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MONITORING OF SLOPES AND RETAINING STRUCTURES RELATED TO INFRASTRUCTURES CASE STUDY HYDROELECTRIC POWER PLANT JIU RIVER LIVEZENI ROMANIA

Olteanu Andrei Constantin, Associate Professor, PhD. MSc. Eng., Technical University of Civil Engineering of Bucharest, Department of Geotechnics and Foundations, e-mail:, andrei.olteanu@utcb.ro
Tomşa Cristina, MSc. Eng., Technical University of Civil Engineering of Bucharest, Department of Geotechnics and Foundations, e-mail: tomsa.cristina@utcb.ro

Rezumat

Articolul prezintă rezultatele monitorizării inclinometrice, interpretarea măsurătorilor efectuate și măsurile de intervenție stabilite pentru o lucrare de susținere executată pentru realizarea unei amenajări hidrotehnice pe râul Jiu. Realizarea amenajării hidrotehnice în zona de defileu a Jiului a condus la necesitatea executării unei structuri de sprijin cu lungimea de aproximativ 100m care să pună în siguranță versantul care urma să fie excavat în zona aval. Versantul a cărui stabilitate a fost asigurată prin realizarea structurii de sprijin din piloți de 1500mm este traversat de linia de cale ferată Tg. Jiu - Simeria și este despărțit de traseul de drum E79 prin cursul râului Jiu.

Monitorizarea comportamentului unei structuri de sprijin și a versantului pe care îl pune în siguranță, modalitatea de amplasare a sistemelor de monitorizare și adâncimea de realizare a acestora este rezultatul unei analize complexe a obiectivului, a vecinătăților și a riscurilor care trebuie monitorizate și gestionate. Lucrarea de față prezintă rezultatul Proiectului de Monitorizare implementat pentru amplasamentul în discuție, fiind rezultatul analizei etapelor de monitorizare: stabilirea problemelor geotehnice sau structurale care necesită soluționare/urmărire, stabilirea conceptului monitorizării, alegerea planului și sistemelor de monitorizare, stabilirea: punctelor de monitorizat, echipamentelor, frecvenței și tipului de achiziție a datelor, modalitatea de prelucrare, interpretare și emitere a rezoluțiilor pentru datele obținute.

Rezultatele monitorizării inclinometrice, piezometrice și topografice comparate cu prezumțiile obținute în faza de proiectare pot conduce la măsuri de intervenție care să asigure și să redea stabilitatea structurii aflată în faza de construcție sau în exploatare.

Cuvinte cheie: monitorizare geotehnică, înclinometru, deformații, versați instabili

Abstract

The Paper presents the results, interpretation and intervention measures obtained from inclinometer monitoring performed for a retaining structure built for the accomplishment of a hydrotechnical structure on Jiu River. The accomplishment of the hydrotechnical structure on Jiu River required a retaining structure of approximately 100m length adjacent to the slope which is crossed by the railway line Tg. Jiu - Simeria. The retaining structure made of 1500mm piles also keeps in safe condition the adjacent E79 Road section.

Monitoring the behavior of the support structure and of the slope, the layout and the depth of the monitoring equipments, is the result of a complex analysis of the site, of the neighborhoods and the risks to be monitored and managed. This paper presents the "peak of the iceberg" related to site monitoring, being the result of several steps necessary to be performed in order to accomplish the monitoring program: establishing geotechnical or structural issues that require resolution / tracking, establishing the concept of monitoring systems and monitoring plan, establishment of: monitored points, equipment, frequency and type of data acquisition, processing methods, interpretation and issue resolutions for the data.

The results of the geotechnical monitoring and topographical survey compared with the design assumptions can lead to intervention measures to ensure and restore structural stability for the construction during execution stage or exploitation stage.

Keywords: geotechnical monitoring, inclinometer, displacement, sliding slope

1. INTRODUCTION

The retaining structure designed and executed for the hydrotechnical development at Bumbești Livezeni, on the Jiu River, is near major communication pathways, namely the Tg. Jiu - Simeria railway line and the European road E79. The risk analysis and the placement of the retaining structure at the foot of the slope near the Jiu River, traversed by the Tg. Jiu - Simeria railway tunnel, led to monitoring the displacements of the retaining structure and the slope during the excavation works downstream, the Jiu River diversion works, and until the completion of the dam.

The monitored support structure is a discontinuous structure made of a row of piles anchored in two rows with active anchors, with a maximum length of 18.0m and a diameter of 1500mm.

The displacement monitoring of the support structure, slope, and tunnel was performed through topographic and inclinometric measurements correlated to obtain comprehensive information on the effects of ongoing works.

The support structure was instrumented with five inclinometric systems placed in the pile bodies; four inclinometric systems were placed upstream of the support structure in the active prism to record slope displacements near the structure and monitor water levels; five inclinometer tubes were placed on the slope upstream and downstream of the railway line and tunnel.

2. GENERAL SITE DATA

The work presents the results of Inclinometric and Topographic Monitoring of the Retaining Structure adjacent to a Natural Slope, processing the evolution graphs of displacement vectors correlated with the technological phases on-site, exceptional meteorological phenomena (over one year), and applied intervention measures [1].

The Column Retaining Structure was instrumented with vertical inclinometer along the entire element length / reinforcemnet cage, with the primary recording direction of displacement, A0-A180, oriented downstream.

The frequency of inclinometer measurements stages was initially set at one per week, modified due to the observation of special events from site works, excavation works, special weather phenomena, etc. The measurement stages was set based on Work Schedule and based on the Monitoring Report conclusion in relation with the Geotechnical Design [2], [3]

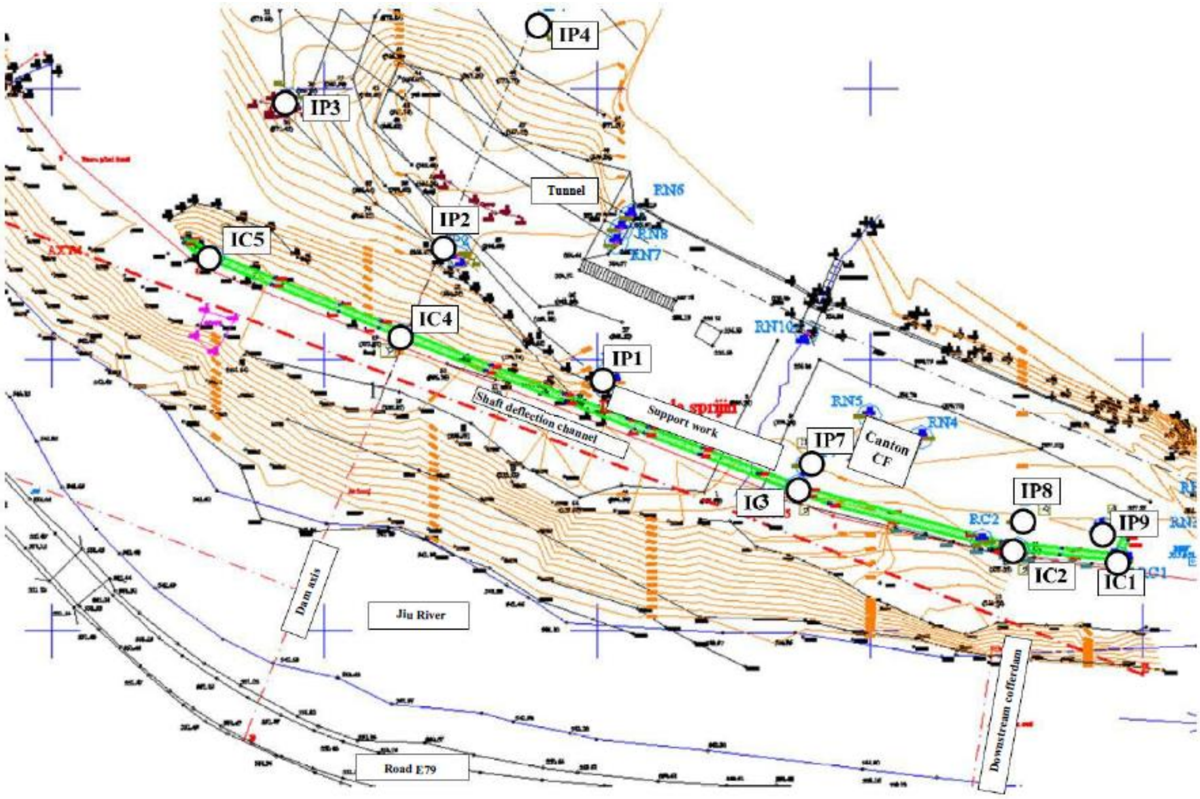


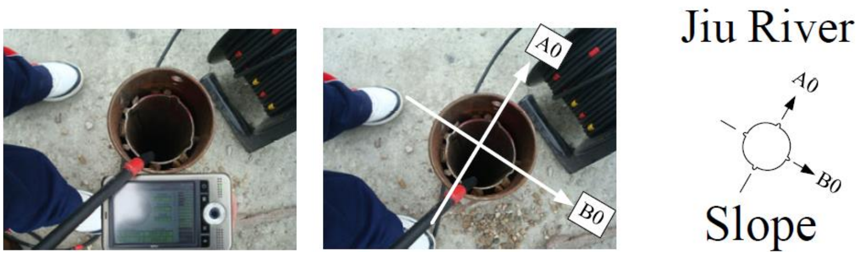
Figure 1. General Site Plan and Inclinometer Systems Position

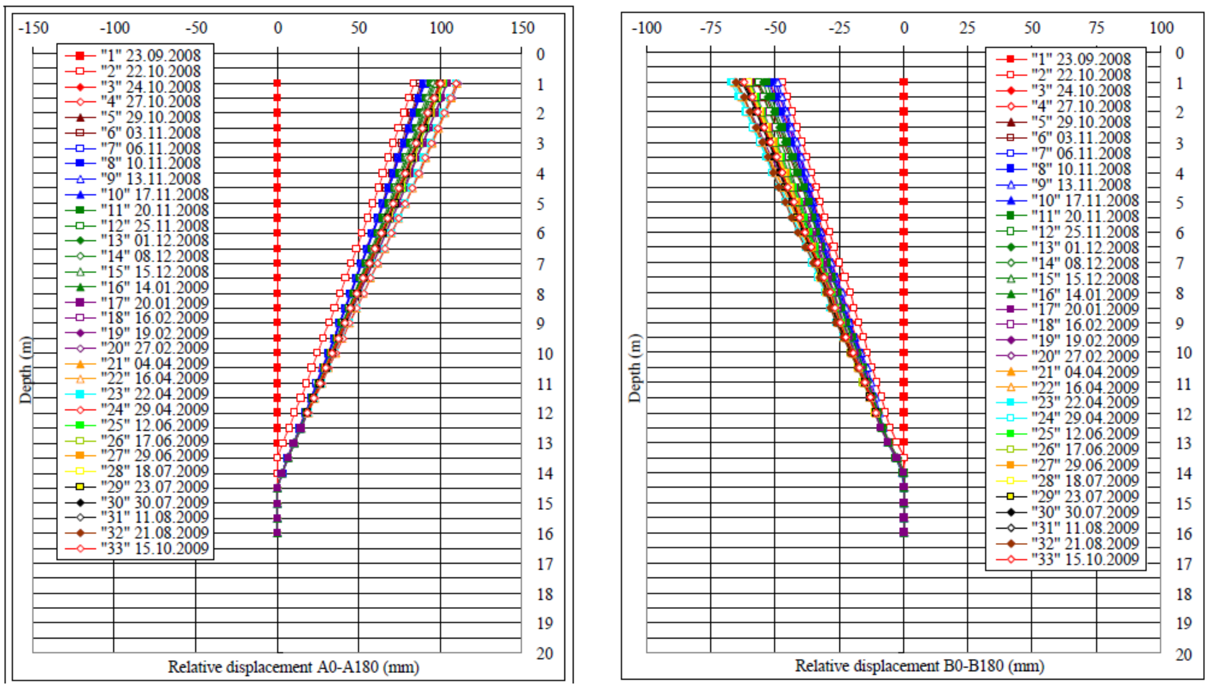
3. INCLINOMETER MONITORING RESULTS

Displacement graphs recorded in the inclinometer systems installed in the retaining structure in the main monitoring directions: A0-A180 and B0-B180 are presented. Displacement is observed in both directions for each inclinometer, and the absolute value of the displacement vector increases from section IC1 to IC4, then decreases for IC5. This variation indicates the torsional effect under the earth mass active pressure.

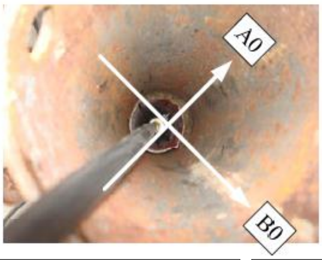
The torsional effect of the structure, caused by the earth mass mouvement, is observed through displacement results and generated by the varied geology of the earth mass, consisting of deluvium with metric boulder elements in size, mass geometry, retaining, structure, rail traffic in the area, etc.

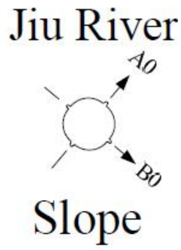
Orientation of the inclinometer system IC3

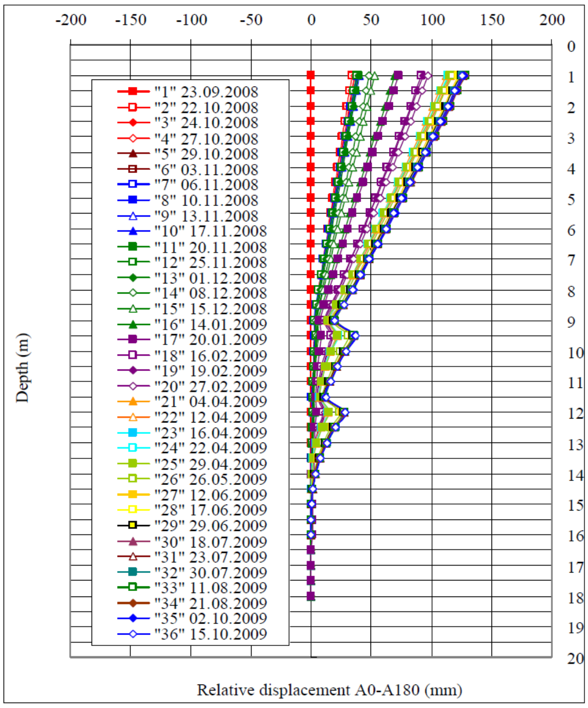


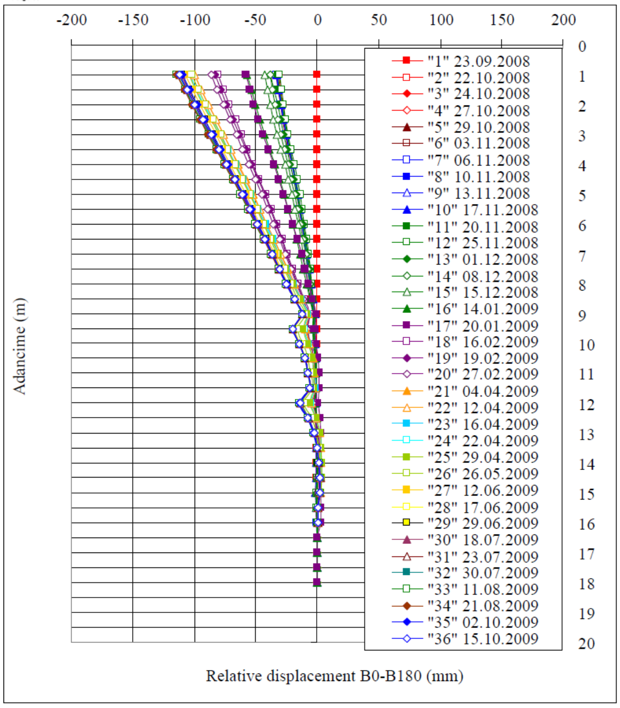


Orientation of the inclinometer system IC4

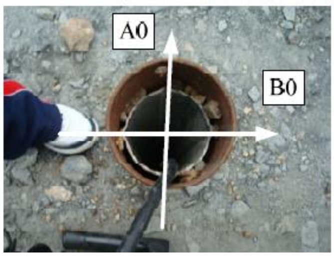



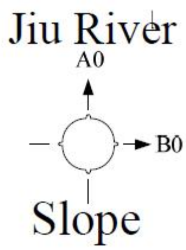


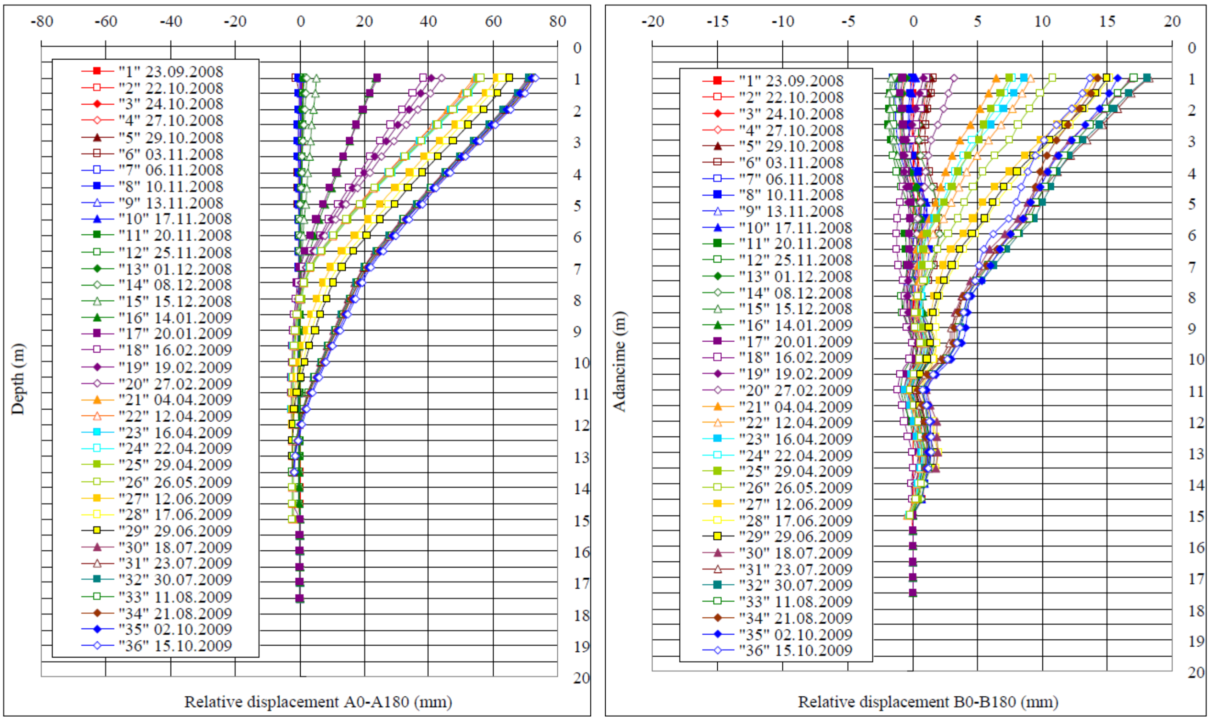




Orientation of the inclinometer system IC5





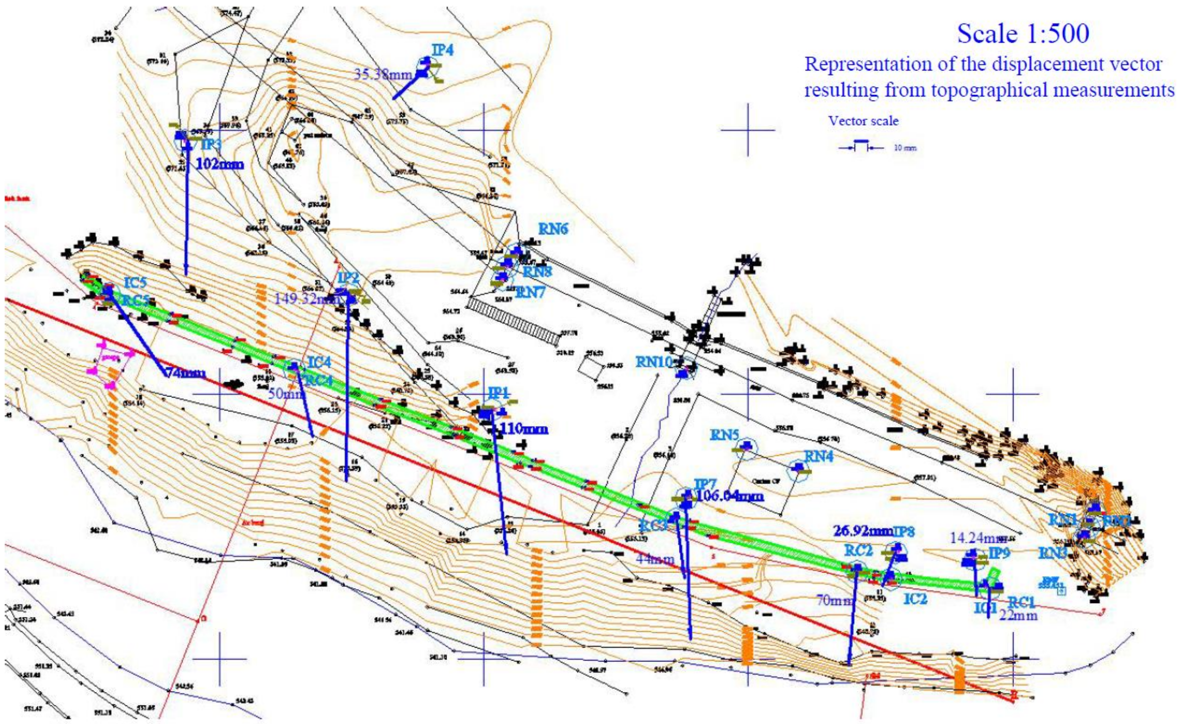


Figure 2. Displacement Vectors recorded from Topographic Monitoring between 01/10/2008 (21.01.2008) and 14/04/2009

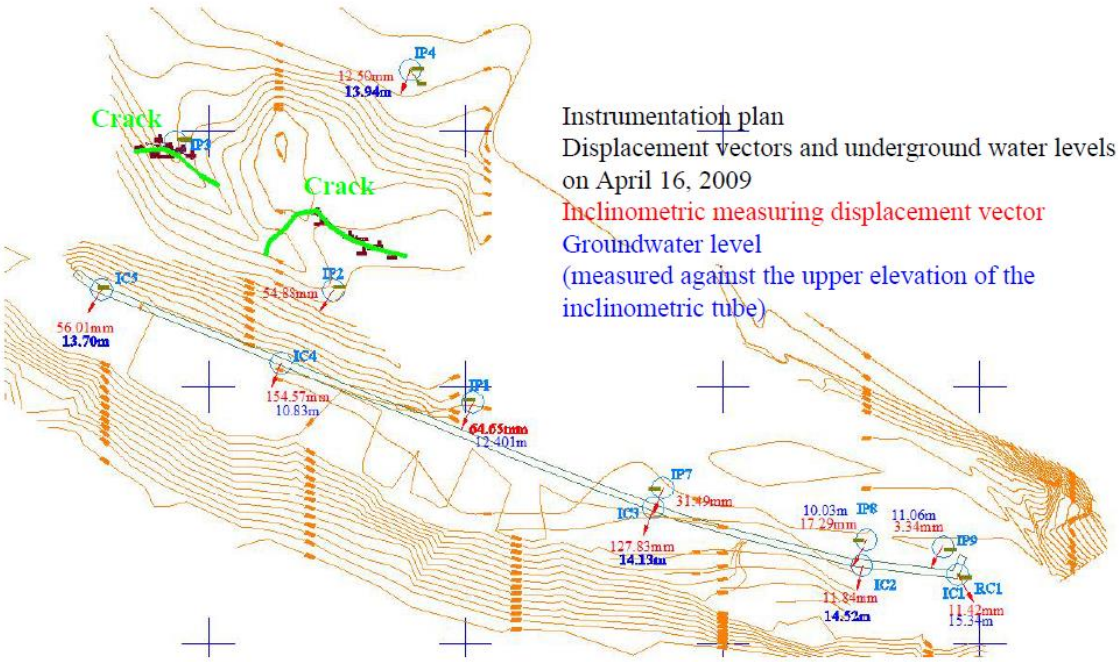


Figure 3. Displacement Vectors recorded from Inclinometer Monitoring between 23/09/2008 and 16/04/2009

Analyzing the topographic and inclinometric monitoring results highlights the need for correlated initiation timing and monitoring frequency for both types. Differences in monitoring results should be analyzed considering potential factors to eliminate their effects: weather conditions on the measurement day, the reference point for topographic monitoring, etc. [4].

Following the morphology, Topographic Elevations, inclinometric monitoring results, the stability of critical slope sections and the retaining structure was analyzed.

Cross-sections were instrumented with inclinometric monitoring information regarding the depth of major displacements and slope changes in the diagram, with the IP4-IP2-IC4 inclinometer section shown in Figure 4.

Following the results of the monitoring actions, stability conditions were reconsidered, leading to the adoption of intervention measures specific to the structural areas highlighted by the monitored section. Thus, for certain sections, additional tensioning of the anchors systems it was decided to carry out, the construction of a temporary berm in front of the retaining structure was implemented, and for the section adjacent to inclinometers IC3-IP7, an additional row of anchors was installed [5], [6], [7].

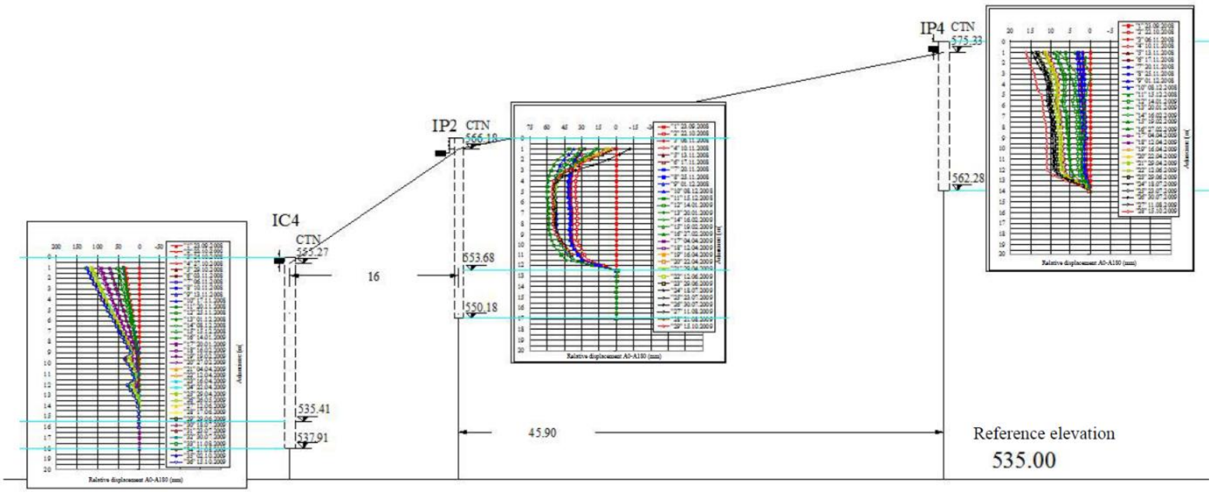


Figure 4. Cross Section through the Slope and Retaining Structure (reference Inclinometric Systems IP4-IP2-IC4)

4. INCLINOMETER MONITORING DATA PROCESSING

Figures 5 to 10 present graphs of the displacement vector evolution at the beam level for the five inclinometers, in absolute value. The results processing and time evolution are correlated with the monitoring dates. Figure 11 summarizes the displacement vector evolution for the five inclinometric columns at the beam level, based on cumulative days from the initial measurements. The displacement level reached by each section over time, the displacement 7speed, future evolution projection, and safety measures can be assessed as Risk Analysis [8].

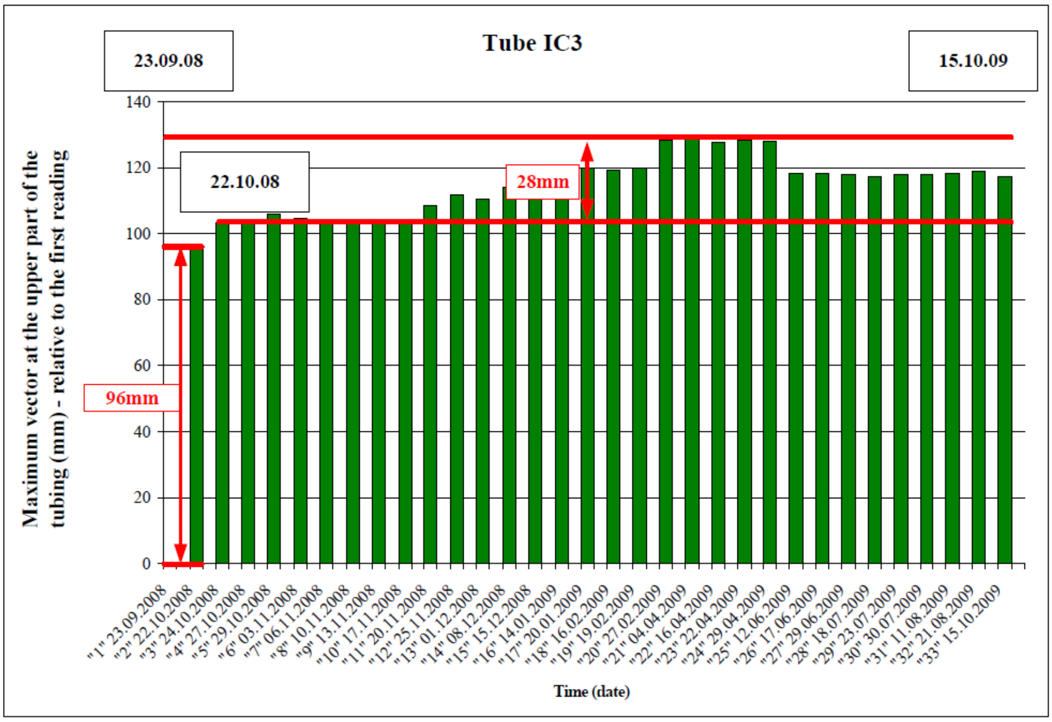


Figure 7. Inclinometer System IC3 details

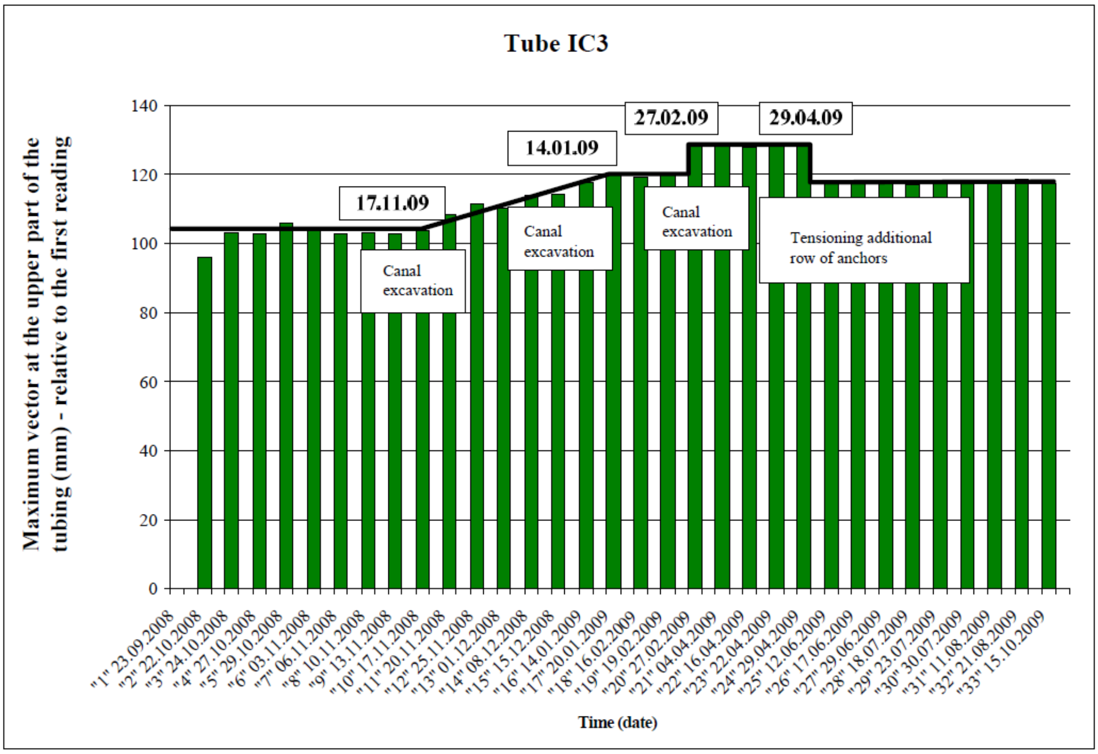


Figure 8. Inclinometer System IC3 details and interpretation

In Figure 8, for the IC3 system, the displacement evolution is correlated with site technological phases, their effect on the structure being highlighted by displacement increase, standby / relative stability, or decrease.

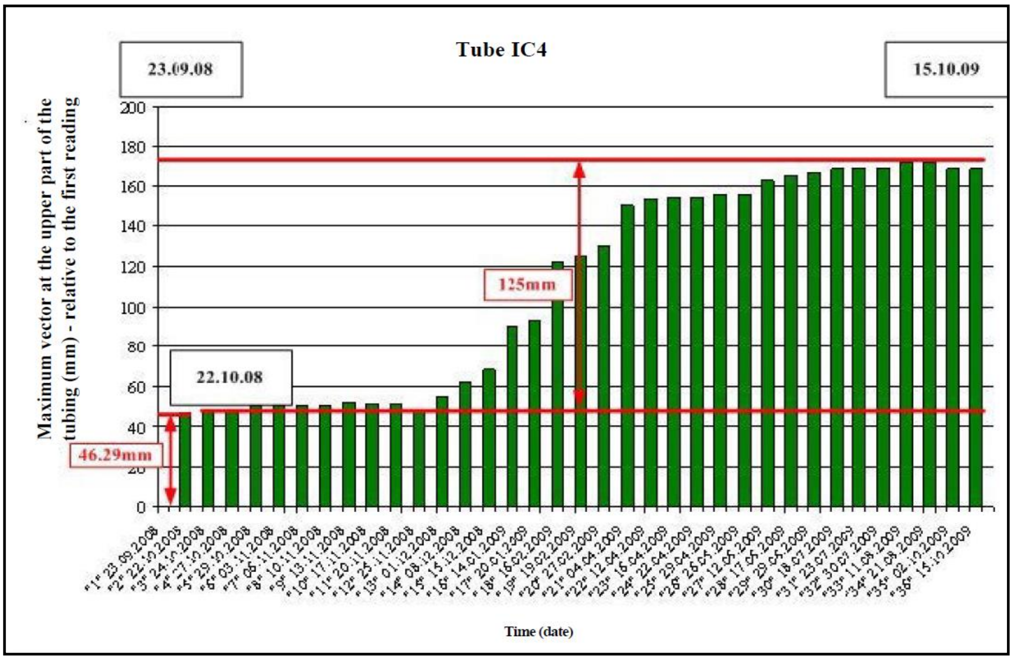


Figure 9. Inclinometer System IC4 details

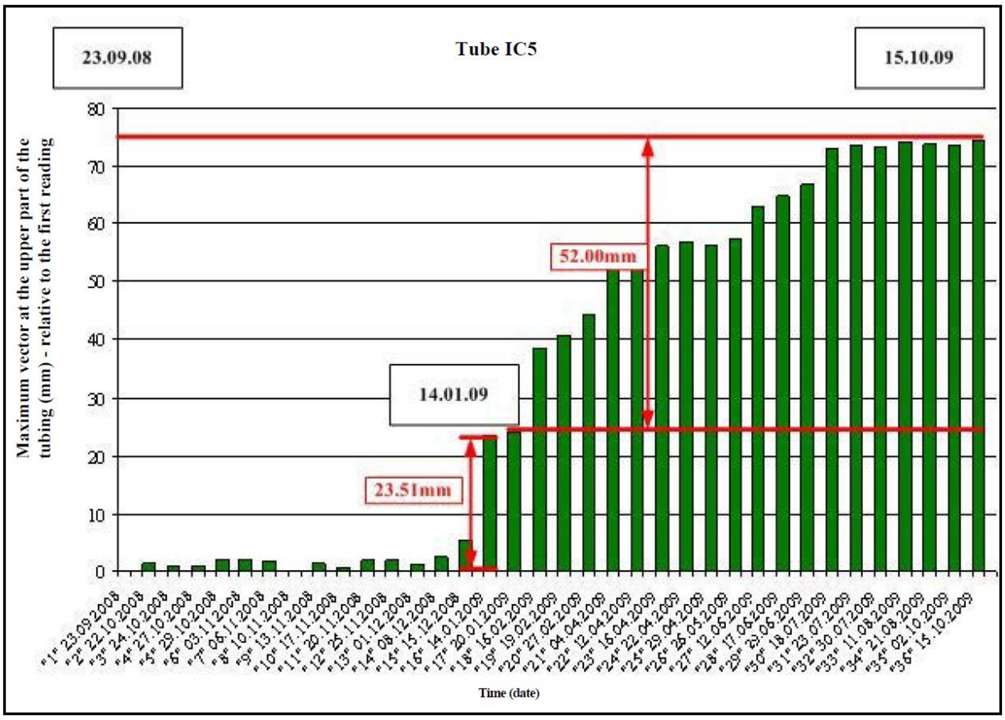


Figure 10. Inclinometer System IC5 details

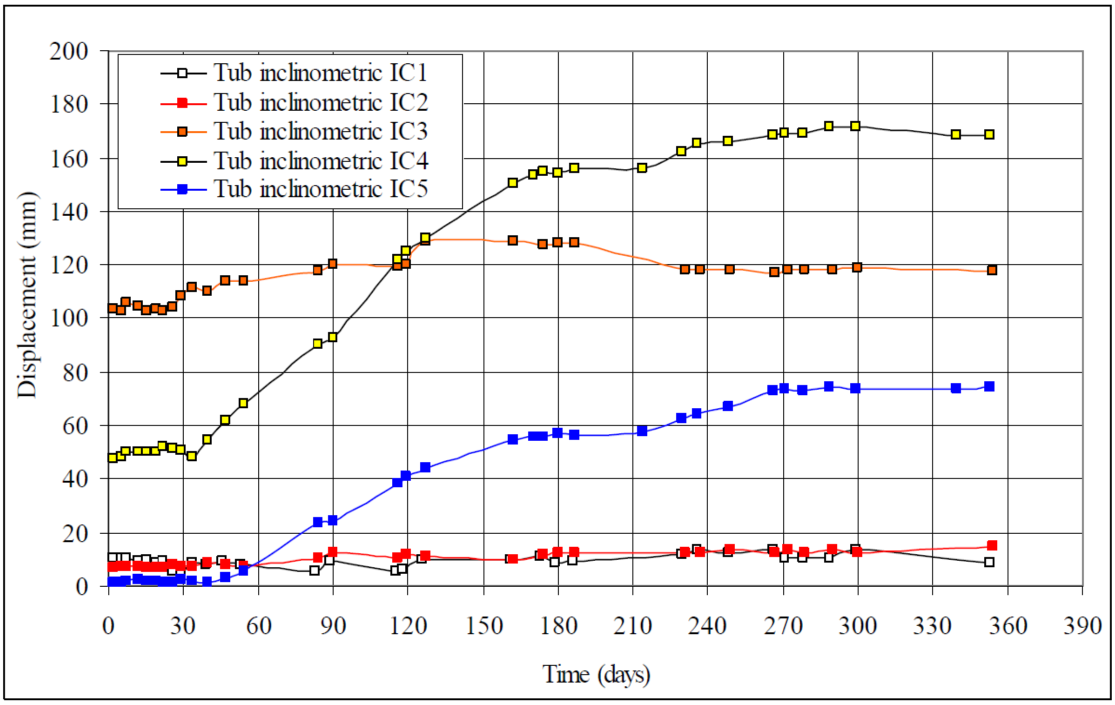


Figure 11. Displacement vector evolution graph recorded by inclinometers at the crown beam level

4. CONCLUSIONS

Geotechnical monitoring provides the necessary technical data to all project stakeholders. The Designer must compare the project's current state with design assumptions and their evolution correlated with on-site works and long term progression. The Beneficiary and Consultant must evaluate the investment's quality and safety level (quality control measure), and the Contractor must ensure the project parameters meet the design and whether corrective measures are needed.

Monitoring results demonstrates the impact of construction works on terrestrial infrastructure on the natural and anthropic environment. The major geotechnical risk of the site, correlated with the project's scale and the presence of communication pathways, required the monitoring action presented, with results reflected mainly in redesign and structural intervention actions. In such a case study, environmental impact occurs not only during the construction phase but also in the exploitation phase, situation that requires a long-term monitoring project. Hence, maintaining and operating monitoring systems is crucial, with details reflected Type of monitoring system and monitoring procedure [9], [10], [11], [12].

Main conclusions from the paper

- The need to develop monitoring projects/studies for large-scale projects that may significantly impact surroundings or whose execution or exploitation safety demands it,
- The monitoring action underpinned intervention measures, including additional tensioning of anchors in the initial project, introducing an additional row of anchors for a support structure zone, creating a temporary berm downstream of the support structure, reducing transit speed on the railway line upstream during construction, and increasing monitoring frequency during precipitation, particularly during Jiu River diversion and escape channel construction;
- The case study highlights the effect of natural and anthropic factors on the overall and local stability of the structure and slope, and the implications of geotechnical and structural monitoring in providing intervention solutions.

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