



Smart Maintenance: AI-Based Detection of Structural Damage and Eco-Friendly Repairs

Thesis Proposal

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Contents

1- Abstract	3
2- Project Overview.....	4
3- Project Goal.....	5
4- Approach	6
5- Project Steps and Timeline.....	9
6- Expected Results	10
7- Resources Needed.....	11
8- References	12

Abstract

Building that have structural damage is a costly and time-consuming affair due to manual inspections. Moreover, when selecting materials for repair decisions, sustainability is rarely considered, causing lasting damage. This research presents an artificial intelligence-based smart maintenance system for structural damage detection using **CNNs and natural language processing NLP** for suggesting eco-friendly materials for the remedy. The smart maintenance system will study pictures of the building and detect cracks and deterioration of the structure. It will also use sustainability reports and material specifications to suggest suitable green material choices. This approach would improve efficiency and accuracy while eliminating bias, which would benefit the construction and maintenance industry overall. This project will deliver a working AI-driven tool to assist and support architects, engineers, and city planners in making informed data-led decisions, reducing expenses, and encouraging green building maintenance.

1- Project Overview

Buildings get damaged over time for many reasons. Such as weather, everyday use, or structural stresses (Fan & Qiao, 2011). Mostly, damage detection methods such as cracks require manual inspections, which cause time, cost waste, and are prone to human errors (Behnood, 2025). In the repair process, many architects and engineers will look for materials without considering the sustainable and long-lasting materials used (Jones et al., 2020).

This project has the vision of making maintenance smarter and with less impact on the environment, which is why we are designing an AI-based tool that will:

- Detects structural damage through a Convolutional Neural Network (CNN) to analyze images to detect cracks with accuracy and speed (Li et al., 2024).
- Recommends eco-friendly materials that enhance and maintain the sustainability of the buildings by using Natural Language Processing (NLP) to analyze and suggest green building materials depending on each situation (Sarmadi & Mahdavinejad, 2023).

The integration of AI-based damage detection with smart material choice will reduce the time and costs of repair and maintenance and will support green construction. In the end, that will offer architects, engineers, and city planners a real-life data-driven way to make sure buildings will be safe and sustainable for the future (Vahdatikhaki et al., 2022).

2- Project Goal

The goal of this project is to develop an AI tool that could assist architects and engineers in evaluating building health to make better and more sustainable renovation decisions.

We will combine computer vision and natural language processing to function in this project, among other things:

- Observe images of the building and locate structural damage, such as cracks and state the cause of the damage to streamline inspections and cut down on the errors (Kostinakis et al., 2022).
- Recommend environmentally friendly materials for the repair, based on sustainability reports and industry databases so that the renovations are not only long-lasting but also eco-friendly (Jones et al., 2020).
- Enhance the effectiveness of building maintenance services by cutting down the time normally spent on manual inspections and directing experts to the most appropriate repair measures (Caldas, 2008).

In the end, this project is meant to address the issue of integration between structural safety and sustainability in the construction industry development and to provide practical AI solutions.

3- Approach

- **Data Collection**

As this project is to combine structural damage detection with the recommendation of sustainable materials, two types of data will be required:

A. Structural Damage Images (for Computer Vision)

We will be collecting images of buildings that show cracks, corrosion, and deformations to the extent that any engineer would want to have a look at them during an inspection.

- Where we'll get them:

1. Open-source building inspection datasets.
2. Drone and satellite images of aging structures.
3. Structural engineering reports with labelled images.

These images will enable the AI to learn to identify and classify damage and do so accurately (Li et al., 2024).

B. Sustainability Reports & Material Specifications (NLP)

We will also be collecting text-based data that describes the types of construction materials that are most durable, most cost-effective, and least harmful to the environment.

- Where we'll get them:

1. Green building certification standards (LEED, BREEAM).
2. Manufacture databases with information on material properties.
3. Research papers and government reports on sustainable construction.

This will enable AI to comprehend which materials are most suitable for which repairs and hence all recommendations would be both practical and eco-friendly (Sarmadi & Mahdavinejad, 2023).

- **Data Processing**

Before we can train our AI models, the data needs to be cleaned and organized for learning.

A. Preparing the Images (for Structural Damage Detection)

- To make sure that all images are of the same size and resolution.
- Some image adjustments such as brightness and contrast to enhance the images so that even small cracks will not go unnoticed.
- Different types of damage are labelled (minor cracks, major structural issues).

B. The Text Data Processing (for Material Selection)

- The text is clear to make sure that it is devoid of unnecessary words and symbols.
- Sustainability reports are broken down into meaningful sections.
- AI-powered text analysis is used to identify key material properties such as durability, carbon footprint, and energy efficiency (Jones et al., 2020).

- **AI Model Selection & Training**

We bring AI into the picture by training two powerful models for detecting structural damage and recommending the best repair materials.

A. Structural Damage Detection (Using Computer Vision - CNNs)

How it works: The AI will 'scan' images and identify cracks, corrosion, or any other weakness (Li et al., 2024).

- What we'll use: A Convolutional Neural Network (CNN), probably a pre-trained model, such as ResNet, YOLO, or Efficient Net, for object detection in images.
- Goal: Learn the severity of the damage and assist engineers in repairing it accordingly (Fan & Qiao, 2011).

B. Sustainable Material Recommendations (NLP & ML-based)

- How it works: AI will read sustainability reports and suggest the best eco-friendly materials for each type of repair.
- What we'll use: To analyze text and extract relevant insights, we'll use a BERT model. To suggest materials by environmental impact and durability, a ranking system (TF-IDF+ XGBoost, for instance).
- Goal: Enable decision-makers to select the most sustainable and cost-effective materials.

- **Testing & Evaluation**

To guarantee the effectiveness of the system, we will test it using real-world scenarios and measure its efficiency.

A. How to Check the Damage Detection AI.

- This will be compared to the accuracy of human experts.
- This is measured by its ability to identify cracks and corrosion in new images.
- To reduce the chances of missing real damage or marking safe structures as damaged, it must be tuned for false positives and false negatives (Kostinakis

et al., 2022).

B. How to Check the Material Recommendation AI.

- This list will be compared to recommendations made by architects and engineers.
- This will ensure that the suggested materials are compatible with sustainability benchmarks such as LEED.
- This will enhance its ranking system by further modifying the weighting factors.

4- Project Steps and Timeline

1. Data Collection and Preparation (Weeks 2-3)

Gather images of structural damage (cracks, corrosion, deformations).

Get sustainability reports and material specifications.

Preprocess and Clean Datasets (Image enhancement, Text tokenization)

2. Model Building and Training (Weeks 2)

Develop and train a CNN model for damage detection.

Teach a model to recommend eco-friendly materials.

Adjust models to improve their accuracy and efficiency.

3. Testing and Evaluation (Weeks 2-3)

Test AI models with real-world images and reports.

Test performance using precision, recall, and F1 score.

Improve the Models with Feedback.

4. Final Adjustments and Reporting (Week 2-3)

Integrate AI models into a web or mobile application.

Put the system to work and teach users.

Prepare project writing and final documentation.

5- Expected Results

We expect to achieve the following with this project.

- Improved Accuracy in Detecting Structural Damage
- Develop a deep learning model (CNN-based) capable of accurately identifying and classifying structural issues such as cracks, corrosion, and deformations.

Our detection system will be more precise compared to old human-based systems and use less money.

- New AI-Driven Insights for Sustainable Repairs
- Use Natural Language Processing (NLP) to analyze sustainability reports and material specifications, providing data-driven recommendations for eco-friendly construction materials.
- Sustainable and cost-effective decisions can be made for renewal and repair through understanding the correlation between the durability of materials and their environmental impact.
- A practical AI-based tool for real-life requests Develop an AI-based web/mobile application that will help engineers/architects/city planners quickly understand the building conditions and material recommendations.
- A tool to ensure regular maintenance and renovation work of buildings with automation, cost-effectiveness, and sustainable urbanism.
- Combining computer vision for damage identification and natural language processing for material suggestion will provide data-driven, intelligent solutions for building repair and maintenance activities under this project.

6- Resources Needed

We will require structural damage images to train our CNN.

- Open-source datasets like SDNET2018, Deep Crack, or industry-provided building inspection images Drone/satellite images of aging infrastructure (if accessible) Manually labeled images from engineering reports Sustainability Reports & Material Data (for NLP training).
- Researchers would leverage information from the following (fifth sentence):
 1. Green building standards (LEED, BREEAM)
 2. Manufacturer product databases (material properties, life cycle assessments)
 3. Government reports & academic research papers on sustainable construction
- Computing Resources. Hardware.
- A computer with NVIDIA RTX 3090 or A100 for deep learning training is called a high-performance GPU.
- A machine with at least 32GB RAM is used for model training/testing.
- Cloud computing is needed.
- A junior architect (expressed interest) who has participated in international projects & nbsp; who has graduated from a premier Institute (IIT/NIT/endowed Institutions) and preferably a foreign university.

The purpose is to ensure the correct working of AI and to understand basic real construction defects and repair materials used by experienced professionals.

- To adjust deep learning models and make them work better.
- To improve/Refine the material selection criteria considering its impact on the environment.

7- References

- Fan, W., & Qiao, P. Z. (2011). Vibration-based damage identification methods: A review and comparative study. *Structural Health Monitoring*, 10(1), 83–111.
<https://doi.org/10.1177/1475921710365419>
- Jones, M., Mautner, A., Luenco, S., Bismarck, A., & John, S. (2020). Engineered mycelium composite construction materials from fungal biorefineries: A critical review. *Materials & Design*, 187, 108397. <https://doi.org/10.1016/j.matdes.2019.108397>
- Li, X., Bolandi, H., Masmoudi, M., Salem, T., Lajnef, N., & Boddeti, V. N. (2024). Mechanics-informed autoencoder enables automated detection and localization of unforeseen structural damage. arXiv preprint arXiv:2402.15492. <https://arxiv.org/abs/2402.15492>
- Sarmadi, H., & Mahdavinnejad, M. (2023). A designerly approach to algae-based large open office curtain wall façades to integrate visual comfort and daylight efficiency. *Solar Energy*, 249, 1–14. <https://doi.org/10.1016/j.solener.2022.12.001>
- Vahdatikhaki, F., Salimzadeh, N., & Hammad, A. (2022). Optimization of PV modules layout on high-rise building skins using a BIM-based generative design approach. *Energy and Buildings*, 258, 111831. <https://doi.org/10.1016/j.enbuild.2022.111831>
- Kostinakis, K., Morfidis, K., Demertzis, K., & Iliadis, L. (2022). Classification of buildings' potential for seismic damage by means of artificial intelligence techniques. *Engineering Structures*, 252, 113592. <https://doi.org/10.1016/j.engstruct.2021.113592>
- Jones, M., Mautner, A., Luenco, S., Bismarck, A., & John, S. (2020). Engineered mycelium composite construction materials from fungal biorefineries: A critical review. *Materials & Design*, 187, 108397. <https://doi.org/10.1016/j.matdes.2019.108397>
- Caldas, L. (2008). Generation of energy-efficient architecture solutions applying GENE_ARCH: An evolution-based generative design system. *Advanced Engineering Informatics*, 22(1), 59–70.
<https://doi.org/10.1016/j.aei.2006.06.002> <https://daneshyari.com/article/preview/242319.pdf>
- Behnood, A. (2025). Artificial intelligence could save time, costs and enhance infrastructure durability, studies show. University of Mississippi. Retrieved from
<https://www.sciencedaily.com/releases/2025/02/250213143918.htm>
- Cha, Y. J., Choi, W., & Büyüköztürk, O. (2017). Deep Learning-Based Crack Damage Detection Using Convolutional Neural Networks. *Computer-Aided Civil and Infrastructure Engineering*, 32(5), 361-378.
- Jahanshahi, M. R., & Masri, S. F. (2013). A Vision-Based System for Non-Contact Structural Health Monitoring. *Structural Control and Health Monitoring*, 20(5), 853-872.
- Ashraf, W., & Noor, M. A. (2020). *Sustainability of Construction Materials Using AI-Based Decision Support Systems*.

Ramesh, T., Prakash, R., & Shukla, K. K. (2010). Life Cycle Energy Analysis of Buildings: An Overview. *Energy and Buildings*, 42(10), 1592-1600.

Devlin, J., Chang, M. W., Lee, K., & Toutanova, K. (2019). *BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding*.

Mikolov, T., Sutskever, I., Chen, K., Corrado, G. S., & Dean, J. (2013). *Distributed Representations of Words and Phrases and Their Compositionality*.