NBSIR 85-3126

Monitoring of Dynamic Response of Floor in "D" Wing of the Main Building, Bureau of Engraving and Printing

Felix Y. Yokel

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Gaithersburg, MD 20899

and

Paul W. Mayne

Law Engineering Testing Company
P.O. Drawer QQ
McLean, VA 22201

March 1985

Prepared for
...au of Engraving and Printing
... and C Street, SW
...hington, DC 20228

NBSIR 85-3126

MONITORING OF DYNAMIC RESPONSE OF FLOOR IN "D" WING OF THE MAIN BUILDING, BUREAU OF ENGRAVING AND PRINTING

Felix Y. Yokel

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Gaithersburg, MD 20899

and

Paul W. Mayne

Law Engineering Testing Company
P.O. Drawer QQ
McLean, VA 22201

March 1985

Prepared for
Bureau of Engraving and Printing
14th and C Street, SW
Washington, DC 20228

U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

ABSTRACT

In December 1981, the National Bureau of Standards investigated structural vibrations induced in the first floor of the "D" wing of the main building of the Bureau of Engraving and Printing. In January 1985, additional measurements were performed to check whether there are any changes in the response characteristics of the floor systems which might indicate structural degradation. The results of these measurements are presented and it is concluded that the results of the vibration measurements give no indication of structural degradation.

Key Words: Floor vibrations; structural dynamics; structural engineering.

1. BACKGROUND

Following the installation of two new coiling machine perforators on the first floor of the "D" wing of the main building of the Bureau of Engraving and Printing, floor vibrations were observed. In December 1981, the Center for Building Technology of the National Bureau of Standards (NBS) conducted vibration measurements in order to determine whether potential structural damage could result.

In an analysis of the December 1981 vibration data [1], NBS concluded that future structural damage as a result of these vibrations would be unlikely. However, it was recommended in the NBS report that machine web speeds which were observed to produce peak displacement responses in the floor systems be avoided. It was also recommended that vibrations be periodically monitored in order to detect potential signs of structural deterioration.

It was recommended to check the natural frequency and damping characteristics of the floor systems in these vibration tests and to compare measured values with those observed in December 1981.

In accordance with the above NBS recommendation, vibrations were monitored on January 7, 1985. The results of this investigation are reported herein.

2. TEST EQUIPMENT

A SINCO S-3[1/] vibration monitor with an oscillographic recorder was used. Vertical vibrations were measured with a geophone which measures velocities and has a flat response from 6 Hz to 150 Hz frequency. Velocities are measured to an accuracy of 0.25 mm/s[2/]. Measurements were graphically recorded to a scale of $4 \cdot 10^{-3}$ g's per mm for accelerations, 0.1 mm/s per mm for velocities, and 0.001 mm per mm for displacements. The time scale for most measurements was 4.21 ms per mm.

1/ Reference to a specific make of equipment does not imply endorsement of this equipment by the National Bureau of Standards.

2/ Information provided by the manufacturer's representative.

3. TEST SCHEDULE

The objective of the tests was to obtain natural frequencies and damping ratios (percent of critical damping) at two critical locations near the machines on the south and north floors, and to duplicate some of the December 1981 measurements at locations and machine speeds which produced the greatest displacement response.

Data were taken for vertical acceleration (a), veclocity (v), and displacement (δ) of the floor at the point of measurement as a function of time (t). Since the equipment used measures velocities and since the acceleration records of the steady-state machine induced vibrations tend to exhibit many discreet spikes while the velocity and displacement records are relatively smooth sinusoidal curves, RMS values for comparison with the December 1981 measurements were estimated from velocity and displacement records only.

Critical machine web speeds which produced peak displacement response amplitudes in the December 1981 tests were 117 fpm (feet per minute) and 160 fpm for the south floor, and 125 fpm and 155 fpm for the north floor. In the present test the machine on the south floor would not run faster than 150 fpm. Consequently, the south floor readings for the fast machine speed were taken at 150 fpm, rather than the 160 fpm for which there are data from the December 1981 tests. This may have resulted in a reduced dynamic response.

The time scale of 4.21 ms per mm used in the recording of data was obtained by advancing the recording tape at a rate of 0.275 m/s. The manufacturer specified the speed of paper advance to be 0.25 m/s $\pm$3 percent. The speed of 0.275 m/s which was used to calculate response frequencies was obtained by calibrating the speed of advance of the recording tape against time intervals measured electronically to an accuracy of $\pm$ 2 percent[2/] and marked on the tape. Measurement inaccuracies may be responsible for slight discrepancies between frequencies measured in the present and the previous test. However, since changes in the magnitude and distribution of floor loads could also lead to slight changes in frequency response, the accuracy of the equipment used was judged adequate for the intended purpose.

Table 1 shows the test schedule. Refer to figure 1 for test locations.

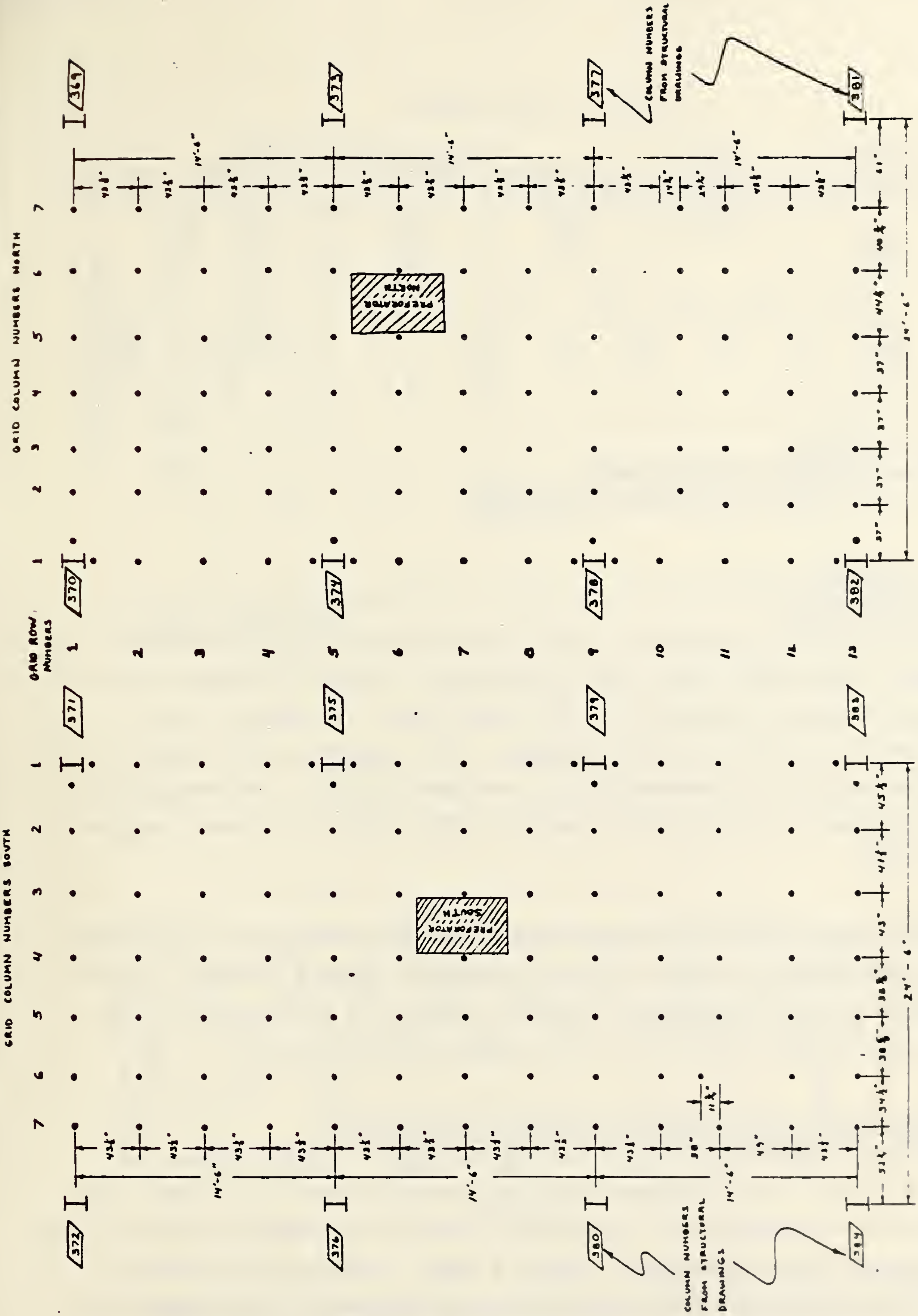


Figure 1. Grid of test points (dots indicate grid points)

Table 1. Test Schedule

Floor	Location Row/Col.*	Free Vibration	Steady-State Vibration 117 fpm**	150 fpm	125 fpm	155 fpm
South	7/4	(1)***	(2)	(3)		
	4/4		(4)	(5)		
	9/4			(6)		
North	6/5	(7)			(8)	(9)
	8/5				(10)	(11)
	10/5					(12)

* Refer to figure 1.
** Machine web speed, feet per minute.
*** Number in parentheses designates test number.

4. TEST RESULTS

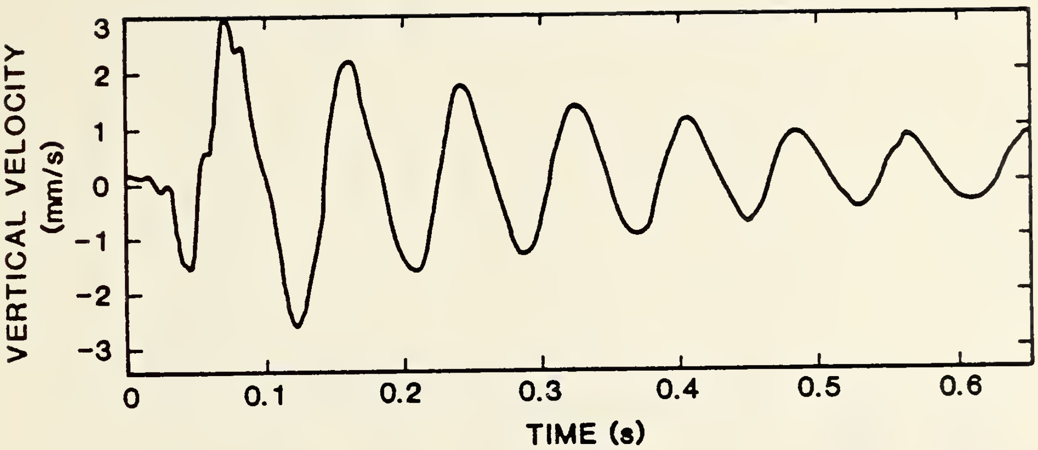
4.1 FREE VIBRATIONS

Free vibrations were generated by a 190 lb person jumping once near the point of measurement. Figure 2(a) shows a plot of vertical velocity (v) versus time (t) for a free vibration at point 7/4 on the south floor. The damping ratio is approximately 5 percent of critical damping. This compares with a damping ratio of 6 percent measured in December 1981 at the same location. The fundamental natural frequency is 13.0 Hz, which compares with a 13.3 Hz frequency measured in December 1981.

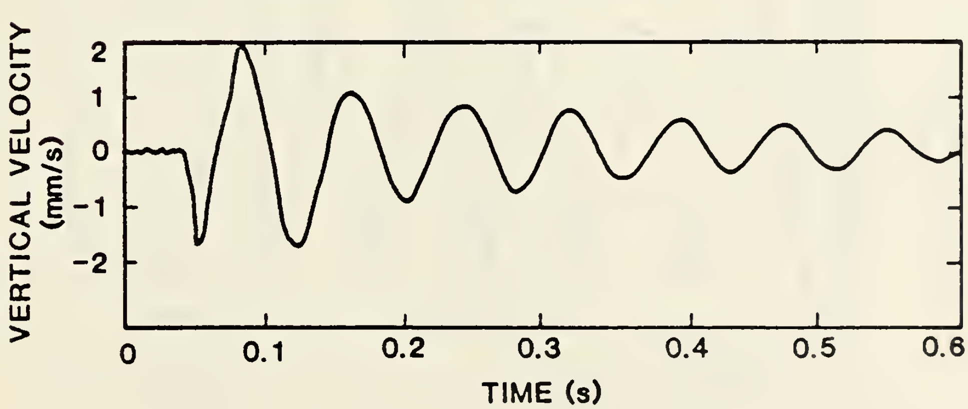
Figure 2(b) shows a plot of vertical velocity for the north floor. The damping ratio is approximately 6 percent and the fundamental natural frequency 13.5 Hz. This compares with a 14 Hz natural frequency observed in December 1981. The damping ratio of the north floor was not measured at that time.

4.2 STEADY-STATE VIBRATIONS WHEN MACHINES ARE OPERATING

Typical traces of vertical velocity and displacement vs. time are shown in figure 3 for point 7/4 on the south floor at a machine speed of 117 fpm. The results of the measurements are summarized in table 2 and compared with RMS values of the December 1981 measurements. Figure 4 shows a comparison of primary vibration frequencies at different machine speeds measured in the present tests with average values obtained in the December 1981 tests.



(a) Trace of vertical velocity vs. time for a free vibration at point 7/4 on the south floor



(b) Trace of vertical velocity vs. time for a free vibration at point 6/5 on the north floor

Figure 2. Free vibration record

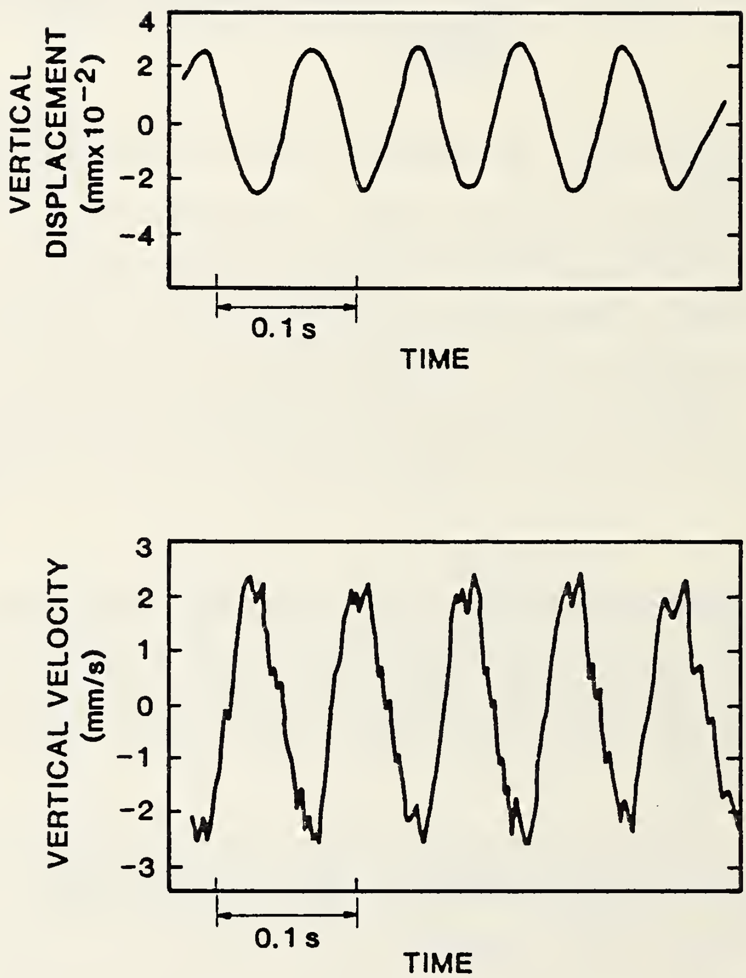


Figure 3. Traces of vertical displacement and velocity vs. time at point 7/4 on the south floor measured at 117 fpm machine speed

Table 2. Comparison Between December 1981 and January 1985 Measurements of Steady-State Vibrations Induced by Different Machine Speeds

Test No.	Floor	Grid Point	Machine Speed (fpm)	Peak, δ mm x 10^{-2} 1/	Estimated RMS, δ mm x 10^{-2}	RMS, δ 1981 Test mm x 10^{-2}	Peak v mm/s	Estimated RMS v mm/s	RMS v 1981 Test mm/s	$\frac{\text{RMS } \delta}{\text{RMS } \delta, \text{ '81}}$	$\frac{\text{RMS v}}{\text{RMS v, '81}}$	f, Hz
2	S	7/4	117	3.0	2.1	4.6	2.5	1.8	3.9	0.46	0.46	13.4
3	O	7/4	150	1.1	0.8	0.8	1.8	0.9	0.9	1.0	1.0 2/	17.9
4	U	4/4	117	1.7	1.2	2.7	1.6	1.1	2.2	0.44	0.5	13.6
5	T	4/4	150	0.6	0.4	0.3	0.8	0.5	0.4	1.33	1.25 2/	18.0
6	H	9/4	150	0.95	0.7	1.0	1.3	1.3	1.1	0.7	0.8 2/	17.8
8	N	6/5	125	1.1	0.8	1.75	1.2	1.0	1.5	0.46	0.67	14.8
9	O	6/5	155	1.2	0.85	0.56	0.2	1.1	0.64	1.52	1.72	18.7
10	R	8/5	125	1.2	0.85	1.4	1.4	1.0	1.3	0.61	0.77	14.5
11	T	8/5	155	2.0	1.4	1.1	2.3	1.6	1.2	1.27	1.33	19.2
12	H	10/5	155	1.0	0.7	1.4	1.6	1.1	1.5	0.5	0.73	18.6

1/ Unless otherwise identified, all data are for the January 1985 tests.

2/ Comparison is with December 1981 measurements which were made at a faster (160 fpm) machine speed.

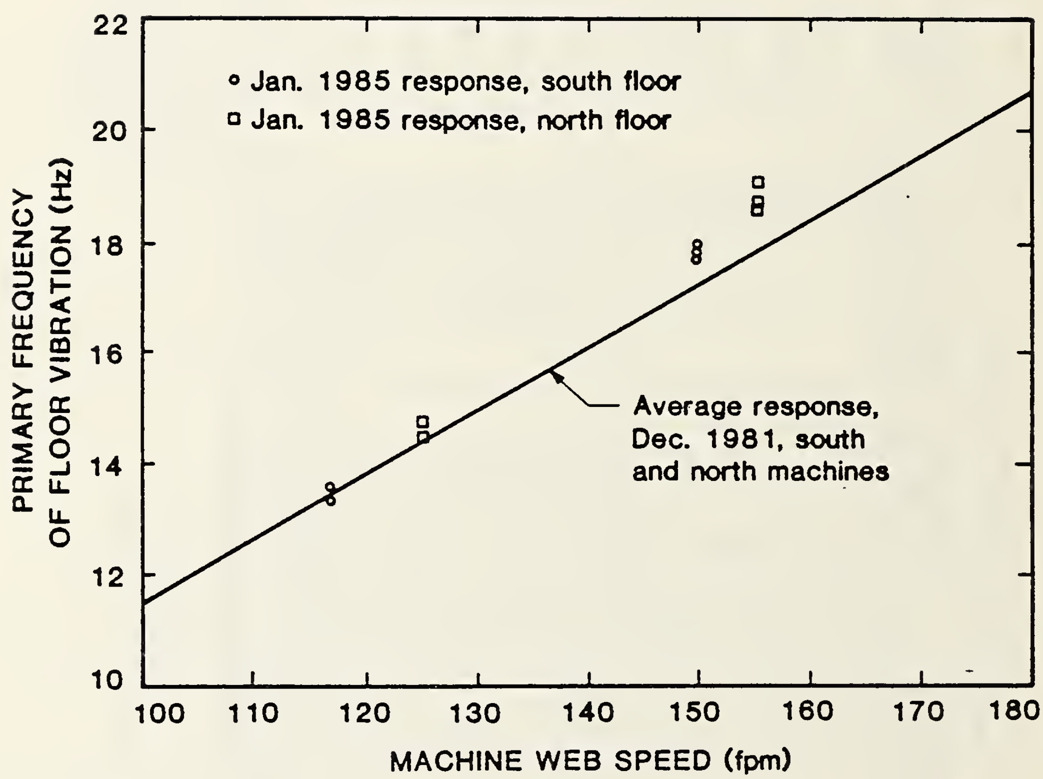


Figure 4. Comparison between primary frequencies of steady-state vibrations as a function of machine speeds measured in December 1981 and January 1985.

5. DISCUSSION OF RESULTS

Any structural degradation of the floor system would tend to increase the damping ratio. It also would tend to decrease the stiffness of the system and thus lower its natural frequency, however, this effect may be more difficult to observe, since the frequency will also be affected by the magnitude and distribution of floor loads which is likely to change from test to test.

The test results indicate that the damping ratio of the south floor observed in the January 1985 test is somewhat lower than that observed in December 1981. Thus, there is no indication of any structural degradation (no data were taken for the north floor in December 1981, however, future tests can be compared with the results of these tests.)

The natural frequencies of the south and north floors observed in these tests are somewhat lower than those observed in December 1981, however, in view of the fact that the natural frequency is also affected by the magnitude and distribution of floor loads, this minor difference is considered to be insignificant.

The comparison of the steady-state displacement responses in table 2 shows that the responses are of the same order of magnitude. For the lower machine speeds the RMS displacement responses measured in the present tests ranged from 44 to 61 percent of those measured in December 1981. For the larger machine speeds, most RMS diplacement responses in the present test tended to be larger than those in the December 1981 test. The RMS displacement responses measured in the present test ranged from 0.7to 1.52 times those measured in December 1981. It can be seen from figure 1a in reference [1], that the response is sensitive to the machine speed and a larger (or smaller) response could conceivably have been produced by slightly different machine speeds.

It is important to note that, as the analysis in the 1982 report shows, displacement responses of the order of magnitude observed in the December 1981 tests and those observed in the present tests are associated with stress levels which are unlikely to produce any structural deterioration [1].

It is concluded from the data presented in this report that the results of the January 1985 vibration measurements do not give any indication of structural degradation of the floor system.

6. REFERENCES

[1] Reinhold, T. A., Yokel, F. Y., Rudder, F. F., "Investigation of Floor Vibrations in the "D" Wind of the Main Building of the Bureau of Engraving and Printing," NBSIR 82-2599, National Bureau of Standards, October 1982.

NBS-114A (REV. 2-8C)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET (See instructions)	1. PUBLICATION OR REPORT NO. NBSIR 85-3126	2. Performing Organ. Report No.	3. Publication Date March 1985

4. TITLE AND SUBTITLE

MONITORING OF DYNAMIC RESPONSE OF FLOOR IN "D" WING OF THE MAIN BUILDING, BUREAU OF ENGRAVING AND PRINTING

5. AUTHOR(S)

Felix Y. Yokel
Paul W. Mayne

6. PERFORMING ORGANIZATION *(If joint or other than NBS, see instructions)*

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

7. Contract/Grant No.

8. Type of Report & Period Covered

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*

Bureau of Engraving and Printing

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

In December 1981, the National Bureau of Standards investigated structural vibrations induced in the first floor of the "D" wing of the main building of the Bureau of Engraving and Printing. In January 1985, additional measurements were performed to check whether there are any changes in the response characteristics of the floor systems which might indicate structural degradation. The results of these measurements are presented and it is concluded that the results of the vibration measurements give no indication of structural degradation.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

Floor vibrations; structural dynamics; structural engineering.

13. AVAILABILITY

[XX] Unlimited
☐ For Official Distribution. Do Not Release to NTIS
☐ Order From Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
[XX] Order From National Technical Information Service (NTIS), Springfield, VA. 22161

14. NO. OF PRINTED PAGES

13

15. Price

$7.00