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APPLICATION OF FINITE ELEMENT TO DEFORMATION MONITORING OF PHYSICS DEPARTMENT BUILDING IN THE UNIVERSITY OF BENIN, UGBOWO CAMPUS, EDO STATE NIGERIA.

A PROJECT SUBMITTED

BY

OGBEIDE DIVINE OGHOSA

ENV1805814

UNIVERSITY OF BENIN

FACULTY OF ENVIRONMENTAL SCIENCES

DEPARTMENT OF GEOMATICS

NOVEMBER, 2025

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BY

OGBEIDE DIVINE OGHOSA

ENV1805814

A PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE (B.SC) DEGREE IN GEOMATICS, AT THE UNIVERSITY OF BENIN, BENIN CITY, NIGERIA.

A PROJECT SUBMITTED TO THE DEPARTMENT OF GEOMATICS, FACULTY OF ENVIRONMENTAL SCIENCES, UNIVERSITY OF BENIN, BENIN CITY.

NOVEMBER, 2025

CERTIFICATION

This is to Certify that this work was carried out by **OGBEIDE DIVINE OGHOSA**, Mat No. ENV1805814, of the Department of Geomatics, Faculty of Environmental Science, University of Benin, Edo State Nigeria.

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EXTERNAL SUPERVISOR DATE

DEDICATION

This project is dedicated to the Almighty God and my loving mum, Mrs. Praise Ogbeide and also to my siblings.

ACKNOWLEDGEMENT

All thanks, honour, adoration and glory be unto Almighty God. For his unfeigned love towards me, His infinite mercy, grace and opportunity given to me to move forward against all odds and for the successful completion of this project and my B.sc program in the department of Geomatics, University of Benin

I owe a debt of gratitude to my project adviser Engr. Professor Ralph Ehigiator-Irughe, R, for his unwavering support, precise guidance,insights and corrections have been vital to the project's success,his constant commitment to research and academic success has served as a constant source of motivation.

Furthermore, I also extend my heartfelt gratitude to my assistant project supervisor, SURV. Mohammed Tijani, for his selfless dedication to ensuring the success of my project. My lecturers, technologists, administrative officers, and non-teaching staff at the Department of Geomatics, University of Benin, Ugbowo. Special acknowledgment goes to the Head of Department, Surv. Oladusu S.O, Surv. (Mrs.) Ekun M.O, Surv. Dr. G. O. Nwodo, Surv. Engr, Dr. Solomon Okonofua., Surv. Ojo Peter, Mr, Chucks and others for their unwavering efforts and contributions to my academic journey.

Lastly, My biggest appreciation goes to my loving mum, Mrs Praise Ogbeide, for her prayers and financial support and unrelenting commitments towards my academics, my entire family members. A big thank you to my Aunt, Mrs Joy Alile Omagbe, Ukpono Bassey and all my friends,and others for their continuous support, assistance and motivation towards the success of my academics. Also my special appreciation goes to Rev. Dr Felix Omobude, Pastor Kelly, Aunty Nosa,Prof Nnimo &Mrs Evelyn Bassey, Mrs Florence Oronsaye (may her soul rest in peace) I am grateful to my colleagues and close friends,

ABSTRACT

This Project undertakes the development and implementation deformation monitoring system for the Physics Department Building, with the primary objective of ensuring the safety and integrity of the structure, For buildings to remain structurally sound and safe, deformation monitoring is essential, especially for those that are subjected to changing loading bearing and climatic conditions over time.

Using a multi-faceted approach, this study will employ a range of geodetic and geo-technical techniques, including Global Navigation Satellite Systems (GNSS), Precise leveling and inclinometry, to monitor the buildings deformation patterns, including subsidence, settlement, and tilt. The project will investigate the effects of various factors such as soil conditions, foundation type and environmental changes on the buildings deformation behaviour, providing valuable insights into the structural health of the building.

The deformation monitoring system will be designed to provide real-time data, enabling prompt identification of any anomalies or potential issues. This will facilitate informed decisions on maintenance, repair and potential retrofitting, ensuring the safety of occupants and the integrity of the structure.

This study contributes to the development of effective deformation monitoring systems for buildings, which is critical for ensuring the safety and resilience of built infrastructure. The findings of this project will have the development of best practices in deformation monitoring and structural health assessment, and will inform the development of more effective strategies for managing and maintaining buildings in a variety of environments.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

From a geological standpoint, regions prone to seismic activity to tectonic movements require vigilant deformation monitoring to assess the impact on infrastructure ad implement measures to enhance resilience. Geological processes like subsidence and landslides also necessitate continuous monitoring to detect ground movements ad prevent damage to structures.

The Physics department building in the Faculty of Physical Science the university of Benin, Edo state has encountered structural deformations.To address this issue, I conducted a comprehensive investigation for our final year project, focusing on designing and implementing a Deformation Monitoring System (DMS). The DMS aims to provide real time data on structural changes in the infrastructure.

Deformation monitoring is crucial for assessing and mitigating potential risk associated with structural changes over time. It plays a vital role in ensuring safety, sustainability, and informed decision making . This systematic observation and analysis of structural changes are imperative across various domains, considering geological, constructional ad historical perspectives.

On the constructional front, deformation monitoring is essential during and after construction to assess structural integrity, identify potential weaknesses ad ensure safety standards. It particularly helps in evaluating foundation performance, especially in situations where soil conditions or groundwater levels may affect stability.

From a historical perspective, deformation monitoring is crucial for preserving heritage structures, guiding preservation efforts, and preventing irreversible damage. It also contributes to understanding long term changes in the built environment, informing future engineering practices and standards.

In recent years, the physics department building has faced deformation issues, necessitating innovative technologies for accurate monitoring and analysis of structural deformations. Traditional methods like periodic manual inspections are often time consuming and labour intensive, highlighting the importance of integrating advanced sensor technologies and data analysis in deformation monitoring.

1.2 STATEMENT OF THE PROBLEM

From our initial Observations, the main issue is the displacement of several structural pillars in the physics lab equipment storage area. The University of Benin's Physics department has existed for over a decade, and no proper monitoring on the structure has been done, thus the essence of this project lead to the acquisition of base data which could be used for subsequent observation for deformation monitoring.

Structural deformation on the physics department building can lead to various problems that compromise the safety, functionality, and longevity of buildings and infrastructure. These problems arises from factors such as material fatigue, external forces, environmental forces, environmental conditions, or design flaws. The investigation will also attempt to determine how urgent it is to address the deformation and provide workable fixes to stop further deterioration and possible structural breakdown If further ignored, it could cause serious repercussions, concerning structural stability and safety the following outcomes could occur:

1. Structural Instability; The presence of a fracture may suggest a weakened structural integrity, which could result in more deformation and eventual structural failure. The safety of the students and lecturers and surrounding structures is directly threatened by this.
2. Safety Hazards: If the structural deformations continue uncontrolled, students and lecturers inside and outside the building could be seriously injured. Accidents or fatalities could arise from falling debris or the building collapsing in parts.
3. Property Damage: As the fracture spreads, it could worsen the building's damage, endangering nearby property, infrastructure, and priceless items.
4. Financial Implications: If the problem is not resolved right away, the cost of restoration and repair may increase. Rebuilding or making considerable repairs might come at a significant financial cost to the university.

1.3 AIMS AND OBJECTIVES OF THE STUDY

The aim of this project is the Application of Finite Element to Deformation monitoring of the Physics Department Building.

OBJECTIVES;

These are the following objectives:

1. To create a database for the Monitoring of the structure.
2. To use a finite element to determine the deformation of the structure.
3. To serve as a base study for the future observations and monitoring.

1.4 SCOPE OF STUDY

The scope of this project entails a comprehensive examination of the deformation issues affecting the Physics Department Building within the University of Benin. It includes a distinctive blend of theoretical physics principles and practical applications in civil engineering and structural health monitoring . Our primary goal is to guarantee the buildings structural integrity, assess its response to environmental and operational factors and proactively address maintenance and safety concerns.

1. **Structural Health Assessment:** The study would Conduct a thorough structural study to better understand the load-bearing capacities and construction specifications of the Physics Department building. Determine the main structural parts and sensitive places that maybe prone to deformations.
2. **Real-time Data Collection:** Real-time monitoring systems will be integrated to ensure accurate and timely data collection on structural changes.
3. **Analyze and understand data:** Create data processing strategies and algorithms for evaluating the gathered data. Analyze the deformation data for trends, patterns, and anomalies to establish the building's structural stability. Examine the effect of operational activities (e.g., occupant loads) and climatic variables (e.g., temperature and humidity) on the building's deformation behavior. Correlate deformation data with external stimuli to discern between possible structural concerns and spontaneous motion
4. **Recommendations for Maintenance:** Based on the found deformations, advise maintenance and repair methods. If necessary, suggest structural modifications or retrofitting methods to ensure long-term viability.

1.5 JUSTIFICATION OF STUDY

The study contributes both academically and practically, enriching the existing body of knowledge and demonstrating how GNSS-integrated FEA methods can be implemented for real-world infrastructure. Additionally, the project supports institutional compliance with safety standards and affirms the university's commitment to innovation, sustainability, and structural resilience.

Applying Finite Element Analysis (FEA) to the deformation monitoring of the Physics Department building enables a more proactive approach to structural integrity assessment. It strengthens the foundation for predictive maintenance by identifying deformation patterns early and allowing informed decision-making this research is rooted in the need to ensure safety and functionality in academic structures, especially as they age. Deformation monitoring using modern tools not only protects infrastructure investments but also provides a repeatable framework for universities across the country seeking to modernize their infrastructure surveillance system.

CHAPTER TWO

LITERATURE REVIEW

2.1. Meaning of Deformation;

Deformation monitoring is a crucial aspect of structural health assessment, enabling the detection of changes in shape or dimension that may indicate underlying structural issues. This is particularly vital for critical infrastructure such as bridges, dams, and high-rise buildings, where failure can have severe consequences. By identifying early signs of instability, engineers can carry out proactive maintenance and repairs, thereby reducing risks (Liu & Xu, 2018).

In geotechnical engineering, deformation monitoring plays a significant role in assessing ground stability, preventing hazards such as landslides and subsidence. In mining and tunneling, it ensures the safety of both personnel and equipment by identifying shifts in surrounding rock or soil. Monitoring helps engineers to adopt mitigation strategies before conditions escalate (Standing & Rivett, 2017).

Deformation monitoring is also fundamental to construction quality control. It ensures that structures meet design specifications and that deviations are addressed before they become significant. Monitoring settlement, tilt, or structural deformation during construction minimizes the risk of rework and guarantees compliance with safety standards (McCuen, 2018).

2.2 Types of Deformation Monitoring

2.2.1. Geodetic deformation monitoring:

This type of monitoring uses geodetic sensors such as levels, total stations, global navigation satellite system (GNSS) receivers, terrestrial laser scanners (TLS), and ground-based synthetic aperture radar (GB-SAR) to monitor deformation, internal stress, seepage, water level, etc. **(Krauter, 2017).** Geodetic deformation monitoring is used to measure precise changes in position and orientation of points on the Earth's surface, and is commonly used in applications such as monitoring ground deformation, landslides, and structural health.

2.2.2. Geo-technical deformation monitoring:

This type of monitoring uses instruments such as extensometers, piezometers, pressure-meters, rain gauges, thermometers, barometers, tilt meters, accelerometer, and seismometers to measure displacements or movements and related environmental effects or conditions **(Fulton, 2000)**. Geotechnical deformation monitoring is used to measure changes in soil and rock properties, and is commonly used in applications such as monitoring soil settlement, foundation stability, and slope stability.

2.2.3. Manual deformation monitoring:

This type of monitoring involves the manual operation of sensors or instruments by hand or the manual downloading of collected data from deformation monitoring instruments **(Liu & Xu, 2019).** Manual deformation monitoring is a simple and cost-effective method, but can be time-consuming and prone to human error.

2.2.4. Automatic deformation monitoring:

This type of monitoring involves the operation of a group of software and hardware elements for deformation monitoring that, once set up, does not require human input to function **(Mishra & Goyal, 2020)**. Automatic deformation monitoring is a highly efficient and accurate method, and is ideal for long-term monitoring applications.

2.3. Types of Deformation

Deformation refers to the change in shape or size of an object due to external forces or stresses. There are several types of deformation, including:

2.3.1. Elastic Deformation: Temporary deformation that reverses when the force is removed. “Elastic deformation is a temporary change in shape or size of a body under the action of applied forces. Upon removal of the forces, the body regains its original configuration." **(Gere & Goodno, 2012,).**

2.3.2. Plastic Deformation: Permanent deformation that remains even after the force is removed Plastic deformation is a permanent change in the shape or size of a material that occurs when the applied stress exceeds the material's yield strength. During plastic deformation, the material undergoes irreversible changes in its internal structure, such as dislocation movement and grain boundary sliding, which result in a non recoverable deformation even after the applied stress is removed. **(Callister, & Rethwisch,2021).**

2.3.3. Creep deformation:

Creep deformation occurs when a material is subjected to constant stress or load over an extended period, resulting in a time-dependent deformation. Creep deformation is commonly observed in materials at elevated temperatures and is an important consideration in high-temperature applications. **(Dowling, N. E. (2012).**

2.4. Advantages of Deformation Monitoring

2.4.1. Predictive Maintenance:

Deformation monitoring helps identify potential issues before they become major problems. **(Wang et al.,2020)**

2.4.2. Alarming:

Deformation monitoring can alert users when a structure has exceeded a certain threshold of deformation**. (Wang et al.,2019)**

2.4.3. Deformation Analysis:

Deformation monitoring helps identify if a measured displacement is significant enough to warrant a response. **(Wang et al.,2019)**

2.4.4. Improved Safety:

Deformation monitoring can help prevent accidents and ensure the safety of people and structures. **(Wout,2016)**

2.4.5. Cost Savings:

Deformation monitoring can help identify potential issues before they become major problems, which can save money in the long run. **(Wang et al.,2023)**

2.4.6. Real-time Monitoring:

Deformation monitoring can provide real-time data, allowing for quick response times. **(Wang et al., 2019)**

2.4.7. Accurate Data:

Deformation monitoring provides accurate data, which can be used to make informed decisions. **(Wang et al., 2019)**

2.5. HISTORY

2.5.1. Early beginnings (1900s–1950s)

During this period, geodetic surveying techniques were first used to monitor deformation in mines and tunnels. Simple instruments like leveling instruments and theodolites were employed. These instruments were used to measure the distance and angle between points, allowing for the detection of small changes in shape or position.

The early 20th century saw the development of new instruments and techniques, such as the use of precision leveling and traversing. These methods allowed for more

accurate measurements and enabled the monitoring of larger areas. **(J.F.A Moore,1992).**

2.5.2. Development of new techniques (1960s–1980s)

The 1960s to 1980s saw significant advancements in deformation monitoring. Electronic distance measurement (EDM) and total stations emerged, enabling more accurate and efficient monitoring. Photogrammetry and remote sensing technologies began to be applied, allowing for the monitoring of large areas and the detection of subtle changes.

2.5.3. Advancement in sensor technology(1990s-2000s)

The 1990s and 2000s saw significant advancement in sensor technology. GPS an InSAR (Interferometric Synthetic Aperture Radar) became popular for deformation monitoring. Fiber optic sensor and other advanced sensors were developed enabling more accurate and efficient monitoring.

GPS allowed for precise location and movement tracking, while InSAR used radar waves to detect subtle changes in shape or position. B. Glisic and D. Inaudi (2008), John Dunnicliff (1988, 1993).

2.5.4. Modern Era (2010s – Present)

The modern era has seen significant advancements in deformation monitoring. Unmanned Aerial Vehicles (UAVs) and drones are increasingly used for monitoring. Advanced data analysis and machine learning techniques are being applied.

UAVs and drones enable rapid and efficient monitoring of large areas, while advanced data analysis and machine learning techniques enable more accurate and efficient detection of subtle changes. **(Zhao et al., 2013).**

2.6. Data Analysis

2.6.1. Time Series Analysis:

This involves analyzing data collected over time to identify patterns, trends, and anomalies. Techniques used include Fourier analysis, wavelet analysis, and machine learning algorithms. Time series analysis helps identify periodic or seasonal changes, trends, and sudden changes in deformation rates. **(Luboš Kovanič, 2020)**

2.6.2. Spatial Analysis:

This involves analyzing data collected from multiple locations to identify spatial patterns and relationships. Techniques used include geo-statistics, spatial auto-correlation, and spatial regression. Spatial analysis helps identify areas of high deformation, spatial patterns, and relationships between deformation and other factors. **(R. S. S. Kumar et al., 2018)**

2.6.3. Statistical Modeling:

This involves using statistical models to quantify deformation rates, magnitudes, and uncertainty. Techniques used include regression analysis, hypothesis testing, and confidence interval estimation. Statistical modeling helps quantify the significance of deformation measurements and predict future behaviour. **(Kumar et al 2018)**

2.6.4. Data visualization;

This involves using plots, charts and graphs to visualize data and communicate results. Techniques used include time series plot , spatial maps and histograms. This helps identify initial trends and patterns, communicate results to stakeholders and facilitate further analysis. **(A.Cairo 2019)**

2.7. Monitoring applications

2.7.1. Structural Health Monitoring; This involves monitoring the condition and behavior of buildings, bridges and other structures to detect changes , damages or deterioration . Deformation monitoring helps identify structural changes, detect potential failures and optimize maintenance and repair **(Rao et al 2020)**

2.7.2. Geo-technical Monitoring; This involves monitoring ground deformation, subsidence and landslides in mining, construction and natural hazard scenarios. Deformation monitoring helps to identify potential hazards, optimize excavation and construction designs and ensure public safety. **(A.M Marshall et al 2018)**

2.7.3. Machine Condition Monitoring; This involves monitoring vibration, temperature and other parameters to detect machine faults, wears and potential failures. Deformation monitoring helps identify potential faults, optimize maintenance schedule and reduce downtime. These applications and data analysis techniques are essential in deformation mon9itoring, enabling the detection of subtle changes,

identification of potential hazards and optimization of maintenance and mitigation measures (**Randall et al 2019)**

2.8. Modelling and Prediction

2.8.1 InSAR crustal deformation monitoring; Interferometric Synthetic Aperture Radar (InSAR) is an effective tool for measuring crustal deformation , which can provide high resolution, high-precision and large scale land surface displacements and their spatial-temporal evolution behaviour.

2.8.2. InSAR Technology; this became a powerful tool for measuring earths deformation with high spatial resolution and precision, Many efficient InSAR approaches, such as PS-InSAR, SBAS-InSAR, DS-InSAR, etc have been widely exploited and have already demonstrated their values. **(Jin, D &Yuian,& Zheng H 2018).**

2.8.3. Deformation fields; Research on deformation fields of recent earthquakes aims to provide useful information to better understand the tectonic background and mechanisms of corresponding regions.

(Ramirez, R.A.A; Lee, G; Choi, S ; Kwon, T.: Kim, Y,; Ryu, H; Kim, S: Bae, B : Hyun, C 2022).

CHAPTER THREE

METHODOLOGY

3.1. LOCATION OF STUDY AREA

The deformation monitoring project was carried out at the Physics Department building located on the Ugbowo Campus of the University of Benin, Edo State, Nigeria. The geographical coordinates of the site are latitude 6.399755°N, 5.615334°E and 6.399720°N, 5.615915° . The length of the stretch is 14.369m(0. 12km).

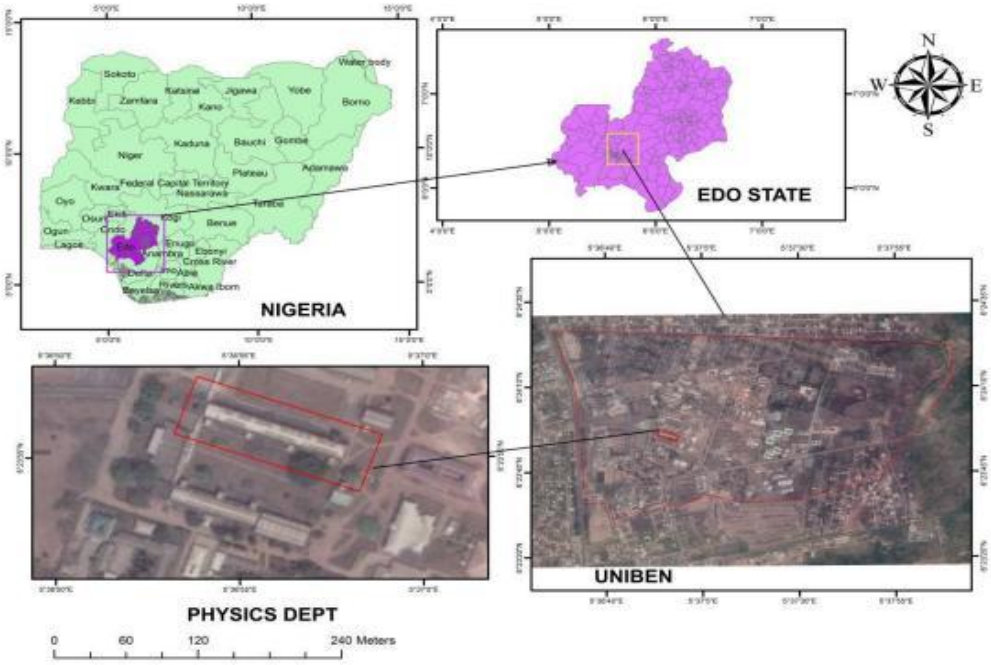

Figure 3.1: showing the study area

3.2 RECONNAISSANCE SURVEY

Before commencing this project , an exhaustive reconnaissance survey is conducted in the project area. During this initial examination, special attention is given to the structure, uncovering a critical issue where the pillar lies are gradually shifting from their original positions within the supporting beam.This structural concern is detected through meticulous on site observation to attain a comprehensive understanding of the situation, advanced satellite imagery is utilized to conduct a thorough reconnaissance of the entire structure. This cutting edge approach facilitates capturing a detailed overview, allowing for a more nuanced assessment of the structural dynamics.

Following the completion of the project planning phase, a subsequent field reconnaissance is executed to delve deeper into the nature of the structure's deformation. This thorough on-site investigation serves the dual purpose of not only identifying the extent of the deformation but also establishing fundamental protocols to effectively address and rectify the issues. This holistic reconnaissance strategy ensures that all necessary measures are meticulously planned ad implemented to deliver a sustainable and enduring solution to structural deformation. The emphasis is placed not only on immediate remediation but also on ensuring the long term stability and resilience of the structure in question

3.3 INSTRUMENTATION

The following instruments and tools were used:

1. - Tersus David GNSS Receiver and staff
2. NUWA-configured Android device
3. 50-meter measuring tape
4. Marker and field pegs
5. External power bank
6. HP Intel Core i7 Laptop (16GB RAM)
7. ArcGIS, Microsoft Word, Notepad

3.3 INSTUMENT SETUP

Before data acquisition, the GNSS device was tested for functionality. The Tersus GNSS rover was mounted on a rod at a height of 180mm and configured via Bluetooth with the NUWA app. The UTM Zone 31N projection and Clarke 1880 ellipsoid were selected, and transformation parameters were set using Bursa-Wolf values The NUWA app was synced with Professor Ehigiator's base station, and a new survey project was initiated.

3.4 DATA ACQUISITION AND PROCESSING;

Data collection involved capturing GNSS coordinates from multiple fixed points along the building's perimeter over several days. Each point was measured repeatedly to ensure reliability.

This formed a crucial phase in this study, as it provided the empirical foundation for evaluating structural deformation in the Physics Department building at the University of Benin. The methodology combined field-based observations using modern geodetic instruments with post-processing techniques designed to enhance data accuracy and extract meaningful structural insights.

The primary instrument employed for this project was the Tersus David GNSS receiver, configured via the NUWA Android-based mobile application. The GNSS receiver was mounted on a calibrated survey staff and connected to a reference base station — provided by Professor Ehigiator — using Bluetooth. Before field deployment, the receiver and the app were synchronized and initialized to use the Universal Transverse Mercator (UTM) Zone 31N coordinate system with the Clarke 1880 ellipsoid. Transformation parameters were defined using the Bursa-Wolf model

Following fieldwork, the GNSS data was exported and organized using Microsoft Excel and ArcGIS. A structural monitoring database was created, which included key variables such as point ID, northing, easting, and elevation. From this dataset, positional shifts were computed using vector-based formulas, allowing the identification of both horizontal and vertical displacements. The resulting displacement data served as input for Finite Element Analysis (FEA) simulations carried out later in the study.

3.5. CREATING A STRUCTURAL MONITORING DATABASE;

The collected GNSS data was processed and organized for monitoring. Calculations for displacement, bearing, and relative shifts were conducted. These served as input for Finite Element Analysis (FEA).

The first step involved sorting and cleaning the raw data exported from the NUWA application. Each observation point was tagged with a unique identifier, and corresponding values such as latitude, longitude, elevation, time of observation, and horizontal dilution of precision (HDOP) were recorded. Redundant or inconsistent measurements were filtered out through manual review and statistical averaging, ensuring that only high-quality positional data were retained for further analysis.

Using Microsoft Excel and ArcGIS, a geospatial database was created to house the processed coordinates. The database was structured with multiple fields including:

1. Point ID
2. Northing and Easting (UTM)
3. Elevation (in meters)
4. Time stamp
5. Observation epoch

This format ensured that the dataset was both human-readable and machine-compatible for integration into modeling software. Data validation procedures were also implemented, including range checks for elevation differences and comparison of repeated measurements to detect anomalies or drifts in positioning.

Once the cleaned GNSS data was grouped together, displacement vectors were computed to quantify relative movement between observation periods. These vectors were derived using basic geometric and vector mathematics to measure positional changes in both horizontal and vertical directions. The calculated displacements were stored in the database alongside the original coordinates to provide a complete temporal record of structural behavior.

The next phase involved visualizing the data using GIS and CAD tools, the final database not only served as the input for Finite Element Analysis (FEA) but also functioned as a historical record for continued monitoring.

3.6. FINITE ELEMENT APPLICATION

Using FEA, the building's structure was modeled as interconnected triangular elements. The data was meshed and analyzed to simulate stress-strain behavior. The stiffness matrix and global deformation matrix were computed for each triangle.Using the processed GNSS data — particularly the displacement vectors and elevation changes — the monitored building was modeled as a series of interconnected triangular mesh elements. Each triangle represented a portion of the structural surface, and its vertices were defined using the coordinates of the GNSS observation points. This meshing process allowed for the translation of spatial measurements into a mathematical model that could respond to simulated external forces and internal stress distributions.

To implement the FEM, displacement values from the GNSS database were input as nodal deformations, forming the basis for solving the global deformation matrix. This matrix included essential parameters such as:

1) Element stiffness coefficients

2) Load distribution across the structure

3) Internal strain and stress fields

The governing equations for plane strain deformation were used to compute element-wise behavior. These included both stiffness matrices for each triangular element and nodal displacement vectors, which together formed the global system equation:

$$[K]\{u\} = \{F\},$$

where [K] represents the stiffness matrix, {u} is the displacement vector, and {F} is the applied force vector derived from actual or assumed loading conditions.

3.7. QUALITY ASSURANCE

Redundant observations, calibration checks, and real-time differential corrections were implemented to ensure data integrity. The entire methodology followed standard geomatics surveying protocols to maintain accuracy and reproductibility.To further ensure the credibility of the deformation results, the data was cross-referenced with visual observations and site reconnaissance records. Locations where field cracks

were identified were compared against GNSS-measured displacements and FEA results, providing multi-source confirmation of structural instability in those zones.

The methods discussed in this chapter provided a solid foundation for capturing and analyzing deformation in the Physics Department building. From field reconnaissance to data processing and finite element application, each step contributed to a reliable structural monitoring system. With the GNSS data now processed and the simulation model in place.

CHAPTER FOUR

Result and Discussion

4.1 Results

Deformation monitoring using GNSS involves the collection of high-precision position data from satellites to track changes in the Earth's surface over time. This technique offers unparalleled accuracy and reliability, making it indispensable in a wide range of industries, including geology, civil engineering, and infrastructure management.

Field data acquisition typically involves the deployment of GNSS receivers at strategic locations across the area of interest. These receivers continuously track signals from multiple satellites, allowing for the calculation of precise 3D coordinates. By comparing these coordinates over time, analysts can detect even subtle deformations in the monitored area, such as subsidence, uplift, or lateral movement.

Several studies have demonstrated the effectiveness of GNSS in deformation monitoring. For example, research by Sładek Sładeczek, & Jędrysiak, J. (2023) showcased the use of GNSS-based interferometric synthetic aperture radar (InSAR) for monitoring ground subsidence with millimeter-level accuracy. Similarly, the work of Xu, Zhuang, & Yu, (2023) highlighted the utility of GNSS in detecting tectonic plate movements and seismic activity. The tables below shows the different data set for the weeks monitored.

WEEK 1

DAY 1

Pt No	Northing	Eastings	Height
Pt A	708078,5399	789418.3798	167.2492
Pt B	708118.7248	789304.7568	168.3008
Pt C	708137.4274	789309.7724	167.3914
Pt D	708096.7590	7894424. 8422	167.3898

DAY 2

Pt NO	Northing	Easting	Height
Pt A	708078.5725	789418.3337	167.3322
Pt B	7088118.7779	789304.5939	168.6772
Pt C	708137.5112	789309.7491	167.3900
Pt D	708096.7390	789424.8098	167.4128

DAY 3

Pt No	Northings	Eastings	Height
Pt A	708078.5879	789418.343	167.2980
Pt B	708118.5412	789304.6911	167.8330
Pt C	708137.4540	789309.7673	167.4230
Pt D	708096.8305	789424.8574	167.2586

DAY 4

Pt No	Northings	Eastings	Height
Pt A	708078.6238	789418.2492	167.2596
Pt B	708118.7601	789304.6958	167.5226
Pt C	708138.5659	789310.8936	168.7222
Pt D	708096.6724	789424.7392	167.5408

DAY 5

Pt No	Northings	Eastings	Height
Pt A	708078.6117	789418.3367	167.2750
Pt B	708118.7229	789304.7053	167.4420
Pt C	708137.5743	789309.6701	167.2568
Pt D	708096.7454	789427.8109	167.3234

WEEK 2 CHAPTER FOUR

DAY 1

Result and Discussion

Pt No	Northing	Eastings	Height
Pt A	708078.5659	789418.3610	167.5858
Pt B	708118.4860	789304.7073	167.0370
Pt C	708137.6068	789309.7957	168.2600
Pt D	708096.7839	789424.7517	167.3234

4.1 Results

DAY 2

Pt No	Northing	Eastings	Height
Pt A	708078.5229	789418.4500	167.2748
Pt B	708118.7446	789304.7117	167.4284
Pt C	708137.4345	789309.8400	167.3788
Pt D	708096.7014	789424.7404	167.3352

DAY 3

Pt No	Northing	Eastings	Height
Pt A	708078.4123	789418.3809	167.1954
Pt B	708118.7394	789304.6800	167.3498
Pt C	708137.7635	789330.8301	167.4720
Pt D	708096.8362	789424.8102	167.2996

DAY 4

Pt No	Northing	Eastings	Height
Pt A	708078.4965	789418.4107	167.3138
Pt B	708118.5808	789304.6463	167.5432
Pt C	708137.5214	789310.0109	167.4030
Pt D	708096.6056	789424.9239	167.3784

DAY 5

CHAPTER FOUR

Pt No	Northing	Eastings	Height
Pt A	708078.5435	789418.5958	167.3138
Pt B	708118.5858	789304.6514	167.5432
Pt C	708137.5214	789309.9355	167.3788
Pt D	708096.6056	789424.8345	167.3784

4.1 Results

Table 4: Showing data collected

4.2 Data Processing and Analysis

The process of monitoring a structure such as dams, reservoir, bridges, buildings, etc using GIS involves collecting and analyzing various and finding different parameters such as the stiffness matrix(K), the distance(l) and the bearing(θ). The parameters contribute greatly to the deformation monitoring analysis on the structure. This process of data analysis involves extracting meaningful information from the collected observations. Data fusion of GNSS data with other geodetic and geophysical datasets to enhance deformation monitoring capabilities. (Kitsakis, Kougioumtzis, & Kapetanidis 2023) Figure 4.2 below represents the section of the building whose deformation status

CHAPTER FOUR

Result and Discussion

4.1 K

D GNSS

E T

F GNSS

T

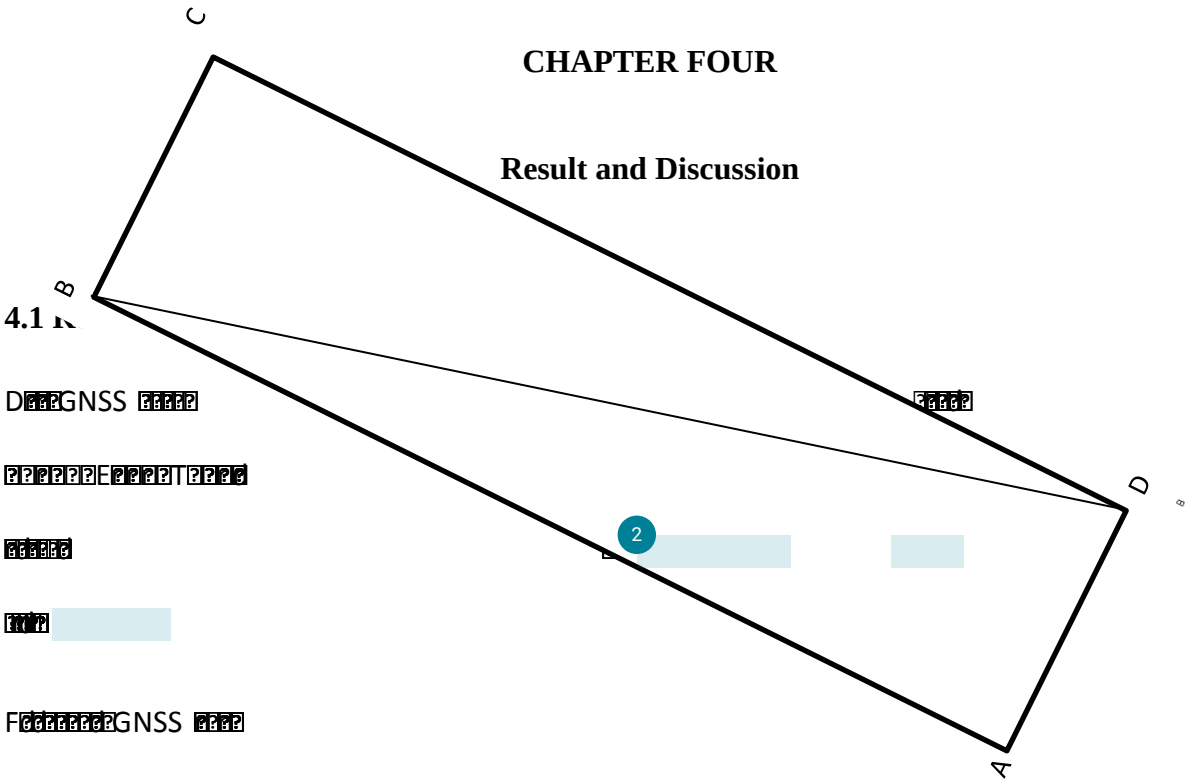

Figure 4.2: Showing the building's cross section

4.2.3 Determination of the Stiffness Matrix of the Elements

The fundamental attributes of a finite element are encapsulated within its stiffness matrix. In the case of a structural finite element, this matrix encompasses both geometric and material properties, providing insight into the element's resistance to deformation under loading. Such deformation can involve axial, bending, shear, and torsional effects (Ehigiator & Irughe, 2019). For finite elements employed in nonstructural analyses like fluid flow and heat transfer, the term "stiffness matrix" is still utilized as it signifies the element's resistance to alteration when subjected to external influences. The equation for the local stiffness matrix is presented in the equation below:

E1

DA1

$$K = \frac{EA}{L}\begin{bmatrix} l^2 & lm & -l^2 & -lm \\ lm & m^2 & -lm & -m^2 \\ -l^2 & -lm & l^2 & lm \\ -lm & -m^2 & lm & m^2 \end{bmatrix}$$

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Result and Discussion

Equation 4.1

4.1 Results

[illegible]

Equation 4.2

[illegible]

WEEK 1

[illegible] Northings		Eastings	
A	708078.5872	A	789418.3285
B	7080118.705	B	789304.6886
C	708137.7066	C	789309.9705
D	708096.7493	D	789424.8119

Table 4.2.1 showing the average Eastings and Northings for week one

WEEK 2

[illegible]

Northings		Eastings	
A	708078.5082	A	789418.3285
B	708118.6273	B	789304.6793
C	708137.5619	C	789309.6424
D	708096.7027	D	78424.8121

Table 4.2.2 Showing the average Easting and Northings for week two

For Week 1 **CHAPTER FOUR**

Result and Discussion

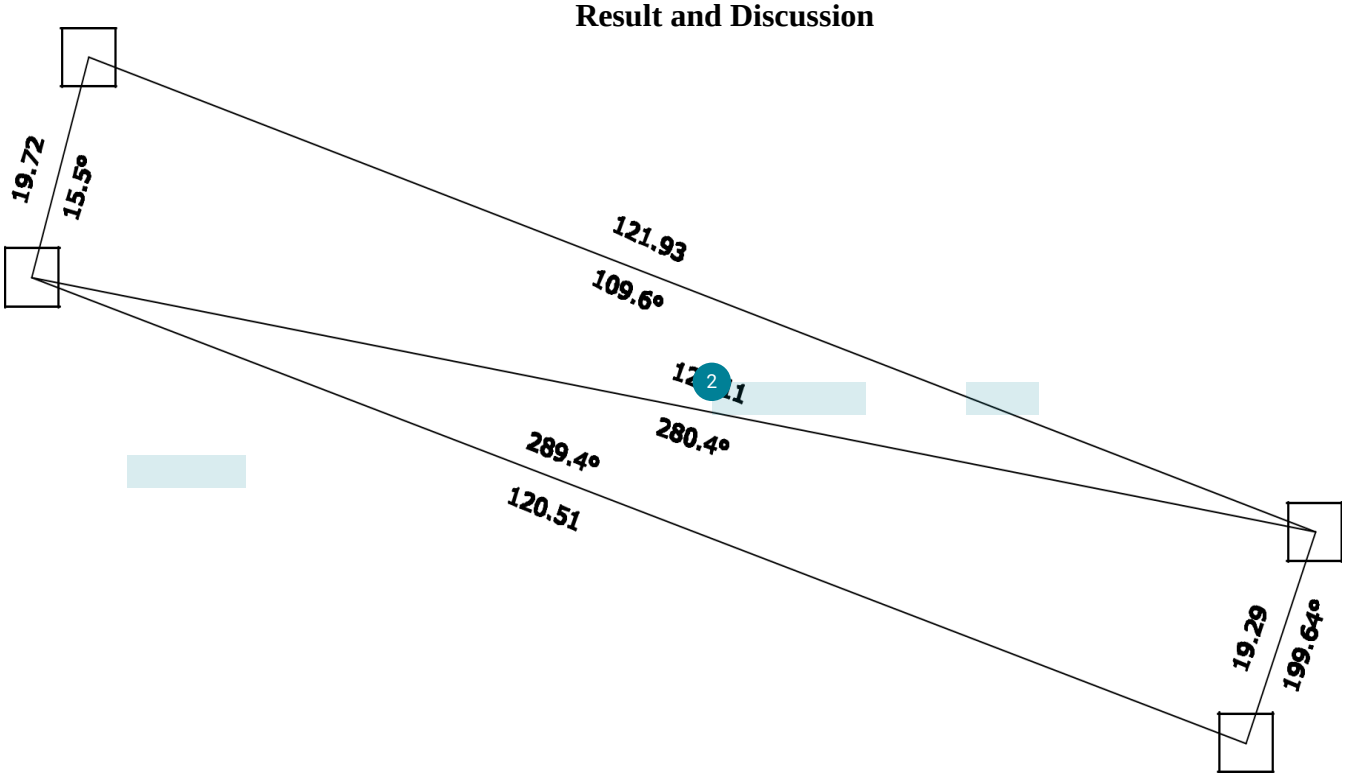
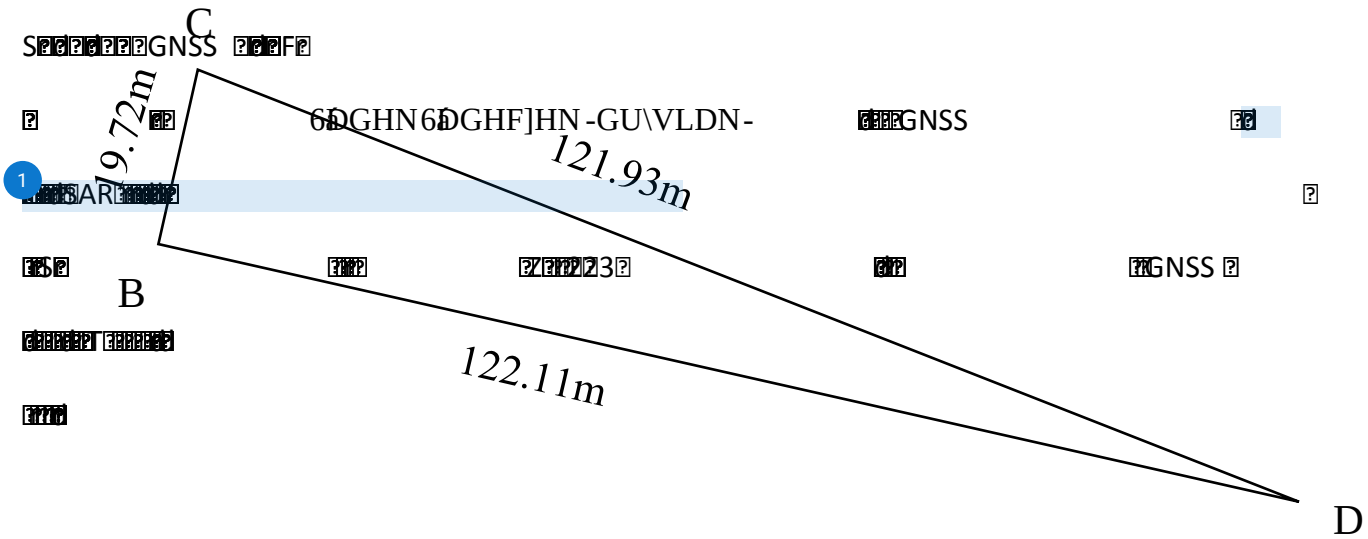


Figure 4.3: Showing the Distance and bearing for data collected in week one



Area= $1199.228m^2$

Result and Discussion

L_1=Lcosθ Equation 4.3.1

M_1=Lsinθ Equation 4.3.2

4.1 Results

L_1=19.72cos(15.5)

D GNSS

L_1=19.00

M_1=19.72sin(15.5)

M_1=5.27

F GNSS

$$K=\frac{EA}{L}\begin{bmatrix} l^2 & lm & -l^2 & -lm \\ lm & m^2 & -lm & -m^2 \\ -l^2 & -lm & l^2 & lm \\ -lm & -m^2 & lm & m^2 \end{bmatrix}$$

3D

$$\begin{bmatrix} u_1 & v_1 & u_2 & v_2 \\ 361 & 100.13 & -361 & -100.13 \\ 100.13 & 27.77 & -100.13 & -27.77 \\ -361 & -100.13 & 361 & 100.13 \\ 100.13 & 27.77 & 100.13 & 27.77 \end{bmatrix} \times \frac{210\times 1199.228}{19.72}$$

S GNSS F

6DGHN6DGHF]HN-GU\VLDN- GNSS

$L_2 = L\cos\theta$

BAR

$L_2 = 121.93\cos(109.6)$

GNSS

$L_2 = -40.9$

$m_2 = L\sin\theta$

$m_2 = 121.93\sin(109.6)$

$m_2 = 114.9$

$$\begin{bmatrix} u_2 & v_2 & u_3 & v_3 \\ 1672.8 & -4699.41 & -1672.8 & 4699.41 \\ -4699.41 & 13202.01 & 4699.41 & -13202.01 \\ -1672.8 & 4699.41 & 1672.8 & -4699.41 \\ 4699.41 & -14202.01 & 4699.41 & 13202.01 \end{bmatrix} \times \frac{210 \times 1199.228}{121.93}$$

4.1 Results

D GNSS

L_3 D cos θ

(280.4)

22.04

$m_3 = L \sin \theta$

m_3 sin(280.4)

20.10

3D

v_3 u_4 v_4

$$\begin{bmatrix} 485.76 & -2647.0 & -485.76 & 4699.41 \\ -2647.0 & 14424.01 & 2647.0 & -13202.01 \\ -485.76 & 2647.0 & 485.76 & -2647.0 \\ 2647.0 & -14424.01 & 4699.41 & 13202.01 \end{bmatrix} \times \frac{210 \times 1199.228}{122.11}$$

GNSS

6DGHN6DGHF]HN-GU\VLDN- GNSS

BAR

GNSS

Result and Discussion

4.1 Results

u_1	v_1	u_2	v_2	u_3	v_3	u_4	v_4
361	100.13	−361	−100.13	0	0	0	0
100.13	27.77	−100.13	−27.77	0	0	0	0
−361	−100.13	−167497.46	130502.62	−1672.8	4699.41	0	0
100.13	−27.77	100.13	366619.81	4699.41	−13202.01	0	0
0	0	−1672.8	4699.41	2282785.402	34945720.47	−485.76	2647.0
0	0	4699.41	−13202.01	12439338.27	190425924.3	2647.0	−14424.01
0	0	0	0	−485.76	2647.0	2647.0	−14424.01
0	0	0	0	2647.0	−14424.01	−2647.0	14424.01

Define the 8x8 matrix

```
A = [361, 100.13, -361, -100.13, 0, 0, 0, 0;
    100.13, 27.77, -100.13, -27.77, 0, 0, 0, 0;
    -361, -100.13, -167497.46, 130502.62, -1672.8, 4699.41, 0, 0;
    100.13, -27.77, 100.13, 366619.81, 4699.41, -13202.01, 0, 0;
    0, 0, -1672.8, 4699.41, 2282785.402, 34945720.47, -485.76, 2647.0;
    0, 0, 4699.41, -13202.01, 12439338.27, 190425924.3, 2647.0, -14424.01;
    0, 0, 0, 0, -485.76, 2647.0, 2647.0, -14424.01;
    0, 0, 0, 0, 2647.0, -14424.01, -2647.0, 14424.01];
```

Define the equations B and C

```
B = (210 * 1199.228 / 263.76)^-1;   Calculate B
C = (54.069 * 10^3);                Calculate C
```

Multiply matrix A by B and C together

```
Result3 = A * B * C;                Matrix A multiplied by scalars B and C
```

Reshape the result into a single column vector

```
Result_column = result3(;
```

Display the results as a single column CHAPTER FOUR

Disp('The result of multiplying matrix A by B and C as a single column is:');

Result and Discussion

Disp(result_column);

The result of multiplying matrix A by B and C as a single column is:

4.1 Results

0 0 0 0 0 0 0 0

0 0 0 0 0 0 0 0

0 0 -0.0009 0.0007 0 0 0 0

0 0 0 0.0021 0 -0.0001 0 0

0 0 0 0 0.0129 0.1979 0 0

0 0 0 -0.0001 0.0704 -1.0784 0 -0.0001

0 0 0 0 0 0 0 -0.0001

0 0 0 0 0 -0.0001 0 0.0001

0= U1

0= V1

-0.0001= U2

0.000667= V2

-0.504= V3

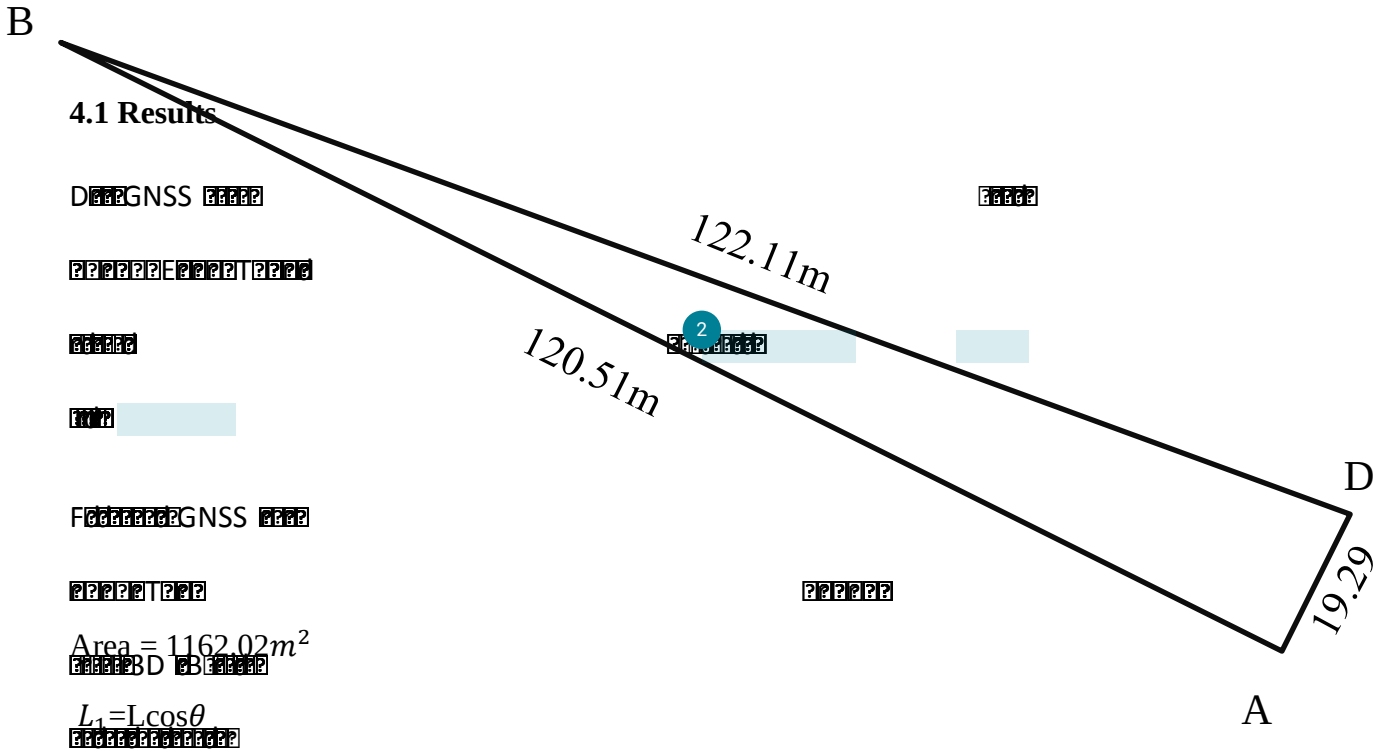
-0.00005= U4

0= V4

Triangle BCD WEEK 1		Triangle BCD WEEK 2		DISPLACEMENT
U1=	0	U1=	0.11725	0.058625
V1=	0	V1=	-0.44735	-0.223675
U2=	-0.0001	U2=	0	-0.00005
V2=	0.000667	V2=	0	0.000333333
U3=	0.1054	U3=	0	0.0527
V3=	-0.504	V3=	0	-0.252
U4=	-0.00005	U4=	0	-0.000025
V4=	0	V4=	0	0

CHAPTER FOUR

Result and Discussion



4.1 Results

D GNSS

E T

F GNSS

T

Area = 1162.02m^2

BD B

L_1=Lcosθ

M_1=Lsinθ

L_1=122.11cos(280.4)

GNSS F

L_1=22.04

M_1=l22.11sin(280.4) 6DGHN6DGHF]HN-GU\VLDN- GNSS

$$\begin{bmatrix} u_3 & v_3 & u_4 & v_4 \\ 485.76 & -2647.0 & -485.76 & 4699.41 \\ -2647.0 & 14424.01 & 2647.0 & -13202.01 \\ -485.76 & 2647.0 & 485.76 & -2647.0 \\ 2647.0 & -14424.01 & 4699.41 & 13202.01 \end{bmatrix} \times \frac{210 \times 1199.228}{122.11}$$

E1

D_2 = $L\cos\theta$

$L_2 = 19.29\cos(199.64)$

$L_2 = -18.17$

$m_2 = L\sin\theta$

$m_2 = 19.29\sin(199.64)$

$m_2 = -6.48$

CHAPTER FOUR

Result and Discussion

4.1 Results

D GNSS

u_2	v_2	u_3	v_3
330.15	117.74	−330.15	−117.74
117.74	41.99	−117.74	−41.99
330.15	−117.74	330.15	330.15
−117.74	−41.99	−117.74	41.99

$\times \frac{210\times 1162.021}{19.62}$

F GNSS

T

$L_3 = L\cos\theta$

3D B

$L_3 = 120.51\cos(289.4)$

$L_3 = 40.03$

$m_3 = L\sin\theta$

$m_3 = 120.51\sin(289.4)$

S GNSS F

$m_3 = -113.67$

6DGHN6DGHF]HN-GU\VLDN- GNSS

1 BAR

u_3	v_3	u_4	v_4
1602.40	−4550.21	−1602.40	4550.21
4550.21	12920.87	−4550.21	−1292087
−1603.40	4550.21	1602.40	−4550.21
4550.21	−12920.87	−4550.21	12920.87

$\times \frac{210\times 1162.021}{120.51}$

GNSS

7 Global Matrix

PE1

DA1

Result and Discussion

u_1	v_1	u_2	v_2	u_3	v_3	u_4	v_4
485.76	−264.7	485.76	264.7	0	0	0	0
−264.7	14424.01	264.7	−14424.01	0	0	0	0
−485.67	264.7	−873907.05	−1698282.937	−330.15	−177.74	0	0
264.7	−14424.01	−311657.78	605664.18	−117.74	−41.99	0	0
0	0	−330.15	−117.74	−188666.516	191063.32	−1602.40	4550.21
0	0	−117.74	−41.99	4550.21	12920.87	4550.21	−12920.87
0	0	0	0	1602.40	4550.21	4550.21	−12920.87
0	0	0	0	12920.87	−14424.01	−4550.21	12920.87

4.1Results

Define the 8x8 matrix A

A = [485.76, -2647, -485.76, 2647, 0, 0, 0, 0;

-2647, 14424.01, 2647, -14424.01, 0, 0, 0, 0;

-485.67, 2647, 873907.05, -1698282.937, -33095, -177.74, 0, 0;

2647, -14424.01, -311657.78, 605664.18, -117.74, -41.99, 0, 0;

0, 0, -330.15, -117.74, -188666.576, 191063.32, -1602.40, 4550.21;

0, 0, -117.74, -41.99, -4550.21, 12920.87, 4550.21, -12920.87;

0, 0, 0, 0, -1602.40, 4550.21, 4550.21, -12920.87;

0, 0, 0, 0, -4550.21, -12920.87, -4550.22, 12920.87];

Define the equation B and C

B = (210 * 1191.740 / 262.25)^-1; % Calculate B (Inverse of 210 * 1191.740 / 262.25)

C = (54.069 * 10^3); Calculate C

Multiply matrix A by B and C together

Result3 = A * B * C; Matrix A multiplied by scalar B and C

Reshape the result to a single column vector

Result_column = result3(;

Display the results as a single column

Disp('The result of multiplying matrix A by B and C as a single column is:');

Disp(result_column);

CHAPTER FOUR

Result and Discussion

4.1 Results

The result of multiplying matrix A by B and C as a single column is:

			0.015	0	0	0	0	0
	-0.0817	0.015	-0.0817	0	0	0	0	0
	0.015	-4.9514	-9.6222	-0.1875	-0.001	0	0	0
	-0.0817	-1.7658	-3.4316	-0.0007	-0.0002	0	0	0
	0	-0.0019	-0.0007	-1.069	1.0825	-0.0091	0.0258	0.0258
	0	-0.0007	-0.0002	-0.0258	0.0732	0.0258	-0.0732	-0.0732
	0	0	0	-0.0091	0.0258	0.0258	-0.0732	-0.0732
	0	0	0	-0.0258	-0.0732	-0.0258	0.0732	0.0732

-0.00093= U1

0.005= V1

-2.94942= U2

-1.056= V2

0.007629= U3

V3

-0.02078= U4

0.00432= V4

6DGHN6DGHF]HN-GU\VLDN-

GNSS

GNSS

3

Result and Discussion

4.1 Results

	Triangle BDA Week 1		Triangle BDA Week 2	Displacement
U1=	-0.000933333	U1=	-1.00885	-0.504891667
V1=	0.005	V1=	-0.1932	-0.0941
U2=	-2.94942	U2=	0	-1.47471
V2=	-1.056	V2=	0	-0.528
U3=	0.007628571	U3=	0	0.003814286
V3=	-0.010585714	V3=	0	-0.005292857
U4=	-0.02078	U4=	-0.43315	-0.226965
V4=	0.00432	V4=	-0.149475	-0.0725775

WEEK 2

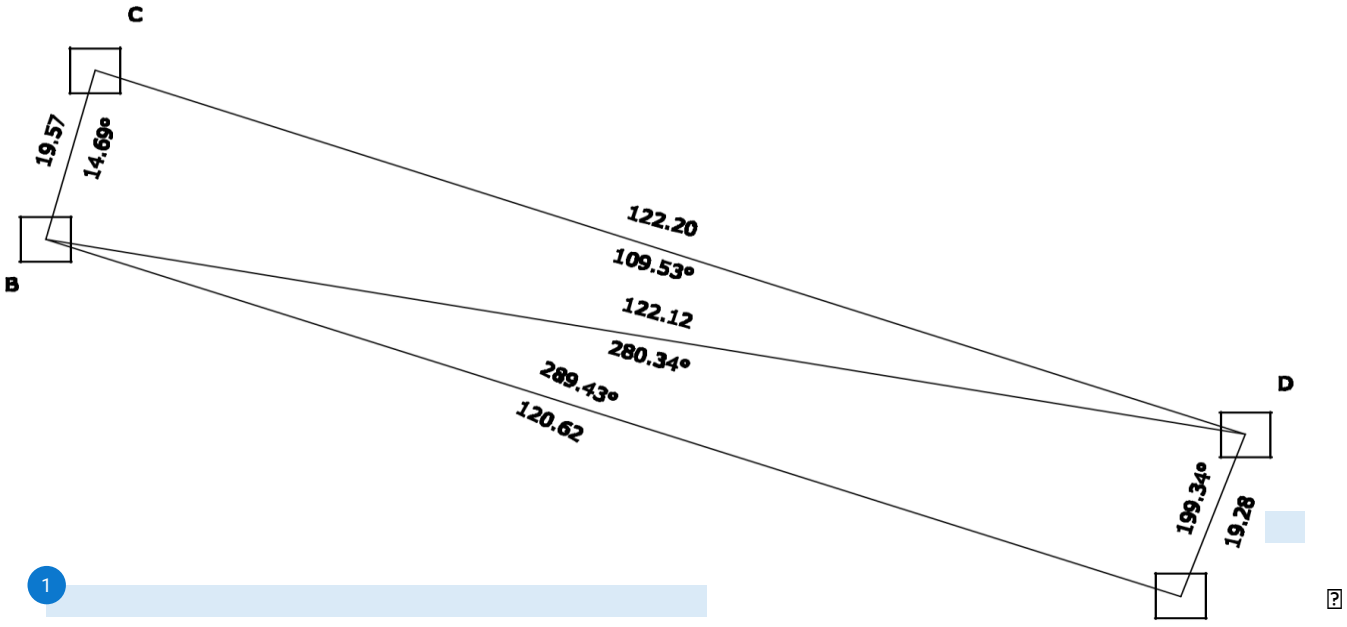
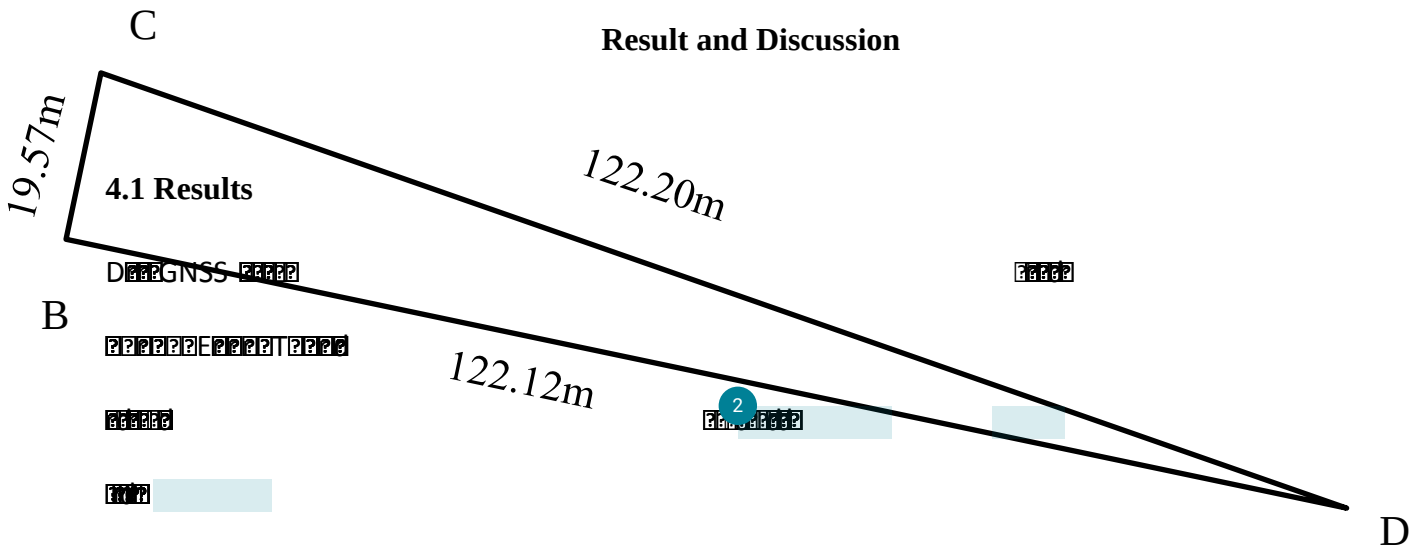


Figure 4.4 Showing the Distance and Bearing for data collected in week 2

CHAPTER FOUR

Result and Discussion



4.1 Results

D GNSS

E T

GNSS

$$Area = 1191.740m^2$$

GNSS

$$L_1 = L\cos\theta$$

T

$$M_1 = L\sin\theta$$

BD B

$$L_1 = 19.57\cos(14.69)$$

$$L_1 = 18.93$$

$$M_1 = l9.57\sin(14.69)$$

$$M_1 = 4.96$$

GNSS F

6DGHN6DGHF]HN-GU\VLDN- GNSS

$$K = \frac{EA}{L}\begin{bmatrix} l^2 & lm & -l^2 & -lm \\ lm & m^2 & -lm & -m^2 \\ -l^2 & -lm & l^2 & lm \\ -lm & -m^2 & lm & m^2 \end{bmatrix}$$

GNSS

$$\begin{bmatrix} u_1 & v_1 & u_2 & v_2 \\ 358.34 & 93.89 & -358.34 & -93.89 \\ 93.89 & 24.60 & -93.89 & -1292087 \\ -358.34 & -93.89 & 358.34 & 93.89 \\ -93.89 & -24.60 & 93.89 & 24.60 \end{bmatrix} \times \frac{210 \times 1191.740}{19.57}$$

$$L_2 = L\cos\theta$$

Result and Discussion

$$L_2 = 122.2cos\{109.53\}$$

$$L_2 = -40.85$$

4.1 Results

$$m_2 = L\sin\theta$$

$$m_2 = 121.20sin\{109.53\}$$

$$m_2 = 119.17$$

$$\begin{bmatrix} u_2 & v_2 & u_3 & v_3 \\ 1668.72 & -4704.69 & -1668.72 & 4704.69 \\ -4704.69 & 13264.13 & 4704.69 & -13264.13 \\ -1668.72 & 4704.69 & 1668.72 & -4704.69 \\ 4704.79 & -13264.13 & -4704.69 & 13264.13 \end{bmatrix} \times \frac{210\times1191.740}{122.20}$$

$$L_3 = L\cos\theta$$

$$L_3 = 122.12cos\{280.84\}$$

$$L_3 = -22.97$$

$$m_3 = L\sin\theta$$

$$m_3 = 122.12sin\{280.84\}$$

$$m_3 = -119.94$$

$$\begin{bmatrix} u_3 & v_3 & u_4 & v_4 \\ 527.62 & -2755.02 & -527.62 & 2755.02 \\ -2755.02 & 14385.60 & 2755.02 & -14385.60 \\ -527.62 & 2755.02 & 527.62 & -2755.02 \\ 2755.02 & -14385.60 & -2755.02 & 14385.60 \end{bmatrix} \times \frac{210\times1191.740}{122.12}$$

Result and Discussion

u_1	v_1	u_2	v_2	u_3	v_3	u_4	v_4
358.34	93.89	−358.34	93.89	0	0	0	0
93.89	24.60	−93.89	−24.60	0	0	0	0
−358.34	−93.89	−156676.12	115735.37	−1668.72	4704.69	0	0
−93.89	−24.60	−441723.34	326297.60	4704.69	−13264.13	0	0
0	0	−1668.12	4704.69	2482288.54	36542943.43	−527.62	2755.02
0	0	4704.69	−13264.13	12961515.04	190812468.5	2755.02	−14385.60
0	0	0	0	−527.62	2755.02	2755.02	2755.02
0	0	0	0	2755.02	−14385.60	−2755.02	14385.60

4.1 Results

Define the 8x8 matrix A

A = [358.34 93.89 -358.34 -93.89 0 0 0 0; 93.89 24.60 -93.89 -24.60 0 0 0 0; -358.34 -93.89 -156676.12 115735.37 -1668.72 4704.69 0 0; -93.89 -24.60 -441723.34 326297.60 4704.69 -13264.13 0 0; 0 0 -1668.72 4704.69 2482288.54 36542943.43 -527.62 2755.02; 0 0 4704.69 -13264.13 12961515.04 190812468.5 2755.02 -14385.60; 0 0 0 0 -527.62 2755.02 2755.02 2755.02; 0 0 0 0 2755.02 -14385.60 -2755.02 14385.60];

Define the scalar values B and C

B = (210 * 1191.740/ 263.25); Calculate B

C = (54.069 * 10^3); Calculate C

Perform the calculation (A * B)^-1 * C

Result3 = inv(A * B) * C;

Reshape the result to a single column vector

Result_column = result3(

Display the result as a single column

Disp(‘The result of (A * B)^-1 * C as a single column is:’);

Disp(result_column);

The result of (A * B)^-1 * C as a single column is:

Result and Discussion

-0.0832	0.3177	0	0	0	0	0	0	0.11725
0.3177	-1.2124	0	0	0	0	0	0	-0.44735
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

4.1 Results

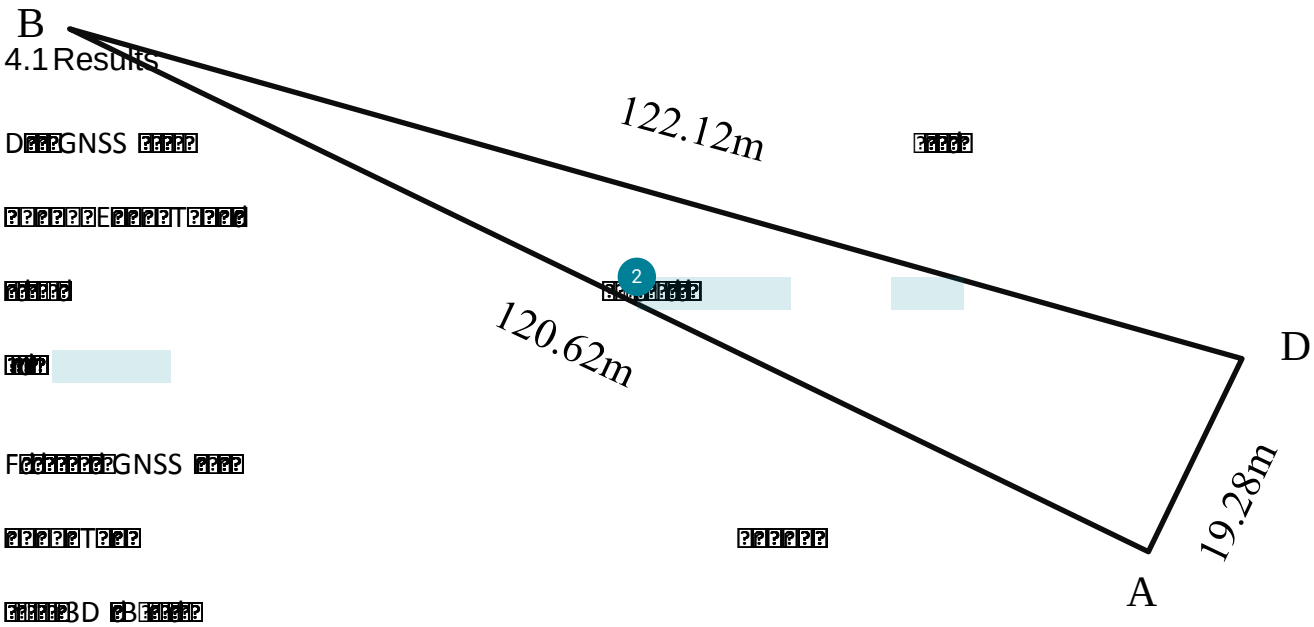
0.11725= U1
0.44735= V1
0= U2
0= V2
0= U3
0= V3
0= U4
0= V4

Triangle BCD WEEK		Triangle BCD WEEK 2		DISPLACEMENT
U1=	0	U1=	0.11725	0.058625
V1=	0	V1=	-0.44735	-0.223675
U2=	-0.0001	U2=	0	-0.00005
V2=	0.000667	V2=	0	0.000333333
U3=	0.1054	U3=	0	0.0527
V3=	-0.504	V3=	0	-0.252
U4=	-0.00005	U4=	0	-0.000025
V4=	0	V4=	0	0

CHAPTER FOUR

Result and Discussion

4.1 Results



$$Area = 1162.867m^2$$

$$L_1 = L\cos\theta$$

$$M_1 = L\sin\theta$$

$$L_1 = 122.12\cos(280.84)$$

$$L_1 = 22.97$$

$$M_1 = l22.12\sin(280.84)$$

$$M_1 = -119.94$$

$$\begin{bmatrix} u_1 & v_1 & u_2 & v_2 \\ 527.62 & -2755.02 & -527.62 & 2755.02 \\ -2755.02 & 14385.60 & 2755.02 & -14385.60 \\ -527.62 & 2755.02 & 527.62 & -2755.02 \\ 2755.02 & -14385.60 & -2755.02 & 14385.60 \end{bmatrix} \times \frac{210 \times 1162.867}{122.12}$$

$$L_2 = L\cos\theta$$

Result and Discussion

$$L_2 = 19.28cos\{199.34\}$$

$$L_2 = -18.19$$

4.1 Results

$$m_2 = L\sin\theta$$

$$m_2 = 19.28sin\{199.34\}$$

$$m_2 = -6.59$$

$$\begin{bmatrix} u_2 & v_2 & u_3 & v_3 \\ 330.88 & 116.23 & -330.88 & -116.23 \\ 116.23 & 40.83 & -116.23 & -40.83 \\ -330.88 & -116.23 & 330.88 & 116.23 \\ -116.23 & -40.83 & 11623 & 40.83 \end{bmatrix} \times \frac{210\times1162.867}{19.28}$$

$$L_3 = 122.12cos\{280.84\}$$

$$L_3 = 22.97$$

$$m_3 = L\sin\theta$$

$$m_3 = 122.12sin\{280.84\}$$

$$\begin{bmatrix} u_3 & v_3 & u_4 & v_4 \\ 1609.61 & -4563.65 & -1609.61 & 4563.65 \\ -4563.65 & 12939.06 & 4563.65 & -12939.06 \\ -1609.61 & 4563.65 & 1609.61 & -4563.65 \\ 4563.65 & -12939.06 & -4563.65 & 12939.06 \end{bmatrix} \times \frac{210\times1162.867}{120.62}$$

Result and Discussion

4.1 Results

$$\begin{bmatrix} u_1 & v_1 & u_2 & v_2 & u_3 & v_3 & u_4 & v_4 \\ 527.62 & -2755.02 & -527.62 & 2755.02 & 0 & 0 & 0 & 0 \\ -2755.02 & 14385.60 & 2755.02 & -14385.60 & 0 & 0 & 0 & 0 \\ -527.62 & 2755.02 & 911581.02 & -1672097.27 & -330.88 & -116.2341 & 0 & 0 \\ 2755.02 & -14385.60 & -320227.27 & 587364.05 & -116.2341 & -40.83 & 0 & 0 \\ 0 & 0 & -330.88 & -116.2341 & -187091.57 & 186333.83 & -1609.61 & 4563.65 \\ 0 & 0 & -116.2341 & -40.83 & -530451.75 & 528301.82 & 4563.65 & -12939.06 \\ 0 & 0 & 0 & 0 & -1609.61 & 4563.65 & 4563.65 & -12939.06 \\ 0 & 0 & 0 & 0 & 4563.65 & -12939.06 & -4563.65 & 12939.06 \end{bmatrix}$$

Define the 8x8 matrix A

A = [527.62 -2755.02 -527.62 2755.02 0 0 0 0; -2755.02 14385.60 2755.02 -14385.60 0 0 0 0; -527.62 2755.02 911581.02 -1672097.27 -330.88 -116.2341 0 0; 2755.02 -14385.02 -320227.27 587364.05 -116.2341 -40.83 0 0; 0 0 -330.88 -116.2341 -187091.57 186333.83 -1609.61 4563.65; 0 0 -116.2341 -40.83 -530451.75 528301.82 4563.65 -12939.06; 0 0 0 0 -16091.61 4563.65 4563.65 -12939.06; 0 0 0 0 4563.65 -12939.06 -4563.65 12939.06];

Define the scalar values B and C

B = (210 * 1162.867/ 262.02); Calculate B

C = (54.069 * 10^3); Calculate C

Perform the calculation (A * B)^-1 * C

Result3 = inv(A * B) * C;

Reshape the result to a single column vector

Result_column = result3(;

Display the result as a single column

Disp('The result of (A * B)^-1 * C as a single column is:');

Disp(result_column);

Result and Discussion

-1.6934	-0.3243	0	0	0	0	0	0
-0.3243	-0.0621	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
-2.8826	-0.5603	-0.0031	-0.0089	0.1231	-0.045	-0.0375	-0.0509
-1.0167	-0.1976	-0.0011	-0.0031	0.0434	-0.0159	0.0132	-0.018

4.1 Results

D GNSS

F GNSS

-1.00885= U1
-0.1932= V1
0= U2
0= V2
0= U3
0= V3
-0.43315= U4
-0.14948= V4

S GNSS F

	Triangle BAD Week 1		Triangle BAD week 2	Displacement
U1=	-0.000933333	U1=	-1.00885	-0.504891667
V1=	0.005	V1=	-0.1932	-0.0941
U2=	-2.94942	U2=	0	-1.47471
V2=	-1.056	V2=	0	-0.528
U3=	0.007628571	U3=	0	0.003814286
V3=	-0.010585714	V3=	0	-0.005292857
U4=	-0.02078	U4=	-0.43315	-0.226965
V4=	0.00432	V4=	-0.149475	-0.0725775

E1

DA1

CHAPTER FIVE

SUMMARY, RECOMMENDATION AND CONCLUSION

5.1. SUMMARY

The project utilized finite element analysis (FEA) to monitor deformations in the Physics Department building at the University of Benin. The primary goal was to assess the building's structural integrity, pinpoint weaknesses, and detect any deformations through modeling and analysis. The study highlights the importance of using advanced computational and numerical techniques to maintain the safety and durability of critical infrastructure. By integrating FEA with regular monitoring and inspections, the project promoted proactive maintenance and provided valuable insights into the building's structural performance. The project successfully reduced the risk of structural deformations and promoted the building's long-term sustainability by establishing a reliable monitoring system and implementing strategic, proactive maintenance measures.

5.2. RECOMMENDATIONS

The project recommends constant monitoring of the structure over time, with the necessary attention given to it. It also suggests that advanced monitoring techniques be used. Additionally, the project advises implementing long-term planning and investment in structural maintenance and renewal programs to ensure the building's durability and longevity.

5.3. CONCLUSIONS

In conclusion, using FEA for deformation monitoring of large structures like the Physics Department building is effective and reliable. The study proved that finite element modeling can accurately detect structural deformations, and its accuracy improves with a higher density of monitoring points. The FEA method not only identified deformation patterns but also offered a complete framework for analyzing structural changes within a single observation period. The study also provided important insights into the distribution of stress within the structure, showing areas with different levels of deformation. Analyzing the variance matrix of displacement vectors revealed that deformation was not uniform, with some points showing more significant shifts than others. This detailed understanding allows for a more targeted approach to structural maintenance and assessment. The findings emphasize that continuous monitoring with FEA is crucial for the early detection of potential structural issues, which allows for timely intervention before serious damage occurs. The integration of this advanced method into routine monitoring practices improves the resilience and longevity of critical infrastructure. The study ultimately underscores the potential of FEA as an essential tool in modern deformation monitoring due to its ability to combine precision with comprehensive structural insights, ensuring the long-term stability, safety, and functionality of large buildings.

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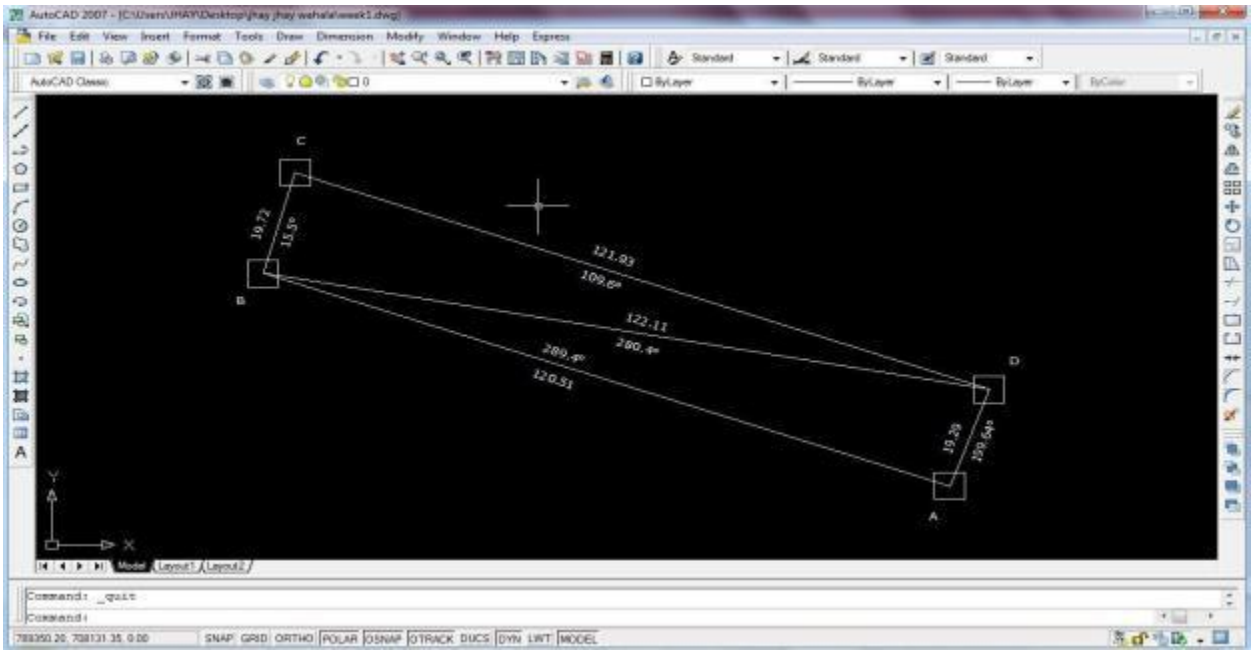
APPENDIX



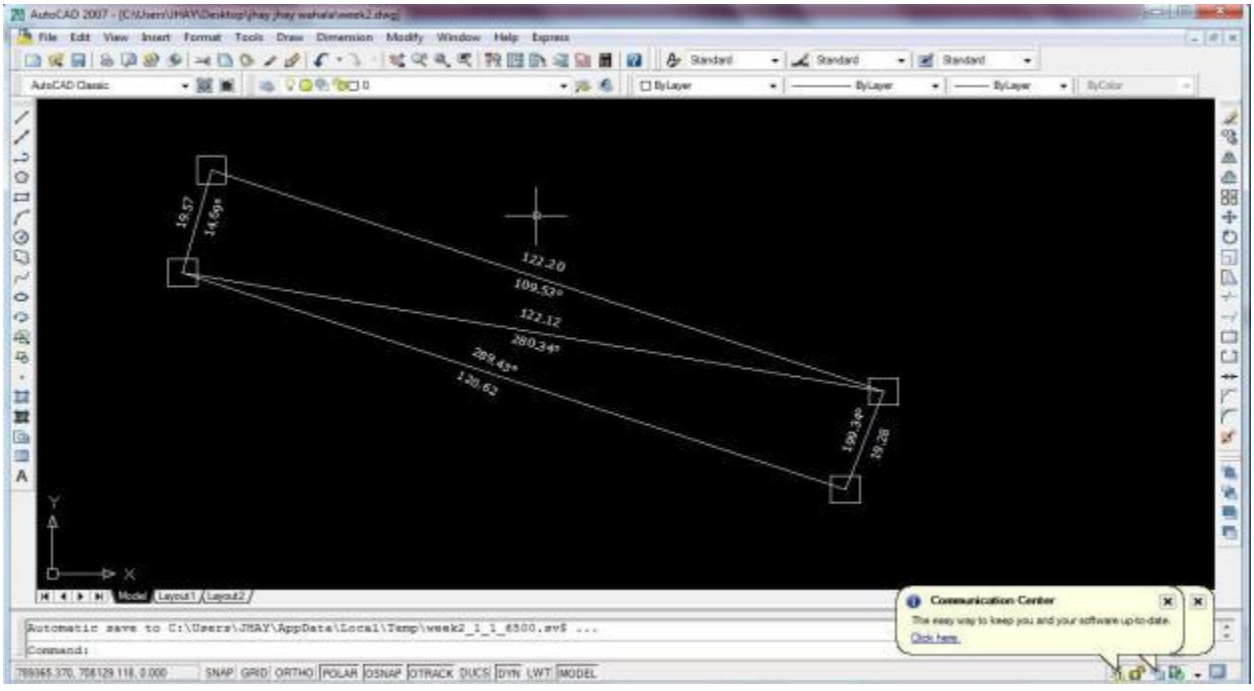


FIGURE A.1 Showing Autocad representation of the study area plotted with coordinates for week 1 and 2

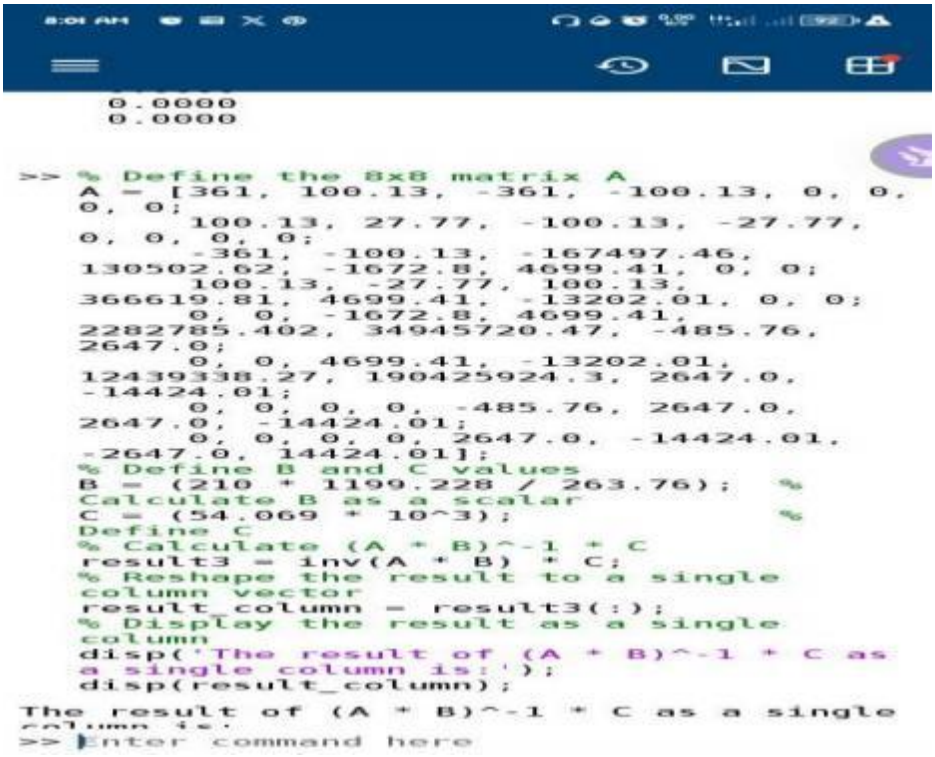


FIGURE A.2 Showing MATLAB Analysis for the Global Matrix, Stiffness Matrix and the Force

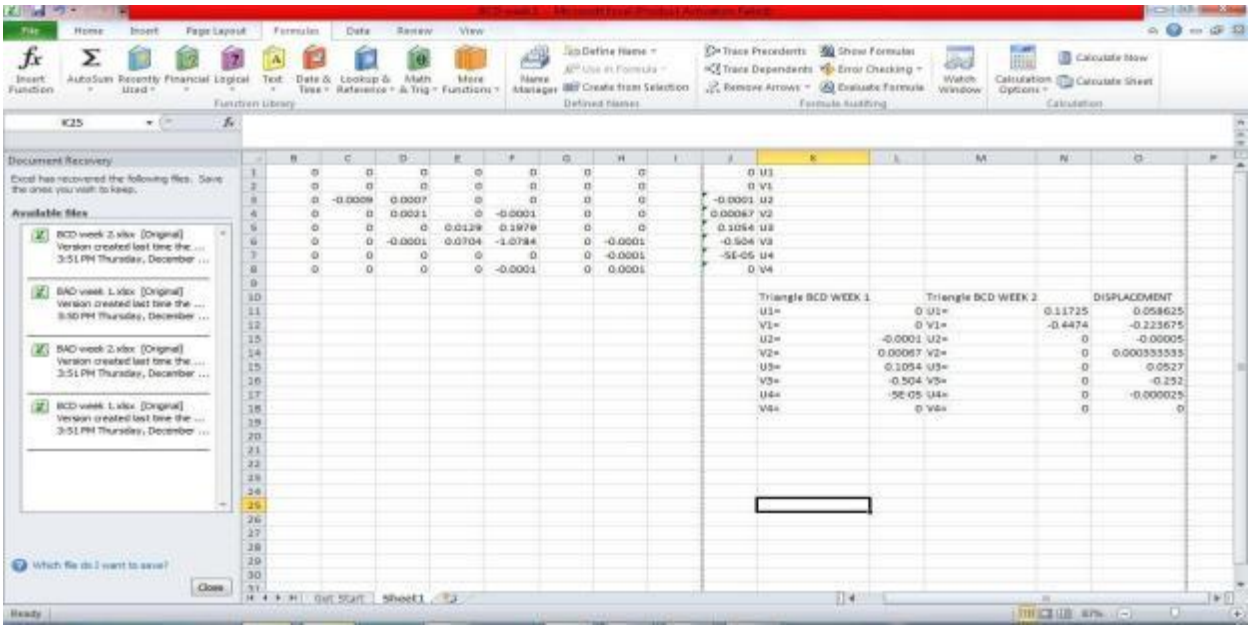


FIGURE A.3 Showing The Displacement Between week 1 and 2 for Triangle BCD

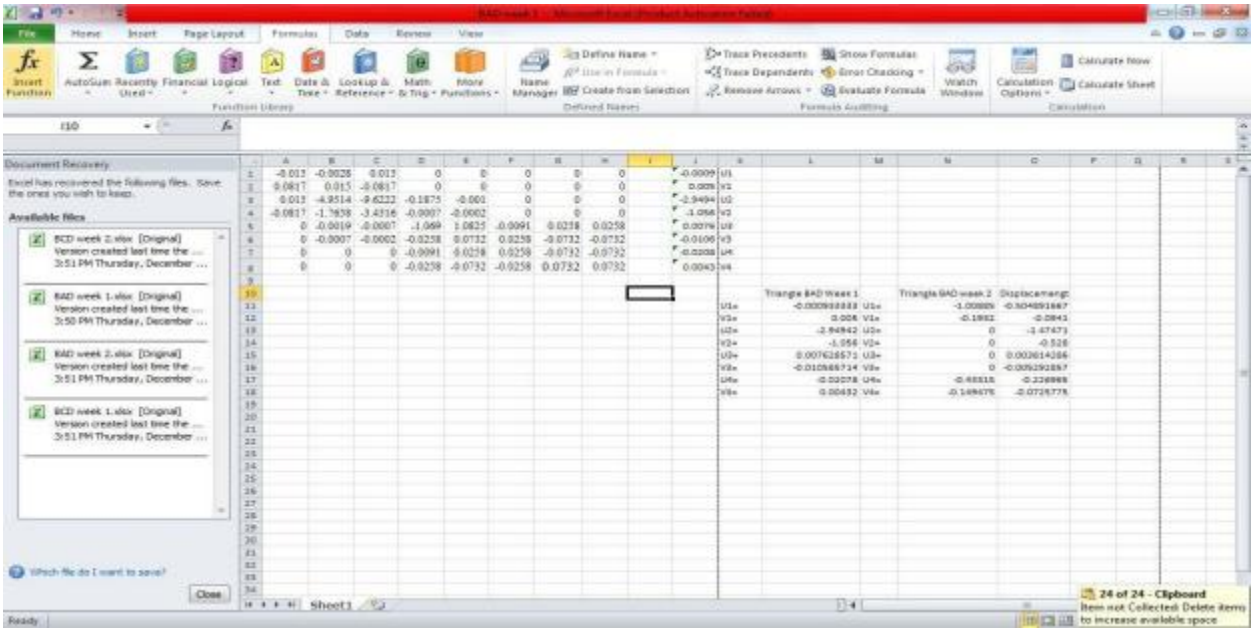


FIGURE A.4 Showing The Displacement Between Week 1 and 2 for Triangle BDA

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