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Improvisations in Traditional Lime Work, Punjab, India

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Abstract*: *Restoration work with traditional materials is a challenge. Every material and technique has its own potential, strength and weakness which, should be analysed before implementation. The aim of the paper was through a project of restoration establish that traditional restoration need not be restrictive in usage of traditional materials and techniques alone but can improvise on the same with judicious use of contemporary materials and techniques of building.
Keywords: Traditional Lime work, Restoration, Historic Structure, Lime Mortar, Lime Plaster, Punjab

I. INTRODUCTION

Restoration techniques of traditional structures in India are a crucial aspect to conserve the vast built Heritage it proudly holds. The monuments of national and regional significance mostly are under the able care of Archaeological Survey of India, an autonomous Government organisation restoring and preserving sites. The unattended unlisted privately owned smaller yet significant structures are the subject of concern for conservationists in India. These smaller structures in absence of appropriate guidance and supervision carry out restoration jobs rather detrimental to the structure in long run. Restoration work with traditional materials is a challenge. Every material and technique has its own potential, strength and weakness which, should be analysed before implementation. The aim of the paper was through a project of restoration establish that traditional restoration need not be restrictive in usage of traditional materials and techniques alone but can improvise on the same with judicious use of contemporary materials and techniques of building.

The case for study is a traditional historic Havelli (Mansion) in Punjab restored by the author as site Conservation Architect under the guidance of CRCI, New Delhi. The project was completed in a span of 6 months in 2008. Many a restorative techniques used are non-conventional and help in giving a new direction to the traditional processes of restoration.

A. The most common and critical defects found in traditional Punjab residences alike the Havelli in consideration are:

1) Rising Damp in walls sometimes upto 3ft.
2) Seepage and sagging of Roofs
3) Cracks and other defects in walls

To rectify the above defects and restore the Havelli, the following measures were planned:

B. To treat rising damp

1) Cause: The traditional residences were constructed of thick masonry walls (ranging from 500mm to 1500mm) either in brick or stone protected by lime or mud plaster. These traditional plaster renders had a typical feature; they were porous in nature which allowed for air movement across the thick wall sections. This movement of air ensured effective evaporation of trapped moisture in walls, thus rising damp of walls due to movement of ground water and capillary action was never stagnant in walls(Jan Válek, 2012). Thus the removal of cement plaster and re-plastering in traditional lime was effective. Another cause for rising damp was non-existent damp proof course in walls and surrounding areas in traditional structures(M. Isabel M.Torres, 2007). Thus provision of a porous plinth protection both from inside and outside of wall becomes a significant measure to arrest rising damp in walls. damp is also high in present times as against earlier since the surface and roof top water has no permeable surface to recharge the ground water due to introduction of impermeable cement concrete flooring layer. Thus the measure of removal of concrete flooring and laying of traditional porous brick flooring in courtyard was undertaken.

2) Remedial Measures taken:

a) Removal of internal wall plaster upto 3ft
b) Removal of complete external wall plaster.
c) Excavation and checking for broken pipe lines for water leakage source.
d) Removal of concrete flooring from courtyard and replacement by brick traditional flooring
e) Introduction of a porous plinth protection both inside and outside of rooms

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f) Racking of loose motor joints and repointing in lime
g) Re-plaster of internal wall in lime

C. To treat seepage and Sagging of Roofs

1) *Cause:* The seepage of the roofs was primarily due to absence of any kind of waterproofing layer and deterioration of mortar joints on the top layer of bricks. This can be arrested by relaying the roofing layers and introduction of a water proofing layer that shall ensure complete water tightness. The slopes of terrace need to be worked out appropriately to ensure efficient water drainage and avoid stagnation of water at any point which may lead to seepage. The sagging of roof and other structural distresses in roofs can occur due to deterioration / weathering of members of roofing like; wooden beams/purlins, iron beams/purlins etc. The members in most cases might seem structurally stable on visual inspection but the ends of these members embedded in walls are the most vulnerable areas for deterioration and might be in a state of distress. Thus checking of ends of these members by inspecting the wall ends by opening them up is absolutely essential to understand the state of the roofing.

2) *Remedial Measures taken*

a) Removal of each layer of roofing
b) Checking of wooden beams and purlins embedded in wall ends for signs of deterioration
c) Study of structural distress
d) Consolidation of wooden beams wherever possible
e) Replacement of deteriorated wooden/iron beams and purlins
f) Reroofing with appropriate water proofing layer
g) Finishing of roofing with khurra and water channel complete.

D. To treat cracks and other defects in walls:

1) *Cause:* Cracks in masonry walls can be of different types and may have varied causes, both the type and the probable cause of the crack need to be identified first before restoring it. Cracks can be majorly of two types; structural and non-structural(Sowden, 1990). The plasters of the walls from areas immediate to the crack need to be removed for inspection as the first step. If the crack is non-structural it would be a crack in the fabric, i.e. in the plaster and shall not be evident in the masonry. Such cracks are least harmful and a re-plaster job can take care of such superficial cracks, but if the crack is seen evident in the masonry then it is structural in nature and has to be stitched back to avoid further structural distress and possibilities of future collapse. The position, direction, width and length of crack determine to a large extent the severity of the crack and the probable cause of the crack. Most common causes are uneven settlement of foundation due to movement of earth or overloading of the structural members. In case of settlement of foundation, the foundation has to be unearthed at concerned locations and strengthened. In the Havelli in consideration the point load subjected to the iron beams due to absence of wall plate caused majority of the cracks. Other structural masonry cracks were also observed on the external wall surface. In critical projects is advised to monitor the cracks to see if the cracks are alive or dead. This can be done by fixing a piece of spanning across the width of the crack, with passage of time if the glass breaks then it becomes ovious that the crack is alive and growing. This is monitoring is done over a period of a few months to a year. Live cracks are more critical and need to be addressed with utmost care.

2) *Remedial Measures taken*

a) Checking of cracks by removal of plaster
b) Analysing of cracks: their type and cause
c) Measures to check further development of cracks like introduction of wall plates underneath beam/purlin heads
d) Filling up of cracks with lime grouting
e) Consolidation of wall by re-walling

II. THE WORK IN SEQUENCE OF EXECUTION

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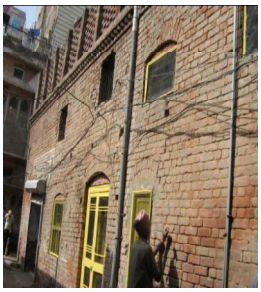
Cement Plaster removal



Raking of Pulverised Joints

Nature of Crack exposed by removal of plaster.

Plaster removal for hydration of masonry

A. Removal of external fabric for defect condition exposure

1) *Plaster removal*: The very first step taken was to expose all the wall surfaces and get rid of the multiple layers of white wash and cement plaster. The complete external wall was exposed to check the status of the masonry beneath; the condition of the brick and the mortar joints. Salt of crystallisation was observed on the wall surfaces due to rising damp. The plaster on the internal wall surface was removed till the height of 2ft. the thus exposed wall surface was left to dry and the trapped moisture in the walls to evaporate due to aeration. This process of drying can take days and months together depending upon the extent of moisture content. Processes in restoration are time taking and need a lot of patience to be dealt with for best results as against the tendency of fast production in contemporary construction.

2) *Raking of joints*: The mortar joint at many places was found pulverized (deteriorated into powdery form due to weathering). Thus the mortar joints were raked from the complete external wall surface. This step as well as the removal of the plaster is done with utmost care so that the masonry material; brick is not damaged.

3) *Analysis of Cracks*: The plaster along the cracks on the internal surfaces of the walls was removed to check the nature of the cracks.The cracks were caused due to point load subjected on the walls through the iron purlins embedded directly over the wall and not evenly distributed over a plate bed/plate. At many other places wide structural masonry cracks were also observed, stitching of which was planned as the next course of action in due time.

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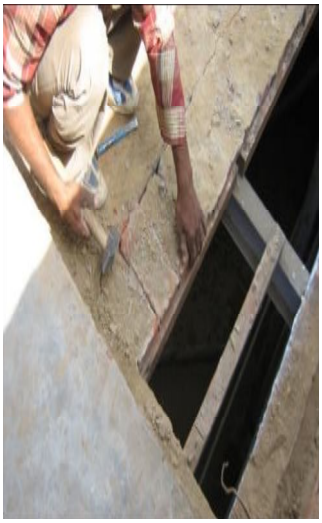
Removal of finishing brick

Removal of earth layer



B. Removal of layers of roofing for defect condition exposure

1) *Shifting of valuables:* A plan was worked out to understand the sequence of rooms to be restored. Before the roofing works begin the movable furniture and other valuables from the room were shifted to other rooms to be restored at the later phases.
2) *Removal of finishing layer of roof:* The top finishing layer of the roof was traditional bricks in mud mortar. These were carefully removed piece by piece and were neatly stacked after cleaning with water. In traditional restoration works the objective is to reuse traditional materials as much as possible so all process of removal and stacking of the older material are done with utmost care. Wastage during removal process is minimized.
3) *Removal of earth*: The earth filling is removed by ploughing all the earth to the room below
4) *Removal of brick layer*: The bottom most layer of the traditional bricks are removed. These again are done with care to reduce on breakage and wastage so that they can be reused at a later stage. The brick surface at the soffit of the roofing was white washed white; this shall be upturned and reused.

This process of removal of the roofing layers is done to a few roofs simultaneously.

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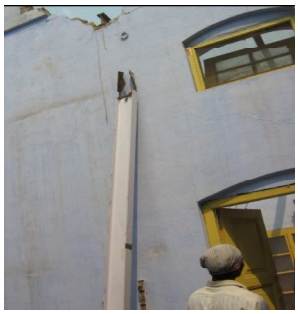

Corroded iron girder end

Insertion of wall pad

Welding of hollow steel pipes

Strengthened beams

C. Checking of Iron Girder Ends and structural strengthening

1) *Iron girder ends*: The iron girders in one room seemed to be sagging while in rest of the rooms the girders on visual inspection seemed stable before removal of the roofing. Once the roofing layers were removed, the ends of these girders embedded in wall were exposed. This brought to light the most precarious condition of the girders, unimaginable during visual inspection. In the past it seems that the original wooden purlins were replaced by iron girders, during which time a blunder was committed by the masons. The iron girder was embedded in masonry with lime mortar joints. Lime has a highly corrosive effect on iron, hence they should never be placed in close proximity to each other, this was not taken into cognizance by the earlier masons, due to which the iron girder ends in contact with lime mortar corroded over the years. The girders would have collapsed any moment if not checked and replaced. The masonry in immediate contact with iron girders were laid in cement mortar 1:2, while rest of the wall was restored in lime mortar 1:2.
2) *2. Wall pad insertion*: The cracks in masonry due to point load of girders positioned directly over wall surface were a cause for concern. Thus, a wall pad of deodar wood, 450mm x 200mm x 300mm treated with anti-termite portion was inserted as a wall pad over which the iron girders were made to rest at the centre. This would ensure that load of the girders gets evenly distributed over the wall and cracks would not develop due to point load.
3) *Structural strengthening*: As per the advice of structural engineer the iron girders were structurally strengthened by stiffening of ends. This was achieved by welding iron hollow pipe sections 32mm nominal bore size, 2.60mm thick weighting 2.54kg/m at the ends of iron girders.

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Removal of wood end Deodar wood planks

Insertion of wood pad Wooden purlins laid

D. Wooden beam consolidation

The original wooden beam in one of the rooms was in a good state but the ends were deteriorated due to moisture content in wall. This end section of the wooden beam was consolidated. The weathered part of the beam was chiselled and removed. The end was encased within new planks of deodar wood 20mm thk. and the gap was filled with wood shavings mixed with resin of industrial bonding. This beam was then rested upon wooden wall pad.

Anti-Termite treatment of purlins Wooden spacers for purlin placement

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First layer of tile laid Soffit of roof restored

E. Re-roofing

1) *Laying of wooden purlins*: Wooden purlins were checked for any defects and those found structurally stable were reused. Others were replaced by purlins of same size as originals, 65mm x 50mm in cheer wood. Purlins were cleaned of any dirt and grime. Thereafter, all the purlins were treated with application double coat of termite proof mixture of burnt engine oil and turpentine oil in 1:2 proportions. The centre to centre distance between purlins was maintained at 230mm c/c. as wide as the brick length. The wooden purlins are fixed in position c/c by fixing small wooden batten pieces as spacers between two purlins. These spacers are positioned above iron girders and they help in avoiding the dislocation of purlins while placing the top layer of brick tiles.
2) *First layer of brick*: the first layer of brick was laid over the wooden purlins, reusing most of the original bricks and by inter changing the face of the brick. Whitewashed brick faces were laid facing the terrace as against their earlier positions when they were facing below.

Second layer of brick tiles PCC Layer

Water proofing layer laid Mud Phaska Fill

3) *Second course of brick*: The second layer of brick tiles was introduced to increase the load bearing capacity of the original roof. This second layer was laid in opposite direction to the first layer of bricks making sure to break the joints. This layer was laid in cement mortar as against the traditional system of laying in lime mortar. This variation was undertaken to make the joints water tight. Lime is porous in nature and cement is impervious ensuring water tightness
4) *4. PCC Layer*: Plain cement concrete layer 50mm thk. is laid over the double tile layer. This is an improvisation of the traditional system of roof layering to ensure water tightness.

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5) *Waterproofing layer*: A five layered polyethylene water proofing layer was laid above the PCC layer. The most important aspect to be taken care at this stage is that the waterproofing layer should be continued upto one feet of the parapet wall and tucked in properly into a jhirri (niche) cut into the parapet wall.

6) *Mud layer*: The PCC layer was covered by mud phaska layer to slope of 1 in 40. The mud used for mud phaska has to be free from impurities and aggregate. The right amount of moisture is ensured in mud. The mud layer is well compacted with wooden thapis (wooden bats for compaction). This layer of mud is laid in not more than 100 mm compacted thicknesses.

Mud mortar preparation

Brick tile on mud mortar

Finished brick tile layer

Neat cement slurry

Casting of drainage

Finished drainage at terrace

Khurra at Terrace

Restored Roof

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F. Terracing finishing layer

1) *Brick tiles in Mud mortar*: The maximum no. of original tiles were reused for the final layer of brick tiles in mud mortar as the finished layer for terracing. Mud mortar was worked out and the thickness was 20mm for laying the brick tiles. This top layer is then finished with a neat cement slurry layer. Curing was undertaken for seven days and cracks in joints were re-filled to achieve an even sloped water tight terrace surface. The entire surface of terrace was divided into two parts for efficient drainage of water. Open water channel was constructed at the junction of the two terrace surfaces. This water channel was constructed in PCC 1:2. The terrace was completed with gola in cement mortar 1:2 and khurra at appropriate positions to drain terrace surface water in parts of terraces isolated.

G. Consolidation of walls

The walls which were scraped off their plaster at the very beginning of the restoration process has enough time to dry off and the moisture content was negligible making them ready for consolidation. The walls were to be consolidated by repointing in lime mortar 1:2, lime grouted , masonry stitched with lime mortar 1:2 and finally lime plastered 1:1 on the internal surfaces.

1) *Lime mortar preparations*: Lime products are derived from naturally occurring limestone (Calcium Carbonate $CaCO_2$). Limestone from quarries is grinded and fired in kilns at the appropriate temperature, which results in emission of carbon dioxide (CO_2) and as a result Quick Lime (Calcium Oxide CaO) is formed. This form of quick lime is then brought to sites for further treatment. Care should be taken to select freshly fired quick lime and not the batch exposed to atmospheric moisture, since such a lime is already undergone the process of hydration. Quick lime on site is slaked in pits dug in ground for months together. The longer the duration of slaking the better shall be the strength of the lime mortar. Care should be taken to immerse quick lime chunks into a water tank and the reverse of pouring water over lime chunks is avoided since hydration of lime (slaking process) is highly exothermic in nature. Lime after hydration forms Calcium Hydroxide ($Ca(OH)_2$). This hydrated lime is then grinded with traditional stone chakki and other ingredients like sand and surkhi in 1:2:0.5 proportions are added. The entire mixture is grinded slowly and thoroughly mixed to get the appropriate consistency. Use of metal grinders as used for cement concrete mix. Should be avoided as lime has a corrosive effect of metal and metal chunks from the drum of mixer erode and get mixed with lime mortar and results in reduced strength of mixture. The lime preparation when used in buildings with time undergoes the process of carbonation and the evaporation process lets out the water content in the mixture, thus by emission of moisture (H_2O) and combining with carbon dioxide (CO_2) the mixture attains back its original natural form of Calcium Carbonate ($CaCO_2$) and becomes most stable and hence most sturdy(Alison Henry, 2012). This entire process of lime cycle is extremely slow and thus it is seen that lime applied in buildings attains maturity and strength with passage of time slowly with the process of carbonation.

Local Small Lime Kiln

Lime Chakki Amritsar

Monolith stone for chakki to grind mortar

Lime mortar storage to retain moisture

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Soaked Methi seeds

Soaked Bel fruit Pulp

Urad Dal (Pulse)

Jaggery

Lime mortar for pointing (masonry mortar joints) was mixed in lime: sand: surkhi 1:2:0.5 proportions. Lime mortar for lime plaster was mixed in lime:sand:surkhi 1:1:0.5 proportions. Other locally available additives are added while preparing lime mortar for plaster. Lime mortar needs to be saved in a hydrated form so that the process of carbonation dose not initiate before its application on the building. Thus a hollow mound of lime mortar is filled with water to provide for adequate moisture at times of storage.

2) *Lime mortar additives for plaster:* The additives used for the case in consideration were methi seeds (fenugreek seeds), urad dal (black lintel), dry Bel fruit pulp (Aeglemarmelos) and raw jaggery. The above ingredients are soaked in water for days together and then mixed in the lime mortar at the time of application while working the lime mortar into a completely grounded consistent mixture. 0.05 Cubic feet of additives are added to 10 cubic feet of lime mortar approximately, just enough to make the lime mixture workable and not too slurry, yet enough to infuse the qualities of the additives into the mixture. Methi seeds, Bel pulp and jaggery add starch to the lime mixture and enhance the plaster's adhesive quality while the grounded lintel acts as an air entrainer in the mortar mix. The additives have regional variations as per suitability to particular whether conditions and availability of material, the general effect on mortar being the same. The ratio of surkhi added to the lime mortar renders the different shades of plaster ranging from buff to light pink shades.

Lime plaster is done traditionally in three coats, the thickness of the coats reduces from base layer being 45mm thick to final top layer being 20mm thick. Each layer is allowed to mature before the next layer is coated. Appropriate curing is carried out during this intermediate period. The two base layers are consolidated by beating the rendered surface with a wooden thapi and a retouch is done till no fine cracks appear on the dried surface. The layers of plaster are smoothen with wooden flat bars as against iron metal flats used in cement plaster rendered surfaces, since lime as stated earlier has a corrosive effect on iron.

Restored lime plaster

Restored Lime pointing

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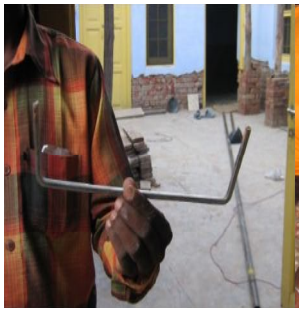
3) *Lime grouting*: lime pressure grouting was undertaken for consolidating a crack in masonry. The crack was first stitched with mild steel C Pins of 10mm dia. Thereafter, the crack was filled with lime grout forced into the fissures of the masonry through a grouting machine. The lime forced with pressure reaches the internal fissures of the masonry and fills in the gap. This operation though proved to be a failure in the said case and the wall in 24hrs time bulged out. After further investigation into the cause of the same, it was learnt that the wall so treated has internal mud mortar layer and the thus the mud after absorption of moisture from lime grout swelled up causing the bulging effect in the wall.

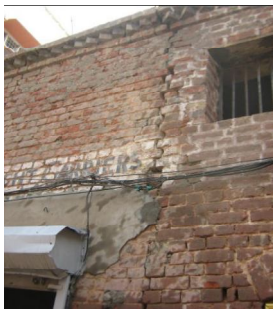


Mild steel C pin

C Pin Staple on wall crack

Lime grouting mixture

Lime grouting of crack



Crack in masonry

Crack masonry opened up

Consolidated restored wall

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4) *Masonry consolidation through rebuilding*: Many cracks in the masonry which were only one course deep were restored by removing the bricks and re-laying the masonry in lime mortar, carefully building in interconnected joints between the new and old masonry. The important aspect to take into account though is that before consolidating the masonry the probable cause for crack was identified and the corrective measures were taken so that the restored masonry might not fall under stress.
5) *Plinth protection to walls*: plinth protection was provided to walls both from the inside and outside of the building. This ensured check of rising damp in case of traditional walls lacking the damp proof course.

Plinth protection layer is built by filling up a trench 750mm wide and 200mm deep. The bottom layer is filled with dry lime mortar 50mm thk. Second layer is of sand 100mm thk. Third layer is of brick bats 50mm thk. Over this the brick tile on edge layer laid in dry lime mortar sloping outward. The rainwater drain pipes open on to the plinth protection.

The central courtyard was restored to traditional brick on edge concentric square in lime mortar. The base was lime concrete base with brick bats, judiciously avoiding cement concreting, hence providing a pervious layer of flooring to recharge rain water. All floorings were treated with anti-termite solution to avoid infestation in future.

Sand and brick bat layer in plinth protection

Brick on edge plinth protection in dry lime

Plinth protection interiors of rooms

Restored brick on edge courtyard flooring

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Vegetation in wall joints

Parapet in distress

Vegetation removed

Terracotta tile restored

H. Miscellaneous

A Peepal plant had taken roots into the masonry of the Havelli, this could cause collapse of the wall if the plant was not removed. Plants if not carefully and completely removed have a tendency to regrow. The plant was injected with chemical compound which slowly dried up the plant. The masonry along the roots was removed to pull out the entire vegetation growth. Terracotta jaalis from the adjacent property belonging to the client were carefully removed and cleaned. These jaalis are rare as they are not casted anymore and have been replaced steadily be cement jaalis in the market.

I. Happy Hours

The young workers on site were mostly school drop outs due to varied reasons, but most of them reflected great potential and an outstanding level of grasping power for knowledge. The lack of basic education made them dependant on others in many ways. The objective hence was to provide them with basic knowledge of any one regional language and some understanding of basic mathematics so that they can manage their life and their earnings in better fashion. A retired school teacher was requested to come and teach the students Hindi and Punjabi while, author engaged in teaching basic numeric calculations. One hour of schooling in the morning everyday was very gracefully agreed upon by the client. The workers were incentivised to develop essential habits by taking small measures. Golak (terracotta saving pots) were gifted to all of them to inculcate much needed habits of saving. They were strictly prohibited to indulge into any intoxicating drugs and were informed about the risks in addiction.

Imparting basic education

Value of savings

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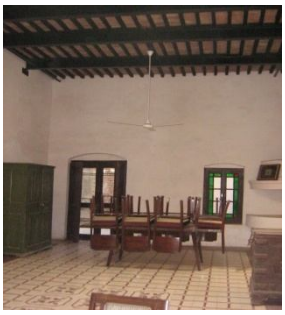
II. COMPLETED PROJECT



Restored roof & flooring

Traditional wiring restored

Restored Façade

Walls consolidated in lime

Traditional brick staircase

The Team

III. CONCLUSION

Every material whether traditional or contemporary should be used after analysing its potential, strength and weakness. Judicious use of traditional material should be done and compatibility of materials should be thoroughly checked before using a composite material culture. Otherwise, it might cause great risks and threats, like the case discussed in the Havelli where in Iron girders were exposed to Lime mortar in masonry ends, which resulted in corrosion of steel and thus structural instability. Understanding of materials plays a vital role in decision making, for instance in the Havelli, the issue of riding damp was resolved by dismantling concrete floors and cement plasters and replacing them by pervious brick flooring and lime plaster respectively. On the other hand the impervious nature of cement mortar joints and a PCC bed along with waterproofing sheet were used to attain a completely water tight roof. Thus in Historic buildings other than A and B grade heritage structures, changes in construction techniques using contemporary materials and know how should be encouraged but after taking into account the properties and potential of the same.

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IV. ACKNOWLEDGEMENT

The restoration work was being carried under the able Guidance and Supervision of the Head of Cultural Resource Conservation Initiative, New Delhi, India. CRCI, aims to preserve and promote India's cultural heritage with active community participation. The author was an employee on the organisation while executing this project and is only responsible for execution of project under guidance and documentation of the same, while the credit of improvisation of traditional techniques of restoration completely goes to CRCI. The well trained and experienced labour force having expertise in lime works and other traditional restoration works were the strength of the project. Their support and co-operation brought the project to a successful completion.
Lastly the author would like to acknowledge the unwavering support of the Client and her complete trust and faith in the team.

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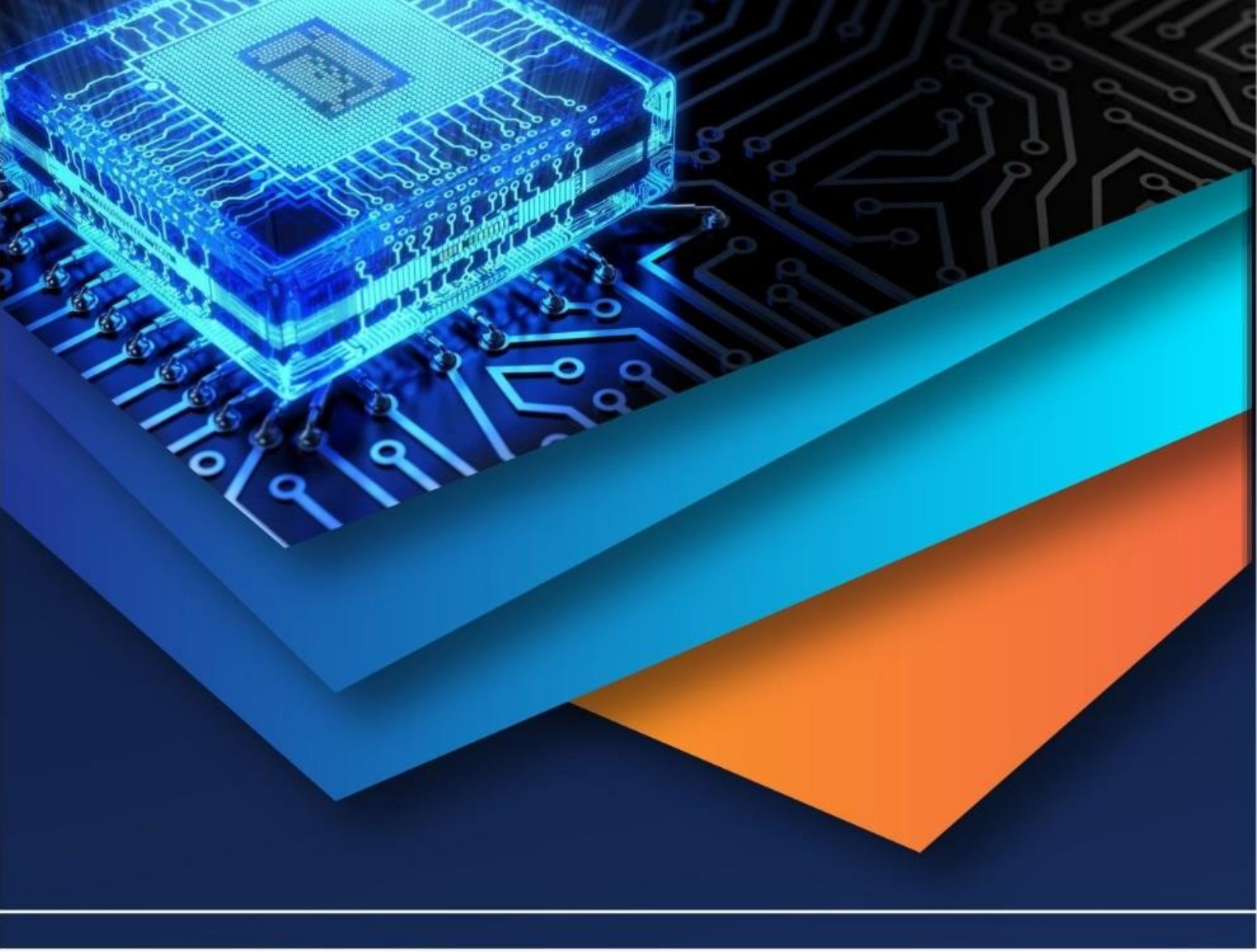

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