COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

RECORDS
1959 NO.121

VIBRATION TEST AT THE M.M.B.W. SEWER PROJECT, SPOTSWOOD, VICTORIA

by

E.J. POLAK

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C O N T E N T S.

1. INTRODUCTION.

This report describes an investigation which was carried out by the Bureau of Mineral Resources, Geology and Geophysics, at the request of the Melbourne and Metropolitan Board of Works in connection with the construction of a new sewerage project at Spotswood. The purpose of this investigation was to measure the amplitudes of vibrations resulting from explosive blasting in a tunnel.

Measurements of the ground vibration were recorded from the blast of the explosive charge normally used in the tunnel on 18th September, 1959. The vibration test was carried out by E.J. Polak, geophysicist.

The charge which was exploded consisted of 27 lbs. of AN 60 gelignite and was divided into 24 sections and fired using a delay technique.

2. RECORDING TECHNIQUES.

Two recording instruments were used:-

1) A Leet vibrograph, which records photographically the three mutually perpendicular components of ground movement with a magnification of 50; this is achieved by optical means. The scale of the record, therefore, is such that a ground movement of 0.02 inches is represented on the record by a movement of one inch. The timing lines are at 10 millisecond intervals.

2) A Sprengnether portable blast and vibration seismograph, which gives, like the Leet Vibrograph, a three component record of vibration, the magnification being 100 times and the timing lines at 20 millisecond intervals.

The instruments were placed on a concrete footpath in Hudson Street, Spotswood, at distances shown on Plate 1. The floor of the excavated tunnel is 103 ft. below the footpath level. The Leet Vibrograph requires an outside supply of electric current and therefore had to be placed near the shaft. The distance from shot point to Leet Vibrograph was 200 ft.

Plate 1 shows copies of records taken with both instruments during the test.

From the record measurements are made of the amplitudes and frequencies of the three components of a vibration. The component amplitudes are measured as a maximum value of the peak-to-trough displacement. The total resultant amplitude equals the square root of the sums of the squares of the component amplitudes. The frequency is defined as the predominant frequency in cycles per second at the maximum amplitude of the ground displacement.

From the above mentioned values, the accoleration of the ground particles is calculated from the formula:-

$$a = 4 \pi^2 f^2 A$$

where :

a = acceleration in inch/sec.^{2}

f = frequency in cycles per second

A = amplitude peak-to-trough in inches.

3. RESULTS.

The low amplification of the Leet Vibrograph imposes a limitation on the amplitude which it is possible to record on the instrument. The lowest amplitude which can be measured on the record is about 0.01 inches peak-to-trough. This value corresponds with an actual ground displacement of about 0.0002 inches.

An examination of the Leet Vibrograph record indicates that the vibration from the blast is too small and obscured for the purposes of this investigation. The record shows a continuous small amplitude vibration with frequency of about 20 cycles per second. It is possible that this vibration was started by a compressor or pump.

The record obtained on the Sprengnether seismograph shows that the ground vibrations had a predominant frequency of approximately 70 cycles per second. From the magnitudes of the components of ground movement in three mutually perpendicular directions, it has been calculated that the peak-to-trough amplitude of ground movement in the direction of the maximum movement was 0.00127 inches. The acceleration, "a", of the ground particles will therefore be:-

$$a = 4 \pi^2 f^2 A$$

$$= 4 \times 3.14^2 \times 70^2 \times 0.00127$$

$$= 246 \text{ inch/sec.}^2$$

To express this in the form of acceleration as a fraction of the acceleration due to the force of gravity, A_g,

$$A_g = \frac{246}{12 \times 32.2} = \frac{246}{386.4} = 0.64$$

The amplitude of a seismic wave travelling through any attenuating medium decreases exponentially with distance, according to the formula:

$$A_x = A_o \text{ exp. } (- m x)$$

where:

A_o = Amplitude of wave at one point

A_x = Amplitude of wave at a point further distant from explosion

x = distance between the points (in feet)

m = attenuation coefficient.

Applying this formula in the investigation -

A_x = less than 0.0002 inches

A_o = 0.00127 inches

x = 200 - 110 = 90

$$\frac{\ln 0.0002}{\ln 0.00127} = - 90 m$$

$$m = -0.003$$

The coefficient of attenuation of the seismic wave in the basalt at Spotswood is not less than 0.003. This value is higher than is usually found in igneous rock. The higher rate of attenuation is the result of the saturation of the rock with water.

Table 1 gives values of the attenuation coefficient of some rocks:-

TABLE 1.

Rock type	Attenuation coefficient	Locality
Trachyte	0.0008	Kalbar, Queensland
Granite	0.0008 - 0.0012	Koomboloomba, Queensland
Quartzite	0.0011 - 0.0014	Kuranda, Queensland
Sandstone	0.0016	Theodore, Queensland
Phyllites, dry	0.0018 - 0.0025	Kuranda, Queensland
" wet	0.0043 - 0.0050	" "
Overburden	0.010	Clayton, Victoria
"	0.016	Kuranda, Queensland

Appendix 1 contains a series of excerpts from authoritative reports and regulations which deal with amplitudes of displacement of frequencies of vibrations from blasts, together with recommended safe amplitudes of vibrations that may be applicable to buildings.

APPENDIX I.

The following are references to and extracts from regulations and authoritative publications in the United States and Great Britain covering or recommending safe amplitudes of vibrations that may be applicable to buildings:

(Note: f = frequency in cycles per second.
A = peak to trough amplitude, inches).

Reference 1.

State of New Jersey, U.S.A. Extract from rules and regulations governing Quarry Blasting and Related Operations. March 26, 1954.

"6.1. Allowable Limits. Allowable Limits of ground motion and sound pressure contained in this section shall be considered neither to produce structural damage in any structure that has been reasonably well constructed according to accepted engineering practice nor to constitute a nuisance to persons."

"6.3. Frequency - amplitude relations. When ground frequency and displacement characteristics in relation to known quantities of detonated explosives in primary blasts have been determined by approved means of instrumentation to the satisfaction of the Commissioner, the allowable limits of the maximum amplitude of ground vibrations related to frequencies of vibration shall be as indicated in the following table:

Frequency of ground motion in cycles per second.	Maximum amplitude of ground movement, in inches.
up to 10	not more than 0.0305
20	0.0153
30	0.0102
40	0.0076
50	0.0061
60	0.0051"

Reference 2.

Rules Concerning Blasting in Strip Mine Operations in the Anthracite Region, Pennsylvania, Act No. 472, June 27, 1947.

"Section 20.

..in no case shall the ground displacement be in excess of 0.03 inches at any dwelling house, public building, school, church, commercial or institutional building."

Reference 3.

Teichman, G.A. and Westwater, R.

Blasting and Associated Vibration.

Engineering, April 12, 1955, pp. 460/465.

> "Because of the variation in the types of structure it has been recommended that they should be broadly classified into four groups:
>
> (a) structures of great value and frailty. This will include certain ancient monuments, such as churches and certain badly designed properties.
>
> (b) Property, houses etc. closely congested.
>
> (c) Isolated property.
>
> (d) Civil engineering structures.
>
> Taking suitable safety factors and after the site has been investigated by a vibrograph caution limits are applied. These limits usually are 0.004, 0.008, 0.016, 0.030 inches, respectively."

Reference 4.

Crandell, working on behalf of a United States Insurance Co., suggests fA as a suitable relationship and quotes -

"fA = 0.745 as the damaging level

fA $\leq$ 0.527 as safe level."

Reference 5.

C. Morris - Vibrations due to blasting and their effect on building structures.

The Engineer, Nov. 3, 1950. pp. 394/395, 414/418.

> "the limiting amplitude of 8.2×10^{-3} (0.0082) inches gives a conservative estimate of the limiting amplitude for conventional structures. The state of repair of the building does not seriously affect this estimate, as an old building technically less strong than a new one will have benefitted by a process of "bedding in" due to long-continued small movement."

Reference 6.

Thoenen, F.R. and S.L. Windes, 1942. Seismic Effects of Quarry Blasting.

United States Bureau of Mines Bull. 442.

"f^2 A $\geq$ 10 Damage

f^2 A $\leq$ 1 Safe "

"Vibrations of very low amplitude and short duration were neglected, even though the accelerations may have been high, because these conditions were noticeable in the records of many tests that did not cause damage."

LEGEND

1 — State of New Jersey as specified by regulation

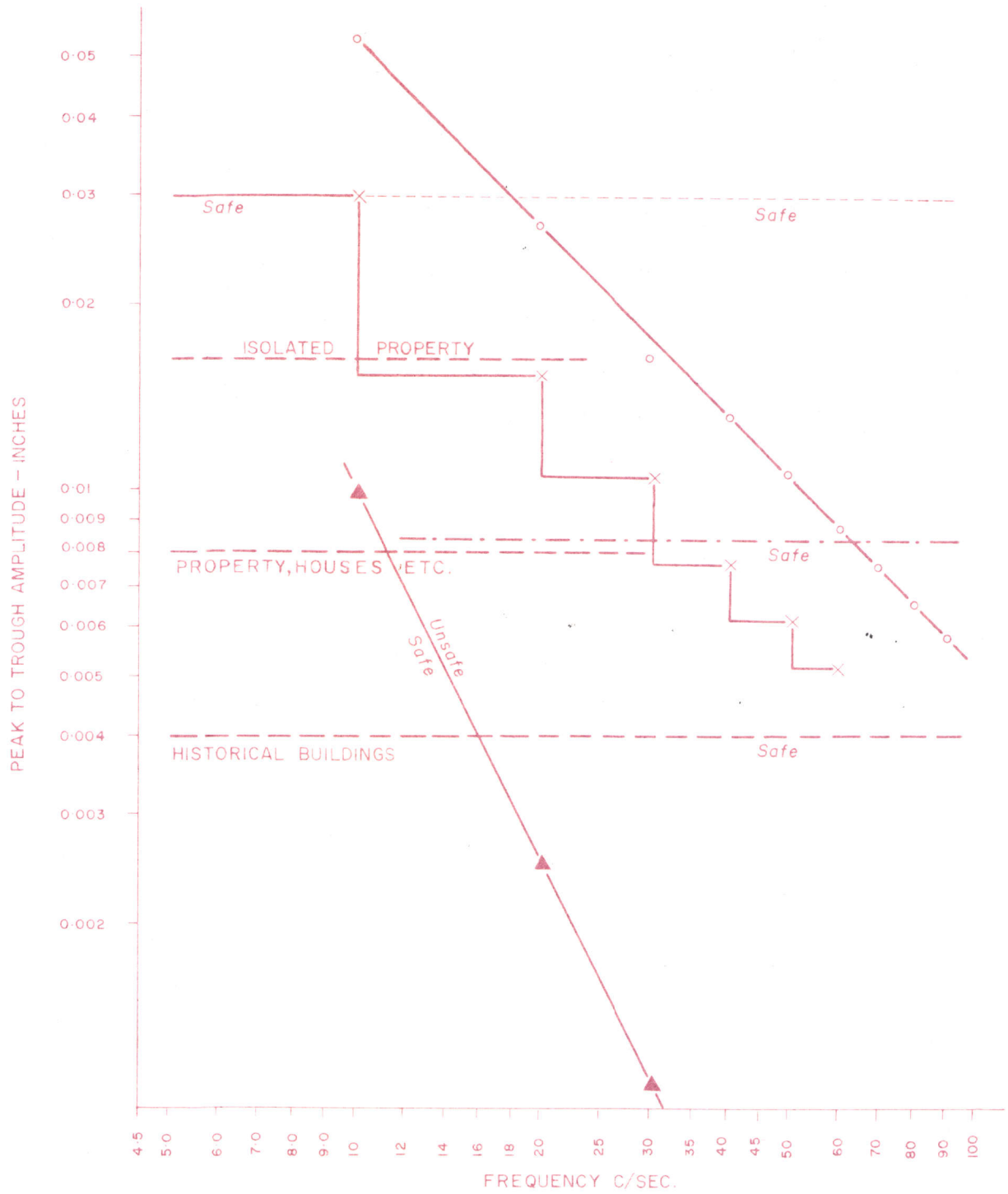
2 — State of Pennsylvania as specified by regulation for any structure

3 — As recommended by Teichman

4 — As recommended by Crandell to a United States Insurance Co.

5 — As recommended by Morris

6 — As recommended by U.S. Bureau of Mines



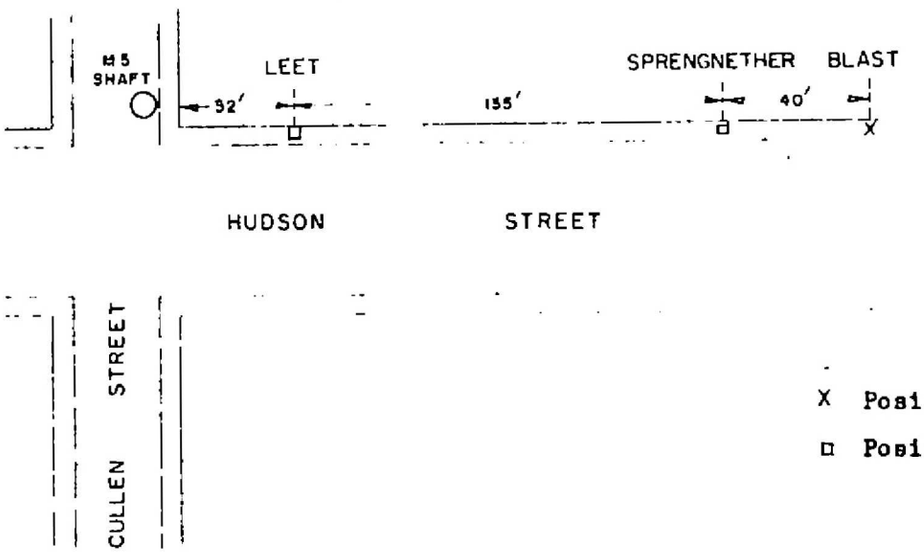
MAXIMUM SAFE PEAK TO TROUGH AMPLITUDE OF VIBRATION PLOTTED AGAINST FREQUENCY AS SPECIFIED AND RECOMMENDED BY VARIOUS U.S. GOVERMENT AUTHORITIES AND BY INDIVIDUALS

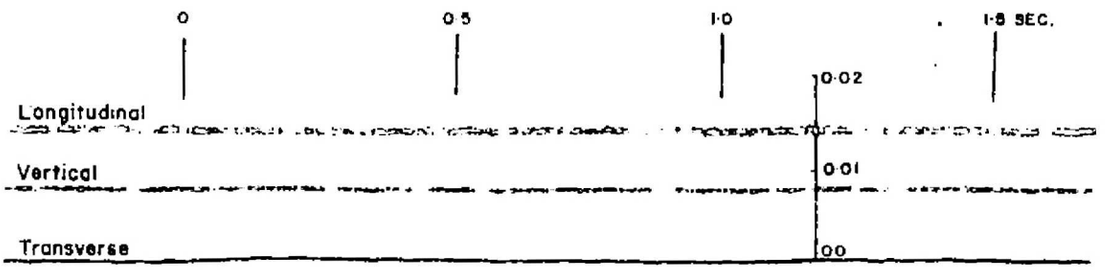
Date : 18/9/1959

Observer : E.J.Polak

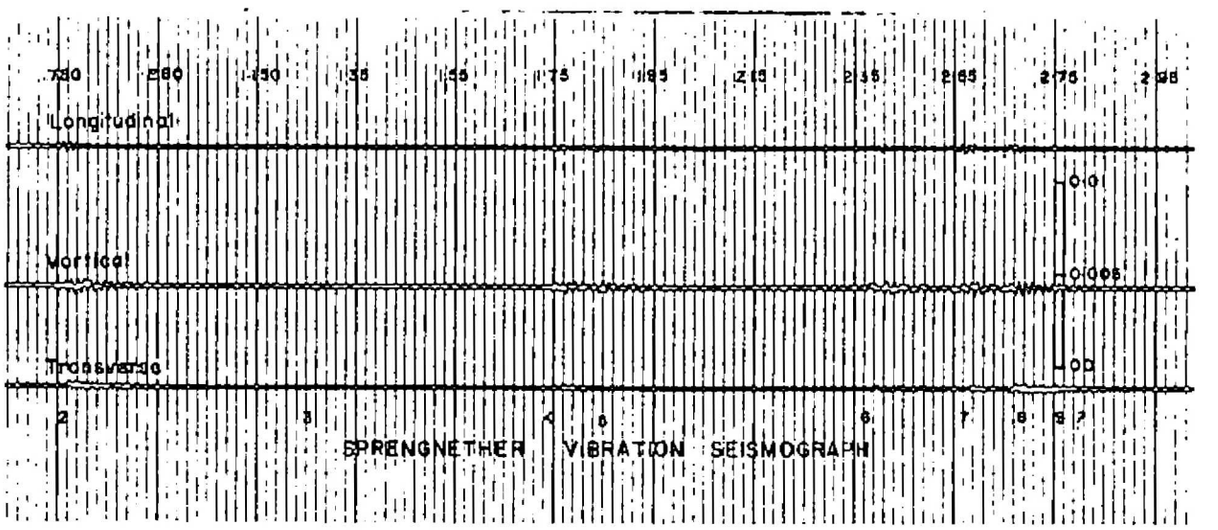
Charge : 27 lbs. A60 Gelignate in 24 sections.

ARRANGEMENTS OF INSTRUMENTS.
(not to scale)





LEET VIBROGRAPH RECORD



VIBRATION TEST,

M.M.B.W. SEWER TUNNEL,
HUDSON STREET, SPOTSWOOD, VIC.