A Four Hundred Meters Long Underground HLS at XFEL/SPring-8 Site

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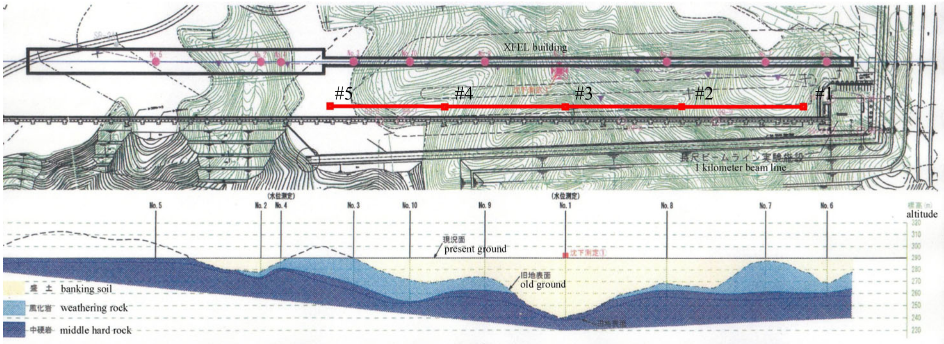
Constructing the Monument line

Site of XFEL/SPring-8 and a reference line of monuments

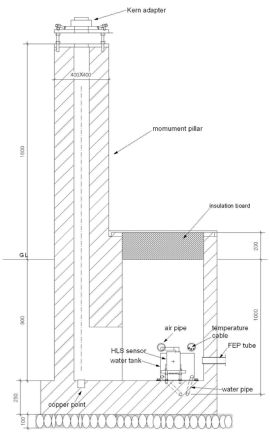


The XFEL is built at the altitude of 290m, the same level as the storage ring of SPring-8. On this level, the ground is either excavated rock or banking soil. The XFEL building for the accelerator, which is on the soil area, will be constructed by driving pile to the bedrock.

To measure the ground movement at the site, and to monitor the deformation of the building of XFEL tunnel, a monument line in 400 meters long is built. It is composed of 5 monument complexes in 100m intervals and connected with HLS. The monuments are parallel to XFEL accelerator tunnel, setting on the places of geologically different ground.

The monument complex

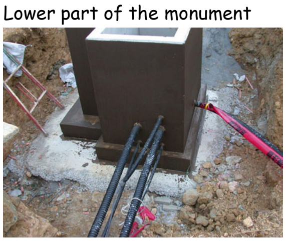
Drawing of monument cross section



The monument complex is made to comprise a height reference point of HLS, and a point for the measurement with GPS or laser system.

The height of the monument complex is about 2.8m, with upper part of 1.6m above ground level. Laser system, plus the fixture will be in a height around 2m, in consideration of not hitting people's eyes. The HLS is set inside a pit. The depth of the HLS system into the earth is the more the better, because the temperature fluctuation becomes less. For the reason of cost one meter is chosen.

Lower part of the monument



The monument has to be built heat insulating and water-proof.

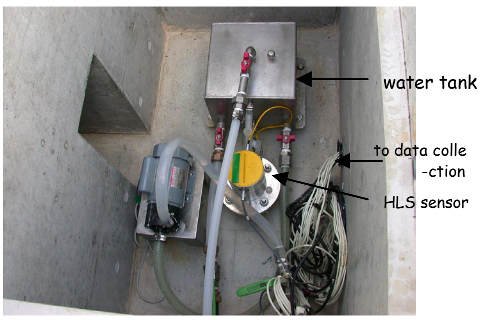
To proof against underground water, the lower part of the monument is painted with water-proof material and its base is embed with water-proof sheet.

Partial underground monument

The monument as well as the communicating pipe is buried with sand to dredge the rainfall and for protection to guarantee their function.

400 meters underground HLS

Inside of the HLS pit



In side the HLS pit is the sensor (FOGALE 15mm range), the water tank and bump. Cable of sensor and temperature are led to a house of beam line where has data acquisition units.

The full-filled system is chosen because the idea of using half-filled system is proved to be impractical. Half-filled system needs the pipe to be laid in identical height and build such a system therefore will be so expensive that we have to abandon it. The problem of full-filled is its temperature dependence. It is estimated that if only consider the expansion of the water, 15 degree temperature change yearly will cause 2cm level change in the sensors.

To reduce temperature effect a water tank is used beside the sensor. It will reduce the fluctuation of water level by factor 13.

Communicating pipes connecting HLS sensors

100m long communicating pipes between monuments are buried one meter beneath the earth's surface. The water pipes are hard type polyethylene of 19mm diametrical. The communicating cubes for air are relatively soft. So, FEP tubes are employed to protect them from pressure.

Temperature probes are attached to the pipes and distributed in the soil, apart from the monument for 5m to 30m.

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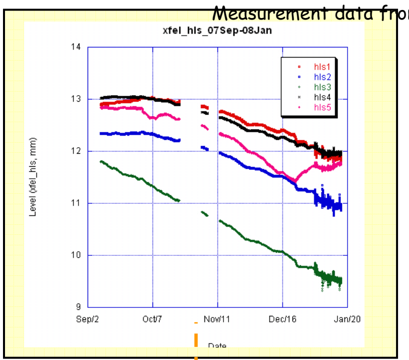
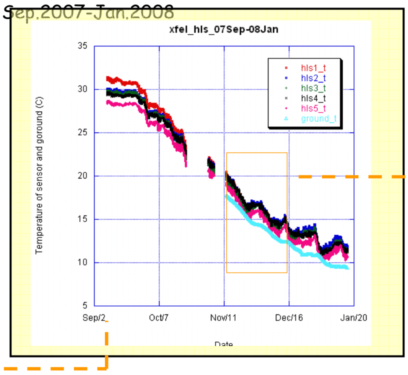
Measurement with the HLS

Measurement data

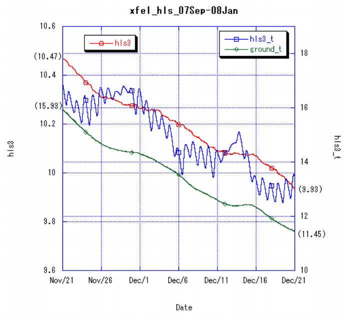
Measurement data from Sep.2007-Jan.2008





This is measurement data from Sep. 2007 to Jan. 2008. 'Hls' is the distance between sensor electrode and water surface, indicating the level of a measuring point. 'Hls-t' is the temperature at the bottom of sensor. And, the 'ground-t' is the temperature of the pipe in the soil, 5m away from hls3. Ground temperature dropped about 20 degree for the period. And, it shows some temperature dependence.

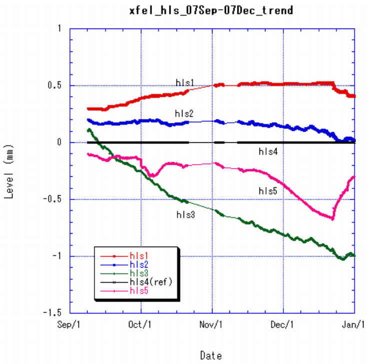
Water level and the temperature at pipe and sensor bottom



Measurement shows the level increased (distance decrease in figure) as the temperature become low. And, the change is mainly correlative with the temperature of the pipe that berried in the soil and the temperature of sensor bottom makes daily modification. By the data of November to December the temperature coefficient is derived as -0.12mm/C.

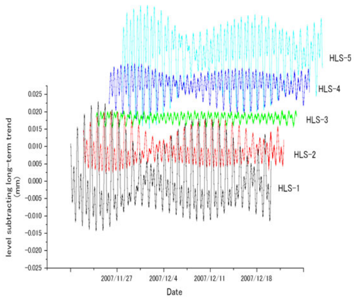
Data processing and results

Trend of long-term movement



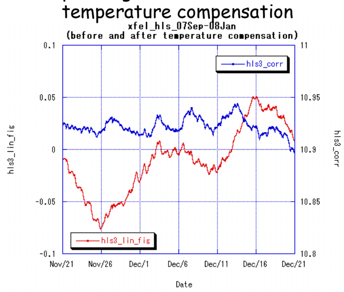
Measurement data are normalized to 20 degree with the temperature coefficients derived and decomposed with a tidal analysis program BAYTAP-G into the long-term trend and the short-term variation. The figure shows the trend of level changes for the 5 monuments, taking 4^{th} point as the reference because it seems relatively stable. There are no significant changes at hls-1, 2, or 4. While the place of hls-3 is subsiding continuously, where was a gully for the old ground. The rate is about 1mm/4months (3 mm per year). The subsidence at hls-5 from mid of November coincides with the beginning of the progress of ground reinforcement work.

Variation of short-term



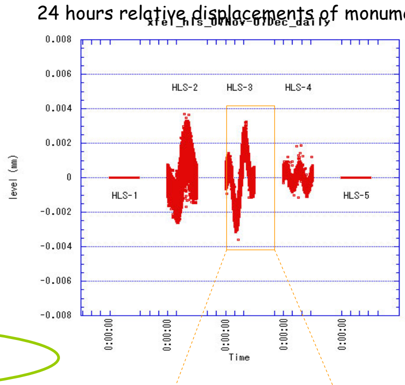
This is the levels that are subtracted the component of the long-term trends. They are mainly the component of the tides. Because of the tidal effect, the ground moves on the tilt. Maximum amplitude is 60μm for 400 meters (0.15μrad).

Lose up seeing of before and after the temperature compensation



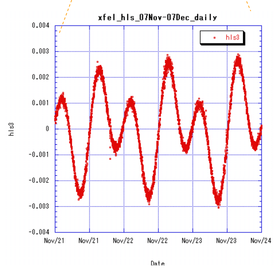
Temperature effects are compensated with the coefficients derived. After the compensation detail trend of the level change can be seen. It is implicit that the temperature induced measurement bias is well corrected.

24 hours relative displacements of monuments



This is 24-hour relative movement of the monuments, taking two end monuments as references. The data of one month are plotted for one day's length. It can be seen the relative movement is in regular and repeated every day, with some phase shift. The maximum is ±3μm at the 2^{nd} and 3^{rd} point.

Relative movement for three consecutive days



Resolution of System

The relative movement of the middle (hls-3) with respect to the two ends for three consecutive days is shown in the figure. The movement within sub-micron can be clearly seen. It is implicit the system's resolution is less than one micrometer.

Conclusion:

A reference line of monuments is built at the SPring-8 site, on purpose to measure the ground movement at the XFEL site, and to monitor the deformation of the building complex of XFEL tunnel. At present, a 400m HLS (hydrostatic leveling system) is made, one meter beneath the earth surface.

The construction of the monument and the HLS system is illustrated. Because the HLS system is built out of doors, severe temperature change usually limits the measurement capability. However, the measurement data show that the system has an ability to measure not only long-term ground movement but also minute earth tides in detail, gives a promising result. With the HLS the daily movement or distortion of a straight line of several hundred meters can be clearly seen.