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Documentation for Restoration of a Heritage Educational Monument: A Case Study

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ABSTRACT
Restoration is the process of accurately depicting the form, features, and character of a property as it appeared at a particular period by removing features from other periods in its history and reconstruction of missing features from the restoration period. Heritage documentation is known as a systematic collection of tangible and intangible elements of historical structures and environments. This topic has become the subject of extensive research in recent years as it directly affects cultural value. This research study provides such documentation required for the restoration of a heritage educational monument. Two buildings from the College of Engineering Pune, Maharashtra (India), were selected, and documentation in plans, 3D Revit modelling, digital photography was used. The type of stone used for construction was basalt. The collected data was used in the identification of various defects and damages of the two structures. The classification of digital photographs according to the type of defect was done using a labelling tool, i.e., LabelImg software. The defects or damages identified were spalling, discoloration, jointing defect, fungal growth and stone damages. The factors responsible for these defects or damages were vibrations caused in the vicinity of structure and weather conditions such as rainfall, sun and wind. This study incorporated the suggestion of proper material and techniques such as Nano lime cement, Indentation, and Plastic repairs. This research work serves as proper documentation required for the restoration of the selected buildings.

Keywords **-** Restoration, Documentation, Digital photography, Revit 3D software, LabelImg software.

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I. INTRODUCTION

Restoration refers to the process of correctly revealing the state of a historic building, the way it looked in the past and recovering the structure same by various methods while respecting its heritage value. Heritage monuments and buildings are mute testaments of the glorious past of any country. In 2015, all United Nations (U. N.) members adopted the 2030 Sustainable Development Goals Agenda. The Agenda 2030 consist of 17 goals and 167 targets. Out of 17 goals, goal 11 focuses on heritage conservation, which states "strengthen efforts to protect and safeguard the world's cultural and natural heritage". The Archaeological Survey of India gives 116 monuments. However, there are more other monuments that various organizations and institutions are monitoring.

The preservation of heritage structure is a challenge faced by many countries. Documentation is the need for the restoration of any heritage structure. It stands as the systematic collection and archiving of records to preserve or restore them for future reference. Documentation should involve measured drawings, materials for construction plans, 3D prototype model, condition mapping via digital photography, identification of factors responsible for the occurrence of such defect/damages and suggestion of materials and techniques which can be used for future restoration [21].

This study aims to prepare such documentation for future restoration of a heritage educational monument using it as a case study. The monument selected in this study is India's third oldest engineering college, "College of Engineering, Pune (Maharashtra)". The College of Engineering Pune is 167 years old educational monument constructed in 1854 under the British regime using naturally available basalt stones.

II. LITERATURE REVIEW

Heritage conservation is a complex subject that requires many documentations from the past and present. Documentation is the first step towards the conservation of heritage structure. Generally, the heritage conservation authorities use the visual inspection method to investigate and assess the monument's condition. However, many heritage structures are assessable and unsafe due to complex designs and heights [25]. Various new equipment's and technologies were used to overcome such problems. The restoration study of the Roman monument "The Praetorian Gate in Aosta, Italy" was performed using Pentax Total Station for positioning of damages, Lecia Laser Distance Meter for surface crack detection and Z-scan calibration method [6].

Manual investigation and reports increased time and cost project. Hence digital close-range photogrammetry served as an alternative [5]. Other various technologies, equipment's and methods were devised to reduce the tedious work. The tacheometry, photogrammetry and computer graphics were used to restore the monument Neoria in Greece [14].

At times, stone monuments were challenging to analyze. Various monuments of different countries have different architectural construction and design types; hence different equipment, technologies, and methods were used for the restoration study. Pressure Stimulated Currents served as an adequate technique [16]. The Acoustic Emission and Digital Image Correlation techniques proved to be effective for restoring the monument Acropolis of Athens in Greece [13]. In the past times, various additives were used in lime mortar to enhance its properties. This study uses egg-white, surkhi, batasha, urad dal, jaggery, bel giri as an additive to examine the effect in lime mortar. The addition of animal glue increases compressive strength and reduction of porosity and is suited for jointing. Effects of the addition of olive oil, nopal in powder and mucilage form were also studied [7].

With the development of more technologies, 3D Laser Scanning and photogrammetry served as a tool for preventing, documenting, and disseminating heritage sites [17]. The Archaeological Survey of India (ASI) has 3691 sites under its vigilance which are national heritage monuments [21]. The educational monuments of India posed a problem for restoration. The modern codes, building standards, conservation criteria posed a significant challenge in restoring the Main Building of Pune University [10]. In India, a well-defined system was needed to classify various monuments such as Grade I, Grade II and Grade III [20]. According to Letellier et al., the meaning of documentation is the systematic collection of information and archiving of records to preserve them for future reference; this relates to the conservation definition specifically about extending the physical life of the historic place. The documentation for the stone monument St. Lambertus Church Monschau Kalterherberg / Germany was the first step towards its restoration [2]. West façade. The documentation of cultural heritage resources has significantly evolved over the 21st century and continue to evolve as long as technological advancements are made.

Many heritage structures of India are made up of stone and are firm to date. The type of stone used for a structure depended upon its availability and properties at that time. The Maharashtra region in India has basalt and laterite stones. Such stone in the construction of temples and forts in ancient times can be easily seen in Maharashtra. Some of the structures are old as the 7th century.

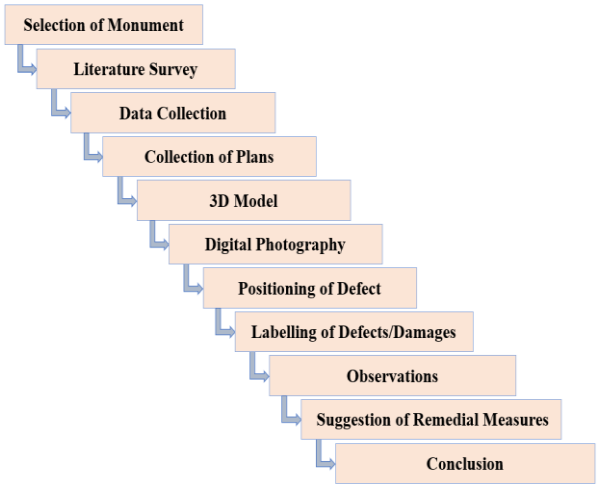
However, due to the age of structures, the deterioration of stone has been occurring. A research study was conducted on monuments of Khidrapur (Kopeshwar) temple and Panhala Fort of Kolhapur district of Maharashtra state. These monuments are made up of basalt and laterite stones. The X-ray diffraction and Scanning Electronic Microscope techniques were used to determine the chemical composition, and the effect of environmental factors on the stones was analyzed [27].

Moving from hand recording techniques to digital approaches like digital photography and laser scanning, we have documented and continue to document heritage sites in advance. With advancements in technologies and artificial intelligence tools, such tools have been essential in documenting heritage structures. The Surat city of Gujrat, India, has a rich amount of heritage structures. However, due to time, the heritage structures have been damaged. The artificial intelligence-based tool R-CNN has been used for its documentation purpose [26]. Such advanced technologies made the documentation work easier.

However, more technologies are being developed to facilitate the restoration and conservation of heritage structures.

III. RESEARCH METHODOLOGY

The adopted research methodology is given in the form of a flowchart. From the literature review, the methods and equipment's were identified, and suitable method and equipment's for this research study were selected accordingly.



IV. CASE STUDY: COE, PUNE

The College of Engineering is situated in the Shivaji Nagar area of Pune city of Maharashtra state in India. Maharashtra state is rich in basalt and laterite stone; the College of Engineering was built using basalt stone and lime mortar. Basalt contains plagioclase, pyroxene, feldspar, augite, hornblend, olivine and iron oxide as minerals [27]. The monument consists of many buildings; the criteria for selecting buildings were that the structure should be more than 100 years old. Based on this criterion, two buildings were selected, which is Civil Engineering and Mechanical Engineering buildings. Both the buildings are made up of basalt stone and lime mortar. The age of Civil Engineering and Mechanical Engineering building is 134 years and 109 years, respectively.

V. DATA COLLECTION

The data collection involves 4 steps – collection of plans, development of Revit 3D model, digital photography and positioning of defects of the selected buildings. 3D modelling of a heritage structure with all specific features is a long and tedious process and require much more time due to the complexities involved in heritage structure. Therefore, performing digital photography and 3D modelling separately should be used to eliminate the above disadvantage. Digital photography helped collect features, present conditions, and identify types of defect/damage in the Civil Engineering and Mechanical Engineering building of College of Engineering Pune.

A. Collection of Plans

Permission from different authorities was taken for work, and from the Town and Planning Department of the college, the plans for two buildings were collected. The collected plans contain floor plans, external elevation plans, side elevation plans for both structures.

B. Revit 3D Model

3-Dimensional (3D) modelling of a heritage structure serves as a digital tool for documenting any heritage structure. 3D modelling is defined as developing a mathematical coordinate-based representation of any object's surface in three dimensions via specialized software. A prototype model has to be developed to establish a relation between measured drawing and actual structure. Organizations like UNESCO have created a list of "World Heritage Sites in Danger" to prioritize their conservation. UNESCO stated that the cultural and artistic value of these sites had been compromised, and they are carrying out the process to create 3D models of all sites to be restored. Autodesk Revit 3D software developed a 3D model for this research study for the Civil Engineering and Mechanical Engineering building. Figures 6 and 7 represents the Revit 3D model of Civil Engineering building and Figure 8 represents Revit 3D model of Mechanical Engineering building.

C. Digital Photography

Digital photography uses cameras containing arrays of electronic photodetectors to produce images focused by a lens instead of an exposure on photographic film. The captured images are digitized and stored as a computer file ready for further digital processing, viewing, electronic publishing or digital printing. This technique provides information on the

state of an object and potential interventions on the structure, which are essential for reaching an optimal decision in the restoration of heritage structures. Imaging of heritage structures is a needed part of the long-term preservation of heritage structures. The physical condition of heritage structure changes over time; hence, imaging serves to document and represent heritage structure in a moment in time of life. For this research study, photography was performed using two camera's NIKON P900 Point and Shoot Camera and CANON EOS 700D. Two different zoom lenses used were NIKKOR 83X Wide Optical Zoom ED VR 4.3-357mm and CANON Slick 58mm U.V filter lens.

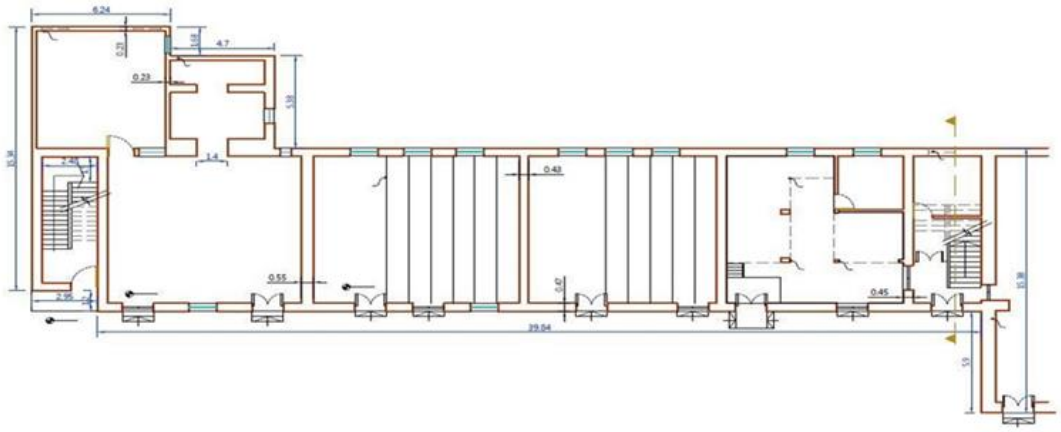


Fig. 1: Ground Floor Plan of Civil Engineering Building

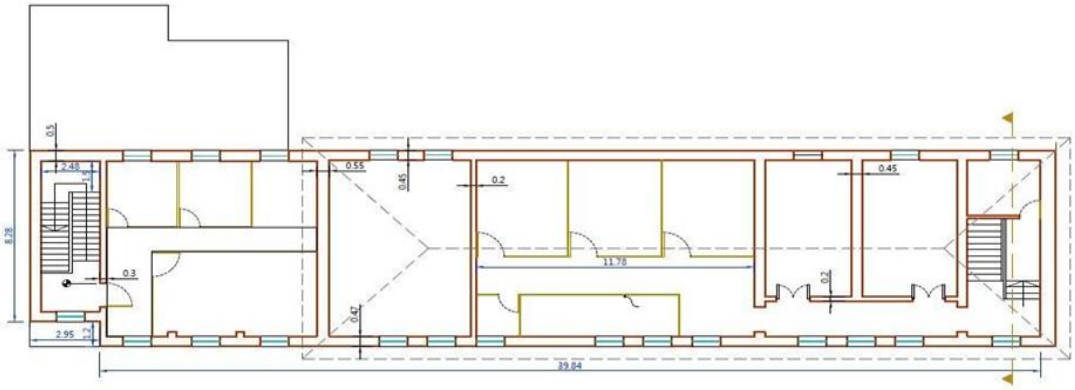


Fig. 2: First Floor Plan of Civil Engineering Building

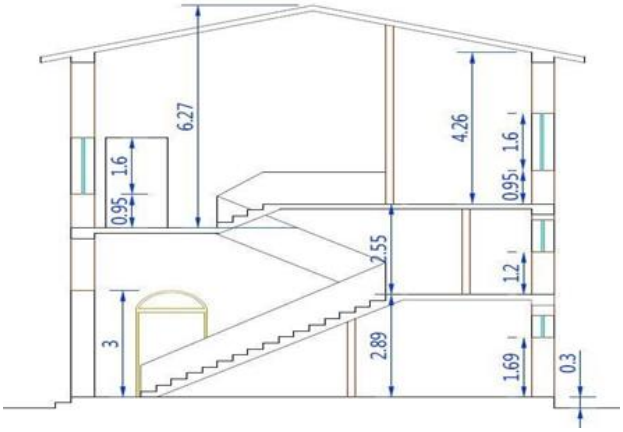


Fig. 3: Side Elevation of Civil Engineering Building

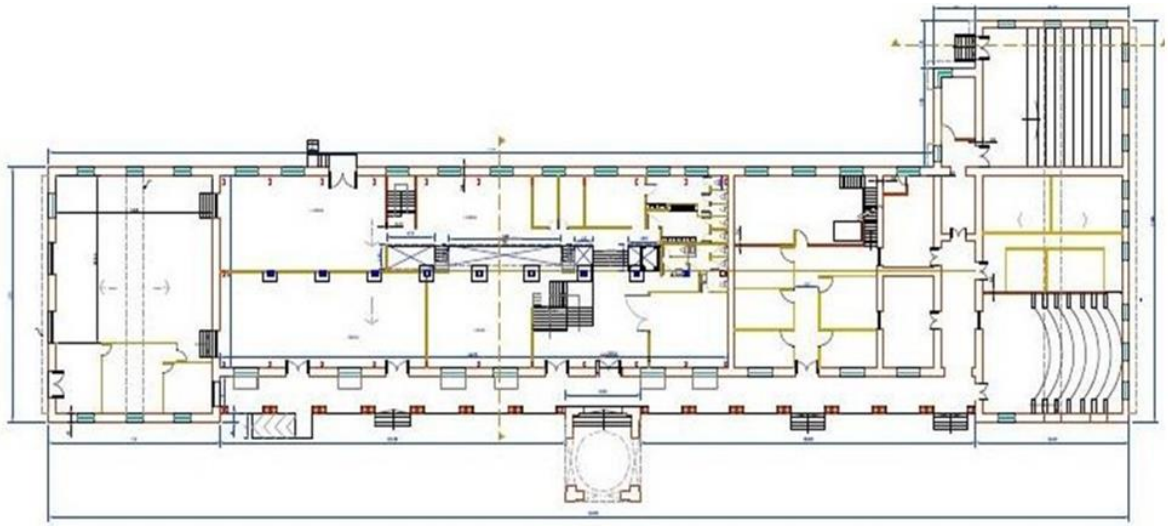


Fig. 4: Floor Plan of Mechanical Engineering Building

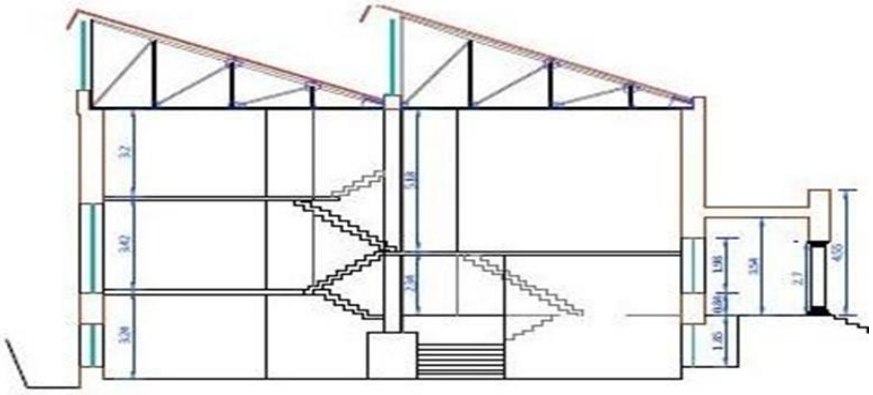


Fig. 5: Side Elevation of Mechanical Engineering Building

Fig. 6: Revit 3D Model of Civil Engineering Building (Left-Side View)

Fig. 7: Revit 3D Model of Civil Engineering Building (Right-side View)

Fig. 8: Revit 3D Model of Mechanical Engineering Building

a) Digital Photography of Civil Engineering Department

Two different ways of digital photography were performed- long-range photography and close-range photography. The work serves as digital documentation of the structure. Close-range photography helped identify defects and damages present, whereas long-range photography helped evaluate the present features and condition of the building. A total of 192 photos of the Civil Engineering building was collected. Figures 9 and 10 represent digital photography of the Civil Engineering building, Figure 9 represents close-range photography, and Figure 10 represents long-range photography.

Fig. 9: Close-range photography of Civil Engineering Building

Fig. 10: Long-range photography of Civil Engineering building

b) Digital Photography of Civil Engineering Department

Two Similarly, for the Mechanical Engineering building, both long-range and close-range photography was performed. The total number of photos collected was 180 and served as digital documentation. Figures 11 and 12 represent digital photography of the Mechanical Engineering building, where Figure 11 represents long-range photography, and Figure 12 represents close-range photography.

Fig. 11: Long-range photography of Mechanical Engineering building

Fig. 12: Close-range photography of Mechanical Engineering Building

D. Positioning of Defect

Restoration is the work that requires a minimum number of repairs to maintain the structure's originality. To keep the repair works exact minimum position of defect/damage were identified. In this research study, the position of jointing/pointing defects was only found because all other defects/damages were visible in digital photography. The laser distancing method was used to find out the coordinates; this method uses laser light to point and calculate the distance. Laser light is less likely to disperse and give an accurate result. The equipment used for this purpose was a laser distance meter, specifically Bosch Laser Distance Meter. This equipment can cover a maximum distance of 120ft or 40meters. Several reference points were considered to find out the horizontal and vertical coordinates of the jointing/pointing defect. Tables 1 and 2 represent the jointing defect position in Civil Engineering and Mechanical Engineering buildings, respectively.

Table 1: Coordinates of Jointing Defect in Civil Engineering Building

Sr. No.	Reference Point	Coordinates of Defect from Reference Point (In m)	
		Horizontal	Vertical
1.	Right side face of the door of Room Number 8	0.496	0.626
2.	Left side face of the door of Room Number 8	0.496	0.906
3.	Left side face of the door of Room Number 8	3.564	0.481
4.	Left side face of the door of Room Number 8	3.503	0.481
5.	Left side face of the door of Room Number 8	4.130	0.987
6.	Right side face of the door of Room Number 7	0.544	0.629
7.	Right side face of the door of Room Number 7	0.568	0.595
8.	Left side face of the door of Room Number 7	0.635	0.833
9.	Left side face of the door of Room Number 7	1.481	1.007
10.	Left side face of the door of Room Number 7	1.560	1.714

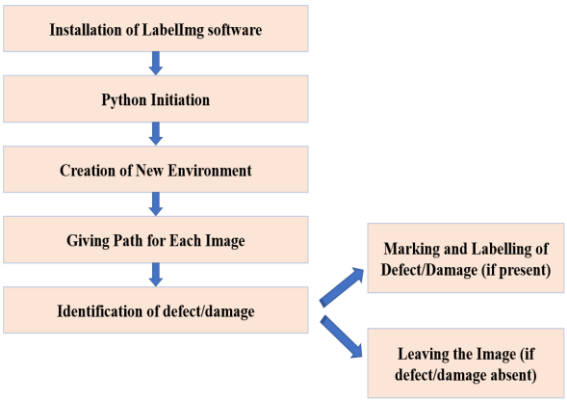
Table 2: Coordinates of Jointing Defect in Mechanical Engineering Building

Sr. No.	Reference Point	Coordinates of Defect from Reference Point (In m)	
		Horizontal	Vertical
1.	Left corner of Side Elevation	5.170	1.584
2.	Left corner of Side Elevation	7.827	1.584
3.	Left corner of Side Elevation	8.346	0.182
4.	Left corner of Side Elevation	8.346	1.584
5.	Left corner of Side Elevation	10.849	1.584
6.	Left corner of Side Elevation	13.520	0.365
7.	Window 1,2 and 3 front elevation Left Corner	Base of Windows	2.139
8.	All Pillars front elevation	Base of Pillars	-
9.	L-shaped Porch right column inner face	-	2.982
10.	back side elevation of door basements first right wall	4.085	0.152

E. Labelling of Defects/Damages

Labelling is defined as the process to give a label to anything. Labelling helps in the systematic classification of data. In this study, digital

photographs collected of the selected buildings were vast, these photos were carefully examined, and the type of defects/damages present were identified. Labelling served as a tool for proper classification of them. This part of the documentation helped in the clear marking of the defect/damages. For labelling, a tool LabelImg software was used; it gives labels and annotations to the photographs. Both manual and automatic detection for labelling can be performed on this tool. Annotation of images includes identifying features, information in images and drawing rectangular boxes around each defect/damage. LabelImg software runs on python; the output is an Extensible Markup Language (XML) file corresponding to a labelled image in Pascal Virtual Object Class (Pascal VOC). The XML file contains information about the image, such as name, size and bounding box coordinates. Flowchart 1 represents the work done in this software.



Flowchart 1: Use of LabelImg software

The defects identified were spalling, discoloration, jointing/pointing defect, fungal growth and stone damages. Spalling describes the process of surface failure in which spall is shed; spall is flakes of material broken off a stone body. Spalling can be partial or complete. Partial spalling causes unevenness on the surface, and complete spalling exposes the stone's internal structure to the outer environment. The discoloration is the defect in which the colour of the stone structure changes from the original stone colour. A jointing/pointing defect is when the material used to connect two stones deteriorates and falls away, resulting in cavity formation between two stones. In fungal growth, the growth of fungi on the structure takes place. In stone damage, the stone does not maintain its original shape.

a) Civil Engineering Building

The digital photographs of the Civil Engineering building were examined, and three defects were identified spalling defect, discoloration and jointing/pointing defect. Total 192 photographs of Civil Engineering buildings were run on the LabelImg software, and labelling was done on the photographs having a defect. Out of 192 photos, 11 photos had a spalling defect, 12 photos had discoloration defect, and 10 photos had jointing/pointing defect. Figure 13 represents sample labelled images where the first row represents spalling defect, the second row represents discoloration defect, and the third row represents jointing/pointing defect.

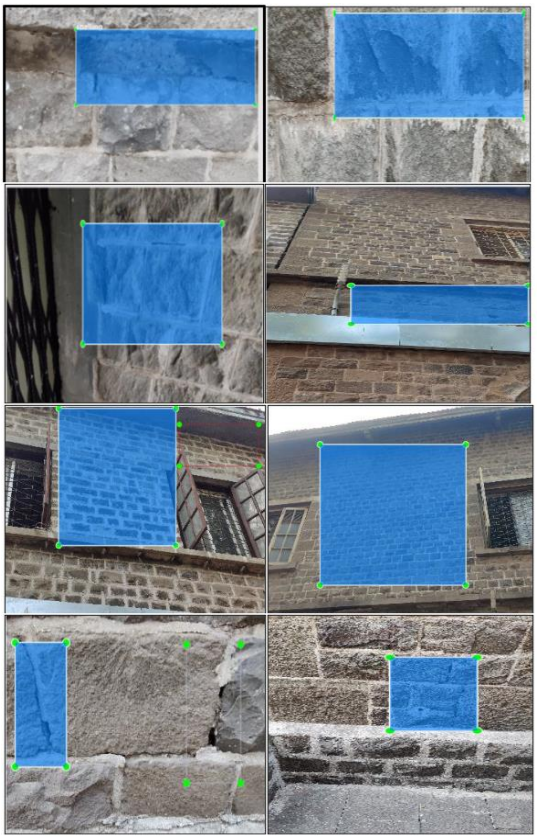


Fig. 13: Labelled Photos of Civil Engineering building (Spalling, Discoloration, Jointing/Pointing defect)

b) Mechanical Engineering Building

The 180 photos of the Mechanical Engineering building were examined, and five types of defects/damages were identified spalling defect, discoloration, jointing/pointing defect, fungal growth and stone damages. The 180 photographs were run on the LabelImg software, and defects/damages were labelled accordingly. Out of 180 photos, 5 photos had a spalling defect, 10 photos had discoloration, 10 photos had jointing/pointing defect, 4 photos had fungal growth, and 2 photos had stone damage. Figure 14 represents sample labelled images where the first row represents spalling defect, the second row represents discoloration defect, the third row represents jointing defect, and the fourth row represents fungal growth. Figure 15 represents stone damages.

Fig. 14: Labelled Photos of Mechanical Engineering Building (Spalling, Discoloration, Jointing/Pointing defect, Fungal growth)

VI. OBSERVATIONS

The type and extent of deterioration of a heritage structure are governed by the association between environmental factors and building stone material. The defects/damages in any heritage structure is a long-time phenomenon. The type of stone used for the construction of the College of Engineering Pune is basalt stones along with lime mortar. Identifying factors responsible for the defects mentioned above/damages is an essential part of the documentation required for restoration. For this study, the physical and chemical properties of basalt stone were scrutinized from the literature. The effect of weather conditions such as rainfall, sunlight, and wind on the basalt properties and the structure's surrounding condition were studied. College of Engineering is situated in the Shivaji Nagar area of Pune city; this area is one of the main areas that has seen enormous development in the last 100 years. Based on the observations, the factors identified for the type of defect are:

- Spalling defect occurred due to the salt crystallization phenomenon. The structures are situated in an area which sees large traffic volumes every day, the pollutants from the air pollution get adhered to the surface along with dust particles. When rainfall occurs, these pollutants and water penetrate the stone surface; the sulphate and nitrates in basalt stone react with water and undergo salt formation. When evaporation due to sunlight occurs, these salts crystallize and comes to the surface of the stone. The crystallize salts eventually withers away, creating partial or complete spalling. If the stone surface is in a protected environment, these salts form a black crust on the stone surface.

- Discoloration defect occurred due to alternate wetting and drying of the stone surface. The basalt stone has pyroxene, olivine and iron minerals. These three minerals are affected easily by weather conditions as pyroxene is susceptible to temperature changes, olivine is unstable to weathering, and iron reacts with rainwater, resulting in the formation of iron oxide. As the selected buildings are more than

100 years old, it has seen 100 or more cycles of wetting and drying of the stone surface, resulting in discoloration.

- Jointing/pointing defect occurred due to two reasons. First is vibrations, the past and the current construction activities in the vicinity of the structure caused vibration in the jointing material between the stones. As the selected buildings are more than 100 years old, such vibrations over a long time caused the pointing material at the stone surface to wither away. Second is alternate expansion and contraction of jointing material, lime mortar tends to absorb water and expand quickly, the rainwater causes the lime mortar to expand, and due to evaporation, the lime mortar again contracts, such alternate expansion and contraction of lime mortar between stone over long-time caused the jointing/pointing defect.

- The most necessary condition for fungal growth to occur is dampness. The presence of dampness over a long period leads to fungal growth on the structure. The areas where this defect was visible were the ones directly exposed to rainfall. The rainfall got absorbed on the stone's surface, which was porous and created dampness, resulting in fungal growth.

- Stone damages can be an instantaneous or long-time phenomenon. The loss of parts of stone may be due to vandalism, and inappropriate equipment uses.

VII. SUGGESTION OF REMEDIAL MEASURES

The environmental factors were the primary cause of the occurrence of defects/damages. These factors cannot be diminished, but proper materials or techniques for restoration can reduce such defects/damages. The materials and techniques used for restoration work of heritage structures were studied from the literature review, and the suitable materials, techniques that can be used for basalt stone restoration work were identified as:

- The best way to remove the jointing defect is to do repointing. Repointing in heritage structure is defined as injecting the material between stone connections and filling the cavity. The materials suitable for basalt stone and lime mortar joints are Nanolime, Polyurethane Injection and Epoxy Injection. Nanolime is a mixture of nano-sized calcium hydroxide particles suspended in alcohol such as ethanol. Polyurethane is a resin polymer, and the polyurethane injection method uses a mixture containing polyurethane resin, isocyanate and polyol. The epoxy injection uses epoxy resin suspended in an alcoholic medium. Out of all three, nanolime is considered best due to its compatibility with lime mortar. Nanolime consists of nano-sized calcium hydroxide particles that get highly activated due to alcohol medium, making it suitable to work with ancient lime mortar and a nano-sized particle with deep penetration property.

- To reduce the discoloration defect, using a suitable sealant material as a coating serves as the way. For the basalt stone, the use of titanium dioxide as a sealant is considered as suitable. This solution serves as a coating to the stone surface, which reduces the discoloration and helps retain the structure's aesthetic appearance. It has the property to withstand weathering effects such as heating, cooling and rainfall.

- The material to remove fungal growth is glyphosate, ammonia solution, and lime mortar mix. It's a three-step process; in the first step, physical or chemical cleaning is performed. In physical cleaning use of soap water solution, pressure water sprays or moist pulp paper is used for cleaning the surface. In contrast, chemical cleaning, diluted acid or alkali is used for cleaning such as sulphuric acid, acetic acid, sodium hydroxide or potassium hydroxide. In the second step, the mix is prepared, and in the third step, the mix is applied on the surface in thin layers to prevent future fungal growth.

- For stone damages, the use of the indentation technique is suitable for basalt stones. In the indentation technique, initially damaged stone is given a plane, sharp surface after that, the size of the missing stone is accurately measured. The size of the missing stone is cut from the same type of stone then holes are drilled in both existing and new stones. Stainless steel dowels are prepared, and then drilled holes in the new stone are partially filled with grout and dowels are inserted. The new stone is taken to place of the old stone having damaged, the drilled holes of the old stone are partially filled with grout, and new stone is jointed using steel dowels inserted in the new stone; finally, the joints are filled.

VIII. CONCLUSION

India has a rich historical background, evident from various forts, temples, buildings, and objects of the historical era. Therefore, restoration study is needed for bridging the gap between the ancient era and the modern era. By the guidelines provided by UNESCO and ASI, the importance and need of documentation for restoration were studied, identified which plays an essential role in any restoration work. College of Engineering Pune is one of the leading institutes of Maharashtra and is a heritage educational monument. Revit 3D modelling was performed and documented for future reference to get an idea about the appearance of selected structure digital photography. The study revealed that selected buildings were maintained correctly. However, due to the age of the structure and surrounding environmental conditions, various defects/damages were visible. Vibrations caused the jointing defect due to surface or sub-surface construction activities and alternate expansion and contraction of jointing material due to weathering conditions. Both structures showed spalling and discoloration defects; spalling occurred due to salt crystallization and discoloration due to alternate wetting and drying of the stone surface due to weather conditions.

The fungal growth and stone damages were identified only in the Mechanical Engineering building. Labelling and annotations were given to each type of defect via LabelImg software. The suggestion of proper remedial measures was given according to basalt stone. This research further concluded that maintenance of existing monuments should be done by using mentioned materials and techniques. For this, a proper maintenance manual should be drafted, which help to increase the aesthetic appearance of the structure. The manual can be used for timely inspection and routine maintenance, which are the key factors to conserve a heritage monument.

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