The Results of HLS Measurement and Geological Investigation at Pohang Light Source

Y. C. Kim, K. W. Seo, B. I. Moon, C. W. Chung, I. S. Ko
PAL, POSTECH, Pohang, Kyungbuk, 790-784, Korea

In the PLS (Pohang Light Source) uneven deformations of the storage ring floor slab in a similar manner at every year have been recorded for more than a decade. To understand the yearly time distributions of the deformation we installed the HLS (Hydrostatic Leveling System) along the circumference of storage ring and have gathered data. The gradual and linear like deformations in the several months time span were found from data analysis. No seasonal variations are distinctive. In this poster, the results of the HLS measurement/analysis are reported. And the results of geological investigations to identify the reasons of uneven deformation are also briefly introduced.

1. INTRODUCTION

Pohang Light Source (PLS) is the 3rd generation synchrotron radiation facility with the beam energy of 2.5 GeV. As the number of users increased, more stable photon beam with micro-spot high resolution and high intensity are required. For the last few years many effort to improve the orbit stability of the electron beam have been conducted in the PLS in the various related fields such as RF, magnet power supply, conventional HVAC system, etc. Beside those activities, control system was also upgraded by reinforcing the feedback algorism. Even though most of mechanical problems degrading the beam quality have been improved, the slow movement of the bedrock of the PLS has not even been studied to improve the situation.

As was reported before, there has been a big amount of uneven settlement at the storage ring (SR) floor along the circumference of SR. Annual uneven settlement reaches about 2 mm in amount from the point of valley to the point of peak this year. That amount was almost 3 mm in the beginning of PLS operation and it has gradually become smaller for more than 10 years and converges into about 2 mm. These measurements are shown in Fig. 1 and 2. These annual measurements were carried out mainly at every summer maintenance period by use of optical survey instrument (level). If more data needed, additional measurements are done at winter maintenance period also.

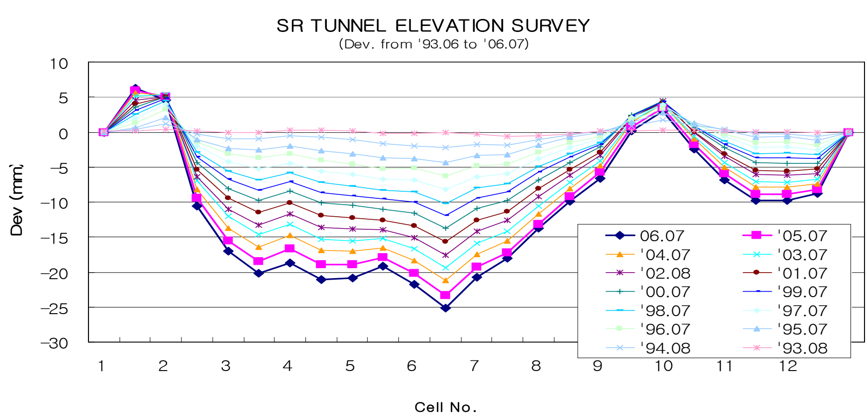

Figure 1: Elevation survey of storage ring tunnel floor for 13 years

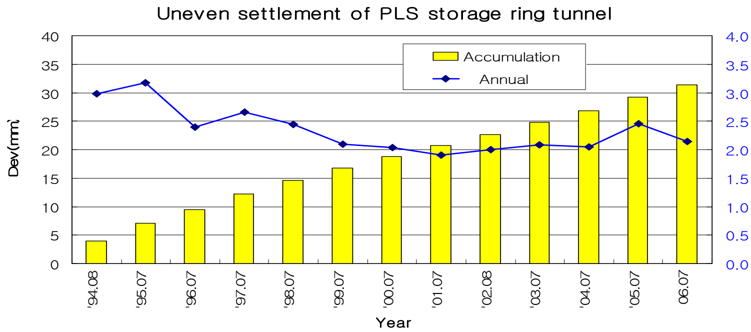

Figure 2: Yearly uneven settlement of storage ring tunnel floor

To understand the real time movement of the SR tunnel floor we installed the hydrostatic leveling system (HLS, Fogale Nanotech, France)) with 24 sensors in equidistance along the circumference of SR. We also prepared 4 survey posts outside the storage ring building and keep surveying the network including those posts and a point in the storage ring in an available time interval so as to identify the absolute vertical movement of the storage ring tunnel floor by analyzing the surveying data. Two of four surveying posts were piled into deep undisturbed bedrock on the edge of PAL (Pohang accelerator laboratory) compound. The rest two locate near linac building and a little southern part of storage ring building respectively, with also piled into undisturbed bedrock.

During our measurement of uneven settlement of SR tunnel floor, geological survey of the bedrock of storage ring and linac building were performed by the professional geological survey company to identify the causes of such uneven settlement and further to design the remedial engineering work.

2. HLS MEASUREMENT

2.1. HLS Installation

For the record of the real time floor movement and to compare it with the optical measurement data shown in the above Fig.1, 24 HLS were installed near the optical survey benchmarks in equidistance along the circumference of the storage ring. The installation map is shown in Fig. 3 and 4. Two numbers of HLS correspond to a cell in Fig. 1, with

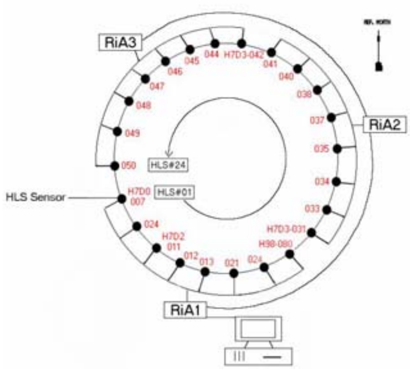

Figure 3: HLS installation map

Figure 4: Direction view for analysis

the same point of cell #1 and HLS#24. The HLS we bought from the maker was called 4th generation HLS which has been reported in some papers to have very good accuracy with small amount of standard deviation for a few months data collections [1][2]. For the fluid medium we used LCW (low conductivity water) that were used for the cooling of all the mechanical components of the PLS without any additives. The water tank was installed in the storage ring tunnel for the filling up the evaporation amount of water periodically. This installation is the same one as we did in 2004 with the 2nd generation HLS of the same maker [3]. At that time the HLS was so sensitive to the environmental factors that the accuracy of the measurement was not good enough.

2.2. Test

Before the installation of HLS on site, they were tested on the test bench for a month. The 24 HLS captors with sensors were arranged on a marble table. The room in which the test was performed was air conditioned with the temperature fluctuations of ±0.5℃ in about 20 days. The test result is shown in Fig. 5. As shown in the graph, the standard deviation of the system reaches to 11 ㎛ for 20 days measurement, which is quite bigger than the test result carried out at Soleil [3]. As for the long term measurement, standard deviation was not defined. But, for our purpose to understand the time distribution of uneven settlement of storage ring floor this accuracy would be enough.

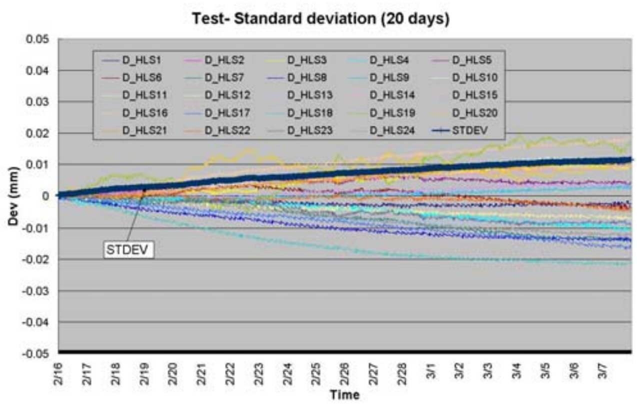

Figure 5: Test measurement for error estimation

2.3. Data Acquisition and Analysis

We have gathered the measurement data for a year from the beginning of September, 2005 to the end of August, 2006 so as to understand the real time behavior of the storage ring floor and to compare the HLS data with optical surveying data. It was found that there were tilt movement of the horizontal plane of the storage ring from the beginning of the measurement. The directions are shown in Fig 6, and x-direction goes to East sea with a distance of a few kilometer. The facts that the bedrock underneath the storage ring sink toward x- and y-directions are shown in Fig. 6 and 7. According to the graph in Fig 6, very linear sinking of the storage ring floor plane toward the x- and y-direction i.e., east and north direction had been occurred. The amount of tilting in x-direction is almost twice of that in y-direction at the first half of a year of measurement. East sea locates a few kilometer apart in x-direction. Hence the tidal effect is clearly seen in the graph. In the last half of a year of measurement the tilting movement in x-direction was almost stopped and that of y-direction kept moving with a steady amount. Finally, after one year measurement the total tilting

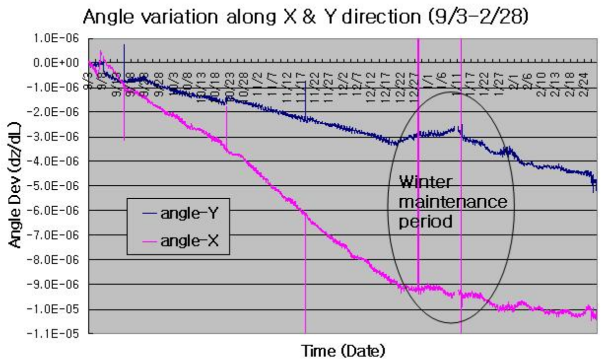

Figure 6: Tilt movement of SR plane in 1st half year

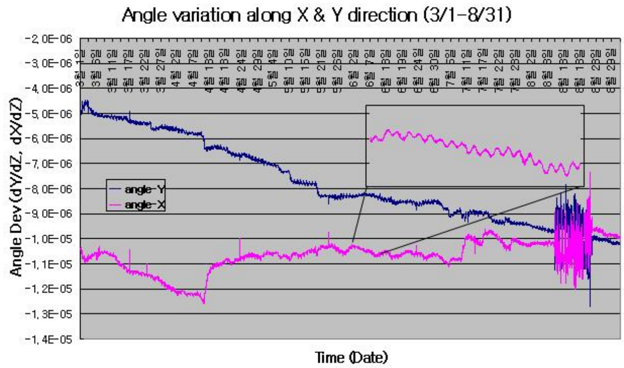

Figure 7: Tilt movement of SR plane in 2nd half year

movements in both directions reaches about to 1E-5 in angle, which is about 1 mm in vertical distance for the diameter of storage ring of about 90 m.

The vertical movements of the 24 HLS with the time span of a year is shown in Fig. 8. The movements seem to be

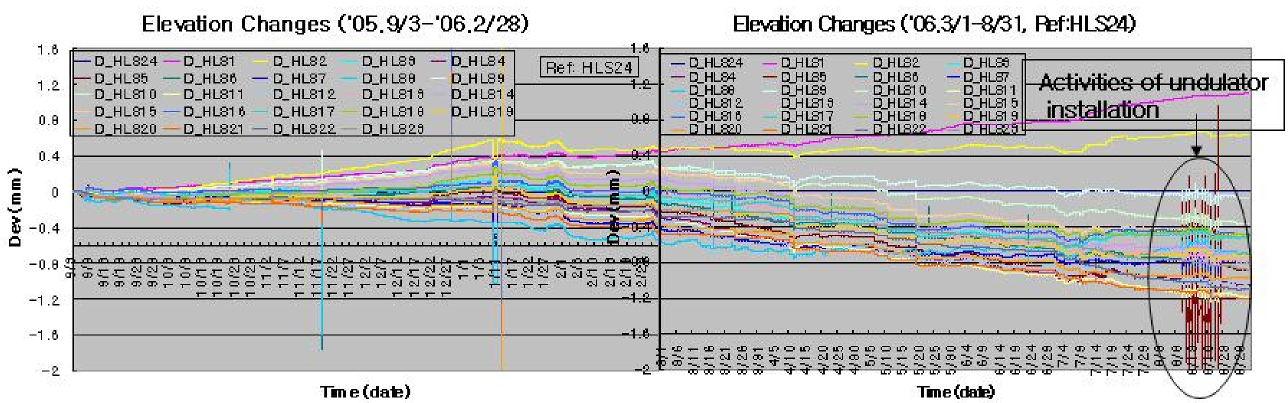

Figure 8: Vertical movement of 24 HLS for a year with reference of HLS24

well distributed along the time without any clear seasonal effects. In the graph of Fig. 8 the tilting movement of the storage ring plane was already taken into account. The comparison between the measurements of HLS and of optical surveying instrument (DNA) for a year was done and displayed in Fig. 9. Though there are a bit differences in most locations between the data from two measurements, both data show almost the same movement trend and shape. Though the actual accuracy of these 24 HLS for this long term measurement is not sure, we roughly estimate from the above data that the uneven settlement arise from the geological problems.

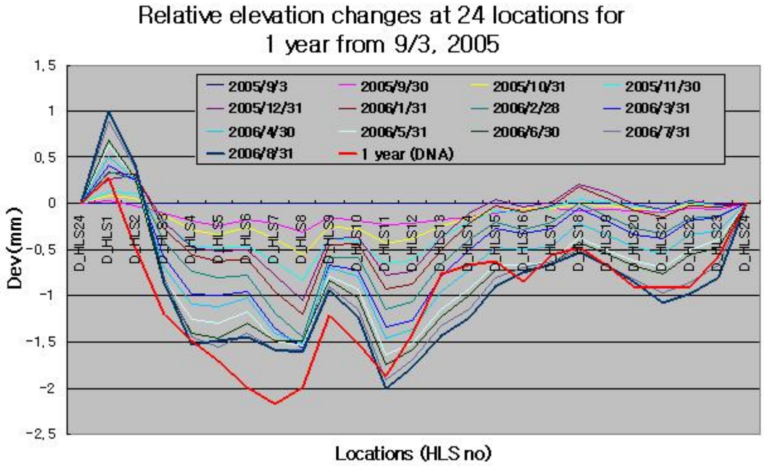

Figure 9: Relative elevation changes of 24 locations for a year with reference to HLS24

3. OUTSIDE ELEVATION MEASUREMENT

3.1. Survey Posts for Absolute Elevation Changes of SR

Optical survey and HLS measurement we performed for the maintenance of PLS provide the only relative vertical movements. For our further understanding of the floor movement and any additional activities against it, we need to find out if the vertical movement is differential uplift or sinking, i.e. absolute movement. So, we prepared the survey posts inside and outside the PAL (Pohang accelerator laboratory) to link the data from them to the one from the HLS or SR optical survey. The locations of those surveying posts are marked in Fig. 10. The posts outside PAL compound (P1 and P2) are deeply piled into undisturbed bedrock and the rest two posts (P3 and P4) are near linac building and SR building respectively, with almost same depth of piling into undisturbed bedrock.

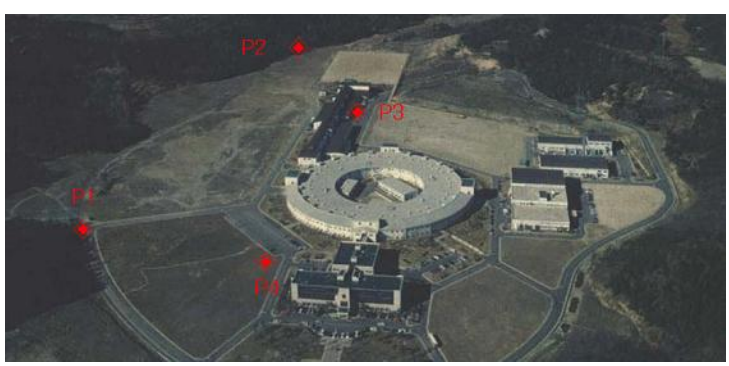

Figure 10: Survey posts for the absolute elevation measurement

3.2. Data Analysis

The measured data are shown in Fig. 11. In Fig. 11, L1 indicates the point cell#1 and HLS1 mentioned in the previous Fig. 1 and 3 respectively. According to the measurement, the point L1 is uplifting if the points P1 to P4 are assumed to keep level. On the other hand, if the point L1 keeps its elevation, the posts outside building are to be sinking.

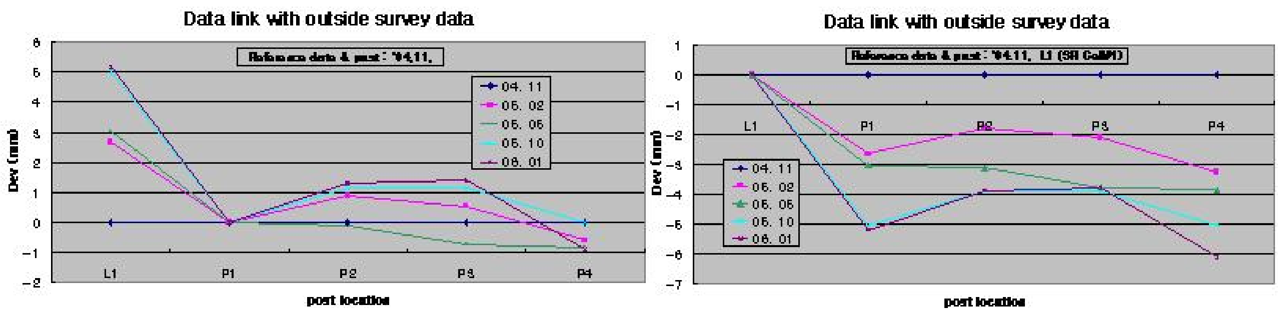

Figure 11: Results of absolute elevation measurement

From the above statement, we can reach interim conclusion about the absolute vertical movement that point L1 i.e., cell #1 in the storage ring tunnel and point of HLS1 is uplifting relative to the lower points of SR tunnel as contrary to our thinking. 5 times measurements were performed from November, 2004 to January, 2006.

4. GEOLOGICAL INVESTIGATION

4.1. Distance Survey for Preliminary Check

We provided the old distance survey data to the professional geology survey company for their preliminary check on the outside survey network. The survey network outside the building with some distance remarks are shown in Fig. 12. According to the report from the company, the PAL building area settles down a little. But, this is very preliminary survey and no more can be stated on the building floor.

Figure 12: Distance survey for the outside survey network

4.2. Geological Investigation and Analysis

Since we got a interim conclusion that this kind of uneven settlement is due to geological problem, we let the professional geological survey company (Sanha E&C) perform the geological investigation on the bedrock of the PLS machine area [4]. The items of investigation he performed are listed in Table 1 with mentioning the purpose of the test. The details of the geological survey, i.e., the locations of test, number of test, etc. are not mentioned here in this paper because those belong to other subject. After those tests, the analysis was performed based on the test results. According to the results of analysis, the cause of uneven settlement can not be defined as a simple one, but very complex and the following issues contribute in some manner to the problems: 1) effects of unloading of original load by preparation of PAL site at the beginning of construction. 2) effects of ground water level changes after the construction of PLS. 3) long term creep due to the characteristics of unconsolidated mudstone. 4) swelling phenomena due to the expansive miner materials contained in the bedrock. 5) uneven settlement due to different type of foundation and uneven loading. 6) distribution of sandstone in the bedrock and the effect of unconsolidated mudstone stratum intercalated in the bedrock. 7) effects of other characteristics of geological structure.

Table I: Items of geological survey

Classification	Purpose
Vertical and Inclined Boring	• Estimation of stratigraphy state and rock quality of bedrock • Undisturbed sampling for experimental mechanics test • Making boring hole for field test
Standard Penetration Test	• Estimation of relative density and consistency with Boring • Disturbed sampling
Seismic Refraction Survey	• Complement and precision elevation of boring data • Estimation of geologic structure and abnormal zone
Multichannel Analysis of Surface Waves	• 2-dimension analysis of dynamic characteristic of basement ground • Estimation of bedrock position
Pressuremeter Test	• Estimation of strain characteristic for each layers
Permeability Test and Hydraulic Test	• Estimation of soil and rock mass hydraulic characteristic
Suspension P.S Logging	• Estimation of dynamic characteristic and fracture grade of new building region
Flowmeter test (Measurement of direction and velocity of the groundwater flow)	• Estimation of groundwater flow characteristic (direction and velocity of the groundwater flow)
Borehole Image processing System	• Estimation of bedrock state of storage ring building and experimental hall

4.3. Suggestion and Recommendation

Since there were some differences in the absolute movement of the bedrock from the results of outside survey and from the geological survey, we suggested the ground monitoring activities so as to define the exact behavior of the bedrock underneath the PLS machine. This monitoring will give us the direction of ground movement and the size of remedial work. This ground monitoring will include the precision leveling, settlement plate, multi point borehole extensometer, tiltmeter and water level meter. The locations and number of monitoring, etc are roughly sown in Fig. 13,

Further to the suggestion, the two countermeasures were proposed by the company (Sanha E&C). One is floor lifting method which is the method of structure recovery. The rough expression of this method is shown in Fig. 14. As shown in Fig. 14, several boreholes are prepared in every radial section and those holes are injected with cement like special material. This method, however, seems to be very difficult to keep control of precise levelling of floor slabs including

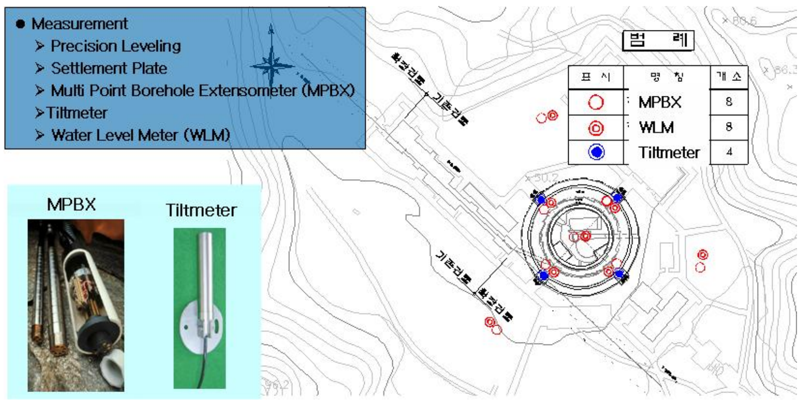

Figure 13: ground monitoring

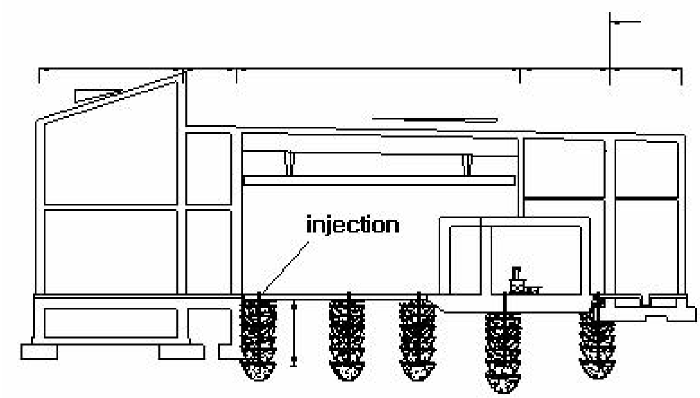

Figure 14: Floor lifting method

all the adjacent floors, while injection is being done. Since the machines in either storage ring or experiment hall are very well aligned specially in vertical direction, this injection can be very harmful against the aligned machine components on the neighboring floors. The other method is doing reinforcement on the bedrock which shows uneven settlement. This method is graphically shown in Fig. 15. The outstanding feature for this method is to use duplex resistance micro pile which has good resistances for both tension and compression forces. The details of the duplex resistance micro pile can be referred to the report from Sanha E&C [4]. This method is strongly recommended because

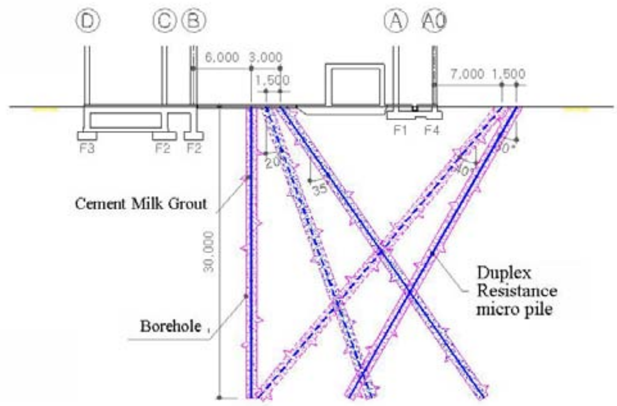

Figure 15: Ground reinforcement method

absolute movement direction is not clearly defined yet. The problem, however, is that both methods of structure recovery and bedrock reinforcement can not be performed while the accelerator machine is operating. Further more, according to the geology investigation report, the boring holes to be injected or to be equipped with duplex resistance micro pile to accomplish the purposes of the methods are too many to be realized. For reference, the layout of the boring hole arrangement for both methods are shown in Fig. 16 and 17.

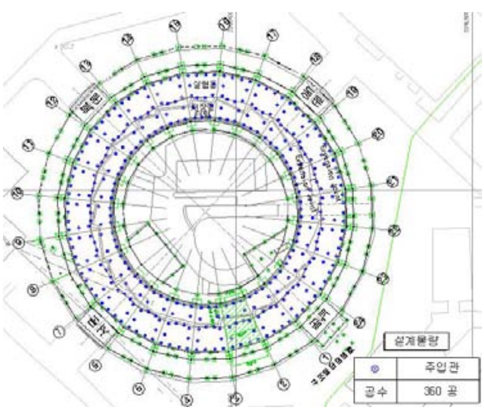

Figure 16: Hole arrangement for floor lifting method

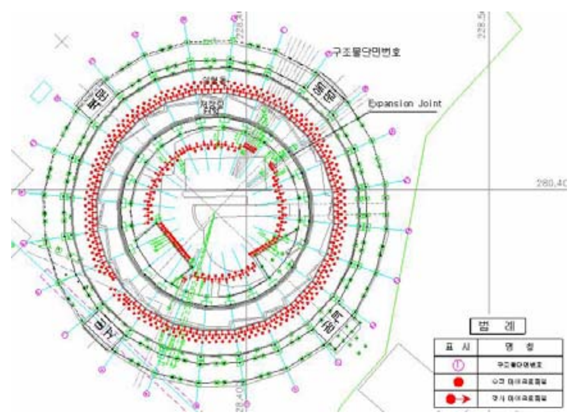

Figure 17: Hole arrangement for reinforcement method

5. SUMMARY

To identify the cause of SR floor vertical deformation and to improve the situation real time HLS measurement for a year and the geological survey were performed. As a conclusion, we summarized the results of those activities as follows:

- One year HLS measurement of vertical movement of SR floor shows similar deformation shape as that of optical survey measurement
- Uneven settlement of SR floor is very linearly time distributed without any outstanding seasonal effects.

- Outdoor survey shows that the peak area (cell#1-2) in the deformation graph is uplifting instead of settlement of other area
- Geological survey, however, shows that it's a partial settlement due to complex geological status
- To secure the stability and usability of the SR floor, floor lifting method or ground reinforcement method will be applied

As mentioned above, to figure out the size of remedial work, we need to find out the real direction of vertical movement. Therefore, the ground monitoring should be performed first by use of settlement plate, multi point borehole extensometer, tiltmeter, etc.

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