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Professional paper

ESTIMATION OF THE QUALITY OF BUILT-IN CONCRETE BY THE ULTRASOUND OBSERVATIONS

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Abstract: This paper presents results of the propagation velocity investigations of ultrasound waves in the concrete construction - so called non-destructive method - "in situ" due to inspection of concrete quality that is inbuilt into the body of the Durutovići dam, built for the Pljevlja coal mine. By the velocity of ultrasound waves measures, the following parameters will be defined: concrete homogeneity, presence of gaps, cracks and other defects in concrete, as well as concrete quality related to its strength.

Key words: concrete, concrete quality, spreading speed of waves, ultrasound waves

1. INTRODUCTION

For the purposes of enlargement PK "Potrlica" of the Pljevlja coal mine, it was necessary to divert the river Ćehotina stream. Divert of the Ćehotina river stream, under the actual field conditions is realised by the designed and constructed facilities that include: concrete arch dam "Durutovići", "Rudine" tunnel, the canal located in the rim of the expanded open pit mine boundaries, "Velika Pilješ" tunnel, and the canal, located downstream of the exit portal of the tunnel to the discharge point into the old river Ćehotina stream. The functioning of this system should be developed in two phases. In the first phase, which is anticipated to last for about 20 years, the dam will serve only for diverting of the river Ćehotina stream in the expanded part of the OP "Potrlica". In the second phase, it is anticipated that the dam serves as a facility that will, after the hydro turbines are built, become energy facility, while the other buildings, tunnels and canals will lose their function.

In the village Durutovići, an arch dam was built in order to divert the river Ćehotina stream. Constructed height of the dam is 25.85 m (760.00 - 785.85 m), arch length is of 61.72 m in the dam crest, and thickness in the central area around the joints is 1.0 to 1.5 m at a level of 780.00 m and up to 3.5 m at a level of 762.50 m above the sea level.

Concreting is realized by the independent system of vertical strips, where only the dam body is covered with four strips, and two are in segments. Concrete blocks for dam body or independent blades are ranged from 1.00 m to 2.50 m with five joints. For

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concreting the dam, concrete type MB-30 is used. After the dam concreting was completed, primary and secondary injection of vertical radial couplings formed between independent strips was realized, due to dam body concrete consolidation.

2. TESTING METHOD

Ultrasound non-destructive tests on "Durutovići" concrete arch dam body were carried out using the ultrasound method. The ultrasound sonic apparatus V-Meter Mark II, James Instruments, produced in the USA, with the possibility of ventilation of concrete samples - from several centimetres to 30 m thick concrete (in situ) - was used (NTD James Instruments Ltd, 2003). For tests in concrete, transducers (transmitter and receiver) of 54 KHz were used. This equipment allows: direct tests, if two opposite sides are available, semi direct, if two lateral sides are available, and indirect, if only one side of the dam is available (Slimak, 1996). In this case, the direct method was applied. The transmitter of the ultrasound pulses was located on the upstream dam side, while the receiver was located downstream.

Time intervals between ultrasound waves arrivals, between the transmitter and the receiver, with the accuracy of +0.1 µs, were measured. The coordinates *x*, *y*, *z* of the measuring points, which were located upstream and downstream of the dam site, were obtained by a geological measurement. Those were used for calculation of the ultrasound waves trajectory lengths from the transmitter to the receiver. Measurements were carried out along the profiles, which were located according to the possibilities of access. On the upstream side, access was enabled from the scaffolding that is assembled for the injection of horizontal concrete extensions, while the downstream side access was enabled from a crane. Measurements on the left and right side of the dam were performed on spots that were available from the existing dilapidated wooden scaffolding. These points were not geodetically recorded, so these data will be shown separately.

2.1. The description of the used apparatus

The apparatus that was used for this test is the V-Meter MK II and its purpose is to estimate quality and condition of concrete by the non-destructive method. Figure 1 provides an overview of ultrasound apparatus V-Meter Mark II, produced by James Instruments*.

Propagation velocity of ultrasound waves in a solid material depends on density and elastic properties of the material. The quality of some of the materials is sometimes related to his elastic compaction, so measuring of the velocity in such materials can often be used to indicate its quality, as well as to define its elastic properties.

This device can be used for measurements:

- The samples (cores from boreholes, cubes, etc.),

* Bureau of Geophysical Engineering "Geofizikal" – Belgrade and Department of Mining and Production of Underground Rooms - Mining Department of Mining and Geology, Belgrade, have such an apparatus.

- On the field - in situ - the thickness of concrete up to 30 m (depending on the problem to be solved, a measurements may be realized from a few centimetres to 30 m),
- Non-reinforced, reinforced and pre-stressed concrete no matter if it is was poured before or poured in situ.

Figure 1 - Apparatus V-Meter Mark II, James Instruments

The velocity measurements can be used to define: the homogeneity of concrete, the presence of gaps, cracks and other defects (failures) in the concrete; changes that can occur due to time flow (i.e. caused by the cement hydration) or due to the impacts of fire, frost or chemical impact; quality of concrete in connection with (or depending on) specified required standards, which are generally related to its strength; the effect of concrete injecting (before and after it).

Small changes of velocities often indicate (reflect) in relatively significant changes in the condition of the concrete. To obtain a high accuracy rate of ultrasound waves trajectory lengths of ±2%, the error in measuring the trajectories length and time of wave arrival of just over 1% is allowed.

The accuracy of wave arrival intervals time can be achieved if there is a good connection between the transducers and the concrete surface. If the concrete surface is considerably rough, smoothness could be achieved by using available materials with minimum thickness such as gypsum (plaster of Paris), cement mortar or epoxy resin, but it takes some time for these filling materials to become solid.

These tests can be performed in three ways (Figure 2):

- Direct transmission - if both opposite sides of the tested object are available,
- Semi-direct transmission - if two lateral sides are available,
- Indirect, or surface transmission - if only one side of the object is available.

Application of this method is practically possible for all concrete constructions and products (dams, girders, pillars, walls, towers, tunnels, plates, etc.).

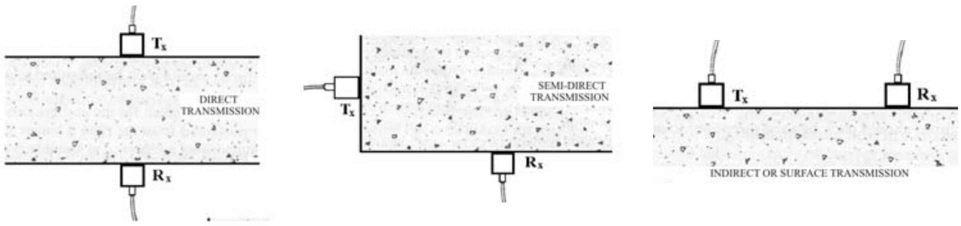

Figure 2 - Methods of propagation of the ultrasound pulses

2.1.1. The impact of measuring conditions

The propagation velocity in the concrete may be affected by: trajectory length; transverse (lateral) dimensions of the tested sample; the built-in reinforcement, concrete moisture.

The impact of the reinforcement is generally very low if the reinforcing bars are built-in longitude to the pulse directory and the amount of steel is small, compared to the trajectory length. Figure 3 shows the way we can eliminate this effect when the diameter of the rods is located directly along the pulse trajectory. If we know the L_S/L ratio, measured value of velocity can be adjusted by multiplying with the correction factor corresponding to this ratio and concrete quality.

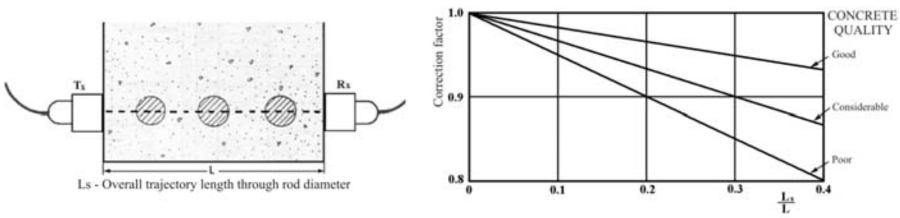

Figure 3 - The impact of steel reinforcement on the velocity; the rods perpendicular to the ray's trajectory

If reinforcement steel rods lie in the direction parallel to the pulse trajectory, the impact of steel is much harder to remove, as it is shown in Figure 4. It is not easy to do adjustments for the impact of steel and the correction factors given in Figure 4, so those should be considered as approximate. Generally, it is established that these factors represent the bottom-line limit of steel impact. It is recommended to choose the pulses trajectories in the way to avoid the impact of steel reinforcement as much as possible.

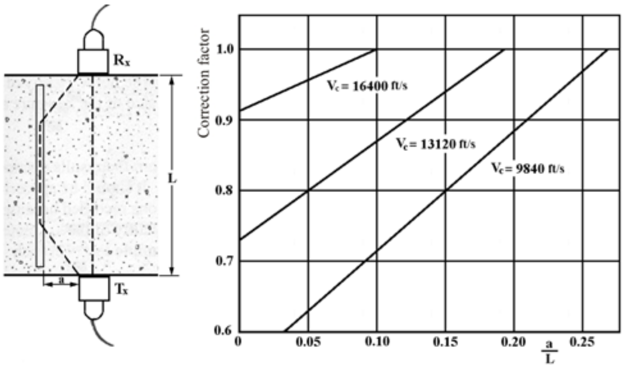

Figure 4 - The impact of steel reinforcement on the velocity; the rods parallel to the ray's trajectory

Concrete moisture can have a low, but significant impact on velocities. Generally, velocity increases with increasing moisture content and the impact is more obvious in less quality concrete. Velocity in saturated concrete can be up to 2% higher than in dry concrete of the same composition and quality, although this appearance is lower for more solid concrete.

3. PROCESSING OF MEASUREMENTS

Position and a profile of measurement points on the downstream side the Durutovic dam are shown in Figure 5. On the upstream side, access was possible from the scaffolding that was constructed for injection of horizontal concrete extensions, while the downstream side access was possible from the basket (of the crane). The left and right side of the dam measurements were performed on spots that were available by the existing wooden scaffolding. These points were not geodetically recorded so these data are shown separately. Ten profiles were determined (UP: I - X), and distance between measurement points is 50 cm. From these profiles, this paper will show the results which were achieved after measuring only four central profiles: UP-IV, UP-V, UP-VI and UP-VII.

The results obtained by individual ultrasound profiles are shown in the respective tables. Each table contains the number of measurements, the coordinates *x*, *y*, *z*, measuring points with the upstream dam side, the block casting number, coordinates *x*, *y*, *z*, measurement points downstream from the dam face, the number of concreted block, concreted part, the trajectory length *d* [m], measured wave arrival interval *t* [μs] and calculated values of ultrasound wave propagation velocity *v* [m/s]. Bottom of the table gives the range of velocity values obtained by ultrasound wave velocity, below, the values of velocity and average velocity along the profile. The average velocity in the individual blocks or parts of the concrete is shown in the right side of the table. In Table 1, 2, 3 and 4 the results obtained along the ultrasound profiles UP-IV, UP-V, UP-VI and UP-VII are shown (Trajković et al. 2010).

Figure 5 - Position of profiles and measurement points on the downstream side of the "Durutovići" dam

The results of measurements in the profile UP-IV: velocity values in the range 3973 to 4553 m/s were obtained. The lowest value of velocity is obtained in block 18 in the 5th (V) part of the concreted zone, and the highest in block 22, or 6th (VI) concreted part. The average velocity value for the whole profile is 4309 m/s.

Table 1 - Ultrasound profile UP-IV

No.	UPSTREAM Coordinates			Block	DOWNSTREAM Coordinates			Block	Concreted part	Parameters			
	x	y	z		x	y	z			d [m]	t [μs]	v [m/s]	v_{sr} [m/s]
1.	689.703	530.019	776.127	26	689.520	531.855	776.329	26	VII	1.856	442.5	4194	4194
2.	689.659	529.981	775.572	22	689.492	531.854	775.784	22	VI	1.892	462.3	4092	4336
3.	689.684	529.908	774.671	22	689.485	531.858	774.686	22		1.960	443.7	4375	
4.	689.741	529.944	775.034	22	689.460	531.850	775.271	22		1.941	453.3	4323	
5.	689.648	529.861	774.143	22	689.421	531.839	773.962	22		1.999	439.0	4553	
6.	689.671	529.844	773.645	18	689.422	531.842	773.537	18	V	2.016	445.0	4530	4263
7.	689.588	529.825	773.129	18	689.348	531.837	773.061	18		2.027	490.1	4136	
8.	689.765	529.811	772.547	18	689.334	531.841	772.519	18		2.075	522.3	3973	
9.	689.620	529.780	772.105	18	689.339	531.851	771.970	18		2.094	474.7	4411	
10.	689.288	529.482	772.201	18	689.328	531.851	771.551	14	IV-V	2.457	526.0	4504	
Wave propagation velocity range and average value										(3973 – 4553)			4309

Value decreasing were detected at point 2 in block 22 – the 6th (VI) part and it is 4092 m/s; in point 7 in block 18, or the 5th (V) part (4136 m/s); and in point 1 in Block 26 - the concreted section 7 (VII) (4194 m/s). Comparing obtained average values of velocity by blocks or concreted parts, the following order can be spotted (in going from lower to higher values): 4194 m/s for block 26 in the 7th (VII) part, 4263 m/s for block 18, part 5 (V), and 4336 m/s for block 22 or the 6th (VI) part. It is interesting to note that between blocks 14 and 18, or concreted parts 4 (IV) and 5 (V), the increased value of velocity 4504 m/s is obtained. Table 1 shows the results obtained along the ultrasound profile UP-IV.

The results of measurements in the profile UP-V: velocity values in the range 3750 to 4595 m/s were obtained. The lowest and highest value of velocity is obtained in points No.6 and No.7 in block 18 in the 5th (V) part of the concreted zone. Next, relatively low velocity (3818 m/s) is obtained in point No.2 between blocks 22 and 26, or the 6th (VI) and 7th (VII) part of concreting. The average velocity value for the whole profile is 4269 m/s. Comparing obtained average values of velocity by blocks or concreted parts, the following order can be spotted (in going from lower to higher values): 4210 m/s for block 18 in the 5th part, 4363 m/s for block 14 or the 4th (IV) part, 4423 m/s in block 26 (7th part) and 4425 m/s in block 22 – the 6th (VI) concreted part. Table 2 shows the results obtained along the ultrasound profile UP-V.

Table 2 - Ultrasound profile UP-V

No.	UPSTREAM Coordinates			Block	DOWNSTREAM Coordinates			Block	Concreted part	Parameters			
	x	y	z		x	y	z			d [m]	t [μs]	v [m/s]	v_{sr} [m/s]
1.	693.677	530.974	776.015	26	693.652	532.916	776.592	26	VII	2.026	458.0	4423	4194
2.	693.753	530.931	775.508	22	693.660	532.888	776.059	26	VI-VII	2.035	533.0	3818	4336
3.	693.866	530.889	774.921	22	693.642	532.856	775.547	22	VI	2.076	477.2	4350	4425
4.	693.867	530.836	774.445	22	693.681	532.841	774.978	22		2.083	463.0	4500	
5.	693.835	530.782	774.024	18	693.666	532.808	774.459	18	V	2.079	486.0	4278	4210
6.	693.733	530.710	773.514	18	693.670	532.774	773.835	18		2.090	585.4	3570	
7.	693.735	530.691	773.021	18	693.707	532.783	773.302	18		2.111	459.2	4595	
8.	693.730	530.580	772.510	18	693.701	532.771	772.676	18		2.197	509.0	4322	
9.	693.725	530.541	772.020	18	693.646	532.740	772.111	18		2.202	514.0	4284	
10.	693.715	530.520	771.496	14	693.695	532.754	771.497	14	IV	2.234	513.0	4355	4363
11.	693.708	530.508	771.031	14	693.685	532.758	771.066	14		2.250	519.0	4335	
12.	693.652	530.481	770.482	14	693.660	532.757	770.810	14		2.300	523.0	4398	
Wave propagation velocity range and average value										(3570 – 4595)			4269

The results of measurements in the profile UP-VI: velocity values in the range 3581 to 4887 m/s were obtained. The lowest value of velocity is obtained in block 13 in the 4th (IV) and highest value is obtained in block 25 or the 7th (VII) part the concreted zone. Lower values of velocity (under 4000 m/s) were detected in point 6, block 21, the 6th (VI) part (3695 m/s), point 15, block 13, the 4th part (IV) (3925 m/s), point 8, block 17, the 5th (V) part (3968 m/s), as well as point 7 between blocks 17 and 21, the 5th (V) and 6th (VI) part (3970 m/s). The lowest average velocity value (4076 m/s) are obtained in block 13, concreted part 4. Next are 4113 m/s (block 17, part 5), 4136 m/s (block 21, part 6) and 4153 m/s (block 29, part 7). Considerably higher average velocity comparing to early mentioned, were obtained in part 3 (4620 m/s) and block 25, part 7 (4878 m/s). It is important to note that between block 7 and 9 (2 and 3 concreted part); the relatively high value of velocity (4530 m/s) is obtained. Table 3 shows the results obtained along the ultrasound profile UP-VI.

Table 3 - Ultrasound profile UP-VI

No.	UPSTREAM Coordinates x	y	z	Block	DOWNSTREAM Coordinates x	y	z	Block	Concreted part	Parameters d [m]	t [μs]	v [m/s]	v_{sr} [m/s]
1.	697.496	532.670	777.344	29	696.654	534.272	777.244	29	VIII	1.813	436.5	4153	4153
2.	697.612	532.627	776.765	25	696.673	534.216	776.580	25	VII	1.855	381.0	4869	4878
3.	697.523	532.542	776.288	25	696.692	534.196	776.089	25		1.862	381.0	4887	
4.	697.678	532.559	775.797	21	696.689	534.160	775.548	21	VI	1.898	421.8	4500	4136
5.	697.778	532.547	775.170	21	696.735	534.144	774.925	21		1.923	456.5	4212	
6.	697.546	532.379	774.701	21	696.744	534.115	774.479	21		1.925	521.0	3695	
7.	697.663	532.382	774.204	21	696.735	534.088	774.001	17	V-VI	1.953	492.0	3970	3970
8.	697.733	532.356	773.782	17	696.784	534.096	773.461	17	V	2.008	506.1	3968	4113
9.	697.722	532.199	772.766	17	696.832	534.087	772.903	17		2.092	513.0	4078	
10.	697.716	532.141	772.424	17	696.834	534.069	772.327	17		2.122	508.2	4176	
11.	697.601	531.992	771.903	17	696.833	534.036	771.776	17		2.187	517.0	4230	
12.	697.645	531.950	771.392	13	696.830	534.015	771.254	13	IV	2.224	508.0	4378	4076
13.	697.702	531.946	770.921	13	696.805	534.016	770.747	13		2.263	632.0	3581	
14.	697.766	531.941	770.385	13	696.832	534.039	770.226	13		2.302	546.5	4212	
15.	697.868	531.961	769.975	13	696.787	534.030	769.731	13		2.347	598.0	3925	
16.	697.858	531.917	769.458	13	696.756	534.020	769.222	13		2.386	557.0	4284	
17.	697.963	531.960	769.043	11	696.769	534.150	768.031	11	III	2.692	570.3	4720	4620
18.	697.968	531.985	768.312	11	696.856	534.283	767.239	11		2.769	602.3	4582	
19.	697.893	531.992	767.820	11	696.820	534.318	766.660	9		2.812	597.0	4682	
20.	697.880	531.988	767.300	11	696.771	534.350	766.114	9		2.866	625.0	4560	
21.	697.858	531.963	766.898	9	696.759	534.362	765.670	9		2.910	639.0	4554	
22.	697.870	531.850	766.342	9	696.781	534.320	765.120	7	II-III	2.963	654.0	4530	
Wave propagation velocity range and average value										(3581 – 4887)			4307

The results of measurements in the profile UP-VII: The velocity values in the range 3438 to 4835 m/s were obtained. What is characteristic in this case is that the obtained minimum and maximum velocity values are detected between blocks 17 and 21 – concreted parts 5 (V) and 6 (VI). The obtained average velocity value for the whole profile is 4455 m/s. Observing the values obtained at this profile, their increasing values at all measuring points, which amounts to over 4260 m/s, were detected. Related to obtained average speed values by blocks and concreted parts, situation is as follows: the lowest values of average velocity were obtained between blocks 17 and 21 (parts V and VI) - 4136 m/s, and between blocks 21 and 25 (parts VI and VII) - 4286 m/s. In block 17 (concreted part V), the lowest obtained velocity value is 4405 m/s. In going from lower to higher values obtained velocity values can be placed in the following order: 4454 m/s in block 21 (part VI), 4462 m/s in block 29 (part VIII), 4534 m/s in block 25 (part VII), 4518 m/s in block 11 (part III). From the foregoing, it is evident that in this profile, the lowest average velocity value is obtained in part V, and the highest in part IV. Between blocks 13 and 17 (concreted parts IV and V) the highest average speed of 4582 m/s on this profile is obtained. Table 4 shows the obtained results of along the ultrasound profile UP-VII.

Table 4 - Ultrasound profile UP-VII

No.	UPSTREAM Coordinates			Block	DOWNSTREAM Coordinates			Block	Concreted part	Parameters			
	x	y	z		x	y	z			d [m]	t [μs]	v [m/s]	v_{sr} [m/s]
1.	702,709	536,004	777,336	29	700,388	536,476	777,142	29	VIII	2,376	532,5	4462	4462
2.	702,745	535,968	776,800	25	700,406	536,447	776,165	25	VII	2,471	540,5	4534	4534
3.	702,741	535,917	776,280	25	700,402	536,424	775,589	25	VI-VII	2,491	581,2	4286	4286
4.	702,761	535,882	775,798	21	700,430	536,421	775,029	21	VI	2,513	551,7	4555	4454
5.	702,750	535,824	775,302	21	700,453	536,415	774,540	21		2,491	572,3	4353	
6.	702,849	535,825	774,746	21	700,461	536,409	773,908	17	V-VI	2,596	755,0	3438	4136
7.	702,790	535,727	774,256	21	700,461	536,403	773,364	17		2,584	534,4	4835	
8.	702,713	535,606	773,658	17	700,464	536,398	772,814	17	V	2,529	576,9	4384	4405
9.	702,829	535,656	773,200	17	700,500	536,421	772,301	17		2,611	571,5	4568	
10.	702,707	535,519	772,683	17	700,498	536,407	771,777	17		2,547	597,6	4262	
11.	702,849	535,593	772,179	17	700,497	536,407	771,133	13	IV-V	2,700	589,3	4582	4582
12.	702,895	535,585	771,589	13	700,472	536,392	770,644	13	IV-V	2,723	586,3	4644	4578
13.	702,801	535,477	771,084	13	700,477	536,404	770,102	13		2,688	581,9	4619	
14.	702,819	535,467	770,652	13	700,486	536,425	769,562	13		2,747	583,5	4708	
15.	702,871	535,439	769,441	13	700,457	536,408	769,090	13		2,625	604,4	4343	
16.	702,895	535,426	768,923	11	700,414	536,529	768,119	11	III	2,832	628,5	4506	4518
17.	702,893	535,427	768,402	11	700,436	536,563	767,582	11		2,828	647,7	4366	
18.	702,869	535,413	767,849	11	700,307	536,608	767,137	11		2,915	653,0	4464	
19.	702,845	535,396	767,328	11	700,234	536,679	766,477	9		3,031	640,0	4734	
Opseg brzine prostiranja talasa i srednja vrednost										(3438 – 4835)			4455

4. EVALUATION OF THE OBTAINED RESULTS

Velocity of ultrasound waves in concrete depends on its density and its elastic properties. With the increasing quality of concrete, which depends on the used aggregate, the type of cement, water-cement ratio, additives, temperature, pouring procedure, the pouring time, etc. the velocity of ultrasound waves increases. In this way, the velocity values reflect the quality of concrete.

Concrete is an artificial creation made of selected materials with a certain grain size and physical-mechanical properties for making appropriate technological processes in order to achieve required physical-mechanical characteristic necessary for the designed objects. Accordingly, the concrete should theoretically be homogeneous and isotropic. However, like most things in nature, concrete is, depending on the scale of observation, quasi-homogenous and quasi-isotropic. Testing of concrete quality and its physical-mechanical properties is usually performed in the laboratory on samples - cylinders or cubes - taken from objects, where this method is classified as a destructive method. In addition, the matter of representativity of samples is questionable, because those are, practically, the points in relation to an object. The method of ultrasound is, in the moment, one of the best methods for testing concrete structures in situ and in laboratories, due to its non-destructivity, non-invasiveness, as well as for its representativeness of the obtained results.

Concrete is tested according to the existing international standards, according to which the adequate measuring instruments of sufficient accuracy, to meet the prescribed technical conditions of performance, were constructed.

On the basis of numerous and long-term measurements made in the world, classification of concrete quality on the basis of ultrasound (pulse) wave propagation velocity was made and shown in Table 5.

Table 5 - Concrete quality classification based on pulse velocity

Longitudal pulse velocity		Concrete quality
km/s	ft/s x 10^3	
> 4,5	> 15	Excellent
3,5 – 4,5	12 – 15	Good
3,0 – 3,5	10 – 12	Insufficient
2,0 – 3,0	7 – 10	Poor
< 2,0	< 7	Very poor

As shown in Table 5, five categories of concrete quality were separated - going from higher to lower – excellent - good - insufficient – poor - very poor, according to obtained range of the velocity values.

Excellent quality of concrete is indicated on the parts of the profiles: UP-IV, UP-V, UP-VI and UP-VII.

On the profile UP-IV indications for the excellent quality of concrete was obtained at point 6, (4530 m/s), of concreted part V (5th) at point 5 (4553 m/s), part VI (6th) of point 10 (4504 m/s), and parts IV-V - interruption in the concreting.

On the profile UP-V such indications were obtained at a point 7, V (5th) part of concreting (4595 m/s), and point 4, concreted part VI (6th) - 4500 m/s.

On the profile UP-VI indications are obtained on the following concreted parts and points: part III (3rd), points 17-21 (4554-4720 m/s), part VI (6th), point 4 (4500 m/s), and part VII (7th), measuring points 2 and 3 (4869 m/s and 4887 m/s). It should be noted that results on points 2 and 3, part VII, indicating the highest quality of concrete obtained by these tests. Also, the similar results which are obtained in the discontinuation of concreting zone in the part II-III, point 22 (4530 m/s) shows that concrete quality is very good.

On the profile UP-VII the indication were obtained on: part III (3rd), points 16 and 19, (4506 m/s and 4734 m/s), part IV (4th), points 12, 13 and 14, (4644, 4619 m/s and 4706 m/s), part V (5th), point 9 (4568 m/s), part VI (6th), point 4 (4555 m/s) and part VII (7th), point 2 (4534 m/s). These indications are obtained in the discontinuation of concreting zone in the part IV-V, point 11 (4582 m/s) and part V-VI, point 7 - 4835 m/s.

5. CONCLUSION

On the "Durutovići" arch dam concrete geophysical tests were carried out using the direct method of ultrasound in order to gain insight into the quality of the built-in concrete. Based on the obtained results, it can be concluded as follows:

- The obtained velocity values are in the range 3141 m/s to 4835 m/s which indicates the following quality of concrete: *insufficient*, *good* and *excellent*.

- *Insufficient quality of concrete* - is obtained only at one measuring point in the discontinuation of concreting zone in the parts VI-VII, on the UP-VII.
- *Good quality of concrete* - is obtained in the most points, the lowest value of speed in this separate category is 3570 m/s, obtained in the part V of the porfile UP-V.
- *Excellent quality of concrete* – is obtained at several places along the profiles and concreted parts.
- The results from vertical and horizontal line indicate the good and excellent quality of concrete in the concreted sections as well as good quality concrete with interruptions in concreting zones.
- The most number of average velocity results (vertically and horizontally) is above 4000 m/s, which is in the upper half of the separate categories of concrete - good.

Since the concrete is, during its lifetime, exposed to negative effects such as chemical processes and atmospheric effects (mostly frost), it is recommended to observe its condition, so the adequate procedure can be taken, due to bring concrete in a state which is given by the project.

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