ASSESSMENT OF THE IMPACT OF EXTERNAL STIMULI ON THE FLOOR STABILITY OF DIAMOND

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Abstract

Continuous vibration monitoring is carried out and the stability of the Diamond floor slab has been assessed with regard to how it has responded to various external stimuli. Data has been collected on weather conditions and comparison made at extremes with floor vibration. The impact of a high level walkway bridge on the hall floor has also been assessed and there was a unique opportunity for an operational facility to measure the vibration response during a complete power black-out. The impact of local construction work is also presented.

INTRODUCTION

Diamond Light Source is a 3rd generation synchrotron light source built in the UK. The 3GeV Storage Ring has 24 cells and it commenced operations in January 2007 and there are now 11 beamlines in operation with a further 4 due to become operational in October 2008. An excellent floor stability is a key requirement of any high brightness light source [1] and Diamond has made a significant investment in equipment and expertise in order to measure the vibration response of Diamond. The floor vibrations at Diamond are continuously monitored by 2 sets of Velocity sensors mounted diametrically across the storage ring. A Guralp CMG-3ESP 1/60 to 50 Hz is mounted close to Storage Ring Cell 1 and a Geotech KS-2000M 1/120 to 50 Hz is mounted close to Cell 12.

EXTERNAL WEATHER CONDITIONS

The Energy Research Unit [2] continuously monitor weather conditions at the site shared with Diamond including solar gain, rainfall, wind velocity and direction at various heights. In an analysis of 6 months weather data comparing extremes with measurements of floor stability, there was no identifiable correlation between sun and rain with stability but there is a clear correlation between wind and floor vibration (see Table. 1).

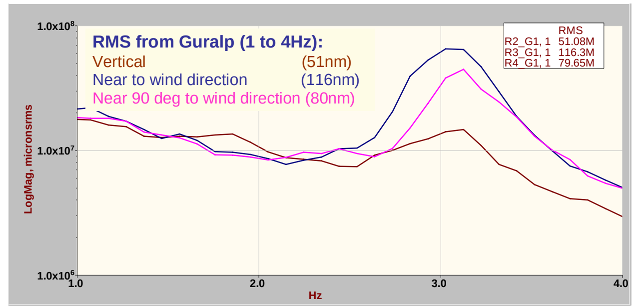

Figure 1: 3Hz vibration in three directions

Table 1: Floor vibration due to wind

	RMS nm 1-100Hz	
Wind Speed	**Vertical**	**Horiz'**
Highest 23m/s at 18m,13:00 on 18/1/07	23.1	30.9
Median 13m/s at 18m, 03:00 on 21/1/07	17.4	28.1
Lowest 0.3m/s at 18m,09:00 on 30/1/07	17.1	15.0

During windy conditions from any direction there is a general increase in vibration response across the spectrum but there is a clear 3 Hz ground vibration excited in the floor that has a larger effect in the horizontal than the vertical even at median wind speeds. From Figure 1, it is noted that the highest peak of 3Hz is in the horizontal near to the wind direction. Clearly the wind causes horizontal vibration which in turn effects vertical movement.

The simultaneous monitoring in 2 locations across the diameter of Diamond was used to analyse the 3Hz component and as can be seen in Figure 2 there is a clear coincidence of the Vertical signals measured in the 2 locations which means that the whole of Diamond is responding in phase at 3Hz and no effect should be seen between storage ring and beamlines.

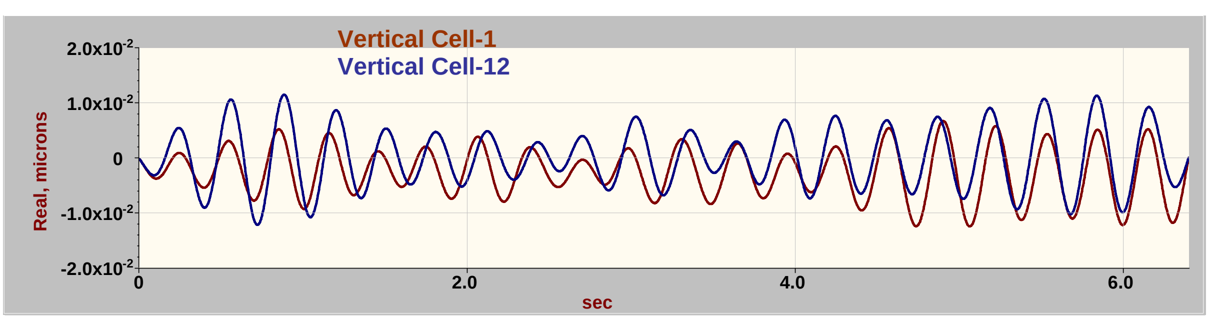

Figure 2: Correlation of 3Hz vibration across Diamond

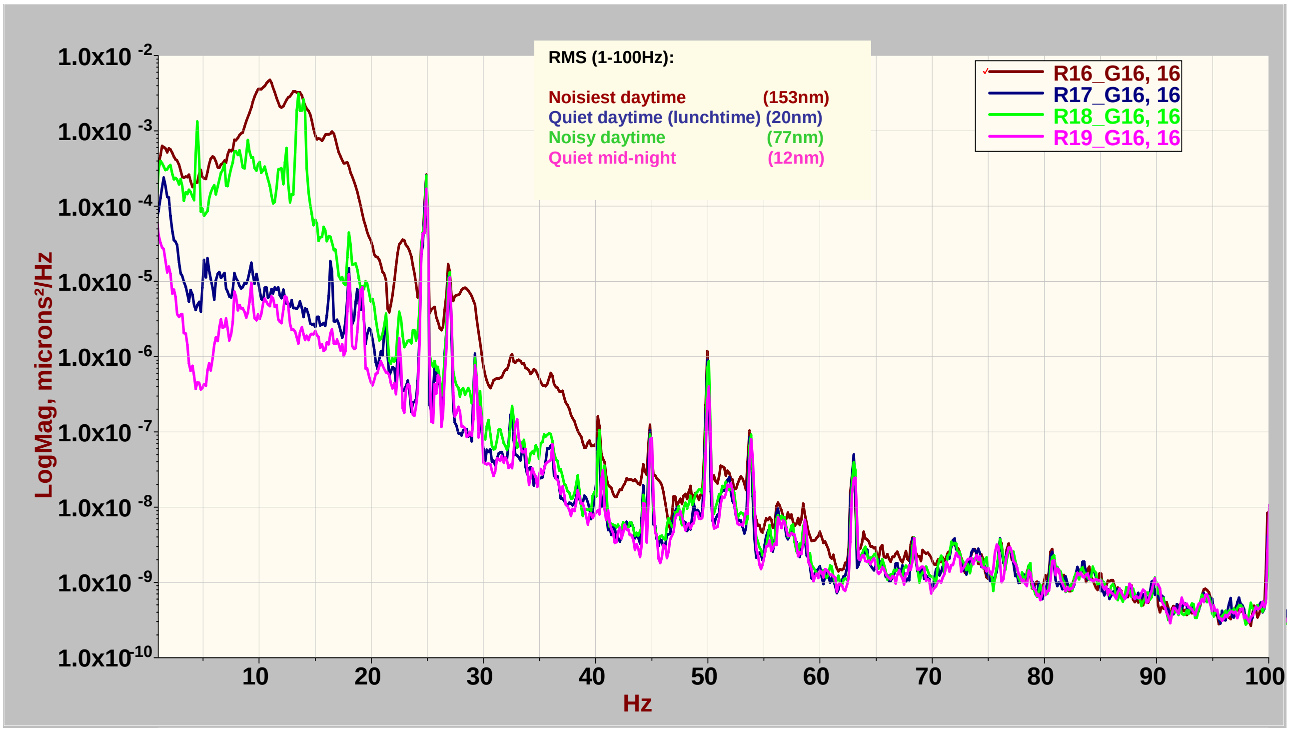

Figure 3: Diamond Floor vibration spectra measured during neighbouring construction work.

NEIGHBOURING CONSTRUCTION

A number of large scale construction projects are being developed adjacent to Diamond including the first long beamline and a large research complex. Some roadworks are planned and also a new RF test facility. Whilst construction work is generally short lived, the impact on daily beamline activity can be significant. Figure 3 portrays some typical ground spectra where the quietest time at midnight the RMS ground motion between 1-100Hz is almost 12nm, at lunchtime with no construction almost 20nm which is the Diamond day-time average but with construction work 77nm has been measured with peaks during the use of a concrete crusher at 153nm. The impact of heavy construction work has most effect below 50Hz.

INTERNAL FOOTBRIDGE

A 16.9m long by 2m wide footbridge above the Experimental Hall Floor connects the 1st floor offices and control room with the Storage Ring tunnel roof. Beamline I20 is under construction at Diamond and the Optics Hutch will be directly under this bridge. Due to the very sensitive nature of the beamline a series of measurements have been carried out to assess the impact of the bridge on the hall floor. Figure 4 shows some of these measurements taken at 9.0am on a typical working day with busy foot traffic across the bridge. The floor in zone 4 is well away from the bridge and exhibits a more typical 23nm response but the Zone 1 floor underneath the bridge is clearly noisier at 86nm with identifiable peaks at 2 and 5Hz. There is a strong 2, 3.5, 5 and 7Hz component on the bridge but it appears that only the 2 and 5Hz are strongly transmitted to the ground. Experiments have been carried out using temporary props under the bridge which eliminate the 5Hz component and reduce the floor RMS to 41.5nm. Preliminary structural redesign of the bridge has also been carried out to show that a simple stiffening of the bridge by making the handrails structural elements would raise the 1st mode of natural frequency to as high as 200Hz. Damping pads will be employed to absorb the 2Hz component which is solely due to the frequency of foot fall.

COMPLETE POWER OFF

On Saturday 15th March 2008 Diamond commissioned some new electrical supply transformers which meant that the whole site was without power for an 8 hour period. There was a complete power outage for around 30 minutes before emergency generators were started. This presented a unique opportunity to measure the floor slab stability before and after a complete power off. At Diamond the experimental hall floor slab is supported on piles with a void cast under the slab to keep the ground separate from the slab. See Figure 5. Survey holes have been cast into the slab which allows contact with the virgin soil underneath. Inside the survey holes steel pins are fitted to the ground in separate slabs to enable height measurements of the ground compared with the floor and these pins have been used to measure the vertical vibration of the soil

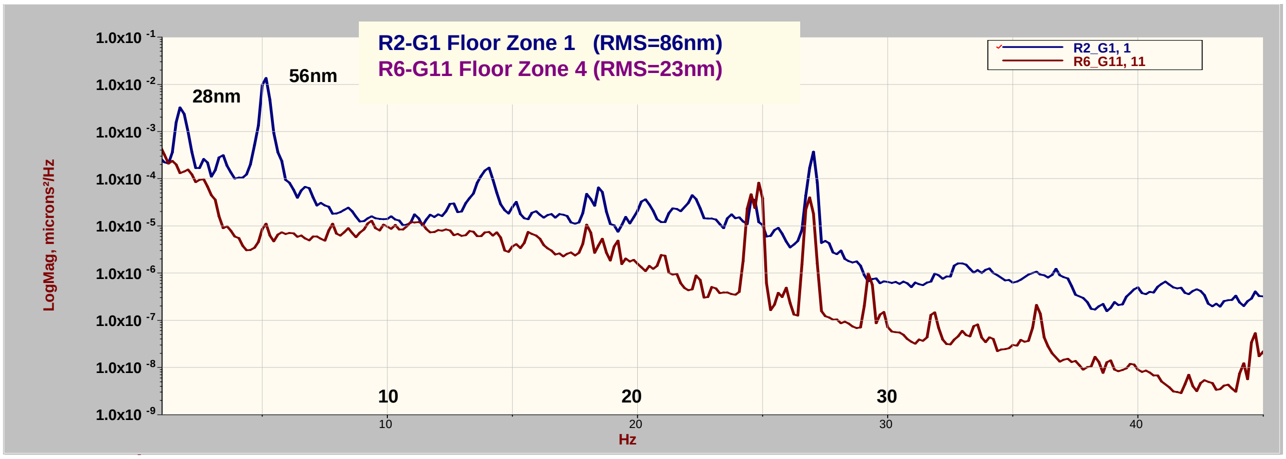

Figure 4: Ground Vertical spectra measurements under the link bridge

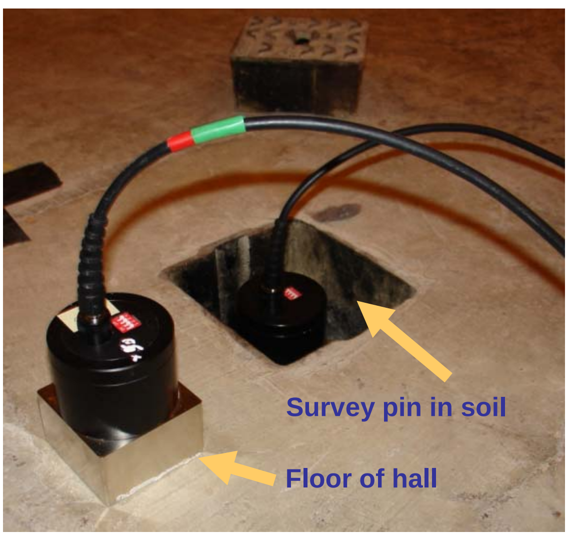

Figure 5: Simultaneous measurement on floor and soil

simultaneously with the floor slab. Figure 5 shows IEM (China) Mini-seismometers HBA-L1 in the range 1 to 100Hz employed for this purpose.

Considering the results in Table 2 it can be seen that measurements on the hall floor with power on are less than on the ground underneath but when there is no power the response is the same. This clearly shows that the built mass of floor combined with piled foundations has a nett damping effect on facility induced noise. It is also clear that the horizontal component of vibration is less than the vertical. Vibration results are normally published as integrated between 1-100Hz, but if the integration is carried out between 4-100Hz then as can be seen there is a significant reduction in the vertical with power on from 15nm down to 10nm. This analysis can be justified on the basis that the wavelength of ground waves with a frequency <4Hz are >1.8km [3] which is large in relation to the Diamond facility diameter of 235m.

Table 2: Power ON/OFF Vibration results summary

	RMS nm 1-100Hz		RMS nm 4-100Hz	
Test	Vertical	Horiz'	Vertical	Horiz'
Hall floor power on	14.9	13.6	10.5	7.6
Hall floor power off	9	11.4	3.5	3.1
Hall floor Gen' only	10.7	12.5	5.3	4
Survey pin power on	20.6		17.9	
Survey pin power off	9		3.9	
Survey pin Gen' only	10.7		7.1	

CONCLUSION

Continuous measurements of floor vibration are taken at Diamond and the normal day-time average of 20nm RMS 1-100Hz is very quiet [4]. The foundations and floor solution is very good and has a nett damping effect on facility noise. The impact of various external stimuli has been assessed including wind, construction work and a bridge and the effects are manageable or low impact. Synchronous measurements across Diamond confirm the whole facility moves in phase at 3Hz.

REFERENCES

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[3] Sid Perkins, "Humming Along: Ocean waves may cause global seismic noise" From Science News, Vol. 166, No. 14, October 2, 2004, p. 212

[4] H. Ehrlichmann, http://vibration.desy.de/download 'Overview of measured sites'