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ACOUSTIC EMISSION MONITORING OF THE FOUNDATION ON SOFT SATURATED SOIL

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Abstract

Large scale long time experiment is carried out in situ on foundations of hydro power station located on soft soil. Cracked concrete and soft soils are realy nonlinear Loading assessment and analyses of recorded response are developed. It varied from quasi static to strong motion regimes. Acoustic emission (AE) spectra configuration, amplitudes, energy in different frequency ranges in 23 measurement point (MP) in 3D were investigated. AE spectra are high sensitive to static and dynamic load changes. Real concrete massifs are characterised by structural alterations, opening of fractures and their closure under load, i.e. transitional processes. They are reflected in the spectra of emitted acoustic signals, in the Q-factor of response, in surface wave velocity. To places with low velosity of surface wave corresponde low values of Q.

Choose of saving regimes of exploitation from response analyze is the primary tasks of monitoring. Eestimations of remain changes in the foundation after boosting regimes of exploitation are the second tasks of this investigation. Role of underlying soft soil emission in response forming is discussed. All measurements are carried out during usual work of hydroelectric power station.

INTRODUCTION

The nonlinear methods of investigating the earth's crust rapidly were developed in the recent decades, soft soil, rocks; concrete cracked and fractured massifs were under research. The nonlinear methods of the analysis of response require medium with the clearly expressed nonlinearity. Requirement of the practice of forecast and analysis of the response of cracked media to dynamic loading- this is the main stimulus of concentration of attention to intensive studies of nonlinear processes in these media.

Information about the nonlinear phenomena in geophysics was accumulated from the last quarter of past century [1,4,5] during the study of the propagation of waves in the earth's crust, in the grainy media, with the vibration action to the earth's crust and with studies of the strong earthquake. To the class of nonlinear materials, relates concrete [4]. Nonlinear wave methods for examination of damage in materials are the new frontier of acoustical nonlinear non-destructive testing [4]. Nonlinear attenuation, harmonic generation, resonant frequency shift, frequency modulation interaction and slow dynamics are interrelated. Nonlinear behavior is observed early on in a degradation process, long before linear parameters start to show damage dependent effects. Any increase in the values of nonlinear parameters is related to an increase in micro-structural features in the material considered. Laboratory experiments on thin, cylindrical rod of Berea sandstone shown attenuation1/Q dependence of the strain [3]. The study of spatial and temporal variation in1/Qc-attenuation coda waves - may bee promising for understanding the loading process that leads to earthquake [1]. As practice shows, in the process of operation concrete is cracked and it becomes ever more nonlinear material. The goal of this research is develop analyze, made in [6, 7] and assess Q factor informatively in time and in space along the foundation.

MEASUREMENTS

Measurement location

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The work was carried out in, investigating foundation concrete structures of an operational hydroelectric power station. The length of the concrete structure is 200 m, height – 56 m, width in the flow direction comprises 60 m. Fig. 1 shows a cross section dam along the axis of a hydraulic turbine generator in the flow direction. The station has 10 such generators, situated approximately 20 m from one another. There is a measurement gallery along the whole length of structure (200 m) that is vertically the lowest accessible site for measurements. There are 23 MPs (measurement points) in the gallery; their locations and configuration are shown in Fig. 2.

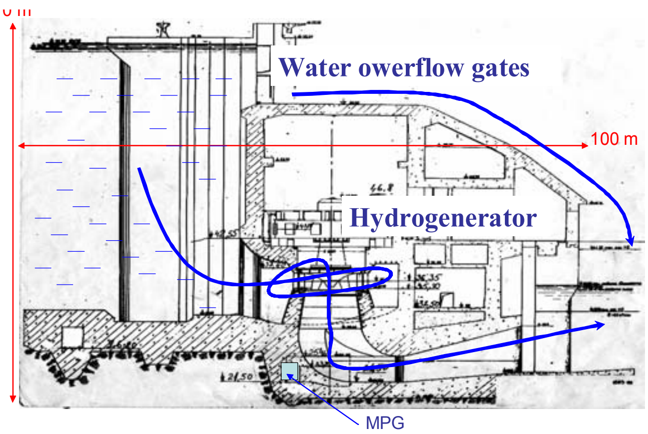

Figure 1. Cross section of the dam (schematic)

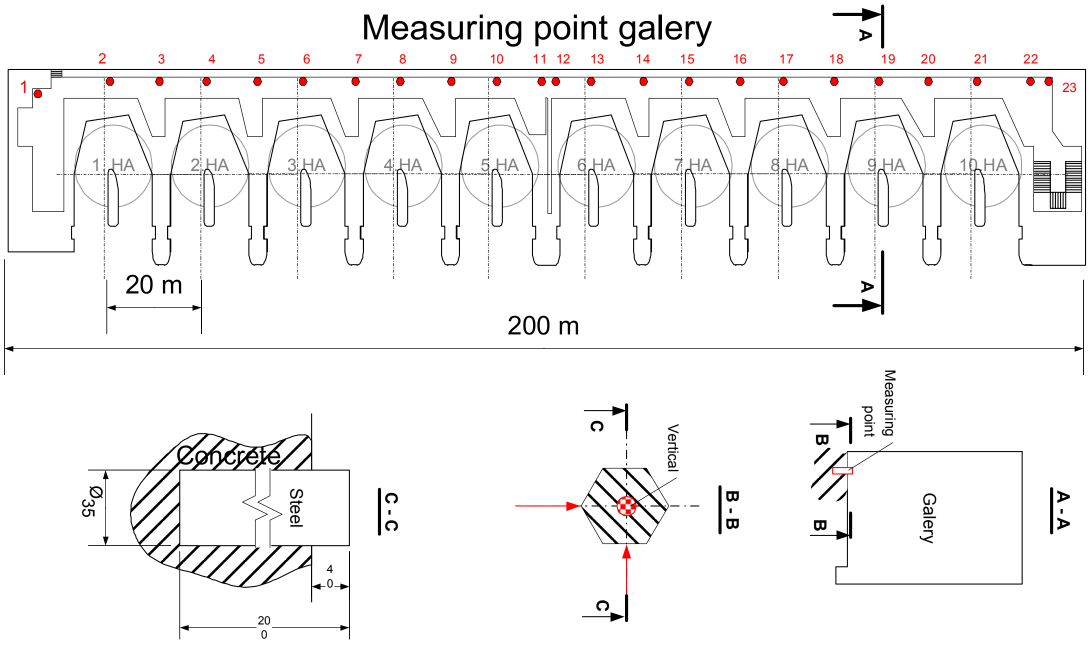

Figure 2. Measurement points location and its configuration in MPG.

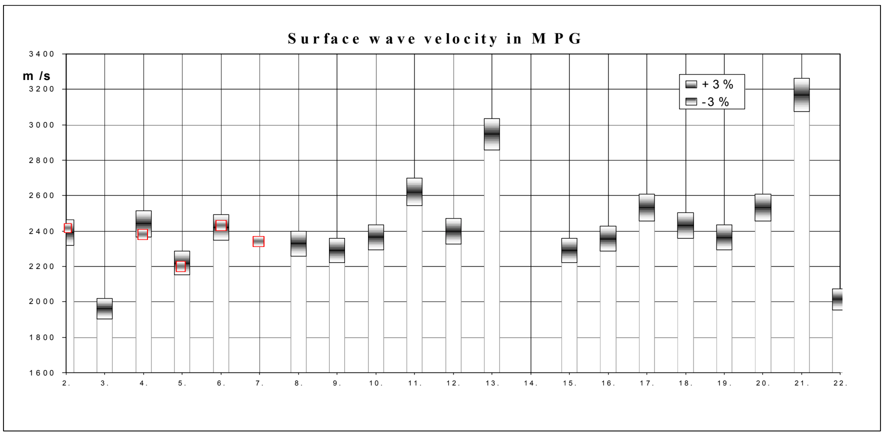

Figure 3. Surface wave propagation velocity along the measurement point gallery

Load analyze

Both dynamic and static forces load the concrete structure foundation. The static ones come from the water column on the reservoir side – 42 m ± 2m. Downward dynamic loads are caused by working machines, mostly, hydraulic forces. Changes in the dynamic loads occur, when different hydro generators are used in different regimes – starting with the regime when not a single hydro generator is operational and ending with the regime when all of them are operational. Maximum dynamic loads occur when all the units are operational and overflow floodgates are open. Such loads occur once per some year. The response of the basement to loads is recorded at each measurement point for further analyses. Records are sieved for possibility to repeat any analyses.

Load assessment

Dynamic load assessment is made for future analyze of response spectra in frames of nonlinear elasticity [4].

Quasi-static realization: Power station foundation 200 m. long based on soft soils and preloaded with total vertical stress approx. 350 kPa. Basement of foundation is soft soils (siltly-clay and clayey-silt) with non-uniform settlement and non-uniform relaxation time. All hydro generators are idle. Static stressed state of the foundation changes with the change of previous history of grouping of working hydroelectric units and duration of their work. The possible explanation for that phenomenon: the impact of vibrations of the working hydroelectric unit on the bearing capacity of weak soil directly under the unit, as well as the difference in consolidation time for clayey sand and sandy clay. That means that the relaxation processes take place in a different way, and the process of consolidation of weak soils is at a different stage under each unit, causing slow and weakly changing stress in the body of the foundation. Thus, in the “silent” regime, the conditions of “quasi-static” loading of the dam foundation due to relaxation processes are complied with, and response spectrum in the “silent” regime contains all the resonant frequencies under the dynamic loading regime.
Slow dynamic realization: Working some hydro generators.
Strong motion realization: Working 10 hydro generators + overflow

Assessment of the dam as the source of a seismic event during the spring flooding based on the:vibration accelerations RMS of the response in MP = 0.02 – 0.08 g assessment of the emitted and dissipated energy: 25-73 MJ

The bulk of the energy was emitted in the high frequency range – (1- 4) kHz, thus ensuring that the event is local. There still remained a possibility of the excitation of the medium by high-frequency energy, which later is emitted in the low-frequency range.

MEASUREMENT RESULTS AND ANALYZE

1 *The surface wave* propagation velocity along the gallery is distributed as given in Figure 3. The latter reflects the fractures inside the concrete body (the lass wave velocity, the higher is crack concentration). Measurements are made in silence – that mean quasi-static loading regime.

2 Response RMS in MPs and response spectra are given as results of response records analyze (Figure 4, 5)

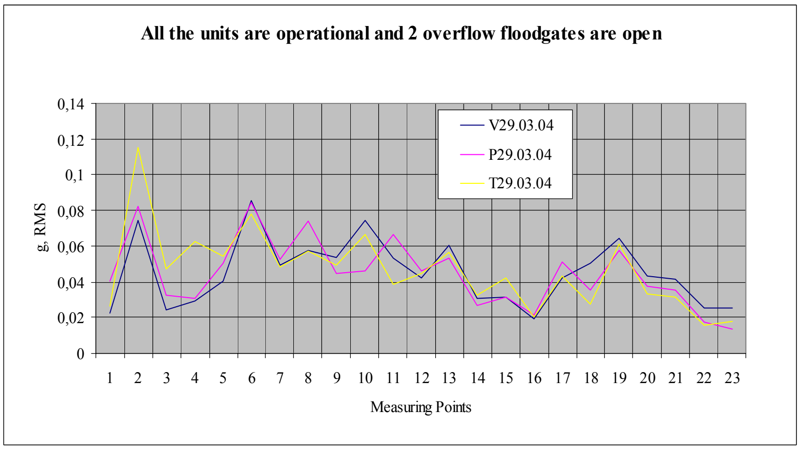

Figure 4. RMS in MPs 29.03.04 - strong motion regime.

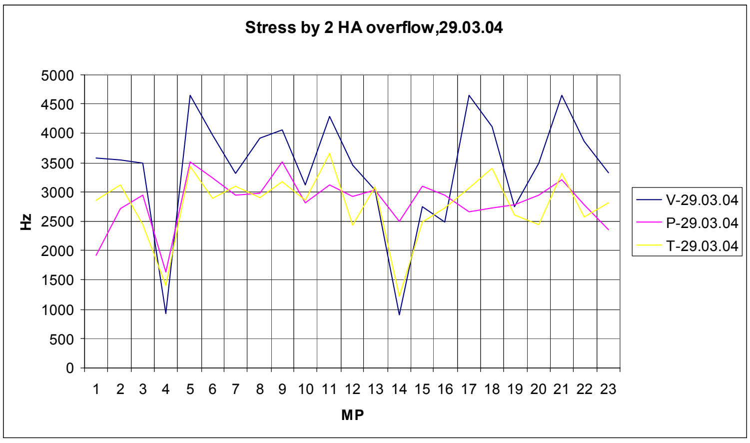

Figure5 V-direction stresses in foundation, according emitted energy carried frequencies in MPs29.03.04. Limit pressure in concrete of the investigated base emitted signals of AE on frequencies up to 4000 Hz. If AE occurs on higher frequencies stress fault by means of a crack order slide will follow.

3 Q-factor in MPs, correspond response maximum stresses in MPs. V-direction, (Figure 6).

4 Q-factor in 23 MPs V-direction, from 29.03.04 till 22.03.06 Figure 7

5 V direction MP 5 Q changes in time,(Figure 8)

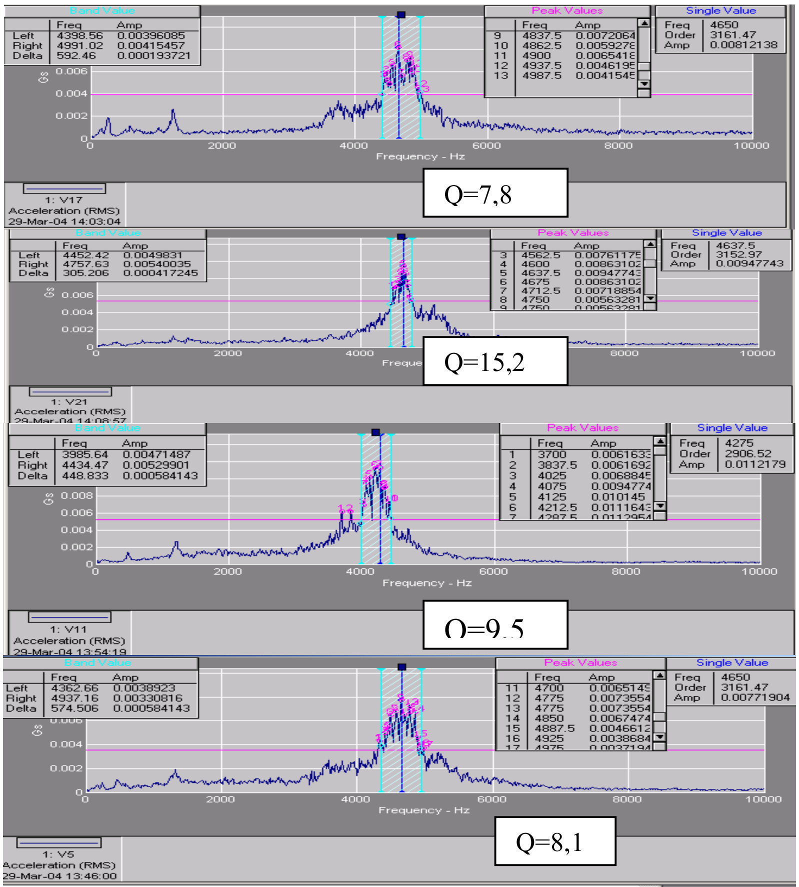

Figure6. Q factor in MPs (response max. stress points) 29.03.04: all HA +2 overflow

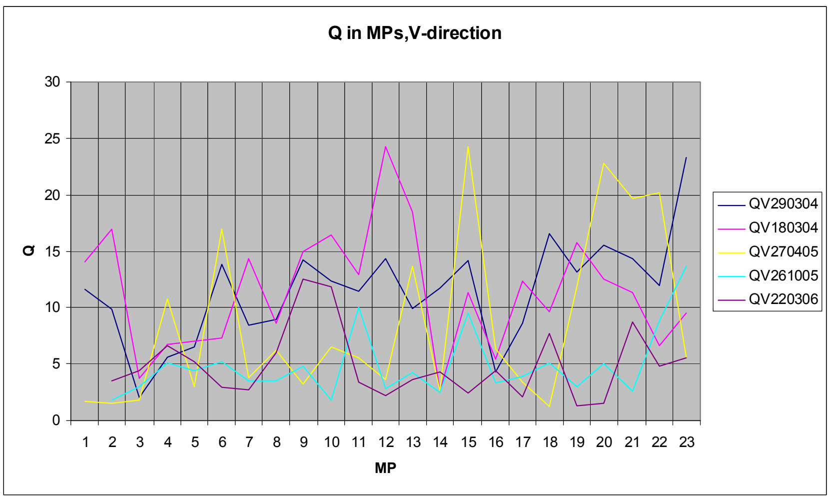

Figure 7.Q-faktor in 23 MPs V-direction, from 29.03.04 till22.03.06

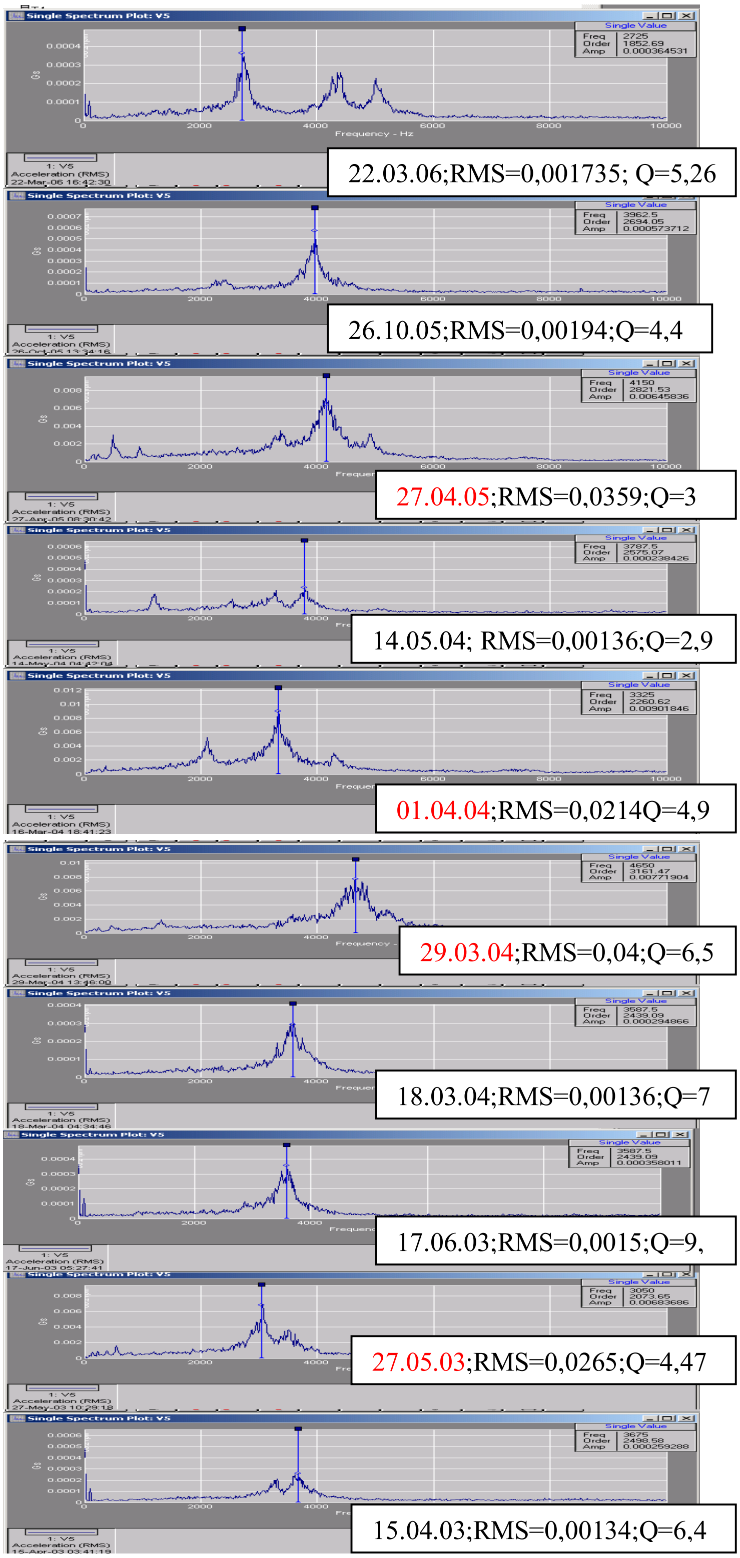
22.03.06;RMS=0,001735; Q=5,26
26.10.05;RMS=0,00194;Q=4,4
27.04.05;RMS=0,0359;Q=3
14.05.04; RMS=0,00136;Q=2,9
01.04.04;RMS=0,0214Q=4,9
29.03.04;RMS=0,04;Q=6,5
18.03.04;RMS=0,00136;Q=7
17.06.03;RMS=0,0015;Q=9,
27.05.03;RMS=0,0265;Q=4,47
15.04.03;RMS=0,00134;Q=6,4

Figure8. Response spectraV5 development from15.04.03 till 22.03.0615.04.03-silence; 27.05.03-HA 2, 3, 6, 7, 8, 9 worked; 17.06.03-silence; 18.03.04-silence (night); 29.03.04-worked all HA + two HA overflow; 16.03.04-realy measurements were made in 01.04.04 worked all HA+ three HA overflow; 14.05.04-silence (night); 27.04.05-worked all HA; 26.10.05-silence (daytime); 22.03.06-silence

EQUIPMENT.

The following equipment was used during the work: 8 accelerometers manufactured by Wilcoxon Research, a SONY 8-channel digital data recorder, type PC208A, an 8-channel data analysis software PCscan MKII and a specialised 8-channel spectrum analysis programme. In some cases, a one-channel data collector-analyser CMVA55 and vibration sensor by SKF Condition Monitoring were used, allowing carrying out the signal analyses in situ.

SUMMARY

Real concrete massifs are characterized by structural alterations, opening of fractures and their closure under load, i.e. transitional processes. They are reflected in the spectra of emitted acoustic signals (Fig.6,7), in the Q-factor of response (Fig. 8), in surface wave velocity (fig. 3). To places with low velocity of surface wave corresponded low values of Q. Low-velocity, low-Q zone estimated as fault zone with shear velocity of 2,0-2,2 km/s and Q~=50zone in an earth's crust describes Aкі [1].

For object under research Q value changes from 1, 2- 12, 59 (last measurement) and surface wave velocity Vs=1900-3100 m/s.

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