Enhancing Safety and Efficiency in Underground Marble Quarries through Statistical Analysis of Geotechnical Data

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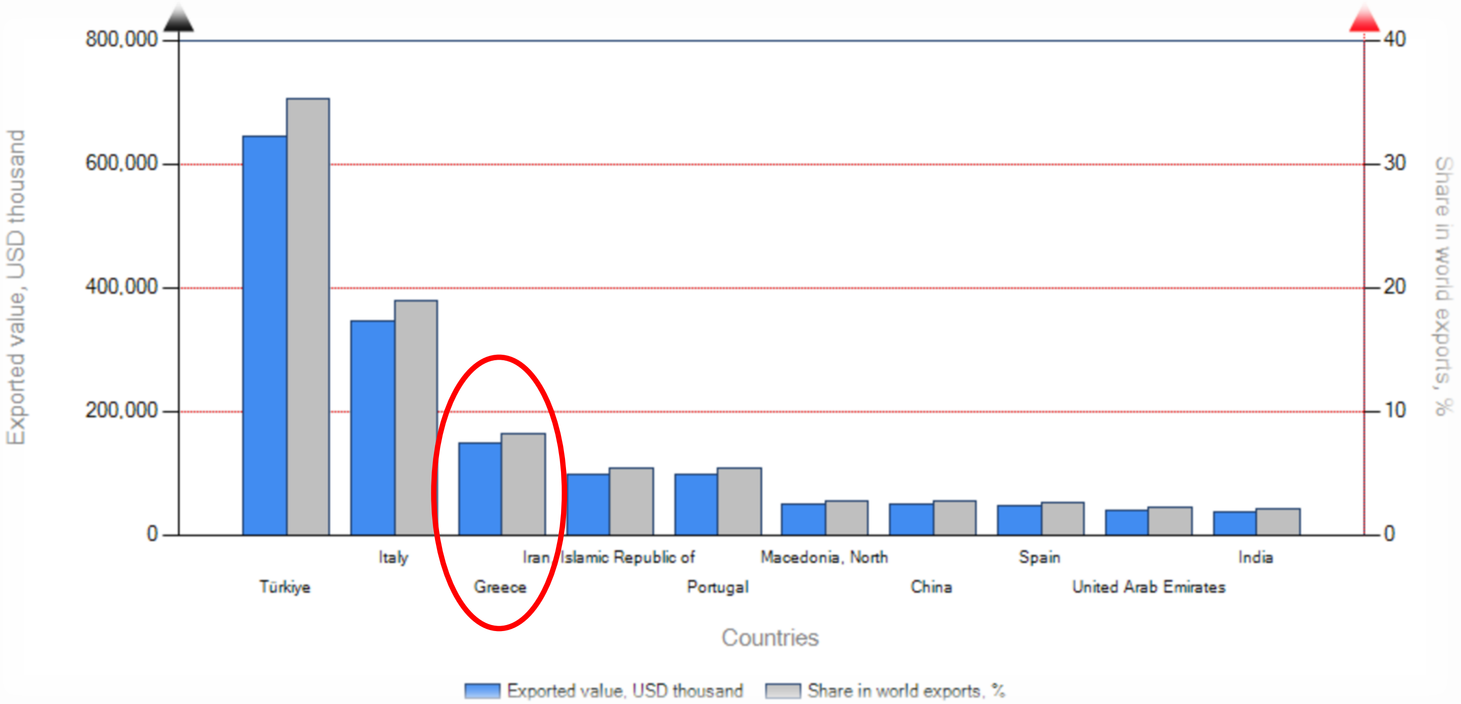
Table of contents

01 Stone quarrying

Marble quarrying
has been steadily growing
for the last ten years in Greece

01 Stone quarrying



Greece among top 3 countries in exported value regarding marble blocks

260 Total Number of licensed operating marble quarries in Greece

189 90% of activity in North Greece _ Macedonia & Thrace

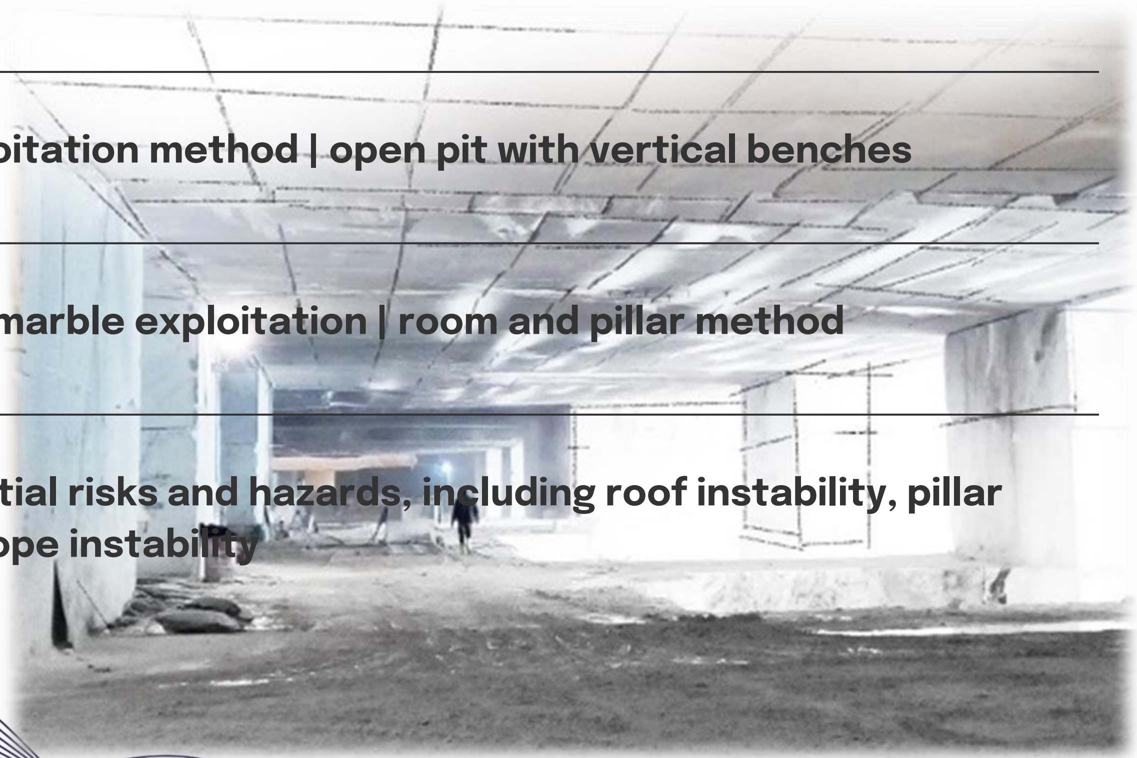
500.000 m^3

Production of marble blocks for Y2022

sustainable development

Stone industry move forward using modern underground excavations procedures

1	**Classical exploitation method | open pit with vertical benches**
2	**Underground marble exploitation | room and pillar method**
3	**Several potential risks and hazards, including roof instability, pillar failure, and slope instability**



02 Case study

Large excavation in underground dolomite deposit
Location: North Greece | Method: Room & Pillar | Started: May of 2013

02 Case study - milestones

1st level of excavation

May 2013

May 2018

2nd level of excavation

3rd level of excavation

Sep 2019

high excavation rate in multiple underground levels

1st level of excavation

Trying different tunnelling dimensions

Pillar dimensions
9,00m x 9,00m

Distance between pillars
17,00m

Typical tunnel dimensions:
Height – 6,00m
Width – 12,00m

2nd level of excavation

No of underground benches excavated in parallel
2,00

Total tunnel bench height
12,00m

Excavation step
in Depth – 9,50m per shift

Average Daily Production
600,00 tons

3rd level of excavation

High production rate

No of underground benches excavated in parallel
3,00

Annually production per machine
20.000,00 tons

Fully operating chain saw machines
10,00

Real-life application

How to identify and monitor geotechnical risks and provide recommendations for improving risk management and geotechnical safety in underground marble quarries ?

Facing high excavation rate

Installation of geotechnical sensors

Searching new technology and specialised monitoring equipment

Data collection

Automatic data logger synching in a dedicated database

Data analysis

Ccalculation of safety factor for each pillar.

Risk management

Matching geotechnical "events" with mining expansion

Table of contents

03 Geotechnical equipment

Wireless geotechnical sensors

- Optical displacement sensors
- Triaxial tilt sensors
- Crack meters

03 Geotechnical equipment

Wired geotechnical sensors

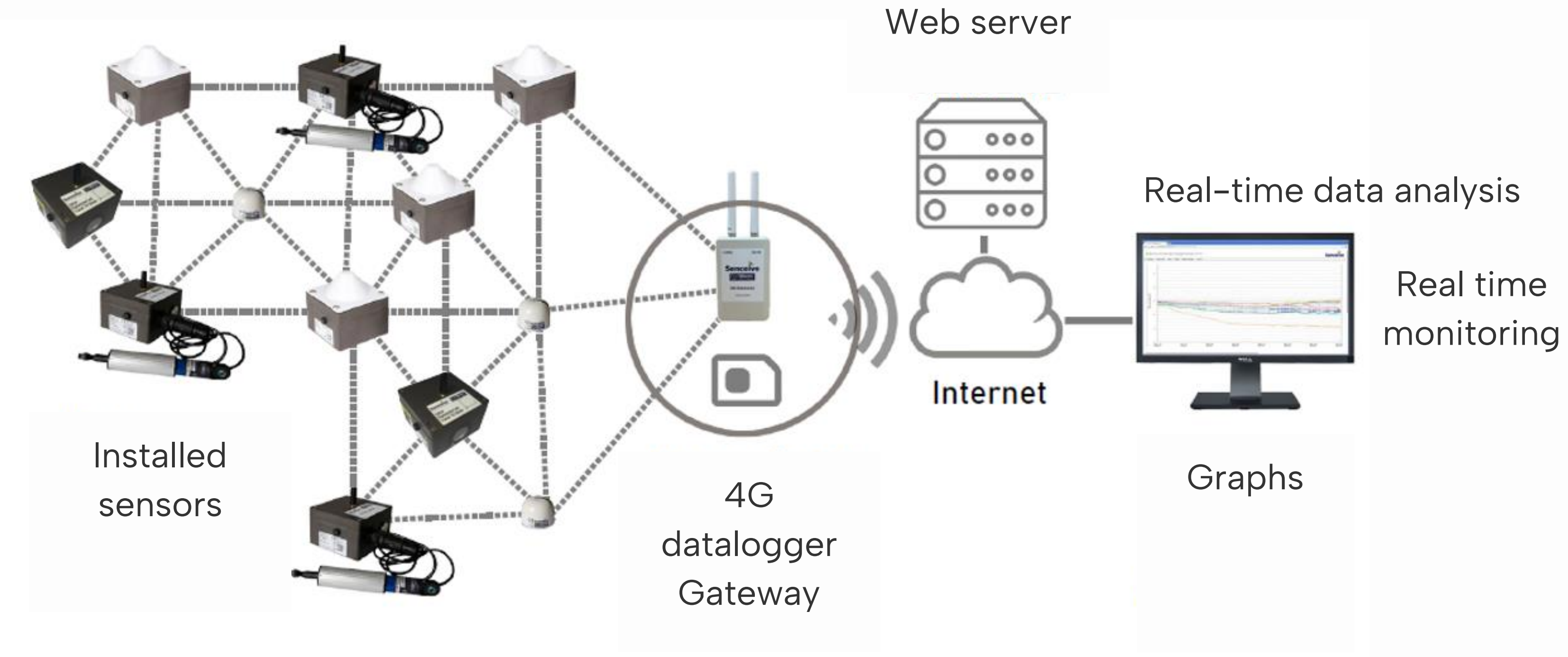
- Extensometers
- Biaxial stress meters
- Load cells

03 Geotechnical equipment

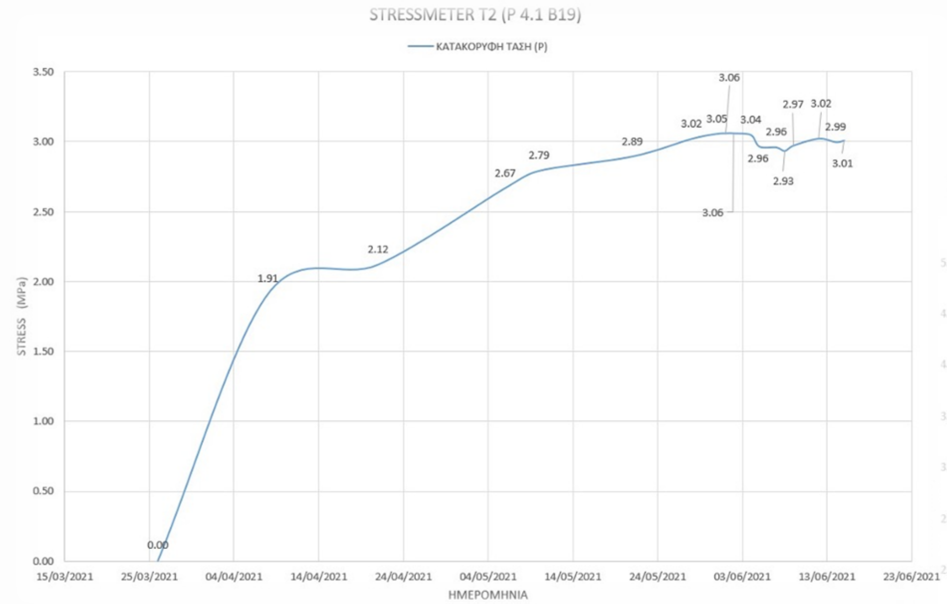
- Georadar: arcsar technology
- For open pit
- For underground

04 Geotechnical data

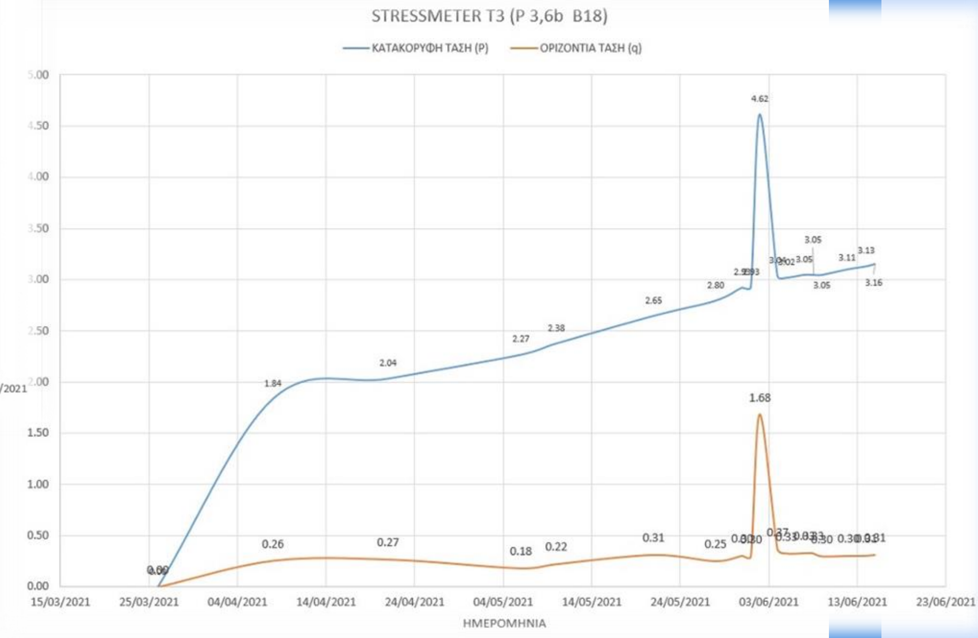
Integration of data using automatic data logger



04 Geotechnical data analysis

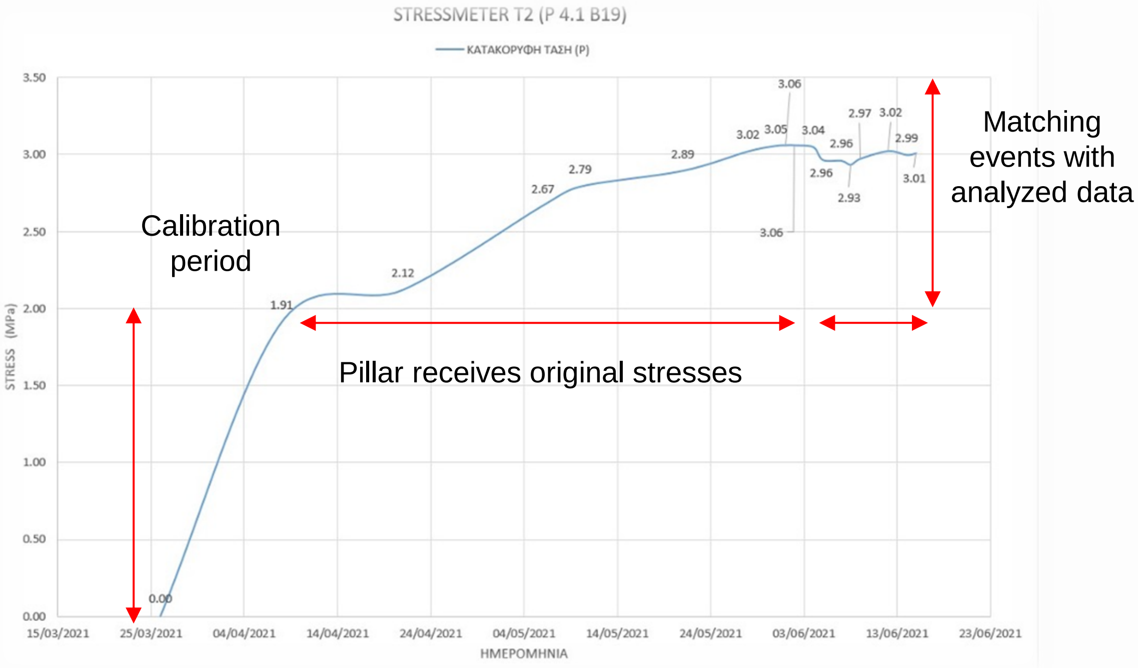


Time-series analysis for detecting patterns



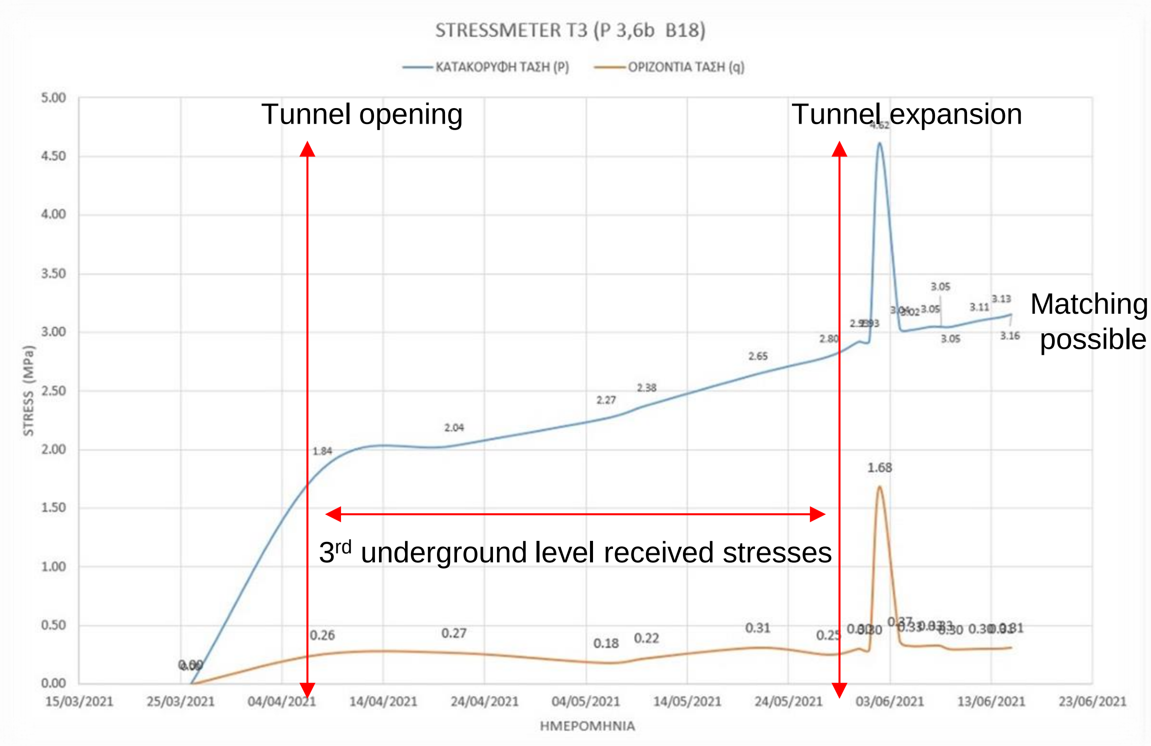
04 Geotechnical data analysis

Statistical Tools and Techniques → **time series analysis**
Analyse data collected over time to **predict future conditions** and **detect abnormal behaviour** such as **sudden shifts in pressure** or other critical indicators that may **suggest instability or hazards**.



04 Geotechnical data analysis

Data correlation between different stresses

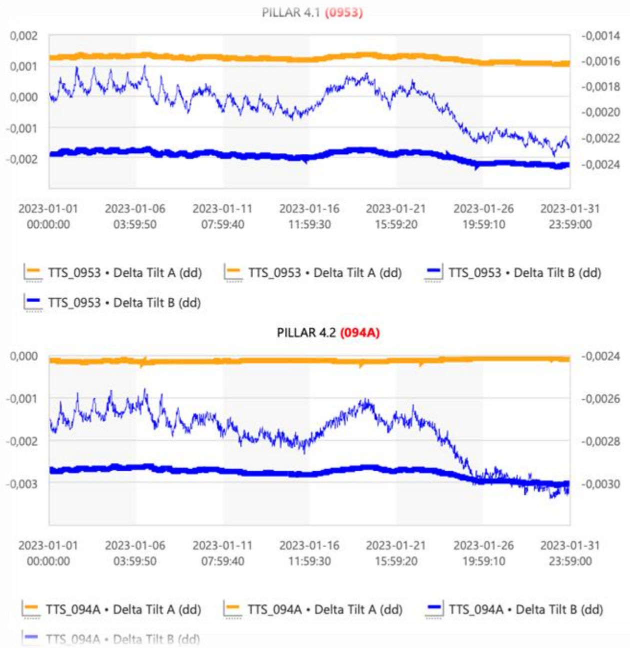


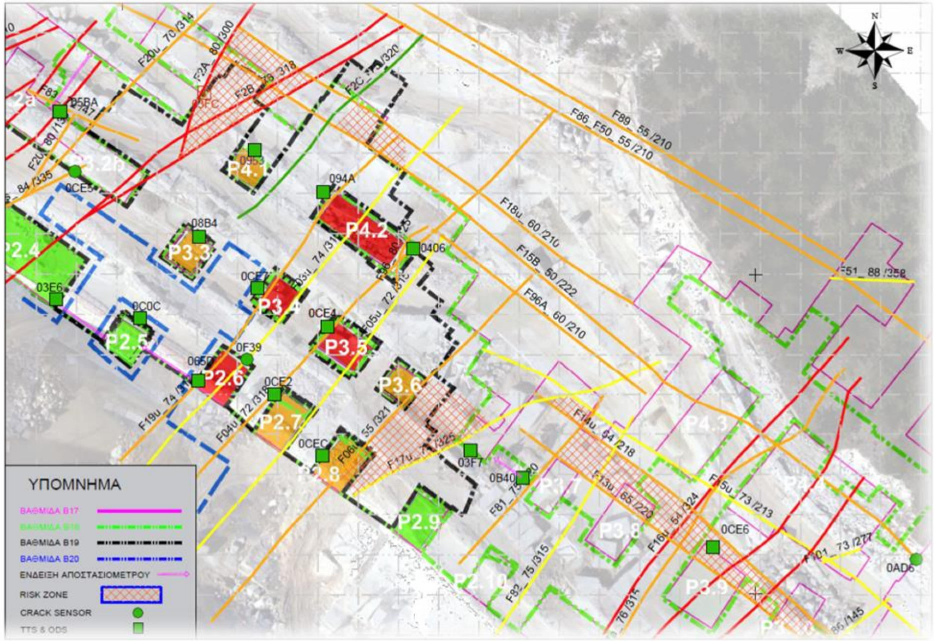
04 Geotechnical data analysis

Real-time Data Streaming and Analysis: monitoring data that is continuously generated by sensors → **processing**, **storing**, and **analysing** the data in real-time to quickly respond to **potential risks**.

04 Geotechnical data analysis

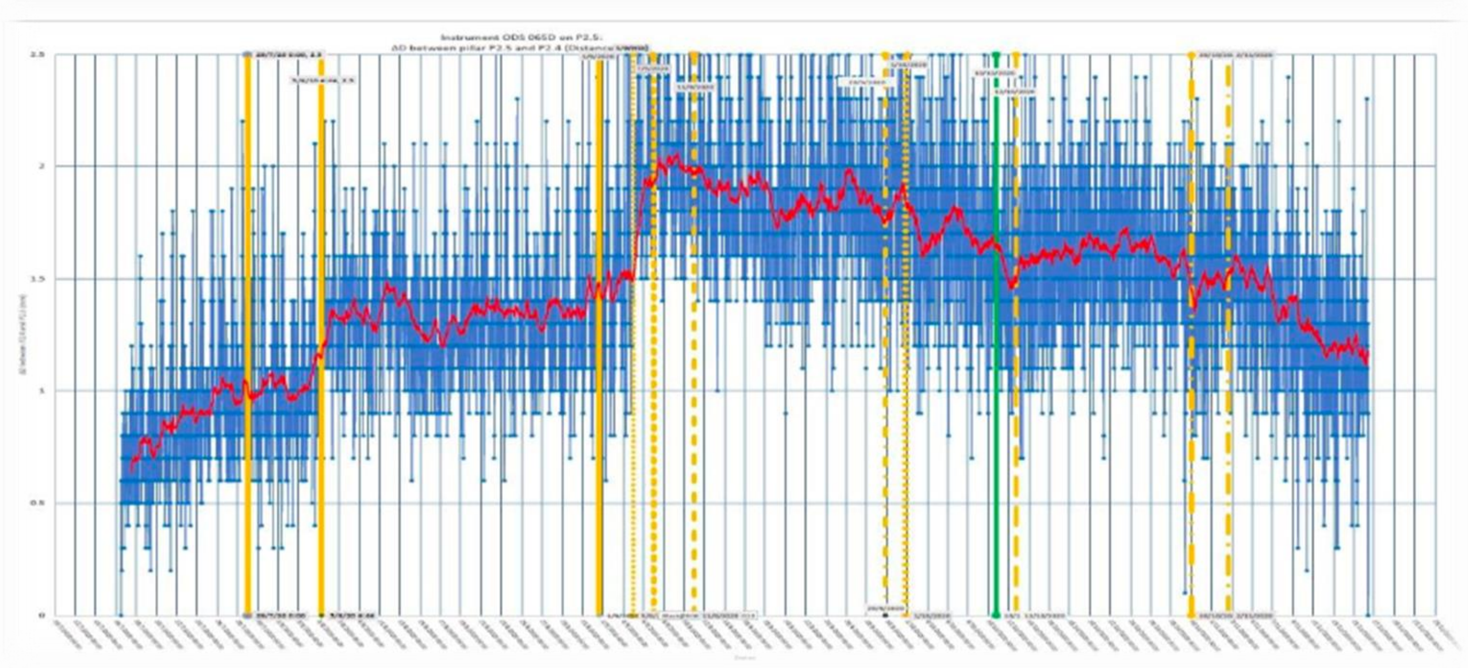
Overview of the **data distribution**, **identifying mean values**, **variability** and **trends**





04 Geotechnical data analysis

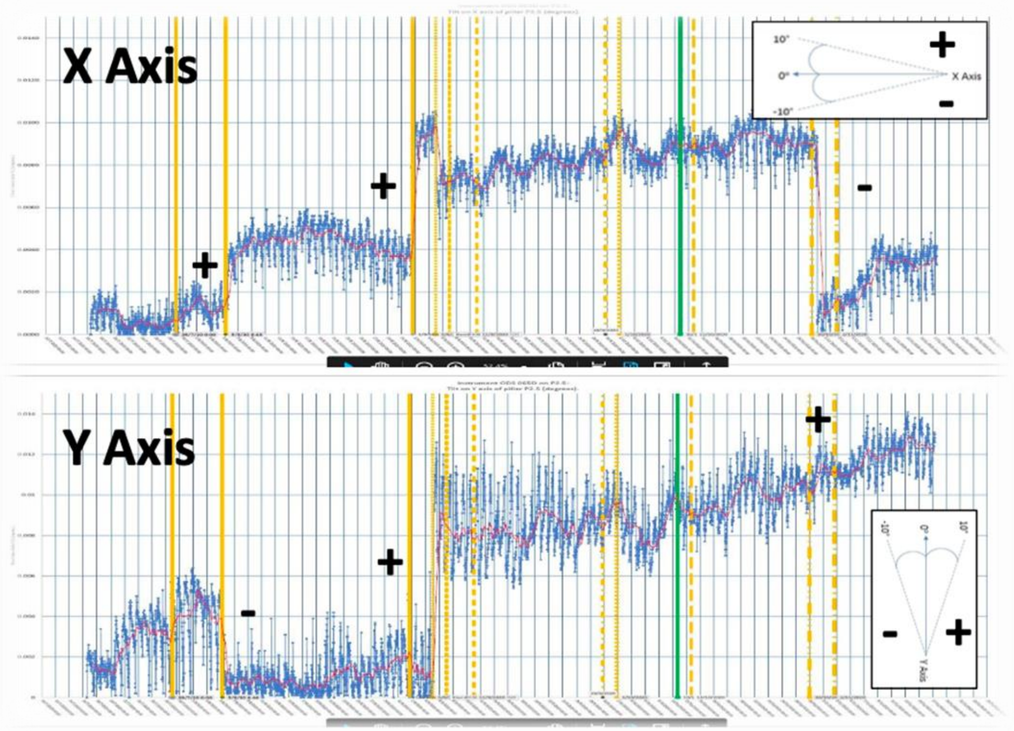
Forecast models about future quarry behaviour under similar geotechnical conditions



Blue: real data with Standard Deviation
Red: calculated mean value

04 Geotechnical data analysis

Machine Learning: Utilize historical data to predict possible failures
models can **identify patterns** that precede certain failures, aiding in **proactive** and **risk management**.



Blue: real data with Standard Deviation
Red: calculated mean value

Results

Statistical analysis of geotechnical data has profound implications for quarry operations.

Real-time data analysis can **trigger** automated alerts in case of detected anomalies, allowing for immediate response to mitigate risks.

Long-term data analysis aids in the planning of **quarry expansion**, optimizing the extraction process while ensuring stability and safety.

Statistical & machine learning models developed from **historical data** can serve as benchmarks for comparing current quarry conditions, enabling the identification of deviations that might signify emerging risks.

Conclusions

Main objective

understand the way that the rooms and pillars are behaving in relation to progress of the excavation.

Data integration

improves operational efficiency through data-driven decision-making

Data analysis

monitoring technologies and statistical methodologies framework for risk assessment and mitigation

Thank you !

Do you have any questions?