

Microseismic Assessment of Deformation-Related Elastic Parameters in Structurally Different Dam Types: Evidence From Rockfill and Reinforced-Concrete Dams in Uzbekistan

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MICROSEISMIC ASSESSMENT OF DEFORMATION-RELATED ELASTIC PARAMETERS IN STRUCTURALLY DIFFERENT DAM TYPES: EVIDENCE FROM ROCKFILL AND REINFORCED-CONCRETE DAMS IN UZBEKISTAN

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Abstract. This paper presents a microseismic-based assessment of deformation-related elastic parameters in two structurally different hydraulic facilities: the rockfill dam of the Ohangaron

Reservoir and the reinforced-concrete dam of the Andijan Reservoir. The central concept of the study is that the natural vibration characteristics of a dam body, the H/V spectral ratio, compressional and shear wave velocities, and density-derived elastic moduli can be used as non-invasive diagnostic indicators for identifying zones potentially susceptible to deformation under hydrostatic pressure. Ambient microseismic records obtained from field measurements were processed using the H/V spectral ratio technique. For each measurement point, frequency-amplitude relationships, V_P and V_S velocities, density, velocity ratio, shear modulus, Lamé parameter, Poisson's ratio and Young's modulus were calculated. The results show that the spatial distribution of elastic parameters varies significantly depending on the structural type of the dam. In the rockfill dam, variations in deformation-related parameters are mainly controlled by hydrostatic loading, material density, and the geometrical and lithological heterogeneity of the dam body. In contrast, in the reinforced-concrete dam, these variations are associated with concrete density, acoustic stiffness, and localized stress concentration zones near water-release structures. The findings demonstrate that microseismic methods can be effectively used for evaluating the technical condition of dams, identifying stress-deformation zones caused by hydrostatic pressure, and improving monitoring approaches for hydraulic structures located in seismically active regions.

Keywords: microseismic methods, H/V spectral ratio, dam, hydrostatic pressure, deformation parameters, Young's modulus, shear modulus, seismic wave velocity, rockfill dam, reinforced-concrete dam.

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Introduction. Dams are among the most critical hydraulic engineering structures because their long-term stability depends not only on their design parameters, but also on the continuous interaction between the dam body, foundation, reservoir water level, hydrostatic pressure, material heterogeneity, and seismic loading (Darbre et al., 2000; Chopra, 2012). In seismically active regions, this interaction becomes especially important, since even small variations in the dynamic properties of a dam may reflect changes in stiffness, density, internal stress redistribution, or deformation-prone zones (Aki and Richards, 2002; Sheriff and Geldart, 1995; Mavko et al., 2009; Foti et al., 2014). Therefore, the assessment of deformation-related parameters in dam bodies is a key task for structural health monitoring and seismic safety evaluation (Daniell and Taylor, 1999; Darbre and Proulx, 2002).

Traditional approaches to dam condition assessment are usually based on geodetic observations, visual inspection, engineering-geological investigations, piezometric monitoring, and numerical modelling. These methods are important, but they may be limited in detecting spatial variations of dynamic stiffness within the dam body, especially when deformation processes are still at an early or hidden stage (Sevieri and De Falco, 2020; Cheng et al., 2015). In this context, microseismic methods provide a useful non-invasive tool for evaluating the dynamic response of hydraulic structures. Ambient vibration records make it possible to identify natural vibration characteristics, frequency-amplitude relationships, and spectral anomalies that may be associated with changes in the physical-mechanical condition of dam materials (Brincker et al., 2001; Calcina et al., 2014; İlgaç et al., 2025).

One of the widely used approaches in microseismic analysis is the horizontal-to-vertical spectral ratio method. The H/V technique allows the dominant frequency and amplitude characteristics of a site or structure to be estimated from ambient vibration records (Nakamura, 1989; SESAME, 2004; Ismailov et al., 2025; Bard, 1999). When applied to dams, this method can help reveal variations in the dynamic behaviour of different parts of the dam body. In combination with interpreted compressional and shear wave velocities, as well as density values, H/V-based analysis

can be extended to the calculation of deformation-related elastic parameters, including the velocity ratio, shear modulus, Lamé parameter, Poisson's ratio, and Young's modulus (Ismailov et al., 2025; Bonnefoy-Claudet et al., 2006).

The scientific problem addressed in this study is that deformation assessment in dams is often considered separately for each structural type, while comparative analysis between different dam constructions remains insufficient. Rockfill and reinforced-concrete dams differ significantly in material composition, internal structure, stiffness, permeability, and response to hydrostatic loading. However, both types are affected by reservoir water pressure and may develop zones of stress concentration or reduced stiffness. This creates a methodological question: can microseismic parameters be used as a common diagnostic basis for identifying deformation-related elastic behaviour in structurally different dam types?

To address this question, the present study compares two hydraulic structures in eastern Uzbekistan: the Ohangaron Reservoir dam, representing a rockfill dam, and the Andijan Reservoir dam, representing a reinforced-concrete dam. The Ohangaron Reservoir dam is characterized by significant influence of hydrostatic pressure, variable relief conditions beneath the reservoir, and spatially uneven dynamic response along the dam body. The existing data indicate that microseismic measurements were carried out at different parts of the dam, and H/V amplitude-frequency curves were used to interpret the natural vibration behaviour of the structure.

The Andijan Reservoir dam, in contrast, represents a reinforced-concrete structure, where deformation-related behaviour is expected to be controlled by concrete density, acoustic stiffness, and local stress redistribution near hydraulic elements. In the available field data, measurements were conducted on the rigid concrete part of the dam using a Guralp-6TDE seismometric instrument, with recording durations of approximately 20-30 minutes at each measurement point. The H/V method was then applied to obtain frequency-amplitude relationships and to estimate V_P , V_S , density, and elastic parameters.

The novelty of this study lies in the comparative use of microseismic-derived elastic parameters for two structurally different dam types under the same conceptual framework. Instead of treating the Ohangaron and Andijan dams as two independent case studies, this paper considers them as contrasting structural models for testing whether microseismic diagnostics can identify hydrostatic-pressure-related deformation patterns in both rockfill and reinforced-concrete dam bodies. This approach makes it possible to evaluate not only individual dam behaviour, but also the applicability of a unified microseismic methodology for hydraulic structures with different material properties.

The main objective of this paper is to assess deformation-related elastic parameters of rockfill and reinforced-concrete dams using microseismic methods and to compare how hydrostatic pressure and structural type influence the spatial distribution of these parameters. The specific objectives are:

1. to analyse H/V spectral characteristics obtained from microseismic measurements at the Ohangaron and Andijan dams;
2. to estimate V_P , V_S , density and derived elastic parameters for different measurement points;
3. to compare the distribution of Young's modulus and related deformation indicators within rockfill and reinforced-concrete dam bodies;
4. to identify zones where elastic parameter anomalies may indicate increased sensitivity to hydrostatic loading or potential deformation concentration.

The results of this study are expected to contribute to the development of non-invasive diagnostic approaches for dam safety monitoring. The proposed methodology may be useful for preliminary assessment of deformation-prone zones, planning detailed engineering investigations, and improving seismic monitoring strategies for hydraulic structures located in regions of elevated seismic hazard.

Materials and Methods. This study applies a comparative microseismic approach to evaluate deformation-related elastic parameters in two structurally different dam types: the rockfill

153 dam of the Ohangaron Reservoir and the reinforced-concrete dam of the Andijan Reservoir. The
154 methodological concept is based on the assumption that ambient vibration characteristics, H/V
155 spectral ratios, seismic wave velocities, and density-derived elastic parameters can be used as
156 diagnostic indicators of the internal deformation state of dam bodies under hydrostatic loading.

157 The research methodology consists of four main stages:

- 158 1. field microseismic measurements on different parts of the dam bodies;
- 159 2. processing of ambient vibration records using the H/V spectral ratio method;
- 160 3. estimation of compressional wave velocity, shear wave velocity, density, and elastic
161 parameters;
- 162 4. comparative interpretation of deformation-related indicators for rockfill and reinforced-
163 concrete dam structures.

164 Figure 1 shows the location of the investigated dams in Uzbekistan and presents representative
165 views of the Andijan and Ohangaron reservoir dams. The measurement layout along the Ohangaron
166 dam body is shown in Figure 2, while the field measurement points at the Andijan Reservoir dam are
167 presented in Figure 6. The original data indicate that microseismic measurements were carried out at
168 different points of the dam bodies in order to obtain frequency-amplitude characteristics and to
169 evaluate the spatial variability of dynamic parameters.

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Figure 1. Location map of the Ohangaron Reservoir



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Figure 2. Microseismic measurement points along the Ohangaron Reservoir dam



Figure 3. Microseismic measurement points at the Andijan Reservoir dam

Field microseismic measurements. Field measurements were performed using passive microseismic observations. The main purpose of these measurements was to record ambient vibrations of the dam bodies and to identify their dominant frequency response. In the Ohangaron dam, measurements were conducted at several points along the dam body, including the main dam section and a reference point located approximately 1 km away from the dam. This made it possible to compare the dynamic response of the dam body with the surrounding geological environment.

In the Andijan dam, measurements were carried out on the rigid reinforced-concrete part of the dam. According to the initial field description, a Guralp-6TDE seismometric instrument was used, and the recording duration at each point was approximately 20-30 minutes. These records were used to obtain the natural vibration characteristics of the dam and to calculate the deformation-related parameters of the reinforced-concrete body.

The measurement scheme was designed to cover zones where hydrostatic pressure, structural heterogeneity, and local stress redistribution may influence the dynamic response of the dam body. This is especially important because the Ohangaron dam represents a rockfill structure, while the Andijan dam represents a reinforced-concrete structure. Therefore, the same microseismic methodology was applied to two different structural systems in order to compare their deformation-related elastic behaviour.

H/V spectral ratio analysis. The recorded microseismic data were processed using the horizontal-to-vertical spectral ratio method. The H/V method was used to determine the relationship between vibration frequency and amplitude ratio for each measurement point. In this study, H/V curves were not interpreted only as site-response indicators, but also as diagnostic signals reflecting the natural vibration behaviour of the dam bodies.

For the Ohangaron dam, the H/V amplitude ratio versus frequency curves obtained from nine measurement points are presented in Figure 4. These curves were used to identify the natural vibration characteristics of the dam body after separating the useful vibration signal from different types of seismic noise.

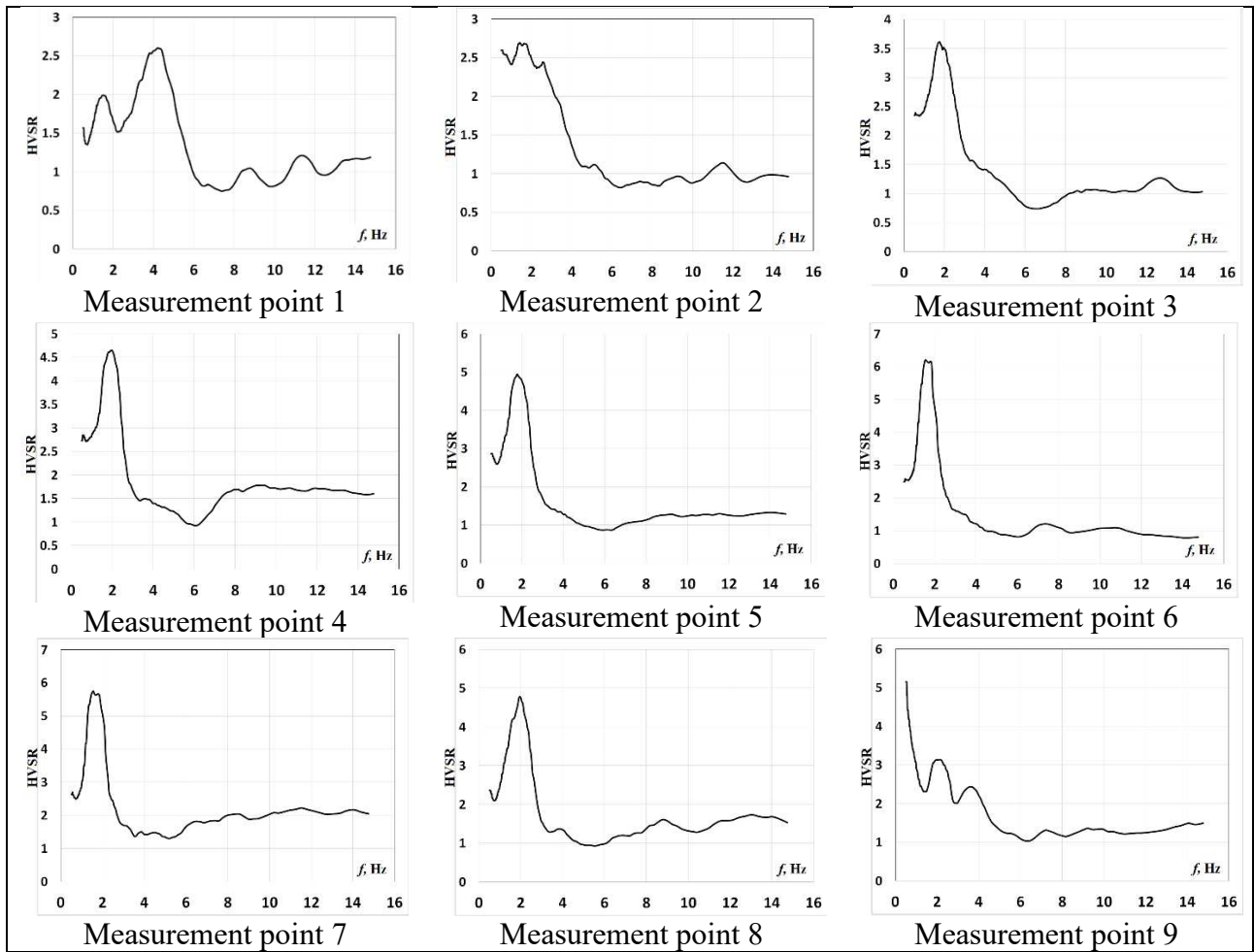
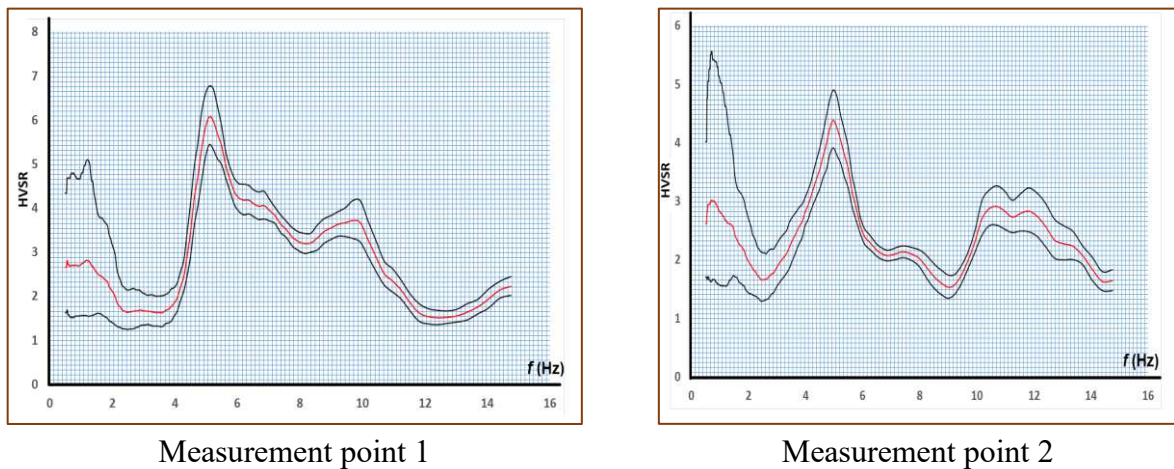
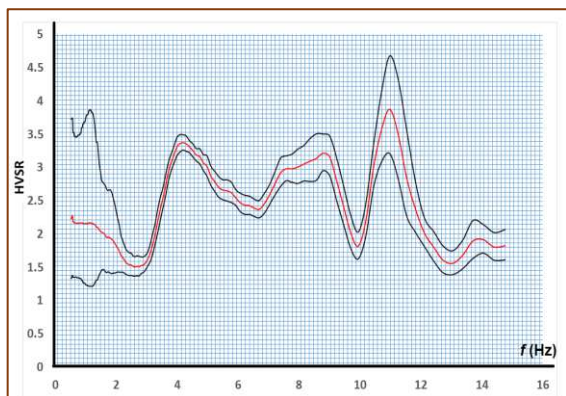


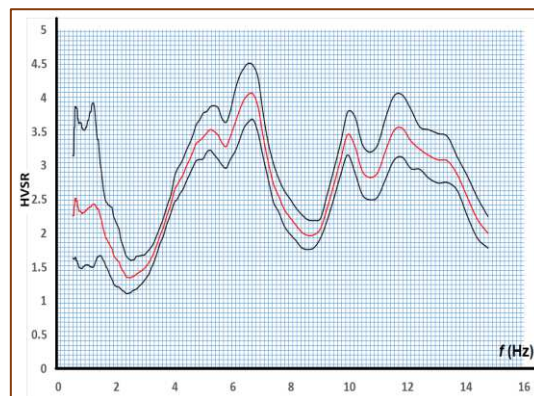
Figure 4. *H/V amplitude ratio versus vibration frequency curves obtained from the Ohangaron dam measurement points*

For the Andijan dam, H/V curves were obtained from five measurement points located on the reinforced-concrete part of the dam. These results are presented in Figure 5. The interpretation of these curves provides the basis for evaluating the dynamic response of different parts of the concrete dam body.

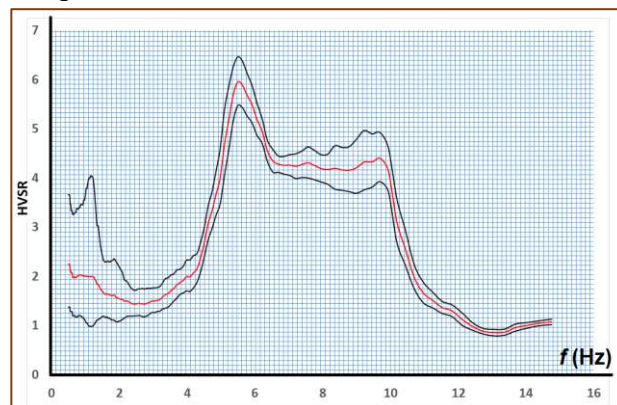




Measurement point 3



Measurement point 4



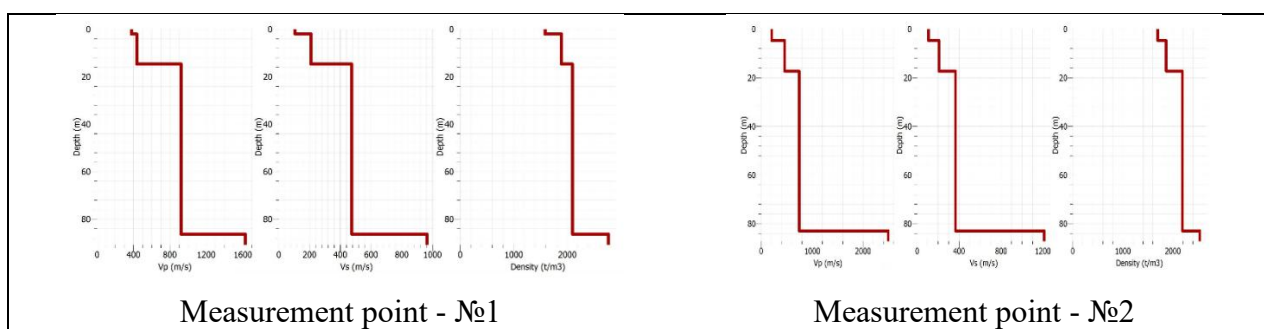
Measurement point 5

Figure 5. *H/V amplitude ratio versus vibration frequency curves obtained from the Andijan dam measurement points*

The comparison of H/V curves between the two dams allows the dominant vibration behaviour of rockfill and reinforced-concrete structures to be evaluated under the same methodological framework. In this context, changes in amplitude and frequency are considered as indicators of possible variations in stiffness, density, and hydrostatic-pressure-related deformation response.

Estimation of seismic wave velocities and density. Based on the interpretation of microseismic records, the values of compressional wave velocity V_p , shear wave velocity V_s and bulk density ρ were determined for different depths and measurement points. These parameters are necessary for calculating the elastic constants of the dam body.

For the Ohangaron dam, the depth-dependent variation of V_p , V_s and ρ is presented in Figure 6. The original material shows that these parameters were obtained for nine measurement points along the dam body.



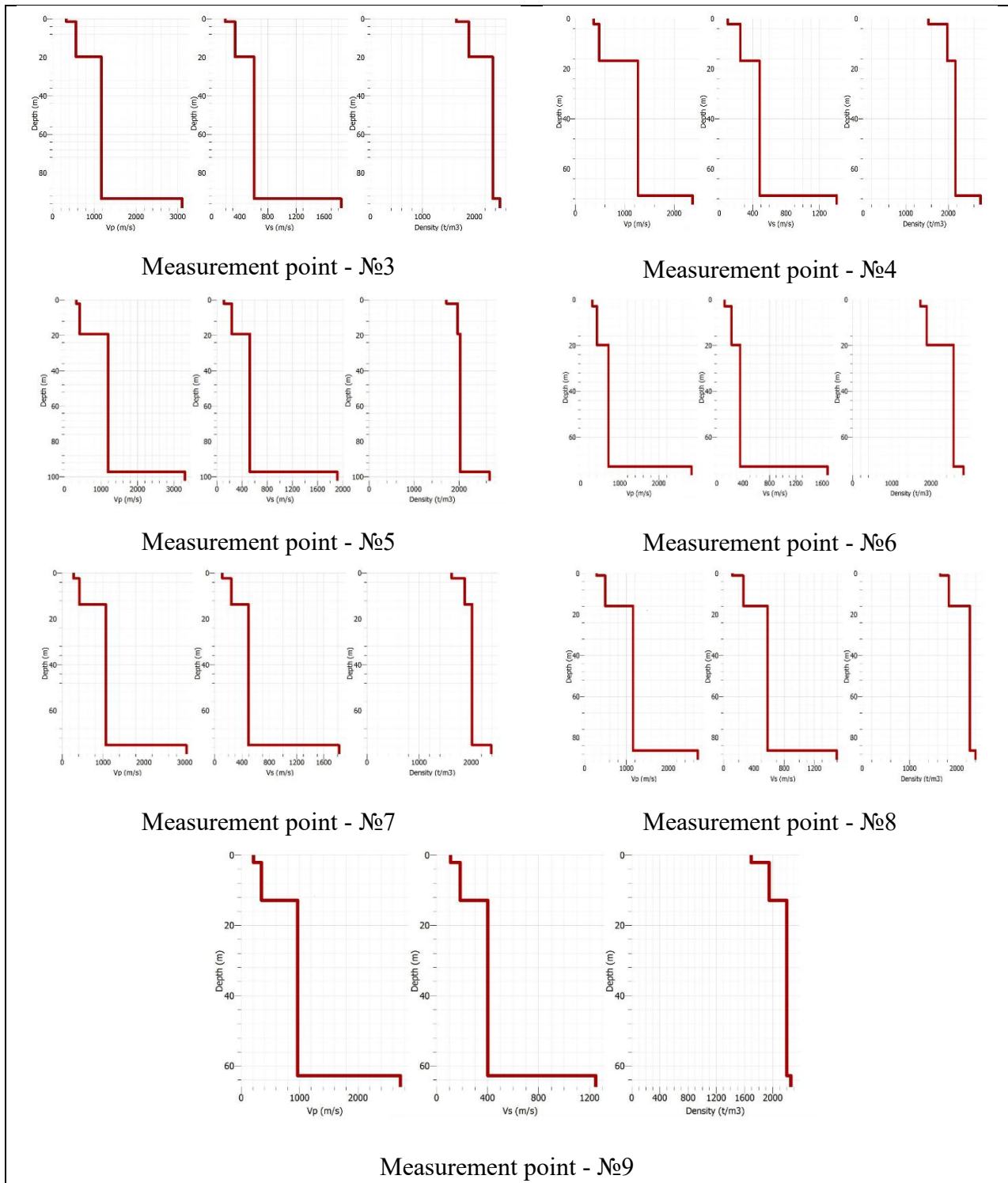
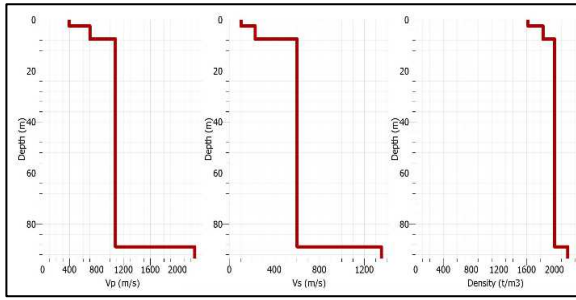
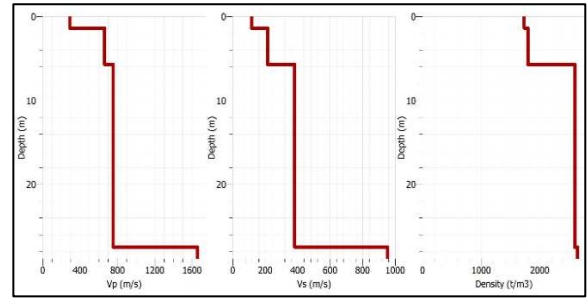


Figure 6. Depth-dependent variation of shear wave velocity V_S , compressional wave velocity V_P , and bulk density ρ within the Ohangaron dam body.

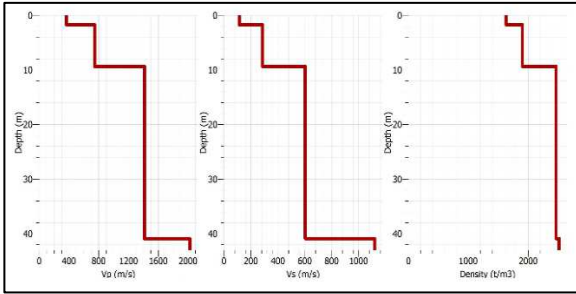
For the Andijan dam, the corresponding depth-dependent variation of V_S , V_P and ρ is shown in Figure 7. These values were used to assess the deformation-related elastic properties of the reinforced-concrete dam body.



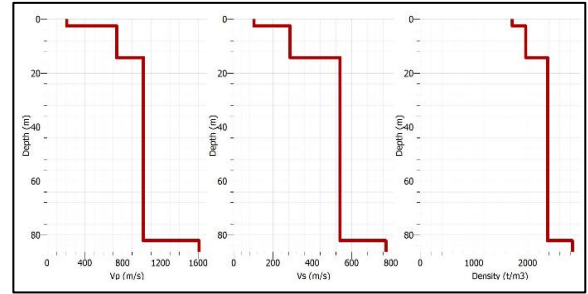
Measurement point - №1



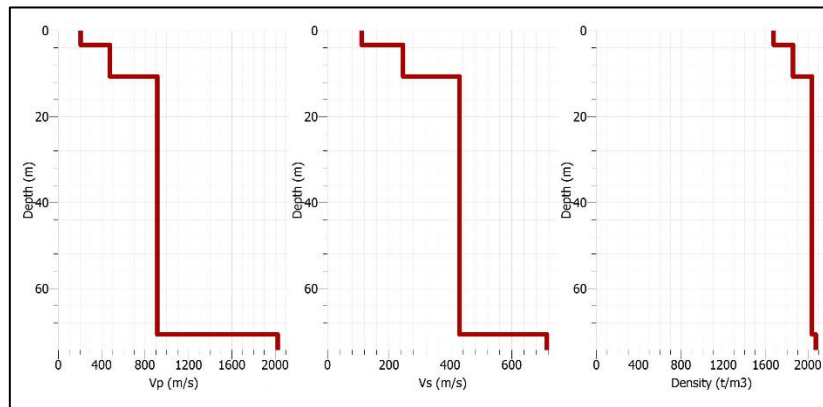
Measurement point - №2



Measurement point - №3



Measurement point - №4



Measurement point - №5

Figure 7. Depth-dependent variation of shear wave velocity V_s , compressional wave velocity V_p , and bulk density ρ within the Andijan dam body.

The use of V_p , V_s and ρ is methodologically important because these parameters directly control the calculated values of shear modulus, Lamé parameter, Poisson's ratio, and Young's modulus. Therefore, the interpretation of deformation state in this study is based not only on H/V spectral characteristics, but also on physically derived elastic parameters.

Calculation of deformation-related elastic parameters. The deformation-related parameters were calculated using the values of V_p , V_s and ρ obtained from the microseismic interpretation. The following elastic parameters were considered: velocity ratio, K ; Lamé constants ratio, q ; shear modulus, μ ; Lamé parameter, λ ; Poisson's ratio, ν ; Young's modulus, E (Telford et al., 1990; Mavko et al., 2020).

These parameters have the following characteristics:

- The velocity ratio K is used to determine the ratio between the velocities of longitudinal and transverse waves. The average value of K is taken as 1.73 for strong earthquakes. Since the wave parameters of micro-seismic oscillations are small, this coefficient can take on a large value.

$$K = \frac{V_P}{V_S} \quad (1)$$

- Shear modulus – μ . Under the influence of shear force, the shape of rocks changes, while their volume remains unchanged. This change is a characteristic of transverse waves. This is because the distance between rock particles does not change when transverse waves propagate. In liquids, transverse waves do not propagate. The displacement modulus is determined by the following formula.

$$\mu = V_S^2 \cdot \rho \quad (2)$$

where $\rho [\frac{g}{cm^3}]$ is the bulk density of the rock.

- Lamé constants (μ, λ). They are the quantities that connect the elastic wave components at some point in a linearly elastic or rigidly deformable isotropic medium to the deformation components at that point.

The Lamé constant is λ ;

$$\lambda = q \cdot \mu \quad (3)$$

The ratio of Lamé constants is – q ;

$$q = \frac{\lambda}{\mu} = \left(\frac{V_P^2}{V_S^2} \right) - 2 \quad (4)$$

- Poisson's ratio – ν . The modulus of elasticity is a measure of the change in the geometric shape of rocks in an elastic medium. In rocks, $\nu=0.18-0.5$; in water, $\nu=0.5$.

$$\nu = \frac{1}{2 + 2\frac{\mu}{\lambda}} \quad (5)$$

- Young's modulus – E . It is the modulus of elasticity that indicates the resistance of rocks in a medium to elongation or longitudinal compression. It is used as a parameter indicating the resistance of the dam body to longitudinal compression due to hydrostatic pressure in reservoirs.

$$E = 2V_S^2 \rho(1 + \nu) \quad (6)$$

Data Analysis. The calculated deformation-related elastic parameters for the Ohangaron and Andijan reservoir dams are summarized in Table 1 and Table 2. The values were obtained using the interpreted compressional wave velocity V_P , shear wave velocity V_S , and bulk density ρ . The calculated parameters include the velocity ratio K , Lamé constants ratio q , shear modulus μ , Lamé parameter λ , Poisson's ratio ν , and Young's modulus E .

Calculated deformation-related elastic parameters of the Ohangaron Reservoir rockfill dam

Table 1

Measurement points	H (m)	V_P	V_S	ρ (kg/m ³)	K	q	μ (GPa)	λ (GPa)	ν	E (GPa)
Point 1	1.9	367	109	1572	3.37	9.34	0.02	0.17	0.45	0.05
	14.7	425	207	1870	2.05	2.22	0.08	0.18	0.34	0.22
	86.1	917	470	2111	1.95	1.81	0.47	0.84	0.32	1.23
Point 2	4.1	191	105	1691	1.82	1.31	0.02	0.02	0.28	0.05
	17.2	447	217	1847	2.06	2.24	0.09	0.20	0.35	0.23
	83.1	728	366	2173	1.99	1.96	0.29	0.57	0.33	0.77
Point 3	1.1	302	188	1644	1.61	0.58	0.06	0.03	0.18	0.14
	19.4	525	350	1874	1.50	0.25	0.23	0.06	0.10	0.51
	93	1177	604	2359	1.95	1.80	0.86	1.55	0.32	2.27
Point 4	2.1	365	104	1538	3.51	10.32	0.02	0.17	0.46	0.05
	16.5	474	245	1961	1.93	1.74	0.12	0.21	0.32	0.31
	71.1	1252	490	2187	2.56	4.53	0.53	2.38	0.41	1.48
Point 5	2.2	342	108	1708	3.17	8.03	0.02	0.16	0.44	0.06
	17.3	408	221	1964	1.85	1.41	0.10	0.14	0.29	0.25
	97.2	1201	533	2034	2.25	3.08	0.58	1.78	0.38	1.59

Point 6	2.1	276	130	1713	2.12	2.51	0.03	0.07	0.36	0.08
	20.3	422	216	1887	1.95	1.82	0.09	0.16	0.32	0.23
	73.3	712	362	2570	1.97	1.87	0.34	0.63	0.33	0.89
	100	2822	1672	2816	1.69	0.85	7.87	6.68	0.23	19.36
Point 7	1.6	265	113	1604	2.35	3.50	0.02	0.07	0.39	0.06
	13.8	411	237	1897	1.73	1.01	0.11	0.11	0.25	0.27
	72.7	1060	500	2032	2.12	2.49	0.51	1.27	0.36	1.38
Point 8	1.2	276	107	1647	2.58	4.65	0.02	0.09	0.41	0.05
	16.3	485	260	1831	1.87	1.48	0.12	0.18	0.30	0.32
	86.5	1162	566	2274	2.05	2.21	0.73	1.61	0.34	1.96
Point 9, measured 1 km from the dam	2.3	195	102	1700	1.91	1.65	0.02	0.03	0.31	0.05
	12.8	335	180	1955	1.86	1.46	0.06	0.09	0.30	0.16
	62.9	951	396	2209	2.40	3.77	0.35	1.31	0.40	0.97

Calculated deformation-related elastic parameters of the Andijan Reservoir reinforced-concrete dam

Table 2

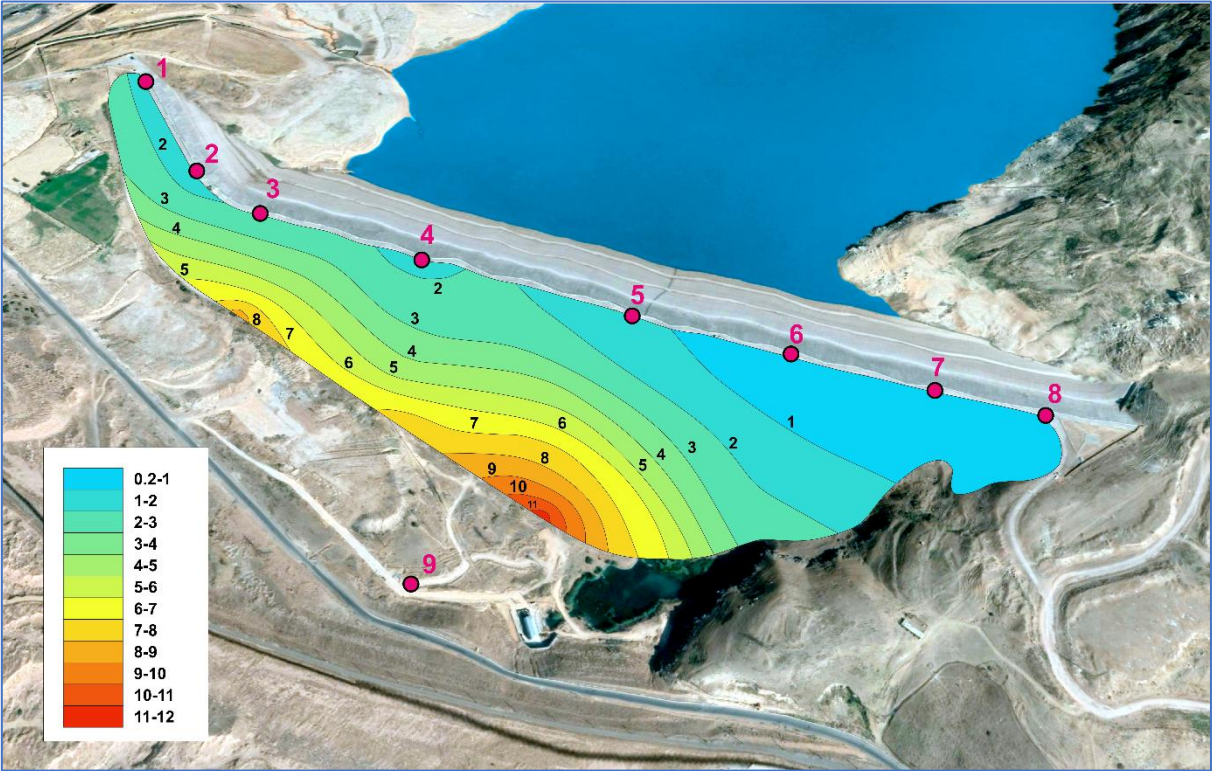
Measurement points	H (m)	V _P	V _S	ρ (kg/m ³)	K	q	μ (GPa)	λ (GPa)	ν	E (GPa)
		m/s								
Point 1	2	381	110	1630	3.46	10.00	0.02	0.20	0.45	0.06
	7.2	717	242	1844	2.96	6.78	0.11	0.73	0.44	0.31
	89	1064	609	1979	1.75	1.05	0.73	0.77	0.26	1.84
	121	2245	1350	2192	1.66	0.77	3.99	3.06	0.22	9.72
Point 2	1.2	280	117	1693	2.39	3.73	0.02	0.09	0.39	0.06
	5.6	663	210	1815	3.16	7.97	0.08	0.64	0.44	0.23
	27.3	756	386	2601	1.96	1.84	0.39	0.71	0.32	1.03
	121	1649	953	2669	1.73	0.99	2.42	2.41	0.25	6.06
Point 3	1.5	363	108	1639	3.36	9.30	0.02	0.18	0.45	0.06
	9.4	726	286	1897	2.54	4.44	0.16	0.69	0.41	0.44
	41	1421	602	2478	2.36	3.57	0.90	3.21	0.39	2.50
	121	2012	1106	2504	1.82	1.31	3.06	4.01	0.28	7.86
Point 4	2.4	189	105	1713	1.80	1.24	0.02	0.02	0.28	0.05
	14	742	281	1930	2.64	4.97	0.15	0.76	0.42	0.43
	82	1037	539	2352	1.92	1.70	0.68	1.16	0.31	1.80
	121	1602	777	2831	2.06	2.25	1.71	3.85	0.35	4.60
Point 5	3.15	197	110	1668	1.79	1.21	0.02	0.02	0.27	0.05
	11	477	246	1859	1.94	1.76	0.11	0.20	0.32	0.30
	71	902	429	2039	2.10	2.42	0.38	0.91	0.35	1.02
	121	2032	716	2082	2.84	6.05	1.07	6.46	0.43	3.05

The results show that the elastic parameters vary considerably with depth and measurement position. In both dams, the general tendency is an increase in seismic wave velocities, density, shear modulus, Lamé parameter, and Young's modulus with depth. This tendency reflects the increase in compaction, confining pressure, and stiffness of the dam body materials. However, the depth of interpretation should not be considered uniform for all measurement points, especially for the Ohangaron Reservoir dam.

291 The Ohangaron dam is located in a mountain valley formed by an old river channel. Therefore,
 292 the geometric height of the dam body varies along its length: the central part of the dam is higher,
 293 while both side parts are lower. For this reason, the elastic parameters were interpreted according to
 294 the actual investigated depth interval at each measurement point, as given in Table 1. In the lower
 295 side parts of the dam, the interpretation was limited to the dam body itself and was not extended
 296 artificially into the underlying foundation layers.

297 In the Ohangaron Reservoir rockfill dam, Young's modulus at the deepest interpreted layer of
 298 each measurement point varies from approximately 0.77 GPa to 19.36 GPa. The highest value is
 299 observed at measurement point 6, where Young's modulus reaches 19.36 GPa. At the same point, the
 300 shear modulus also reaches its maximum value of 7.87 GPa, while the Lamé parameter is 6.68 GPa.
 301 This indicates that the zone around measurement point 6 is characterized by a localized increase in
 302 stiffness and higher resistance to longitudinal compression.

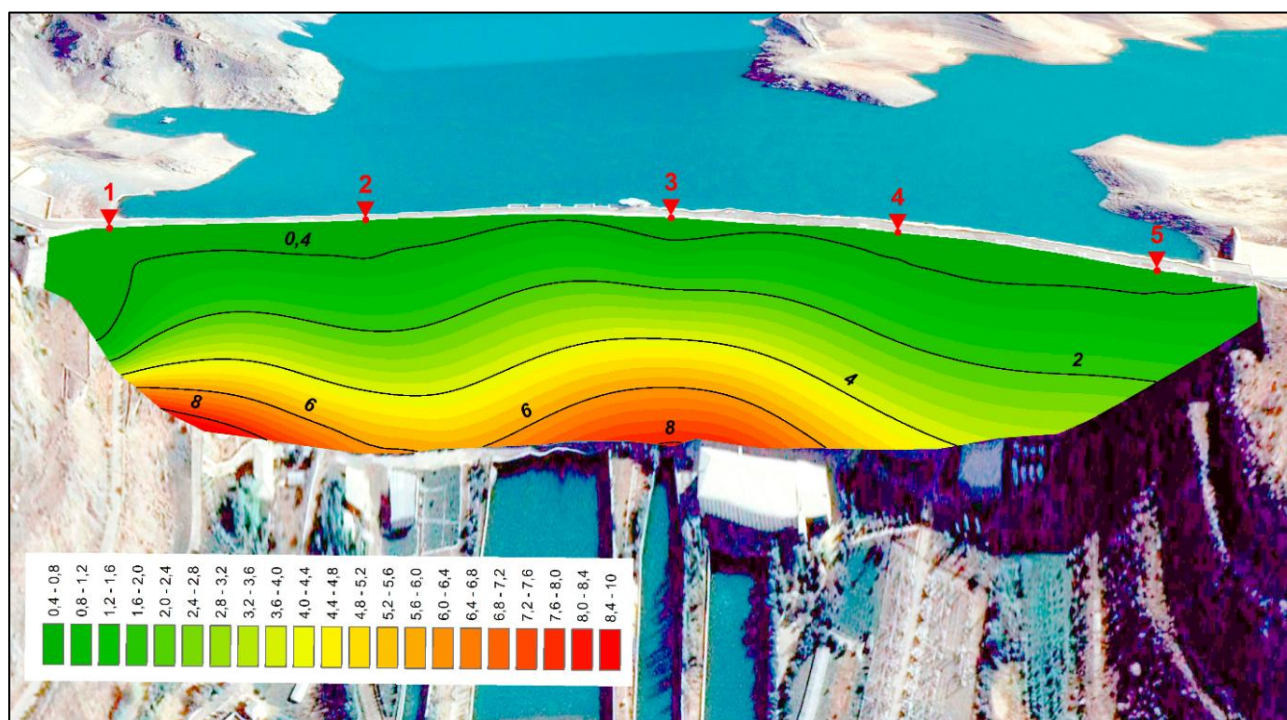
303 The other measurement points show considerably lower Young's modulus values at their
 304 deepest interpreted layers: 2.27 GPa at point 3, 1.96 GPa at point 8, 1.59 GPa at point 5, 1.48 GPa at
 305 point 4, 1.38 GPa at point 7, 1.23 GPa at point 1, and 0.77 GPa at point 2. The reference point
 306 measured approximately 1 km from the dam shows a Young's modulus of 0.97 GPa at its deepest
 307 interpreted layer. This contrast demonstrates that the Ohangaron dam body is not characterized by a
 308 uniform stiffness distribution. Instead, the main diagnostic feature is a sharply expressed stiffness
 309 anomaly at point 6 compared with the neighbouring dam-body points and the external reference point.
 310



311
 312 **Figure 8. Spatial distribution scheme of Young's modulus within the Ohangaron Reservoir**
 313 **rockfill dam body**

314 The high Young's modulus at point 6 should not be interpreted directly as structural damage.
 315 A high value of (E) reflects increased stiffness and higher resistance to longitudinal compression.
 316 However, a sharp lateral contrast between point 6 and the surrounding measurement points may
 317 indicate a zone where internal stress redistribution is more likely under hydrostatic loading.
 318 Therefore, the key diagnostic indicator is not only the absolute value of Young's modulus, but also
 319 the spatial gradient of stiffness between adjacent measurement points within the real geometric limits
 320 of the dam body.

321 For the Andijan Reservoir reinforced-concrete dam, the interpretation is more straightforward
 322 because the measurements were taken along the rigid concrete part of the dam. The Young's modulus
 323 values at the deepest interpreted layer of each point range from approximately 3.05 GPa to 9.72 GPa.
 324 The maximum value is observed at measurement point 1, where ($E = 9.72$) GPa. Relatively high
 325 values are also observed at points 3 and 2, where Young's modulus reaches 7.86 GPa and 6.06 GPa,
 326 respectively. Lower values are observed at points 4 and 5, where ($E = 4.60$) GPa and ($E = 3.05$) GPa.
 327 These results indicate that the reinforced-concrete dam body is also dynamically non-uniform,
 328 although its variability is more localized and structurally controlled than in the rockfill dam.
 329



330
 331 **Figure 9. Spatial distribution scheme of Young's modulus within the Andijan Reservoir**
 332 **reinforced-concrete dam body.**

333 In the Andijan dam, the distribution of Young's modulus is mainly controlled by the acoustic
 334 stiffness of the reinforced-concrete body, local structural conditions, and stress redistribution near
 335 hydraulic elements. Point 1 shows the highest stiffness, which may indicate a zone of stronger
 336 resistance to longitudinal compression. By contrast, point 5 has the lowest Young's modulus at the
 337 deepest interpreted layer.

338 A comparison of the two dams shows that the Ohangaron rockfill dam has a more sharply
 339 expressed local stiffness anomaly, especially at point 6, whereas the Andijan reinforced-concrete dam
 340 shows a more gradual distribution of stiffness values along the dam body. This difference is consistent
 341 with their structural types. In the rockfill dam, elastic parameters are strongly affected by material
 342 heterogeneity, compaction, moisture conditions, foundation relief, and the variable geometric height
 343 of the dam body. In the reinforced-concrete dam, the variations are more likely related to concrete
 344 stiffness, structural joints, foundation interaction, and local stress concentration zones.

345 Thus, the corrected interpretation indicates that the key deformation-related feature in the
 346 Ohangaron dam is a localized stiffness anomaly at point 6, evaluated within the actual geometric
 347 configuration of the dam body. The side parts of the dam should not be interpreted using the same
 348 depth assumption as the central valley section. For the Andijan dam, the main contrast is between the
 349 high-stiffness zone at point 1 and the relatively low-stiffness, high-Poisson-ratio zone at point 5.
 350 These zones should be considered priority areas for further monitoring and integrated engineering
 351 assessment.

The obtained results show that ambient microseismic measurements can be effectively used for evaluating deformation-related stiffness variations in dam bodies. However, the interpretation of these parameters must consider the structural type, geometry, material composition, and hydrostatic loading conditions of each dam.

Similar approaches have been applied in international studies for the dynamic characterization and health monitoring of dams. For example, Calcina et al. used ambient vibration tests to study the dynamic behaviour of an arch dam under different reservoir water-level conditions and showed that water level can influence the modal properties of the structure (Calcina et al., 2014). Sevim et al. and Tarinejad et al. applied operational modal analysis to concrete arch dams and demonstrated that ambient vibration records can be used to identify natural frequencies, mode shapes, and damping characteristics. These studies confirm that low-amplitude vibration data are useful for diagnosing the dynamic state of large hydraulic structures (Sevim et al., 2013; Tarinejad et al., 2016).

The present study differs from these works because it does not focus only on modal parameters. Instead, it uses microseismic-derived (V_P), (V_S), and density values to calculate deformation-related elastic parameters, including shear modulus, Lamé parameter, Poisson's ratio, and Young's modulus. Therefore, the proposed approach provides not only information about vibration behaviour, but also a spatial indication of stiffness contrasts within the dam body.

For the Ohangaron Reservoir rockfill dam, the main diagnostic feature is the localized stiffness anomaly around measurement point 6. This point shows the highest Young's modulus and shear modulus values compared with the other measurement points. Since the dam is located in a valley-type setting, this anomaly should be interpreted within the actual geometric configuration of the dam body. The side parts of the dam are lower, while the central part follows the old river valley and is affected by greater hydrostatic loading. Therefore, the interpretation should not artificially extend all points to a uniform depth. Each point must be analysed according to the actual investigated depth interval given in Table 1.

The Ohangaron results are also consistent with studies on embankment and earthen dams, where passive seismic methods have been used to detect internal velocity or stiffness changes. For example, Planès et al. showed that ambient seismic noise can be sensitive to internal changes in earthen dams and levees (Planès et al., 2016). In the present study, the identified anomaly at point 6 should not be interpreted directly as damage, but as a stiffness-contrast zone that may require repeated monitoring.

For the Andijan Reservoir reinforced-concrete dam, the distribution of elastic parameters is more structurally controlled. The highest Young's modulus is observed at point 1, while point 5 has the lowest Young's modulus at the deepest interpreted layer. At the same time, point 5 is characterized by relatively high (K), (q), (λ), and (ν) values. This combination may indicate increased sensitivity to volumetric strain and local stress redistribution under hydrostatic pressure. Similar conclusions are reported in vibration-based monitoring studies of concrete dams, where local stiffness changes are often linked to structural joints, concrete-foundation interaction, boundary conditions, and reservoir effects.

The comparison of the two dams shows that the Ohangaron dam represents a heterogeneity-controlled rockfill system, whereas the Andijan dam represents a structure-controlled reinforced-concrete system. In the Ohangaron dam, elastic parameters are mainly affected by material heterogeneity, compaction, moisture conditions, valley geometry, and non-uniform hydrostatic pressure. In the Andijan dam, the variations are more likely related to concrete stiffness, structural joints, hydraulic elements, and local stress concentration zones.

It is important to emphasize that the calculated elastic parameters are indirect indicators. They do not directly measure displacement, cracking, seepage, or irreversible deformation. Therefore, the identified zones should be described as stiffness-contrast or hydrostatic-pressure-sensitive zones, not as damaged zones. For reliable engineering conclusions, the microseismic results should be integrated with geodetic monitoring, piezometric observations, reservoir water-level data, visual inspection, and numerical stress-strain modelling.

Future studies should include repeated microseismic measurements under different reservoir water-level conditions. This would make it possible to distinguish stable stiffness patterns from time-dependent changes caused by hydrostatic pressure, seasonal loading, temperature effects, or possible deformation processes.

Conclusion. This study demonstrates that ambient microseismic observations can be used not only for identifying the vibration characteristics of dam structures, but also for deriving diagnostic indicators related to their internal stiffness condition. The proposed approach integrates H/V spectral analysis with seismic velocity and density-based elastic parameter estimation, allowing different dam types to be evaluated within a single methodological framework. The comparative assessment of the Ohangaron and Andijan dams shows that microseismic-derived parameters reflect the influence of structural type, material heterogeneity, dam geometry, and hydrostatic loading. This confirms that the same diagnostic method can be adapted to both rockfill and reinforced-concrete dams, provided that the interpretation accounts for their engineering and geological setting. The innovative aspect of the study is the use of passive microseismic data as a non-invasive tool for preliminary identification of stiffness-contrast and hydrostatic-pressure-sensitive zones in dam bodies. Such an approach can improve dam monitoring practice by helping to select priority areas for repeated measurements and detailed engineering investigation. The obtained results should be regarded as diagnostic indicators rather than direct evidence of damage. Therefore, future monitoring should combine microseismic observations with geodetic, piezometric, hydrological, and numerical modelling data to provide a more reliable assessment of dam safety.

Author Contributions

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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