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Lasergrammetry: New Approach for Monitoring Structural Behavior of Vaults Dams

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***Abstract*— For safety control and economic improvement, the surveillance of the dams and their structural behavior requires observation and monitoring with high accuracy. As well, the stability of concrete vault dam depends on its overall geometry, and the analysis results strongly rely on the accuracy in which this geometry can be measured in practice. And, with the progress of modern technology using the Terrestrial Laser Scanners (TLS) in deformation measurement, the accuracy is much improved. Currently, this technology (TLS) is used in large and complex engineering structures such as dams to better understand their behavior due to its accuracy and speed in obtaining a cloud points 3D in different time intervals. In fact, for the first time in Morocco, the concrete vault dam named Asfalou, located in city of Taounate, is used for case study in order to verify the efficiency of the TLS results. This paper describes the main steps of this approach and the assessment of its effectiveness compared to the conventional method.**

Index Terms—**Vault dam, monitoring, TLS, point cloud 3D.**

I. INTRODUCTION

The dams lead to economic and social benefits such as irrigation, production of electrical energy, drinking water supply, the fight against flooding and navigation along the tank… They are also exceptional structures, not only in their size, but perhaps above all by their duration [1]. It results that the observation of dam behavior is a requirement to ensure their safety. If monitoring of civil engineering structures was first developed for the dams, it is because more than others, these structures present risks that it was imperative to control [2] and require appropriate measures in the early stages to increase their lifespan. Currently, damage and breakages of dams are in increasing quantities due to ageing, earthquakes and climate change. For these reasons, the dam safety has gained more importance than ever in terms of disaster management at the national. Considering the importance of these structures, the International Commission of Large Dams (ICOLD) has created in 1982 a technique for monitoring which includes several activities: the design of the monitoring plan, the installation of devices monitoring, the reading of these devices at pre-established frequency, the conversion of measures to significant engineering quantities, the interpretation of these quantities, the comparison with the models, the visual inspection of the dam and the delivery of a safety report. Monitoring activities are mainly related to security, but also to collecting valuable data to improve understanding of the behavior of these structures. During the last decades, remote sensing technique or lasergrammetry based on terrestrial laser scanner (TLS) has improved [3] and become a complementary technique to measure with high precision infrastructure displacements [4] and without physical contact with the object [5]. It should be noted that the operation of the high data redundancy provided by TLS tools is a key to getting good performance for measuring deformations [6]. This study, based on the 3D point cloud, focuses on vaults dams given the complexity and geometry of these structures. The paper describes the main steps of the procedure : the 3D survey by Leica C10 TLS, the point clouds registration, the 3D drawing of cracks affecting the downstream face of the vault, modeling and estimation of different deformations. It also outlines the main advantages of the proposed approach in comparison to the traditional means for measuring surface deformation of vaults dams, using as case Asfalou dam at the city of Taounate.

II. PROBLEMATIQUE

It should be remembered that: preventive maintenance improves the functioning of a dam, increases its lifespan and significantly reduces risks to populations at the downstream of the structure [7]; the stability of a masonry arch dependent on its overall geometry; and analysis results are highly dependent on the precision in which this geometry can be measured in practice [8]. Monitoring is carried by the operator of the dam. It takes two complementary forms: first, visual surveillance leading to regular inspection tours and the eye of an experienced technician can be considered as one of the best available sensors; secondly, auscultation of the dam with periodic surveys by using measuring instruments [9].

The significant parameters of dam behavior usually adopted are:

- Absolute or relative displacements
- Local deformations, possibly considered as constraints
- Pore pressure or under-pressure
- Flow of drainage or leakage.

Thereafter, the development of measuring instruments and operating and interpretation procedures results from the need to answer to the designers and constructors questions in order to understand the behavior of structures and ensure their safety at any time of their existence[10]. With regard to the visual inspection, it looks at the occurence of external pathologies that may affect the dam face such as seepage and cracks. A crack that appears in a gallery or in a place accessible to the dam team can be

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monitored by traditional means such as Vinchon system or fissurometers [11]. In 1922, an important program of instrumentation of arch dams was launched in the United States. It aimed at the understanding of the mechanical behavior of this type of dam in order to reduce costs and increase their security. As part of this initiative, fissurometers and inclinometers placed on the upstream and downstream of the structures were used. In addition, the internal deformations of concrete were measured by using instruments constituted of sensors with variation in resistance [12].

But for a large dam, detection of new cracks by visual inspection can degrade the factor of fidelity to reality as the agent identifies a number of cracks that might not match the existing. In addition, until now the representation of these cracks is done manually on a sketch.

For the geodesic auscultation, it looks at studying the movements of dams through conventional topographic instruments by measuring the absolute displacements in a surveillance network referenced to fixed points materialized by benchmarks outside the area of influence of dam.

In the last few years there has been an increasing interest in exploiting the Terrestrial Laser Scanning (TLS) data for deformation measurement and monitoring purposes [13] with exceptional resolution and accuracy [14]. The TLS became an instrument extensively used both in architecture [15], civil engineering, [16]-[17] archeology [18]-[19] and environmental studies [20]. It allows quick acquisition of dense and textured 3D point cloud with great precision and without direct contact with the structure [21] .The acquired point cloud is attached to the same reference coordinates system of the dam. Its combination with geo-referenced images leads to the creation of a real visualization model of the structure.

In the light of all these TLS features and in order to take advantage of its efficiency and efficacy, an experiment was carried out, the first in Morocco, on an vault dam named Asfalou regard on its geometry and its importance.

III. OBJECTIVES

The objectives of this study are:

- Selecting stations surveying and 3D acquisition of the downstream of the dam by TLS
- Assessment of the accuracy and efficiency of TLS performance for movement control and monitoring the structural behavior of a dam.
- Comparison between measurements and derived products by TLS and those provided by conventional means during the dam monitoring.
- Creating a 3D database of the dam that can be updated by the various surveys to ensure better management of the structure.
- Archiving the real time and real position witness, in videos generated by the True View Application, which can check the dam in case we doubt an external pathologies that may affect the dam.
- Standardization of a methodology for dam surveillance by TLS from planning to results presentation with maximum precision.
- The development of a prevention action plan according to the ageing evolution of the studied structure.

IV. EXPERIMENTATION

A. *DAM DESCRIPTION*

The chosen dam in this study is a vault dam named Asfalou built in 1996 on the Asfalou River, located 65 km from the city of Taounate Fig.1.

Fig 1 : ASFALOU dam, pecture taken from Hydraulic Developments Direction of Morocco

B. *SELECTION CRITERIA OF THE DAM*

The choice of this dam is based on:

- Size: Presence of high hydrostatic pressure on the upstream face of the dam given its important height, 112m.
- Design: thin vault dam
- The existence of a population downstream
- The flood control to enhance security at the dam ALWAHDA
- Attenuation of siltation risk of the dam ALWAHDA
- Energy production: 30 million Kwh
- Contribution to the development of irrigation in the basin Ouarga
- Adjustment of nearly 120Mm3 of water annually mainly for the benefit of small and medium hydraulic perimeters (PMH) located downstream.

In addition, some reasons related to the monitoring of dam behavior including the occurrence of micro cracks on the downstream face of the dam, whose appearance dates remain not well known. It is a question to make a 3D survey of the downstream face of the Asfalou dam for two thermally different periods: March and June 2012, to analyze the different apparent deformations or displacements and to compare with the results provided by the traditional means of auscultation.

IV. MATERIELS AND METHODS

USED MATERIELS

The inspection of a dam by TLS requires two phases:

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1. *Field phase*

Scanning the downstream face of the Asfalou dam was conducted by a laser scanner C10 with a resolution <1mm over a range of 300m to which is integrated a camera of very high definition and large focal length Table1. The field survey required 6 hours for the survey of the dam downstream side without any contact by creating a topographic polygonal attached to the system of the dam Fig. 2.

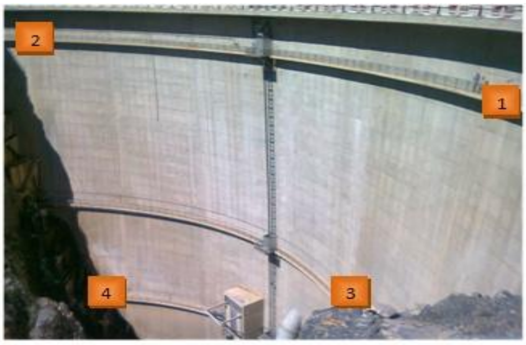


Fig 2: Image obtained from 3D point cloud

2. *Office Phase*

To process the 3D point cloud, several software are combined such as Cyclone, Cloud works, Cyclone topo2 and 3DRechaper. They are used for restitution and mapping of different cracks and pathologies affecting the downstream face of the dam during different times of the survey in the same coordinates system of the dam Fig.3.

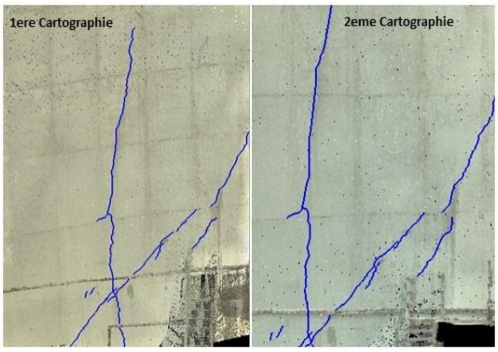
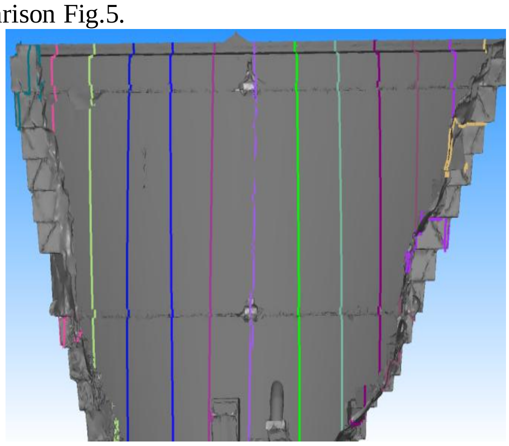


Fig. 3: Real mapping of cracks

They also allow 3D modeling and inspection of dam deformation Fig.4 with the possibility to export files to CAD software such as AutoCAD for overlay and comparison Fig.5.



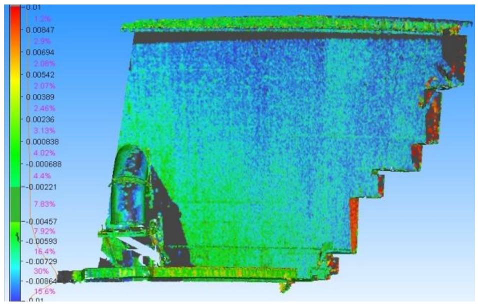


Fig 4: from top to bottom : Modeling and inspection of deformations

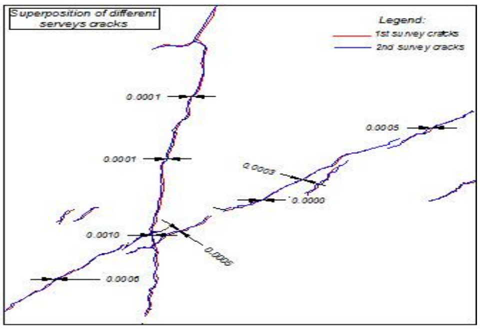


Fig 5: Mapping cracks and their overlay on Autocad

V. RESULTS AND ANALYSIS

A. *RESULTS PROVIDED BY TRADITIONAL AUSCULTATION MEANS*

Currently, the monitoring of Asfalou dam behavior is achieved by a number of conventional instruments such as: direct Pendulum, inverted pendulum, extensometer, Vinchon, glass lamp on the cracks and scale staff gauge for measuring the level in the reservoir.

To monitor the development of cracks, glass witnesses or paint Fig.6 are used to identify them. They are numbered in a sketch Fig.8. This method is effective for the quick detection of any development because the glass witnesses breaks at the opening of the crack, provided that it is well stuck because if not the crack can develop without being detected. Whereas for monitoring of the behavior of the joints between the sections of the face of the dam, a Vinchon system is installed on each joint, and measures are regularly taken by the dam agents Fig.7.

Fig 6: from left to right: glass witnesses or paint

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Fig 7: Vinchon on joint

The results of all these methods are shown in manual sketches which unfortunately remain a schematic representation of cracks Fig.8, of seeps localization Fig.9 and do not cover the entire surface of the downstream face of the dam because there are cracks inaccessible given the height of the dam.

In addition, the measures provided by direct and inverted pendulums to get the direction of the dam displacement and the temperature probe in the same dates of the TLS survey (March-June 2012) are summarized in the table 2.

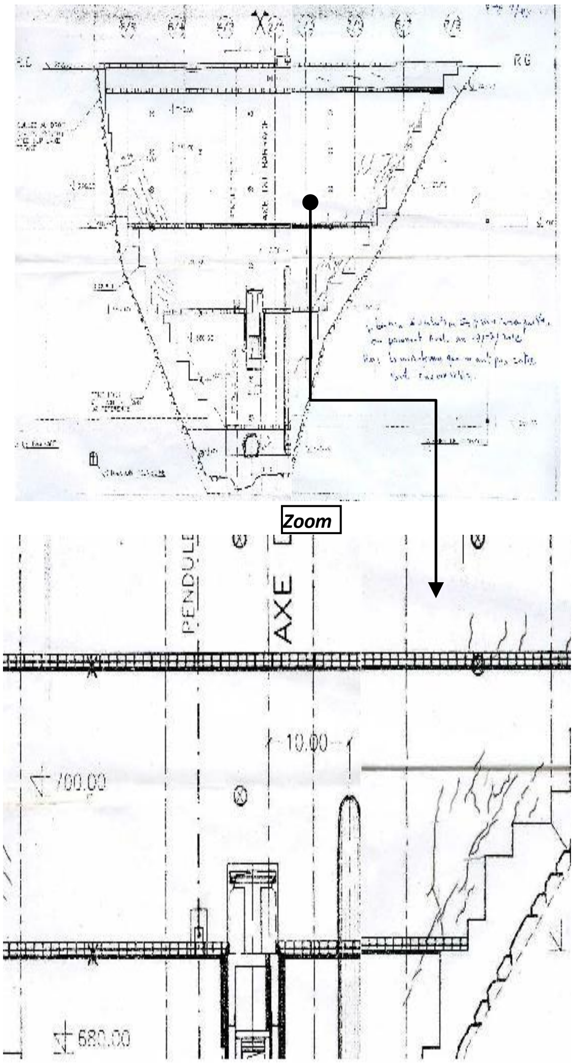

Fig 8: Sketches of cracks, from Hydraulic Developments Direction of Morocco

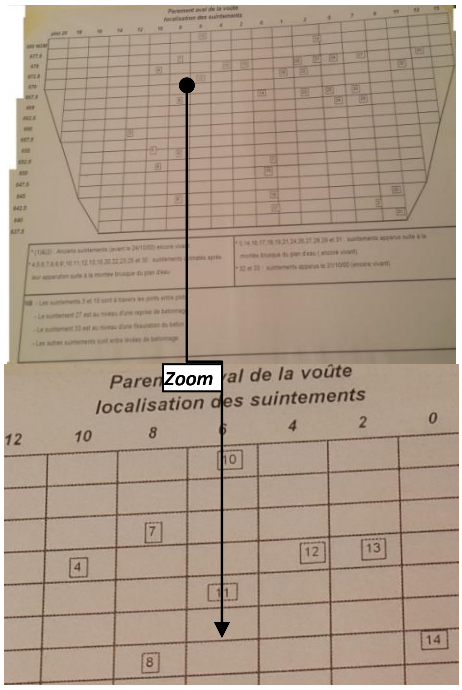

Fig 9: Sketches of seeps, from Hydraulic Developments Direction of Morocco

B. ANALYSIS OF RESULTS PROVIDED BY AUSCULTATION TRADITIONAL MEANS

From table 2, it can be noticed that the measures taken by the direct pendulum showed variation of 2.97mm from downstream to upstream and of 0.29mm bank-bank. This implies that the high point of the direct pendulum has shifted to upstream from the low point of 2.97mm. The same to the inverted pendulum, the measures showed a displacement of 0.42mm, which shows that the vault has moved 0.42mm from downstream to upstream. Therefore, the downstream face of the dam has tends to expand more than the upstream face and the vault will lean upstream. This can be also confirmed by the thermal effect which has increased from March to June.

C. RESULTS PROVIDED BY TLS

In addition to the mapping and 3D localization in the dam coordinates system of all cracks and seeps present on the downstream face Fig.10, the point cloud provided by the C10 laser scanner allows modeling and inspection of the different deformations along the face and offers a real photographic coverage and a rich archive of 3D real videos of all that is visible in the field of view of the TLS.

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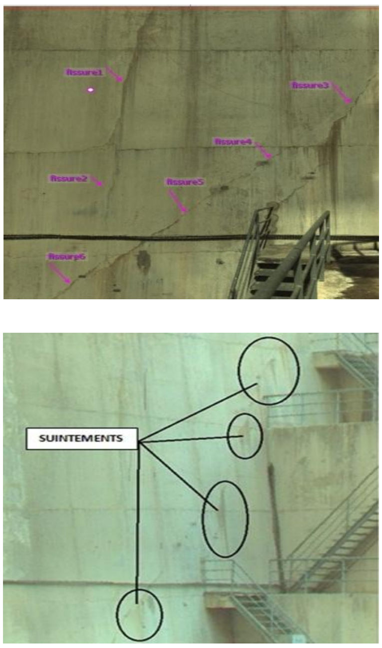

Fig 10: from top to bottom : defects of drains, seeps and images of cracks.

D. ANALYSIS OF RESULTS PROVIDED BY TLS

The analysis of the results provided by TLS shows that cracks have undergone extensions during the period from March to June table 3. This explains that the downstream face of the dam has expanded more than the upstream face between the two survey periods. Also, the inspection of deformations provided by 3DReshaper Fig. 4 and the overlay of mapped cracks in both periods Fig. 5 show that the dam has moved a few millimeters in the directions upstream-downstream and bank-bank. This joined the same interpretation of Table 1 and clearly confirms the results obtained by conventional means.

VI. CONCLUSION

The rapid acquisition of 3D information with very high density is among the strengths of the Lasergammetry in monitoring dams. Scanning by TLS is the most appropriate way to acquire various pathologies affecting a dam in a record time. It offers a dense 3D point cloud, can scan dangerous and inaccessible parts whose distance from the face of the dam can reach tens or even hundreds of meters. Results representation is also considered among the benefits of this technology in the inspection of cracks and deformations: compared to a manual sketch, DXF or DWG plan of cracks is more advantageous that the control and monitoring of the cracks evolution is automated and more accurate. Also, the combined use of laser scanning and digital imaging allows the generation of textured model of the scanned part of the dam. The fusion of these two data types is a valuable advantage for semantic interpretation of several significant phenomena for dam safety: it enhances the visual inspection by giving clearer information on pathologies including their precise location. Likewise, a 3D video, accurate in time and position, allows performing measurements and adding comments. With this type of model, the production of new documents for the visual inspection of the dam will improve the ability to assess in less time and more precisely the history or the status of a dam. Thus, we recommend benefiting of the advantages of TLS and of Geographic Information Systems (GIS) to develop a GIS application for automating the dam inspection.

Table 1: Technical characteristics of the TLS C10, www.leica-geosystems.com/hds

Laser Scanning System	
Type	Pulsed; proprietary microchip
Color	Green, wavelength = 532 nm visible
Laser Class	3R (IEC 60825-1)
Range	300 m @ 90%; 134 m @ 18% albedo (minimum range 0.1 m)
Scan rate	Up to 50,000 points/sec, maximum instantaneous rate
Scan resolution	
Spot size	From 0 – 50 m: 4.5 mm (FWHH-based); 7 mm (Gaussian-based)
Point spacing	Fully selectable horizontal and vertical; <1 mm minimum spacing, through full range; single point dwell capacity
Field-of-View	
Horizontal	360° (maximum)
Vertical	270° (maximum)
Aiming/Sighting	Parallax-free, integrated zoom video
Scanning Optics	Vertically rotating mirror on horizontally rotating base; Smart X-Mirror™ automatically spins or oscillates for minimum scan time
System Performance	
Accuracy of single measurement	
Position*	6 mm
Distance*	4 mm
Angle (horizontal/vertical)	60 µrad / 60 µrad (12" / 12")
Modeled surface precision**/noise	2 mm
Target acquisition***	2 mm std. deviation
Dual-axis compensator	Selectable on/off, resolution 1", dynamic range +/- 5', accuracy 1.5"

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Table2: Measured parameters of the dam Asfalou taken from Hydraulic Developments Direction of Morocco

Date of mesure in 2012	Direct pendulum **(mm)**		Inverted pendulum **(mm)**		Temperature probe **(°)** **(TS)**					
	AA	RR	AA	RR	TS1	TS2	TS3	TS4	TS5	TS6
March	9.26	2.26	-2.47	-0.13	14.30	14.39	13.92	12.62	15.67	12.55
Iune	12.23	2.55	-2.05	-0.18	13.57	14.24	16.11	12.66	16.63	15.49

Legend:

- AA: Displacement measure by pendulum from upstream to downstream
- RR: bank-bank displacement measure by pendulum

Table 3: Cracks evolution

Crack number	Length in March (m)	Length in June (m)	Difference (mm)
Crack 1	7,3157	7,3169	**1,2**
Crack 2	3,1378	3,1383	**0,5**
Crack 3	3,0498	3,0498	**0,0**
Crack 4	1,0032	1,0085	**5,3**
Crack 5	1,8270	1,8333	**6,3**
Crack 6	0,5980	0,6006	**2,6**

REFERENCES

[1] Jean-Louis Bordes, "DAMS AND LARGE SCALE EXPERIMENTS: MONITORING AND CONTROL," pp. 97-106.

[2] Jean-Pierre Chabal, Jean-Louis Bordes "PUENTES, 1802, LA RUPTURE DU PLUS GRAND BARRAGE DU MONDE, OU LE DOUBLE ECHEC D'ANTONIO DE ROBLES," le rapport Betancourt, Quaderns d'Historia de l'Enginyria, Barcelone, Escola technica superior d'Enginyria industrial de Barcelona, pp. 151-167, 2009.

[3] K. Gumus, H. Erkaya and M. Soycan, "INVESTIGATION OF REPEATABILITY OF DIGITAL SURFACE MODEL OBTAINED FROM POINT CLOUDS IN A CONCRETE ARCH DAM FOR MONITORING OF DEFORMATIONS," APR-JUN 2013.

[4] R. Tomás, M. Cano, J. García-Barba, F. Vicente, G. Herrera, J.M. Lopez-Sanchez and J.J. Mallorquí, "MONITORING AN EARTHFILL DAM USING DIFFERENTIAL SAR INTERFEROMETRY: LA PEDRERA DAM, ALICANTE, SPAIN," (Engineering Geology) vol. 157, pp. 21–32, 2013.

[5] Deodato Tapete, Nicola Casagli, Guido Luzi, Riccardo Fanti, Giovanni Gigli and Davide Leva, "INTEGRATING RADAR AND LASER-BASED REMOTE SENSING TECHNIQUES FOR MONITORING STRUCTURAL DEFORMATION OF ARCHAEOLOGICAL MONUMENTS," Journal of Archaeological Science 40, pp. 176-189, 2013.

[6] O. Monserrat, M. Crosetto, "DEFORMATION MEASUREMENT USING TERRESTRIAL LASER SCANNING DATA AND LEAST SQUARES 3D SURFACE MATCHING," (ISPRS Journal of Photogrammetry & Remote Sensing 63,pp. 142–154, 2008.

[7] El Mehdi BENZEKRI, ingénieur en chef des Ponts et chaussées, président du Conseil général de l'Equipement, "GESTION DE L'EAU, DEFIS DU XXIEME SIECLE TROISIEME PARTIE: LE MAROC EST EN PANNE DEVANT CE QUI EST LE PLUS FACILE," Edition N° 901 du 23/11/2000 Sur le site http://www.leconomiste.com.

[8] Luc Schueremans, Bjorn Van Genechten, "THE USE OF 3D-LASER SCANNING IN ASSESSING THE SAFETY OF MASONRY VAULTS—A CASE STUDY ON THE CHURCH OF SAINT-JACOBS," pp. 1.

[9] Patrick Le Delliou, "LES BARRAGES, CONCEPTION ET MAINTENANCE," Lyon, ENTP, chapitre13: AUSCULTATION, 2007.

[10] Jean-LouisBordes, "LES BARRAGES RESERVOIRS EN FRANCE, DU MILIEU DU XVIIIE AU DEBUT DU XXE SIECLE," Paris, Presses des ponts et chaussées, forme et conception des barrages, pp. 287-323, 2005.

[11] Jean-Marc Tacnet et Didier Richard, "DE LA CONCEPTION A LA SURETE DES BARRAGES DE CORRECTION TORRENTIELLE," sur le site: set-revue.fr

[12] Paul Caufourier, "BARRAGE D'ESSAI DE STEVENSON CREEK," Le Génie civil, pp. 9-11, 2 janvier 1926, pp. 382-386, 15 octobre 1927.

[13] O. Monserrat, M. Crosetto, "DEFORMATION MEASUREMENT USING TERRESTRIAL LASER SCANNING DATA AND LEAST SQUARES 3D SURFACE MATCHING," (ISPRS Journal of Photogrammetry & Remote Sensing, vol. 63, pp. 142, 2008.

[14] Dimitri Lague, Nicolas Brodu, Jérôme Leroux, "ACCURATE 3D COMPARISON OF COMPLEX TOPOGRAPHY WITH TERRESTRIAL LASER SCANNER: AP-

PLICATION TO THE RANGITIKEI CANYON (N-Z)," ISPRS Journal of Photogrammetry and Remote Sensing, vol. 82, 10–26, 2013.

[15] Barrile V, Meduri G, Bilotta G. , " LASER SCANNING SURVEYING TECHNIQUES AIMING TO THE STUDY AND THE SPREADING OF RECENT ARCHITECTURAL STRUCTURES," In: Proceed- ings of the 2nd WSEAS International Conference on Engineering Mechanics, Structures and Engineering Geology, pp. 25–8, 2009.

[16] D. González-Aguilera, J.Gómez-Lahoz, J. Sánchez, "A NEW APPROACH FOR STRUCTURAL MONITORING OF LARGE DAMS WITH A THREE-DIMENSIONAL LASER SCANNER," Sensors 8, pp. 5866-5883, 2008.

[17] A. Berenya, T. Lovas, A. Barsi and L.Dunai, "POTENTIAL OF TERRESTRIAL LASER SCANNING INLOAD TEST MEASUREMENTS OF BRIDGES," Civil Engineering, pp. 53:25–33, 2009.

[18] K.Lamberts, H.Eisenbeiss, M.Sauerbier, T.Gaisecker, D.Kupferschmidt, S.Sotoodeh, T.Hanusch, "COMBINING PHOTOGRAMMETRY AND LASER SCANNING FOR THE RECORDING AND MODELLING OF THE LATE INTERMEDIATE PERIOD SITE OF PIN- CHANGO ALTO, PAPA, PERU," Journal of Archaeological Science, vol.34, pp. 1702-1712, 2007.

[19] G. Gigli, F. Mugnai, L. Leoni, N. Casagli, "ANALYSIS OF DEFORMATIONS IN HISTORIC URBAN AREAS USING TERRESTRIAL LASER SCANNING," Nat. Hazards Earth Sys. Vol.9, pp. 1759-1761, 2009.

[20] H.Gonza´ lez-Jorge n, B. Riveiro, J. Armesto, P. Arias, "STANDARD ARTIFACT FOR THE GEOMETRIC VERIFICATION OF TERRESTRIAL LASER SCANNING SYSTEMS," Optics & Laser Technology, vol.43, pp. 1249-1256, 2011.

[21] Julia Armesto-González, Belén Riveiro-Rodríguez, Diego González-Aguilera, M Teresa Rivas-Brea, "TERRESTRIAL LASER SCANNING INTENSITY DATA APPLIED TO DAMAGE DETECTION FOR HISTORICAL BUILDINGS," Journal of Archeology Science, vol. 37, pp.3037-3047, 2010.

AUTHOR'S PROFILE

MOMAYIZ Kaltoum, presently she is a PhD Student and directress of the company Globétudes of topography studies and engineering.

Education

- 1996: the State Engineer degree in topography at the Agro nomic and Veterinary Institute HASSAN 2 (IAV HASSAN2), Rabat, Morocco;
- 2012: Obtaining the Master in Civil Engineering at Faculty of Science and Techniques, Hassan 1st University, Settat, Morocco;
- 2012-2015: PhD Student.

Academic guidance and teaching

- 2006-2008: Supervision of engineers in machinery at IAV hassan2;
- 2008-2015: Referee and examiner several theses at IAV hassan2;
- 2012-2015: Supervision of Masters in Civil Engineering, agricultural engineering and management and quality to the FST SETTAT.

SOUNNY SLITINE Hafid, Engineer dams in the Hydraulic Developments Direction, graduated from the Mohammedia School of Engineering in 1995.

Education

- 1995: State Engineer in Civil Engineering, Option Buildings, Roads and Bridges at Mohammedia School of Engineering, Rabat,Morocco;
- 2003-2004: Masters in Télélédétection and Geographic Information Systems – CRASTE.

Professional Experience and Academic guidance

- Responsible for auscultation of 12 major dams at Hydraulic Developments Direction, Morocco;
- Establishment of auscultation projects of dams and monitoring their implementation (Choosing the auscultation device and establishment of site plans);
- Realization of a study of siltation project Taifine basin by resources of GIS and Remote Sensing;
- Realization of an application of auscultation report management;
- Contribution to feedback between dams in operation and execution dams;

Supervision of studies ends of project engineering students.

ANOUAR Abdellah, the head of the chemistry department of Applied and Environmental also Professor of Higher Education in the Faculty of Science and Techniques Settat, Hassan 1st University, Morocco.

Education

- 1989: Degree in Chemistry;
- 1992: Ph.D in France;
- 2001: Ph.D in Morocco.

Publication

He published 8 researches in 2014 primarily in Water Treatment, below some of his publications:

- Belbahloul Mounir, Anouar Abdellah and Zouhri Abdeljalil. Low Technology Water Treatment: Investigation of the Performance of Cactus Extracts as a Natural Flocculant for Flocculation of Local Clay Suspensions. International Journal of Engineering Research & Technology. Vol. 3 Issue 3, March – 2014;
- Asmaa Karboubi, Abdeljalil Zouhri, Abdellah Anouar² Characterization of Domestic Waste water and Performance Indicators of the Waste water Treatment Plant of the City of Settat.International Journal of Engineering Research & Technology, Vol. 3 - Issue 2 , February – 2014;
- Aziz Akhiate, Al alami Semma, Abdelah Anouar, « Austenitic grain size quantification of martensitic low carbon stainless steel», IOSR Journal of Mechanical and Civil Engineering

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