REPORT TO:

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SUBJECT:

Vibration Monitoring Program for McConnell's Mill State Park

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EXECUTIVE SUMMARY

Quality Aggregates requested Vibra-Tech Engineers, Inc. to conduct an evaluation of the potential effects of blasting vibrations on the stability of the Homewood slump blocks in the area closest to their proposed Myers Mine. These boulders are located in an area popular with hikers and tourists. Since many of these large boulders are on slopes or overhanging, it was thought that the blasting might induce some movement of the rock.

Vibra-Tech visited the park and identified two possible modes of movement of the rocks. An engineering analysis was used to predict the potential for rock slippage in response to ground vibrations induced by blasting. The response of a typical overhanging cliff to ground vibration was also calculated using the finite element analysis method. Based on these analyses, a set of recommendations was made, including the establishment of vibration criteria and monitoring locations.

It is our professional opinion that by following the recommendations in this report there will be no effect on the integrity of the McConnell's Mill State Park resulting from blasting at the proposed Myers mine.

1-INTRODUCTION

1-1 Introduction:

Quality Aggregates Inc. operates the Princeton Quarry in Slippery Rock Township, Lawrence County, Pennsylvania. The quarry has been in operation since 1988, mining and processing a seam of Vanport limestone, and selling its products to a variety of customers who require high quality crushed limestone for construction projects.

The quarry is located west of the McConnell's Mill State Park, and Slippery Rock Creek, which flows from the north through the Park within a deep scenic gorge. Quality Aggregates is presently applying for a new permit from the Pennsylvania Department of Environmental Protection (DEP), to be known as the Myers Mine. This permit would allow quarrying operations to within 300 feet of Rim Road, which in this area marks the western property line of the Park.

Rim Road is located along the top of the steep lower portion of the Slippery Rock Creek gorge, and upon a geologic rock unit known as the Homewood Sandstone. The Homewood is a 40 to 50-foot thick layer of resistant and sometimes massive sandstone that forms cliffs in many areas of the gorge.

The northern portion of Rim Road also marks the top of what is known as the Rim Road Climbing Area. The Homewood is particularly massive in this area, and large blocks have separated from the outcrop and slumped downslope to create a spectacular "rock city" of narrow walkways between boulders. Further downslope, many other large sandstone boulders lie separated from the outcrop and jut upward from the wooded slope at various angles. This area typifies the impressive geologic features seen in several areas of the Park.

McConnell's Mill State Park is obviously a valuable natural treasure and its present aesthetic beauty and physical features must not be harmed in any way by commercial activities on nearby properties. As part of their commitment to this goal, Quality Aggregates has commissioned Vibra-Tech Engineers to study the possible effects of blasting vibrations on the stability of the 'rock city' slump blocks in the area closest to their proposed Myers Mine.

This report documents this study and the vibration limits recommended by Vibra-Tech to assure the stability and safety of the rock structures in this area of the park. It also discusses, in general, the appropriate measuring and other control procedures to assure conformance with our recommended limits.

1-2 History of the Gorge:

McConnell's Mill State Park began as private property, which contained a gristmill catering to the local community. This mill burned and was later rebuilt in 1868 by then owner, Daniel Kennedy. Thomas McConnell bought the property in 1875 and continued the operation of the mill until 1928. The property was later conveyed to the Commonwealth of Pennsylvania and was formally dedicated as a state park in October 1957. Slippery Rock Gorge was designated a National Natural Landmark by the U.S. Department of the Interior in 1974 and became a State Park Natural Area in 1998.

The park's geologic history started 300 million years ago during the Pennsylvanian Period during which a completely different landscape was present, and what is now Pennsylvania was south of the equator. Rivers heavily laden with clay, sand, and gravel flowed from the highlands in what are now eastern Pennsylvania, New Jersey and Delaware across Pennsylvania. At the mouths of the rivers, this sediment formed large deltas along the shoreline of an ancient sea, which covered what are now Ohio and western Pennsylvania.

Thick layers of sand accumulated in river channels and as beaches and barrier bars along the coast. High energy waves and currents moved some of the sand into large ripples and dunes. Extensive swamps formed on the river floodplains and behind the beaches. In that quiet water of the swamps, with low energy levels, layers of silt and clay accumulated with mats of thick vegetation (peat). As the river systems changed course or the sea rose to cover the low delta areas, early sediments were buried and new sequences of swamps, sand, and mud formed. Several times, the shallow sea spread and deposited marine clays and mud.

As each layer was buried, compaction and cementation changed the soft, loose sediment to solid rock. The peat bogs became coal. The sand became the Homewood and Connoquenessing Sandstones, and the silts and clays formed the Kittanning, Clarion, and Mercer Formations. The thickest marine lime mud became the Vanport Limestone. About 250 million years ago, as the continents moved northward, the area was uplifted.

About two million years ago, thick masses of continental ice began to periodically accumulate in central and northeast Canada and spread southward. At least four of these ice sheets, many hundreds or thousands of feet thick eventually reached northwestern Pennsylvania. As the ice front moved southeastward into the area about 140,000 years ago, it dammed northwest-flowing Slippery Rock-Muddy Creek.

Although the latest glacier left the area 23,000 years ago, at the ice-advance maximum, separate lakes formed in the Slippery Rock (Lake Edmund) and Muddy Creek (Lake Watts) lowlands. A third, much smaller lake, (Lake Prouty) formed in the "McConnell's Run" valley when it was dammed south of Muddy Creek. Lakes Edmund and Watts drained through outlets at their eastern ends, far from the glacier dams, into Connoquenessing Creek.

As each pass opened, a short-term vast flood from these lakes surged into the gorge. These floods deepened the gorge and eroded the soft shale beneath the hard Homewood Sandstone, leaving the sandstone as overhanging cliffs in some areas. Because the sandstone is cut by many intersecting cracks, unsupported large blocks fell from the rim. Some of these large blocks moved only a few feet downslope, but others now fill the bottom of the gorge. This has widened the gorge, but left it about 45 feet less deep than originally carved.

The gorge is deepest and narrowest near Cleland Rock on the divide and becomes progressively shallower and wider both to the north and to the south. Today, Slippery Rock Creek still has a steep gradient through the gorge (28 ft per mile compared to 8 feet per mile north of Kennedy Mill). The following graph illustrates a typical cross section of the gorge:

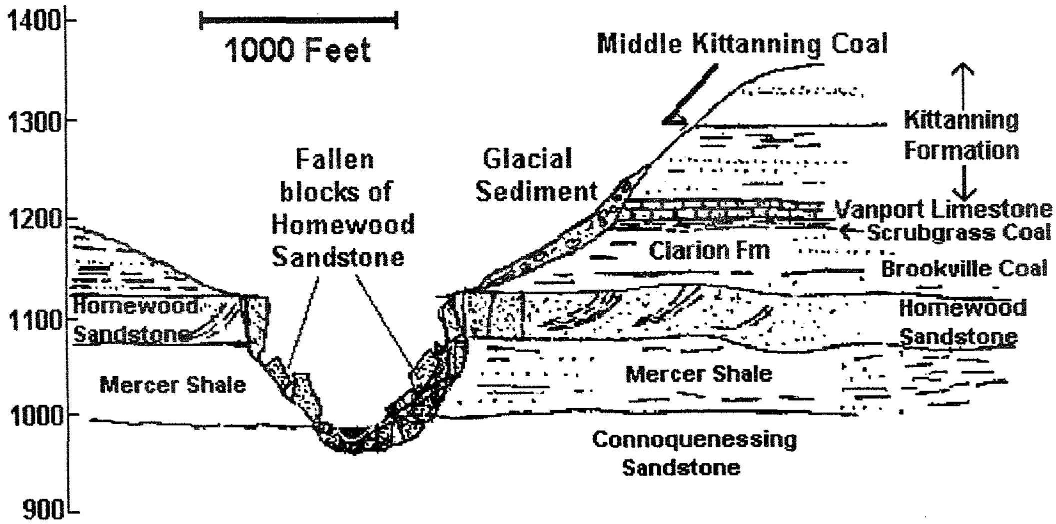


Figure 1-2-1 Gorge Cross Section

1-3 Mining Operations in the Area:

This section of our report provides a brief summary of the past and present operations in the Princeton quarry, as well as a general overview of past coal and limestone mining by others in the area of McConnell's Mill State Park and the Slippery Rock Creek gorge.

Quality Aggregates was originally founded in 1988 as the Aloe Stone Company, at which time it began its Princeton Quarry operations. Over the years, Quality Aggregates has been granted a number of permits by the DEP allowing continuance of the Princeton Quarry operations. The issuance of these permits by the DEP is based on regulations and policies designed to protect the ground and surface waters of the Commonwealth, as well as any other natural and man-made structures, both public and private.

Prior to the opening of the Princeton Quarry, surface coal mining was conducted on the same lands for many years by a number of different companies. Much of this mining required the use of commercial blasting to remove rock overlying the coal. For instance, when Quality Aggregates obtained its permit to quarry on the Fisher property, approximately 75% of this area had already been surface mined for the Lower Kittanning coal, which overlies the Vanport limestone. When it began quarrying on the adjacent Withers property, about 50% of the overlying coal had already been mined. On the pending Myers permit, about 35% of the area has been previously mined.

The Vanport limestone is about 20 feet thick in this area, and lies 60 to 70 feet above the Homewood. It has also been extensively mined for over 30 years along the eastern border of the park by Sechan Limestone Industries. In the area south of Kildoo Falls, blasting and mining by Sechan for the Lower Kittanning coal and Vanport limestone progressed to about 300 feet of the Homewood Sandstone outcrop of the gorge.

2-ANALYSIS

In order to analyze the effects of ground vibration induced by blasting at Myer Mine on the rock structure at McConnell's Mill Park, Vibra-Tech Engineers visited the Park. We detected two types of failure that may occur as an effect of high ground vibration. The first failure would be the descent of the rocks resting on the slope with the second being the possibility of an overhanging cliff breaking. The following sections examine both possibilities and establish a limit to prevent these incidences:

2-1 Sliding Rock:

As a boulder rests on the slope, there are three types of forces applied for it to maintain its equilibrium. These forces are the weight of the boulder (W), normal force (N), and friction force (F_F). Friction is the amount of force that is required to slide one object over another. Surface irregularities between the two objects interlock to produce high friction. The force of friction between two surfaces is proportional to the normal force between the surfaces. The coefficient of static friction μ_s depends on the materials and the roughness of the surfaces but is independent of the area of contact between the surface.

Based on our observation at the park, boulders are typically located on slopes of less than 45 degrees. On this basis, the force required to cause the boulder to slide was calculated assuming a 45-degree slope. Based on the results, a ground vibration level was recommended. The graphs and calculations on the following pages establish vibration criteria to prevent any sliding of rock.

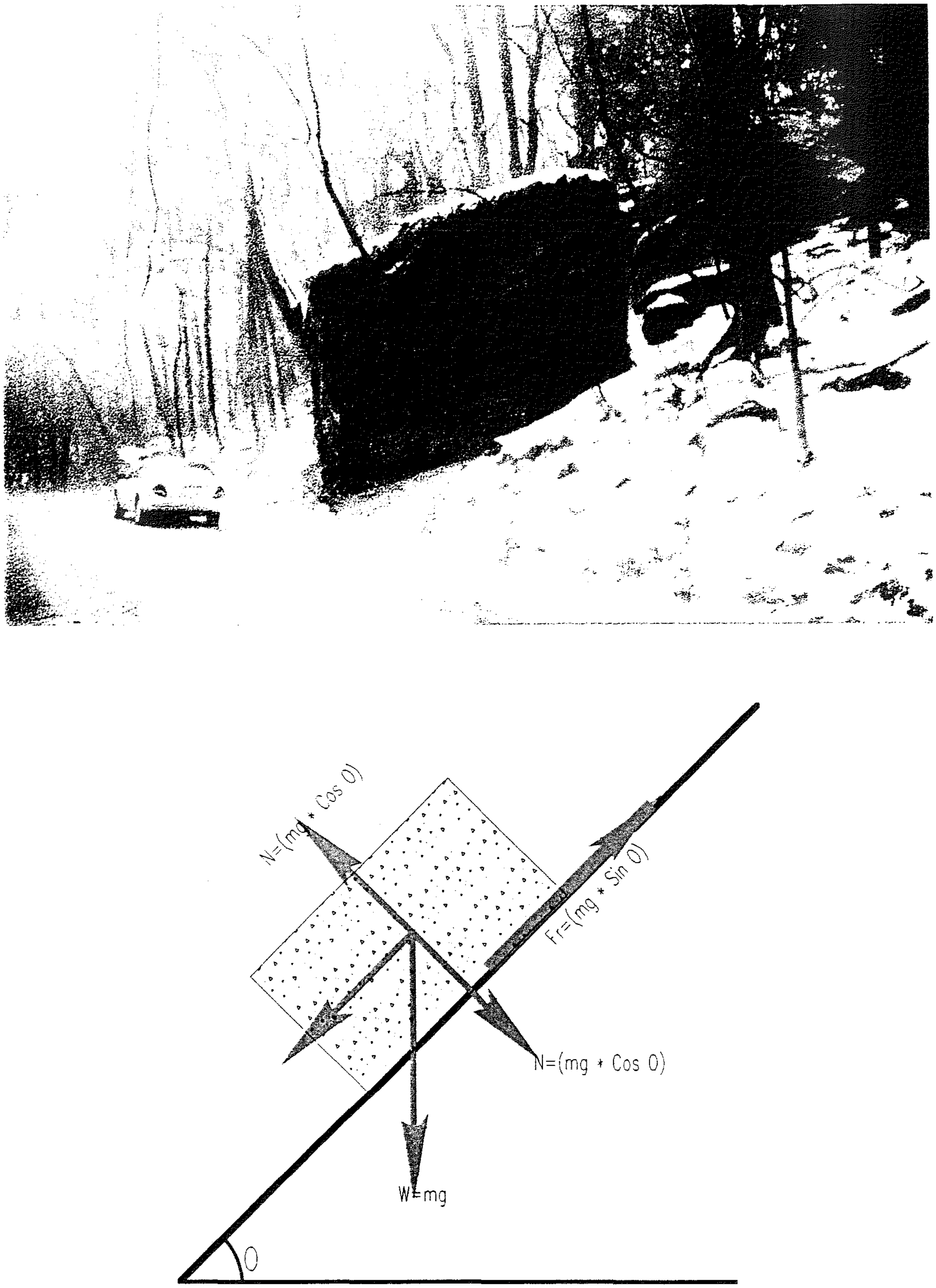


Figure 2-1-1 Boulder Resting on Slope (Actual Photo & Model)

$\mu_s = 0.5$ Static Friction of Rock on Rock or Rock on Earth

$\phi = 45^\circ$ Angle of Incline Degrees

$$\mathrm{N} = \mathrm{m} \cdot \mathrm{g} \cdot \cos\left(\frac{\phi\pi}{180}\right) \text{ Normal Force}$$

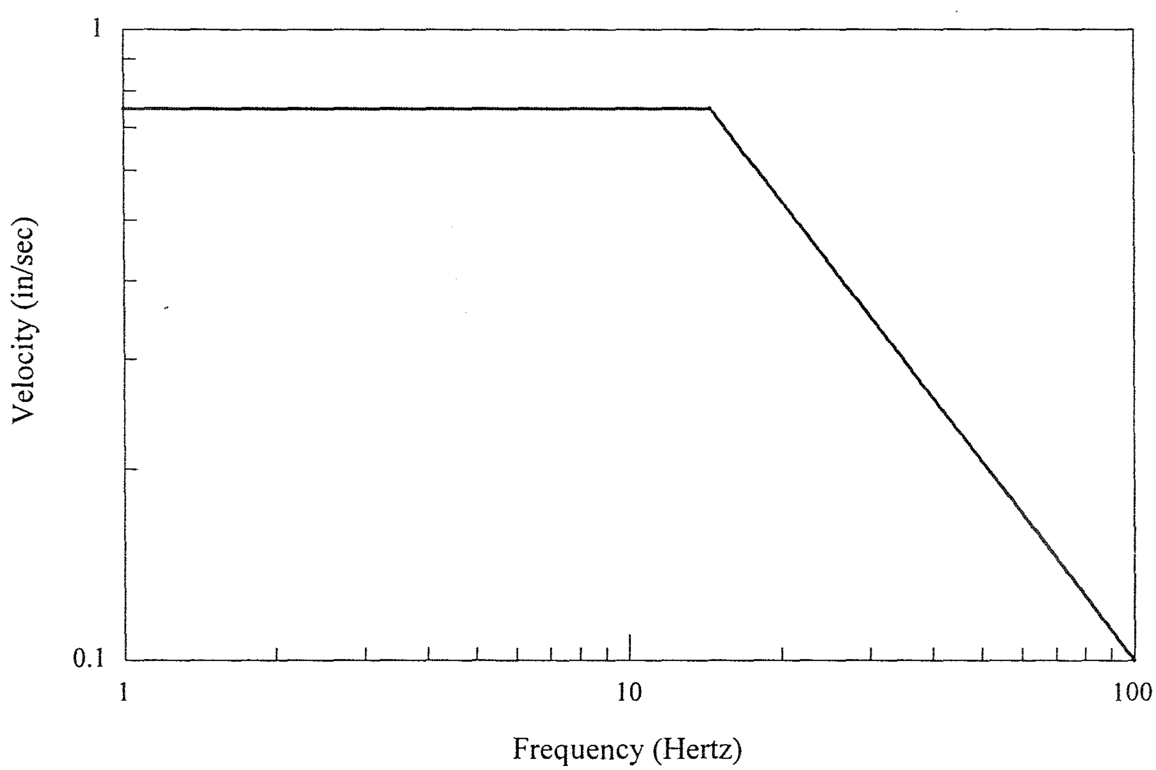
$$\mathrm{F_s} = \mu_s \cdot N \text{ Maximum Static Friction}$$

$$\mathrm{a} = \sin\left(\frac{\phi\pi}{180}\right) - \mu_s \cdot \cos\left(\frac{\phi\pi}{180}\right) \text{ Mass starts to slide at this acceleration}$$

$$\mathrm{a} = 0.354\mathrm{g}$$

$$0.5 \cdot \mathrm{a} = 0.177\mathrm{g} \text{ Safety Factor of 2 (Recommended peak acceleration iduced by blasting)}$$

Figure 2-1-2 Allowable Peak Particle Velocity vs Frequency



In this calculation, a 50% factor of safety is included. Also, according to our observations at the park, all of the boulders we observed are resting on slopes that are less

2-2 Overhanging Cliff:

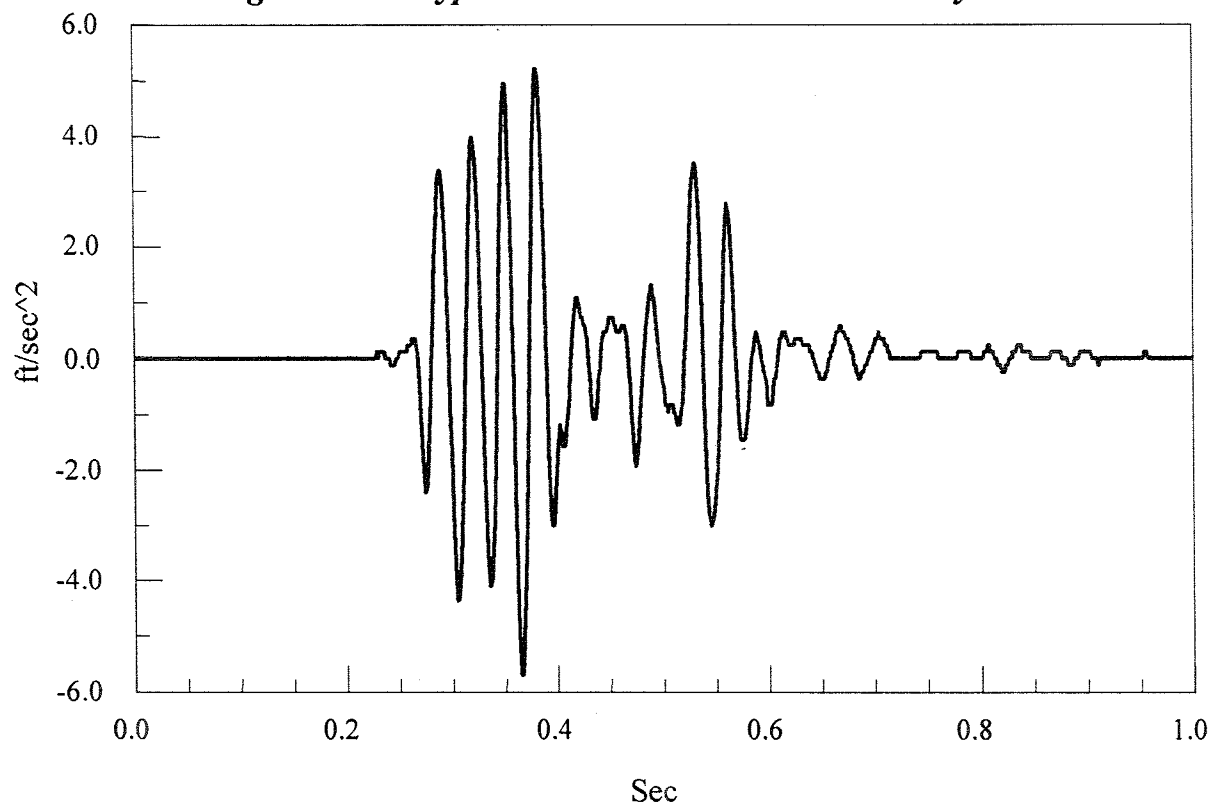
Another potential form of damage to rock due to high levels of vibration is the collapse of overhanging cliffs. In this scenario, high vibration would excite the support of the cliff and cause excessive vibration of the overhang. The excessive shear stress would result in separation of the overhang from its support. In order to evaluate this potential, we used the finite element technique. In this analysis, we developed a computer model of a typical section of the overhanging cliff. A typical blast vibration with amplitude similar to the allowable level in the previous section (0.177g or 5.7 ft/sec^2) was then applied to the support.

The Finite Element Analysis technique simulates structural response to certain loads (e.g. blasting) by using mathematical equations and knowledge of structural physical properties. In this study, we modeled one foot of a typical cross section of the cliff that included 139 nodes and 118 plate elements. The following material properties were used in the model:

Modulus of Elasticity =77.24E6 (psf)
Weight Density = 143 (lbs/ft^3)
Poisson's Ration = 0.25
Compressive Strength = 1.81E6 (psf)
Shear Modulus = 30.9E6 (psf)
Shear Strength =173,800 (psf)

The stresses that developed within the rock surface were calculated. The graphs on the following pages illustrate the time history of the vibration and the stress levels within the rock. The stress values are given in pounds per square foot (psf). The review of the stress distribution on the finite element model indicates that the stress levels are far below the compressive and shear strength of the rock.

Figure 2-2-1 Typical Blast Vibration Time History



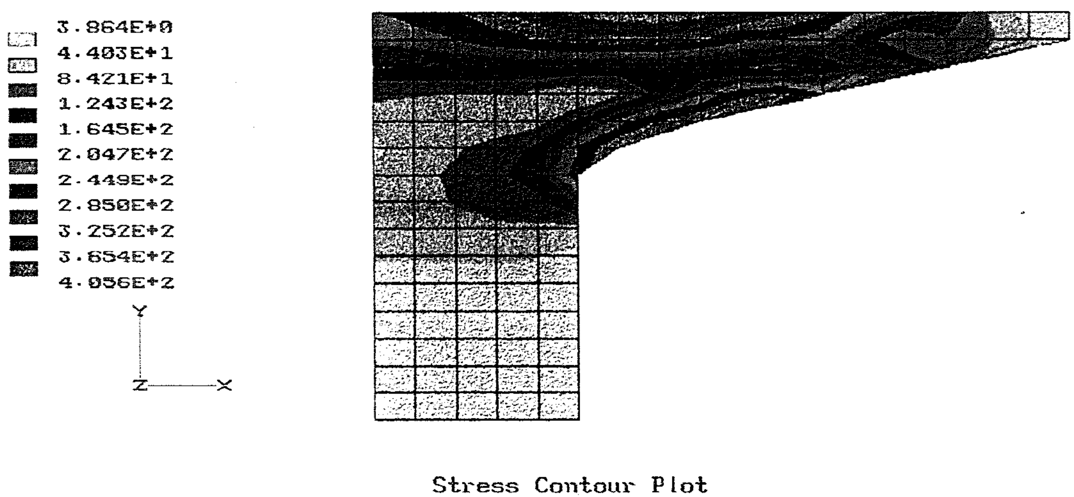


Figure 2-2-2 Stress Contour Distribution Caused by a Typical Blast.

3-CONCLUSION

The results of this investigation indicate that the sliding boulders control the vibration criteria. The recommended vibration criterion is 0.18 g. This value is in particle acceleration, and is different from typical blasting practice that uses particle velocity to protect against damage to buildings. This criterion has a safety factor of at least two. The following formula may be used to convert the acceleration value to velocity:

$$V = \frac{A * 386.19}{2 * \pi * f}$$

Where:

V = Velocity (in/sec)

A = Acceleration (g)

f = Dominant Vibration Frequency of Blast (Hz)

Figure 2-1-2 shows the allowable peak particle velocity at different frequencies. It is also recommended that blasting patterns be designed to limit the induced peak particle velocity to no more than 0.75 in/sec. This value will result in a particle acceleration of less than 0.18 g, assuming that the dominant frequency is less than 15 hertz. It is also recommended that the ground vibration along Rim Road be monitored during each blast. It will be beneficial if the seismograph has the capability to directly measure particle acceleration rather than velocity.