III d 3

DYNAMIC INVESTIGATIONS

Dr.L. BENDEL ING.

Privatdozent

an der Ecole Polytechnique de l'Université de Lausanne

LUZERN.

1. PURPOSE OF THE DYNAMIC INVESTIGATIONS.

The dynamic investigations became necessary:

a) because in the present cases, the ground has been put into vibration by the driving of the trams. We are still badly informed about the intensity of the vibrations and their influence on the substructure.

b) With the compression of the natural soil and the subsequent building-in, artificial shaking by vibrators was produced. These artifically produced oscillations are to compress the natural soil and the inner building. Too little is still known about the efficacy of the compressing through vibrators.

c) It had to be determined how great was the influence of the shaking through the vibrators and of the tram upon the houses next to the street.

2. GROUND-VIBRATORS USED.

Two types of ground vibrators V_1 and V_2 were used. The vibrator V_2 was no longer used because of the results of measurements. The amplitudes became too small; also the surface of the gravelly foundation was becoming smooth through vibration. The effiency in the depth was little cf. Figs. 1, 2 with typical vibrations diagrams for ground vibrators V_1 and V_2.

The disadvantage of the vibrators used was that they ran with only one single frequency. On the suggestion of the Author, ground vibrators with adjustable frequencies were installed in order to be able to assimilate the frequency of the vibrations to the natural frequencies of the ground, i.e. to obtain resonance-effect.

3. KIND OF DYNAMIC INVESTIGATION.

The following kinds of dynamic investigations were carried out:

a) Determining the natural oscillations of the lower strata of the ground.

b) Determining the natural oscillations of the ballast.

c) Determining the natural oscillations of rails.

d) Size of amplitude of the vibrations of the soil dependent upon the distance of place of measurements from the vibrator.

e) Size of the amplitude of vibrations of a stratum of sand, dependent on the water-content of the sand-stratum.

f) Size of the frequencies and amplitudes of well and badly wedged-in sleepers.

g) Size of frequencies and Amplitudes of the houses alongside the old and alongside the new rails.

To measure the vibrations and the frequencies, an Elektron-Ray-oscillograph was used. See fig. 3.

About the single kinds of vibrations measurements it is to be noticed:

a. DETERMINATION OF THE NATURAL OSCILLATIONS OF THE LOWER STRATA OF THE GROUND.

aa) Essential

The natural vibration of a needle is obtained by setting the needle vibrating and afterwards letting it vibrate freely. The number of vibrations of the needle per second gives the number of natural vibrations of the needle in Hertz.

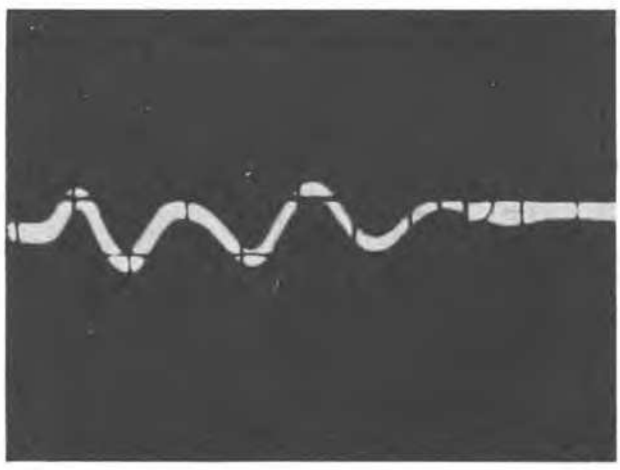
bb) Production of vibration of the soil

In order to obtain the number of natural vibration of the soil a weight of 15 kg was dropped from a height of 1.5 m at the first trial. The vibrations were measured for number and size at a distance of 3 m. The vertical

The amplitudes of vibrators.

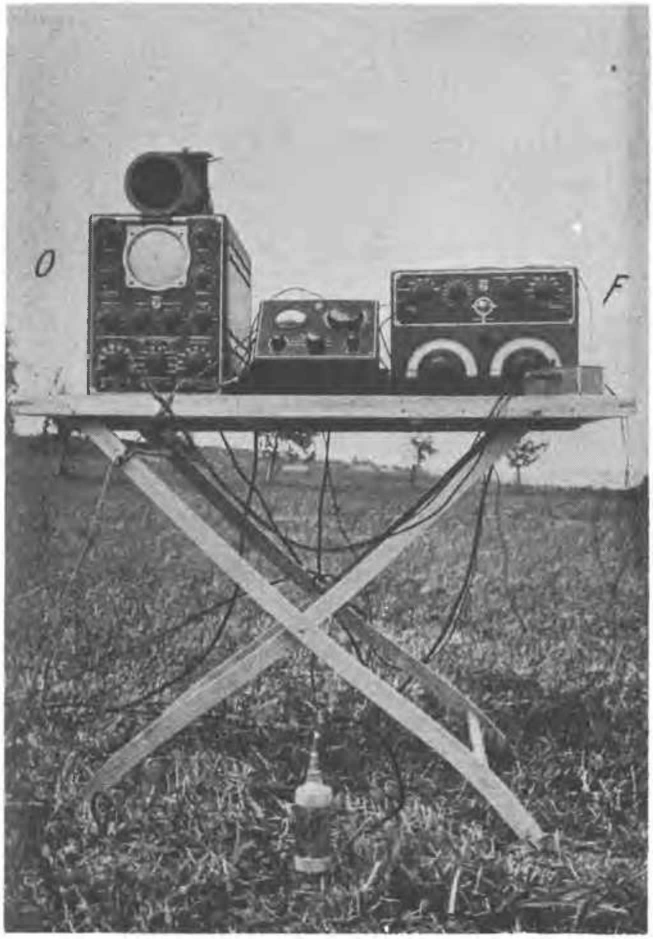
Vibrator 1. The amplitudes of vibrator with great efficacy.

FIG.1



Vibrator 2. The surface was becoming smooth through vibration. Small efficacy.

FIG.2



Electron Ray - Oscillograph

O - Oscillograph
F - Instrument for measurement of frequency
S - Instrument for vibration indication

FIG.3

vibration in cutting was measured.

cc) Nature of the soil at the point of disturbance.

The ground consisted of grey loam mixed with organic matter. It was in a moist, soft, plastic condition. The physical dynamic and chemical indices of the soil are shown in Tables 1 to 8.

dd) Results of measurements.

The determination of the number of natural vibrations of the ground gave the following value

Table 1
Natural frequency of the soil

Weight of tup	Amplitude	Frequency
from a height of 1,5 m		
15 kg	10 μ	21 Hz
30 kg	10 μ	21 Hz
45 kg	15 μ	21 Hz

Inferences

1) The natural frequency of the soil, i.e. the number of natural vibrations of the ground has independently of a weight of tup, been ascertained to 21 Hz. This value agrees with the results of other trials carried out on ground of similar nature. Cf. Table 210. Vol. II, Bendel, Eng. Geology 1948.

2) The amplitude of soil increases with increasing weight of tup, as was to be expected.

During investigations on the Aerodrome at Emmen the following values were found:

Table 2

	Substructure of the track consisting of road metal		Natural soil
	unvibrated	vibrated	
Frequency	21 Hz	24 Hz	23,7 Hz
Amplitude	12,8 μ	26,5 μ	17,5 μ
Speed of propagations of ground-waves	375 m/S	910 m/s	1000 m/s
Deadening between 1st to 2nd amplitude	1,22 : 1	1,13:1	1,16: 1
Deadening between 2nd to 3rd amplitude	1,60 : 1	1,70:1	1,62: 1

b) Determination of natural vibration of the ballast

aa) The determination of natural frequency of built-in materials is shown on Table 3

Natural frequency of **built-in material** under the rails.

Table 3

Weight of tup from height of 1,5 m	Amplitude	Frequency
15 kg	8 μ	25 Hz
30 kg	12 μ	23 Hz
45 kg	18 μ	21 Hz

bb) Inferences

I. The natural frequency of the hard road metal material alters somewhat the weight of tup is raised; this was to be expected, as according to the amount of the falling weight the hard ballast is more or less compressed. When the trials are repeated with an equal weight of tup, the result is that after the 5th trial the number of natural vibrations remains the same.

II. The Amplitude increases perceptibly with an increasing weight of tup.

III. For the installation built-in it is important that it should have approximately the same natural frequency as the natural soil. When this is not the case a foreign body is present in the construction of the streeet which shows other qualities of vibrations than its surroundings.

IV. Resonances.

Between the disturbing vibration of the tram and the building-in material there often occur resonances. In this case distruction occurs in the covering next to the rails.

c. DETERMINATION OF THE NUMBER OF NATURAL VIBRATIONS OF THE RAILS.

aa) Production of the vibrations.

For the production of the vertical and horizontal vibrations, a hammer weighting 8 kg, was dropped from a height of 0,10 m vertically or in longitudinal direction on the rails. The vibrations were measured for amplitude and frequency at a distance of 3 m from the point of disturbance.

bb) Nature of the rails.

TABLE 4.

Results of measurement of vibrations in the tram rails

Direction of vibrations	place of measurement I		place of measurement II	
	Amplitude	Frequency	Amplitude	Frequency
Vertical Components	6 μ	140 Hz	6 μ	140 Hz
Horizontal Components	9 μ	140 Hz	12 μ	140 Hz
Cross Components -	9 μ	250 Hz	16 μ	150 Hz

cc) Inferences.

I) The amplitudes are small as the excitement was feeble; with a passing tram a greater amplitude must be expected.

II) The natural frequencies of the rails are heigh.

III) The vibrations of the rails have a result that they loosen themselves from the concrete, and that the concrete is ground down to a thin layer.

Magnitude of the amplitudes of the vibrations of the ground, depending on the distance of the place of measurements from the vibrator.

d. PRODUCTION OF VIBRATION

Two differently built vibrators V_1 and V_2 were used for the production of vibrations.

aa) Results of measurements.

TABLE 5.

Distance of the Pulsator from the Place of measurements.

	- 15 m	- 10 m	- 5 m	0	5	10	15	20	25	30 m
Amplitude in μ Vertical components	15	30	40	50	33	20	11	10	7,5	2,6
Frequency	14	--	13,5	12,5	14,5	14,5	12	13	14,5	14,5

TABLE 6.

bb) Amplitude dependent on

Moisture content of sand	Vertical component	Horizontal vertical to direction of movement	in direction of movement	Frequency
4,36 %	45 μ	6 μ	13 μ	15 Hz
6,00 %	36 μ	12 μ	11 μ	15 Hz
10,00 %	40 μ	38 μ	26 μ	15 Hz
Natural soil	18,9 μ	19 μ	16,7 μ	15 Hz

bb) Inferences from Results of measurements

I) The measurements allowed to draw conclusions a posteriori as regards the course of the vibrations at different distances as also regarding the magnitude of the deadening influences in case the ground vibrator, vibrated at the same place. Fig.4.

II) The frequency, dependent on the pulsator, remains essentially the same for the different distances.

III) The amplitudes of the Pulsator approaching the place of measurements are greater for the same distances than those of the pulsator going away from the place of measurements. This is shown by the moving forward of the pulsator and the horizontal components arising from this in the oscillations of the soil which is directed forward.

e. DYNAMIC BEHAVIOUR OF A LAYER OF SAND AS BUILDING - IN MATERIAL.

aa) Directions for measurements.

Vibrator I

Place of Measurements : 3 m distant from
Place : section 8, loamy soil.

cc) Inferences

I) Horizontal vibrations

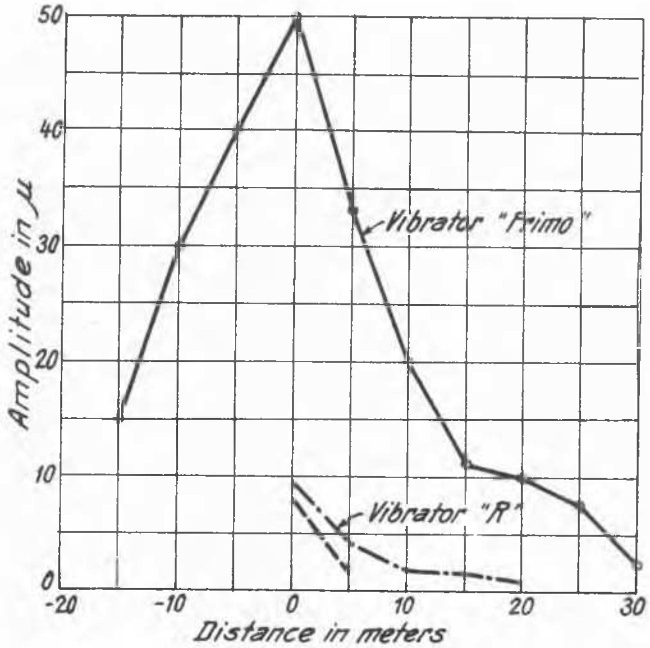
The measurements show that sand with the least moisture content of 4,36 % (in a state of being carried on) shows only small horizontal vibrations. With an increasing moisture the latter become greater, as is shown clearly by the measurements with 10% moisture.

II) Vertical vibrations

The vertical vibration is smallest with 6% moisture-content of the sand. Cf. Fig. 5 which shows that the smallest weight per unit of volume, and the greatest heaping together appears with a 6% moisture content.

III) Vibrations on the surface of the earth

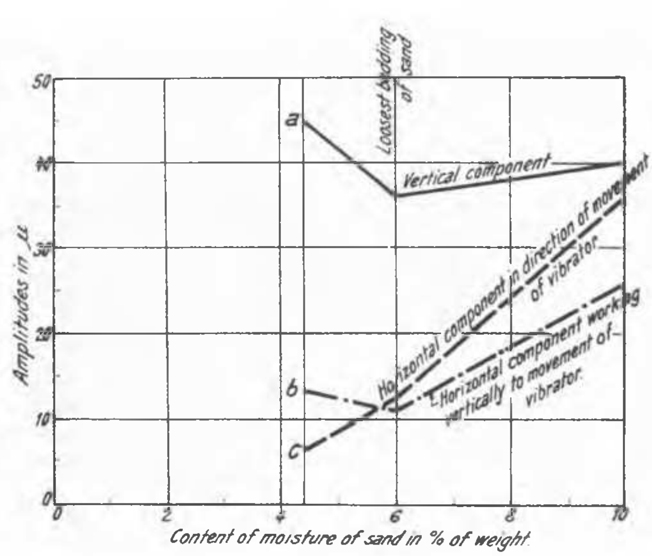
The measurement on the earth shows a considerably smaller vertical amplitude than the measurement on the sand. The vibrations on the earth and on the sand were measured at the same distance from the vibrator. The result of the measurements are evaluated graphically in fig. 5.



—— on stony bed
---- in rock

Amplitude of forced vibrations in various distances from vibrator.

FIG.4



Amplitudes in dependance of moisture of sand.

—— Vertical component
--- Horizontal component in direction of vibrator
—.— Horizontal component vertically to vibrator

FIG.5

f. DYNAMIC BEHAVIOUR OF WELL-WEDGED - IN AND BADLY WEDGED - IN SLEEPERS.

aa) Directions for measuring.

Disturber: a passing tram with a speed of 18 km/h.
Place: layer with profile 8.
Place of measurement: the end of a sleeper.

bb) Results of Measurements.

Amplitudes and frequencies of rails dependent on the kind of wedging-in of the stone basin.

Table 7.

Vertical	well wedged Ampl.	Freq.	badly wedged Amplitude	Frequency
Vertical	230 μ	26 Hz	280 μ	31 Hz
Horizontal lengthwise	55 μ	37 Hz	70 μ	90 Hz
across direction of travel	110 μ	25 Hz	120 μ	31 Hz

cc) Purpose of Measurings

It can very often be observed that the covering breaks first at the end of the sleeper. With these measurings it was investigated whether with a side ways wedging of the sleepers through the stony bed, the sideways vibrations could be reduced.

dd) Inferences

I) Cross-directions

As table 7 shows the amplitudes of the vibrations in a cross-direction with well and badly wedged sleepers like great. As the vibrations-frequency of the sleeper is in order of size of natural vibrations of the stone bed(cf. table 3, according to which the number of natural vibrations of the broken stones amounts to about 25 Hz) there is resonance.

II) Vertical vibration

With the vertical vibration the Amplitude is, with good wedging-in, somewhat less than with a sideways badly wedged-in rail. Therere is, moreover approximately resonance between the number of natural vibrations of the ballast and the forced vibrations. Hence the relatively great amplitude with 230 μ

III) Lengthwise vibration

The lengthwise vibration has for well wedged - in rails a somewhat smaller amplitude as with sideways badly wedged in rail. It is worthy of note is the great frequency with badly wedged-in rails.s.

IV) Frequencies

The frequencies are, with sideways well wedged sleepers smaller than with sideways badly wedged-in sleepers. The frequency diminuish substantially, as against sideways badly wedged-in sleepers. There is a danger that the frequency sinks down to the frequency of the tram vibrations, through which there would be a possibility of a resonance between the number of vibrations of the sleeper and that of the tram.

g. PRODUCTION OF VIBRATIONS THROUGH A TRAM ON THE OLD AND ON THE NEW RAILS.

aa) Directions for measuring

Measurements of vibrations in section 8 :
Passing tram with a speed of 18 km/h on the old and on the new rails.

bb) Results of Measurements.

TABLE 8.

Vibrations with the old and the new rails, measured in μ

Place	Vertical Rails		Horizontal I Rails		Horizontal II Rails		Remarks
	old	new	old	new	old	new	
The place or measurement is 1 m distant from the rail	17	6 18 Hz	9	5	5,5	1	The new produces deadening of vibrations. Amplitudes have been reduced by 64,5 %, 44,5 % and 82 %
Curb stone	11	3 15 Hz	9	2,5 19 Hz	5,5	0,3 14 Hz	On the curb stone the diminuition of amplitudes was 73%, 72 % and 85,5 %
1 m on the side - walk	11	3	3,5	1			On the side-walk the diminuition of amplitudes was 73% and 7,15 %

cc) Inferences.

The measurements of vibrations entered in Table 8 which were taken for a tram going on the original rails, as producing the vibrations are compared with the vibrations which the tram produces when travelling at the same rate of speed (18 km/h) on the new rails.

The measurements showed that the amplitudes of the vibrations had been greatly reduced by the new stone bed. The substructure put in has a good deadening effect.

The inhabitants of the street, in which this rebuilding had been undertaken, formerly found the passing of the trams very troublesome as they were awakended in the morning. After the re-building they noticed nothing more.

On the original rail-track repairs to the surface were constantly necessary, as it always loosemed itself from its foundation. This is partly attributable to the strong shaking which loosened the joints of the foundation. After the building-in of the rails no further damage could be noticed.

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SUB-SECTION III f

AREAL STUDIES

III f 1 REGIONAL STUDY OF THE SOILS FROM SÃO PAULO - BRAZIL

E. PICHLER, assistant engineer

Soils and Foundations Division, Instituto de Pesquisas Tecnologicas - São Paulo - Brazil

SYNOPSIS.

The paper deals with the regional soil conditions of São Paulo - Brazil. The different soil strata are considered from the geological point of view as well as from that of applied Soil Mechanics. Results from routine soil tests run on undisturbed samples taken from six inch borings are presented.

Soil studies acquired special importance in São Paulo mostly in connection with foundation problems of reinforced concrete buildings (up to 36 floors). These studies were carried out during the last ten years mainly by the Soils and Foundations Division of the Instituto de Pesquisas Tecnológicas. To present the results of these investigations on the principal characteristics of the São Paulo soils constitutes the main purpose of this paper.

Fig. 1 presents a general map of the city of São Paulo showing the outlines of the geological formations as well as the area of most intensive construction. The location of the generic profile presented by fig. 2 has been indicated also on this map.

The bedrock is formed mostly by gneisses and schists of the "São Roque" series, of Algonkian age. These rocks, which show signs of advanced decomposition whereever they appear, are covered by the São Paulo beds ("Camadas de São Paulo") considered by most geologists