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STRESS LEVEL ESTIMATION FOR THE GROUND BENEATH THE 15TH OF MAY CITY BUILDINGS, HELWAN, CAIRO, EGYPT

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Abstract- The quarry blasting is one of the artificial explosions that produces stresses in the ground and may have a great effect on the near foundations. The estimation of the stress level either in the weathered or the foundation layers is necessary for the safety of the existing buildings near the quarries.

Cement Companies has been in operation long time ago close to Helwan City. Since then, new buildings and new communities were established in the area, as the 15th of May community. For the safety of these buildings and the new communities, the detailed and continuous monitoring of the peak particle velocity of the quarry blasting operations was carried out since Jan. 1997 up till now. This is in order to define the stress level of the P- and S- waves in the weathered and the foundation layers.

The maximum values of the stress level for the weathered layer has been found smaller than that for the foundation layer for both the P- and S - waves. The damage observed in the buildings close to the quarry blasting operations, indicates that these stress levels are high.

INTRODUCTION

The detonation of an explosive charge in the rock gives rise to a strong initial shock wave, which then decays, into stress waves in the surrounding rock. For a borehole fully charged with a strong explosive, the initial shock wave pressure exceeds the strength of the rock, and a very complicated shear deformation pattern occurs which ultimately leads to crushing of the rock around the hole. As the wave moves radially out from the borehole, the amplitude (pressure) decreases and the wave become a purely elastic compressive wave, the P-wave. Additional waves, S -wave and the Rayleigh wave, are formed as a result of the interaction of the P-wave with the free surface.

When the wave strength in this far-field are discussed, it becomes useful to use the peak particle velocity as a measure. Certainly, very close to the charge, the stresses are highly enough to cause cracking and crushing of the homogeneous rock material between joints. The maximum tensile or shear stress in homogeneous rock increases approximately as the square root of the charge diameter and decreases approximately linearly with increasing distance from charge (Persson et al,1994).

However, by applying the experience gained from the study of ground vibrations and the associated rock damage in the real life rock blasting, reliable predictions have been able to made surprisingly, where incipient rock damage will occur some distance away from a given charge. The vibration particle velocities in the near region around an extended charge can be estimated, taking into account the influence of nearby free surface. The calculated velocity values are used to estimate the tensile stresses and rock damage.

GEOLOGICAL SETTING AND GROUND PATTERN

The 15th of May community lies in the northeastern side of Helwan City and it represents in the same time the northeastern extension of Helwan buildings. It is built on a rocky lowland or platform of the Middle and Upper Eocene rocks (Said, 1962 and CONOCO, 1987). These rocks belong to Gebel El – Mokattam that represents a hill that borders the eastern part of Cairo City. Farag and Ismail (1959) studied the Lower Mokattam section (Middle Eocene) in the area to the south of Gebel El- Mokattam in the eastern cliffs of Helwan . They found that this section consists of white limestone and subdivided it into; El-Qurn Formation; Observatory Formation (typically developed at the plateau of Helwan Observatory) and Gebel Hof Formation (typically developed at Gebel Hof cliffs). While upper Mokattam section that belongs to Upper Eocene and consists mainly of red-brown limestone was subdivided also into; Wadi Hof series (particularly developed at Wadi Hof graben) and Wadi Garawi series (especially developed throughout the area between Wadi El- Gibbu and wadi Garawi). Wadi El-

Gibbu represents the main quarry for the Helwan Portland Cement Company, while Wadi Garawi constitutes the mother source for the National cement company.

DATA COLLECTION AND PROCESSING

Detailed and continuous monitoring of the quarry blasting operations that carried out by the National and Portland–Helwan cement companies from Jan. 1997 till now have been studied intensively. The continuous monitoring were carried out using three units of Strong Motion Accelerographs, which are placed, in three sites within the buildings and near to the quarry blasting at the same time. One of these sites lies inside the quarry itself to monitor the exactly values of peak particle velocity that results from the blasting operations. While the other two are distributed in the near buildings with a geometrical pattern around the first one and at the same time near to quarry blasting operations. These Peak Particle velocity values have been subjected to processing methods and corrections in order to achieve the original values of peak ground velocities.

STRESS LEVEL ESTIMATION

Over the last 30 years, the number of quarries of both the governmental quarries for the cement companies and the private ones are increased covering a large areal extension in and around residential areas. Hence the amount of dynamite charges is increased also, therefore it is expected that the propagation of the stress waves is extending to a large distance away from the borehole. Further more, these blasting have mainly been done without taking into consideration a certain vibration level smaller than a safety margin in order to avoid the buildings damage.

By means of vibration measurements and damage surveys in adjacent buildings, a relationship between the peak particle velocity and the possible risk for damage has been established. This has increased the need for vibration measurements and in turn facilitated the management of blasting work in order to prevent damage. Control of the particle velocity is important, as it has shown to be directly proportional to the stress level to which the ground material beneath the building as well as the building material is exposed. The relationship between peak particle velocity and the stress in an idealized case, when a plane shock wave passes through an infinite elastic medium, can be expressed as (Persson et al, 1994):

$$\sigma = \varepsilon \mathrm{E} \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ (1)$$

$$\varepsilon = {}^{v}\!/_{c} \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ (2)$$

$$\sigma = {}^{v}\!/_{c}\, \mathrm{E} \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ (3)$$

where, σ is the stress, ε is the strain, E is the modulus of elasticity, v is the peak particle velocity and c is the propagation velocity of the seismic wave.

The formulae indicate that the propagation velocity of the wave is very important, for a given underground rock mass on which a given building is found. The propagation velocity as well as the modulus of elasticity of the rock is mainly constant in magnitude. Thus, for a given building, the stress level primarily depends on the particle velocity.

Depending upon the wave type, the stress σ or strain ε in the rock can be estimated considering the motion as a simple harmonic oscillation. Solid and hard rock may be expected to fail in tension at a high stress value. But normal fissured rock will undoubtedly show damage at lower stress levels and the orientation of the fissures in relation to the wave propagation direction may also be important.

ESTIMATION OF PROPAGATION VELOCITY (C)

In the present study and in order to estimate the stress level under15th of May buildings, the values of propagation velocity must have been previously estimated as well as the value of modulus of elasticity for the ground. These are the main constants of the ground and the differentiation of their values is accompanied with changes in the stress level values.

According to the internal report of NRIAG (1996), that has been carried on the northern part of 15th of May buildings and close to the quarries of the National Cement Company, the vibrational characteristics of this site were precisely studied. Using a seismic prospecting station, the refraction method was used for the determination of the longitudinal or P- wave and transverse or S – wave velocities for the ground structure. These waves were generated by hitting the ground; vertically to produce P- waves and horizontally for the generation of S-waves. The ground structure obtained was a two – layers structure. In case of P – wave its velocity in the first or the weathered layer was found to be 385 m/sec and 952 m/sec for the second or the foundation layer. While in the case of S- wave, the velocity of the weathered layer was 226 m/sec and 560 m/sec for the foundation layer.

MODULUS OF ELASTICITY DETERMINATION *(E)*

In a general case, the elastic properties of a foundation rock are adversely affected by various geological conditions such as fault zones, fractures, small igneous intrusions in sedimentary rocks, and lenticularty of bedding, which permits the introduction of occasional soft zones into generally hard rocks (Brown and Robertshaw, 1953; Krynine and Judd, 1957).

In engineering seismology it is very important to obtain the elastic constants of the ground for different purposes such as in the case of civil construction of dams, tunnels, nuclear power plants, new housing communities, high rise buildings and the strategic projects….etc. These elastic constants could be calculated from both P- and S- wave velocities. The most important parameters of elastic properties of the ground are both of modulus of elasticity *(E)* and Poission's ratio *(μ)* and their relation to each other (Dobrin, 1976) is:

$$(Vp)^2 = \frac{(1-\mu)E}{(1+\mu)(1-2\mu)\rho} \quad \Lambda \quad \Lambda \quad \Lambda \quad \Lambda \quad (4)$$

While,

$$(Vs)^2 = \frac{E}{\rho} * \frac{1}{2(1+\mu)} \quad \Lambda \quad \Lambda \quad \Lambda \quad \Lambda \quad \Lambda \quad \Lambda \quad \Lambda \quad \Lambda \quad (5)$$

Where, V_p and V_s are P- and S- wave velocities, ρ is the density of rock material and μ is the Poisson's ratio of the rock material which can be computed using the following relation:

$$(\mu) = \frac{1-2\left(\frac{Vs}{Vp}\right)^2}{2-2\left(\frac{Vs}{Vp}\right)^2} \quad \Lambda \Lambda \Lambda \Lambda \Lambda \Lambda \Lambda \; (6)$$

For the focussed site, the first layer is considered to be weathered limestone and its Poisson's ratio was found to be 0.24. While, for the second layer which is known to be limestone, the Poisson's ratio was found to be 0.235. The density of both the weathered limestone and the limestone was found to be 2.4 gm/cm^3, then by applying the equations (4) and (5), the modulus of elasticity for the first or weathered limestone layer and for the second or the limestone layer can be calculated (Tables 1 and 2). It is obvious that the elastic parameter E is the most important variable controlling the velocity of seismic waves in rocks.

After calculation of the propagation velocity and the modulus of elasticity for the ground material, it becomes easily to calculate the stress and stain levels in both the weathered limestone and the limestone layers for P-and S- wave velocities. As an example, the relations between the peak particle velocity (ppv), stress level and strain values for the weathered layer are presented in figures (1 to 4) that indicate the linear behavior of ground.

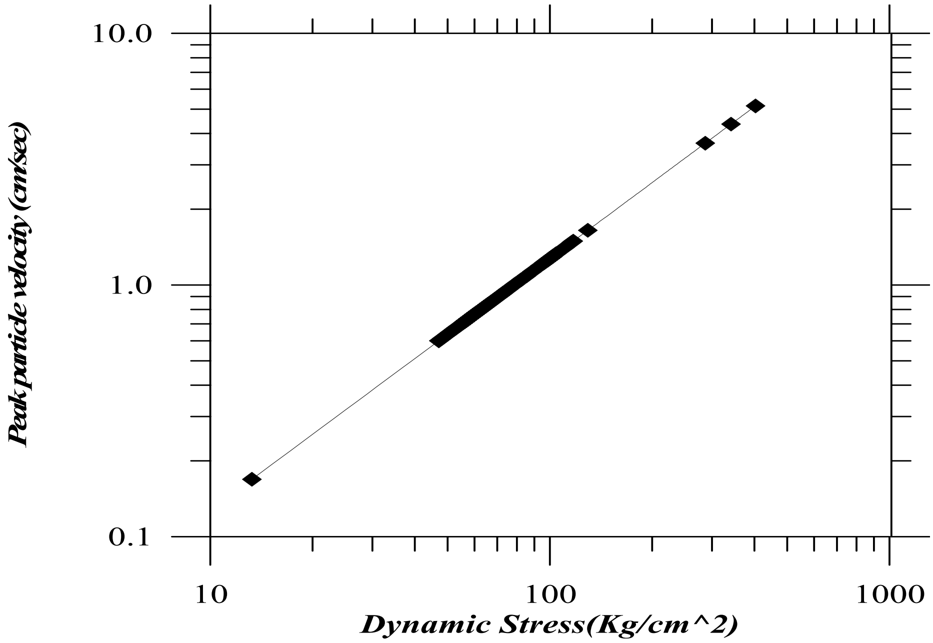

Fig.(1) The observed relation between PPV and Stress for P- wave in the Weathered layer.

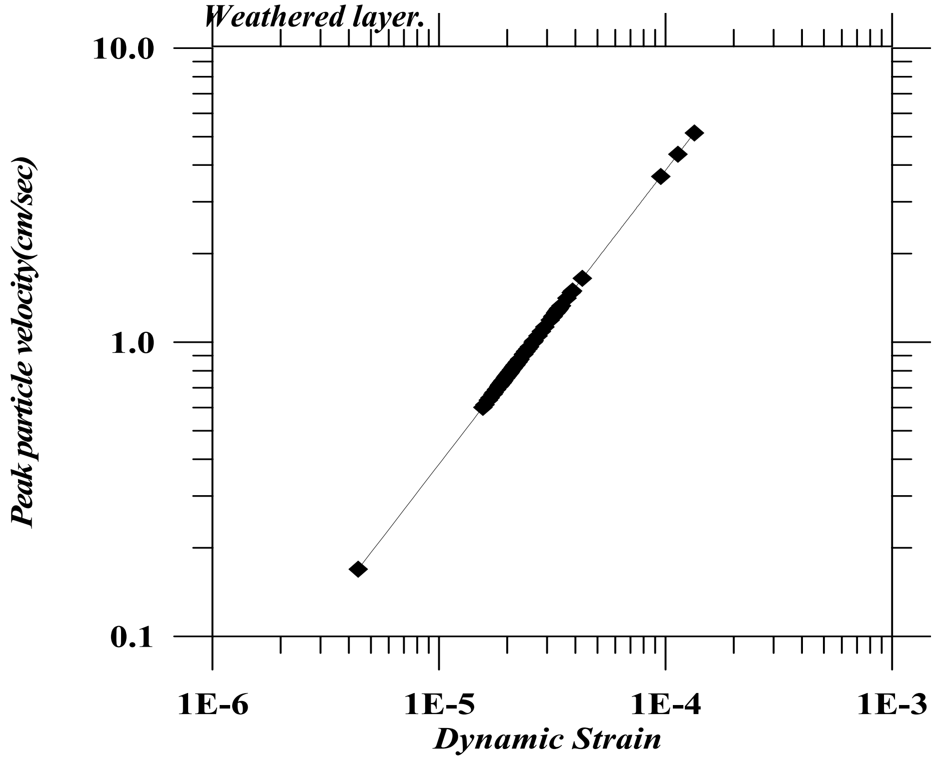

Fig.(2) The observed relation between PPV and Strain for P-wave in the weathered layer.

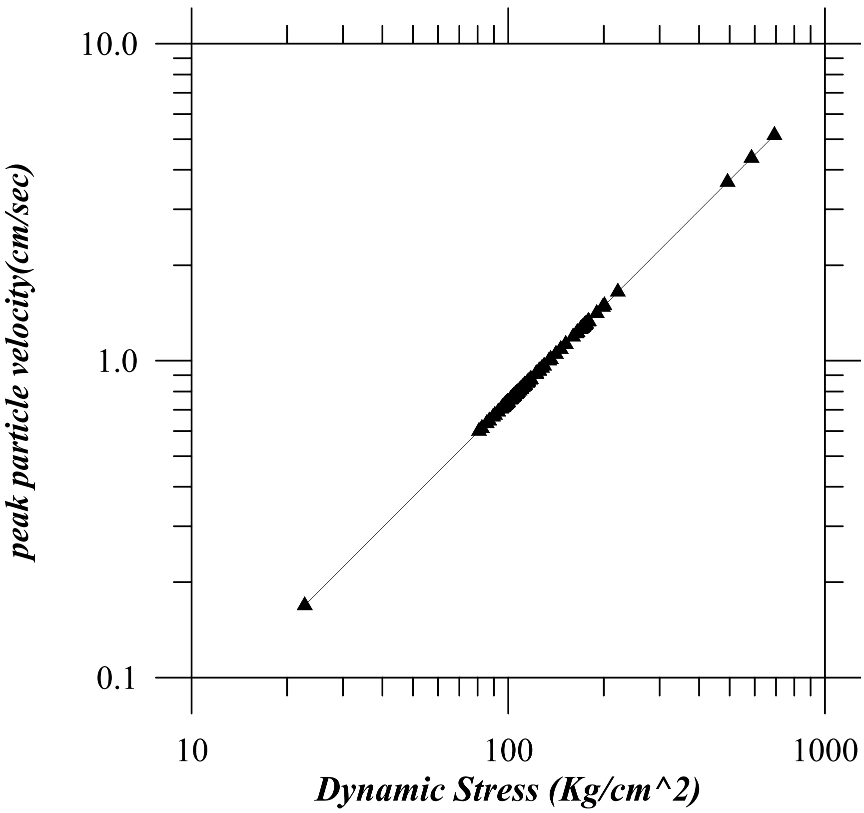

Fig.(3) The observed relation between PPV and Stress for S-wave in the weathered layer.

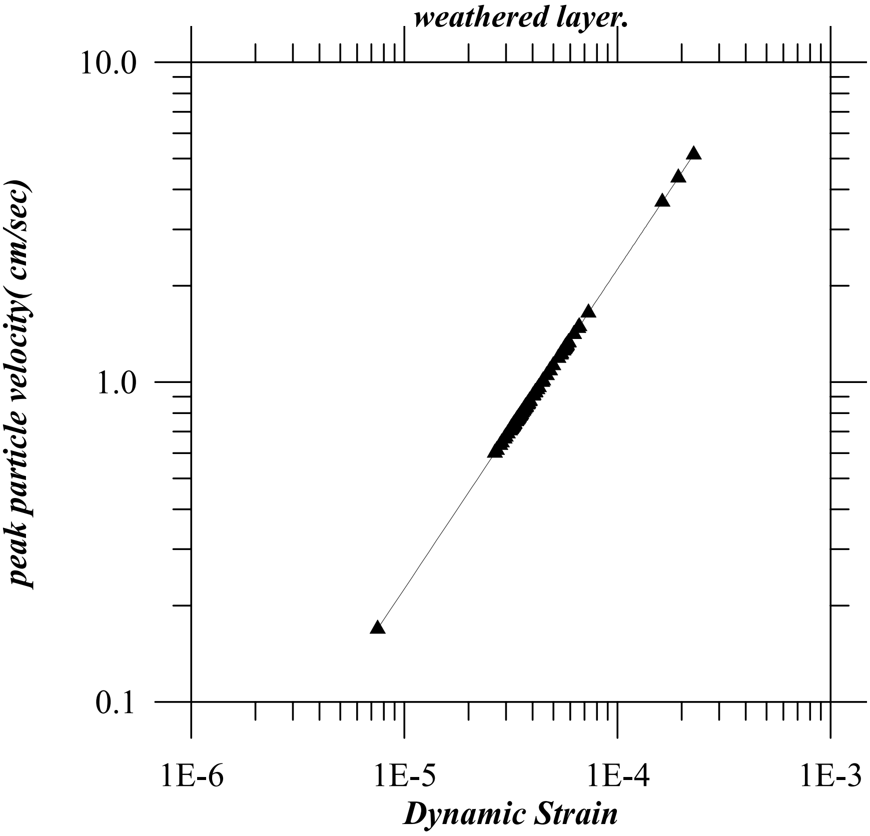

Fig.(4) The observed relation between PPV and Strain for S-wave in the weathered layer.

ANALYSIS OF DATA AND RESULTS

From the interpretation of the quarry blasting records, the values of peak particle velocity ranges from 0.169 cm/sec to 5.15 cm/sec (Fig. 5). Some of these values are higher than the recommended values in the reports of Swedish and German rock blasting as well as many authors as Langefors and Kihlstrom, (1965); American Insurance Association, (1972); Albert et al, (1995); and Othman et al, (2000). So it should be accompanied with some damage effects in the nearby buildings as recorded in 27th suburb. The stress level differs with the changes of particle velocity and the damage intensity also changes. The distribution of the estimated values for both stress and strain throughout the area in case of P- and S-waves, which lies in front of the quarry blasting operations, are shown in figures 6 to 14 and tables 1and 2.

Table (1) Estimated values of the stress and strain levels in case of P- wave.

Type of layer	***P-wave velocity*** *(m/sec)*	***Elastic modulus*** *(Kg/cm^2)*	***Minimum stress*** *(Kg/cm^2)*	***Maximum stress*** *(Kg/cm^2)*	***Minimum strain***	***Maximum strain***
Weathered	385	3.018E+6	13.24	403.7	4.3896E-6	1.3376E-4
Foundation	952	18.61E+6	33.03	1006.72	1.7752E-6	5.4096E-5

Table (2) Estimated values of the stress and strain levels in case of S- wave.

Type of layer	***S–wave velocity*** *(m/sec)*	***Elastic modulus*** *(Kg/cm^2)*	***Minimum stress*** *(Kg/cm^2)*	***Maximum stress*** *(Kg/cm^2)*	***Minimum strain***	***Maximum strain***
Weathered	226	3.04E+6	22.73	692.7	7.4778E-6	2.2787E-4
Foundation	560	18.59E+6	56.13	1709.61	3.0178E-6	9.1964E-5

CONCLUSIONS

The quarry blasting operations were continuously monitored from Jan.1997 till now. Then it has been subjected to processing and analysis methods to deduce the maximum value of Peak Particle Velocity. After that the maximum values of both stress and strain have been estimated in case of P-and S-waves. The observed damage in the buildings nearby to the quarry blasting operations indicates that these stress levels are considerably high. According to the analysis of the recorded data the following are recommended; the values of Peak Particle velocity must be controlled by the operating team; continuous and precisely monitoring and analysis of the quarry blasting operations around the 15th of May City buildings; estimation of both stress and strain levels for weathered and foundation layers to define the dangerous limit; evaluation of 27^{th} suburb buildings that represent the nearby one and all other suburbs that lie in front of the quarries operations.

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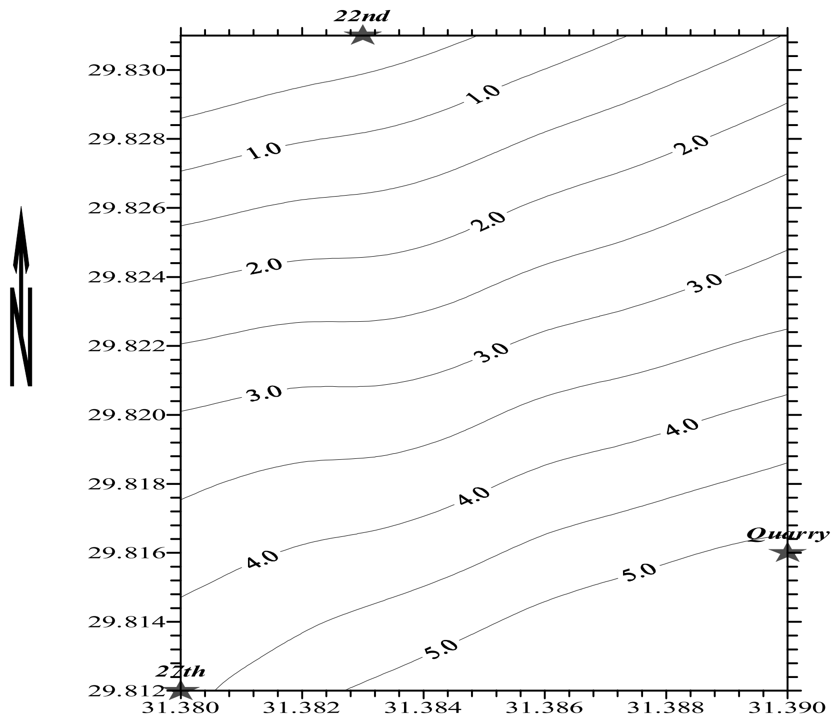

Fig.(5) Distribution of Peak Particle Velocity in the study area.

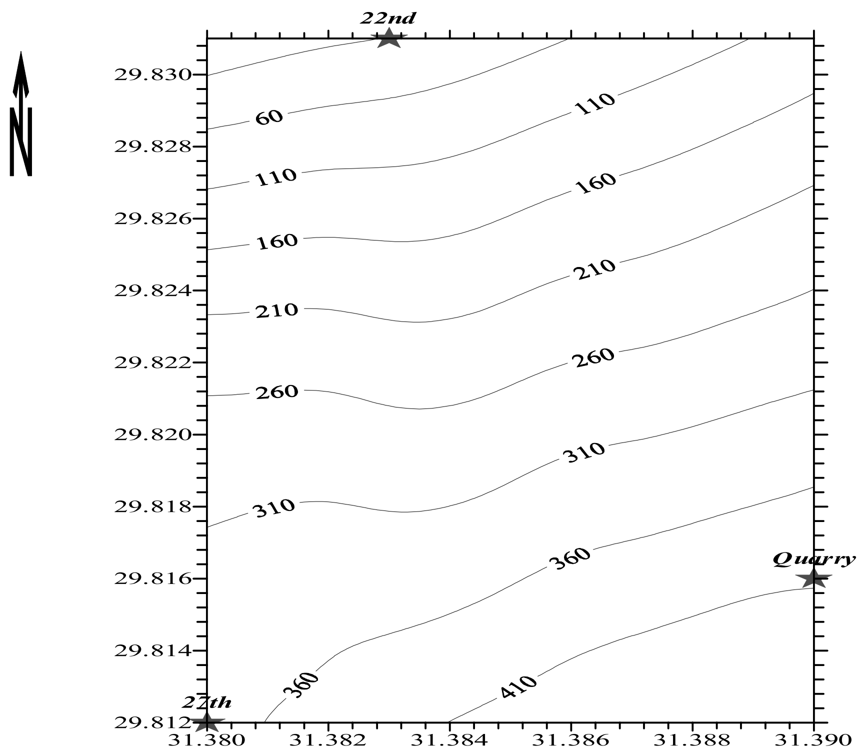

Fig.(6) Distribution of stress values(Kg/cm^2) in the weathered layer for P- wave velocity.

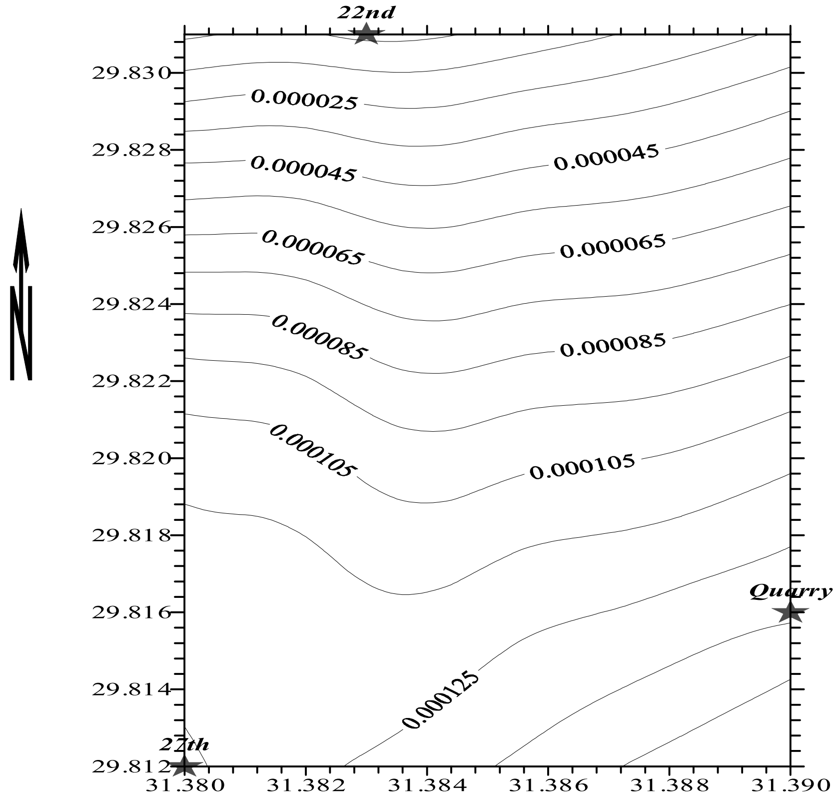

Fig.(7) Distribution of strain values in the weathered layer for P- wave velocity.

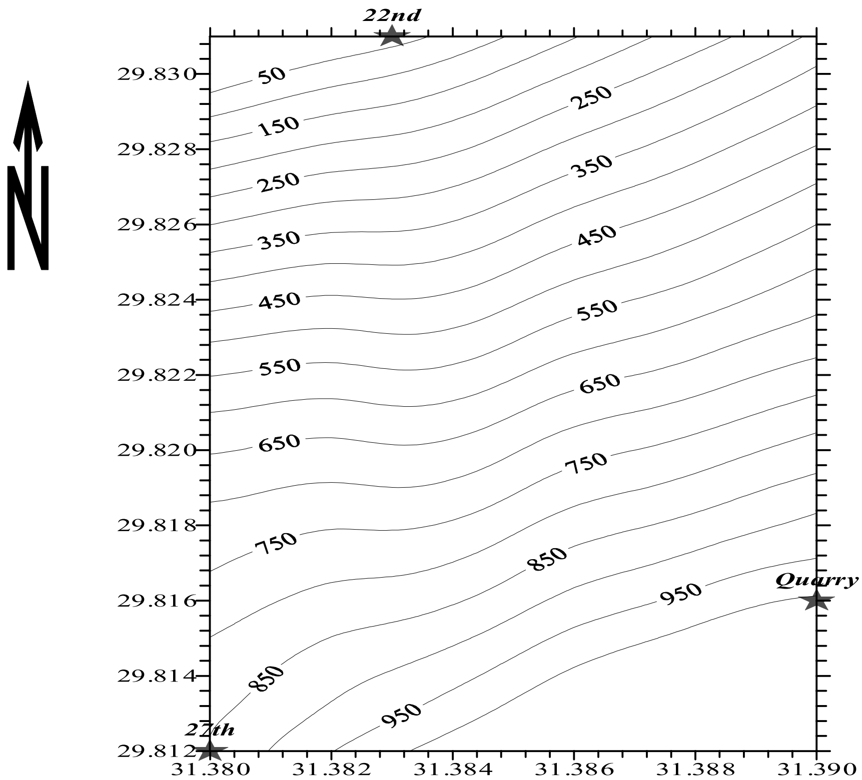

Fig.(8) Distribution of stress values(Kg/cm^2) in the foundation layer for P- wave velocity.

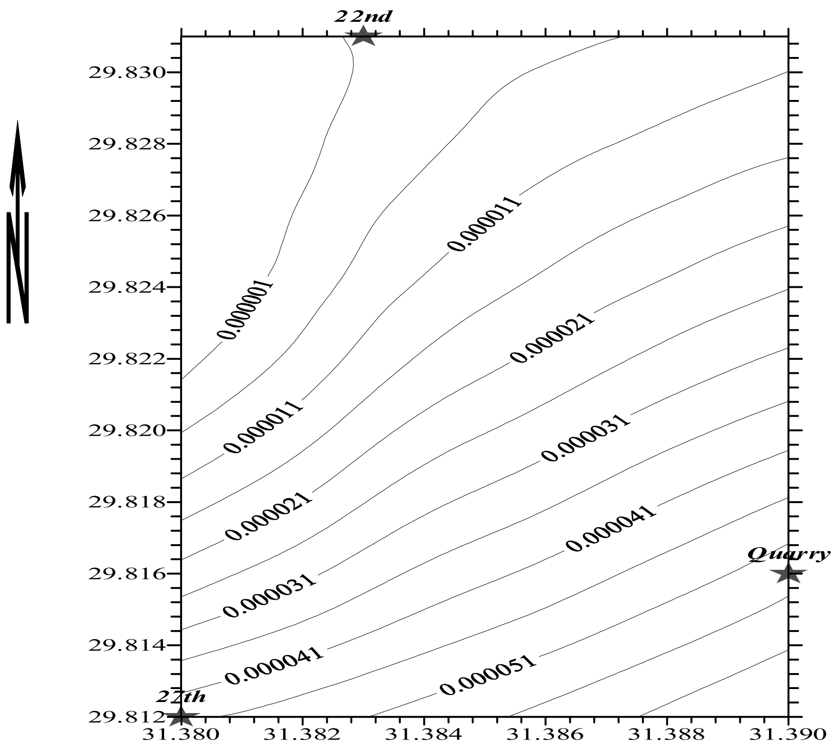

Fig.(9) Distribution of strain values in the foudation layer for P-wave velocity.

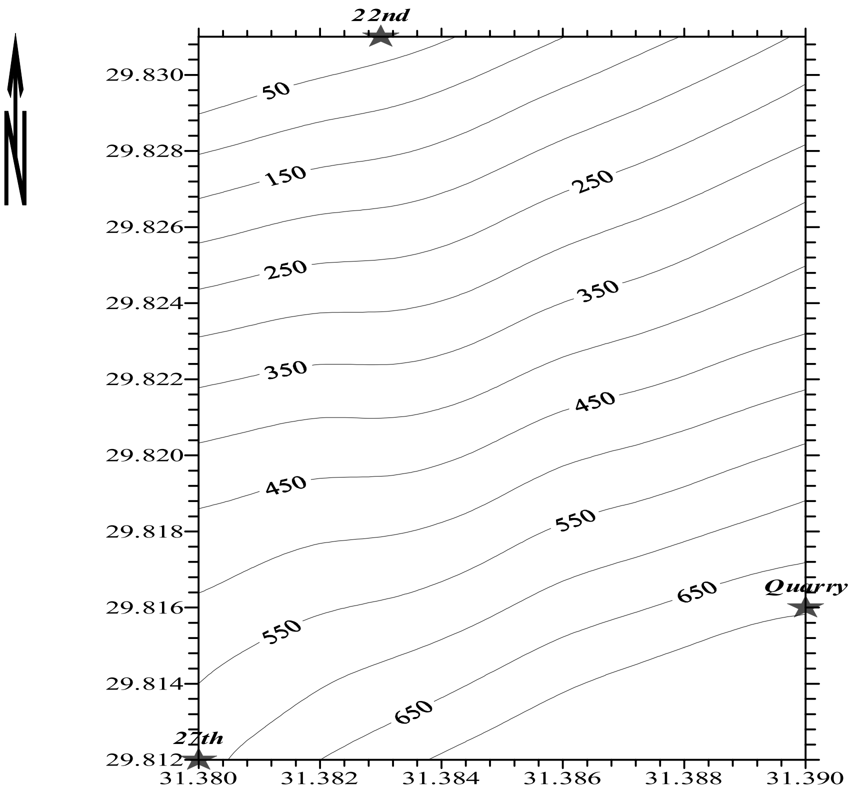

Fig.(10) Distribution of stress values (Kg/cm^2) in the weathered layer for S-wave velocity.

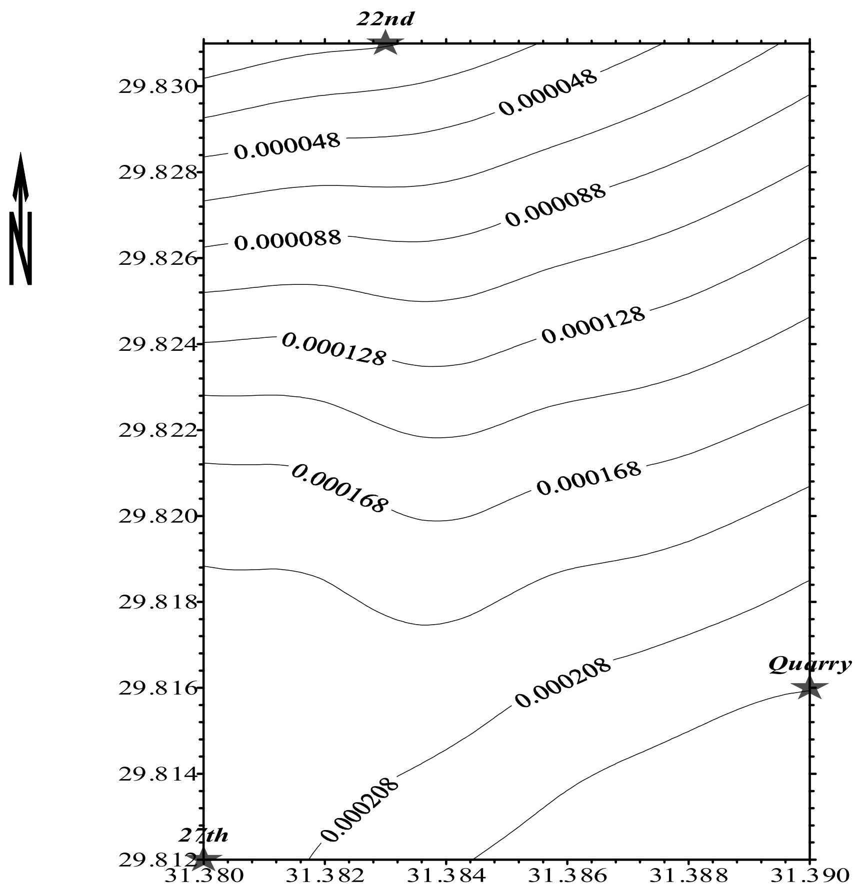

Fig.(11) Distribution of strain values in the weathered layer for S-wave velocity.

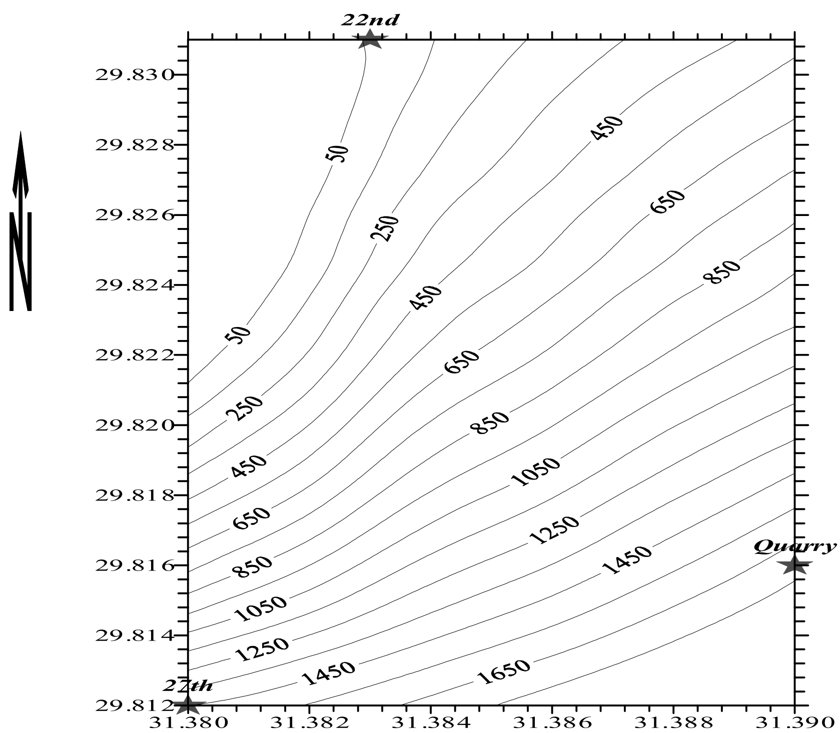

Fig.(12) Distribution of stress (Kg/ cm^2) values in the foundation layer for S-wave velocity.

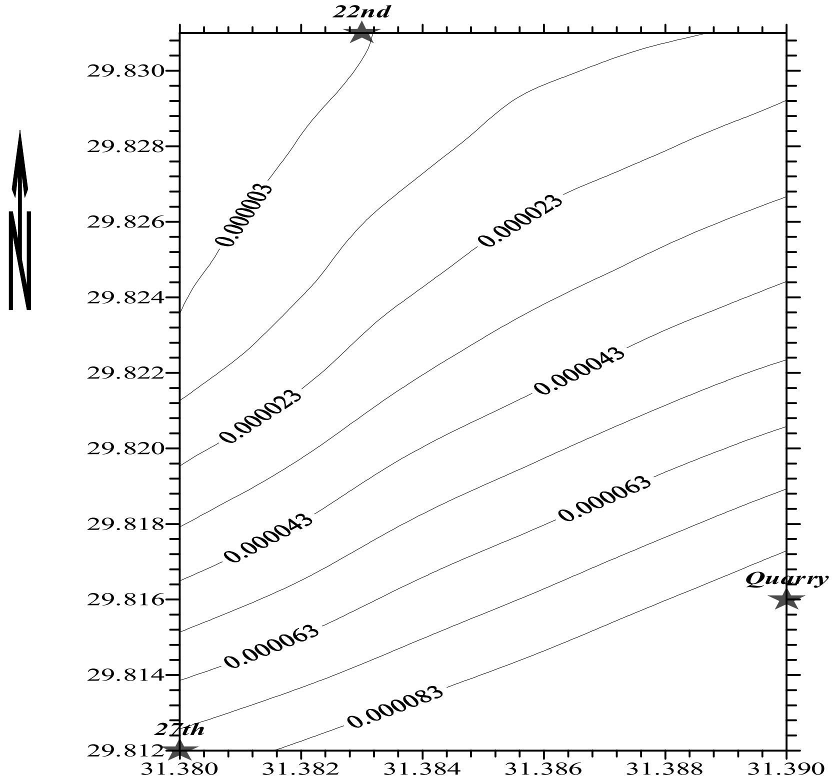

Fig.(13) Distribution of strain values in the foundation layer for S-wave velocity.