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GENERAL VIBRATION MONITORING

Coupling between the Experimental Hall Structure and Storage Ring Tunnel and Basemat

by

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The primary objective of this study was to measure the coupling between the experimental hall structure and the storage ring tunnel. The study was motivated in part by concern over the potential for wind excitation of the building to couple through the ground and/or piping/ductwork to the storage ring basemat. Unfortunately, there was very little wind on the measurement date. However, it can be assumed that the wind turbulence would excite the experimental hall structure at one or more of its resonant frequencies. Similar coupling information can be obtained by using ambient vibration as the excitation source and measuring the resultant structure/basemat response and associated coupling. This was the approach taken in this study.

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APS VIBRATION MONITORING

Location: EAA/STORAGE RING

Date: 2/3/93

Time: 14:00-21:30

File #: 9

Objective: To measure vibration response/coupling between building and storage ring

Site/Location Conditions: Site quiet, cold, dry. About 60° F in EAA area

Instrumentation:

<u>Storage Device:</u>		<u>Transducer:</u>		<u>Mount:</u>	
FM tape	<u>x</u>	S-500	<u>x</u>	Single	<u>x</u>
On line	<u> </u>	333C	<u> </u>	Biaxial	<u> </u>
Other	<u> </u>	Other	<u> </u>	Triaxial	<u>x</u>

Orientation and Identification:

<u>Ch. #</u>	<u>Acc. Loc.</u>	<u>Orientation</u>	<u>Scale/Range</u>	<u>Approx. Noise Floor</u>
1	On Column 58	Vertical, Y	0.2	NA
2	On Column 58	Horizontal, Z	0.2	NA
3	On Column 58	Horizontal, X	0.2	NA
4	Top surface of storage ring roof	Vertical, Y	0.2	NA
5	Top surface of storage ring roof	Horizontal, X	0.2	NA
6	Top surface of storage ring roof	Horizontal, Z	0.2	NA
7	On storage ring floor, in tunnel	Vertical, Y	0.2	NA

Comments/Conclusions: See Attachment 1

Other Attachments:

Table 1. Observed frequencies

Fig. 1. Seismometer layout

Fig. 2. Seismometers mounted on column 58

Fig. 3. Seismometers mounted to top surface of storage ring ceiling

Fig. 4. Seismometer mounted to floor of storage ring

Fig. 5. Displacement response vs. time plots (1-100 Hz)

Fig. 6. Displacement response vs. time plots (4-100 Hz)

Fig. 7. Displacement response vs. time plots (10-100 Hz)

Fig. 8. Displacement response vs. time plots (20-100 Hz)

Fig. 9. Displacement response vs. time plots (26-27.5 Hz)

Fig. 10. Power spectral density plots at time = 18:10

Fig. 11. Power spectral density plots at time = 18:22

Attachment 1

Observations/Conclusions

Measurement Locations

Figure 1 is a schematic showing the location of the seismometers. Figures 2-4 are photographs showing the seismometers installed on the experimental hall building column (column number 58), the storage ring tunnel roof, and the storage ring basemat, respectively.

RMS Displacements

The RMS displacement response vs. time plots are presented in Figs. 5-9. The results given in Figs. 5-9 correspond to frequency ranges of 1-100, 4-100, 10-100, 20-100, and 26.0 - 27.5 Hz, respectively, and are discussed below.

1-100 Hz (Fig. 5)

There is considerable displacement on column 58 in the three orthogonal directions, with a large displacement peak at 16:16. This coincides with similar peaks observed in the data from the storage ring tunnel roof and basemat measurements. Since the storage ring basemat exhibits the largest response, one can conclude the excitation source was located external to the storage ring tunnel. A similar peak at 16:10, where the response in the vertical direction is equal on both the storage ring tunnel roof and basemat, with no peak observed on the column, indicates that, in this case, the excitation source was located in the storage ring tunnel system.

4-100 Hz (Fig. 6)

The overall RMS displacements in the frequency range 4-100 Hz are considerably less than the 1-100 Hz data from both the column and storage ring tunnel/basemat. This indicates that most of the contribution to the measured displacements in the 1-100 Hz range are at less than 4 Hz. Excluding any large resonant response, these can be controlled with the feedback control system. These data were included primarily to allow for comparison with previous data obtained with the PCB 393C

accelerometers/integrators, which have a low frequency cutoff of approximately 4 Hz.

10-100 Hz (Fig. 7)

The overall RMS displacements on both column C58 and the storage ring tunnel/basemat show a considerable reduction in amplitude from the previous (1-100 and 4-100 Hz) frequency ranges; this, again, indicates that the major contributions to the displacements are from frequencies less than 10 Hz. The measured amplitudes are well within the established vibration criteria for the storage ring quadrupole magnets. An interesting observation on the 16:16 displacement peak is that the displacements of both the storage ring roof and basemat are equal, an indication of the good high frequency (> 10 Hz) coupling between the tunnel roof and basemat.

20-100 Hz (Fig. 8)

A still greater amplitude reduction in amplitude is observed in the 20-100 Hz data, again, an indication that most of the displacement occurs at frequencies less than 10 Hz, which is within the frequency range of the feedback control system. The motion of the storage ring tunnel roof and basemat are basically equal in the vertical direction for this frequency range, indicating a 1:1 coupling. Therefore, any high frequency vibration source which will be located on the top of the storage ring tunnel roof, such as the de ionized water pumps, can be expected effectively couple to the storage ring floor and, therefore, to the quadrupole magnets or other vibration sensitive equipment on the storage ring girder system.

26.0-27.5 Hz (Fig. 9)

There was a large resonant response of the I-beam support structure, which is cantilevered off the inside top of the storage ring tunnel, at a frequency of 26.8 Hz (see APS/IN/VIB-93/5) in the z (beamline) direction. While there is some coupling to column C 58, there is very little coupling to the storage ring basemat. This relatively large response was produced from ambient vibration excitation; a much larger response can be expected with a larger excitation force, such as rotating machinery, placed on the steel grating or on the I-beam support structure proper. A large response amplitude was also observed when a person was walking on the grating.

Power Spectral Density Plots

Power spectral density plots of displacement at two selected times are shown in Figs. 10 and 11. The power spectral density plots are used primarily for the determination of the principal frequencies excited by the ambient vibration. The principal response frequencies are listed on the plots of Figs. 10 and 11, and are tabulated in Table 1, together with a listing of the identified or probable excitation sources. The frequencies of the yellow railing (15-15.7 Hz) and those of the cantilevered I-beam support structure (26.8, 42.0, and 73.1 Hz) were determined from impulse testing. The 29.7 Hz response frequency corresponds to the rotational frequency of 4-pole electric motors, which, due to magnetic "slip", rotate at a speed of slightly less than 1800 RPM, corresponding to 30 Hz. Likewise, the 59.3 Hz response is due to 3600 RPM equipment. The frequencies associated with the column are coupled building/column responses and the amplitudes are a function of measurement location (mode shape); measured amplitudes will vary considerably with measurement location.

Conclusions

- Based on ambient excitation, coupling between the experimental hall column and storage ring basemat was very small.
- The contribution to overall RMS displacement response amplitude from ambient vibration excitation was predominantly from frequencies less than 10 Hz; there was a significant reduction in RMS amplitude at frequencies greater than 20 Hz.
- At frequencies above 20 Hz, the storage ring tunnel roof and basemat moved basically at the same amplitude in the vertical direction, indicating a coupled response. This must be considered when installing any vibration excitation sources on the storage ring tunnel roof.
- The resonant response of the yellow railing on top of the storage ring tunnel can be detected on the storage ring basemat. However, the amplitude was very small, considering the impact force used for excitation.
- A large response of the I-beam structure cantilevered off of the inside of the storage ring tunnel was observed at its lowest resonant frequency. Although the response amplitude was small, this resonant response frequency was detected on the storage ring basemat. If a large excitation source frequency were to coincide with the resonant frequencies of the I-beam

structure, the large magnification factor associated with resonance may result in a significant increase in vibration of the storage ring basemat. The measured resonant frequencies can be expected to change as loads on the structure change.

Table 1. Observed frequencies

X, C58	Y, C58	Z, C58	X, St.Rng.Top	Y, St.Rng.Top	Z, St.Rng.Top	Y, St.Rng.Fl.	Comments
5.51							
	7.85				7.7		
8.43		8.43					
					10.2		Previously Observed, Unknown Source
		15	15.7		15.7		Yellow Railing Response Frequency
					17.9		
		19.3					
		22.6			23.3		
26.8	26.8	26.8	26.8	26.8	26.8	26.8	Z Dir. Overhung Girder Assembly
29.8	29.7	29.7	29.7	29.7	29.7	29.7	Rotational Frequency
	34				34.2	34.2	
		35.7					
38.6	38.6	38.6					C 58 Response Frequency
		41.9	42.2	41.9			Overhung Girder Assembly
52.1		52.1					C 58 Response Frequency
			59.3	59.3	59.3	59.3	Rotational Frequency
62.9	62.9						
			64.8		64.4		
68.4	68.4	68.4	68.4	68.4	68.4	68.4	??????
			73.1	73.1	73.1		Y Dir. Overhung Girder Assembly
80.1	80.1	80.1	80.4				C 58 Response Frequency
92.4	93.7		91				
106	106	106					C 58/Building Response Frequency ?
117	117	117					C 58/Building Response Frequency ?
120	120	120	120	120	120	120	Power Line Frequency, 120 Hz "Buzz"
Note: Frequencies are in Hz

Seismometer Layout, File # 9

Fig. 1. Seismometer layout

Fig. 2, File 9
thermometer mounted on column 58

Fig. 3, File 9
Seismometers mounted on top surface of storage ring ceiling

Fig. 1. File 9
cr. mesometer mounted to floor of storage room

STORAGE RING/EA DISPLACEMENT

AMBIENT EXCITATION, Condition 1

File 9

1-100 Hz Measurement date: 2/3/93

Fig. 5. Displacement response vs. time plots (1-100 Hz)

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 1

File 9

Measurement date: 2/3/93

Fig. 5. Displacement response vs. time plots (1-100 Hz)

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 1

4-100 Hz Measurement date: 2/3/93 File 9

Fig. 6. Displacement response vs. time plots (4-100 Hz)

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 1

File 9

Measurement date: 2/3/93

4-100 Hz

Fig. 6. Displacement response vs. time plots (4-100 Hz)

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 1

File 9

10-100 Hz Measurement date: 2/3/93

Fig. 7. Displacement response vs. time plots (10-100 Hz)

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 1

File 9

Measurement date: 2/3/93

Fig. 7. Displacement response vs. time plots (10-100 Hz)

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 1

File 9

20-100 Hz Measurement date: 2/3/93

Fig. 8. Displacement response vs. time plots (20-100 Hz)

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 1

File 9

Measurement date: 2/3/93

20-100 Hz

Fig. 8. Displacement response vs. time plots (20-100 Hz)

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 1

File 9

Measurement date: 2/3/93

26-27.6 Hz

Fig. 9. Displacement response vs. time plots (26-27.6 Hz)

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 1

File 9

Measurement date: 2/3/93

26-27.6 Hz

Fig. 9. Displacement response vs. time plots (26-27.6 Hz)

STORAGE RING/EAA DISPLACEMENT

AMBIENT EXCITATION, Condition 1

File 9

Measurement date: 2/3/93

26-27.6 Hz

Fig. 9. Displacement response vs. time plots (26-27.6 Hz)

STORAGE RING/EAA DISPLACEMENT

File 9

Ambient Excitation, Condition 1

Measurement date: 2/3/93 Time: 16:10

Fig. 10. Power spectral density plots at time = 16:10

STORAGE RING/EAA DISPLACEMENT

File 9

Ambient Excitation, Condition 1

Measurement date: 2/3/93 Time: 16:10

Fig. 10. Power spectral density plots at time = 16:10

STORAGE RING/EAA DISPLACEMENT

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Ambient Excitation, Condition 1

Measurement date: 2/3/93 Time: 16:10

Fig. 10. Power spectral density plots at time = 16:10

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Ambient Excitation, Condition 1

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Fig. 10. Power spectral density plots at time = 16:10

STORAGE RING/EAA DISPLACEMENT

File 9

Ambient Excitation, Condition 1

Measurement date: 2/3/93 Time: 16:10

Fig. 10. Power spectral density plots at time = 16:10

STORAGE RING/EAA DISPLACEMENT

File 9

Ambient Excitation, Condition 1

Measurement date: 2/3/93 Time: 16:22

Fig. 11. Power spectral density plots at time = 16:22

STORAGE RING/EAA DISPLACEMENT

File 9

Ambient Excitation, Condition 1

Measurement date: 2/3/93 Time: 16:22

Fig. 11. Power spectral density plots at time = 16:22

STORAGE RING/EAA DISPLACEMENT

File 9

Ambient Excitation, Condition 1

Measurement date: 2/3/93 Time: 16:22

Fig. 11. Power spectral density plots at time = 16:22

STORAGE RING/EAA DISPLACEMENT

File 9

Ambient Excitation, Condition 1

Measurement date: 2/3/93 Time: 16:22

Fig. 11. Power spectral density plots at time = 16:22

STORAGE RING/EAA DISPLACEMENT

File 9

Ambient Excitation, Condition 1

Measurement date: 2/3/93 Time: 16:22

Fig. 11. Power spectral density plots at time = 16:22

STORAGE RING/EAA DISPLACEMENT

File 9

Ambient Excitation, Condition 1

Measurement date: 2/3/93 Time: 16:22

Fig. 11. Power spectral density plots at time = 16:22

STORAGE RING/EAA DISPLACEMENT

File 9

Ambient Excitation, Condition 1

Measurement date: 2/3/93 Time: 16:22

Fig. 11. Power spectral density plots at time = 16:22

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11/01/93