

GROUND MOTION DATA FOR INTERNATIONAL COLLIDER MODELS

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Abstract

The proposed location for the International Linear Collider (ILC) in the Americas region is Fermilab in Batavia Illinois. If built at this location the tunnels would be located in the Galena Platteville shale at a depth of 100 or more meters below the surface. Studies using hydro static water levels and seismometers have been conducted in the MINOS hall and the Lafarge Mine in North Aurora, IL to determine the level of ground motion. Both these locations are in the Galena Platteville shale and indicate the typical ground motion to be expected for the ILC. The data contains both natural and cultural noise. Coefficients for the ALT law are determined. Seismic measurements at the surface and 100 meters below the surface are presented.

Introduction

The proposed location for the International Linear Collider in the Americas region is at Fermilab in Northern Illinois. The preferred depth is 100 or more meters below the surface in the Galena Platteville dolomite. Fermilab and Budker institute have been collaborating on Hydro Static Level systems to measure ground motion for many years. Two of the current systems are in the near MINOS hall on the Fermilab site and the Lafarge (formerly Conco Western [1]) mine in North Aurora Illinois). Both systems are in the Galena Platteville dolomite. Both systems use Budker institute designed and produced HLS systems to measure the change in floor level. Understanding ground motion due to natural and cultures sources are important for modeling the ILC accelerators and storage rings.

Apparatus

The MINOS system has 4 HLS sensors and the Lafarge Mine has 6 sensors. In both systems the sensors are spaced 30 meters apart. This is similar to the quadrupole spacing proposed for the ILC (37.956 meters). A sensor consists of a stainless steel pool connected with 12.7 mm ID

polyethylene tubing to adjoining pools. In the body of the pool there is a temperature sensor that records the water temperature and allows for corrections to be made for expansion due to temperature changes. Each pool sits on a plate with adjustable legs to allow for leveling of each sensor relative to the others.

On top of the pool is the sensor and electronics. The sensor measures the capacitance of the gap between the sensor face and the top of the water. The sensor is heated to prevent condensation; this would interfere with the precision of the measurements. Each sensor has been calibrated before installation. The gap measurement is accurate to 1 micro meter over a range of 10 mm.

A power and data cable daisy chains between each sensor. The data is read out through a National Instruments card into a PC. Software reads out the data at 1 minute intervals and stores the data for later analysis. Both systems are checked every business day to ensure the sensors and computers are functioning. At the end of every month data taking is automatically stopped and re started. A reset pulse is sent out to each sensor in case a software hang occurred. Figure 1 shows a pool and sensor.

The MINOS hall system became operational in December of 2005 and the Lafarge Mine was rebuilt and became operational in September of 2006.

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Figure 1: Budker HLS sensor

With few exceptions for computer hangs there are data for every minute of every month since then. These data are available via a Fermilab data base. The data base is updated every month. The data base is available at <http://dbweb1.fnal.gov:8100/ilc/ILCGroundApp.py/index> The data is timed stamped in one minute intervals using Central time. All levels are in micro meters, temperatures are in degrees C and pressure is in kilo Pascal.

Long Term Trends

Data for both systems were compressed by doing a ten minute average of levels and temperatures. This allowed for time plots and Fast Fourier Transforms (FFTs) to be done on the data to reveal trends in natural and cultural noise. Figure 2 is a plot of the difference between 2 sensors 90 meters apart in the MINOS hall for the month of January 2006.

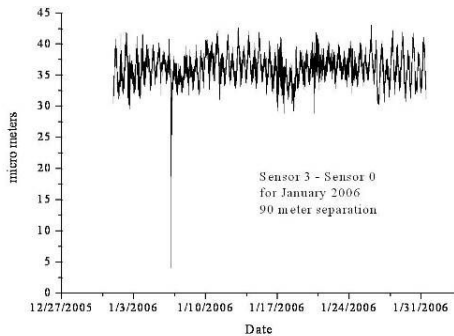


Figure 2: Differences in two sensors 90 meters apart at the MINOS hall for Jan 06

The fast sine wave is due to tidal motion this has a period of 12.4 hours. There is a slower sine wave with a period of 1 week these are the spring and neap tides caused by the relative phases of the sun and moon. The spike that

occurs in the first week is due to monthly sump pump testing. There are two electric sump pumps that drain water from the sump pit. The water in the pit varies from a maximum of 75% full to 25% full. As a back up there is a diesel powered sump pump that is run for 30 minutes each month. This test fully drains the sump pit thereby causing a tilt in the floor. After the test is finished the floor tilts back to its nominal position. Figure 3 shows an expanded view of the sump pump test.

Figure 4 is the same data for December 2005 through January of 2008. The sump pump tests are visible as sharp lines the dip that occurs in the summer months of 2006 may be seasonal more data is required to evaluate this. The sudden changes in floor tilt can be attributed to one of two events. First is sudden and large rain fall infiltrating into the tunnel. The other is small seismic events and subsidence of the rock. Two such events were recorded on Dec 19th 2007 and January 9th 2008. Local seismometers recorded seismic events then several hours later there was a shift in the floor tilt. See figure 5 and 6.

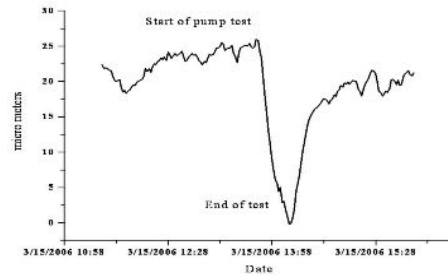


Figure 3: Tilt in floor due to sump pump test

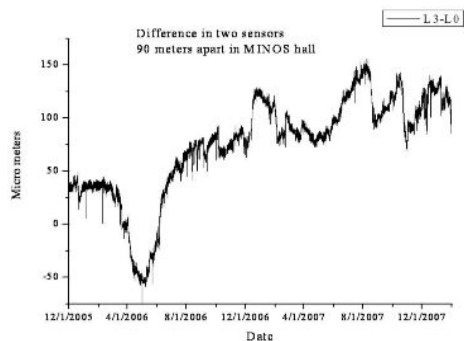


Figure 4: Differences in two sensors 90 meters apart at the MINOS hall for Dec 05 to Dec 07

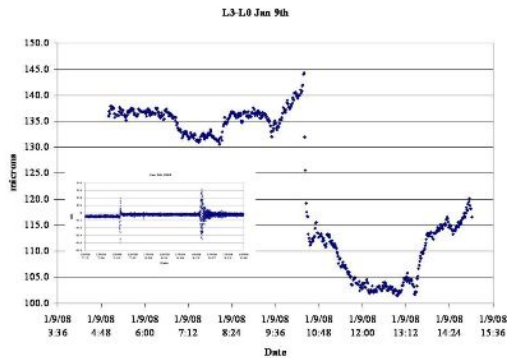


Figure 5 December 19th earth quake at 04:00 hrs followed 7 hours later by subsidence.

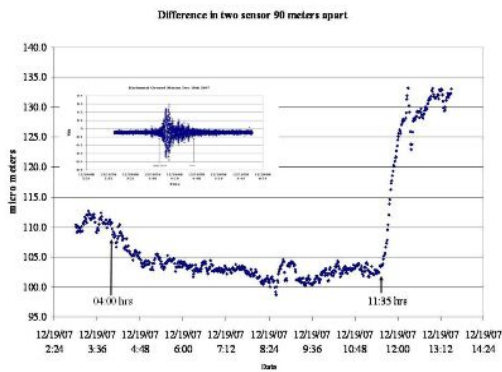


Figure 6 January 9th earthquake at 8:30 followed by subsidence at 10:30

Figure 7 is a plot of the Lafarge mine data for September 2006 through January 2008. The sudden shift in July of 2007 is due to a flood in the mine caused by more than 5 cm of rain falling in 2 hours. Figure 8 is a Fast Fourier transform of the MINOS data. There is a clear spike at 12.4 hours from the tidal motion. Also peaks at 59 and 29 minutes. These are feed down of 60 hz noise from pumps in the MINOS experiment.

ATL Law

The ATL law was originally proposed in 1991 [2 & 3] to describe the relative displacement between two distant ground points. The empirical rule states that the relative displacement dX of two points at distance L apart grows in time T as

$$\langle dX^2 \rangle = ATL$$

Where A is on the order of $10^{-5 \pm 1} \mu\text{m}^2/\text{s}\cdot\text{m}$ and depends on location. The MINOS and Lafarge mine data can be used to determine this constant for the Fermilab area.

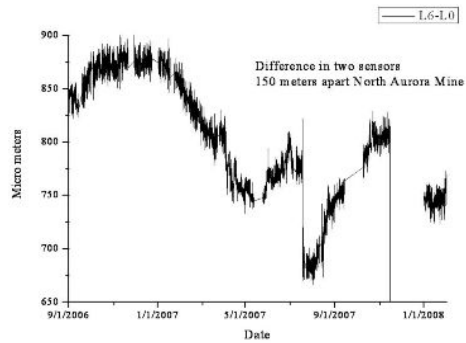


Figure 7 Difference in two sensor 150 meters apart in Aurora mine the sharp jump is due to a flood in the mine.

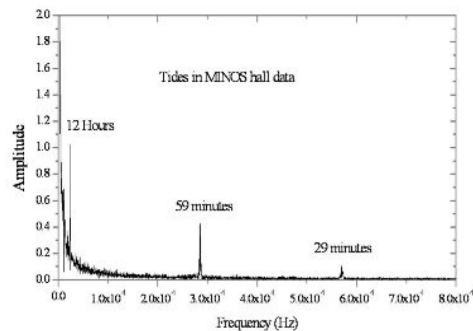


Figure 8: shows the FFT for the MINOS data the two spikes correspond to the sump pump test every 28 days and the tidal motion at 12.4 hours

The process is to first calculate the second differences for the system. In the case of the MINOS data there are four sensors L0 through L3 two second differences can be calculated these are;

$$\begin{aligned} SD012 &= L0-2L1-L2 \\ SD123 &= L1-2L2-L3 \end{aligned}$$

Where $L0, L1, L2$ and $L3$ are the levels recorded for each sensor in micrometers. The dispersion is then calculated by subtracting the second

differences for various time increments ranging for 1 minute (the smallest time value) up to several weeks.

$$D_SD012 = SD012(t) - SD012(t+i)$$

$$D_SD123 = SD123(t) - SD123(t+i)$$

These values are then squared and average for each time increment. The slope of a plot of the means square dispersion versus time yields twice the value of A. The data were analyzed for an L of 30 meters.

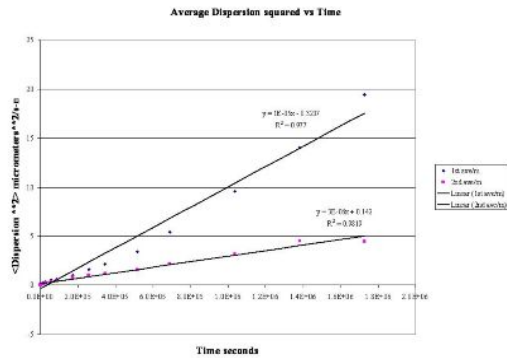


Figure 9 shows data for November 2006 taken in the MINOS hall. The value of A is 5 to 1.5 10^{-6} $\mu\text{m}^2/\text{s}\cdot\text{m}$.

Seismic Motion

Two Budker INP seismometers one for vertical and one for horizontal were used to measure ground motion in the range of 1 Hz to 200 Hz. Base line measurements were made at the surface on a concrete slab similar measurements were made in the MINOS near hall at a depth of 100 meters below the surface. Figure 10 and 11 show the activity for the surface measurements. There are screw compressors at the Central Helium Liquefier that generate at 4.6 Hz signal all over the site.

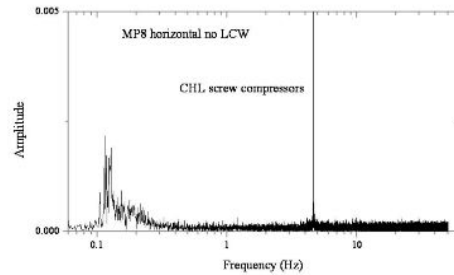


Figure 10 horizontal motions on surface at Fermilab. The large spike is due to the CHL screw compressors.

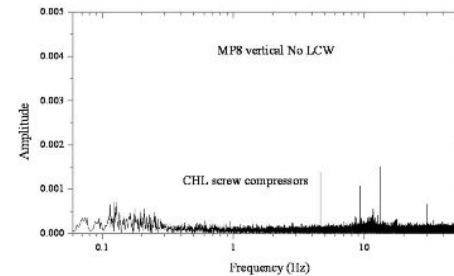


Figure 11 vertical motions on surface at Fermilab

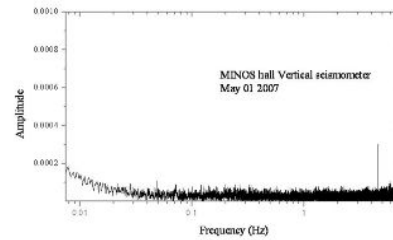


Figure 12 vertical motions in MINOS hall 100 meters below surface at Fermilab

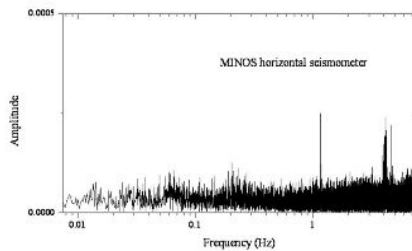


Figure 13 horizontal motions measured in MINOS hall 100 meters below surface.

It is clear that there is some attenuation of the culture noise. This is important for the ILC in that many sources of cultural noise can not be eliminated.

Conclusions

Data has been collected for over 24 months in a HLS system installed at the depth that the ILC would be built in Illinois. The value of the constant A in the ATL law has been determined to be 5 to $1.5 \cdot 10^{-6} \mu\text{m}^2/\text{s}\cdot\text{m}$. In addition a parameterization for tidal motion has been presented. These can be used in modeling the ILC. Cultural seismic noise is attenuated with depth.

References

- [1] V Shiltsev, et. al "VLHC/NLC "Slow Ground motions studies in Illinois" , Proc. 2001 IEEE PAC (Chicago, IL), p.1470.
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