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THE INFLUENCE OF BUILDING VIBRATIONS ON WEIGHING*

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ABSTRACT

Data are used from three different institutes to indicate the influence of building vibrations on weighing.

INTRODUCTION

One of the most important effects on weighing is that due to vibrations in the building. For the present discussion of building vibrations, we shall make use of estimated data concerning these vibrations which were kindly put at our disposal by three different institutes.

(A) A T.N.O. report by H. van Koten states that, in a building at a height of 5 m, the vibrations can be characterized by a frequency of 1 Hz, by an amplitude of the linear vibrations of 1 μm, and by an amplitude of the angular vibrations of 3×10^{-7} radians.

(B) Dr. Ritsma of the Royal Dutch Meteorological Institute at De Bilt provided the following information regarding microseismic vibrations, namely that due to wind the soil can be expected to participate in vibrations which at frequencies of 1/6 Hz have an amplitude of 6 μm whereas at frequencies of 1 Hz the amplitude becomes 0.4 μm.

(C) According to measurements of ir. H. L. Koning of the Soil Mechanics Laboratory at Delft, one can expect that at the facade of a building, facing average traffic at a distance of 8 m, the vibrations at 1 m above street level have a frequency of approximately 20 Hz and an amplitude of 15 μm.

THEORY

For the calculation, we concentrate on a beam-type balance with an ideal feedback. As such feedback system uses a reference which is connected with the building, it will force the balance to participate in the building vibrations. Through elementary mechanics, one finds for the mechanical moment ΔM controlled by the feedback:

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TABLE I

RESULTS OF CALCULATIONS OF THE EFFECT OF BUILDING VIBRATIONS ON WEIGHING

	X (μm)	A (μrad)	f (Hz)	ΔM_{RMS} (Nm)	Δm_{RMS} (ng)
Case A	1	0.3	1	$4 \cdot 10^{-11}$	40
Case B	6		1/6	$0.6 \cdot 10^{-11}$	6
	0.4		1		
Case C	15		20	$300 \cdot 10^{-11}$	3.000

For explanation of symbols see the text.

$$\Delta M = J\ddot{\alpha} - m\ddot{x}h\cos\alpha - m(\ddot{y} - g)h\sin\alpha \tag{1}$$

where

J is the momentum of inertia of the balance,
m is the mass of the balance,
h is the distance between rotation axis and centre of mass,
g is the acceleration due to gravity,
x is the horizontal displacement of the axis of rotation in a direction perpendicular to that axis,
y is the vertical displacement of the rotation axis and α is the angle between the mathematical vertical and the reference direction of the feedback system.

For harmonic vibrations of the building, this in first-order approximation leads to:

$$\Delta M_{RMS} = J\,A\,\omega_x{}^{3/2}T_i{}^{-\frac{1}{2}} + mhX\,\omega_x{}^{3/2}T_i{}^{-\frac{1}{2}} \tag{2}$$

where

$\Delta M_{RMS} = \{\langle \Delta M^2 \rangle\}^{\frac{1}{2}}$ is the RMS value of ΔM
$\omega_x = 2\pi f_x$, f_x being the frequency of the horizontal vibrations,
X is the amplitude of the horizontal vibrations,
$\omega_\alpha = 2\pi f_\alpha$, f_α being the frequency of the angular vibrations,
A is the amplitude of the angular vibrations, and
T_i is the integration time of the feedback system.

In addition to the data mentioned in the introduction, we shall use: $m = 0.03$ kg, $J = 3.10^{-5}$ kg m^2, $h = 10^{-4}$ m and $T_i = 10$ sec. The results of the calculations are given in Table 1. If we assume the armlength of the balance beam to be 10 cm, the RMS value Δm_{RMS} of the erroneous mass Δm is also calculated and shown in Table 1.

DISCUSSION

The above results show that, when the influence of the traffic (case C) is negligible and when no special precautions are taken to reduce the effect of building vibrations, the errors due to these building vibrations are of the order of 10 ng. In case one aims for mass determinations in the nanogram region, one has to note that special measures for the reduction of the influence of building vibrations are necessary.