STABILITY OF THE FLOOR SLAB AT DIAMOND LIGHT SOURCE

J. Kay, K. Baker, W.J. Hoffman and I.P.S. Martin, Diamond Light Source, Oxfordshire, UK

Abstract

A Hydrostatic Levelling System (HLS) has been installed at Diamond Light Source. 8 sensors have been positioned along a 60 metre portion of the floor of the Storage Ring (SR) and the Experimental Hall (EH), stretching out along a typical beamline route from Insertion Device to sample. Results since June 2008 are presented comparing actual performance with the original specification as well as identifying movements associated with environmental factors.

INTRODUCTION

Diamond is a 3rd generation synchrotron light source that has been operating since 2007. There are currently 19 operating beamlines with another 3 to be completed in the next year. A Phase 3 to build a further 10 beamlines has recently been approved. As with all light sources, a very stable floor slab is an essential requirement for the effective utilisation of high brightness photon beams. A floor slab specification was developed and is shown in Table 1. A HLS was purchased from Fogale in order to be able to measure the very small displacements expected. Measurements of how the floor responded to point loads and short term settlements were presented in [1] and results after one year of operation showing how the floor met the longer term settlement criteria were presented in [2]. This paper presents data after 3 full years of operation and in particular explores the seasonal variations in more detail.

Table 1: Floor Stability Specification

Load Condition	Target Performance
5kN point load	6 micron deflection under the load and 1 micron 2 metres away
Short term settlement	1 micron over 10 metres per hour and 10 micron over 10m per day
Long term settlement	100 micron over 10 metres per year for the Storage Ring and 250 micron over 10 metres per year for the Experimental Hall

DIAMOND BUILDING CONSTRUCTION

A cross-section of the Diamond building is shown at Fig. 1. Diamond has a circular building of outer diameter 235m employing a steel frame with 96 equally spaced columns at the inner and outer circumference mounted on pad foundations. The SR tunnel is built on an 850mm thick reinforced concrete slab and the EH slab is 600mm thick. These slabs are cast together with no open radial or circumferential joints between them and are cast onto a network of 600mm diameter piles, each 12-15m deep and arranged on a 3m grid. A 60mm void has been created under these slabs to allow the chalk soil to shrink and swell due to the varying water table without stressing the floor. The peripheral offices, laboratories and workshops as well as the inner plant spaces are built on surface cast slabs with no void under, which are separated from the piled slab by sealed construction joints approximately 30mm wide.

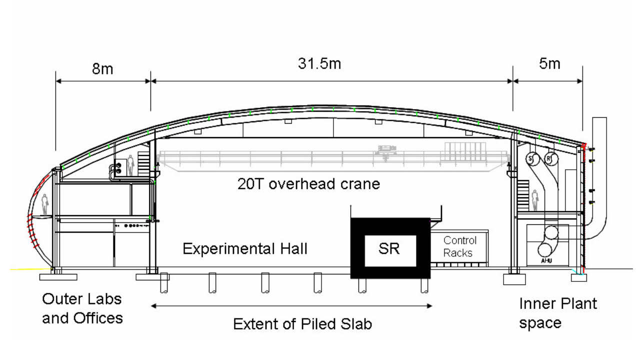

Figure 1: Diamond building cross-section.

Figure 2 is a plan drawing of the installation showing the position of 8 sensors along the route from inside the SR and out between 2 existing beamlines on the EH floor. The sensors are separated typically by 10m to simplify comparison with the specification. The small circles in the plan drawing mark the position and size of the piles. Sensors 1 and 2 are inside the SR tunnel and sensors 3 to 8 are mounted on the EH floor. Sensors 1 to 7 are mounted on the piled slab with sensor 8 mounted just across the construction joint on the surface cast slab at the 3m wide ground floor walk way where there is heavy fork lift truck and foot traffic. The HLS sensors are connected together by 2 tubes, one carrying water and the other air. As the sensors share a liquid surface, as one sensor changes height due to changes in local floor level then a height change is detected within the sensor's capacitive measurement system. All sensors with their electronics are calibrated and the output from each sensor is recorded and processed within the Diamond EPICS control system.

HLS RESULTS

Figure 3 presents a view of the HLS results from all 8 sensors since June 2008. The plot was produced by establishing the mean level through pots 1 to 7 which are on the strong SR/EH slab, and then comparing each pot measurement to that mean plan level. Pots 1 to 7 have behaved quite uniformly with levels diverging gradually over the 3 years but pot 8 has more clearly sunk 0.9mm. Pots 1, 2 and 3 which are in the SR all deviate the least.

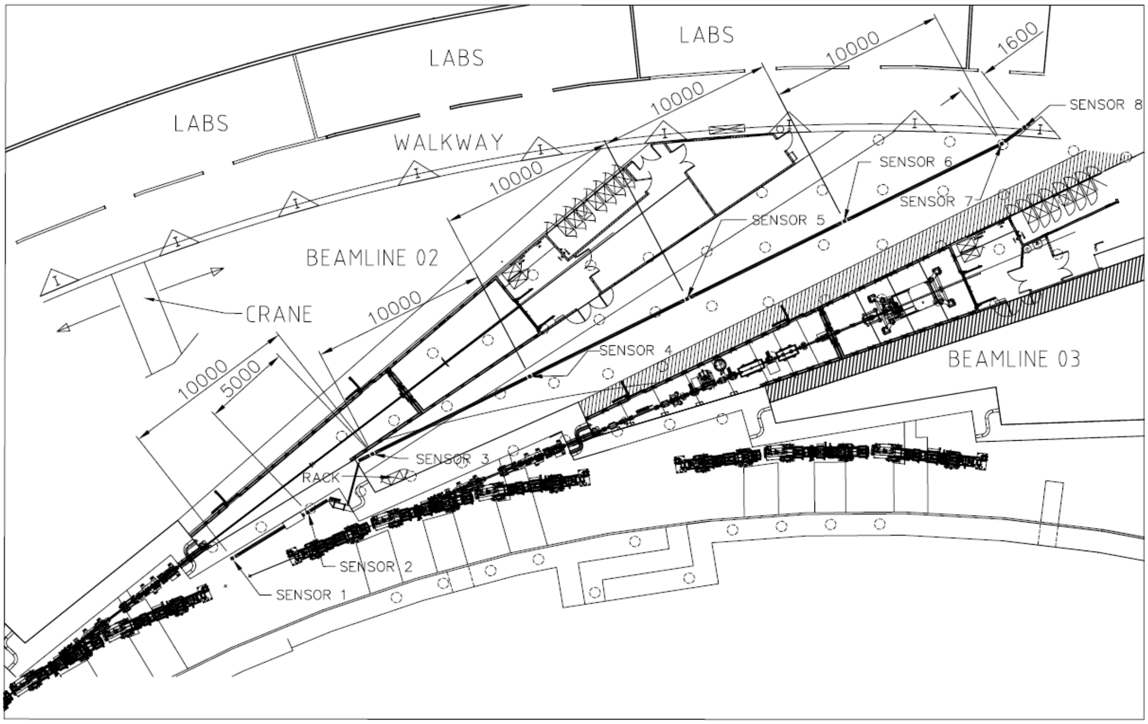

Figure 2: Layout of the HLS from the SR and between 2 beamlines on the Diamond EH floor.

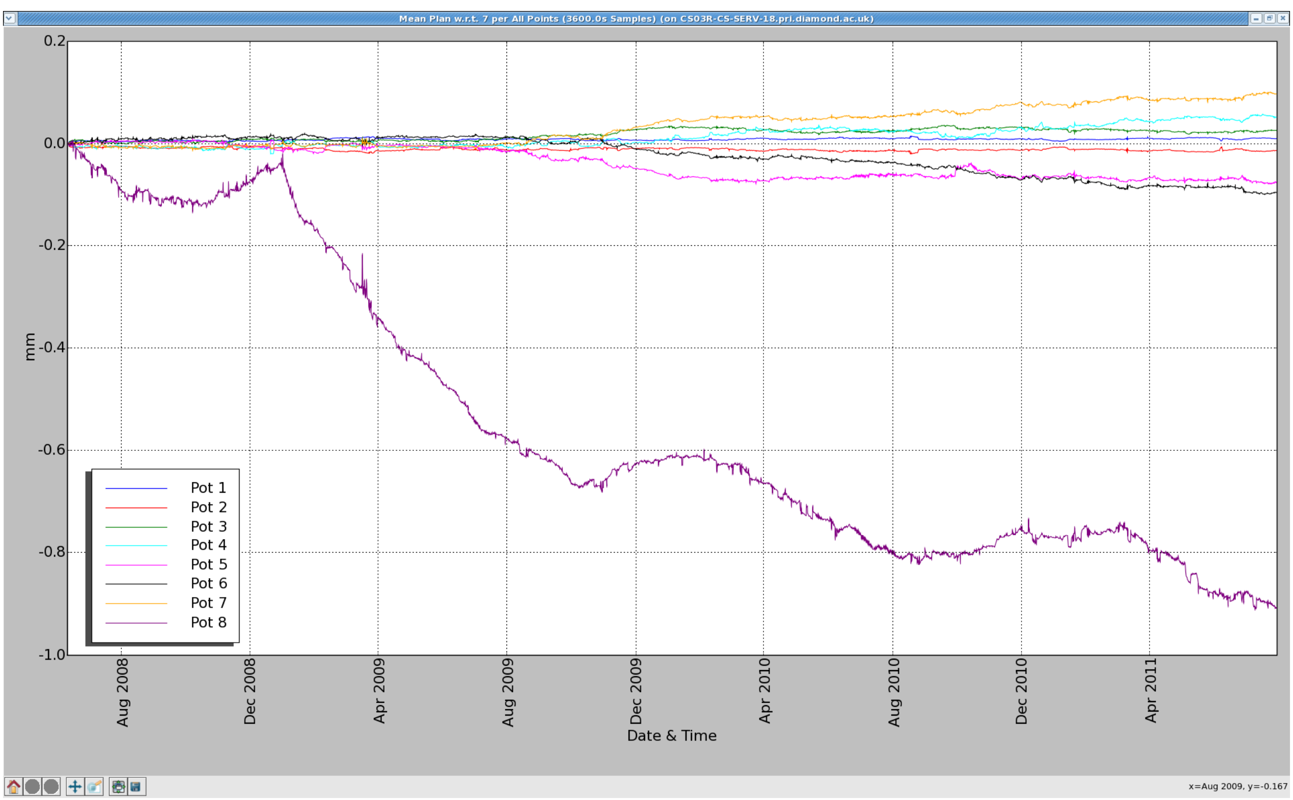

Figure 3: Presentation of HLS results for all 8 pots relative to a mean plan level taken through pots 1 to 7.

Exponential Floor Settlement

Although the unpiled floor slab of the building is sinking, there is an obvious annual variation to the floor level superimposed on a general settlement. Figure 4 represents the pot 8 data with an exponential curve fitted to it where time t is in days and height h in mm.

$$h(t) = 1.0695\exp\left(-\frac{t}{540.9}\right) - 1$$

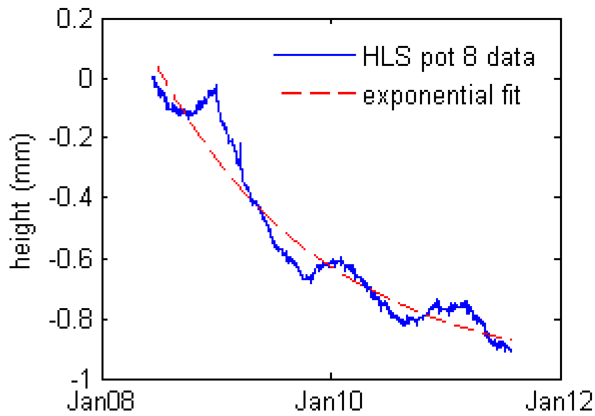

Figure 4: Exponential fit to the pot 8 data.

Link to the Water Table

The geology of the Diamond site is predominantly chalk with a 12 to 15m deep layer of 'structureless' chalk sitting on a 65m thick layer of 'intact' chalk. The water table within this chalk strata varies annually between 12m and 25m underneath the finished floor level of Diamond which is at 123m. The water table is measured continually by the neighbouring Harwell site [3] and the level in the nearest borehole to Diamond is presented in Fig. 5. It can be seen that pot 8 lags the water table by ~ 10 months.

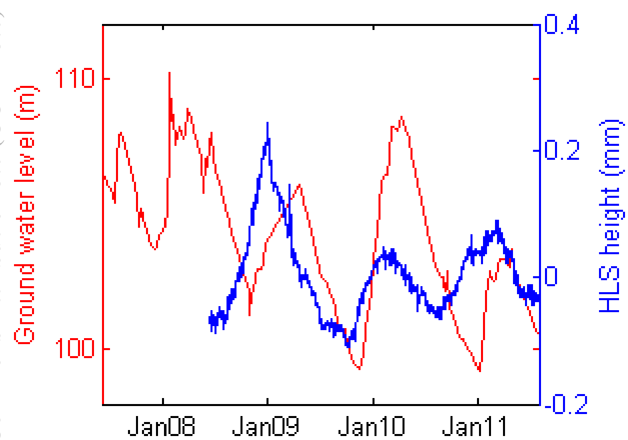

Figure 5: Comparison of water table height with residual pot 8 variation with exponential settlement removed.

Statistical Analysis of Pot Height Differences

The change in height difference between adjacent pots over a given time interval approximately follows a normal distribution. The values of 4 times standard deviation (4σ) are given in Table 2. Histograms for the data describing the SR (Pot 3–1) are shown in Fig. 6. Taking the 4σ value as the reference (representing 95.4% of the data points), the hourly value of 1.3µm for the SR is just above the specification of 1µm /10m/hour, whereas values of 4.7µm and 41.1µm are well within the longer term settlement criteria for the SR of 10µm/10m/day and 100µm/10m/year respectively. For the EH, the largest 4σ value for hourly change is 2.6µm which is greater than the specification of 1.0µm/10m/hour and the largest value for daily change of 10.7µm is very close to the specification of 10µm /10m/day. The largest 4σ for annual variation of 143.0µm is within the specification of 250µm/10m/year for the EH.

Table 2: 4 * Standard Deviation (4σ) of Change in Height Difference Between Adjacent Pots Over Time (microns/10m/time)

Pot Difference	Hourly	Daily	Annual
3-1	1.3	4.7	41.1
4-3	2.1	8.6	55.5
5-4	2.1	10.7	113.5
6-5	2.1	6.9	140.4
7-6	2.6	10.5	143.0
8-7 (scaled at 10m)	28.9	122.6	4030.9

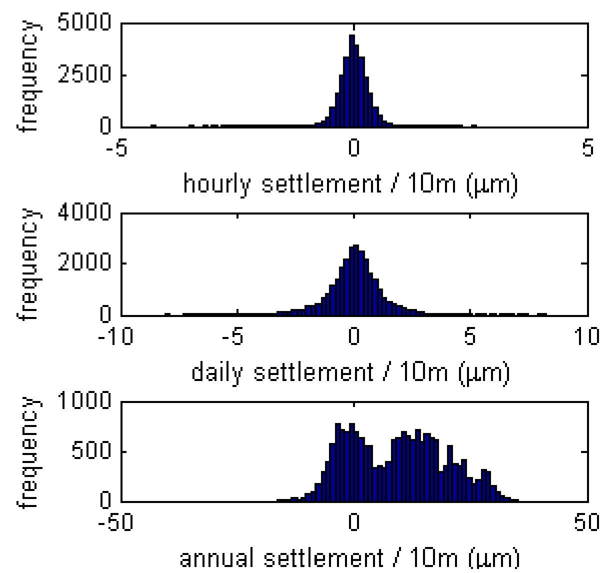

Figure 6: Example differential settlement of pots 3 – 1.

CONCLUSION

A HLS has been installed at Diamond for over 3 years, continuously measuring floor levels along the route of a typical beamline from Insertion Device to sample.

In this time, the office and laboratory building slabs cast onto the chalk surface have exhibited a settlement of 0.9mm. This settlement is made up of exponential and seasonal components. The seasonal variation follows the variation in the water table height but lags behind by around 10 months. The SR and EH floors show no such settlement or seasonal variation justifying the original decision to build on piles with a void between the floor slab and the chalk. The SR and EH floors have met the daily floor stability specification, are close to the hourly and are much better than the annual specifications.

REFERENCES

[1] J. Kay et al., Proc. MEDSI2008, CLS, Saskatchewan.
[2] J. Kay et al., Proc. SRI2009, Melbourne, Australia.
[3] Borehole data supplied by Jon Blackmore, Research Sites Restoration Ltd, 552 Harwell, OX11 0TQ, UK.