ANALYSIS OF THE VERTICAL FLOOR DEFORMATION IN SPRING-8 RING TUNNEL

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Abstract

We have investigated floor level deformations in SPring-8 storage ring tunnel via measurement data from 1996, and identified areas which have relative large deformations and their sources. Changes of height difference between neighboring two control points are used instead of changes of height in our analysis. For a secular level displacement, the maximum and the deviation are evaluated to be 40 µm and 10 µm, respectively. The large sources of the displacement are RF waveguide tunnels and a border of building construction. For a seasonal level displacement, the maximum and the deviation are evaluated to be 300 µm and 75 µm, respectively. And its large sources are found to be an under path, an under road and drain pipes.

INTRODUCTION

In the case of large accelerator facilities, such as SPring-8 storage ring (~1.4 km circumference), a stability of the accelerator tunnel is one of the important factor. 4/5 of the storage ring building is located on bedrock layer (cutting area), and the rest on artificial layer replaced with crusher stones [1]. Thereby, the floor deformation has not been an issue for the accelerator operation, and a re-alignment of the accelerator components in the storage ring has never been performed since starting operation in 1997.

SPring-8 upgrade plan is being designed. Major goal of the new ring is to realize an ultra-low emittance storage ring. The accelerator design team indicated 50 µm (1σ) as a tolerance error between neighboring two girders, in the case of no steering magnets. The tolerance is 4 times smaller than that for the present storage ring.

According to our surveyed data analysis, we consider the long-term vertical floor deformations consists of two components; unidirectional changes due to monotonous bedrock and concrete deformations (secular deformations) and annual cyclic changes due to thermal deformations of building (seasonal deformations). Finally, we identified areas which have relative large deformations and their origins.

LEVEL SERVEY DATA AND CONSIDERATION OF ANALYSIS METHOD

Level survey of SPring-8 storage ring

The storage ring consists of 48 cells (44 normal cells and 4 long straight sections). The normal cell consists of an insertion device, two bending magnets, and 3 common girders with multi-pole magnets (see Fig.1). 6 control points are located on the top of quadrupole magnets at both ends of 3 girders (a1, a2, b1, b2, c1 and c2) for each cell. Total number of control points is about 280[2].

Leica N3 (by 1999) and Trimble DiNi (since 2000) have been employed for our survey. The measuring data of the height difference was converted to the height, and the final height data was evaluated after a correction of closure difference.

Level survey data

Figure 2 shows all survey data from 1996 to 2016 as functions of cell number. 01a1 (cell01) is assumed as a fixed point. In 1996, a range of height was ± 0.5mm, and gradually increased by ± 2 mm. Original altitude distribution along the storage ring before ground breaking is also superimposed. A ground level of storage ring building is 290 m, and about 50 m of variation in altitude was developed. It is found that the recent surveyed height data reflects the original altitude distribution. That means cutting area is not stable even on bedrock area, and the ground improvement with the artificial layer is found to be effective. We understand that a great deal of rock and soil were removed, so rebound has occurred.

Figure 3 is a magnified chart of Fig.2 around cell 25, which is opposite area to the fixed point; 01a1. In this figure, vertical order of the data does not correspond to a

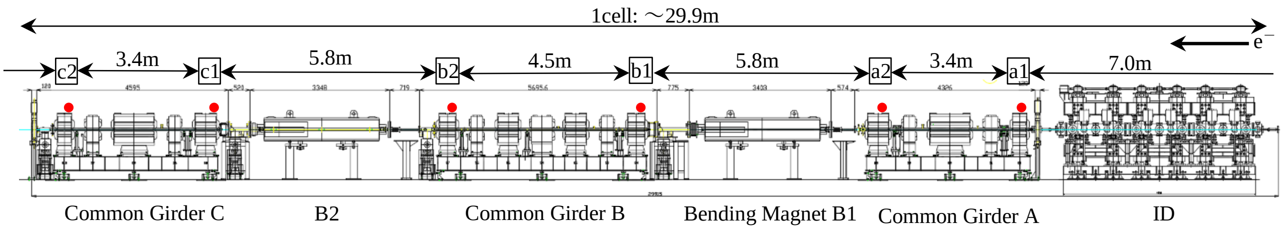

Figure 1: Side view of the normal cell and 6 control points.

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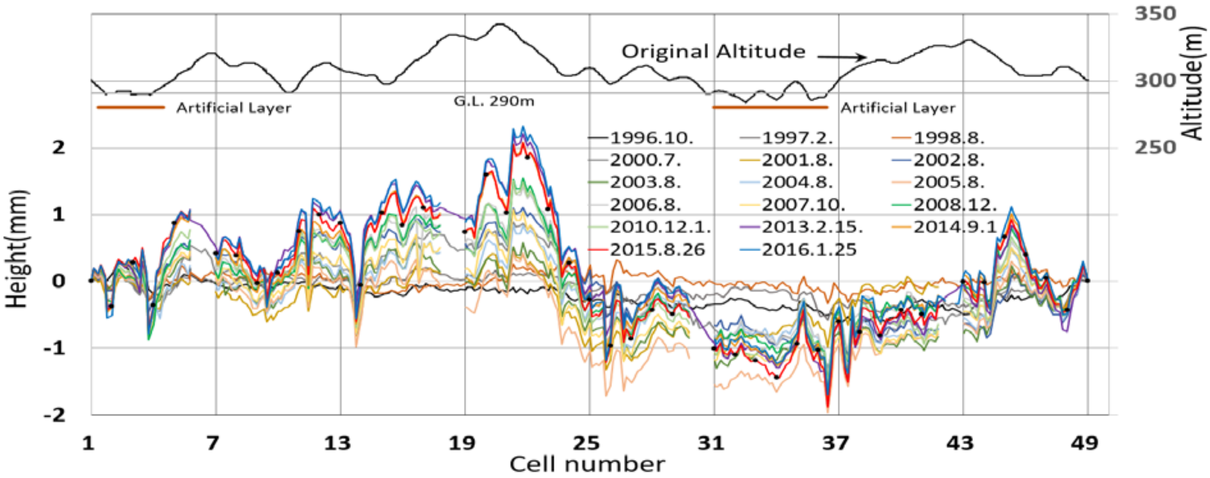

Figure 2: Level survey data from 1996 to 2016 and an original altitude distribution along the storage ring before ground breaking as functions of cell number. 01a1 (cell01) is a fixed point.

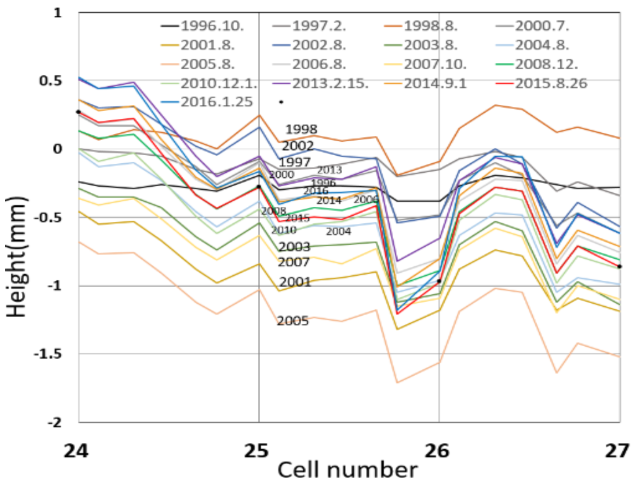

Figure 3: Magnified chart of Fig. 2 around cell 25. Vertical order of the data does not correspond to a measurement year.

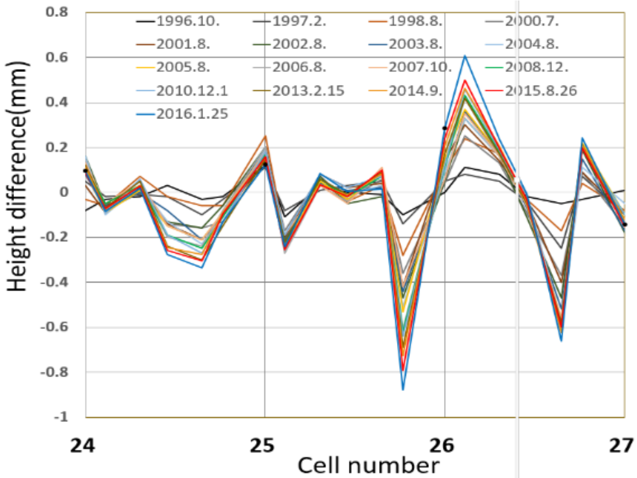

Figure 4: Height difference between neighboring 2 control points data around cell 25. Vertical order of the data almost corresponds to a measurement year.

measurement year. It means these data involved non-negligible error. Therefore, it is difficult to analyze the long term deformation.

Consideration of analysis method

We analyzed a trend of height difference reversed from the height data, and found that the temporal change of height differences was varied in one direction for each control point. Height difference data has no accumulation errors. Figure 4 shows height difference around cell 25 as same as Fig. 3. Vertical order of these data almost corresponds to a measurement year.

The temporal change of the height difference means the local displacement of each control point, i.e. changes of alignment between girders. For the stable accelerator operation, local deformation makes worse influence comparing to global deformation. Thus we analyzed height difference data instead of height data.

Furthermore, height difference data can be compared each year without assuming fixed point, even if the measurement points are partial or discrete.

ANALYSIS OF SECULAR DISPLACEMENT

Figure 5(a) shows temporal displacement of height difference per one year from 1998 to 2005 (1st half) and from 2005 to 2015 (2nd half) with explanations of components beneath the storage ring. There are no data at cell06, 18, 30 and 42, these are long straight sections. The secular displacement in the 2nd half (red-line, STD = 10 μm [σ]) was decreased comparing to that in the 1st half (blue-line, σ = 18 μm). The maximum displacement of the 2nd half was about 40 μm.

The storage ring tunnel at around RF stations, a border of building construction and a drain pipe at cell 19 have large

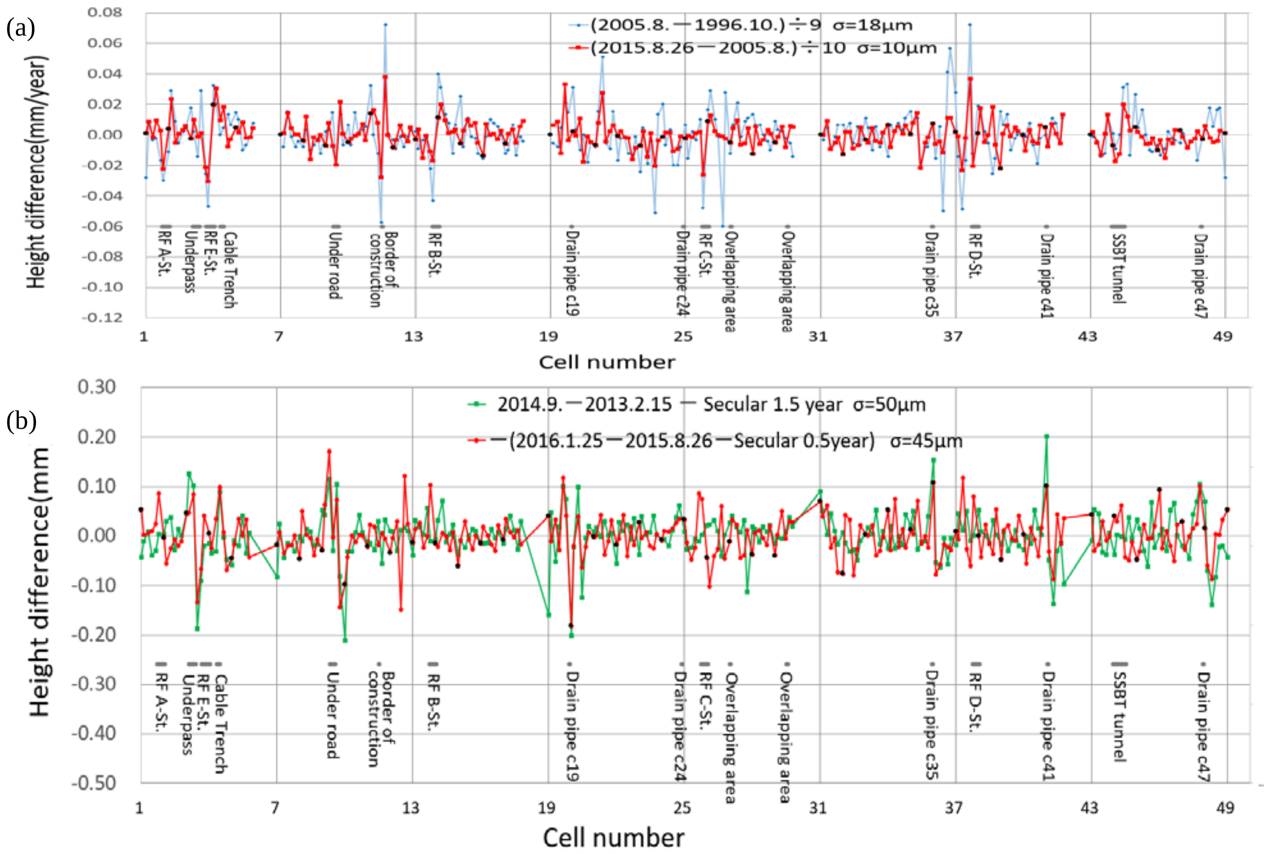

Figure 5: (a) Secular displacement, (b) seasonal displacement of SPring-8 storage ring with explanations of components beneath the storage ring.

secular deformation; ≥ 30 μm as shown in Fig. 5(a). In the case of RF stations, there exists rooms for RF wave guides ~1 m beneath the storage ring tunnel. Effective volume of each room is approximately 10^W x 10^D x 2.2^H m^3 (W: beam direction). The temperature of rooms is controlled, thus seasonal displacements of these above places are small.

SPring-8 storage ring is constructed divided in total four periods surrounding Mt. Miharakuri-yama (altitude ~340 m). And rain water flows from mountain side to outer side of the ring through total five drain pipes (1-m diameter) which were installed ~1-m beneath the ring at cell 19, 24, 35, 41 and 47. Areas beyond the drain pipe at cell 19 and the border of building construction give relatively larger level deformation and its origin is under investigation.

Eventually, the secular displacement is found to be not so large and is expected to be gradually decreased.

ANALYSIS OF SEASONAL DISPLACEMENT

Figure 5(b) shows temporal displacement of height difference from February 2013 to September 2014 and from August 2015 to January 2016. The sign (+ -) of data agrees with the change from winter to summer and the secular displacement is considered. The maximum height difference and its standard deviation are ~200 μm and ~50 μm, respectively, which are 5 times larger than the case of the secular displacement.

Locations with large seasonal displacement, around 200 μm, have under path, under road and drain pipes at cell 19, 35, 41 and 47. Temperatures at these above area are not controlled.

The seasonal displacement is analyzed with data surveyed on August/September and January/February. Hydrostatic levelling system (HLS) is installed beyond under road area at cell 08 – 10 where relatively larger height differences evaluated which is considered to be associated with seasonal displacement.

Figure 6 shows measured level data via the HLS assuming 10a2 as a fixed point. The data take the maximum values at October and the minimum values at April. That means the temporal difference between August and February is estimated to be 60% of that between maximum and minimum.

Then the actual peak value and σ of the seasonal displacement are estimated to be 300 μm and 75 μm, respectively.

IMPROVEMENT OF THE UNDER STRUCTURES

Some sources of the large seasonal displacement are considered to be improved.

In the case of the under path we recently modified its air circulation system from outside to inside air circulation. Currently, the effect is under estimation.

Rainwater flows through drain pipes. In summer or winter season, warm or chilly air also flows. Then a special lid is designed, through which water flows while air flow is prevented. Temperature measurement in the pipes was started.

The under road is prepared for traffic. Thermal insulating panels were already installed on its celling and wall inside of the tunnel. Introducing a temperature control panel is one candidate except for its cost.

SUMARRY

We have investigated a floor level deformation of SPring-8 storage ring tunnel analyzing survey data from 1996.

- Range of height of control points is ± 0.5 mm on 1996, ± 2 mm on 2015. The displacement reflects the original altitude distribution before the ground development.
- The height difference data with no accumulation errors is suitable to estimate the floor local deformation comparing to the height data.
- For the secular displacement, the maximum peak and σ are estimated to be 40μm and 10 μm, respectively. Major sources of the secular displacement are RF waveguide tunnels and a border of construction.
- For the seasonal displacement, the maximum peak and σ are estimated to be 300μm and 75 μm, respectively. And its major sources are the under path, the under road and drain pipes.

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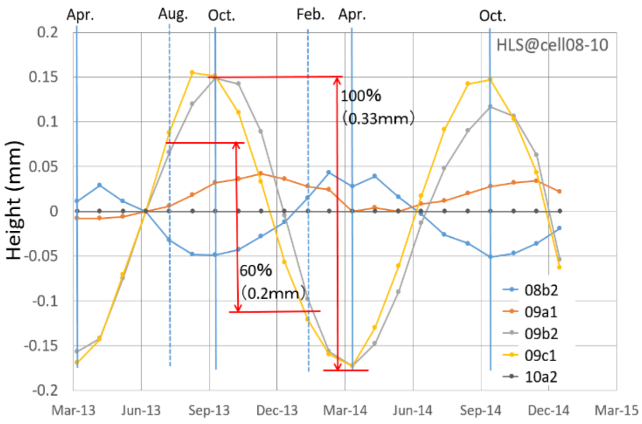

Figure 6: Measured level via HLS at cell08-10. 10a2 is set as a fixed point. The data have the maximum value at October and the minimum at April. The level difference between August and February is estimated to be 60% of its p-v values.

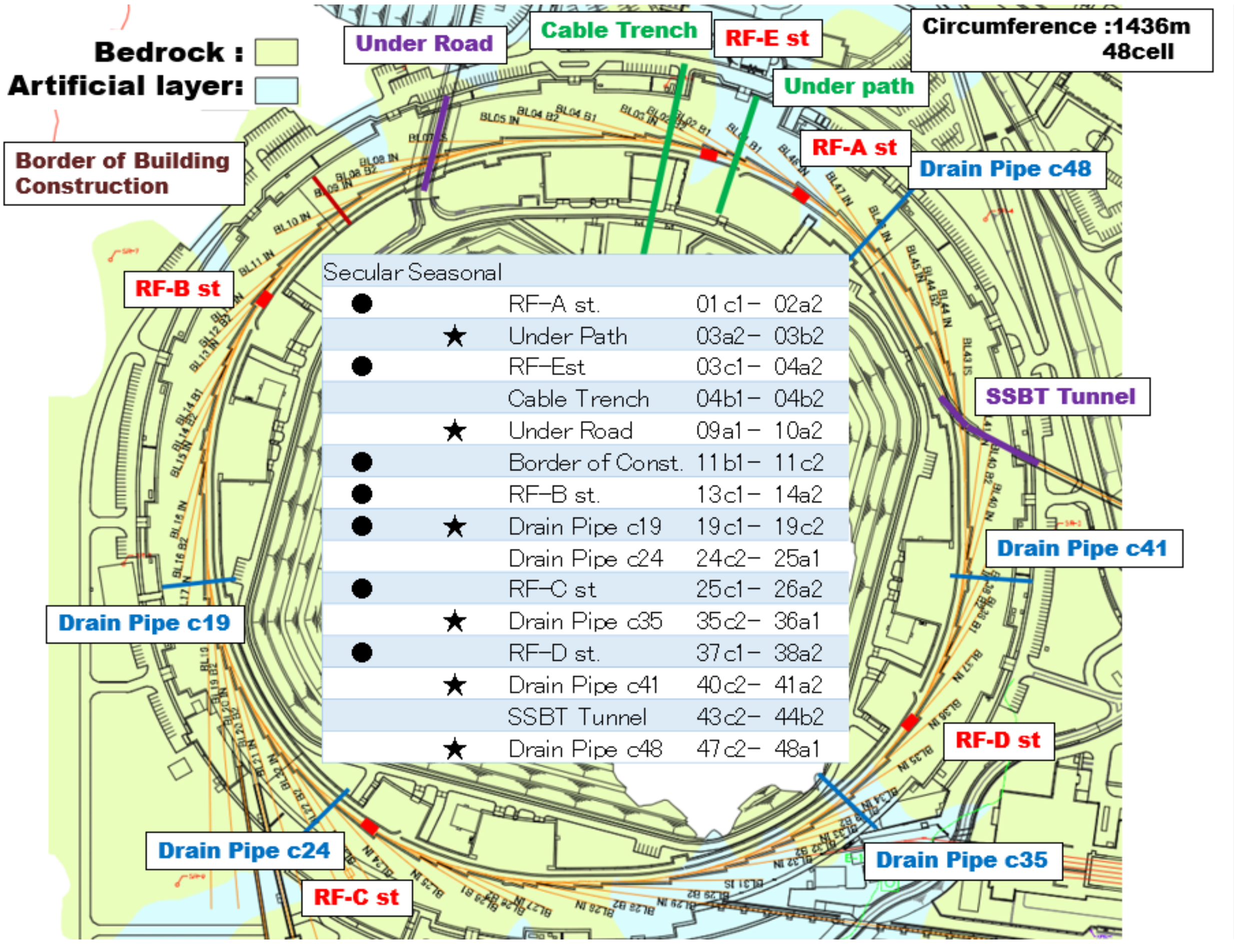

Figure 7: Map of underground structures of SPring-8 storage ring building.