ASSESSMENT OF THE SEISMIC IMPACT ON ISKRETS KARST SPRINGS (CENTRAL WEST BULGARIA) FROM EARTHQUAKES AND FROM GROUPED BLASTS IN THE NEIGHBORING LIMESTONE QUARRY

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Abstract: The aim of the study was the assessment of: 1) the impact of local and remote earthquakes on the discharge rate of Iskrets Karst Springs; 2) the possible seismic impact of grouped blasts from the neighboring limestone carry on the springs. The lowest values of the peak ground accelerations from earthquakes provoking dramatic disturbances of the discharges are evaluated at the rate of 0.046 g. The impact of 10 grouped blasts has been evaluated to be 40 times lower.

Key words: Earthquakes, Ground Acceleration, Grouped Blasts, and Water Discharge.

The present study was made for assessment of the possible impact of the grouped blasts from the limestone carry near the Iskrets Karst Springs on their discharge. The reason to expect some disturbances of the water regime was given by the recorded temporary interrupting of Isktrets Karst Springs discharge. During the 19th century the springs dried up several times. Vranchea Earthquake from 1977 the discharge rate dropped down from 5.5 to 0.5 m^3/s during 7.5 hours (Petrov, 1983). After that the discharge rate raised abruptly to 13.5 m^3/s, and begun to decrease gradually. Similar event happened during the local Svoge Earthquake from 1979, as well as at the 11 of April 1982, when any significant earthquake was not recorded at the localities, nor in the whole Balkan Region. The question for the seismic impact of the grouped blasts from the neighboring limestone carry is of importance for the local authorities because of the significance of the springs as a major source of fresh water for the municipality of the town of Svoge. The normally used quantities are of the rate of 150 l/s.

The Iskrets Karst Springs have a very variable discharge - from 280 to more than 50000 l/s (Benderev, 1989). They drained more than 80% of the territory of Ponor Mountain - a part of Western Balkan Mountain in Bulgaria (Iskrets Karst Bassin - Dinev, 1959; Antonov, 1963; Benderev, 1989;

Paskalev et al., 1992). The springs are related to the rocks of the upper part of the so-called Triassic Aquifer of Iskar Carbonate Group. The atmospheric precipitation on the feeding area of the springs (about 140 km^2) gives the principal quantities of water - about 62% of the average annual discharge of the springs. Geological, tectonic and geomorphological conditions predestine the existence of water saturated zone northern from the springs. It can be seen in the neighboring cave of “Dushnika” where the underground lake surface has a level at 2 m above the springs’ level. The level of the underground lake raises abruptly even to 13 m after intensive atmospheric precipitation and snow melting, and a river appears from the lower entrance of the cave.

Assessment of the peak ground accelerations from earthquakes

The existing empirical relationships between the acceleration ***a***, the earthquake magnitude ***M***, the epicentral distance ***R*** and the hypocentral depth ***H*** have been published by a number of authors. The analyze performed on these relationships (Faccioli, 1977) has shown that in the most common cases for crustal earthquakes (to the depths of 32-35 km) the relationship is:

$$a = a' 10^{bM} (R + 25)^{-c} \text{ (cm/s}^2\text{)} \qquad (1)$$

The coefficients ***a’*** and ***b*** are different according the different authors, depending of the data used. The present study uses the coefficients proposed by Faccioli, 1977, McGuire, 1974 and Donovan, 1973. Other study (Vutkov et al., 1985; Voutkov et al., 1986) uses additionally the hypocentral depth, and the empirical relationship is different and more complicated, but it gives the possibility to introduce the real ground conditions (seismic rigidity) for the concrete site. It exists relationship between the peak ground acceleration ***a*** and the epicentral distance ***R*** especially for the Vranchea Earthquake of March 1977 (after Brankov-ed., 1983).

The all mentioned above relationships have been used for assessment of the peak ground acceleration from Vranchea Earthquake, 1977 (M=7.2; D=110 km; R=442 km), and the local Svoge Earthquake, 1980 (M=4.4; D=25 km; R=9.3 km). The Faccioli’s relationship gives relatively high values for the Svoge Earthquake. The other relationships give similar values, and the average is 0.048 g. The lowest values are calculated by the relationship of Voutkov et al. (1986). When introducing the average ground density of 2.50 g/cm^3 and the seismic velocities recorded at the two seismic profiles near the springs, the peak ground accelerations are 0.070 g for the impact of Vranchea Earthquake and 0.043 g for the Svoge Earthquake. The relationship for the Vranchea Earthquake (Brankov - ed., 1983) gives the value of 0.046 g.

According these results, the most conservative evaluation gives reason to postulate that the impact from the blasts in the neighboring limestone carry have to be lower than 0.042 g peak ground acceleration for the guaranty of the normal discharge rate of the springs. Other studies for different regions have shown that important negative impact from carry blasts appear when the velocity of the ground movement is greater than 5 cm/s (Vovk, 1976).

Interpretation of the seismic records from the experimental blasts The experimental blasts were executed in two vertical 9 m deep holes in the carry. The explosive was of chemical type with single weight of 30 kg for every one of the holes. The records of the seismic waves from the explosions were made along two profiles of 24 seismic recording channels with vertical and horizontal geophones. Two channels were related to geophones inside the cave of "Dushnika" (at approximately 14 m from the cave entrance). The records were made with 24 bits system (High resolution) RAS-24 of the company SEISTRONIX, USA. The seismic station is digital with 0.125 ms sample rate. The self frequency of the geophones was 60 Hz. The average distance between the explosions and the recording devices was 350 m. The procedure for the analyzes of the data was the following:

1) The records were analyzed for everyone of the channels. Only these records were selected, those were useful for the purposes of the study

2) Three group of records were formed:

* records from the vertical and the horizontal geophones in the cave of "Dushnika";
* records of the vertical geophones along the seismic profiles;
* records of the horizontal geophones along the seismic profiles.

3) The ground acceleration ***A*** was calculated for every channel with normal recording of the amplitude ***u*** with a step of digitalization of 0.5 ms:

$$A_i = 4(u_i - 2u_{i-1} + u_{i-2}) \ [\mu V/sec^2] \quad (3)$$

The velocity ***V*** of the ground movement was also calculated:

$$V_i = 2(u_i - u_{i-1}) \ [\mu V/sec] \quad (4)$$

4) The arrival time of the recorded maximal ground accelerations for every channel was determined. A comparison between the records and the calculated maximal ground accelerations from the vertical and the horizontal geophones was made.

5) The channel with the best record of single explosion was chosen for elaboration of synthetic seismogram imitating grouped blast of 10 explosions with delay time of 25 ms. The ground

accelerations were calculated for the all length of the synthetic seismogram. A comparison between the peak ground accelerations from earthquakes with impact on the Iskrets Karst Springs discharge (Vranchea and Svoge Earthquakes), and the maximal acceleration from the synthetic seismogram was made.

6) Theoretical evaluation of the ground displacement was made using the relationship (after Vovk, 1976):

$$u^2 = 18h^{0.6} (r/C^{1/2})^{-1/3} \text{ [mm}^2\text{]} \qquad (5)$$

Where u is the displacement, r - the distance between the explosion and the recording device in meters, h - the average depth from the surface of the explosive in the hole in meters, and C - the quantity of chemical explosive in kg.

7) As a final result, conclusions for the expected impact on the discharge regime of the springs from the explosions in the carry during its exploitation have been made. Recommendations for minimum seismic impact using grouped blasts with a time delay have been elaborated.

Results

The preliminary analyzes of the all records demonstrated clearly that the single explosions of 30 kg chemical explosive had insignificant seismic impact on the area of the springs (Fig. 1). It was calculated theoretically that the ground movement at 350 m from the explosions was only 0.46 mm.

The most informative records were from the 1st and the 2nd channels installed inside the cave of "Dushnika". These records were analyzed also spectrally. Because of the positions of the geophones directly on limestone rock, the registration of the shear seismic wave was assured. The specter of the record from the vertical recorder has showed two maximums, corresponding at the frequencies 48 Hz and 112 Hz. The peak frequency from the horizontal recorder is 71 Hz, and it is for the shear wave. This result is of importance, because it shows that the maximum values of the frequency spectrum from the explosions are higher than these from the earthquakes (1-2 Hz).

The records from the vertical devices along the seismic profiles have shown that the maximum rates of displacement of the alluvial sediments near the springs are of the range of 3 mm. The same rate has been calculated for the horizontal geophones. The calculated average ground acceleration has been evaluated at 0.00024 g.

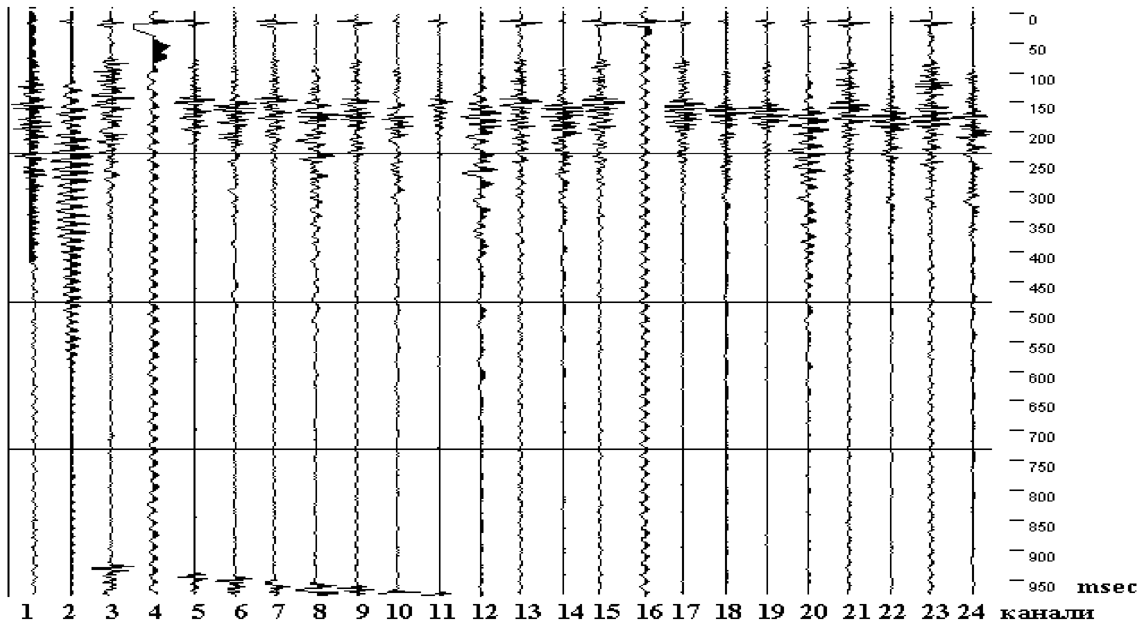

Fig. 1 Seismic records of the explosion in the hole along seismic profile No 1. The impair channels are related to vertical geophones, the pair channels are related to horizontal geophones. The first and the second geophones are inside the cave of "Dushnika".

Synthetic seismogram

The synthetic seismogram was made using the record of the 2nd channel inside the cave of "Dushnika". Grouped 10 blasts with a consecutive time delay of 25 ms between them was imitated (Fig. 2). The acceleration was calculated for the whole length of the synthetic seismogram. The comparison with the assessed acceleration from the earthquakes impacting on the discharge regime of the springs has shown that the grouping of the explosions with a time delay of 25 ms can impact the area of the springs with accelerations 40 times lower than these from the earthquakes. The velocity of the ground displacement is 14 time lower from the critical value of 5 cm/s, calculated for grouped blasts.

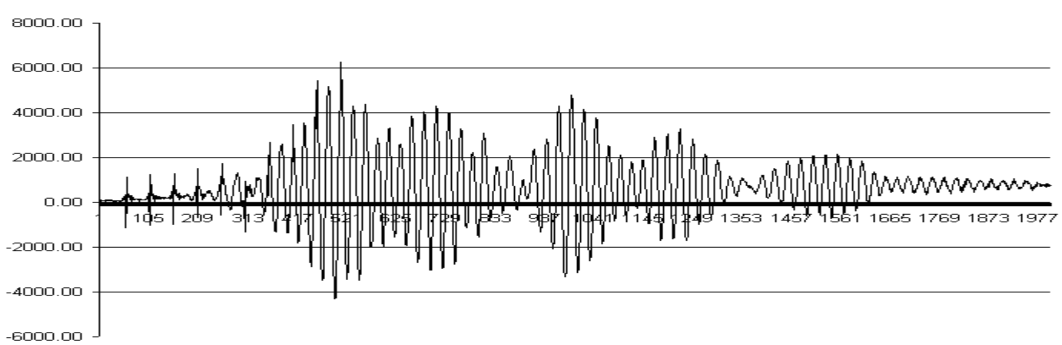

Fig. 2 Synthetic seismogram after 10 time overlapping with a time delay of 25 ms of the real data from the vertical geophone in the cave of “Dushnika”. The seismogram is imitating grouped blasts in 10 holes, everyone of 30 kg of explosive.

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