Safe Blasting Near the Historical Caves of Tourah, Cairo, Egypt.

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ABSTRACT:

A number of blasts using specific blasting techniques were performed at the limestone quarry of Tourah Portland Cement Company (TPCC), to assess the blast vibrations. Initially, the amplitude of vibration velocity was measured at both of Near-Field and Far-Field, and then the attenuation rate of peak particle velocity (PPV) in relation to distance was calculated. Later the study was extended to include the effect of azimuth at different profiles, and the data were analyzed and contoured into a map covering the quarry area. Using contour map, the effect of azimuth and its attenuation rate at different directions could be predicted.

This study helped TPCC limestone quarry not only to be remained opened, but also to be extended, through convincing the authorities that, the blasting operations at TPCC limestone quarry are safe, regarding these nearby caves. The authors found that, the authorities restrictions are unreasonably low, needlessly increasing the cost of the blasting operations, and decreasing the quarry productivity.

1 INTRODUCTION:

There are four large cement factories, located nearby Cairo metropolitan. Blasting operations are used to extract the limestone from their quarries for cement industries. All the quarries have to keep the blast vibrations under control. The oldest quarry of these is TPCC limestone quarry owned by Italcementi Group, which lies near to some historical caves, within Tourah Mountain as shown in Figure (1).

Some previous blasting produced high PPV values, upsetting the local authorities, which express concern about caves stability during the future blasting. In 2005 TPCC recognized the need for advanced drilling and blasting. They elected ASEC Company for Mining "ASCOM" as a company that specializes in quarry management throughout Egypt and Middle East.

Fig. (1) Tourah caves.

A three similar deck charges were designed in the blast hole of the lower bench with 55.0 m, while only two deck charges for the upper bench with 35.0 m height. In each deck, the maximum instantaneous charge weight is 20 kg of gelatin dynamite (primering), and 180 kg ANFO (blasting agent), to keep the total explosive charge per blast not more than 3 ton, to comply the local authorities restrictions, as illustrated in Figure (2).

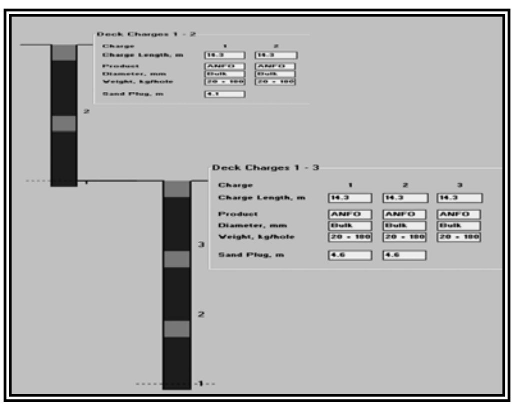

Fig. (2) Charging Plane.

2 LOCATION AND GEOLOGY:

The limestone quarry of TPCC is opened at the southwestern foot slopes of Tourah Mountain, which forms the eastern high escarpments overlooking the Nile River, and situated 23 km south of Cairo, on Maadi - Helwan road, as in Figure (3), geologically this area belongs to Mokattam Formation (Middle Eocene).

The quarry deposit is mainly composed of thick bedded limestone, mostly earthy white to faint yellow in the upper 60.0 m, turning to grayish yellow and grey downwards. In the upper 60.0 m, two segments of 4.0 m each are composed of nodular limestone. The hardness of the limestone deposit is considerably varying from moderately hard to very hard. Fissures are more frequent in the upper bench and less downwards. Most of these fissures are filled with iron oxides and siliceous materials. The noticeable structures in the area are a group of step faults running east-west, and perpendicular to the investigated site.

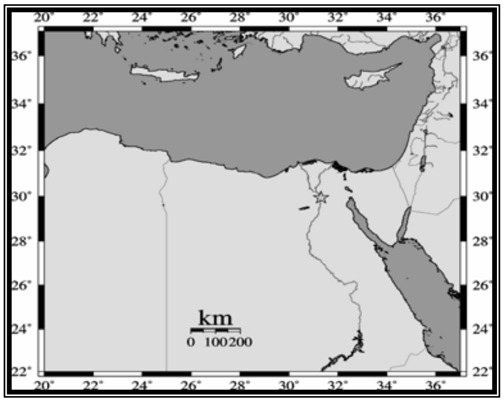

Fig. (3) Location map of the investigated site.

3 QUARRY OPERATION:

TPCC limestone quarry faces form more or less semi-circular shape, with a circumference of 2.8 km. The quarry is consists of two benches, the upper bench varying in thickness, depending on the surface topography with average 35.0 m. while the thickness of the lower bench attains approximately 55.0 m, as shown in Figure (4).

The limestone is excavated by drilling and blasting. The material blasted from the upper bench is pushed by bulldozers from bench down to the quarry floor, and all loading and hauling operations are performed at the quarry floor. In order to keep the upper bench suitable as a drilling and blasting bench, its width is constantly kept narrow, and ranging between 5 to 10 m.

Fig. (4) TPPC Limestone Quarry Benches.

4 INVISTIGATION PROGRAM:

The local authorities arranged many restrictions for the blasting operations in TPCC limestone quarry, in order to protect Tourah caves from blasting vibrations. One of these restrictions is lowering the maximum explosives charge to 3 ton per blast, and the maximum permitted (PPV) is 5.0 mm/second. In order to negotiate with the local authorities about their restrictions, a long term investigations program have been established and preformed by "ASCOM" since 2006, in three steps, as following:

- The objectives of the first step (previous study) were to derive the optimum time intervals, and the effect of using certain appropriate initiation (top or bottom), which could then be employed to minimize PPV produced in both upper and lower benches. It is also highlighted the advantage of using non-electrical detonators, (for the first time in Egypt) in comparison with the conventional electrical detonators. Also the scaled distance at the maximum permitted PPV value was calculated. The results were previously published in 33rd ISEE Conference (Khaled et al., 2007).

- It was planed that the second step (present study) would be to calculate the attenuation rate of PPV in relation to distance, at both Near-Field and Far-Field. Then the study was extended to include the effect of azimuth at different profiles and contouring PPV values into maps covering the quarry area. Using these maps the azimuth effect and the attenuation rate of PPV on different directions, at Tourah caves could be predicted.

- While the investigation protocols pointed that the next logical step will be to study the advantages of using electronic detonators (for the first trial in Egypt) in minimizing PPV values.

5 ATTENUATION EFFECT:

Series of blasts were monitored with four digital strong motion instruments (REF TEK-130 SMA), deployed in a linear array, in order to estimate the attenuation rate of PPV (decreases in vibration amplitude with distance), in both of Near-Field and Far-Field, at distances of (30 – 100 m) and (500 – 900 m) respectively from the shot-point.

All blasts are similar, to great extent, in the burden (6.0 m), spacing (8.0 m), hole diameter (165.0 mm), and deck charge weight loadings (200 kg). The key variables were the different detonators timing intervals and the initiation system (electrical and non-electrical detonators), also some blasts were bottom initiated, while others were top initiated. Different blasting techniques were used, as the attenuation rate of PPV is related mainly to the effect of local geological conditions of the site, and not to the type of the used technique.

5.1 Near – Field Attenuation:

Four blasts were preformed at the Near-Field of the shot-point. The value of attenuation rate of PPV in the upper bench was calculated from the best-fit equation in Figure (5), and it was - 1.15. While in case of the lower bench the attenuation rate of PPV was - 0.32, as in Figure (6). It is noticed from the above figures that, the attenuation rate in the upper bench is greater than in the lower bench. This is because the limestone in the upper bench is anisotropic and fissured, so its absorption of seismic energy is very high. While the low rate of attenuation of PPV in the lower bench can be attributed to the compacted characteristics of limestone in the lower bench. Moreover, the geometrical spreading minimizes the seismic energy density as the distance from the shot-point increases. This is matched well with the previous study.

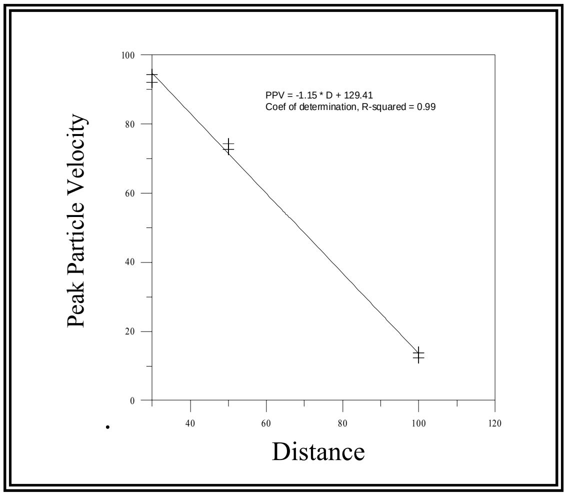

Fig. (5) Near-Field Attenuation of PPV for the upper bench.

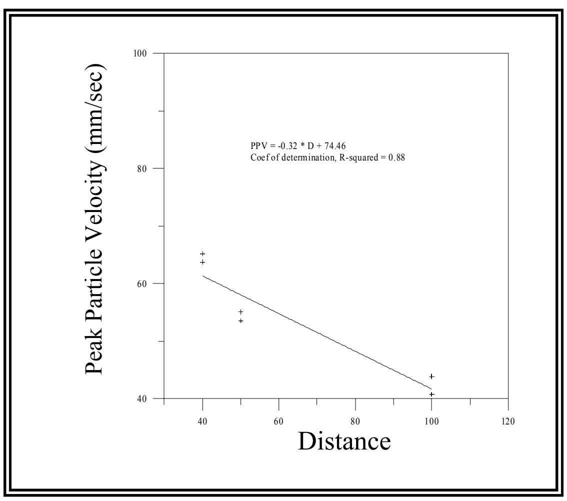

Fig. (6) Near-Field Attenuation of PPV for the lower bench.

5.2 Far – Field Attenuation:

The wave motion spreads concentrically from the blast site, particularly along the ground surface, and is therefore attenuated, since its fixed energy is spread over a greater and greater mass of material as it moves away from its origin. Even through it attenuates with distance the motion from a large blast can be perceived from faraway, (Dowding 1985).

Ten blasts were preformed in the Far-Field of TPCC limestone quarry, and divided between the quarry benches (upper and lower). Figures (7) & (8) showed the following observations:

- The attenuation rate of PPV in the Far-Field was - 0.003 at the upper bench, and is not significantly different from that of the lower bench. This may be reflects the minor influences of the geological conditions of limestone between the upper and lower benches.

- The attenuation rate at distance about 700 m from the shot-point decreased abruptly, and this may be attributed to the presence of a topographically low area (wadi), at this distance.

- The values of attenuation rate of PPV were sharply decreased in the Near-Field, than the Far-Field, due to the effects of the geometrical spreading and the absorption factor of the seismic energy within the limestone deposit of upper bench.

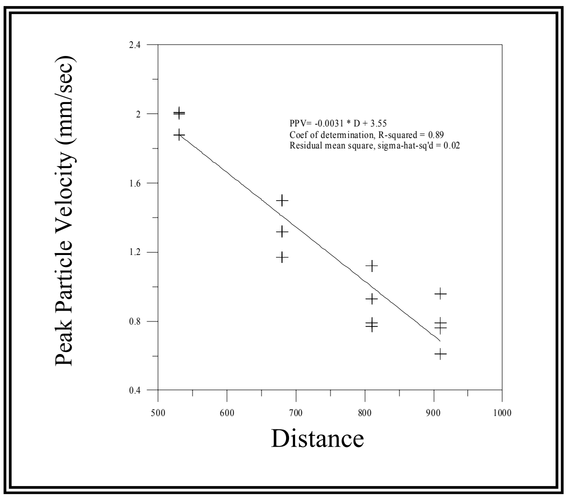

Fig. (7) Far-Field Attenuation of PPV for the upper bench.

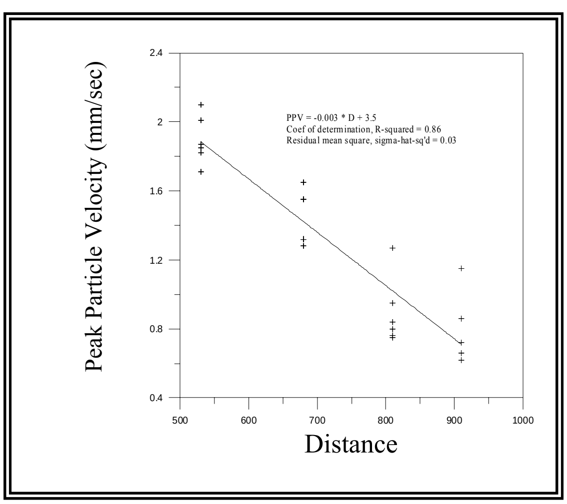

Fig. (8) Far-Field Attenuation of PPV for the lower bench.

6 AZIMUTH EFFECT:

Series of other blasts were recorded by three component velocity sensors (Instantel-Minimate Blaster), installed at a constant distances (100, 150 and 200 m) from the shot-point, along azimuthally different profiles radiated from the quarry face. A standard blast design was selected in order to define the direction of yielded optimum PPV values. All blasts were initiated by non-electrical system, with an inter-deck timing 25 millisecond, and an inter-hole timing 42 millisecond.

It is evident from the distribution of data in Figures (9) and (10), that there is no clear relationship between the azimuth and the resulted PPV values in all directions. This means that, the radiated energy from each blast not equally transferred in all directions, and this reflects the heterogeneity of the deposit, especially in the upper bench.

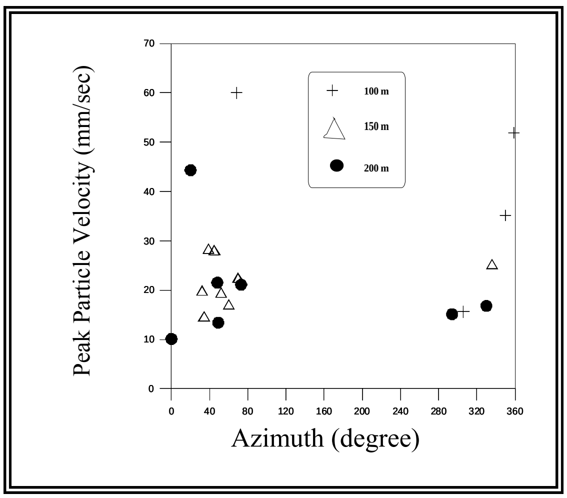

Fig. (9) Relationship between azimuth and PPV for the upper Bench.

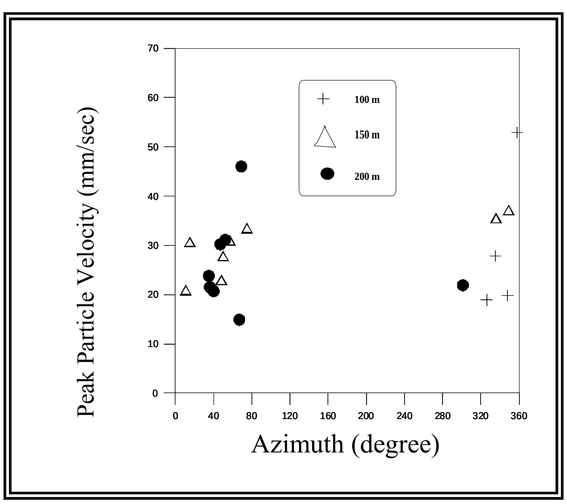

Fig. (10) Relationship between azimuth and PPV for the lower Bench.

Aimone-Martin (2007) stated that, the variation in attenuation in the different directions is not statistically significant and does not warrant special regulatory consideration. This is well correlated with our observation.

This reflects the different factors that constitute the azimuth effects as following:

- Presence, frequency and directions of fissures and joints in the investigated site, as well as the type of fissure filling materials affected the values of PPV, and its rate of attenuation.
- Elevation of the measuring points; some times there is a direct relationship between the values PPV and the sensor elevation.
- Type and thickness of the over-burden materials; as the thickness of loose materials increased, the PPV values tended to be minimized.

7 SCALED DISTANCE:

Scaled distance is defined as the dimensionless parameter for distance. It is derived as a combination of distance and charge weight influencing PPV value.

$$PPV = \frac{K}{\left(\frac{R}{\sqrt{W}}\right)} \alpha \quad \text{...(1)}$$

The above equation depended on two constant factors. Where (K) represents the initial energy transformed from explosives to the surrounding rocks, and it is the line intercept at Scaled Distance = 1 on log-log graph, and (α) represents the attenuation rate of PPV, and it is the slop of the fitting line. The (W) and (R) are the maximum explosive charge per delay, and the distance from shot point respectively.

To assess the azimuth effect on the PPV values and its rate of attenuation, for the upper bench, the above mentioned constants have been determined for two curves represent both of NE and NW directions. This was found to be more precisely than one curve for the whole area.

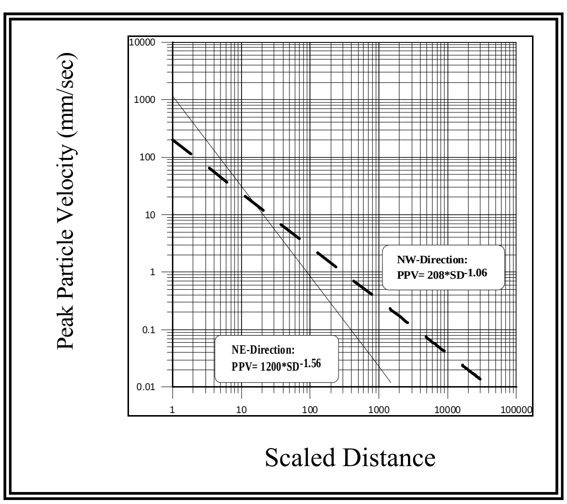

Fig. (11) Scaled Distance for NE & NW directions.

From Figure (11) the following, equations were derived.

NE – direction: $PPV = 1200\ (R / \sqrt{W})^{-1.56}$……….(2)

NW – direction: $PPV = 208\ (R / \sqrt{W})^{-1.06}$……….(3)

The predicted values of PPV have been calculated at different distances along both profiles, Figure (12). It is evident that the NE direction yields significantly high PPV value, combined with high rate of attenuation. This means that, the PPV value was initially higher at NE than NW direction, and then abruptly decreased.

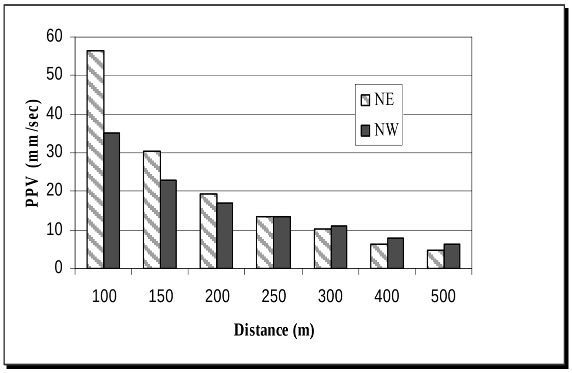

Fig. (12) Predicted PPV values for NE & NW directions.

8 PPV CONTOUR MAPS:

The above significant variations in PPV and its rate of attenuation at NE and NW directions, encouraged authors to collect all the measured data, in order to conduct contour maps for both of upper and lower benches, at TPCC limestone quarry, as in Figures (13) & (14).

These maps help for the prediction of PPV value at any location, in case a suitable instrument is not available, as well as the attenuation rate of PPV at any profile can be easily estimated.

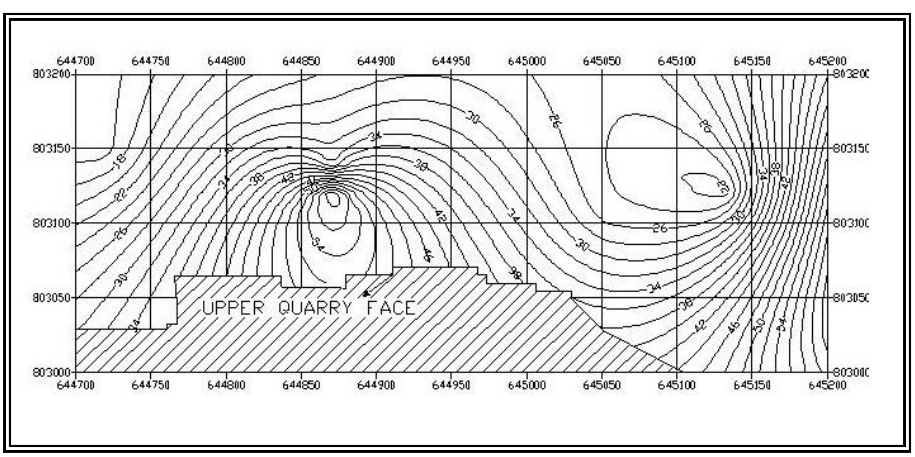

Fig. (13) PPV Contour Map for the upper bench.

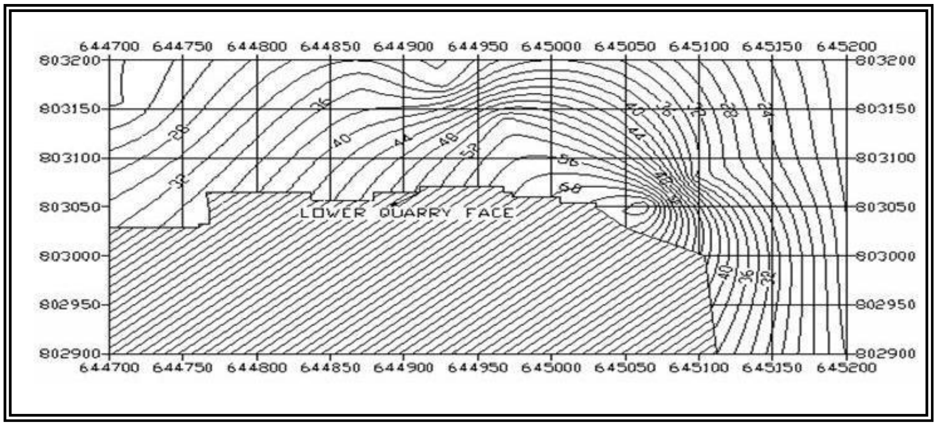

Fig. (14) PPV Contour Map for the lower bench.

9 CONCLUSIONS:

Authority's constraint will restrict more and more blasting works in TPCC limestone quarry. So, vibration study is of great importance for the elimination of authorities problems. From studying the attenuation rate of PPV with distance, it is concluded that;

- Near-Field, for the upper bench: - 1.15
- Near-Field, for the lower bench: - 0.32
- Far-Field, for both of upper and lower benches: - 0.003

This difference in the attenuation rates between the upper and lower benches is due to the presence of anisotropic and fissured limestone in upper bench, so its absorption of seismic energy is very high.

It is also highlighted from the distribution of PPV data that, there is no statistical significant effect of the azimuth on PPV values, which is support the heterogeneity phenomena of the limestone deposit.

By applying the concept of the scaled distance, the constants of (K) and (α) have been determined separately for the NE and NW directions, as following;

- NE direction: (K) = 1200, and (α) = 1.56
- NW direction: (K) = 208, and (α) = 1.06

It is noticed, that the NE direction yields significantly high PPV values, combined with high rate of attenuation. This means that, the PPV value was initiated high in NE than NW direction, and then abruptly decreased. In consequently, TPCC limestone concession can be extended safely in the NE direction.

All the PPV measured data were employed to conduct contour maps for both of upper and lower benches, at TPCC limestone quarry. These maps help in the prediction of the PPV values at different locations, when a suitable instrument is not available in the site, then the attenuation rate of PPV for any profile can be easily estimated.

Based on the results of this study, the presence of fissures in the upper bench, leads to increase in the attenuation rate of PPV, then the creation of an artificial fissure plane in the lower bench is recommended to increase its absorption for ground vibration.

A line of Pre-split blast is recommended to create an artificial fissure plane at the distance of 305 m, from Tourah caves, which previously calculated as the minimum safe distance. The Pre-split line forms as L-shape, where it's longer arm parallel to the cave and running EW direction. While the shorter one perpendicular to the caves in the quarry direction, and running NS direction. Therefore, the ground vibrations will be absorbed in both directions.

To design the Pre-split line, a total of 169 blast hole is required, with 1.25 m hole spacing, and blasted in groups. The number of blast holes in each group will be 13 holes, initiated instantaneously, each hole fired with 14.8 kg of gelatin dynamite (cartridge), and taped with detonating cord. The cartridge length is 0.40 m, and the following 0.40 m will be left as spacing between the cartridges. Ten groups will be blasted in the longer arm, with 162.5 m length, while 2 groups will be in the shorter one, with 48.75 m length.

The blast holes of the Pre-split will be drilled from the top surface of the quarry to the full depth of both benches, while only the lower 60.0 m will be charged according to the above system. By this procedure, the Pre-split will create artificial planes in the lower bench equivalent, to large extent, to that of the upper bench.

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References:

- Aimone-Martin, C. 2007 "Development of An Urban Blasting Ordinance for the City of Hendrson, NV" Vol. 1, Proc. 33rd Ann.Conf. Explosives and Blasting Tech; ISEE.

- Dowding, C. H., 1985, "Blast Vibration Monitoring and control", Prentice-Hall, INC., NJ.

- Farag, I.A.M. and Ismail, A. 1959 “Contribution to the Stratigraphy of the Wadi Hof area (northeast of Helwan)”. *Bull. Fac. Sci.,* Cairo Univ., 34, pp. 147-168.

- Khaled, M.; Abdel Rahman, K. and Makarem, A. 2007 "Experimental Techniques To Reduce Blast Vibration Level, Tourah, Cairo, Egypt." Vol. 1, Proc. 33rd Ann.Conf. Explosives and Blasting Tech; ISEE.

- Persson, P.; Holmberg, R. and Lee, J. 1994 "Rock blasting and Explosives Engineering", Library of Congress, Cataloging – in- publication data, 551 p.

- Singh, V. and Singh, T. 2006 " Safe blasting near important civil structures: A case study" Vol. 1, Proc. 32nd Ann.Conf. Explosives and Blasting Tech; ISEE.