MUGHAL GARDENS IN THE CITY OF LAHORE – A CASE STUDY OF SHALIMAR GARDEN

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ABSTRACT: Although gardens were constructed before and after the Mughal period but gardens of the Mughal era have the most lasting impression on the identity of Lahore. Mughal gardens of Lahore have a powerful impact on architectural history and design in many parts of the world. Almost every introductory textbook on world architecture refers to Mughal gardens as one of the pre-eminent expressions of Islamic art, culture, and values. Lahore has been the capital of Mughal dynasty and became a prominent settlement when the Akbar ordered to make this city fortified. Other Mughal capitals in subcontinent like Delhi, Agra, and Fatehpur Sikri were also graced with different gardens but only Lahore came to be known as a "City of Gardens". Despite of destruction that Lahore endured during the 120 years previous to the inauguration of English rule, these gardens still survive and admired world wide. But due to lack of preservation in present times these landmarks are continuing towards severe dilapidation. Shalimar garden, which is also one of the UNESCO world heritages, is taken up as a case study here. This garden is comparatively in better position today than other Mughal gardens in and around Lahore but it needs a proper maintenance and rehabilitation to restore this national heritage. In this paper, a rational model is proposed for proper rehabilitation of Shalimar Garden. On the basis of that, results and recommendations are made with a proposal of continuation of further research.

Key words: Mughal gardens and architecture, Lahore, Shalimar, repair and restoration.

INTRODUCTION

Gardens integrate the finest features of natural and built environments with the finest traditions of local and regional landscape design. They draw together human aspirations for worldly and spiritual order - merging the paradise-like potential of the world with symbolic representations of the paradise that awaits the faithful in the world to come. Mughal gardens also synthesize the aesthetic and functional needs of society. They provide a context for poetic, artistic, and personal beauty, on the one hand and for social functions, spatial protocol, and norms of social interaction, on the other. Mughal gardens of Lahore have a powerful impact on architectural history and design in many parts of the world. Almost every introductory textbook on world architecture refers to Mughal gardens as one of the pre-eminent expressions of Islamic art, culture, and values. It is also important to narrate that there are two World Heritage sites in Lahore: Shalimar Garden and Lahore Fort (S. Kausar *et al*., 2005).

When Emperor Akbar ordered for fortification of the existing settlement of Lahore, there was a garden running in fortification on other three of the four sides of the city. Inside the fortification, there were small gardens. Environ outside Lahore fort was with garden spotted and spread here and there. The kings of Mughal dynasty well maintained those gardens, although certain local aggressors against Mughal rulers tried to destroy Mughal gardens too. Sikh rulers were responsible for a major destruction of these precious monuments. However, the Mughal dynasty ended in India in 1857, with the fall of Emperor Bahadur Shah Zafar. After that time, there was state connivance over maintenance of these gardens was kept in whirling in the wind. After the British Government took over the control of Indo-Pak subcontinent, they maintained these gardens in a proper manner. Today after 2000 A.D., there is revival of maintenance for these gardens. The maintenance is by state archaeological department Shalimar garden is the one in the list. The Shalimar Garden sometimes written as shalamar Garden.

Brief history of Lahore city: Lahore is second largest city of Pakistan and considered to be one of the ancient cities of the world. According to some historians, Lahore city was developed in 1st century A.D. (S. M. Latif *et al*., 2002). Other historian link the history as early as the times of the Rama, the hero of the famous epic the Ramayana (Z. Ahmed *et al*., 1982). He had two sons, Loh and Kash. Loh who was the mythical founder of Lahore, built a fort that was named Lohkot or Lahawar, and this in centuries that followed came to be known as Lahore.

In 1959, Department of Archaeology embarked upon the digging of the Lahore Fort found terracotta plaques, figurines and 50 ceramics of non-Muslim origin. These traces of Hindu tradition found in Lahore can be related to that fact that there existed a city well before the advent of Islam in the sub-continent at a place exactly where Lahore is located right now. However, the exact date of the foundation of Lahore is still vague and it was not until the Muslim period that Lahore's history is known.

The Muslim period of Lahore began in 1021 A.D. with the defeat of Trilochan Pal by Mahmood Ghaznavi. For about 165 years Lahore remained the provincial capital of the Ghaznavid Empire and in 1186 A.D. fell into the hands of Shahab-ud-din Ghori. Since then Lahore had been under the rule of Turks, Khaljis, Tuglaks, Sayeds, Lodhis and Pathans for more than 300 years. When the Mughals took over, Lahore enjoyed the status of state capital and it was in this short period that we find the glorious period of Lahore's history. Unfortunately, this glorious age was repressed due to the influx of the Sikh in 1767 A.D. to 1846 A.D. Under Sikh rule the architectural monuments of the Muslim period were ruthlessly destroyed. After that the British came from 1849 to 1947, and they greatly improved the ruined state of Lahore. Since then Lahore has begun to leap towards modernity while keeping harmony with its glorious heritage.

Like all ancient cities, Lahore also has two faces, the old and the new. The old city is the reminiscent of the past glory of Lahore and the new city gives a modern look. The old city was built in the shape of a parallelogram and the area within the walls is about 461 acres. Emperor Akbar, during his stay in Lahore, constructed brick wall all around the city to protect it. This walled city is slightly elevated hence protecting it from destruction and any outside invasion. Since the walls had decayed overtime, when Ranjit Singh came into power afterwards he rebuilt these walls and added a deep broad ditch around. This ditch was further filled with fine gardens, and encircled the city on every side except the north. Access to the city was possible through the twelve gateways provided in the Mughal's walled city of Lahore (figure 1). Lahore Despite the suffering and destruction that Lahore endured during the 120 years previous to the inauguration of English rule, it was lead to immense restructuring and adornment when the Mughal dynasty gained control over sub continent.

Before Mughals, there were no architectural edifices in Lahore. The city got prime importance under the rule of the Mughals. The Fort, the tomb of Jahangir, the Badshahi Mosque, the mosque of Wazir Khan, the

Pearl Mosque and the Shalimar garden were the buildings that truly marked the city of Lahore during the Mughal period, and are still admired world wide despite a lack of preservation.

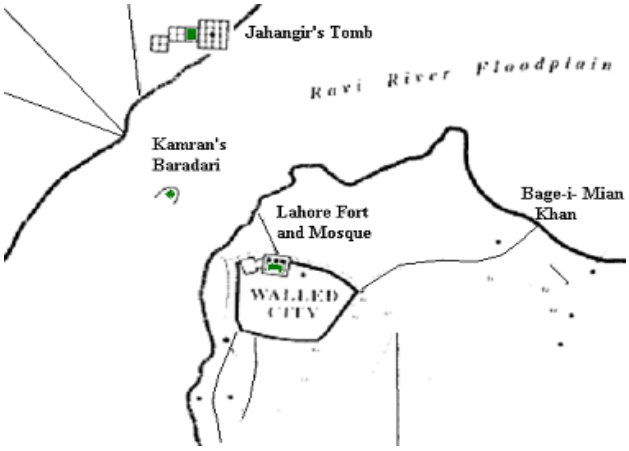


Figure – 1: Map of historic "walled city"

MATERIAL & METHODS

Analysis of Mughal gardens in Lahore: This section of the paper begins with a series of photographs (figure 2-6) showing the rich heritage of Mughal gardens built at imperial and sub-imperial scale. Though the basic concepts in these gardens remained the same, significant innovations responded to the local cultural, geographical and environmental contexts in which they were built.

In literature review, basic idea about the Mughal gardens in the Lahore city was assessed. The first serious historical study of Mughal gardens was made by Constance Villiers-Stuart, with the title Gardens of the Great Mughals (1913) (F.S. Aijazuddin *et al*., 1991). The origin of Mughal gardens can be traced to Central Asia, while the climax was reached in India over a long period of time.

These garden projects were initially commissioned in the Mughal emperors, nobles and elites era. By the end of eighteenth century, gardens had been built in the suburbs of all major cities and small towns throughout Central Asia mid Mughal India. Saifur Rehrnan Dar convincingly shows that Mughal gardens in the Punjab have ancient roots and modern manifestations. They were influenced by gardens of other regions and times and identified five regional influences (R. Nath *et al*., 1982):

1. Central Asia
2. Kashmir
3. Western Punjab
4. Persia
5. Delhi Sultanate

Other Mughal capitals in subcontinent at Delhi, Agra, and Fatehpur Sikri were also graced with gardens but they did not have the same effect on the identity of those cities. Agra is best known for individual monuments such as the Taj Mahal and Fort; Fatehpur Sikri for its ceremonial palace complex; and Delhi for the planned city of Shahjahanabad. Each had gardens, but only Lahore got the title of "City of Gardens" (M. Brand *et al*., 1985).

Figure - 2: Photograph of Jahangir's Tomb Garden

Figure -3: Main entrance of Jahangir's Tomb-garden.

Figure – 4: Photographs of Lahore Fort Garden.

Figure - 5: View of Hazoori Bagh, Lahore

Figure- 6: A view of Shalimar garden, Lahore.

A significant number of garden are still survived in Lahore even after the invasions from many invaders in the sub continent. Shalimar garden, Jahangir' tomb garden and Lahore fort garden constitute three monumental examples of garden design in the city. During Mughal times, they transformed the spatial and cultural development of Lahore. When Shalimar garden was built in northeastern Lahore, for example, it redirected circulation and settlement patterns in the entire eastern suburbs of the city (S. Kausar *et al*., 1990). Although gardens were constructed before and after the Mughal period but gardens of the 17th century had the most lasting imprint on the form and identity of Lahore. They influenced subsequent patterns of garden design. The importance of Mughal gardens in Lahore is thus jointly regional and global, historical and spatial, spiritual

and political, natural and cultural, aesthetic and functional (S.R. Dar *et al*., 1982).

During the stable Mughal regime (1526-1707) a lot of gardens and other architectural buildings were constructed, but just after the death of King Aurangzeb in 1707, anarchy spread all over the subcontinent in eighteenth century. Mughal gardens became camping grounds for the invading armies. Nadir Shah, a Persian invader, conquered Delhi in 1739, staying at Shalimar garden on their way. Similarly Ahmed Shah Durrani, general in Nadir Shah's army, invaded subcontinent many times in eighteenth century. The garden suffered much destruction during this period but worse to befall was happened when a war was fought in its vicinity between the local ruler Muin-ul-Mulk and Ahmed Shah Durrani. Ganda Singh narrated this destruction in his book (G. Singh *et al*., 1959).

"The neighboring of Lahore was at time full of beautiful gardens and orchards, reminding them the old grandeur of the capital, but they were all cut down for the purpose of entrenchments"

Brief Analysis of Shalimar Garden: Lahore was conceived as a project by Ali Mardan Khan in 1641 A.D., the Persian governor of Punjab and Shahjahan granted permission to construct it. The Shalimar garden was one of its projects and it was launched under the supervision of a noble Shahjahan's court, Khalilullah Khan and other prominent figures by that time. The project was completed in a remarkable short period of one year 5 months and 4 days. Shalimar garden is considered as one of the Shahjahan's finest achievement after Taj Mahal, and it is indeed a landmark in the history of Mughal garden architecture. In the opinion of many historians, Shalimar garden is one of the most elegant achievements of Mughal culture being at its peak (R. Nath *et al*., 1982).

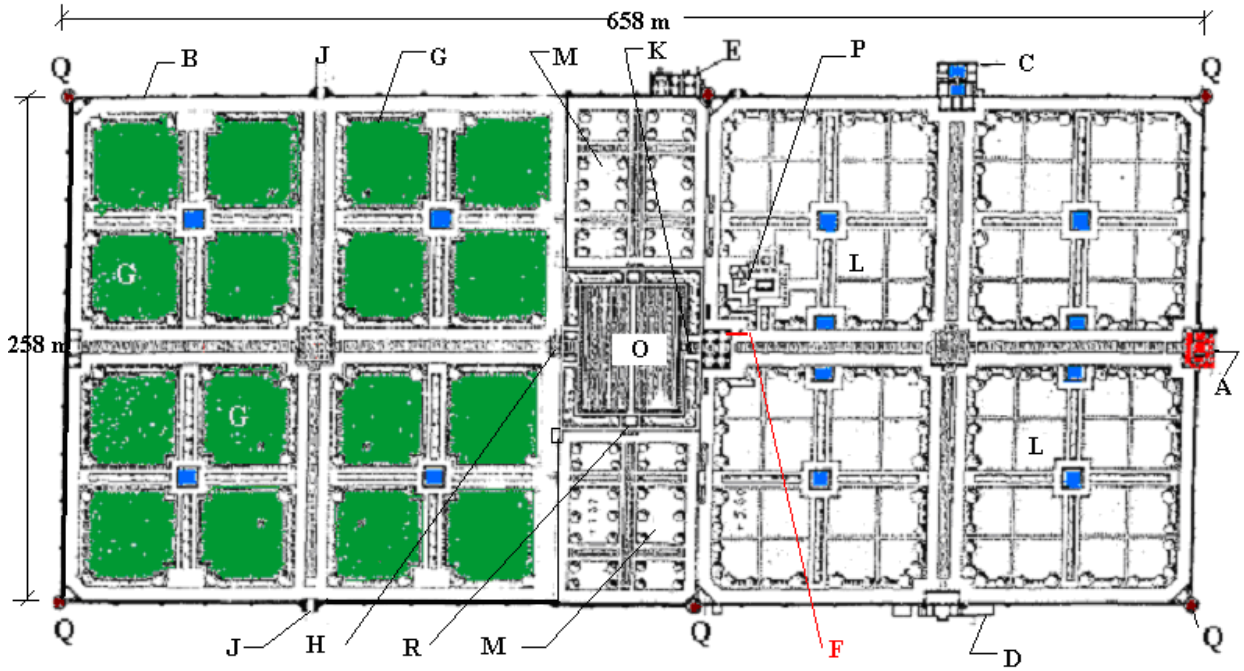
The garden measures 658 meters North to South and 258 meters East to West. It has five cascades, including the great marble cascade and Sawan Bhadoon, while the main building situated in the premises included Sawan Bhadoon pavilions, Naqar Khana (room of coloured artwork), Khawab Gah of Begum Sahib (resting room of the Queen shown in figure 9 represented by A), Baradaries to enjoy the cool breeze produced by the surrounding fountains. Two huge gateways and minarets are located in the corners of the garden called Diwan-e-Khas-o-Aam. (S. Kausar *et al*., 1990).

The neglect of Shalimar garden in recent times: The historic Shalimar garden is losing height of construction work, which continues decay and deterioration due to lack of interest by the authorities. Eastern and northern walls of the monument, with the previous artwork executed by the Mughal era artists have been completely lost or on the verge of collapse. The conditions of the boundary walls of the monument are miserable. They are already at the verge of collapse, high dilapidations at many places and can be seen on the outer side of wall possibly due to massive rains in the last three years. The reason for the fast deterioration of the monument is due to poor drainage system causing rain water ingress in the foundations of walls, as the location is now a bit below than the normal ground level. Massive growth in population in Lahore in past decades left the garden feets below the natural ground level. The problems are adding up due to negligence of proper care from government departments and other archaeological preservation authorities, which are supposed to preserve the national assets and a master piece of its time.

The northern and the Eastern walls are in the much worse conditions than the other two walls. The renovation progress seen on site was thoroughly studied and found to be unsatisfactory and seems to be the absence of concerned skills and expertise in relevant field. Most of the old structures, especially floors are being replaced with new floors instead of preservation, which is un ethical in preservation of such a great monument Northern main gate of the garden is also removed, while huge garbage may be seen around the wall (figure 11). Drain water is one of the major reasons of the decays of the wall foundation, which can be seen from figure 8 that super structure is in a reasonably good conditions but the foundations seems to be collapsing.

Figure – 7: A satellite image of Shalimar garden taken on 17-02-2008, showing massive development in the surroundings of Shalimar garden

Figure – 8: Pictures showing decay in the northern walls of Shalimar Garden. Photographs were taken on 08-02-2008



A- Aramgah
B- Boundary wall
C- Jharoka-i-Daulat
D- Begam ki Khawab Gah (Residence of Queen)
E- Hammam (Royal Bath)
F- Aiwan
G- Gardens
H- Sawan Bhadon
IJ- Gate ways with tile work
LM- Smaller gardens
O- Water tanks
P- Pavilions constructed during regime of Rangit Singh
Q- Alcove
R- Red sand stone Pavilion

Figure – 9. Plan of Shalimar garden

Causes of deterioration in Shalimar garden: The primary causes of damage in the brick work especially of outer walls of Shalimar garden is due to damage in mortar and plaster as environment effect, weathering (physical and chemical) decomposition. Some other causes may be the unavailability of proper drainage of rain water, which entered in the foundation of wall due to the raising of road level. Rising of road level resulted due

to the development process in the surroundings of the Shalimar Garden. Figure 10 shows the main gate of northern wall, which is in a miserable condition and the Ground Level of the garden, is now lower than road level and the natural ground level of the surrounding areas. Improper care and negligence in maintenance for a significantly longer time caused major deterioration in the foundations and walls of the masonry structure. However, inside the garden periodic repair and maintenance was carried out. With respect to the nature of defects and damages, it is possible to group the most commonly observed causes of damage into two basic groups. Other main cause of deterioration to major structures present inside the garden and the exterior walls was the negligence of the city government and poor governance (figure 10).

Figure – 10: Picture showing the northern main gate of Shalimar Garden. The levels of thee surroundings road is higher than the natural ground level of the garden, causing water ingress in the foundations.

Figure – 11: Example of poor governance by the local and city government to protect the national heritage

Repair, maintenance and alteration of Shalimar garden: Since the time of construction, Shalimar garden has gone through many alterations, repair, maintenance and restoration. On the time line this repair, maintenance, alteration and restoration may be divided into following phases:

Alterations in Shalimar Garden in Mughal times: Shalimar garden is unique for combining all the typical elements of the Mughal pleasure garden in a very elegant manner. Prince Aurangzeb was one of the earliest visitors of the garden, who visited garden after nine years of its construction.

Abdul Hamid, the court historian narrated that the Chini Khanas present within the central open pavilion – the Aiwan (figure 12) was removed within two decades of Shalimar's construction, which was a major alteration. Besides that, new floors were laid where chini khanas had existed and water chute was delicately carved in white marble with black stone inlay in front of open pavilion (Aiwan)

Prior to the construction of the Shalimar Garden, wells were generally the only source of water supply. To Shahjahan the idea of constructing Shalimar garden came later than the Shah Nahr Canal, which was built earlier by Ali Mardan Khan, who had services of an eminent

hydraulic engineer Mulla Allah ul Mulk Tuni, mainly to irrigate various gardens around the city of Lahore (Kamboh *et al*., 1974). The device of supplying water through a canal at Shalimar was altogether an innovation for the plains. Water from canals was mainly used to irrigate gardens and was not used for fountains since it carried silt. So, for fountains, clear water was needed. This additional water supply was provided from a hydraulic complex constructed on the southern side of the highest terrace. A well with a Persian wheel ensured the constant supply of clean water. The overhead reservoir was constructed at height of approximately eight meters from the bed of the central canal of the highest terrace. In the west of the garden, behind the building of "Begum ki khawab gah" a huge twelve sided well was digged, which still existed and the water was lifted by Persian wheels into tanks from there it fed to fountains and channels of the lower terraces through aqueducts. Another such well existed behind the eastern wall of the middle terrace until the late nineteenth century (W.G. Osborne *et al*., 1973). It fed water to Royal Bath (hammam) represented by E in figure 8.

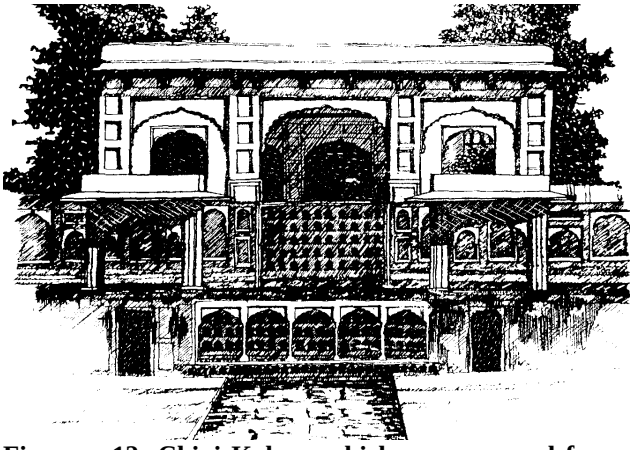


Figure – 12: Chini Kahan, which was removed from Shalimar garden within two decades of its construction

Alterations from mid 18th to start of 19th centuries: By the mid of eighteenth century, the Sikhs, who were by now an organized force, became the new rulers of Punjab. The builders at Shalimar were robbed of their decorative works by Sikhs during the politically unstable times of Ahmed Shah Durrani and later by Sikh rulers of eighteenth century. A costly pavilion of a gate was removed by Lahna Singh, one of the local Sikh rulers who sold it to a stone polisher in the city (S.M. Latif *et al*., 1981).

The water supply to Shalimar garden was blocked before the Ranjit Singh came into power in 1799. However, in 1806, Ranjit Singh ordered the restoration of Shahjahan's Canal. Two years later water supply to garden became adequate. During Ranjit Singh's period, although the garden was restored but some building continued to be vandalized. Towards the end of Ranjit rule in 1838, the water supply to Shalimar garden was failed, but once again it was restored in 1848. Punjab became part of the British empire in 1849. Charles Masson, a British traveler who visited Lahore in 1826 gives following comments (S.M. Latif *et al*., 1981):

"About three miles north-east of Lahore is the renowned and one delightful garden of Shalimar. There are still the marble tanks and fountains, with costly machinery, that once supplied water. The pavilions and other buildings of the immense garden have suffered not so much from the dilapidation of time as from the depredation of the Maharaja, who has removed much of the marble and stone of which they were composed to employ them in his new constructions at the favourite religious capital of Amritsar, and the contiguous fortress of Govind Ghar. Still in its decline of splendour, Shalimar has sufficient beauties to interest and delight a visitor."

Repair, Maintenance and Alterations during the British Period: In the early years of British rule, certain buildings continued to be vandalized. A complex comprising palaces for the royal ladies, Khawaspura, existed to the south of the Aram Gah (an open fronted summer house and a resting place of the king situated on the southern side of the highest terrace). In 1888, the foundations of the Khawaspura were dug out and sold for bricks. Similarly, a new door was introduced on the southern wall of the Aram Gah by destroying a Shahnashin royal seat built inside the royal pavilion (W.G. Osborne *et al*., 1973). According to Captain H. H. Cole, the first curator of Ancient Monuments in India, the eastern and western gates of Shalimar were damaged significantly. Both the gates were originally decorated with Kashi or glazed tile mosaic which was not conserved; instead many Kashi panels were removed. In 1883, the garden was let out on lease for the cultivation of fruit, which resulted in thick plantation of the upper and lower terraces (H.H. Cole *et al*., 2000).

Shalimar was placed under the control of the Department of Archaeology in 1913. In 1922, a hundred mango trees were removed from the lower garden. The middle terrace was totally cleared out and a rose garden introduced there on the English pattern (H. R. Goulding *et al*., 1996).

Conservation of Shalimar garden (1947-2008): The traditions of conservation of historical building and heritage started at the beginning of the twentieth century and continued more or less up until the present. During the British period, which lasted for almost one hundred years in Punjab, Shalimar garden was generally well looked alter in terms of daily maintenance. Many memorable measures were taken and small repairs were also carried out from time to time but major conservation works were not attempted.

After the Pakistan came into existence in 1947, it went through very difficult times in the initial stages like any newly independent country. In the first two decades, due to lack of funds and trained professionals, conservation of historical buildings was not managed to a large extent. However, the first major restoration work was carried out at Shalimar Garden in 1950 subsequent the late Shah of Iran's visit to Pakistan.

Recently, a total fund of Pak Rs. 300 million were allocated from which Rs.15 million was granted by UNESCO and the rehabilitation and preservation work was started in June, 2007 and will be finished in June 2008.

Water supply and drainage system: The first major restoration work was carried out at Shalimar Garden in 1950 for the late Shah of Iran's visit. The original terra-cotta pipe line had choked and broken. The pipeline was not restored at that time. Rather, a cast iron pipeline was provided and the terra-cotta pipeline was filled up with mud under pressure. In 1978, water was found to be seeping out of the northern wall of the middle terrace. PINSTECH (S. H. Dildar *et al*., 1996) investigated in and found that a terra-cotta line of 30 cm diameter supplies water to the fountains was damaged. The terra-cotta line was protected by laying brick in lime mortar about 30 cm underneath 60 cm on the sides, but following the tradition of 1951, a galvanized iron pipeline was introduced hurriedly in 1980, in order to accommodate the ceremony of the Aga Khan's awards for architecture (N.A. Jiabajee *et al*., 1956).

Flooring: The brick floors of the highest and lowest terraces were well restored under the supervision of Mr. Wali Ullah Khan and Later under Mr. Akbar Khan in the sixties and seventies. In the original design of Shalimar garden, upper and the lower terraces were subdivided by secondary water channels and narrow walkways, making sixteen plots in all (Figure 9). The source of inspiration was the Royal Paradise carpel of Shah Abbas ol Persia made in the seventeenth century for the Selari Palace at Isfahan. The red sandstone floor was replaced by the present marble floor between 1983-85.

Figure – 13: New flooring of pathways provided in gardens between 2007-08, which give a good architectural look and an esthetic match towards the Mughal architecture. Photograph was taken on 12-02-2008.

Roofing: At the highest level, a reinforced cement concrete roof was introduced over the building called Aram Gah in 1968, and marble floor in that building was laid in 1975, which was replaced by red tiles presently (2007). The central roof of the Aiwan (from the Sikh period) was dismantled and restored in 1980-81. The other two buildings of the highest terrace, namely the Begum Ki Khawab Gah and Jharoka, which were more or less in a state of ruin. The current repair and restoration of Shalimar garden is being done appropriately but some architectural and design changes are required at some places.

Pavilion: In the middle terrace, the red sand stone pavilion on the western side of the tank was restored between the years 1977-79 and the one on the eastern side during 1980-83. As narrated earlier, marble from Sawan Bhadon Pavilion was removed by Ranjit Singh and minor repairs were carried out in 1921 and in 1936-37 and, a small repair was carried out in the Sikh period wooden roof of the eastern pavilion.

Hammam and Terraces: The Royal Bath or hammam on the second terrace was decorated with beautiful mosaic work during Mughal times which was removed in Sikh period. This is the most neglected building of the whole garden and during previous repair and maintenance works, building material was usually stacked here. The main entrance of the hammam has also been served as toilets for visitors. Covers over the skylights of the hammam were taken out at an early stage. In the absence of covers, the skylights were fallen as mere holes in the roof allowing the free entrance of rainwater into the building. Finally, in 1986, concrete covers were introduced. The lowest terrace has, by and large, suffered the most.

Gates: Both lofty gates, which are in eastern wall, are in urgent need of conservation (figure 14). In 1968, a minor attempt was made to conserve the Kashi work by applying binding mortar. Due to development process, the Finish Floor levels of one gate in eastern wall is much more lower than the original ground level. The remains of Kashi work and other decorated work may seen even today (figure 10)

Figure – 14: Gate in eastern wall of Shalimar garden

RESULTS & DISCUSSION

Proposed methodology for repair and restoration of Shalimar garden: The work of rehabilitation and restoration is very important with regard to its match to existing structure so that the structure is not only able to resist environmental impact but sustain its original condition. Therefore, restoration and rehabilitation should be scientifically based. Professionals such as historians, restorators, physicians, chemists, biologists, engineers and architects should be involved with in the same time during analysis, evaluation and restoration process. Unlike, in the Shalimar Garden only one supervisor was available, with meager knowledge of rational repair and restoration process. Here the purpose of analysis of the structural members, surfacing, mortars and over all building is to determine the physical and chemical properties of already used material and compatible to that a restoration plan is needed to develop. For that purpose it is very important to know the properties of traditional mortars or binding materials and mix design for new mortar should be designed keeping in view of the mix design of traditional mortar being used in the historical building, so that they match not only properties but also the look and aesthetics. Since there is lack of academic research and publication on this issue in our country, different problems in reaching the accurate and sufficient information are encountered. This leads to develop an empirical method for restoration and rehabilitation process of historical building as shown in figure 15.

Figure 15. Author and co-author discussing restoration methodology of Shalimar Garden with contractor's construction supervisor, in the background mason is repairing fountain side walls with ordinary black cement.

In order to make the ideal repair methodology and selection of final choice should be based on systematic and rational methodology. Figure 16 shows model for restoration work of Shalimar Garden, which includes planning, analysis, evaluation and restoration of historical building may involve five basic phases:

i. Planning of restoration work
ii. Visual inspection and documentation
iii. Experimental research and testing
iv. Evaluation and monitoring based on experimental results and testing
v. Decision making on appropriate material and method of restoration and rehabilitation.

i. Planning of Restoration work: The first step in restoration and rehabilitation work is planning of restoration work to be done on site. In this phase the strategy including goals and objective for the restoration work is set which is monitored in the other phases of process. Tentative quantity of restoration work is also estimated. Consultants are appointed and course of action is determined for the repair and restoration.

ii. Visual Inspection and Documentation: The second stage is visual inspection and documentation by a panel of experts. It is also important to observe where already rehabilitation work has taken place. Since there is a possibility that building may have more than one

restoration in its life. Therefore original plaster or brick work should be determined and analyzed carefully by removing the layers that belong to new period. It is also important to document all important features in a proper manner so that they may be used not only in the restoration of this building but for other structures of similar nature and period. It is better that pictures should be taken and kept in record for future references and restoration of similar works. At initial stage visual inspection of the boundary walls was done as shown in the figure 17. Visual inspection and documentation includes:

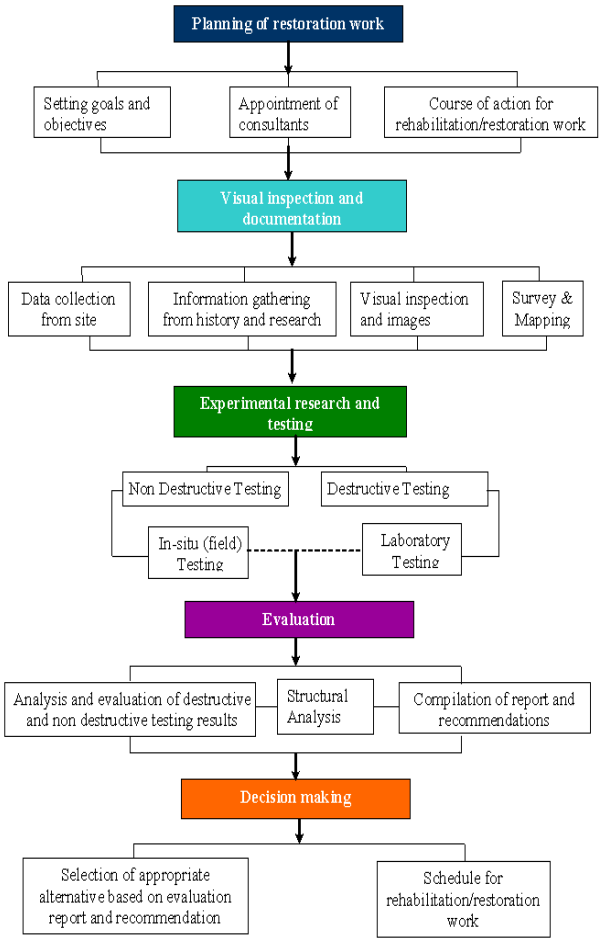


Figure 16. Proposed model for the restoration and rehabilitation work of Shalimar garden

- Mapping of morphology of the deterioration by making drawing or other computer aided techniques based on visual inspection.
- Measurement of historical timeline of the structure in chronological order of the previous restoration work by searching historical documents.

Determination of the decay and decomposition caused in the structure with the passage of time

Figure 17. Visual inspection and collection of mortar sample from outer side of northern wall of Shalimar Garden

iii. Experimental research and testing: In this phase a systematic approach can be followed to determine the current structural condition which can be used to analyze the structural stability and to propose the type and specification of restoration work. Experimental research and testing can be done into two ways; 1) Destructive and 2) Non Destructive. In destructive tests the physical properties of various component of structure is measured by directly destructive methods of testing e.g. compressive tests give the ultimate compressive strength of the brick or other element of the structure. Non destructive tests provide information about the physical and mechanical properties of structural element to determine the level of deterioration. NDT can remove doubts about the determination of damages during visual inspection. In addition, they provide a sub-knowledge accumulation for required laboratory tests. Non Destructive Testing can be helpful in finding hidden characteristics (internal voids and flaws and characteristics of the wall section) which cannot be known through destructive tests. Sampling of masonry specimens is a costly operation, which also can lead to misunderstanding when the operation is not carried out in the appropriate way. When an overall knowledge of the wall is needed, ND tests can be useful.

The types of tests available at present are mainly based on the detection of the physical properties of the object to be tested. The in-situ mechanical tests available are flat-jack, hardness, penetration, pull out tests and somewhere ultrasonic method is also used. The flat-jack tests give local measurements and are slightly destructive; nevertheless they can give directly the values of mechanical parameters. In the case of NDT, a correlation between the measured parameters and the mechanical ones is usually difficult, but they can give an overall qualitative response of the masonry. At present the most diffused Non-Destructive (ND) techniques are represented by the sonic (or ultrasonic), radar and thermography tests (J. Brozovsky etal, 2007).

On the other hand, some additional tests can be performed such as sieve analysis to determine the grade and types of materials used as binder and other aggregates used in construction of filler material of mortar. If lime is used as binder in original mortar then sieve analysis is carried out after solving lime in acid. If soil is used as binder then sieve analysis is carried out after dissolving soil in water. Other chemical tests can also be performed which enable to find chemical composition of the mortar and other building materials. They may include chloride analysis, sulfate and carbonate analysis, nitrate analysis, protein analysis and saponifiable oil analysis (G. Croci *et al*., 1998).

The petrography and mineralogical analysis is sometimes made to determine the mineral type and structure of mortar aggregates. Other methods of analysis are to determine color, tissue and crystal structure, shape and grain dimension are found out by using scanning electronic microscope (SEM) and element dispersive analysis (EDAX). In addition, these features are also examined by X-ray diffraction.

The choice of test procedure for detailed study of the building must be guided by parameters, which can be used to define the entity of the time and budget dedicated to these operations. The artistic value of the monument, the resources available, the entity of the damage and the type of intervention are some of these parameters. These operations can be accomplished with the help of experts in the field. Therefore, information is needed for architects and engineers on the availability and reliability of the investigation techniques, which should be used taking into account limits and benefits, always compared to the cost.

iv. Evaluation: On the basis of experimental research and testing results and recommendations are evaluated. Since the quantitative and qualitative results of the mix design of original mortar and the physico-mechanical properties on the site obtained after inspection and testing are evaluated and a best possible material, methodology and specification is proposed for restoration work. Other modeling techniques may also be used for this purpose. The following items may be recommended in evaluation process for further final decision making.

Mix design of repair mortar/material: Aesthetic aspects like color and structure should be taken into account for providing mix design and specification of material in order to make repair compatible to original work so that they give same look as they were constructed. In previous rehabilitation and restoration work of Shalimar garden, this aspect was not emphasized as we can see from some part of the eastern wall that the black cement, sand mortar was used for plastering on some places of the wall which destroy the original aesthetic look of the structure.

Properties of raw material and their specification used in restoration: It is very important to give emphasis to the type and size of aggregates to be used in newly produced mortar together with the chemical properties of different material used in restoration work so that they are chemically stable to produce a strong bond between old and new work. Instead of market available admixture natural material such as pozzolanic materials, fly ash, silica fumes, white cement has been used historically in restoration work.

Figure – 18: Picture showing Eastern wall of Shalimar Garden, which shows a bad workmanship and improper restoration during maintenance of the wall in the past. Aesthetic look has not been taken into account during restoration process which gives a adverse impact to the viewers/visitors.

Properties of repair mortar: After finalizing the mix design and specifying the material samples of repair, mortars are prepared and tested for the physical and mechanical and chemical properties in order to make comparisons of the properties between the old mortar and new mortar to be provided in restoration work. Similarly the test are conducted for the durability of new mortars. In determining the durability the following tests should be performed: wetting-drying and aging test in sodium sulfate decahydrate solution. These tests will give information about the behavior of new designed mortar and its life (M. Weaver *et al*., 1997).

v. Decision Making: Based on the information gathered through process of visual inspection, experimental research, testing and recommendations obtained through evaluation process, the final decision is made to select the material, material type, material specification, mix design, methodology of restoration work etc. are finalized in this stage.

Conclusion: In this paper a brief history of Lahore city and the Mughal gardens is discussed. Due to ignorance of governing bodies and administrative departmebrs some

gardens and historical buildings have completely vanished and some are sufferings critical deterioration. If due care is not given for their proper maintenance, repair and rehabilitation they may also be lost. An immediate action is required in this regard so that they may remain in their original or close to original conditions. Due to the influence of public living in the surroundings and illegal encroachment, they are loosing their original shape. As, Shalimar garden was taken as a case study so it was visually observed and inspected. On the basis of visual inspection it was found that brickwork of eastern and northern walls are in critical bad conditions. Samples were taken for analysis and further experiments and research. The repair and maintenance already made to this structure was not appropriate and compatible to the original work. Furthermore, this study has tried to propose a methodology for restoration work of Shalimar Gardens, which may be followed in the repairing and restoration work. The suggested experimental methods can be applied for every type of mortar or building related to Mughal Architecture and particularly Shalimar garden. The proposed model may be used to continue for obtaining a standard data archive mortar in accordance to the time period in which they were constructed.

Recommendation: Visual inspection of the Shalimar garden's boundary walls and interior structure has been made by the authors. Samples of mortar and bricks were taken for further analysis and testing the physical and chemical properties of mortar and bricks to propose a compatible restoration and repair method and material for these historical building. The samples where proposed to analyze with microscopy followed by XRD analysis to design a suitable repair mortar (G. Croci *et al*., 1998). It is also recommended to formulate a standard for the repair and restoration work of historical buildings.

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