architects, engineers and craftsmen, who are aware of the importance of these historical monuments.

The research also shows that main causes of deterioration of brick walls of Shish Mahal are general neglect, bad repair, faulty restoration, dampness through walls and poor drainage system. An appropriate conservation plan for its brick walls is discussed below:

#### Masonry walls (basement walls) of Shish Mahal




An appropriate and long term conservation plan is needed for the conservation of masonry walls of Shish Mahal. These could be tackled through indigenous resources without raising financial issues. Remedial works required for these conditions are:

- Existing surface and bricks should be cleaned properly.

- All the removed brick patches should be re-fixed with lime mortar.
- Bricks should have the same size and strength as used originally used by Mughals. (Brick sizes detail used by Mughals is given in Table 1, strength in Table 2 and chemical analysis in Table 3).
- Preparation of the bricks is very important and should be carefully monitored. The presence of salts in the bricks reduces the strength and ultimately life of the structure. Hence, the choice of the raw material and process of burning are very important in manufacturing. The extraction of salts makes a brick more stable against natural and man-made causes of deterioration.
- Strength of lime mortar should be equal to the strength of bricks for equal distribution of stresses. Mortar of high strength causes unequal distribution of stress and causes deterioration, which is an example of bad repair and faulty restoration.
- After the bricks have been fixed the walls need to be plastered with original *kankar* lime plaster, which was originally used by the Mughals.

Table 3 shows traces of chlorides in the bricks made during Jahangir Period and the strength of these bricks is relatively low. It concludes that salts, sulphates and chlorides reduce the strength of bricks. To avoid this selection of raw material the manufacturing process is very important. Table 2 shows that strength of bricks used in the Mughal Period. The bricks used for conservation of masonry walls of Shish Mahal should have the same strength as used in Shah Jahan period to save the historical structure from further deterioration.

**Table-1:** Size of bricks used in walls of Shish Mahal.

S. No.	Size	Picture
1	Length=175 mm	
2	Width=140 mm	
3	Thickness=25 mm	

**Table-2:** Strength of bricks used in Lahore Fort (Arshad, 2003).

S. No.	Structure	Average Strength (Mpa)
1	Akbar Period	66
2	Jahangir Period	54
3	Shah Jahan Period	86

**Table-3:** Chemical analysis of bricks used in Lahore Fort (Arshad, 2003).

S. No.	Structure	Total Dissolved Solids %age	Sulphates %age	Chlorider %age
1	Akbar Period	0.03	Nil	Nil
2	Jahangir Period	0.05	Nil	Traces
3	Shah Jahan Period	0.03	Nil	Nil

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### **Kankar Lime Plaster**

Lime plaster used for the plastering of the masonry walls must have the following contents:

- **Lime:** Calcium hydroxide, traditionally called slaked lime, is an essential part of the chemical formula. It is a colorless crystal or white powder. It has many names including hydrated lime, builders' lime, slack lime, Cal or pickling lime (Rodriguez-Navarro, 2005)
- **Kankar:** Smallest particles of crush found in river beds and formed after dissolving with moving water. These are hardest particles, which should be used in powder form after grinding.
- **Fiber of jute:** It stops cracks from happening. It is very fine fiber and hardly visible.
- **Gur (Raw Sugar):** To bind all the materials.
- **Yoghurt:** Should be used to add smoothness to the aggregate.
- **Daal mash (white lentil):** Should be used to add smoothness to the aggregate.

### **HOW TO CONTROL CAUSES OF DETERIORATION OF BRICK WALLS:**

#### **Dampness**

The brick joints should be filled with lime mortar. Gutters and down pipes should be rechecked for leaks and cracks. Their joints should be sealed. Blockage in pipes should be released. Raised plinth protection must be provided to avoid penetration of water. Any kind of water body should be kept away from historic buildings. There should be proper ventilation and the existing ventilation in the walls should not be blocked. The Mughal lime plaster with all ingredients should be used. Disposal of rain water on brick walls should be avoided.

#### **Erosion of Mortar**

If proper materials are used for mortar and lime plaster with skilled hands, then erosion could be avoided.

### **Fungal Stain and Plantation**

The fungus problem can easily be controlled if moisture and dampness is controlled. There should be no room in the walls for growth of seed which comes through birds. The walls should be examined time to time for growth of any vegetation.

### **Bad Repair Works**

To avoid bad repair works skilled staff should be appointed who knows the worth of historical antiquities. Material used should also be according to the desired standards.

### **Pigeons**

Spaces could be created for pigeons or other birds in nearby vicinity. Measures should be taken to keep the birds away from historic monuments.

### **Human Interventions**

There should be proper security arrangements to avoid wear and tear by general visitors. There should be sign boards for visitors to create awareness for the historic monuments and visitors should be penalized for not respecting the monument.

### **CONCLUSIONS**

Lahore Fort has always been an important monument of Pakistan. The above study concludes the present condition of the masonry walls of Shish Mahal. The condition of the masonry walls is a wakeup call for the Walled City of Lahore Authority to take appropriate measures for its conservation. Detailed remedial solutions are discussed in this paper which should be implemented. Furthermore, systematic documentation of deteriorated bricks is required along with surveys of the present condition of the monument. There is also a need to deploy a permanent restoration team for masonry walls of Shish Mahal. Shish Mahal and all structures in Lahore Fort need to be further explored for various other aspects of damage to save them from further deterioration, so that the future generations can enjoy them.

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