# THE ANALYSIS OF DYNAMICAL CHANGES OF BEHAVIOR OF ENGURI ARCH DAM

***,**Sborshchikovi A., *Mepharidze E., *Chelidze T., *Matcharashvili T., *Zhukova N., *Tepnadze D., *Laliashvili L.**

** Mikheil Nodia Institute of Geophysics of Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia*
*** Business and Technology University, Tbilisi, Georgia*
a.sborshchikov@gmail.com

***Abstract.*** *The main goal of this research was the analysis of dynamic changes in dam foundation displacement according to the periodic variation in water level in the lake around the Enguri Arch Dam. We used a database, for the information collected from 1974 to 2021. In this work, we have tested and analyzed the dynamical changes by modern several nonlinear methods. We choose one of the most effective methods Multifractal Detrended Fluctuation Analysis (MF-DFA). From the results of our research, we can see that dynamic changes in dam foundation displacement are connected with the process of dam behavior. One of the main facts is that water level change in the reservoir behind the Enguri high dam also affects this process.*
***Key words:*** *Dynamical changes, nonlinear analyses, datasets.*

## Introduction

The first step of our research was studying the literature close to our task. During this process, we have found a lot of mentioned facts that the construction and functioning of large water reservoirs have a strong influence on the environment. Here, we can list some of them: influence on the local seismic activity, changes in local weather, initiation of landslides, etc. As we conclude the attention to this fact is great, so, naturally, the question must be studied deeper and paid attention to multidisciplinary. We have used this location of the Enguri Dam area because it is one of the highest dams in the world. The high of our dam located in West Georgia is 271 meters. Nowadays, the Enguri arch dam is part of the Enguri Hydro Power Plant (HPP) located in the river Enguri Gorge, Georgia. Since the start of construction, contemporary, to that time, multi-disciplinary geodynamical–geophysical monitoring was organized in the dam area [1-3].

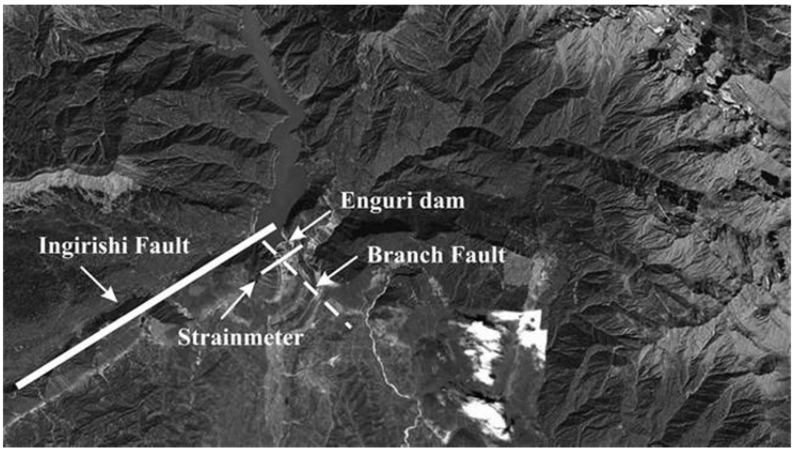



Fig. 1. Enguri dam and reservoir area with locations of the main Ingirishi fault and the branch fault.

The geological survey documented that the branch fault of the large active beneath the Enguri dam, the Ingirishi fault crosses the right wing of the dam foundation. At the same time, it is known that the presence of the active (or potentially active) fault in the large dam foundation is a serious threat to dam safety [1,4,5]. It was quite logical that the monitoring of the fault zone started well before the beginning of dam construction and reservoir filling. The branch fault of the main Ingirishi fault (Fig.1) crosses the foundation of the Enguri dam and, thus, poses a significant hazard to the dam.

Actually, the studying area is a natural large-scale laboratory for the investigation of tectonic, man-made, and environmental impacts on the fault zone deformation pattern. Two main facts influenced the fault. The first (tectonic strain) leads to piecewise linear displacement, which we define as a trend component, and the second to quasiperiodic oscillations, decorating the main trend.

The information from the dam is recorded for the period from 1974 to 2021. This database is unique because it contains such important characteristics, such as high weir foundation and weir body tilts, deformation of foundation, weir body temperature, water level variation in the reservoir, etc. Some of the results from datasets we have already published in scientific periodicals [2-6]. In this work, we aimed to be focussed on dam foundation displacement datasets of Enguri arch dam during the period from 1974 to 2021 (Fig. 2).

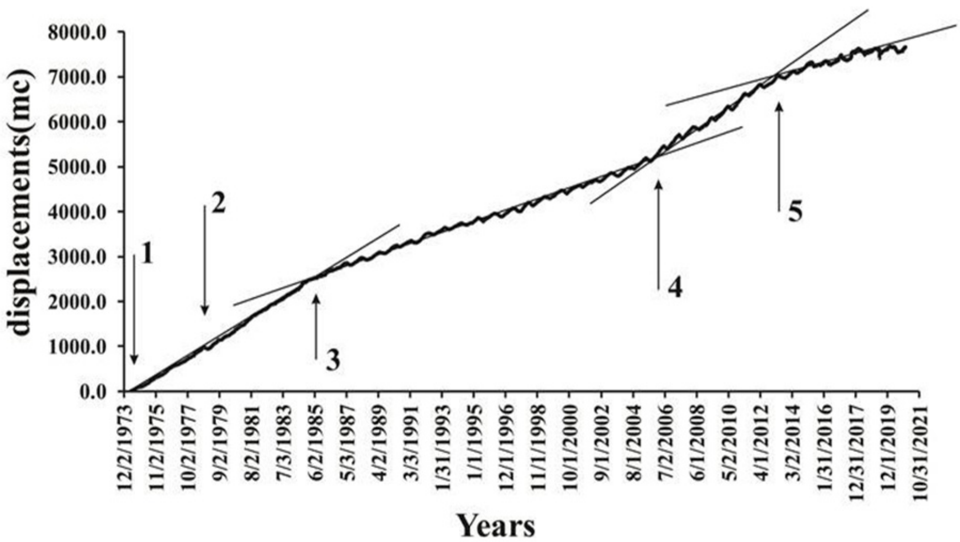



Fig. 2. Dam foundation displacement data sets around Enguri in period from 1974 to 2021. Arrows 1, 2, 3, 4, 5 correspond to the start of 5 periods of fault zone extension.

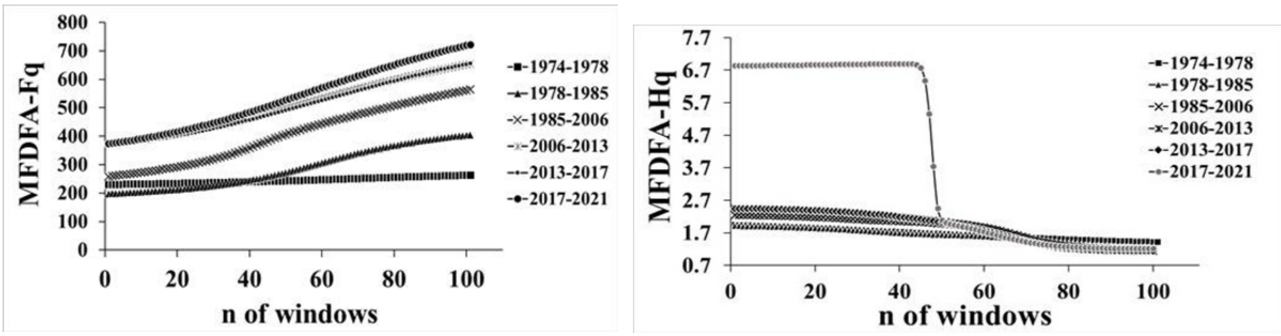
To control the fault behavior permanently, 4 years before the first filling of the reservoir, in 1974, the quartz strainmeter, crossing the fault zone was installed. The strainmeter recorded the displacement of the blocks, divided by the fault zone (the thickness of the zone is around 10 m) in the normal to the fault plane direction, so it shows fault zone extension/contraction. The length of the quartz tube is 22.5 m and the free end of the tube is equipped with a photo-optical recording system (now in parallel with a laser system). The tube was placed so that both fixed and free ends are on the opposite sides of the fault zone, separated from it by several meters. The readouts from the photo recording were made once per day at the same time. The displacements sensitivity of the system was of the order of 0.18 m/mm.

Since 15 April 1978, the reservoir was filled step by step. Since 1987, the water level in the reservoir has been changing seasonally, almost periodically. Seismic datasets were obtained from monitoring systems created around the Enguri area. The representative threshold for the local earthquake catalog from 1974 to 2021 was M2.2.

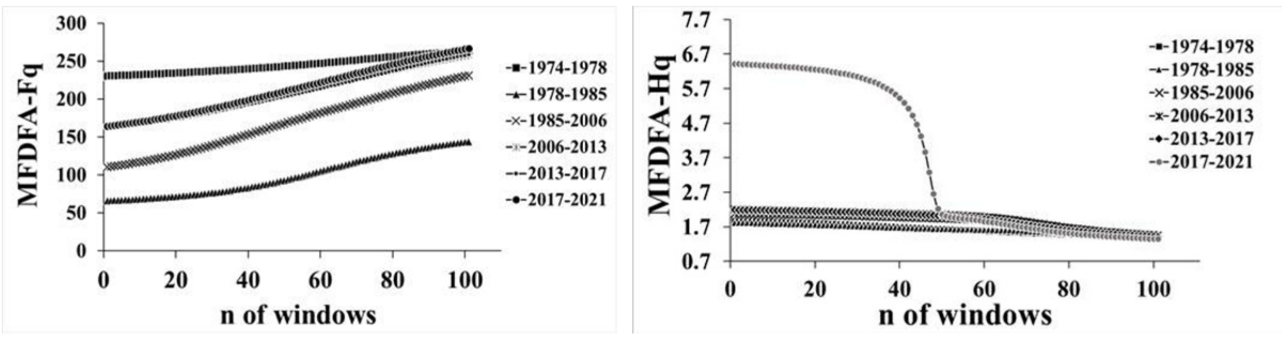
During our research, we take datasets from a strainmeter, which fixed measures of displacements of high dam foundation. As we have noted above, filling the Enguri reservoir influences the seismic activity around the dam. For investigating the dynamical changes of the dam foundation displacements behavior, we have taken multifractal detrended fluctuation analysis (MF-DFA). Based on Ivane Javakhishvili Tbilisi State University, M. Nodia Institute of Geophysics the software for calculating MF-DFA was created.

The first method of our analysis is multifractal detrended fluctuation analysis. MF-DFA method founds higher-dimensional fractal and multifractal characteristics hidden in time series. The MF-DFA was proposed by [7] and is based on DFA (detrended fluctuation analysis). This method is considered to be an effective tool for measuring whether multifractal characteristics exist in displacement time series [7,8]. Our research group has done this analysis for a different fluctuation degree q. According to the results, we can study the multifractal scaling behavior of time series. In this work we have used three main characteristics: Hurst exponent (H(q)), Multifractal Dimensions (D(q)), and Fluctuation functions (F(q)). The slope H depends on the fluctuation degree of it is the regression line, called the Hurst exponent (Hurst, 1951). The MF-DFA method determines positive generalized Hurst exponents h(q), and it becomes inaccurate for strongly anti-correlated signals – where h(q) is close to zero.

The Hurst exponent will be in the interval between 0 and 1 for noise-like time series, whereas above 1 for a random walk-like time series. So, we have a long-range correlated structure – the Hurst exponent is in the interval 0.5–1, an anti-correlated structure – the Hurst exponent is in the interval 0–0.5 and uncorrelated Hurst exponent H = 0.5. One more situation is when we have H = 0.5, in this case, we can say that we have a short-range dependent structure [9,10]. The MF-DFA method represents the best method for carrying out multifractal nonstationary time series. The datasets for the period 1974–2021 were fixed for different external influences: filling the reservoir, weather conditions, and seismic activity. Before starting our analysis, we have detrended the displacement datasets. We divided the study period into several periods (1974-1978, 1978-1985, 1985-2006, 2006-2013, 2013-2017, 2017-2021) where changes in movement are actively noticeable. For Example, the analysis was done for the polynomial degree p2, p5. (Fig. 3(a,b)).




a.




b.

Fig. 3. MF-DFA (Fq, Hq) analysis of displacements of Enguri Arc Dam foundation (a. polynomial degree =p2; b. polynomial degree =p5).

From the results of the MF-DFA analysis, we can see how the three main characteristics, H(q) and F(q) are changed (so active changes in period 2017-2021). We can conclude from the results that increasing the polynomial degree leads to a decrease in the value of F(q). The H(q) is in the numerical range 0.5–1 and above, which indicates that we have a long-range dependent (i.e. correlated) structure of time series. According to our studies, we can conclude that increasing the degree of polynomial makes changes in the dynamical structure of the system and decreases the fluctuation.

## Conclusion

From the task of our analysis, we have investigated the dynamical characteristics of Enguri high weir foundation displacements dynamical changes. All databases of dam foundation displacements datasets were collected in the period started from 1974 to 2021. In our analysis, we used the MF-DFA modern method of data analysis. With our research, we conclude that the dynamics of dam foundation displacement are strongly influenced by the process of Arc Dam construction and especially by water level change in artificial helps us savor behind Enguri high dam. From MF-DFA analysis, we got clear results, which helps us to define the degree of dynamic changes and behavior of our system.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