Weathering of historical monuments by climate change-A case study of Kaiser Bagh Palace, Lucknow

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Abstract

Lucknow boasts a very rich architectural heritage, built by the nawabs of Awadh during18001856 and is a glorious example of hybrid architecture - Mughal and European styles. The monuments are characterised by bulbous octagonal domes, lofty recessed arched entrances having a distinctive feature of a decorative fish pattern, floral and geometrical motifs in lime stuccos. A special feature of the Awadhi monuments is that they are built without iron beams by usinglakhauri bricks and chunam. The monuments of Lucknow are only 200-250years old but environmental pollution and climate change have accelerated their weathering manifold. The present study was undertaken to highlight the status of weathering in historical monuments of Kaiser Bagh. Severe fluctuations in temperature(ΔT), moisture(ΔRH), together with environmental pollution especially greenhouse gases(CO_2, CH_4, SOx, NOx, VOCs) have damaged *Makbara Saadat Ali Khan*, *Makbara Mushir Zadi*, *Pari Khana*, *Poorvi* and *Paschim Lakhi Darwaja*, *Chaulakhi Kothi*, *Kotwara* House, *Kaiser Bagh Circle* and *Kothi Roshan-ud-daula*. Thestatus of the monuments is visible by colour change, detachment of parapet, crack formation with plants, material loss as powdering, rusting, granular disintegration, exposure of bricks, deposition of black crust, *Flostectorii*, rotting of wooden doors, doorposts, windows, blinds, beams etc. The monuments in Kaiser Bagh urgently need retrofitting to restore, preserve and bring back the lost glory.

Key words: Kaiser Bagh, Awadhi Architecture, climate change, corrosion, lime stucco, biodeterioration.

INTRODUCTION

Lucknow city boasts a rich architectural heritage having around 60 buildings that are protected by the Archeological Survey of India(ASI). The Nawabs(rulers) of Lucknow built fine structures in traditional styles and experimented with European architecture to create a novel hybrid style-Awadhi or Lukhnavi architecture. Structurally, the monuments had a conventional plan of a Mughal mosque with minarets at the sides, vaulted halls, *taikhanas*, kiosks, gigantic fluted columns, multiple entrances on the façade, use of umbrellas(*chhatris*), parapets, bulbous octagonal domes, balconies, courtyards, gardens, lofty recessed arched entrances having a distinctive feature of a decorative fish pattern, floral and geometrical motifs and colourful paintings. These large masonry structures were built without iron beams by usinglakhauribricks(thin palm-sized baked clay bricks) and lime crushed brick aggregate mortar(*Surkhi*). The lime-mortar was used in the ratio of approximately 1:2 to 1:4 by volume. The final coating over the coarse plastering of walls, floors and roofs of buildings(*Tarras*) was done by stuccos in delicate floral and fish motifs to imitate the stonework effect.The monuments of Lucknow are only 200-250 years old but are in a very dilapidated state(ASI, 2011).The rapid urbanization and environmental pollution has led to climate change that has accelerated the weathering of monuments. This paper aims to- i) highlight the status of historical monuments in the Kaiser Bagh area, ii) to diagnose the cause of weathering, iii) to give innovative solutions for restoration.

Site description

Lucknow 'the city of Nawabs' lies at the Latitude $26^0$58'N and Longitude $80^0$56'E on the banks of river Gomti, with a population of 2,817,105(Census, 2011). It is home of nearly100 most majestic and lavish monuments listed under the control of State Archeology Department.

Fig-1 Map of monuments of Lucknow (ASI, 2011)

The architecture of monuments of Lucknow (Tandan, 2001) reflect the style of 18th and 19th century India and can be classified as: i) Pre Nawabi or Mughal style(1775-1800) ii)Nawabi Indo-European – Awadhi style (1800-1856) iii) European (1857-1947)

Fig-2 Cloth painting of Kaiser Bagh, Lucknow

The Awadhi architecture comprises of religious monuments/shrine(*Imambaras)*,burial places(*Karbalas*), residential *(Kothi*), gateways(*Darwaja*), gathering places(*Baradaris)* and cultural institutions (*PariKhana*). The Kaiser Bagh palace is a glorious example of Awadhi architecture built in 1847, by NawabWajid Ali Shah(Fig-2). It was a beautiful, multi-structured complex with four grand gateways and some minor gates with bustling bazaars, mosques, Nawab's durbar, residence and *Zenana*.After the uprising of 1857, the British Raj annexed the Kaiser Bagh area and demolished most of the northern and southern walls of the palace, residential quarters, enclosures of the mausoleum and part of the ChaulakhiKothi and built wide roads in 1858. Presently the Bus station, Collectorate, High court, Medical directorate, police station and NariShikshaNiketan school and College are all located in Kaiser Bagh having a very heavy vehicular traffic and footfall. The global temperatures have risen during the past century at a rate of 0.11^0F per decade because of climate change(Papayianni and Stefanidou, 2001) and the historical monuments too are affected by it.

Lucknow has a composite climate, with four seasons: the summer is hot with dry dust laden winds(loo); the monsoon is less hot and humid; the autumn is with moderate temperatures and lower humidity; and cold winter. The average climate is given below(Climate data, 2011):

Air Temperature and humidity

May is the hottest month of the year with average maximum temperature being 41.2°C, while January is the coldest month with average minimum temperature being 5°C. In summers the relative humidity(RH) is below 25%; during monsoons the RH is about 78%-82%, with an average temperature of 32.5°C to 34°C.

Rainfall

Monsoon season is between June to September with an average annual rainfall about 940mm.

Solar Radiation and Sunshine

Lucknow experiences 8-10hours of sunshine from October to June and 5-6hours during July to September. The average solar radiation on a horizontal surface in June is 20.2MJ/m2 per day.

Wind Speed

Easterly wind flows with the speed in the range of 8 to 10km/hour from May to September. Though the winters are not bitterly cold but are marked by temperature fall to 3^0-4^0 with mist and fog in the mornings and chilly winds.

METHODOLOGY

The research design consisted of the observation method which was a primary survey of the historical monuments/site and samples of lime stuccos were collected for analysis in the lab (Fig-3a,and b). A comparison was drawn with the earlier photographs and literature. The extent of weathering was studied by considering physical, chemical, biological and microbiological factors.

Fig-3 a) weathered lime-stucco collected from Kothi Roshan-ud-Daula b) New plaster prepared for restoration

RESULTS AND DISCUSSION

The architectural heritage is unfavourably affected by the changing natural environment and extreme climatic conditions(Tavukçuoğlu, 2000). Atmospheric environment affects the historical monuments and their structure beginning from the day of their construction. Weathering results from temperature differences between summer-winter and day-night, water movement in the building due to capillary action, abrasive effects of rain-water and chemicals dissolved in water, particles carried by wind and air pollution. The environmental factors influence the degradation processes in the following way- **Physical Changes-**

Neil Gate

Lucknow's Neil Gate(Sher Darwaja) was a Gateway to Kaiser Bagh, constructed 150 years ago, and situated at the southern end of the present Globe Park. It has a pair of tigers seated on its top and was painted white and red. The upper part of the gate is missing due to weathering (Fig-4b).

Victoria Memorial(Begum Hazrat Mahal Park)

Victoria Memorial was built in 1904-1908 by the British, as a marble *chhatri*, on a raised platform of red sand stone with steps all around with a bronze statue of Queen Victoria. The main*chhatri* is a marble dome placed on an inverted lotus with four octagonal*chhatris* and four doorways. It has elegant*toranas*, *mehrabs*, pillars with carved floral motifs(Gupta, 1997). The monument is preserved by ASI and the statue of Queen Victoria is missing.

Tomb of Saadat Ali Khan

Located opposite Begum Hazrat Mahal Park, the tomb(*Makbara*) was built by the King Ghaziud-din Haider(1817-1827). It has five octagonal *chhatris* with the central one being the biggest and fluted and octagonal marble floor in a chessboard pattern. The main hall has rectangular verandas on two sides and pillared kiosks with domes at the corners. The ceilings within the tomb has intricate motifs. There is a perfunctory tomb in the main hall and the actual one is in the basement. Over grown plants have created cracks in the chunam and exposed the lakhauribricks(Fig-4a).

Fig. 4 a) b) c)

a: MakbaraSaadat Ali khan; black crust and flaking of plaster exposing *lakhauri* bricks b: Neil's Gate; visible colour change, loss of plaster as powder c: Tomb of MushirZadi; *Flostectorii* degradation by Actinobacteria

Tomb of KhursheedZadi

Another tomb of KhursheedZadi was built by Ghazi-ud-din Haider by the side and similar in structure to Saadat Ali Khan's tomb. The underground vault contains two graves(KhursheedZadi and her daughter). *Flostectorii* degradation by Actinobacteria is visible all around(Fig4c).

PariKhana

NawabsWajid Ali Shah built a PariKhana between the tombs and Safed baradari for cultural activities. The central hall of the building was adorned with several chandeliers and has a marble courtyard with ceramic flower pots. Opposite the main building is the garden with lamp posts, marble sculptures and a canal with a marble bridge. Today, the PariKhana houses the Folk Art Museum and Bhatkhande Music University. Severe weathering was observed in PariKhana with change in colour, detachment of parapet, material loss as powdering, granular disintegration, exposure of bricks, deposition of black crust, crack formation with numerous plant species inhabited by fungi, microorganisms and insects (Fig-5).

Fig-5. PariKhana: visible change in colour, detachment of parapet, crack formation with plants

Safed baradari

Safed baradari or qasr-ul-aza of Lucknow was built in 1854by Wajid Ali Shah in white marble on a raised platform or plinth with twelve doors, elaborate corridors, halls with stained glass windows, glass chandeliers and two marble statues. The entrance has octagonal pillars having intricate floral patterns. The hall is now used as a community centre. There was visible material loss as powdering, granular disintegration and deposition of black crust with seepage. The stucco work had been replaced by cement during restoration but has weathered again.The metal emblem and the tiger statue is damaged. Both the marble baradaris in outer gardens are blackened and heavily damaged(Fig-6).

Fig-6 Safed Baradari visibly damaged.

Ameer-ud- daula library

The present library building is an Awadh-European architectural beauty, which was gifted to the Government of the United Provinces by the Talukdars of Awadh in 1926.The library houses 2lakh books and offers ancient Buddhist, Islamic and Hindu literature. It has been recently restored by ASI.

LakhiDarwaja

NawabWajid Ali Shah built two LakhiDarwajas in a lakh rupees each in 1850. Both have a central intricate polygonal gateway with two smaller pseudo gateways on either sides. The passage is rectangular and vaulted which is buttressed by two large semi-circular platforms and rectangular chambers. A pair of rectangular *"burjis*" with spiral staircases are present on the top corners. The rounded archways are superimposed with intricate stucco designs. The first two spandrels of the arch have mermaids in metal and stucco respectively. The topmost spandrel bears a pair of nawabidecorative fishes.

The visible damages in LakhiDarwaja are: change in colour, crack formation with plants, material loss as powdering, granular disintegration, loss of stuccos, *Flostectorii*deposition of black crust on the plasters, growth of fungus and microorganisms, inhabited by insects, pests rodents and birds etc., the mechanico-biochemical decomposition of the wooden gates, roof, damaged, rusted iron gates (Fig-7).

Fig-7 LakhiDarwajas in dilapidated state.

Kaiser Pasand/ Kothi Roshan-ud-Daula

It was built around 150 years ago by Mohammad Hussain Khan(Roshan-ud-Daula) and later used by NawabWajid Ali Shah who renamed it as *QaiserPasand*. The Kothi was built on the Indo-French style with two basement levels and four levels above the ground. The north east and north west corners on the ground floor have two edifices designed as Nawabi Mosque with a portico in the north supported by gigantic fluted columns. The Kothi is replete with beautiful and creative artistic minarets, columns, arches and art galleries. The Kothi served as the District Court during the British rule (Roshan-ud-Daula*Kutchehry*) and now houses District Election Office and State Archaeology Directorate.

The original Kothi was defaced by the demolition of the top floor. Change in colour is obvious with black crust deposition, with detachments as scales and flakes of the chunam, crack formation with plants, material loss as powdering, granular disintegration, development of fungus and microorganisms, and is infested with insects and termites(Fig-8).

Fig-8 Defaced Kothi Roshan-ud-Daula

Chaulakhi Kothi

The ChaulakhiKothi was made by Wajid Ali shah's barber Azimullah khan that was later seized by the Nawab and used as a palace. It was mostly destroyed by the British troops and is presently used as residence. Weathering is seen in falling parapets stuccos, chunam, windows, doors and blinds (Fig-9).

Fig-9 Remains of ChaulakhiKothi , Kaiser Bagh Circle, Kotwara house The ambient air quality (AAQ) for the year 2008, 2009 and 2010 as depicted in the figures indicate PM_{10} much above the NAAQ level and NO_2 is almost the same as the threshold limit (Fig-10)

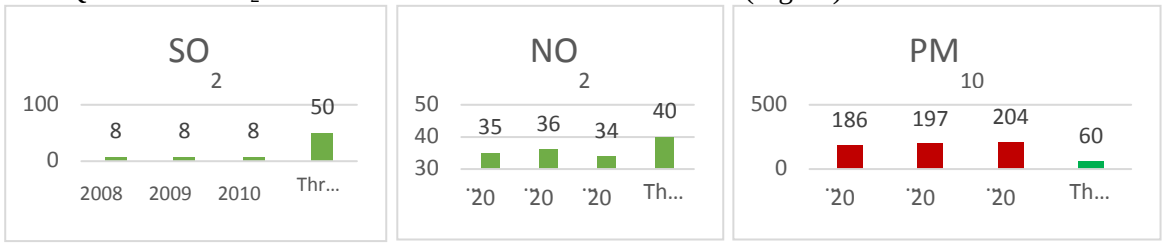

Fig-10 Ambient Air Quality of PM_{10}, SO_2 and NO_2 (µg/m)

- The high velocity winds carried these solid micro-particles (PM_{10}) that was responsible for the abrasions of the exterior surface
- Repeated salt hydration and dehydration cycles, lead to change in colour of the lakhauri bricks to light orange.
- increased intensity of UV rays due to ozone depletion was responsible for early change in colour.
- change in temperature(ΔT), causing the precipitation reaction of water with chunam and *Surkhi*to stain the exterior.
- change in relative humidity(ΔRH)by seepages in stucco increases the adsorption of water causing swelling and detachment in form of powder.

Efflorescence

The sulphates of the magnesium, calcium or sodium after dissolving migrate to the surface and crystalize as spots or stripes on evaporation as efflorescence(powdery deposits).

Chemical Change

The heavy vehicular traffic due to the bus station opposite Kothi Roshan-ud-Daula is responsible for the high level of NO_2 and SO_2 causing acid rain(Kanani and Zandi, 2011). Calcium carbonate, the main component of marble, lime stone chunam and mortar is not soluble in water. Nevertheless, the acids carbonic, nitric and sulfuric acid, transform $CaCO_3$ into soluble salts which are washed away, causing corrosion on the surface.

Carbonation -

$CO_2 + H_2O + CaCO_3 \rightarrow Ca(HCO_3)_2$

Sulphation -

$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + CO_2$

$CaCO_3 + SO_2 + H_2O \rightarrow CaSO_4.2H_2O$

Nitration -

$CaCO_3 + HNO_3 \rightarrow Ca(NO_3)_2 + CO_2 + H_2O$

$Ca(NO_3)_2 + 4H_2O. \rightarrow Ca(NO_3)_2.4H_2O$

Black-crust formation –The formation of the soluble mixture of calcium carbonate, nitrate and sulphate sometimes evaporates leaving black carbon particles on the surface, black crust. The degradation processes corrodes 50% of marble structures by salt crystallization and black crusts.

Weathering of chunam

$CaCl_2 + H_2O \rightarrow Ca(OH)_2 + HCl$

$CaSO_4 + H_2O \rightarrow H_2SO_4 + Ca(OH)_2$

$CaCO_3 + H_2O \rightarrow Ca(HCO_3)_2 + H_2CO_3$

Metal corrosion: More precipitation, particularly in a warmer climate, increases the corrosion in *chattris*, iron hinges and iron gates.

Rusting of Iron-

i) $4Fe + 3O_2 + 6H_2O \rightarrow 4Fe(OH)_3$ ii)

$Fe(OH)_3 \rightarrow FeO(OH) + H_2O$ iii)

$2FeO(OH) \rightarrow Fe_2O_3 + H_2O$

iv) $Fe_2O_3.32H_2O$ (Rust)

Biological factors

Biodeterioration is the degradation in colour caused by biogenic pigments and accumulation of biomass by photosynthetic microorganisms(Gaylarde and Morton, 1999).The bio receptivity (Guillitte, 1995) of lime mortars and lime plasters depends on environmental factors, such as availability of moisture RH, low pH, and source of nutrients, and petrological changes(Ariño*et al*. 1997). High porosity leads to a deep penetration of moisture (Warscheid, 1996) and with solar radiations stone flaking and crusting provide protection for the microflora colonization. Increase in relative humidity in the warm climate of Lucknow creates an ideal environment for the development of fungus and microorganisms (Yaldiz and Balwois, 2010, Nedelcheva, 2011). Salts and biological growth of Actinobacteria act together and produce degradation in a flower like pattern called *Flostectorii*(Brancato, 1986).

Biocorrosion

Biocorrosion is caused by the microbial secretion of inorganic and organic acids causing little holes (Kurakov*et al.*, 1999) and flaking of the surface (Resende*et al*. 1996). The different types of degradation was observed due to following t biotic agents-

i) Photo-litho-autotrophic organisms(algae, cyano- bacteria, mosses and higher plants) causing blackening of the surface by photosynthesis and trap CO_2 from the atmosphere producing organic carbon.

ii) Chemo-litho-autotrophic bacteria (*Nitrosospira, Hydrogenophagapseudoflava, Thiobacillusthiooxidans, Methanobacteriumthermoautotrophicum*) use inorganic compounds (i.e. NH_3, S) to obtain energy and produce (HNO_2, HNO_3, H_2SO_4).

iii) Chemoorganotrophic bacteria(*Pseudomonas pseudomonas*) and fungi use organic substrates and release complexing bio-corrosive organic acids or weaken the mineral lattice through the oxidation of metal cations such as Fe^{2+}or Mn^{2+}

Plants and trees like *F. benghalensis, F. religiosa, Azadirachtaindica*, *Punicagranatum* were found to grow randomly on buildings by lodging of seeds through winds, birds and animals. They grow on the surface of the buildings by developing the roots deeply inserted in the wall and roof resulting in cracks. The secretions of roots attack building materials, and together with their mechanical force opens cracks, crumble and loosen bricks and large fragments of wall. The plants grow on stuccoes too, causing the plaster to fall away. Partial removal of the plants are an insufficient and temporary measure because the root living inside the wall acts as a substrate for microbial activity and the decaying of roots creates space which gets infested by ants and termite.

Wood: Decay by fungi, algae, mould, lichens and termites led to the collapse of Darwaza or wooden gates. (Brimblecombe*et al.*, 2011) The energy used by fungi, termites etc is derived from cellulose and hemicellulose of wood (Kirk and Cowling,1984) Respiration by fungi and other destructive organisms -

$$6nCO_2 + 5nH_2O + 677{,}000n \text{ calories} \longrightarrow (C_6H_{10}O_5)_n + 6nO_2$$

(cellulose and hemicellulose of wood)

Experimental

1. 1gm powder of sample **a** and**b** were dissolved in concentrated HCl.

Result: the sample b dissolved in HCl by the evolution of CO_2 indicating the presence of lime. The residues was washed with H_2O which dissolved partly in ethanol and chloroform indicating that the chunam contained organic material.

CONSERVATION

The remains of Kaiser Bagh palace is still a home to the descendants of nawabs and talukdars of Awadh, and over the course of time, the monuments have incurred significant loss in their structural integrity due to the weakening of the foundation pillars, columns, ceilings, etc. Vegetation, mostly weed is also found growing over older buildings. Water seepage is another problem which renders older buildings weak. Conservation of buildings has to be done sustainably by minimising the use of new natural resources by preventing the wastage of existing resources and providing economic value through tourism revenue and maintaining the well-being of residents(Tepper*et al.*, 2011)Planning policies for both heritage conservation and sustainable design can be done by 1)Structural Conservation and 2) Chemical Preservation.

1) Structural Conservation by Retrofitting on foundations, roof ceilings and walls to restore the basic structure of the building. Reductions in greenhouse gas emissions with minimum damage to plaster can be achieved by Energy efficient air-conditioning.
2) Chemical Preservation

The weathering of the earlier restoration of lime stucco indicates that it lacks that the right ratio of lime (*surkhi)* marble dust, sand and organic component(Khan, 2009). Therefore it is important to identify the exact combination of soft lime-stucco suitable for restoration as prevalent in other part of the world (Grimmer *et al*., 1995).

Conclusion

In recent years, the alterations in the natural environment and climate change have negatively affected the historical monuments of Kaiser Bagh. The severe fluctuations in temperature (ΔT), moisture (ΔRH), and together with environmental pollution especially greenhouse gases (CO_2, CH_4, SOx, NOx, VOCs) causing acid rains have damaged the construction. Local authorities and the state archaeological department should recognise that heritage assets are an irreplaceable resource and must conserve them in a manner appropriate to their significance.

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