A Critical Review on Building Pathology

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Abstract- Building Pathology is a field of study on causes, diagnosis, treatment of defects and malfunctions in buildings where pathos means suffering Logos means discourse or study. The study of building pathology is developed in the ancient world in ancient Rome and Greece to diagnosis and repair but today it is a well-established field extend to various defect assessment and remedy action. The importance of this field is developing each and every due to various factors such as climatic change, invention of new materials, new method of construction etc. In this paper Building pathology is critically reviewed on basis of Structural Cracks, Non Structural Cracks, Non Destructive Techniques, Crack detection and calculation, Case studies on various buildings and Building Information Modelling.

Index Terms- Building Pathology, Building Condition Assessment (BCA), Detective approach, Cracks.

I. INTRODUCTION

Building pathology is the study of the causes and effects of physical and functional defects in buildings, as well as the diagnosis and treatment of these defects. It is a multidisciplinary field that combines knowledge from various areas including engineering, architecture, materials science, and environmental health. Building pathology professionals work to identify and resolve issues that can affect the safety, functionality, and value of buildings. To diagnose and treat building pathology issues, building pathology professionals may use a variety of techniques, including visual inspections, moisture readings, and testing of materials and air quality. They may also recommend repairs or renovations to address identified problems and prevent future issues from occurring Some examples of building pathology include are

1. Structural defects, such as cracking or settling foundations, which can affect the stability and integrity of a building.
2. Moisture-related issues, such as water infiltration, condensation and mold growth, which can lead to health problems and damage to building materials.
3. Electrical and mechanical problems, such as faulty wiring, broken pipes, and malfunctioning HVAC systems, which can cause safety hazards and disrupt the functioning of a building.
4. Environmental hazards, such as asbestos, lead paint, and radon gas, which can pose health risks to building occupants.

What Authors says about Building Pathology…….

The term Pathology is defined as systematic study of diseases with the aim of understanding their causes, symptoms and treatment.

-David Watt

Define Building Pathology?

Pathology is this methodical and often forensic practice that has come to be termed Building Pathology

-David Watt

Pathology is derived from Greek language

Pathos means suffering

Logos means discourse or study

Defects, like diseases, can be classified into three broad areas Aetiology (causes) e.g. Poor design, fault workmanship, neglect. Mechanisms (the agency/agencies that triggered the defect) e.g. Dampness, pollution, fungi, moulds. Symptom or set of symptoms (syndrome) e.g. staining, leaks, cracking. The systematic Treatment of building defects, their causes, their consequence and their remedies

-Building Pathology A state-of the-art report

Building pathology is an aspect of natural laws operating the rates of which are constantly changing which is one way of saying that the changes are changing and the changes in the changes are changing in non-linear ways.

-Samuel Y. Harris

According to Watt (2007) building pathology is a holistic approach to understanding building which demands a detailed of how buildings are designed, constructed, used and changed the various mechanism by which their material and environmental condition can be touched by an external factor

-Efstratius Stylianidis

According to Azeredo (1987) pathology is the Segment of engineering that studies the causes, origins and nature of failures that arise in construction. After its manifestation depending on its severity the pathology can become in damage, which is final result. For Ripper et al (1998) the pathology may

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be noticed as low or even failure of the structure performance regarding its stability, static and durability.

-Joao M.P.Q Delgado Editor

Building pathology is the scientific study of nature of building failure and its causes, Process, development and consequence to help create the right remedial and management resolutions

-J.M.P. Q Delgado

According to Construction Industry Board (1993) Building Pathology is defined as systematic study of treatment of building defects, their causes(aetiology), their consequence and their remedies.

- James Douglas and Bill Ransom

In buildings a study of defects, why they arise, what the symptoms are and what can be done to rectify/ameliorate/reduce etc.

-Melanie Smith, Christopher Garse

The fundamental process of assessing a particular defect within a building whether it be water ingress or distress cured by subsidence is exactly same as medical pathology hence the term ' building pathology '

-Ernis Jowsey

Building pathology can be simply described as: The systematic treatment of building defect, their causes consequences and remedies (Beuhel 1991)

-Clive Briffet

Construction (or building) pathology is an area of the applied science. It determines the causes of project problems (or defects) and with the structural and functional changes which occur. The knowledge based for the study of pathology may be from defunct Constructive such as collapses or a study and analysis of malfunctioning ones. (AEEBC, 1994 quoted by watt,1999, P.L)

Building pathology is the Identification, investigation and diagnosis of defects in existing buildings.

Prognosis of defect diagnosed and recommendation for must appropriate course of action regard to the building out future and resources available.

Design, Specification, implementation and supervision of appropriate programmes of remedial works and monitoring and evaluation of remedial works in term of their functional, technical and economic performance in use

- Enrique David and John Michael Kirby

According to Thomas (2013) Building Pathology is define as the systematic treatment of building defects, its causes, its consequence and its remedies

-Anthony Higham, Jashon Challender, Greg Watts

Building pathology is the systematic study of the damage that can occur to buildings in order to understand the cause based on the symptoms and to develop appropriate treatment methods

-Manuela Greechi

Building pathology is study of building and structure diseases or functional and structural changes similarly to the effects well known from field of living organisms

-B.S.Neale

The study of failures in the interrelationship of building structure and materials with their environments, occupants and contents Hutton and Rostron The study of failures over time in building material and components

-Groak

The systematic treatment of building defects, their causes, their consequence and their remedies

- CIBW86

Building Pathology commission 1993 The scientific study of abnormalities in structure and functioning of the building envelope and its parts, it seeks to study the interrelationships of building materials, constructions, services and spatial arrangement with their environment, occupants and contents

– Singh

II. LITERATURE REVIEW

1. Building Condition Assessment

Vlad Lupașteanu et.al (2021) carried out a study on Building Condition Assessment(BCA) in Romania as a country declared a mandatory to made building assessment for regular intervals but It didn't propose a procedure or Survey assessment so this paper take initiative to fill the Research gap in Building Condition Assessment(BCA) in Romania and other European Countries. A method named PEST (procedură de evaluare a stării tehnice) a Romanian acronym for method of assessing technical condition. It has two main parts first part is to preliminary investigation follows site inspections and other part is methodology for evaluating the various damage using various equipment. In First Stage Document verification of building is made the building is then discretized to various sub system of components for more accuracy on assessment more discretization is made then a checklist is made on possible defects on that particular building and carrying out the inspection. The second part includes the evaluation of damages such as structural damages and Non Structural damages separately. To assess the damages a flow chart is made which consist of a continuous process which should be made. A degradation class is formed with criteria of no damages to severe damages and a rating is made from 1 to 100 with scale of good condition to severe damages. A colour is used to represent the nature if damages using all factors a final result is made on condition assessment of building. To make an experimental study this method of building assessment is applied to 62 various type of existing building in and around Romanian and obtained a good result by greatly reducing time which 205 days totally for 62 building with an average of 3.3 day per building. Checklist are very useful and efficient in field of damage phenomenon, remaining useful life, previous repairing works and maintenance work and the method features associating each degradation classes with condition rating and a colour code proved to be very useful during the dissemination of results.

Antonio Vilhena et.al (2020) carried out a study on to give a comparative review of the techniques employed in European nations to evaluate the state of buildings. An English housing health and safety rating system, a French way to examine buildings that may be certified inhabitable, a Dutch standard concerning assessing the status of structures, and the assessment methodologies created as part of the European

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projects EPIQR & TOBUS were all compared. Three tasks were included of the comparison analysis. The methods were first each discussed in isolation. The key aspects of the techniques were then contrasted. Eventually, several recommendations for enhancing the Portuguese approach were developed. The goals and scope of the assessment, the level of global assessment disaggregation, the calculating method used to combine partial assessments, the end findings type, and the instruments created for their application are the primary variations between the methodologies. The main similarities include the fact that the assessment is primarily done by visual inspection, that the condition of the building is evaluated through a systematic analysis of the entire building divided into functional elements, that the severity of defects is the assessment criterion used, that weighting coefficients are used to determine the significance of each partial assessment in the final result, and that surveyors require specialized training.

Muhd Zubair Tajol et.al (2019) studied about the building condition assessment of four countries namely Hong Kong, India, Malaysia and Singapore related to what are the improvements to be made in Malaysia Building condition assessment. In India Building condition assessment is done based on identifying the causes and sources of defects using visual inspection with checklists and instruction guideline by India Central Public Work Department then the defects are recorded by various methods and it is classified into classes of damage, type of cracks and illustration pattern. In Hong Kong it is to check the status and condition of building with scope of external, structural, fire safety and drainage system to find the causes of structural elements and external flaws then a remedy is prepared to rectify or repair based on thorough research. In Singapore Building Condition Assessment is done based on visual inspection on structural elements using checklist, Instruction guidelines then the defects are listed and a plan for rectification or repair is done by recommendation of professional engineers. By comparison of these Building Condition assessment the following suggestion are made for Malaysia PWD: The inspection method is to be maintained consistent, attributes assessed, attributes criteria and surveyor and Suggested a website or blog for easily access of assessment, checklist and guideline. Improvement on guidelines for NDT test procedure and illustrations of common defects and Suggested a chapter in Malaysia standard on concrete repair material and factor of defect.

Goncalo SA et.al (2015) discussed about a statistical survey on the Building pathology, diagnosis and rehabilitation of wall renderings. The survey was based on the Building pathology such as defects, Cracks (Structural & Non-Structural), deterioration, Settlement and voids their most principle causes, diagnosis methods, repair and maintenance techniques. The survey is done on-site work considering 55 buildings at Lisbon capital of Portugal consist of 150 wall renderings 100 external and 50 interiors. The Different room wall renderings samples are collected such as Kitchen, corridor, common places, living room etc. and age of building is made from 1955 to 2007 In addition to validating the inspection and diagnosis method, a survey is conducted and data is gathered in inspection. A statistical analysis was then conducted with further details regarding the pathology of wall renderings. A defect requires an average of 2.7 causes to form, according to the visual identification of 476 anomalies in the 150 rendered surfaces and their association with 1277 causes, of which 887 are direct and 390 indirect. Also, 908 diagnosis techniques, or an average of 1.9 techniques per anomaly, were discovered to be effective for analysing the flaws. Eventually, 1731 repair/maintenance approaches—or 3.6 techniques per anomaly—were found as a cure to handle the anomalies, faults discovered, and their causes. Repair methods not only to the correction but it also has the capacity to eliminate its original causes and another fact is that some repair techniques are alternative to each other and finally concluded that a continued process of surveying and registering anomalies in wall renderings will enable dependable degradation models to be built.

2. Structural Cracks

Pooja Nama et.al (2015) carried out a study on Causes and preventive measures of Cracks the study is divided into four parts. First part of the study consists of basic information of building defects and its causes by using various reference books and various study by researchers second part contains the case study made on Career Point University, Kota is done by visual identification of cracks and causes with preventive measures. The cracks are classified with respect to width of crack as a) Thin - less than 1mm in width b) Medium - 1 to 2mm in width c) Wide - more than 2mm in width. The third part contains techniques to cure crack such as Epoxy injection, Routing and sealing, Stitching, Drilling and plugging, Gravity Filling. Dry packing and Polymer impregnation. Finally concluded that if proper consideration is given to construction material and technique to be selected in designing phase will able to minimise the problem of cracking in our structure.

Anwesa Satapathy et.al (2019) carried out a study on type of cracks, its causes and effects of the structure and states that for remedy suggestion necessary to observe the crack pattern, location, shape, size, width, depth and other characteristics such as time of construction and history of the structure. By these observations and according to the situation of the site, funds available the type of remedial measures, repair and rehabilitation are suggested. A case study is done Nagpur Maharashtra Residential apartment (G+4), Ramdas Peth Nagpur Maharashtra Residential apartment (G+3) 30+ year old building and Nagpur Residential building (G+3) and various defects are observed predominantly cracks and dampness are assessed. Epoxy injection, Stitching, Routing and sealing, Drilling and plugging and Gravity Filling are the remedy methods recommended. By these case studies following conclusion are made: For Recommending curing techniques it is important to know about the causes of cracks. The main causes of plastic shrinkage are water cement ratio and curing, Slab should be rest on hardened surface or foundation to prevent settlement cracks, periodic maintenance is needed for distress of members to avoid complexity.

Manuel J. Carretero-Ayuso et.al (2021) carried out a study on 2030 cases that correspond to current Spanish buildings, from which the pathology combinations are categorised. To put it another way, each case studied is linked to and quantified with the type of existing damage, the construction unit in which the

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damage occurred, and its original cause, thereby displaying the most prevalent and common combination as well as the construction typology where pathology combinations occurred. In the horizontal envelope, a total of 10 groups of pathological combinations and 34 groupings were identified. The external building envelope's five construction units are examined in order to identify the defects and their underlying causes. Coated facades and flat roofs are the construction materials that have the most cases Infiltration humidity, direct infiltrations of water and/or dripping, and condensation humidity are the most common types of harm. The lack of sealing, improper placement of the waterproofing sheet, and the presence of thermal bridges are the primary factors with a higher proportion of occurrence. Based on the investigation, 228 distinct types of pathology combinations are identified, and the issues related to the presence of water are the most common pathology combinations in each building unit. The most significant connections are those between flat roofs and damages owing to direct water infiltrations and/or dripping brought on by inadequate waterproofing sheet disposition and window frameworks where damages of infiltration humidity produced by the absence or deficiency of sealing happened. Additionally, the 20 different types of damages have been assessed and broken down based on the building typology in which they occurred. The results show that 54.93% of the damages occurred in building blocks. The highest concentrations of them are seen in infiltration humidity.

Pieter Desnerck et.al (2014) carried out a study on applying a test method to investigate the bond behaviour of reinforcing bars in cylindrical cracked reinforced concrete specimens. Investigated are the effects of crack quantity, crack direction, confinement, and concrete cover. Pre-crack specimens are tested using the concepts of a controlled split tensile test in this study. Rough crack surfaces are subsequently created in this manner along a predetermined cracking plane that passes through the axis of the reinforcing bar. The specimen can be cast inside of a plastic ring to prevent brittle failure and give some post-cracking containment. Both the pre-cracking and pull-out phases are possible with this ring still in place. The specimens utilised are cylindrical, with a height of 100 mm, and a diameter of either 107 mm or 60 mm. The specimen has a centrally positioned reinforcing bar with a diameter of 10 mm, resulting in a cover-to-diameter ratio of 4.8 or 2.5. A robust load frame with a 150 kN capacity is used for the test. The specimen is loaded at a constant deformation rate of 0.4 mm/s until the first break appears. Two sets of two linear variable differential transducers are used to record the slide of the bar on both the passive and active sides (LVDT). After the specimens are unloaded, the crack widths are once again examined under an electron microscope.

These LVDTs are fastened to the bar using a steel collar affixed to the reinforcing bar. Pull-out tests were then conducted on the fractured specimens to ascertain the bond qualities. The cylindrical specimens had a central reinforcing bar with a 10 mm diameter and a compressive strength of 25 MPa. The results of the tests showed that the bond strength is significantly decreased by the presence of cracks, even those with moderate crack widths of 0.03-0.04 mm. The average reduction for specimens with a single crack was 44%, and the average reduction for specimens with two cracks was 54%. The resultant bond characteristics are not significantly affected by the fracture orientation in relation to the rib pattern of the reinforcing bars. The findings of three separate fracture orientation tests revealed comparable ultimate bond strengths. In the absence of a constraining force, pre-existing cracks can fully expand and the reinforcing bar can more readily slip out of the specimens. This affects the eventual bond strength of a pre-cracked specimen. The remaining bond strength following cracking is also decreased when the concrete layer is diminished. The uncracked concrete's failure mode changes from a pull-out failure to a splitting failure for smaller covers. In cracked cylinders implanted in a 23 mm uncracked concrete ring, the bond strength of the reinforcing bars is 18% lower than in uncracked specimens with the same total concrete cover. The collected test results show that longitudinal cracks can have a considerable impact on how well ribbed reinforcing bars adhere to concrete. This implies that when performing load bearing capacity evaluations on existing reinforced concrete structures, bond reduction factors are required for cracks that run along the reinforcement bars.

Cedric Giry (2014) et.al carried out a study on a reinforced concrete beam evaluated under four-point bending, the behaviour of this beam is analysed at all levels, from the global reaction to local data like cracking. A damage model coupled with a stress-based non-local regularization technique is utilized to characterize the beam's ongoing deterioration. The finite element analysis is then subjected to a post-treatment in order to characterize the cracking pattern. In this work, the topological search, continuous/discontinuous crack opening, and global/local analysis are two post-treatment techniques that are contrasted. Model error evolution for a fracture at the surface of the beam for two average stress levels in the lower rebar's: 150 MPa (a) and 219 MPa (b) throughout the loading of the stress profile for both CDCO technique methods. For robustness proof and an engineering perspective, damage mechanics at the structural scale are still used to determine crack opening. Hence, some post-treatments are required. This study demonstrated two distinct methods for post-treating a structural scale Finite Element Analysis. On the one hand, a damage strain field is analysed as part of a topological search strategy to find cracks. By comparing the regularized strain field and the analytical strong discontinuity displacement field caused by a discrete crack, the crack openings are calculated. The global/local technique, on the other hand, uses the finite element displacement field as Dirichlet boundary conditions to derive fracture properties of a Region of Interest at a finer scale. The two methods have been compared with regard to the crack opening prediction for a reinforced concrete beam exposed to a four-point bending test using the identical macroscopic damage model. Findings demonstrate both techniques' ability to provide a reliable cracking estimation. The first approach's primary benefit comes from the employment of an identifiable, exclusive mechanical model.

3. Non Structural Cracks

Faisal Faqih and Tarek Zayed (2021) carried out a study on established a paradigm for defect-based building condition assessment that consists of two different types of evaluations: environmental condition assessment and physical condition assessment. It is established which environmental elements and

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physical building flaws affect the building's state. In order to analyze the paired comparison of physical and environmental problems, a questionnaire survey was conducted. Using the Analytical Network Process (ANP), which takes into account the interconnections of faults, this pairwise comparison was then utilized to calculate the relative weights of defects. Fuzzy set theory and the evidential reasoning algorithm were employed to account for uncertainty in the judgment of inspection staff. Defect levels, determined from standards and codes of conduct, were used to create fuzzy membership functions. These thresholds applied to both environmental and physical flaws. To determine the required degree of belief needed to judge the severity of problems, condition grading scale and environmental instrument readings with their related fuzzy membership functions are used. In order to create an integrated condition assessment that takes into account both physical and environmental condition, an evidential reasoning algorithm based on the Dempster-Shafer (D-S) theory was used. This algorithm used the degree of belief calculated from fuzzy membership function and relative weights derived from ANP as input. The weighted average defuzzification procedure yields a crisp value that represents the final condition rating. The created recommended model was evaluated using a structure as a case study. A plugin software is created that uses the BIM model for information interchange, better documentation, and graphical display of condition assessment results in order to apply the suggested defect-based condition assessment model on a case study building. One of the following four options is available when the defect-based condition evaluation is finished: no action, small repairs, large repairs, or rehabilitation. The case study examined every floor of the university building and found that there were very few cracks, such as hairline cracks, to indicate that the structure was in good condition. This is evidence of the success of the defect-based condition assessment model's implementation, as it provides better documentation for the building inspection process, which can save time and money.

Jessica S. de Souza et.al (2016) studied to determine damage intensity and distribution in the different regions of the facade. The façade of three buildings that are included in the Materials Testing Laboratory database of the Universidade de Brasilia were the subject of this study. The degradation was measured in terms of a methodology Silva (2014) presented to produce a degradation index expressed in m2. Several indexes relating to the percentage of degraded area, applied to the facade regions, are offered after the quantification of damages. The data noted in each location could be standardised methodology to these weighted indices and Getting these indices is crucial for understanding deterioration. Based on data from three structures with features typical of the construction systems of residential buildings in Brasilia, this study suggests applying a damage factor to building areas. The information gathered from the mapping of the three buildings allows for the conclusion that the methodology was effective in determining the deterioration brought on by age. It is feasible to quantitatively detect the variation in deterioration behaviour in the various facade regions, allowing for further in-depth analysis such the investigation of weather-related building degradation. The ability to compare several facade portions is crucial, even though there is no physical criterion to measure degradation. The CW is generally the most damaged, albeit not usually with the highest intensity. The variety of degradation intensities of different regions at different ages can be explained by the different construction process, design, exposure to degradation agents, and even maintenance operations. The findings demonstrate the need to rectify the observed values for the proportionality of each region's area to the facade's total area before comparing the regions. Additionally, it was observed that while continuous walls are frequently the areas with the most damage, they do not always do so.

Sara Madureira et.al (2017) investigated the implementation of a facade maintenance strategy is described in detail. The theoretical idea was tested and modified in a survey of 30 structures and is based on pertinent research. The concept is founded on organised processes and includes thorough information about the facade. The use of many factors, such as environmental, extension, repercussions, and safety requirements, is suggested as a framework for prioritising maintenance tasks. They are utilised to address the primary anomalies in facades by taking into account four types of maintenance, such as aesthetical, adhesion loss, and fastening faults operations. This study suggests a facade maintenance schedule for existing structures. Three primary steps make up the implementation methodology: thorough inspection, follow-up maintenance, and preventive maintenance planning. This study also suggests a method for prioritizing facade post-inspection maintenance. It takes into account the exposure to the environment while in use, the severity of anomalies, the repercussions of taking no action, and required non-compliance. By taking a variety of information into account when defining maintenance strategies, costs can be reduced. Appropriate scale and frequency, such as routine cleaning of windows, walls, gutters, or even fixing small detachments, can delay or prevent major interventions in the building (like premature replacement of renders or drainpipes), not to mention the significant added value in the building's overall appearance. The recommended plan should be implemented and monitored while taking into account the in-service conditions of each facade for this study to be effective. This study also suggests a method for prioritising facade post-inspection maintenance. It takes into account the exposure to the environment while in use, the severity of anomalies, the repercussions of taking no action, and required non-compliance. By taking a variety of information into account when defining maintenance strategies, costs can be reduced. Appropriate scale and frequency, such as routine cleaning of windows, walls, gutters, or even fixing small detachments, can delay or prevent major interventions in the building (like premature replacement of renders or drainpipes), not to mention the significant added value in the building's overall appearance. The recommended plan should be implemented and monitored while taking into account the in-service conditions of each facade for this study to be effective.

Elton Bauer (2015) et.al carried out on an investigation on the influence of age and climatic agents on the deterioration processes. In order to measure the degree of degradation as a function of the solar radiation incidence, this research describes a façade mapping and visual inspection degradation survey approach on 8 buildings. The calculating procedure is effectively analysed, and the evaluation of degradation brought on by ageing

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and sun exposure has improved. Cracks and ceramic separation were the clinical signs that were most common in facades. The pathological symptoms examined revealed a significant correlation with the solar incidence. The overall deterioration level (ODL) of buildings over 30 years old demonstrated a progressive decline, i.e., it demonstrated consistency in the calculation model for degradation and service life. ODL results demonstrated the effectiveness of its applicability and weighted analysis accuracy by assessing the total degradation level of facades through damage level and repairing cost. The final results revealed higher degrees of deterioration on older buildings' facades and those exposed to higher sun incidence. This study emphasises the importance of inspections to find and measure damage so that the behaviour and service life of facades exposed to intense sunlight may be evaluated.

Maurício M. Resende et.al (2022) carried out a study to evaluate the presence of pathologies on the façades of the Municipal Market of Sao Paulo using infrared thermal imaging. By comparing thermograms taken at various times, infrared thermal imaging is a non-destructive technique used to assess building diseases and utilised to monitor cultural asset conservation. In comparison to traditional photos, thermograms made it easier to identify damaged areas. Therefore, while structural defects are difficult to identify using visual analysis, they could be assessed using infrared thermal imaging. The qualitative analysis of thermograms made it possible to spot defects to the façades, such as moisture intrusion, rendering mortar separation, mould growth, and crack development. Identifying architectural components made of various materials was also possible. High-resolution cameras should be used for infrared thermal imaging façade inspection. The detection of micro cracks in less superficial locations is then made easier with the help of high-definition thermograms. When reconstructing missing pieces that have aesthetic and historical significance, restoration techniques must take into account the principles of minimal interference. After significant repairs have been made, the building should undergo annual inspections and monitoring to look for flaws and anomalies that could shorten its service life. By doing this, information may be gathered to create safeguards to protect such historical assets.

4. Non-Destructive Technique

Prof. P. S. Lande and Ansari Mohd. Adil (2019) investigated the Impact Echo testing method is applied on masonry wall structure for the measurement of thickness in masonry wall, locate and measure depth of defects such as flaws and voids inside structure. Initially it discusses about the history of impact echo its working principle and how the testing is developed from Earthquake waves will affects the buildings to the p waves is passed to measure the strength of the concrete. A software is used named WinIE for analysis of results it requires National Instruments Data Acquisition (NIDAQ) Software to run the program by using this software we get amplitude-frequency graph, Time domain waveform and frequency graphs to determine the flaws. Impact Echo test is done only at a single point. For experimental test a masonry walls with size of 1.0 x 1.0 x 0.23m which it consists of 9 brick layer with different class of brick, the thickness of wall is 230mm. The wall is constructed with different mortar preparation Ratio for each three layer with voids, cracks in bricks, poor mortar proportion for bonding to find the effectiveness of Impact Echo. In this specimen they find the thickness of the wall it predicts correctly as per ASTM 1383-15, bonding condition as good and depth voids present. A case study is done using Impact echo testing on old masonry building (G+1) located near Jawahar Gate, Amravati (India) and concluded that top story brick masonry wall the bonding condition was good Where as in bottom story wall the bonding between brick is fair and in back side wall some layer consist of serious damage condition need to be repaired. Finally, this paper concluded that thickness, presence of voids, discontinuities, bonding condition is estimated correctly using Impact Echo in Masonry structures.

D.Breysse (2012) carried out an analyses of how the strength of onsite concrete is measured using Non Destructive Testing (NDT) such as Ultrasonic Pulse Velocity (UPV) and Rebound Hammer and this paper is based on an extensive critical review of existing models, an analysis of experimental data gathered by many authors in laboratory studies and on site, the development and analysis of synthetic simulations designed in order to reproduce the main patterns exhibited with real data while be able to replicate the patterns with synthetic simulations. Based on assessments of strength, variability, and uncertainty in ultrasonic velocity and rebound hammer, a review is conducted. Review of the link between ultrasonic pulse velocity and rebound hammer strength is based on model parameters, exponential and power law models, and a mix of non-destructive approaches for strength measurement. SonReb is utilized in conjunction. The idea is that while the same issue affected the two approaches differently, their combined use can counteract its effects and increase the strength's accuracy. Another combination strategy is bivariate relationships, which involves dividing the entire data set into subsets of equal strength and creating (R, V) curves for each strength class as well as taking into account subsets of equal rebound values and creating fc(V) curves for each rebound class. The paper's first conclusion is that the effectiveness of NDT depends on three factors: the sensitivity of the strength, the range of variation of the measured NDT values, and the magnitude of measurement error. These three factors are all directly related to the range of variation of strength for the investigated concrete. The effectiveness of combining two or more NDT measurements has been difficult since the field's inception, and this paper's analysis of the data reveals that, in some situations, the combination can enhance the assessment. Due to the small number of studies that have been analyzed, the conclusion that combination is only effective when the quality of the two procedures is on par has yet to be proven.

Majdi Flah et.al (2020) investigated a system for automated inspection of concrete structures that uses deep learning and image processing to find flaws in often inaccessible places. Convolutional Neural Networks can be a powerful tool for the classification, localization, segmentation, and quantification of damage in cracked cement-based materials and structural concrete components when paired with improved Otsu Image processing. The first, second, and third classifiers' stated testing accuracy, according to the classification analysis, was 98.25%, 97.18%, and 96.17%, respectively. The quantification analysis revealed that the measurement error for calculating the

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fracture length, crack width, and crack angle of orientation was 1.5%, 5%, and 2%, respectively. The type of structural damage or durability-related damage (such corrosion) and its severity were determined using a variety of international building and bridge standards and norms. While requiring great computational and time efficiency, the damage detection, classification, and measurement method proposed in this work demonstrated increased performance and accuracy when compared to other existing methods.

Shamsher Bahadu et.al (2015) carried out a study on comprehensive investigation and comparison of four distinct techniques for vibration-based damage detection in reinforced-concrete beams with three different support conditions was conducted. The methods chosen are Change in Flexibility (FC), Curvature Mode Shape (CMS), Modal Strain Energy Change Ratio (MSECR) and Principal Eigenvector of Modal Flexibility Change (PE). Damage localization, identification, and quantification for both single- and multiple-damage scenarios are the parameters taken into account in this study. The goal is to suggest the best course of action in both of these situations. Damage is simulated by decreases in effective flexural rigidity in a self-developed finite element model-based programme on MATLABTM that analyses a beam of length 3.15 m. It has been established that each method is effective for locating and detecting single damages. The ability to clearly determine the severity of a single harm is listed in the order below. CMS > MSECR > PE > FC. FC and CMS stand apart from MSECR and PE because to the significantly larger Sp values, as was previously mentioned. The following list illustrates how well the methodologies work at determining the severity of various damages: CMS > FC > PE > MSECR Only the MSECR approach reliably forecasts severity. In this aspect, the other techniques are unreliable. The CMS approach produces many plots, each of which suggests damage at various locations (particularly for higher modes), making it less accurate for detecting multiple damages when higher modes are used. The FC approach operates effectively when only one harm is present, but when numerous damages are present, it is unable to detect multiple damages. Although it produces passable results, the current PE approach, which was anticipated to dominate the older methods, does not appear to be a clear winner.

Xianhua Yao (2021) investigated RC beams of varying strengths with 600 MPa yield strength steel bars were used to determine the crack distribution and widths. By analysing statistical data of the various crack patterns seen in reinforced concrete beams, the characteristics of cracks are taken into consideration. Experimental results were used to develop methods for calculating the depth of the 600 MPa steel bars' effective influence zone in RC beams. The results of the experiments and research done in this work indicate that the parameters for calculating the maximum fracture width are difficult to utilize, time-consuming, and complex to calculate. The experimental data of RC beams with 335-600 MPa steel bars in this study correspond to longitudinal reinforcement stress, reinforcement diameter, longitudinal reinforcement ratio, concrete cover, and concrete strength according to various codes. The acquired findings are displayed, demonstrating the effectiveness of the longitudinal reinforcing stress in determining the maximum fracture width. Because of a specific linear relationship between maximum crack width and longitudinal reinforcement stress, this factor has a greater impact than other parameters like reinforcement diameter, longitudinal reinforcement ratio, and protective layer thickness. The results of the regression analysis show that the test data points are mostly distributed within the straight lines, with the expression between longitudinal reinforcement stress and maximum fracture width wmax being y=0.67x. According to the study's findings, a continuous expansion of cracks under varied loads after an initial cracking, or quick progression and a variety of relationships were developed, according to statistical analysis of the fractures under pure bending. The ratios between the estimated and measured values were very large, and the measured values of average crack spacing obtained in this study differ significantly from those obtained from other codes.

5. Building Information Modelling

Hamidreza Alavi (2021) et.al carried out a study on a data model is presented to integrate the building condition assessment model into Building Information Modelling and this model allows interoperability between the BIM and Bayesian Network(BN) which it is developed by Bortolini and Forcada for Building Condition Assessment it is created based on cause and effect relationship between uncertain elements. The system is used to automatize data workflow, reduce Facility Management time and effort results in improvement of maintenance activities, Good Decision making and increase durability. This model is applied in any type of Building as it worked based on semi-automated way, visualization method is approached and repair preference order is coded in colours from red to green. The workflow of the system is Visualize the condition of building then its sensitivity is analysed for low performance concrete and its causes then to make better remedy plans and finally proposes a solution for the immediate action and maintenance plans with limitation that it considers different elements such as facade, interior partitions, etc. and various systems such as plumbing, HVAC, etc. in assessed building for other elements and system further analysis must done. The other limitation is to recommended that the end user is to facilitate at every step to verify that the exported files is placed on a right location with its correct names.

Raquel Matos (2021) et.al conducted a study to assess a building performance and to organize the maintenance actions employment using Building Information Modelling(BIM). In this paper it involves Building data collection, Building Life Cycle Cost estimation and Automated calculation of Building Performance. This paper aims to extend the materials service life, prevent uncontrolled consumption of resources, buildings durability, wasting of natural resources and consequent environmental impact. To satisfy the above conditions the only way to achieve is predictive and periodic maintenance actions with continuous monitoring at regular intervals of time. This process starts with the BCA consist of parameters such as performance level, detecting early symptoms of defects resulting maintenance procedure. Building condition assessment faces a problems and difficulty such as identification of operational approach, How to prioritize various information, to assess the life cycle of building etc. these defects are overcome by BIM by

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assessing all these factors as key performance indicators and applied results in effective way to evaluate performance of the building, due to its reliable evolution it motivates the implementation and strategy of facility management in a proper and a continuous manner, Information records and reduction of unwanted action. A case study is made at Aveiro University Department of civil engineering in Portugal constructed in 2004 and resulted in 60 to 70 in Building performance institute(BPI) so it needs an immediate solution to correct the unusual behaviour. The methodology is used to know about the whole building performance in an automated way. BPI is calculated by Dynamo programming to receive the global value and life cycle costs. The colour code is given for prioritize in BIM. In this paper it concluded that BIM proves that it was a faster maintenance processes in shorter periods and also add an advantage in easy life cycle information, saving money and coming up with to facilitating managers time.

Silva and J. de Brito (2019) examines the effectiveness of two computational tools created for the building's outer elements in the adoption of condition-based maintenance practices. The first tool serves as a system for expert diagnosis and inspection, allowing comprehension of how to intervene depending on the problematic characterization of the piece under investigation. The second tool provides details on the element's service life based on each element's attributes (when to intervene). This study conducts a market survey with 57 various stakeholders in the maintenance sector, evaluating the usefulness of the offered computational tools, and outlining the characteristics that the software must have to ensure its usage by the sector. The main flaw in these research is the sample's representativeness because of a common problem, namely the low response rate to surveys of this kind. 57 applicable replies from experts in the maintenance and restoration industry were obtained for this investigation. The response rate is fairly low, as expected, despite the fact that the respondents are from diverse countries and actively participate in the market research environment, but it seems to be sufficient to allow generalizing the results to the target population. The statistics therefore make it possible to assess how useful the suggested tools are and how pertinent they are to the sector in the eyes of the stakeholders. The survey also prohibits these tools from being defined in an exclusively academic context, which could lead to the designation of non-pragmatic tools. The survey, on the other hand, makes it possible to create user-centered tools, utilizing the knowledge and helpful suggestions of other researchers and practitioners, as the success of these tools will depend on their acceptance by the industry.

Shoaib M Hanagi and Kiran M Malipatil (2018) carried a study on three RCC beams (A1, A2, and B1) were subjected to an analytical analysis using the ANSYS 15.0 program. Many parameters, including the shear span to depth ratio, stirrup arrangement, crack patterns, and load necessary for initial crack start, were examined. Beams with asymmetrical shear spans and depths ranging from 200 mm to 350 mm were created in order to evaluate the effects of the shear span to depth ratio (ANSYS software). The impact of shear arrangement on the beam when the right and left shear spans are separated by 100 mm and 200 mm, respectively, is also investigated. Numerical estimates of the load required for the first crack are made, and the results from the ANSYS program are contrasted. The crack patterns discovered using the ANSYS program were compared to past studies. Software from ANSYS was used to determine the stress intensity factor for beams. The load required for the first crack in RC beams as determined numerically and using ANSYS software varies by 16.25% for beam A1, 13.04% for beam A2, and 8.22% for beam B1. Beams A1 and A2 differ in deflection by 38%, while beams A2 and B1 differ in deflection by 78%. When compared to smaller beam sizes, larger beam sizes exhibit greater diagonal fracture spacing, which widens the shear crack width. Stirrup configuration leads to the conclusion that the RCC beams' loading point experiences steeper cracks than their support ends. Compared to an open shear arrangement, a closed stirrup configuration shows a narrower shear crack.

III. CONCLUSION

Building Pathology is an emerging field in construction and Rehabilitation Industry. Based on the critical review on Building Pathology it was observed that it should oriented to systemize the knowledge from the past, good previous experience but also focused on the new challenges in rehabilitation industry. From the critical review the following points were observed in regard to Building Pathology,

1) Building Condition Assessment is declared as a mandatory in few countries at regular intervals.
2) Building is evaluated through a systematic analysis by dividing the entire building based on the functional elements.
3) Linear Variable Differential transducer is used to investigate the structural cracks in many areas.
4) Epoxy injection, Routing and sealing, Stitching, Drilling and Plugging and gravity filling techniques were used to cure structural cracks.
5) It was observed that thermograms are easier to identify damaged areas compare to traditional photos.
6) The important tools used to analyses the building pathology are BIM, Neural network, Ansys, etc.

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