IMAGE CORRELAION IN SOIL SLOPE FAILURE

A

PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of the degreeof

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

of

Dr. Saurabh Rawat

Associate Professor

by

Avishya Jaswal (201629)
Paras Sharma 201601)
Aditya Rana (201637)

to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173234

HIMACHAL PRADESH, INDIA

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STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report entitled "IMAGE CORRELAION IN MAPPING OF SOIL SLOPE FAILURE" submitted for partial fulfillment of the requirements for the degree of **Bachelor of Technology in Civil Engineering at Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Dr. Saurabh Rawat**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

Signature of Student
Avishya Jaswal
201629
Date

Signature of Student
Paras Sharma
201601
Date

Signature of Student
Aditya Rana
201637
Date

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"Image Correlation of Soil Slope Failure"** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering**, Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Avishya Jaswal (201629), Paras Sharma (201601), Aditya Rana (201637**) during a period from July, 2023 to May, 2024 under the supervision of **Dr. Saurabh Rawat,** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat. The above statement made is correct to the best of our knowledge.

Date: …………………

Signature of Supervisor	Signature of HOD
Dr. Saurabh Rawat	Dr. Ashish Kumar Rohila
Associate Professor	Professor and Head
Department of Civil Engineering	Department of Civil Engineering
JUIT, Waknaghat	JUIT, Waknaghat

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ABSTRACT

The aim of this project is to investigate crack detection done by image correlation. There are researches being done on using image correlation as a method to study the structural behavior and deformation patterns. Image correlation reduces the man power required for analyzing structural behavior. Using image correlation also gives an edge in predicting the possible future behavior of the structure. In this study, a sand slope was casted in mould using pluviation technique. Sand passing through sieve size 1.18mm was used for the slope. The slope angle was 60^{o}. Load was applied on the crest of the slope. A load of 22.9kN was noted for the failure occurred in the slope. Photographs were taken of this setup. While the load was being applied on the slope crest, images were being taken using a DSLR camera. The clicked images were processed in the Fiji (ImageJ) software. The processed images produced the position of the cracks developed in the slope.

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LIST OF ABBREVIATIONS

CAD	Computer Aided-Design
CMM	Coordinate Measuring Machines
DCA	Deformation Concentration Area
DIC	Digital Image Correlation
DIP	Digital Image Processing
ITZ	Interface Transition Zone
NCC	Normalized Cross-Correlation
ROI	Region of Interest
SHM	Structural Health Monitoring
SIFT	Scale-Invariant Feature Transform
SSA	Salp Swarm Algorithm
SPC	Statistical Process Control
SVM	Super Vector Machine
SURF	Speeded-Up Robust Features
UAV	Unmanned Aerial Vehicles
UTM	Universal Testing Machine

CHAPTER 1. INTRODUCTION

1.1 Soil Slope Failure

Soil slope failure, simply put, refers to the collapse or movement of soil and rock material along a slope. It occurs when the forces acting on a slope exceed the strength of the soil or rock mass, leading to instability and subsequent failure. This failure can manifest in various forms, including landslides, mudslides, slumps, or rockfalls, depending on factors such as the slope's angle, the type of soil or rock involved, and external influences like rainfall or seismic activity. Soil slope failure can have significant consequences, posing risks to infrastructure, property, and human lives, and often requires careful assessment and management to mitigate these risks effectively.

Figure 1.1 Soil slope failure

1.1.1. Causes of Soil Slope Failure

Soil slope failures can result from a combination of natural and human-induced factors. Here are some common causes:

- **Erosion:** Natural processes like water flow, wind, or glacial movement can gradually erode soil and rock material, weakening the slope over time and leading to failure.

Figure 1.2 Soil Erosion

- **Saturation:** Excessive rainfall or melting snow can saturate the soil, reducing its shear strength and increasing the likelihood of slope failure. This phenomenon is prevalent in regions characterized by inadequate drainage.

- **Changes in Water Level:** Fluctuations in groundwater levels or changes in water flow patterns can destabilize slopes by exerting pressure on the soil or rock mass.

- **Earthquakes:** Seismic activity can shake the ground, causing soil and rock to lose cohesion and leading to slope failures.

- **Slope Geometry:** Steep slopes are inherently less stable than gentler ones, and changes in slope angle or shape can increase the risk of failure.

- **Vegetation Loss:** Removal of vegetation through deforestation, land clearing, or wildfires can destabilize slopes, as plant roots help bind soil together and prevent erosion.

- **Human Activities:** Construction, mining, excavation, or improper land use practices can alter the natural stability of slopes, increasing the risk of failure.

- **Geological Factors:** Geological features like faults, jointing, or weak bedding planes can contribute to slope instability, especially when combined with other factors like erosion or seismic activity.

1.1.2. Prevention of Soil Slope Failure

The prevention of soil slope failure involves taking proactive measures to reduce the likelihood of slope instability and minimize potential consequences. Here are some key prevention strategies:

1. Slope stabilization techniques:

- Implement technical solutions for slope stabilization, such as:
- Installing retaining walls, earth nails, or rock bolts to provide structural support.
- Constructing terraces or berms to reduce the slope angle and minimize erosion.
- Using geosynthetic materials like geogrids or geotextiles for soil reinforcement.
- Applying bioengineering techniques, such as planting vegetation, to stabilize slopes and strengthen soil cohesion.

2. Management of surface water:

- Properly manage surface water to minimize soil erosion and saturation:
- Implement drainage systems like surface channels, French drains, or subsurface drains to divert water away from slopes.

- Install anti-erosion measures like swales, gabions, or erosion control covers to protect slopes from runoff.
- Design stormwater management systems to control the volume and rate of runoff and reduce its erosion potential.

3. Vegetation management:

- Preserve or restore natural vegetation to stabilize slopes and reduce erosion:
- Plant native vegetation with deep root systems that anchor the soil and absorb excess water.
- Implement restoration programs in areas prone to erosion or slope instability.
- Maintain vegetative cover through regular monitoring, weed control, and erosion control.

4. Monitoring and early warning systems:

- Implement monitoring systems to detect signs of slope instability and trigger early interventions:
- Install instrumentation such as inclinometers, piezometers, or ground motion sensors to monitor slope movement, groundwater levels, and soil moisture.
- Establish schedules for regular inspections and monitoring to assess slope conditions and identify potential hazards.
- Develop early warning systems to alert stakeholders of impending slope failures or hazardous conditions, allowing for evacuation or corrective action.

5. Territorial planning and regulation:

- Implement land use planning policies and regulations to manage development in areas prone to slope instability:
- Identify and map areas with high susceptibility to slope failures using geotechnical studies and risk assessments.
- Establish setback requirements, zoning restrictions, and building codes to limit development in hazardous areas and ensure safe construction practices.
- Require comprehensive geotechnical assessments and slope stability analyses for

proposed development in high-risk areas.

1.2. Image Correlation

Image correlation is a technique used in image processing and computer vision to measure the similarity between two images or between different regions within the same image. It involves comparing pixel values in corresponding image locations and calculating a correlation coefficient or similarity metric.

There are several image correlation methods, but one common approach is cross-correlation. The template image (or small window) is compared to the larger search image in a cross-correlation. The template is systematically moved over the search image and at each position, the similarity between the template and the corresponding region of the search, image is calculated. This similarity measure is often calculated, using mathematical operations such as dot product, the sum of squared differences, or normalized cross-correlation.

The result of image correlation is typically a correlation map or surface, where each point represents the similarity between the template and the corresponding region of the search image. Vertices on this correlation surface indicate areas of high similarity that can be used to locate objects or features in an image.

Image correlation has various applications, including object detection, image registration, motion tracking, and stereo vision in 3D reconstruction. It is an essential tool in computer vision for tasks that involve comparing or aligning images.

1.2.1. Different methods of Image Correlation

The following are various methods of image correlation used in different fields such as civil engineering, computer vision, remote sensing, and materials science:

- **Cross-Correlation:** This method involves sliding one image (or a template) over another and computing the similarity between corresponding pixel values. It is commonly used for tasks like template matching, object detection, and image registration.

- **Normalized Cross-Correlation (NCC):** NCC is a variation of cross-correlation that normalizes the correlation coefficients to account for differences in image intensity and contrast. This makes NCC more robust to changes in lighting conditions and image variations.

- **Phase Correlation:** This method computes the cross-power spectrum of two images to find their phase difference, which can be used to estimate translation, rotation, or scale differences between the images. It is commonly used in image registration and motion analysis.

- **Feature-Based Methods:** These methods detect and match distinctive features or key points between images, such as corners, edges, or blobs. They often use techniques like SIFT (Scale-Invariant Feature Transform) or SURF (Speeded-Up Robust Features) for feature detection and matching.

- **Optical Flow:** Optical flow methods estimate the motion of objects or features between consecutive frames of a video sequence. They analyze the apparent motion of pixels or image patches over time to compute the velocity field of moving objects.

- **Displacement Tracking:** These methods track the movement of specific points or regions within an image sequence to measure deformation, strain, or motion. They often rely on tracking algorithms such as Lucas-Kanade or template matching combined with particle image velocimetry (PIV) techniques.

- **Correlation Filters:** Correlation filters are used for pattern recognition and target tracking tasks. They learn a filter that maximizes the correlation between a template and the target object in the image, allowing for efficient and robust object detection and tracking.

- **Digital Image Correlation (DIC):** DIC is a technique used in materials science and mechanical engineering to measure deformation and strain in materials under load. It involves applying a grid or speckle pattern to the surface of the material and tracking the movement of individual speckles or grid points between images.

1.2. Image Correlation in Civil Engineering

In the construction industry, image correlation refers to the use of image processing techniques to analyze and monitor the structural behavior, material properties, and deformations of building structures or geotechnical elements. It involves using images taken by cameras or other imaging devices to quantify changes in shape, displacement, stress, or other parameters over time.

Here are some common applications of image correlation in the construction industry:

- **Structural Health Monitoring (SHM):** Image correlation can be used to monitor the health and integrity of building structures such as bridges, buildings, dams, and tunnels. By analyzing images of these structures captured over time, engineers can detect and quantify changes in shape, deformation, or cracking that may indicate structural damage or deterioration.

- **Deformation Analysis:** Image correlation, is used to measure and analyze the deformation of soil, rock, or structural materials under various loading conditions. It allows engineers to understand how structures or geotechnical elements respond to external forces such as loads, temperature changes, or settlement.

- **Materials testing:** Image correlation can be used in laboratory experiments to study the mechanical properties of structural materials such as concrete, asphalt, soil, or composite materials. By monitoring surface displacements or strain fields in real time, engineers can evaluate material behavior under various loading conditions.

- **Geotechnical monitoring:** Image correlation is valuable for monitoring the stability of slopes, embankments, and retaining walls. By analyzing images of these features, engineers can assess the risk of slope failure, identify potential deformation mechanisms, and implement appropriate mitigation measures.

- **Construction Quality Control:** Image correlation can assist in quality control during construction by providing real-time feedback on the accuracy of construction activities such as ramming, excavation, or concrete placement. It allows engineers to verify that manufactured elements meet design specifications and tolerances.

CHAPTER 2. LITERATURE SUMMARY

2.1 Literature Summary Based on Different Research Papers

Minh-Tu Cao, Kuang-Tsung Chang:-

- The paper presents a cutting-edge method for detecting rutting in asphalt pavements through advanced image processing and machine learning techniques. The authors propose an automated system that leverages image processing to identify rutting patterns in pavement surfaces. This system employs a novel metaheuristic optimization algorithm to enhance the accuracy and efficiency of machine learning models used in the detection process. By optimizing key parameters of the machine learning algorithms, the proposed approach significantly improves the detection performance compared to traditional methods. The study's results demonstrate that the optimized machine learning models can accurately and reliably detect rutting, offering a valuable tool for road maintenance and management. The paper highlights the potential of integrating advanced computational techniques with practical engineering applications to address critical infrastructure challenges.

Ming-Chih Lu, Tieng Yu Tang:-

- The paper introduces a sophisticated system for monitoring landslides using image processing technologies. The authors describe a framework that utilizes time-lapse photography to capture and analyze changes in landslide-prone areas. The system employs advanced algorithms to process the images, detect subtle movements in the terrain, and identify early signs of landslides. Key features include the integration of geotechnical data and environmental conditions to enhance the accuracy of the monitoring process. The approach allows for continuous and real-time surveillance, providing critical information that can be used for early warning and disaster prevention. The results of the study demonstrate the system's effectiveness in identifying potential landslide events before they occur, offering a valuable tool for mitigating risks and improving public safety. This research underscores the importance of leveraging modern imaging technologies and data analysis techniques in natural disaster management.

An-Bin Huang, Yu-Jie Huang:-

- The paper presents a novel approach for preparing silty sand specimens in geotechnical laboratories. Traditional methods of specimen preparation often face challenges in achieving uniformity and replicability, particularly with silty sands that have varying particle sizes and compositions. The authors introduce a mist pluviation technique, which involves dispersing water mist during the sand pluviation process to achieve better control over the moisture content and distribution within the specimen. This method aims to create homogenous and reproducible specimens that closely mimic natural soil conditions. The paper details the experimental setup, procedure, and parameters optimized for the mist pluviation process. The effectiveness of this method is validated through a series of tests, comparing the physical and mechanical properties of specimens prepared by mist pluviation against those prepared by traditional dry and wet pluviation methods. Results indicate that the mist pluviation method produces more uniform specimens with consistent density and improved structural integrity, making it a valuable technique for geotechnical testing and research. This innovative approach enhances the reliability of laboratory experiments, contributing to more accurate and applicable findings in soil mechanics and geotechnical engineering.

John Mark Go Payawal and Dong-Keon Kim:-

- The paper provides a comprehensive overview of the current state-of-the-art techniques in image-based structural health monitoring (SHM). The authors systematically review the literature to identify the most effective methods and technologies used in the field. This includes an examination of various imaging techniques, such as digital image correlation, photogrammetry, and infrared thermography, which are employed to detect and assess structural damage in buildings, bridges, and other infrastructures. The review highlights the advantages of using image-based SHM, including its non-invasive nature, high accuracy, and ability to cover large areas quickly. Additionally, the paper discusses the integration of advanced algorithms, such as machine learning and computer vision, which enhance the capability of these imaging techniques to automatically detect and quantify damage. Challenges associated with image-based SHM, such as environmental factors affecting image quality and the need for substantial computational resources, are also addressed. The authors conclude by identifying future research directions and potential improvements, emphasizing the importance of interdisciplinary collaboration to advance the field. This systematic review serves as a valuable resource for researchers and practitioners looking to implement or improve image-based SHM systems.

Chennarapu Hariprasad, Mekala Rajashekhar:-

- The paper explores techniques for creating homogeneous sand specimens for geotechnical testing. The authors compare two primary methods: stationary pluviation, where sand is allowed to fall through air in a controlled manner to achieve a uniform distribution, and vibratory methods, which involve compacting the sand using mechanical vibrations to enhance density and uniformity. The study investigates the effects of various parameters, such as drop height, flow rate, and vibration frequency, on the density and uniformity of the sand specimens. Through a series of controlled experiments, the paper demonstrates that both methods can produce specimens with consistent properties, but the vibratory method is particularly effective in achieving higher densities and uniformity. The research highlights the importance of optimizing these parameters to replicate natural soil conditions accurately. The findings contribute valuable insights into the preparation of sand specimens, which is crucial for reliable and reproducible geotechnical testing. By improving specimen preparation techniques, this study enhances the accuracy of laboratory experiments and supports better understanding and prediction of soil behavior in engineering applications.

Christopher Nonis, Christopher Niezrecki

- The paper investigates the application of DIC for monitoring the structural health of bridges. DIC is a non-contact optical technique that measures full-field displacements and strains on the surface of structures by analyzing images taken before and after deformation. The authors explore the effectiveness of DIC in capturing the structural responses of bridges under various loading conditions. The study involves detailed experimental setups where high-resolution cameras capture images of the bridge surfaces, and specialized software processes these images to detect minute deformations and strains. The findings demonstrate that DIC can accurately and reliably identify structural defects, such as cracks and deformations, providing real-time data crucial for maintenance and safety assessments. The paper also discusses the advantages of DIC, including its high precision, ability to cover large areas, and minimal disruption to bridge operations. Additionally, challenges such as environmental influences on image quality and the need for advanced image processing techniques are addressed. Overall, the study highlights the potential of DIC as a powerful tool for the structural health monitoring of bridges, enhancing the ability to maintain and ensure the safety of critical infrastructure.

Chenglong Jiang

- The paper presents an innovative approach to evaluating pavement conditions using automated crack detection and diagnosis. The methodology leverages advanced image processing and machine learning techniques to identify and classify cracks on pavement surfaces accurately. The system captures high-resolution images of the pavement, which are then processed to detect cracks using sophisticated algorithms that analyze the texture, shape, and pattern of the cracks. The machine learning component is trained on a diverse dataset of pavement images to improve the accuracy and reliability of crack identification. The methodology not only detects the presence of cracks but also categorizes them based on severity, type, and potential impact on pavement integrity. The results demonstrate the system's high precision and efficiency, significantly reducing the time and labor required for traditional manual inspections. The study underscores the potential of automated systems to enhance pavement maintenance strategies, offering timely and precise data for better decision-making. This approach contributes to the development of more resilient and well-maintained road infrastructures by enabling proactive and cost-effective maintenance practices.

K Tharun Kumar Reddy, Srikanth Koniki

- The paper provides a comprehensive overview of the use of DIC in SHM. DIC is a non-contact optical method that measures full-field surface displacements and strains by comparing digital images of a structure before and after deformation. The authors systematically review the fundamental principles of DIC, its implementation in SHM, and its advantages over traditional methods. They discuss various applications of DIC in monitoring different types of structures, such as bridges, buildings, and aerospace components, highlighting its high accuracy, ability to capture detailed strain distributions, and suitability for real-time monitoring. The review also addresses the challenges associated with DIC, including environmental factors that affect image quality, the need for high-resolution cameras, and the complexity of data processing. Advances in DIC technology, such as the integration with machine learning and improvements in software algorithms, are examined for their potential to enhance the effectiveness of SHM. The authors conclude that DIC is a powerful tool for SHM, offering precise and detailed insights into structural behavior, which can lead to improved safety and maintenance strategies for critical infrastructures.

Yijie Huan, Xujia He:

- The analysis process and numerical program for the DIC method were developed to measure displacements and strains in coarse aggregates, cement mortar, and the ITZ, with these measurements verified against experimental results. It was found that axial displacement was unevenly distributed during loading, with ITZs and cement mortar showing larger displacements than coarse aggregates before the formation of macro cracks. The water-to-cement ratio (W/C) did not have a significant effect on horizontal displacement. Test results showed that transverse and shear DCAs emerged when stress reached 30%–40% of the peak stress, crossing cement mortar, ITZs, and coarse aggregates. In contrast, axial DCAs were mainly around coarse aggregates. Higher W/C ratios resulted in more and larger DCAs. Crack propagation varied with different W/C ratios, with high W/C specimens displaying relatively smaller crack values and widths. The W/C ratio had a notable impact on the characteristics of concrete deterioration. Lastly, crack characteristics were assessed by comparing the calculated results.

Pedro J. Sousaa, Francisco Barros

- During the experiments, an image sequence was captured as two 30-ton trucks consecutively crossed the bridge. Despite suboptimal environmental conditions, the results demonstrated the effectiveness of DIC and validated the quality of the DIC algorithms developed at INEGI. The experiments successfully distinguished the bridge's response to static loads at different positions by analyzing the first truck's two stops and compared these responses to the dynamic load from the second truck's passage. Wind gusts caused instability in the speckle pattern, generating measurement noise, exacerbated by heat-induced distortions in the tarmac. These issues could be mitigated by using heavier or painted targets and positioning them closer to the bridge's edge. After filtering the data and accounting for adverse weather conditions, the results remained promising.

Belen Ferrer

- The paper explores the application of image processing techniques to enhance safety assessments in civil engineering projects. The author reviews various image processing methods, such as DIC, photogrammetry, and thermal imaging, which are utilized to detect structural anomalies, monitor deformations, and assess material conditions. These techniques enable the non-invasive and real-time evaluation of infrastructure, offering high precision and extensive coverage. Ferrer highlights the integration of these image processing methods with advanced data analysis tools, including machine learning algorithms, to improve the accuracy and efficiency of safety assessments. The paper discusses the advantages of these technologies, such as their ability to provide detailed and continuous monitoring without disrupting normal operations. Challenges, such as environmental influences on image quality, the need for sophisticated equipment, and the processing power required for large data sets, are also examined. The author presents case studies where image processing has successfully identified potential safety hazards in bridges, buildings, and other structures. The conclusion emphasizes the significant potential of image processing in improving safety assessment practices in civil engineering, advocating for continued innovation and development to address current challenges and expand its application.

Ji-Woo Kim, Hee-Wook Choi

- The paper offers an in-depth analysis of the latest advancements in using image-processing technologies for monitoring the health of civil infrastructures. The review covers a wide range of image-processing techniques, including DIC, photogrammetry, infrared thermography, and computer vision, which are employed to detect and analyze structural defects such as cracks, deformations, and material degradation. Ji-Woo Kim highlights the strengths of these techniques, emphasizing their non-contact nature, high precision, and ability to provide comprehensive and real-time monitoring over large areas. The paper discusses the integration of these technologies with machine learning algorithms to enhance their diagnostic capabilities and automate the analysis process. Additionally, the review addresses challenges such as the impact of environmental conditions on image quality, the need for high-resolution imaging equipment, and the computational demands of processing large datasets. Case studies and examples from real-world applications are presented to illustrate the practical benefits and limitations of these technologies. The author concludes that image-processing-based SHM offers significant potential for improving the maintenance and safety of civil infrastructures, advocating for further research and development to overcome current limitations and expand their application scope.

Nhat-Duc Hoang

- This paper focuses on employing image processing techniques, particularly an enhanced Otsu method for image thresholding, to identify surface cracks in building structures. The primary objectives are automating crack detection and enhancing accuracy. The methodology involves refining the Otsu method for better crack detection, likely through adjustments tailored to building structure images. The process includes pre-processing steps like noise reduction, followed by applying the improved Otsu method for thresholding. Post-thresholding, cracks are detected based on segmented regions, possibly utilizing edge detection and morphological operations. Experimental evaluation likely involves testing the method on images with known cracks, assessing metrics like accuracy and computational efficiency. The results showcase the method's effectiveness in accurately identifying surface cracks, concluding with insights into limitations and future research directions. Overall, the paper contributes to structural health monitoring, potentially aiding in infrastructure maintenance and safety.

Marcin Malesa, Dariusz Szczepanek

- This paper explores the application of the DIC technique for monitoring civil engineering structures. The study likely involves capturing images of structures, analyzing them using DIC software to track displacements and deformations, and assessing structural behavior. DIC's advantages, such as non-contact measurement and high accuracy, are likely emphasized. The paper may discuss various applications in civil engineering, including infrastructure monitoring and damage detection. Overall, the research contributes to enhancing structural monitoring capabilities using advanced optical techniques like DIC.

Yu-Fie Liu, Soojin Cho

- Concrete Crack Assessment Using Digital Image Processing and 3D Scene Reconstruction" by Yu-Fei Liu introduces a novel methodology for evaluating concrete cracks. The paper proposes an integrated approach that combines digital image processing techniques with 3D scene reconstruction methods. Using cameras, images of concrete surfaces are captured and processed using DIP algorithms to enhance crack detection and characterization. Additionally, 3D scene reconstruction techniques are applied to create detailed three-dimensional representations of the concrete and its cracks. The study emphasizes the potential of this integrated approach for improving the accuracy and efficiency of concrete crack assessment in civil engineering applications, particularly in structural health monitoring and maintenance efforts.

S. Sankarasrinivasan, E. Balasubranian

- It proposes an innovative approach for monitoring the health of civil structures. The study introduces an integrated system that combines UAVs with image processing techniques. Using UAVs equipped with cameras, high-resolution images of civil structures are captured, and these images are then processed using advanced image processing algorithms. The paper aims to demonstrate the effectiveness of this integrated system in detecting and analyzing structural defects such as cracks, deformations, and other signs of deterioration. By leveraging UAVs and image processing technology, the proposed approach offers a cost-effective and efficient method for conducting regular inspections and monitoring the condition of civil infrastructure, ultimately contributing to enhanced safety and maintenance practices.

Natrajan Chidambarathanu

- The paper presents a methodology for accurately measuring crack dimensions in concrete structures using digital image processing techniques. The study proposes a comprehensive approach that involves capturing high-resolution images of concrete surfaces containing cracks and then processing these images using advanced DIP algorithms. Various image processing techniques such as noise reduction, edge detection, and thresholding are applied to enhance the visibility and clarity of the cracks in the images. Subsequently, the dimensions of the cracks, including their length, width, and orientation, are measured accurately using geometric and statistical analysis methods. The paper aims to demonstrate the effectiveness and reliability of this approach in quantifying crack dimensions, which is crucial for assessing the structural integrity of concrete infrastructure and planning appropriate repair and maintenance strategies.

Arun Mohan, Sumathi Poobal

- The paper provides a comprehensive survey of various image processing techniques used for detecting cracks in structures. The review covers a range of methods including wavelet transform, median filtering, morphological operations, Gabor filtering, Otsu's method, and the super pixel algorithm. The authors critique manual inspection methods for their subjectivity and propose automated, image-based techniques as more objective alternatives. They analyzed 50 research papers, discussing the accuracy, error rates, and datasets used in these studies. The paper also identifies key research challenges and suggests areas for future exploration to enhance the effectiveness of crack detection technologies

Nhat-Duc Hoang, Thanh-Canh Huynh

- The paper presents an innovative method for detecting cracks and sealed cracks in asphalt pavement. This method combines advanced image processing techniques with the Salp Swarm Algorithm (SSA) to optimize a machine learning model for enhanced accuracy. The process involves extracting features that characterize the visual appearance and texture of pavement images, followed by employing a multiclass support vector machine (SVM) for pattern recognition. The SSA is used to optimize the SVM model, achieving high accuracy rates of 91.33% for crack detection and 92.83% for sealed crack detection. This integrated approach aims to improve detection performance and reduce false positives, addressing challenges associated with the visual similarity between cracks and sealed cracks.

Bin Lei, Ning Wang

- The paper introduces a novel crack detection method for bridge inspection employing UAVs and image processing techniques. The proposed method combines the advantages of UAVs' mobility and accessibility with advanced image processing algorithms to enhance the efficiency and accuracy of bridge inspection. The process involves UAVs equipped with high-resolution cameras capturing images of bridge surfaces, which are then analyzed using image processing algorithms specifically designed for crack detection. These algorithms effectively identify and categorize cracks based on their size, shape, and severity, providing valuable insights for maintenance and repair efforts. The method offers several advantages over traditional manual inspection methods, including reduced inspection time, improved safety for inspectors, and the ability to access difficult-to-reach areas of the bridge. The study presents experimental results demonstrating the effectiveness and reliability of the proposed approach, highlighting its potential for widespread adoption in bridge inspection practices, ultimately contributing to safer and more resilient infrastructure systems.

J. Valenca, I. Puente

- The paper outlines an assessment method for cracks on concrete bridges utilizing image processing aided by laser scanning surveys. The approach integrates the advantages of laser scanning technology with sophisticated image processing algorithms to enhance the accuracy and efficiency of crack assessment on bridge structures. Initially, laser scanning surveys are conducted to acquire detailed 3D point cloud data of the bridge surface, capturing precise geometric information. Subsequently, high-resolution images of the bridge are obtained and processed using specialized algorithms tailored for crack detection and analysis. These algorithms employ techniques such as edge detection, pattern recognition, and machine learning to identify and classify cracks based on their characteristics, including size, shape, and orientation. The combined data from the laser scanning surveys and image processing analysis provide comprehensive insights into the condition of the bridge, facilitating informed decision-making regarding maintenance and repair strategies. The study presents empirical results demonstrating the effectiveness and reliability of the proposed methodology, showcasing its potential to revolutionize the assessment of concrete bridge structures, leading to improved safety and longevity of infrastructure assets.

Frederique Robert, Guy Lefebvre

- The paper focuses on utilizing image processing techniques to analyze the granulometry of riprap used in dam construction. Riprap, consisting of large stones covering embankments, requires precise measurement of stone sizes to ensure structural integrity. The authors describe a method where images of the riprap are captured and processed to separate stones from the voids between them. Initial thresholding methods proved insufficient, leading to the development of an enhanced edge detection technique. This new approach involved the correlation of distance maps to more accurately detect stone edges, allowing for the measurement of stone diameters. The resulting granulometry curves derived from this process were then compared with experimental results, demonstrating the effectiveness of the method in providing accurate assessments critical for dam maintenance and safety.

Matthias Ehrhart, Werner Lienhart

- The paper presents a novel approach for monitoring the dynamic deformation of civil engineering structures using image-based techniques from long distances. The method employs high-resolution digital cameras and advanced image processing algorithms to accurately measure structural displacements and vibrations in real-time. This technique offers a non-contact, efficient, and cost-effective alternative to traditional monitoring methods, providing high accuracy and the ability to cover large areas. The authors discuss the implementation of the system, its validation through field tests, and its potential applications in structural health monitoring, showcasing its effectiveness in capturing dynamic responses of structures such as bridges and buildings under various load conditions.

Tiago Ramos, Andre Furtado

- This paper focuses on the application of these techniques for measuring deformations in masonry walls. DIC is a non-contact optical method that tracks the movement of a speckle pattern applied to the surface of the structure, allowing for precise measurement of displacements and strains. The study highlights the use of both 2D and 3D DIC approaches, comparing their accuracy and applicability in capturing detailed deformation behavior of masonry walls under load. The paper presents experimental results demonstrating the effectiveness of DIC in providing high-resolution data, which is crucial for assessing structural integrity and performance. Ramos discusses the potential of DIC as a powerful tool for structural health monitoring, offering insights into its advantages over traditional measurement methods.

Sylvie Chambon, Jean-Marc Moliard

- This research paper provides a comprehensive review of the methodologies and technologies used in the automatic assessment of road pavements through image processing techniques. The paper explores various image acquisition systems, including those using cameras mounted on vehicles, and discusses different image processing algorithms designed to detect and classify pavement distresses such as cracks, potholes, and rutting. Chambon compares the effectiveness of these techniques, highlighting their advantages and limitations in terms of accuracy, processing speed, and robustness under varying environmental conditions. The review also examines the integration of machine learning and computer vision technologies in improving the detection and assessment processes. Chambon concludes by identifying current challenges in the field and suggesting potential directions for future research, emphasizing the importance of advancing these technologies for more efficient and accurate road maintenance and management.

2.2 Research Gap

- The technical reliability of image processing in the civil domain addresses the uncertainties of construction sites, adverse weather conditions, and real-time image acquisition, ensuring smooth application and effectiveness.
- To enhance the model's performance, a substantial amount of accurately labeled data is essential.
- Exploring the integration of image detection with advanced civil engineering materials, such as fiber-reinforced composites and smart materials, to monitor their behavior under various loading conditions.
- Integration with other sensing technologies.

CHAPTER 3. MATERIALS AND METHODOLOGY

3.1 Problem Identification

Assessing certain structures or areas manually is sometimes a tedious task to perform with lack of accuracy as well. In huge structures such as skyscrapers, it is very hard to evaluate the failures occurring within the structure. Thus, image correlation techniques are brought into practice to carry out non-contact detection, analyzing structural behavior and deformation patterns.

3.2 Objective

Using image correlation to measure the displacement in the soil slope after load application.

3.3 Materials Used

For carrying the experiment, we did not require any special materials. We mainly used soil and water.

3.3.1 Soil

Soil was acquired from the ground ahead of the temple was used as a base layer in the mould.

Figure 3.1 Soil

3.3.2 Sand

Sand was used from the lab itself, passing through 1.18mm sieve. Sand was used to form a slope on the soil layer.

Figure 3.2 Sand

3.3.3 Water

Water was mixed with sand in order to stabilize sand and retain its shape as slope.

3.4 Setup and instrumentation

The mould, in which the sand slope was casted, was placed under the UTM and the sand slope was laid in the mould. Sand was mixed with water in order to retain the slope shape. Load was applied on the crest of the slope. The displacements were measured accordingly and the photographs were taken with respect to the application of the load.

Figure 3.3 Mould placed in the UTM

3.4.1 Software used

Fiji (Fiji Is Just ImageJ) is a powerful open-source image processing package based on ImageJ, a well-known program for scientific image analysis. Developed to extend ImageJ's capabilities, Fiji provides an integrated software platform that encompasses a wide array of plugins and tools essential for researchers, particularly in the life sciences. One of the primary advantages of Fiji is its ease of use and comprehensive nature, enabling users to handle complex image processing tasks without requiring extensive programming knowledge. The software supports a vast range of image formats and offers tools for tasks such as image registration, segmentation, and analysis. This makes it an indispensable tool for microscopy, medical imaging, and various other scientific applications.

Fiji's user-friendly interface is one of its most notable features, designed to streamline the workflow of scientists and researchers. It comes preloaded with a multitude of plugins, which significantly enhances its functionality compared to the original ImageJ. These plugins cater to various specialized needs, including 3D visualization, co-localization analysis, and time-lapse imaging, thereby broadening the scope of research that can be conducted using the software. Furthermore, Fiji supports scripting in several languages like Java, Python, and JavaScript, allowing users to automate repetitive tasks and customize the software according to their specific requirements.

Another significant aspect of Fiji is its robust community support. Being an open-source project, it benefits from the contributions of a global community of developers and users who continuously improve the software. This community-driven approach ensures that Fiji stays at the cutting edge of image processing technology, with frequent updates and the addition of new features. The extensive online documentation and forums provide users with resources and support, making it easier for newcomers to get started and for experienced users to troubleshoot complex problems.

Fiji also excels in integrating with other scientific software and tools, facilitating a more cohesive research environment. It can interface with programs like MATLAB and R, and it supports various data formats used in scientific imaging. This interoperability is crucial for researchers who need to combine image analysis with statistical computing or other advanced data analysis techniques. Additionally, Fiji’s compatibility with modern computing environments, including high-performance computing clusters, enhances its utility for handling large datasets and performing computationally intensive tasks.

The software’s versatility extends to its application in different scientific disciplines beyond biology and medicine. Researchers in fields such as materials science, astronomy, and environmental science also use Fiji for tasks like particle tracking, surface analysis, and spectral imaging. This cross-disciplinary applicability underscores Fiji’s role as a fundamental tool in scientific research.

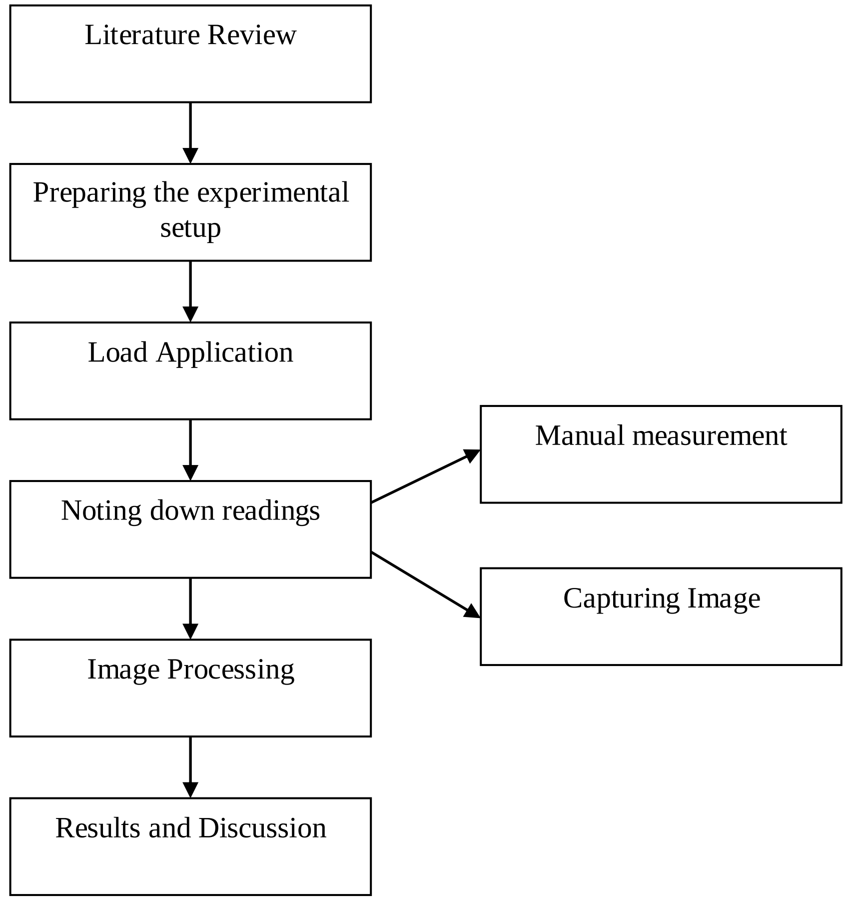
In summary, Fiji stands out as a comprehensive, user-friendly, and powerful image processing software that significantly extends the capabilities of ImageJ. Its extensive plugin ecosystem, robust community support, and ability to integrate with other tools make it an indispensable resource for researchers across various scientific disciplines. By simplifying complex image analysis tasks and providing a flexible, customizable platform, Fiji continues to foster advancements in scientific research and discovery. Its ongoing development and community engagement ensure that it remains a leading tool in the ever-evolving field of image processing.

3.5 Methodology

A mould of dimensions 60*40*60cm was taken. The mould is covered with polycarbonate sheets on the sides and the bottom, leaving the top open. The sheets used are transparent in order to click the pictures of the slope within the mould.

A base layer of soil is laid in the mould. At an angle of 60°, a sand slope is casted. In order to maintain the sand slope, water was added to the sand. After completion of this experimental setup, load was applied on the slope under the UTM. Images are taken after load application and processed in software for image correlation.

A flowchart of the experiment carried out is mentioned below


Literature Review
Preparing the experimental setup
Load Application
Noting down readings
Manual measurement
Capturing Image
Image Processing
Results and Discussion

CHAPTER 4. EXPERIMENTAL ANALYSIS

4.1 Experimental Setup

The mould with the sand slope with an angle of 60°, was placed under UTM. The load was applied and the images were taken during the load application. The failure and the displacement that occurred in the slope were recorded. The images taken was processed using the GOM inspect software. A load of 22.9kN was applied on the soil slope.

Figure 4.1 Mould placed in the UTM

Figure 4.2 Camera setup

Figure 4.3 Half-filled mould under the UTM

Figure 4.4 Readings given by the UTM

Figure 4.5 Load applied on the crest of the sand slope

Figure 4.6 Shift of slope crest after applying the load

Figure 4.7 Sand slope after testing

CHAPTER 5. RESULTS AND DISCUSSION

5.1 General

Sand slope with an angle of 60° was mad inside a mould. This mould was placed in UTM. A uniformly distributed load was applied on the crest of the sand slope. Load was being applied until the slope begun to fail. The load applied was recorded to be 22.9kN.

Figure 5.1 Readings given by the UTM

In the following image, cracks can be observed in slope after failure. Image was processed of the same using the Fiji software. Results can be seen in the following images. The circled area in the two images signifies the crest of the slope.

Figure 5.2 Sand slope after failure

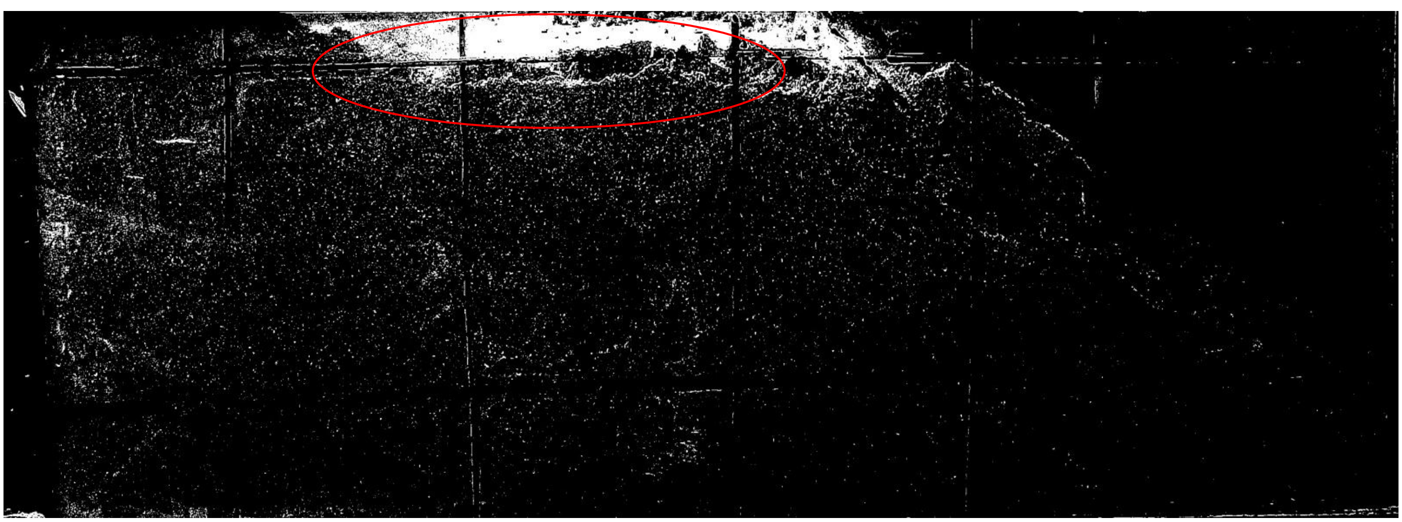


Figure 5.3 Image processed of the slope after failure

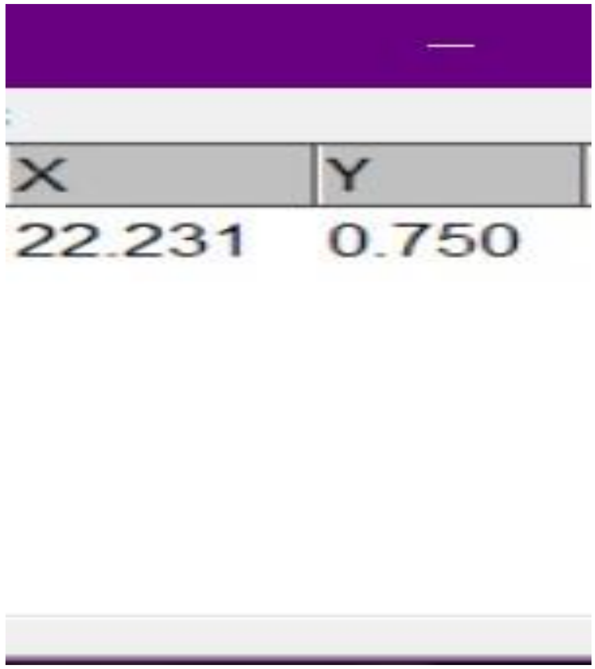


Figure 5.4 Result of the image processed of the crest of the slope

The above image shows the result of the image processed of the crest. Here X and Y are the coordinates. These coordinates indicate the position of the ROI within the image.

X: The X-coordinate typically refers to the horizontal position, representing the distance from the left edge of the image to the ROI.

Y: The Y-coordinate typically refers to the vertical position, representing the distance from the top edge of the image to the ROI.

Here X signifies that the crest region is 22.231cm from the left edge of the image. Similarly, Y signifies that the crest is 0.75 cm from the top edge of the image.

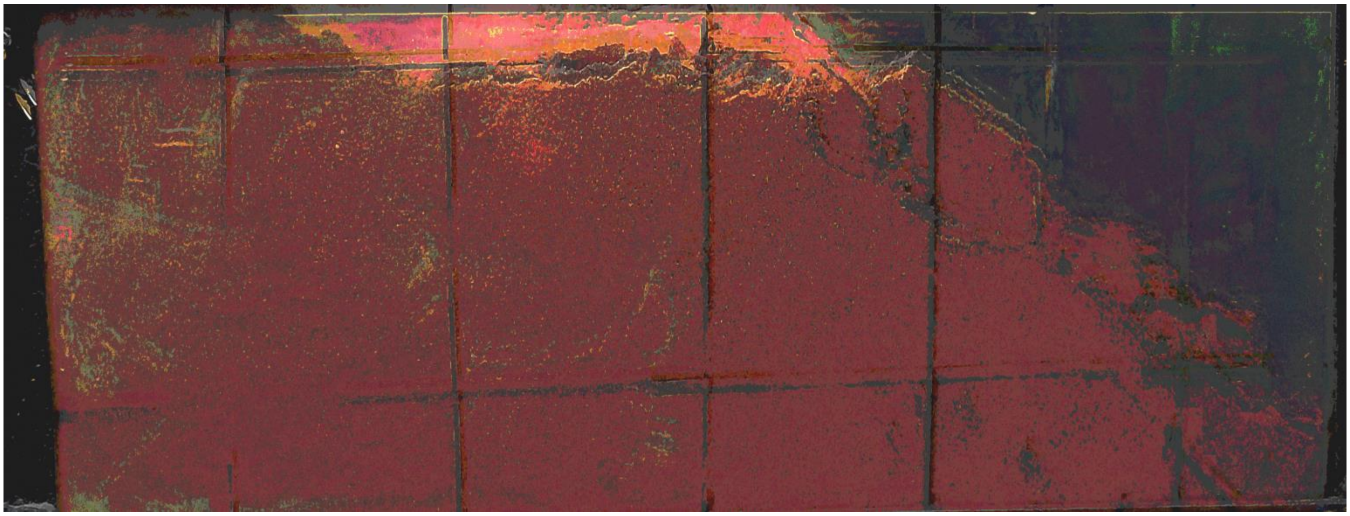


Figure 5.5 Slope failure

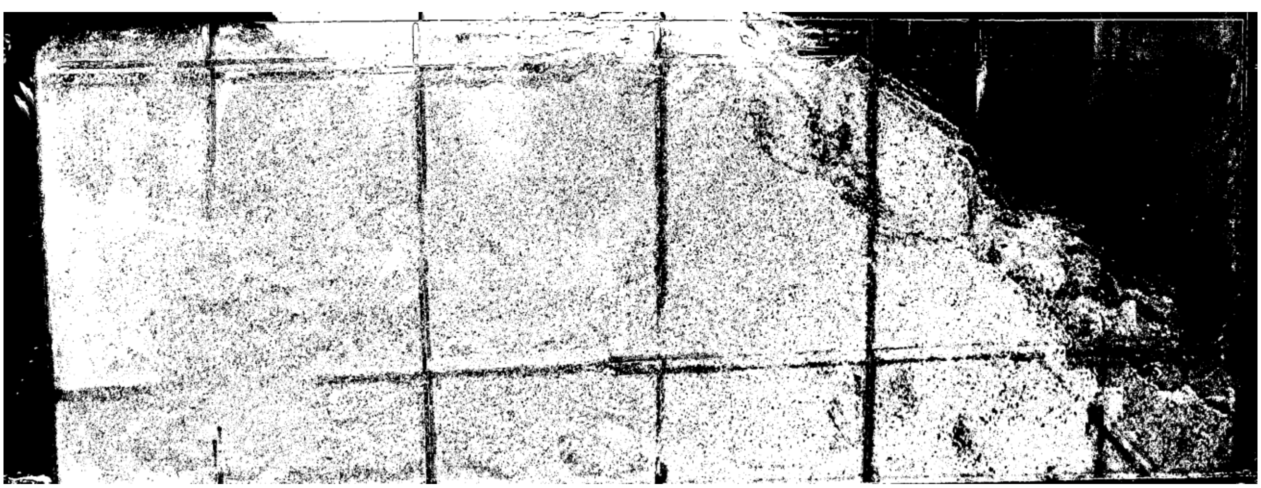


Figure 5.6 Processed image of the slope failure

Results

File Edit Font Results

	Area	X	Y	Perim.
1	467.767	21.667	7.610	417.131

Figure 5.7 Result of slope failure section

The area represents the number of pixels within a selected ROI or object in the image. It gives a measure of the size of the region.

In calibrated images, where the pixel size is known (e.g., in centimeters), the area can be presented in real-world units (e.g., square centimeters).

For the above image of the slope failure, the area represented is the area of the whole shaded region, which is 467.767cm^2. The pixel units were calibrated with respect to centimeters before the beginning of image processing.

The perimeter is the total length of the boundary of the selected region or object.

It is measured by counting the number of pixels along the edge of the ROI or by calculating the actual length in calibrated units if the image has spatial calibration.

Similarly, the perimeter is the boundary of the whole shaded region, which is 417.131cm.

In the above image, the position X is taken from the right edge of the image. Thus, giving a value of 21.667 cm and as for the Y coordinate, the ROI lies 7.61cm from the top edge of the image.

Chapter 6. CONCLUSION

6.1 General

After performing the tests and processing the images taken, we were able to correlate the results that we got by determining manually with the results we got by digital image processing. Thus, digital image correlation is effective with non-contact analysis of the soil slope failure. With the upcoming advancements in technology, digital imaging will come in use very much frequently with its effectiveness and the preciseness given by this technique.

6.2 Limitations

- DIC relies on clear visibility of the structure's surface. Obstructions, shadows, or surface irregularities can impact the accuracy of measurements.
- DIC systems require careful calibration to ensure accurate measurements. Calibration errors or changes in camera parameters can introduce inaccuracies in the results.
- Changes in lighting conditions, such as variations in natural light or artificial lighting, may affect the performance of DIC systems and result in variations in captured images.

6.3 Future Scope

- Advancements in processing speed and algorithms may enable real-time DIC monitoring of civil structures
- The future of DIC in civil structure monitoring may involve the use of higher resolution imaging systems. This can provide more detailed information about structural deformations and behaviour, allowing for more accurate analysis and assessment.
- DIC can be integrated with Internet of Things devices and sensor networks to create a comprehensive structural health monitoring system

DIC, when combined with predictive modelling and simulation, could be used to predict the long-term performance of civil structures. This would assist in making informed decisions about maintenance, repair, or retrofitting strategies.

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