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DELPAT APPLICATIONS AND GROUND VIBRATION ANALYSIS CAUSED BY BLASTING AT EXCAVATION OF BOYABAT DAM AND H.P.P. CONSTRUCTION

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ABSTRACT

DelPat program makes possible to design of blasting operations and cost estimation with ground vibration analysis arising from blasting. In this study, these applications of DelPat program were used for blasting works in excavation of Boyabat Dam and H.P.P. (Hydroelectric Power Plant) construction and the results were researched extensively. Blasting design was done and the results of planned blasting works and ground vibration measurements were analyzed by use of DelPat. At the end of some shots, 35 events were recorded by ground vibration monitors and the data which taken from these measurements were evaluated and ground transmission coefficient and specific geological constant were determined. Thus, the equation of site specific ground vibration prediction was asserted.

In the result of this study, it is shown that the applicational results are in accordance with the estimations which DelPat made before the blasting. Thus, it's demonstrated that DelPat could used confidently in blasting design, analyses of blasting results and prediction of particle size distribution, ground vibration, air shock, fly rock and drilling-blasting cost.

Keywords: Drilling and Blasting, Computer Aided Design, DelPat

INTRODUCTION

The most important results that can be anticipated from a successful blasting can be sorted as eliminating the environmental problems developed in the form of seismic movements and air shock, reducing the costs of production, realizing the planned amounts of production and preventing the hazardous conditions in terms of work safety [1, 2].

In today's classical blasting design studies, because of these connected parameters cannot be evaluated quickly and correctly, the evaluation of the results like guidance the studies, costs, vibration and particle size distribution all together is hard and time-consuming process. This implementation causes some problems such as arising cost of blasting, environmental problems induced by blasting, arising cost of loading, carrying, hauling and primary crushing due to the fact that this method is inadequate in terms of blasting design optimization. Therefore, a design approach must be optimized by taken into consideration with all these results. For this aim, there are some computer programs [3, 4, 5, 6, 7] which could use for blasting optimization. In this study, DelPat software which is one of the lots of package programs of blasting design was used in a case study. The previous studies which were done by Celiksirt & Erkan [8, 9] used old version of DelPat.

In this application of DelPat program, it was used to design and analyze blasting works in excavation of Boyabat Dam, H.P.P. (Hydroelectric Power Plant) construction and the results were researched extensively. Blasting design was done and the results of planned blasting works and ground vibration measurements were analyzed by using DelPat.

TEST SITE

Location

Boyabat Dam and H.P.P (Hydroelectric Power Plant) Project is located 10 km south-west of the Duragan on Kizilirmak River and 65 kilometers away from the Black sea region in the Sinop-Boyabat in Turkey.

Figure 1. The location of the district and the satellite image of the quarry.

Geology

Boyabat Dam Site is located in a very steep and narrow canyon of Paleozoic-Mesozoic aged limestones and Kizilirmak River runs along this canyon. Canyon starts from 1 km upstream of dam axis and continues until 5 km downstream. In this canyon, there is Kepez formation at the bottom that is composed of metamorphic series (epidote-schist, chlorite-schist, clayey-schist, calc-schist, diabase-spilite and schistose limestone) in various characteristics. Metamorphic series are identifiable with a softer topography than limestone and there are thick slope wash - top soil on them. Limestone constituting the rock material areas and the canyon are olistoliths inside crystalline-semicrystalline metamorphic series, lenticular, surrounded by schist in most places, extensively faulted and in schistose structure. At the boreholes drilled in the dam site, thickness of this limestone is found to be more than 500 m in some places. In Kizilirmak riverbed, generally, there is alluvium present reaching a maximum depth of 40 m and it is composed of gravels with fine sand. Gravels are originated from serpentine, radiolarite, limestone and volcanic rocks and are rounded-semirounded. Paleozoic- Mesozoic aged limestones near the dam site are gray-blue gray, beige in color, massive, fresh-slightly weathered, semicrystalline, slightly jointed, frequently fractured in some places and moderately strong [10].

Laboratory Tests

In consequence of laboratory tests of rock mechanics, point load and uniaxial compressive strength tests state that strength of rock was ranging between q_u= 200 - 400 kg/cm^2, and the rock was generally "moderately strong" and less frequently "weak". The average uniaxial compressive strength of limestone was determined as (q_u) = 315 kg/cm. Accordingly, rock can be accepted as 'moderately strong'. Although there is not a definite limit value in DSI and TCK specifications about this, it is known from the general idea that values 300 - 350 kg/cm^2 would be sufficient for concrete aggregate [10].

DELPAT APPLICATION

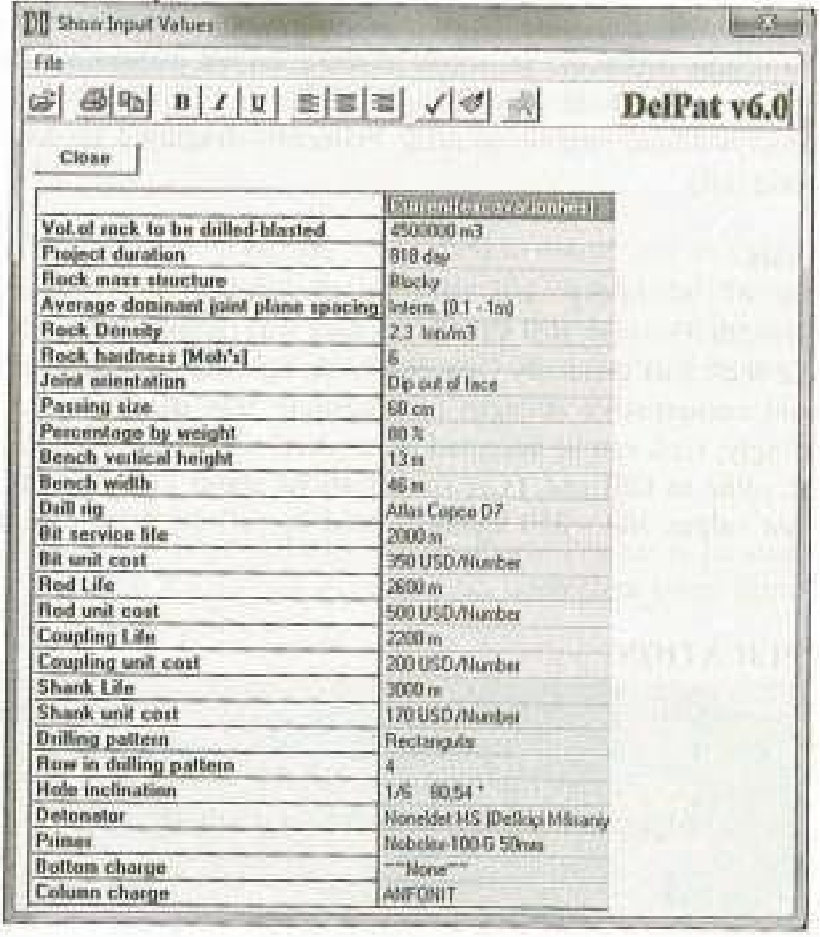
Boyabat dam's excavation process required blasting operations because of formation characteristics described above. Excavation by blasting was inevitable for not only production of aggregates of concentre but also dwelling both side of dam's body. For this purpose, DelPat program was used for design and result analyses of blasting.

Design Parameters

Total required excavation by blasting is determined as 4.500.000 m^3 in the course of project planning. The blasted material requirement of aggregate production which is need to be transport to concrete casting after feeding, crushing and sieving plant. Trucks are being used for transporting of mentioned materials. Primer crusher's feed gap is determined as 60 cm. Thereby; maximum block size for aggregate production is demanded less than 60 cm after blasting operations. From this point of view the input values were given in Figure 2, which were provided a basis for blasting design and analysing of results. The given input values are same for each shot. However, the width of blasting could give a variation because of different application area. These input values were adapted to program interface by refilling the form windows which are given in Figure 3. DelPat could calculate drilling-blasting design parameters for different hole diameters after the filling the form windows which is given in Figure 3.

Drilling and blasting designs were calculated for different hole diameters by using input values and the results for each hole diameter could be seen in summary reports window (Figure 4). The reports of site information, working arrangement and drilling performance values could created by clicking outputs screen's summary reports window's drilling reports tab (Figure 5).

Detailed information of blasting parameters and basic information about maximum particle size (Figure 6) also given in the same window mentioned above. These reports give drilling and blasting costs sequently for each rock excavation in cubic meter. DelPat program interface could create 3D view of blasting design (Figure 7) accordingly determined parameters.



	[illegible]
Vol.of rock to be drilled-blasted	450000 m3
Project duration	918 day
Rock mass structure	Blocky
Average dominant joint plane spacing	Interm. (0.1 - 1m)
Rock Density	2.3 ton/m3
Rock hardness [Moh's]	6
Joint orientation	Dip out of face
Passing size	60 cm
Percentage by weight	80 %
Bench vertical height	13 m
Bench width	46 m
Drill rig	Atlas Copco D7
Bit service life	2000 m
Bit unit cost	350 USD/Number
Rod Life	2600 m
Rod unit cost	500 USD/Number
Coupling Life	2200 m
Coupling unit cost	200 USD/Number
Shank Life	3000 m
Shank unit cost	170 USD/Number
Drilling pattern	Rectangular
Row in drilling pattern	4
Hole inclination	1/6 80,54 °
Detonator	Noneldet HS (Dellcipi Military
Primer	Nobelex-100 G 50mm
Bottom charge	***None***
Column charge	ANFONIT

Figure 2. Blasting design input values.

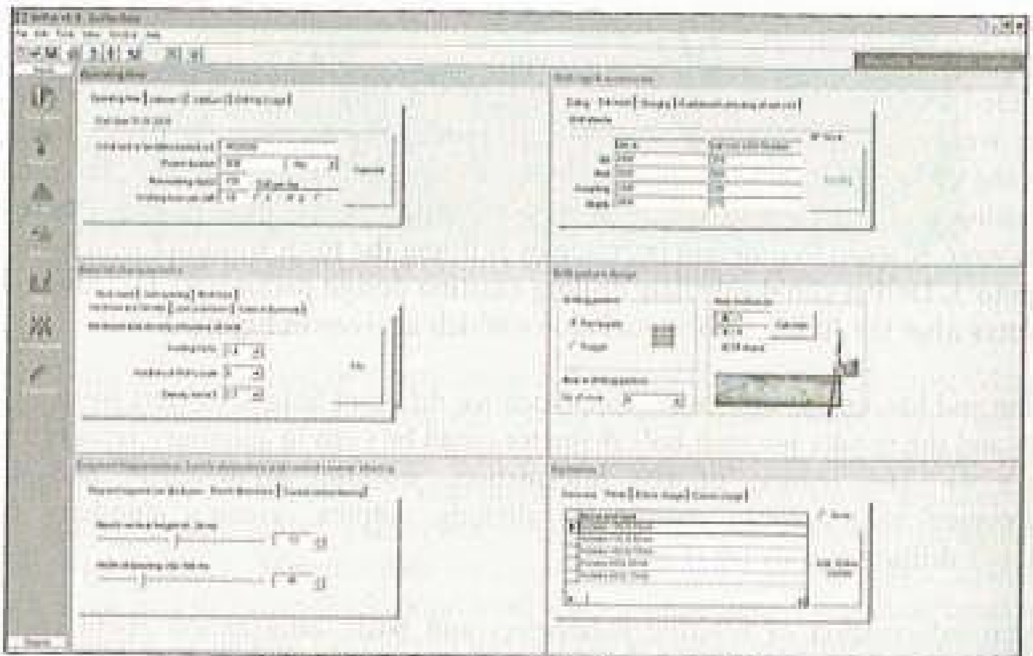


Figure 3. Information interface of DelPat.

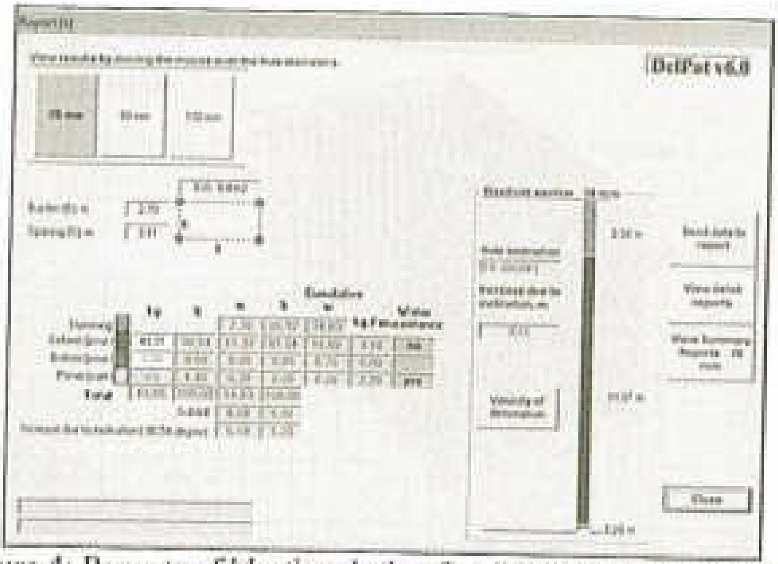


Figure 4: Reports of blasting design for different hole diameters.

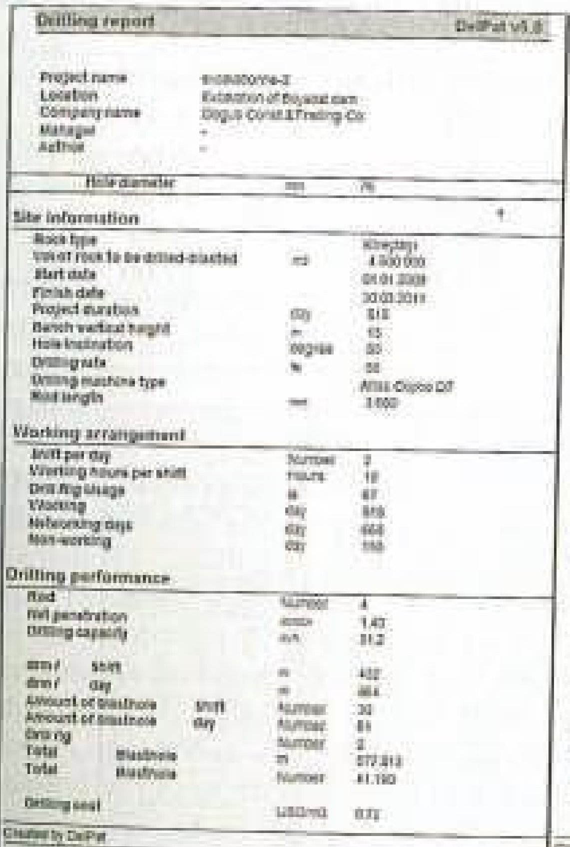


Figure 5: Drilling Report

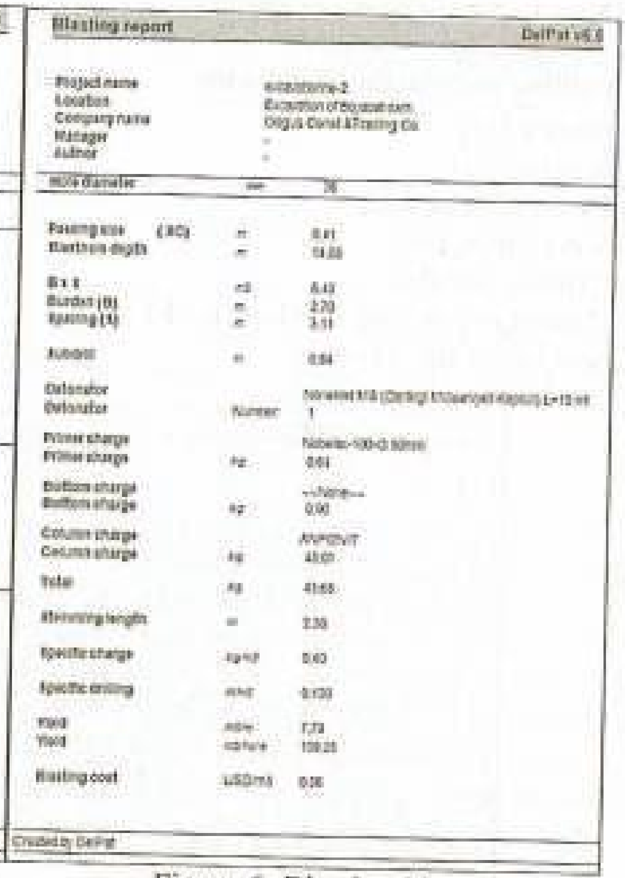


Figure 6: Blasting Report

The comparison of calculated and applied design values for 76 mm hole diameter is given in Table 1. The drilling and charging parameters which are given in Table 1 are used in all of the shots. However, the width of blasting area and bench height could give a variation because of different application area. Therefore, total holes number in one shot, amount of explosive and maximum charge for per delay could be different depending on the width of blasting area and bench height. Different delay pattern and surface delay sequence were simulated by using delay editing menu as a sample (Fig.8).

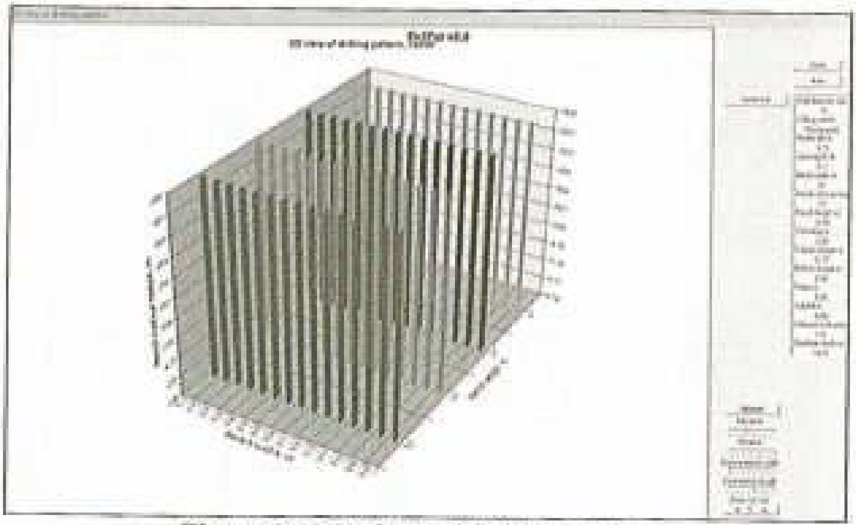


Figure 7: 3D view of drilling pattern.

Table 1: The differences between designed and actual drilling and blasting parameters for 76 mm hole diameter.

Drilling and blasting parameters	Designed by DelPat	Actual
Burden (m)	2.70	2.50
Spacing (m)	3.11	3.00
Hole depth (m)	14.03	14.00
Sub drilling (m)	0.84	0.80
Drilling rate (%)	55.00	57.00
Capacity of drilling machine (m/h)	31.22	32.00
Specific charge (kg/m^3)	0.40	0.40

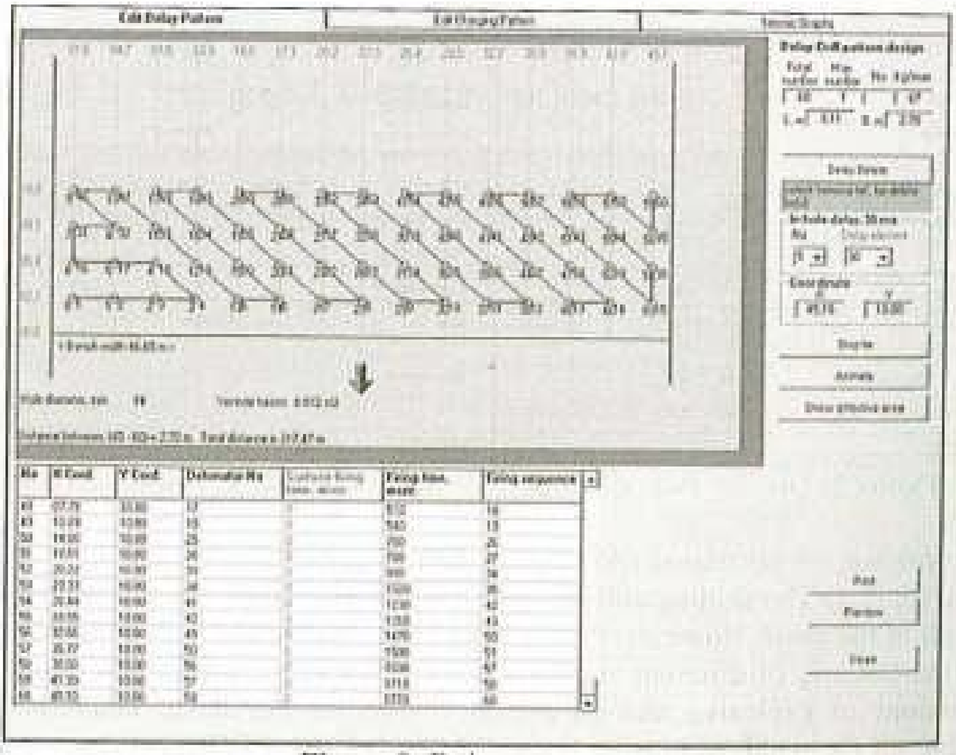


Figure 8: Delay sequence.

THE ANALYSIS OF RESULTS

Particle Size Distribution

The expected weight passing-block size graph is given in Figure 9 according to blasting design which was predicted by DelPat by using chosen holes diameter.

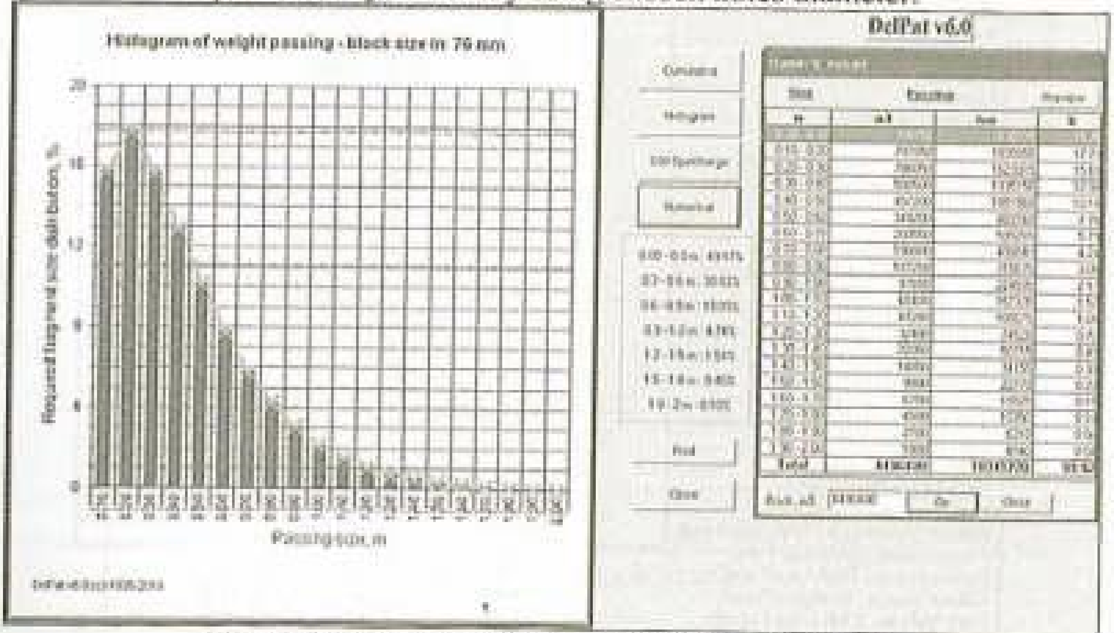


Figure 9: Histogram of weight passing - block size.

The pop-shooting ratio of blasted rock was %3-4 which showed that the particle size of blasted rock and primary crusher gap size were appropriated. In other words, the correspondences between applied and calculated particle size values were correct. This relation is proved with continually working of primer crushers.

Drilling-Blasting Organization

DelPat program has calculated that how much rock could produce in scale of desired particle size as volume (m^3), weight (ton) and percent of weight passing (%) (Figure 10). The amount of blasthole and rock volume couldn't be same for each shot because of the reasons mentioned above. Design parameters are same for all of shots. However, in some shots, the width of blasting area and bench height gave a variation because of different topographic conditions. Therefore, total hole number in one shot, blasthole length, amount of explosive and maximum charge for per delay could be different depending on the width of blasting area and bench height. The chart shows that the total production amount is quite few than the values which were calculated by DelPat program.

The calculated rock production was approximately 200.000 m^3 (Figure 10) for a month however, in practice it was resulted as 43.000 m^3 (Table 2). This is because of the dam construction's concrete casting operation was very slow. The blasting operations were applied for limited numbers due to stocking of blasted rock was not possible. Nevertheless, DelPat design values were applied for each shot along whole excavation operation. Under these circumstances, the drilling-blasting operations were eventuated as about 7 shots/month, 6.560 m^3/shot in April, 2010.

Organization of drilling-blasting

Description		Values
Hole diameter	mm	: 76
B x S	m2	: 2,7 x 3,11 = 8,4
Vol.of rock to be drilled-blasted	m3	: 4.500.000
Start date	Date	: 01.01.2009
Finish date	Date	: 30.03.2011
Working hour per shift	h	: 10
Working shift(s) per day	Shift	: 2
Project duration [Working + Non-working]	day	: 818 (668 + 150)
day(s) late [Working + Non-working]	day	: 840 (818 + 22)
Difference	day	: + 22 (18 + 4)
Networking days	day	: 686 (668 + 18)
Total Non-working	day	: 154 (150 + 4)
Alternative finish date [Working day(s) late]		: + 18 day(s) late: 17.04.2011
Drill Rig Usage(AxB)(%)	%	: (75 x 90) (%) = 67,5
Drilling machine type		: Atlas Copco D7
Drilling rate	%	: 55
Capacity of drilling machine	m/h	: 31,22
Drill rig	Number	: 2
Amount of drilling. [Shift/day/Total]	m	: 421 / 843 / 579.225
Amount of blasthole. [Shift/day/Total]	Number	: 30 / 60 / 41.190
Calculated Blast	Number/day	: 1
Required charging machinery	Number	: 0
Charging machine type		: ***None***
Mixing and charging capacity	kg/min	: 0
Amount of detonator, [Shift/day/Total]	Number	: 31 / 62 / 41.190
Primer charge, [Shift/day/Total]	kg	: 19 / 38 / 26.269
Bottom charge, [Shift/day/Total]	kg	: 0 / 0 / 0
Column charge, [Shift/day/Total]	kg	: 1.290 / 2.581 / 1.771.552
Rock Volume, [Shift / day / month]	m3	: 3.280 / 6.560 / 196.793
Rock Volume, [Shift/day / month]	ton	: 7.549 / 15.098 / 452.946
Blasted rock (swelling) x1,4, [Shift / day / month]	m3	: 4.592 / 9.184 / 275.510
Blasted rock (swelling) x1,4, [Shift / day / month]	ton	: 10.569 / 21.137 / 634.124
Drilling cost	USD/m3	: 0,72
Blasting cost	USD/m3	: 0,56
Tot cost	USD/m3	: 1,28

Created by DelPat v6.0

Figure 10: The report of organization of drilling-blasting.

Table 2: Amount of total blasted rock.

General Total of Primer Feeding

Month	Mercedes truck tonnage	Scania truck tonnage	Volvo truck tonnage	Ton	m^3
December (2009)	19.460	11.935	760	32.155	12.862
January(2010)	17.260	20.055	750	38.065	15.226
February(2010)	1.220	31.815		33.035	13.214
March(2010)	45.740	69.230		114.970	45.988
April(2010)	39.280	68.600		107.880	43.152
Total	**122.960**	**201.635**	**1.510**	**326.105**	**130.442**

Air Shock and Fly Rock

The program has created the air shock wave line (Figure 11) as a function of distance for 76 mm hole diameter by using maximum charge weight values and damage criteries are also given in Figure 11 as legend. Maximum travelling distance of flyrock line as a function of blasthole diameter for specific charge values is given in Figure 12.

The observed air shock and fly rock values caused by blasting were appropriate with theoretical predicted values by DelPat.

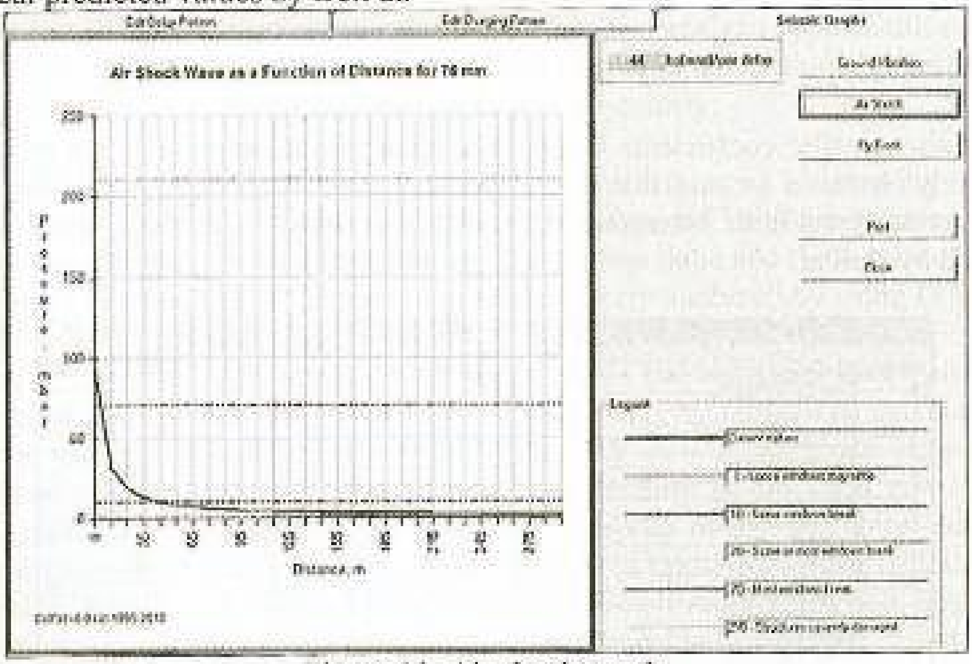


Figure 11: Air shock graph.

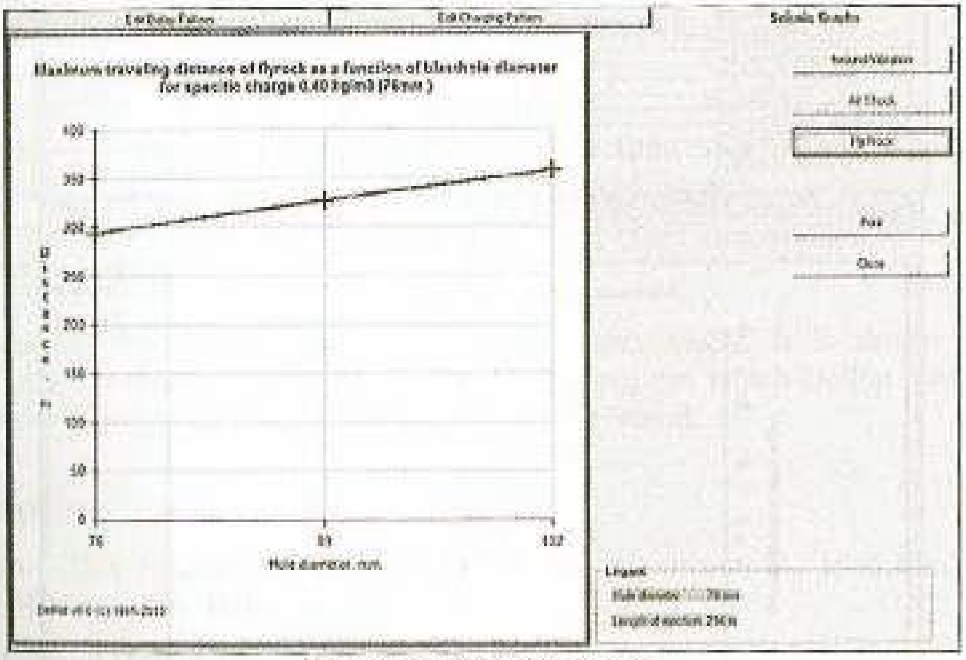


Figure 12: Fly rock graph.

Ground Vibration

During the field study, 35 events at the site were monitored and ground vibrations caused by blasting were measured by using ground vibration monitor. In the results window's daily report section, each blasting parameter and each vibration report were recorded. 35 events were recorded and added to program then the PPV-SD chart was created by DelPat interface (Figure 13). The logarithmic-power regression analysis was done by DelPat and site specific ground vibration attenuation formula was obtained. As a result of these analyses, it was seen that acceptable correlation was given by eq. 1.

$$PPV = 85 \times SD^{-0,75} \qquad (r = 0,73) \qquad (1)$$

K and β site specific coefficients empirically obtain from equation 1. are 85 and 0,75 respectively. It could be said that this correlation coefficient could represent the site. Charge per delay could be determined by using these site specific coefficients which are calculated by DelPat.

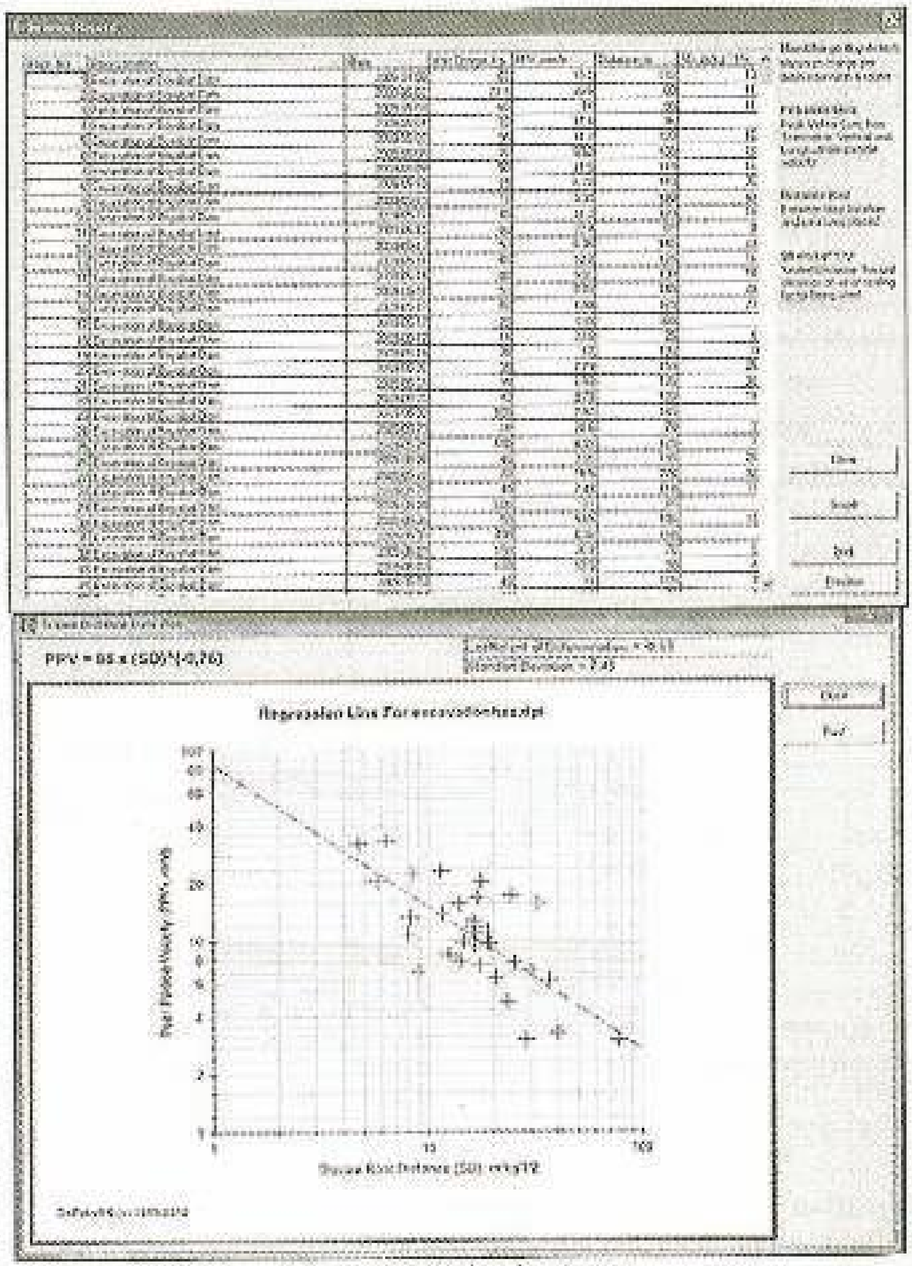


Figure 13: Seismic report.

CONCLUSIONS

In today's classical blasting design studies, because of these connected parameters cannot be evaluated quickly and correctly, the evaluation of the results like guidance the studies, costs, vibration and particle size distribution all together is hard and time-consuming process. These problems are partially removed with developments in computer technology. Use of computer aided design and analyze opportunities provides blasting engineers rapid designs, estimating the results of their designs, recording the blasting data daily and analyze the blasting cost continuously.

In this study, these applications of DelPat program were used for blasting works in excavation of Boyabat Dam, H.P.P. (Hydroelectric Power Plant) construction and the results were researched extensively. Blasting design was done and the results of planned blasting works and ground vibration measurements were analyzed by using DelPat. The trucks were weighed for particular time periods. The amount of feeding of crushing-screening plant was calculated through truck load. The weighed load values have demonstrated that the calculated values by program were accurate. The calculated rock production was approximately 200.000 m^3 (Figure 10) for a month however, in practice it was resulted as 43.000 m^3 (Table 2). This is because of the dam construction's concrete casting operation was very slow. The blasting operations were applied for limited numbers due to stocking of blasted rock was not possible. Nevertheless, DelPat design values were applied for each shot along whole excavation operation. Under these circumstances, the drilling-blasting operations were eventuated as about 7 shots/month, 6.560 m^3/shot in April, 2010. The logarithmic-power regression analysis was also done by DelPat and site specific ground vibration attenuation formula was obtained. As a result of these analyses, it was seen that acceptable correlation coefficient ($r = 0{,}73$) was given by equation 1.

K and β site specific coefficients empirically obtain from equation 1. are 85 and 0,75 respectively. It could be said that this correlation coefficient could represent the site. Charge per delay could be determined by using these site specific coefficients which are calculated by DelPat.

In conclusion, the DelPat design was applied successfully. It is shown that the applicational results are in accordance with the estimations which DelPat made before the blasting. Thus, its accuracy and reliability are confirmed.

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