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CRACK DETECTION ON APARTMENT FACADE USING PHOTOGRAMMETRY – A STUDY

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Abstract - *Real estate sector has become one of India's most dynamic and rapidly growing industries. Over recent years, it has witnessed significant trends and advancements, largely fuelled by the city's thriving IT sector and substantial infrastructure development mainly concentrating on apartment building. The importance of civil engineering in apartment building maintenance plays a vital role, which helps in understanding the structural stability and durability of the building for its entire life-cycle. The structural stability has been assessed via traditional visual inspection method as the initial stage, which is followed by various tests to get to know about the structure in better ways. In recent days various advanced technologies and techniques like photogrammetry and image processing offer several advantages that can make assessments more efficient, accurate, and insightful which helps in improved data collection, enhanced objectivity, predictive maintenance, informed better decision-making, etc… this paper deals with the survey conducted among group of 150 respondents comprising apartment residents building assessment technicians, civil engineers, construction contractors and layman. Survey results clearly states the need for advancement in condition assessment.*

Key Words: **Residential Apartment, Building condition assessment, Causes of Crack, Photogrammetry, Survey, Decision Making Tool.**

1.INTRODUCTION

Maintaining apartment buildings involves balancing expenditure and efficiency to ensure resident safety, property value, and satisfaction. These buildings are both homes and investments, making their upkeep essential. Traditional methods of assessing building conditions are often time-consuming, hindering timely decision-making. Regular inspections are crucial not only for compliance but also for maintaining property value, strengthening resilience in emergencies, and providing managers with the information needed for effective decision-making. This proactive approach ensures the long-term health and value of the property.

Owners living in residential apartments must cover various maintenance costs, including common area electricity, water, elevators, garbage collection, and facility management, averaging Rs. 2 per sq. Ft monthly, depending on the flat size. Additionally, they bear the costs of internal maintenance like plumbing, electrical repairs, and essential civil works, such as addressing leaks and stains. Owners also invest in interior works to enhance their homes. Beyond these expenses, periodic building condition assessments and rectifications are necessary.

Advanced technologies, like photogrammetry, enhance assessment efficiency and accuracy. This technique improves data collection, enhances objectivity, supports predictive maintenance, and informs better decision-making. Data from photogrammetry, even from hard-to-reach areas, can create detailed digital models (Building Information Modelling - BIM), facilitating better visualization and analysis of potential issues.

In this paper survey was conducted among apartment owners and building repair & maintenance experts to know the actual practise and need for advancement in industry.

2. METHODOLOGY

In this paper survey was conducted among apartment owners and building repair & maintenance experts to know the actual practise and need for advancement in industry.

This study analyzes how owner associations in two apartment buildings persuade co-owners to invest in crack rectification as case studies and few other case studies on the photogrammetry can help in better decision making. This paper explores the process of achieving consensus on maintenance expenditures and includes surveys of apartment owners and technical personnel. The surveys assess respondents openness to new crack identification technologies and gather insights into the technical needs and preferences of those involved in the process. This multifaceted approach aims to understand and improve better strategies for building maintenance.

- Literature study on building condition assessment
- Case studies for understanding photogrammetry
- Case studies for understanding the scenario
- Survey

- Survey Response Analysis
- Results and Discussions
- Recommendations

2.1 BUILDING PATHOLOGY

Pathology is the methodical and often forensic practice that has come to be termed Building Pathology
The term Pathology is defined as systematic study of diseases with the aim of understanding their causes, symptoms and treatment.
-David Watt
Pathology is derived from Greek language
Pathos means "suffering"
Logos means "discourse"

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 started in ancient Rome and Greece to diagnose and fix building problems. Today, it deals with issues from climate change, new materials, and construction methods. This field combines knowledge from engineering, architecture, materials science, and environmental health. Experts use methods like visual inspections, checking moisture levels, and testing materials to ensure buildings are safe, functional, and valuable. They suggest repairs or renovations to fix and prevent problems.

Both maintenance and refurbishment are essential aspects of building pathology that contribute to the longevity, functionality and value of structures.

2.2 BUILDING CONDITION ASSESSMENT

Building condition assessment is essential for determining a structure's state and necessary actions for its safety and longevity. Buildings are classified into three categories: those without distress, those needing repairs, and severely damaged ones requiring demolition and reconstruction. The assessment process involves identifying damage, evaluating its extent, and estimating structural strength. It includes preliminary investigations, like visual inspections and safety evaluations, and detailed ones, such as testing materials and analysing structural systems. These steps ensure accurate recommendations for repairs and improvements.

Methodology of Condition Assessment and evaluation is generally carried out in two levels:

(i) Preliminary investigation or rapid (visual) investigation
(ii) Detailed investigation

Non-destructive tests like rebound hammer, ultrasonic pulse velocity, penetration resistance, pull-off testing and core testing are also done based on indirect measurement of concrete strength through measurement of surface hardness and dynamic modulus of elasticity.

With reference to [2] six parameters like objective of method, inspection and method scope, distress assessed/section, assessment criteria, implementation tools and finding of method has been compared between four Asian countries to compare the condition assessment procedure followed and the assessment is mostly carried out by visual inspection, the scope of inspection had to assess structural element and the tools established for its implementation. Among which, Singapore has website which is easy access to manage the entire assessment procedure such as document form related to assessment, checklist and a guideline.

2.3 HANDBOOK ON REPAIR AND REHABILITATION OF INDIA (CPWD)

The "Handbook on Repair and Rehabilitation of India (CPWD)" is a guide by India's Central Public Works Department. It offers advice on fixing and improving buildings and infrastructure, covering structural assessments, material selection, repair methods, and maintenance. The handbook aims to help engineers, architects, and construction workers maintain public structures.

Cracks in concrete can arise from shrinkage, settlement, overloading, freeze-thaw cycles, chemical reactions, corrosion, poor workmanship, design flaws, temperature changes, erosion, and aging. Proper design, construction, and maintenance can prevent and address these issues.

2.4 PHOTOGRAMMETRY

Photogrammetry is a cutting-edge way to find structural cracks using photos and computer analysis. High-resolution pictures are taken from different angles with cameras or drones. These images are then processed with special software to create a detailed 3D model of the building. Cracks and flaws are spotted by looking at surface irregularities in the model. This non-invasive method makes detecting cracks easier and, when combined with AI, it becomes even more accurate and efficient, which is essential for keeping infrastructure safe.

Artificial intelligence algorithms and neural networks have been widely used in various aspects of civil engineering, including structural optimization, structural state assessment and health monitoring. The combination of big data and deep learning is a new research direction for artificial intelligence in civil engineering.

Photogrammetry is a cost-effective and efficient tool, especially for making finite element method (FEM) models of buildings. It allows for structural analysis without needing deep engineering knowledge and helps with conservation, documentation, and restoration efforts.

3. CASE STUDY

3.1 CASE STUDY OF APARTMENTS

Two apartment buildings located in Chennai are taken for study, both are constructed with maivan technology at the completion time period of years 2011 and 2015 respectively.

First apartment building has eight blocks with 3BHK and 2BHK units for about 19 floors. This is the first project in maivan technology for the construction company. At first, they checked materials thoroughly, but over time, the checks became lenient, leading to cracks from poor workmanship, materials and water. Now the owners' association formed a team of civil engineering experts among the residents along with volunteers from each block. They informed others residents about the causes of crack, serious impact on the building structure and its stability due to the leaks which resulted from cracks and organized a sum of Rs.2-crore repair effort. This team of experts and senior consultants successfully extended the building's life.

Second apartment building has 10 blocks with combination of 1,2,2.5,3 & 4 bhk which has duplex, flats with private terrace and pent houses at top three floors. At the time of construction due to various reasons the civil work has been stopped for certain period and when resumed the different materials has been used to complete the project.

Also, the residents are unaware of the material, technology and technique used in this construction, they do alterations and changes as per their requirement without proper approval. As this happens, the proper cause of the internal cracks are not found easily.

Most of the residents are IT professionals and keep migrating as their workplace changes. 60% of the houses are occupied by the tenants and the drilling work is done for AC and TV fixing. As the drilling is done frequently on concrete surface this creates cracks both on the upper and below flats, this results with the confusion of identifying the cause of leakages.

Due to the unknown root cause of the leakage, some individuals are attempting to sell their flats, while others have relocated elsewhere, leaving the flats vacant and locked.

3.2 INFERENCE FROM THE CASE STUDY OF APARTMENTS

The case study gives insights that while the majority of residents demonstrate awareness of cracks and their causes, there is a lack of understanding regarding construction technology and methods used during the building's construction. This results in casual maintenance and inadequate care for the structure, leading to issues such as insufficient monitoring of cracks, seepage, and concrete surface spalling. Additionally, unapproved design alterations and frequent resident turnover further hinder efforts to address deteriorating structures. In the second study, the team found it very difficult to convince co-owners to spend for rectification work, where they had controversies with decision making. Effective collaboration among residents, including experts in crack rectification, has proven successful in preserving the structure's integrity.

3.3 CASE STUDY ON USING PHOTOGRAMMETRY FOR CONDITION ASSESSMENT

Two studies were taken for understanding the role of photogrammetry in condition assessment. First study is to analyse a historical building for over a period of time for the building deterioration. Second study is to analyse an old concrete bridge for the structural stability as it has many cracks.

The study [5] investigates ways to measure damage in old buildings and aid in their restoration. It employs digital photogrammetry, a cost-effective scanning method, along with image processing software to create 3D models of structures. The process is divided into three phases: surveying buildings, analysing the models, and comparing them over time. However, a challenge arises as the software lacks automation, requiring manual intervention to ensure accuracy. Despite this, the approach enhances experts' ability to assess and understand building alterations swiftly, offering a valuable alternative to traditional survey techniques.

The study [8] investigates a new approach for building conservation, in saving time when compared to the state of practice. This new method uses a neural network called Mask R-CNN to automatically survey concrete damage. It trains by adding images of damaged concrete. Photos are then turned into a 3D map through photogrammetry and fed into a BIM system. This system recreates the damage on the model, aiding decision-making. This method is faster than manual checks and doesn't need specific photo angles, making it useful for inaccessible areas and drones.

3.4 INFERENCE FROM THE CASE STUDY ON USING PHOTOGRAMMETRY FOR CONDITION ASSESSMENT

Both studies show that using photogrammetry is very helpful for checking how buildings are doing and making sure they're strong. The first study looks at how well it works for watching old buildings over time and fixing them up when they need it. The second study talks about a faster way to check the damages occurred in the structure. It uses computers to do the work quickly. These studies say it's important to use new technology like photogrammetry, with BIM models and computers to make sure buildings are safe and aids in better decision making about repairing and maintaining the structure.

4. SURVEY

This survey aims to gather insights on awareness of building cracks and its potential damage causes, knowledge on crack identification process and rectification work. The target respondents are apartment owners, architects, civil engineers, contractors, construction masons, crack rectification experts comprising a group of 150 people. The survey was conducted with two set of questioners each comprising twenty questions.

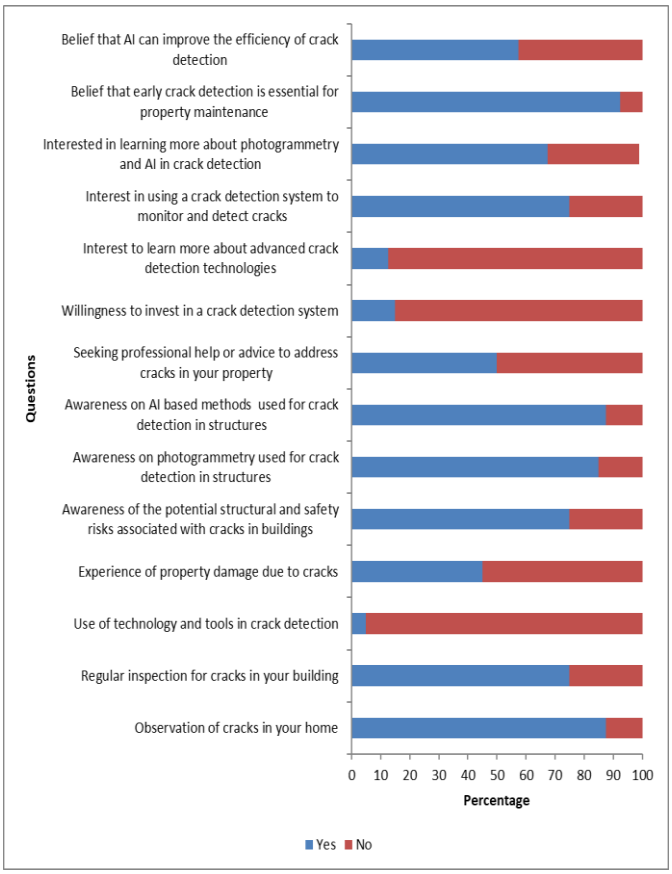

Chart -1: Knowledge on crack detection – questioner for apartment owner

The first set of questioners is for apartment owners, which has responses like 30 percent of respondents are unaware of the potential structural and safety risks associated with cracks in buildings, 85 percentage of respondents are ready to accept new technologies and techniques which helps in early crack detection in order to prevent the future damages. Also, respondents suggested on giving awareness to all potential apartment buyers for periodical maintenance and checking on the structural stability, rather than the visual inspection incorporating any new methods for solid evidence of the crack occurred will help in fast rectification. Most importantly respondents suggested a handout with risk and remedies due to crick would be of more use.

The second set of questioners is for technical peoples, which has responses like difficulty in locating the exact position of a crack when water leakage occurs and the need to address water leakage before effectively stopping the leakage by identifying the crack.

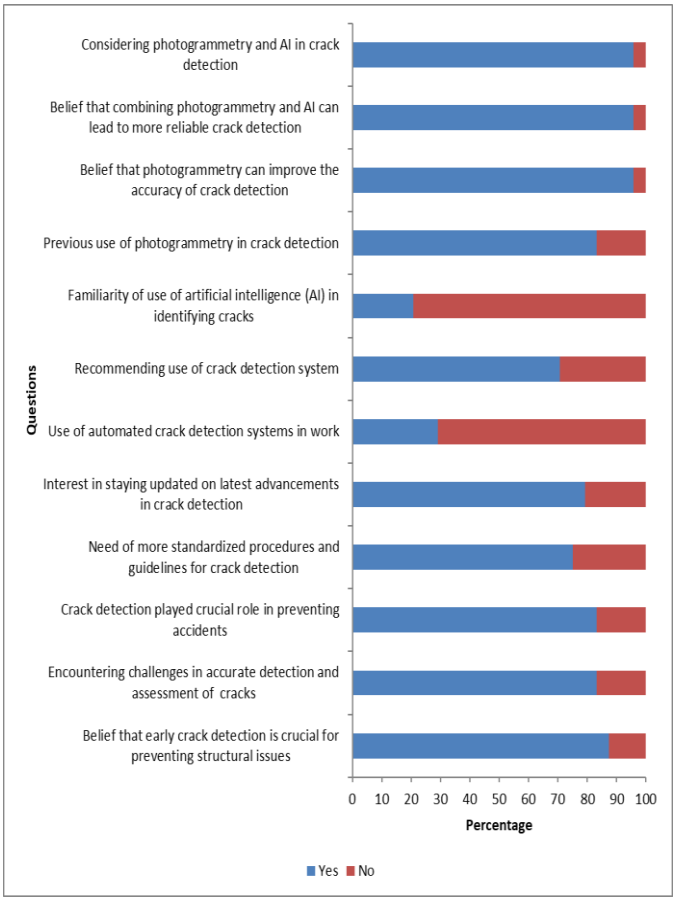

Chart -2: Knowledge on crack detection – questioner for Professionals

Various ways implemented to identify crack and leakages are Rebound Hammer and Ultra Sound Pulse Velocity for crack detection. Additionally, they implemented few more techniques which is listed below:

- The use of air cracks with water for easy identification of crack start point.
- Direct site visits to visually inspect cracks.
- The use of ultrasonic equipment for non-destructive testing (NDT).
- Smoke testing for permeable and impermeable members.
- Visual inspection methods such as pouring water, chipping concrete, and manual inspection to identify crack types.
- Machine learning algorithms for analysis.
- Visual analysis and on-site physical testing using methods like photogrammetry.
- Epoxy injection for repair.
- Identifying crack shapes, types, and locations through visual inspection, paper pasting, and wall hammering.
- Proper work techniques for inspection.
- Break the surface until the crack expands.
- Physical inspection using magnetic particle inspection for metals (MPI).

Different tools are used to find and fix cracks in buildings. Basic tools like hammers, steel blades, and paper are used, as well as advanced methods like ultrasonography to check for cracks. Chemical treatments include using crack pillars, bitumen joints, damp shields, and rubber joints. Cutting machines and tools are used for various tasks, and injection methods effectively seal cracks. Fiber mesh is added during construction to prevent cracks, and injectors and electromagnetic coils are used for specific needs. It's also important to inform maintenance staff quickly for timely repairs.

Respondents suggested using remote sensing systems with sensors during construction and advanced technology for finding and fixing cracks. They recommended using machine learning, especially computer vision, to improve accuracy and make solutions affordable and easy for unskilled workers. They stressed the need for more knowledge, the right materials, and focusing on finding structural cracks with AI and deep learning. Early studies and regular checks would help find serious cracks sooner, saving time and money. They also proposed affordable, easy-to-use solutions with standardized procedures and accessible guidelines.

5. RESULTS AND DISCUSSION

5.1 RESULTS:

The survey shows the experiences of professionals and apartment owners. It is found that 95% of owners have seen surface cracks, and 68% understand the structural risks these cracks can cause. Additionally, 90% of owners don't know much about construction technology or how to maintain their buildings. Surprisingly, 55% had property damage from cracks and leaks within the first five years, worrying them about extra repair costs. However, 85% are open to using new technologies like crack detection systems to protect their homes.

Among construction professionals, only 10% have formal certifications for inspecting cracks, but over 85% stress the importance of early crack detection and the difficulty of finding cracks that cause water leaks. Most support having standardized procedures and 80% are interested in automated systems. The survey highlights the need for cost-effective, easy-to-use methods and better knowledge for early crack detection and monitoring.

5.2 DISCUSSIONS

Apartments are not like any other structure, it's a home to all people living in. We all love our home very much, also we want it to be looking good and stay healthy for long period of time. Apartment maintenance is also very expensive for any individual as he or she needs to pay for basic amenities both for common area and for works within the houses. The cracks occurred on the surface are the key element for leakages and structural un-stability. In most cases we don't know the root cause of the crack and hidden cracks will be left unattended. Activities involved and load acting on the apartment floors are uncontrollable as each apartment belongs to various individual persons. Hence, getting permission for any kind of common work is a difficult task for association and maintenance team.

Crack inspectors or experts use traditional method of visual inspection as the first step and when required other non-destructive tests are conducted to know better about the stability of the structure. Again, the hidden or non-visible or unexpected cracks will be let unattended which leads to further damage of the property. So implementing advanced techniques like photogrammetry which is image processing integrated along with Machine Learning and Artificial Intelligence for obtaining various algorithm and software can generate 3-D model and it can be integrated with BIM to get proper results which will also act as effective decision making tool. A survey has been conducted among apartment owners and field experts to get actual insights of what is happening.

This study examines the process of detecting and maintaining building cracks in apartment complexes. Despite residents noticing cracks, their lack of understanding in construction methods leads to poor maintenance and issues like water seepage and surface damage. Unauthorized alterations and frequent resident turnover further complicate repairs, though collaboration between residents and experts has proven effective in maintaining building integrity. Survey data reveals widespread surface cracks and property damage, emphasizing the need for professional intervention and advanced crack detection technologies. This paper highlights the importance of awareness, technology, and standardized procedures in ensuring the safety and integrity of apartment buildings. We also evaluate

photogrammetry as a precise, non-invasive method for crack detection, enhanced by AI for better efficiency and accuracy in identifying and resolving structural problems.

6. CONCLUSION

This study suggests that using photogrammetry and advanced technologies simplifies data collection and analysis. The collected data can be stored and accessed anytime. According to the survey, both the owners, who are key investors, and the experts, who will fix the damage, agreed on using photogrammetry for better crack identification and planning repairs. Overall, photogrammetry can improve crack detection and analysis, benefiting both investors and workers in various ways.

We will discuss the costs of capturing images, processing methods, and other benefits in my next research paper.

7. RECOMMENDATIONS

- Eminent use of photogrammetry for crack detection in terms of cost saving.
- ML and AI can be used to develop error detection algorithms that automatically identify and flag potential issues in the data or the process of crack detection.
- Automation enhances efficiency but requires robust quality control for validation.
- Creation of highly detailed and accurate 3D models and simulations for building's exterior crack detection.
- Can create mobile app for quick crack detection accessible to everyone.
- User-friendly website for streamlined building assessment, encompassing forms, checklists, guidelines - will help to maintain standard procedures and keep updated in the specific area.

REFERENCES

[1] Nidhi Pise, Trupti Meshram, Yash Doijad, Rahul Gathe, "A Brief Study on Causes of Cracks, Prevention and Pattern of Cracks on Concrete" Ayush Bobade, Anup Kutemate, Swapnil Patil – 2021 doi: https://doi.org/10.32628/IJSRSET2183194

[2] Muhd Zubair Tajol Anuar, Noor Nabilah Sarbini, Izni Syahrizal Ibrahim, Mohd Hanim Osman, Mohammad Ismail and Ma Chau Khun "A comparative of building condition assessment method used in Asia countries: A review" – 2019 doi: 10.1088/1757-899X/513/1/012029

[3] Mufaro Gomera and Yunus Ballim "An artificial intelligence approach to detection and assessment of concrete cracks based on visual inspection photographs" –2022 https://doi.org/10.1051/matecconf/202236405020

[4] Youqin Huang, Jiayong Li and Jiyang Fu "Review on Application of Artificial Intelligence in Civil Engineering" – 2019 doi: 10.32604/cmes.2019.07653

[5] Rosella Alessia Galantucci, Fabio Fatiguso "Advanced damage detection techniques in historical buildings using digital photogrammetry and 3D surface anlysis" – 2019 https://doi.org/10.1016/j.culher.2018.09.014

[6] Fawaz Habbal, Abdualla AlNuaimi, Mohammed Alshamsi, Saleh Alshaibah, Thuraya Aldarmaki "Cracks Detection using Artificial Intelligence to Enhance Inspection Efficiency and Analyze the Critical Defects" - 2020 37th International Symposium on Automation and Robotics in Construction

[7] Saurabh Wankhade, Prajyot Pardhi, Aniket Khawas, Aditya Satpute, Nikhil Rathod "Causes, Detection And Repair Of Cracks in Building "– 2022 www.irjet.net

[8] P. Borin, F. Cavazzini "CONDITION ASSESSMENT OF RC BRIDGES. INTEGRATING MACHINE LEARNING, PHOTOGRAMMETRY AND BIM" – 2019 http://dx.doi.org/10.5194/isprs-archives-XLII-2-W15-201-2019

[9] Licun Yu , Shuanhai He , Xiaosong Liu , Shuqing Jiang , and Shuiying Xiang "Intelligent Crack Detection and Quantification in the Concrete Bridge: A Deep Learning-Assisted Image Processing Approach" – 2022 https://doi.org/10.1155/2022/1813821

[10] Dayal R. Parhi and Sasanka Choudhury "Analysis of smart crack detection methodologies in various structures" – 2011 pp 139-147 Academic journal http://www.academicjournals.org/JETR

[11] A Mohamed Wasim Akram, Dr.K Murali "A Critical Review on Building Pathology" – 2023 http://dx.doi.org/10.29322/IJSRP.13.05.2023.p13725

[12] André Thomsen "HOUSING PATHOLOGY; TOWARDS A HOLISTIC PATHOLOGICAL APPROACH OF RESIDENTIAL BUILDINGS" – 2020 http://dx.doi.org/10.29322/IJSRP.13.05.2023.p13725

[13] Rami Al-Ruzouq, Saleh Abu Dabous, M. Talha Junaid, Fatma Hosny "Nondestructive deformation measurements and crack assessment of concrete structure using close-range photogrammetry" – 2023 https://doi.org/10.1016/j.rineng.2023.101058

[14] Hafiz Suliman Munawar, Ahmed W. A. Hammad, Assed Haddad, Carlos Alberto Pereira Soares and S. TravisWaller "Image-Based Crack Detection Methods: A

Review" Infrastructures 2021, 6, 115. https://doi.org/10.3390/infrastructures6080115

[15] Hafiz Suliman Munawar, Fahim Ullah, Amirhossein Heravi, Muhammad Jamaluddin Thaheem and Ahsen Maqsoom "Inspecting Buildings Using Drones and Computer Vision: A Machine Learning Approach to Detect Cracks and Damages" Drones 2022, 6, 5. https://doi.org/10.3390/drones6010005