FLOOR DEFORMATION OF J-PARC LINAC AFTER THE TOHOKU EARTHQUAKE IN JAPAN

T. Morishita#, H. Asano, JAEA, Tokai, Ibaraki 319-1195, Japan
M. Ikegami, KEK, Tsukuba, Ibaraki 305-0801, Japan

Abstract

The alignment has seriously been damaged due to the large earthquake on March 11th, 2011 in eastern Japan. There has been observed more than 40 mm settlement and about 25 mm horizontal deformation at the straight section in the linac accelerator tunnel. After that earthquake, there was continuous settlement in the straight section for two months. The linac accelerator tunnel has two expansion joints at the transport section to RCS. At these joints, abrupt displacements have been observed more than several millimetres both horizontally and vertically. Now, re-alignment started for restoration of the linac alignment.

INTRODUCTION

The J-PARC has seriously been damaged due to the earthquake at March 11th, 2011on buildings, devices, utilities, alignment, and so on. Now, we are continuing restoration for the resumption of the beam operation [1,2,3].

J-PARC linac has finalized its precise alignment at the end of summer 2006, and the beam provision to the RCS(Rapid Cycling Synchrotron) has been started at September 2007[4]. Since then, the deformation of the accelerator tunnel is small enough to keep the soundness of the alignment accuracy in the beam operation. Therefore, the linac has been operated without re-alignment for these four years. However, a serious deformation of the accelerator tunnel became apparent by the survey after the earthquake. The survey result indicates that the most of all magnets and cavities should be re-aligned for the high power beam operation.

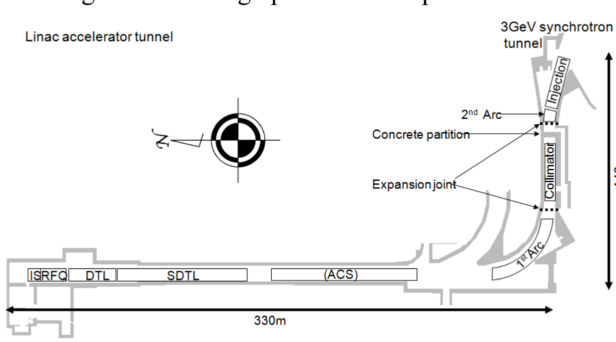

Figure 1: Layout of the J-PARC linac tunnel and accelerators.

Figure 1 shows the layout of the J-PARC linac. The linac consists of the straight section (about 300mincluding the ion source, the RFQ, the DTLs, the SDTLs, and the beam transport line), the collimator line between two arc sections, and the injection line. The straight section and the first arc belong to the linac building. The second arc and the injection line belong to the RCS building. These two buildings are connected by L3BT building, which has the collimator line. We observed a large deformation at the straight section and the expansion joints between these buildings. In this proceeding, the deformation of the linac accelerator tunnel by the earthquake is reported.

FLOOR DEFORMATION AFTER THE EARTHQUAKE

Due to the influence of the underground water and the damages on the air-conditioning equipment, the humidity was too high to use the surveying instrument in the tunnel just after the earthquake. At the end of the March, temporal dehumidifiers were installed and the power feeding was partially recovered. Then we started the survey of the monuments on the tunnel floor and reference bases of the accelerators.

Floor Level

The level monuments are distributed on the tunnel floor. The heights of these monuments were measured using digital level (Leica DNA03 with bar-code stuff). Figure 2 shows the relative level difference of these monuments with respect to the height measured at September 2010. The height difference for the uppermost monument is further subtracted to deduct the settlement of the whole linac tunnel. In the straight section, there are local settlements at the DTL/SDTL sections (more than 40 mm)and at the end of the ACS section (about 20 mm). From the first arc to the injection area to RCS, significant settlements did not occurred. However, the step-like level difference occurred at the expansion joints.

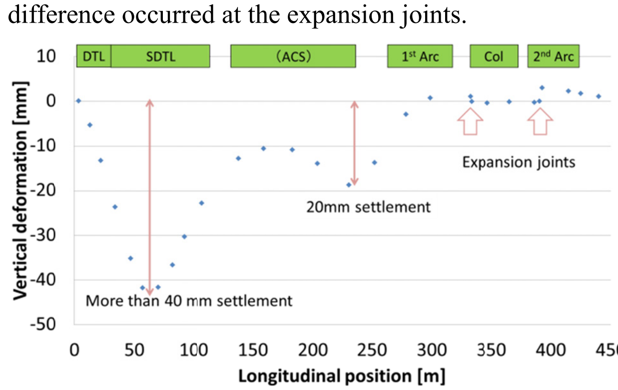

Figure 2: Relative level difference of the linac tunnel floor.

takatoshi.morishita@j-parc.jp

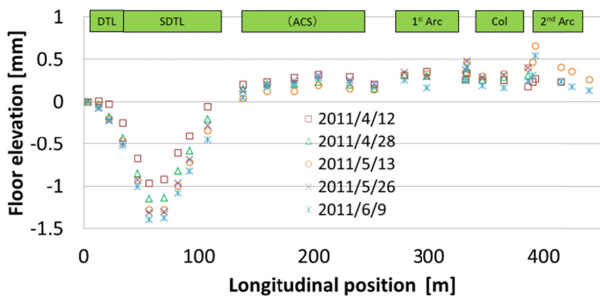

Figure 3: Floor elevation after the main quake.

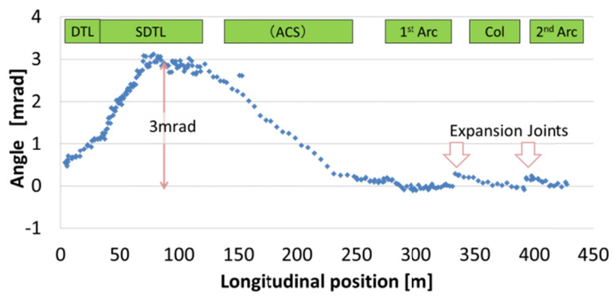

Figure 4: Inclination angles of the cavities and magnets.

There had been frequent aftershocks after the earthquake. Then we continued the level survey every two weeks. Figure 3 shows the floor elevation change after March 31th.The local settlement continued at the upstream side of the straight section, this directional elevation change has mostly ceased two months later.

Inclination

The inclination angles of the cavities and magnets are shown in Fig. 4. The vertical axis is the rotating angle around the beam axis. In the straight section, more than 3 mrad tilt was observed toward westward direction. A small contortion occurred at the expansion joints.

Building Foundation

Figure 5 shows the soil distribution under the linac building. Upper figure is the cross-sectional drawing of the geological formation along the beam direction (north-to-south). Lower figures are those of perpendicular (west-to-east) direction. The upper end of the building directory stands on the mudstone bedrock, and the downstream end has pile foundation. However, at the middle of the straight section, the spread foundation stands on the sandy soil. The settlement noted above might be induced by this unequal foundation and the soil distribution. In the west-to-east direction, the direction of the inclination angle is the same as the soil distribution.

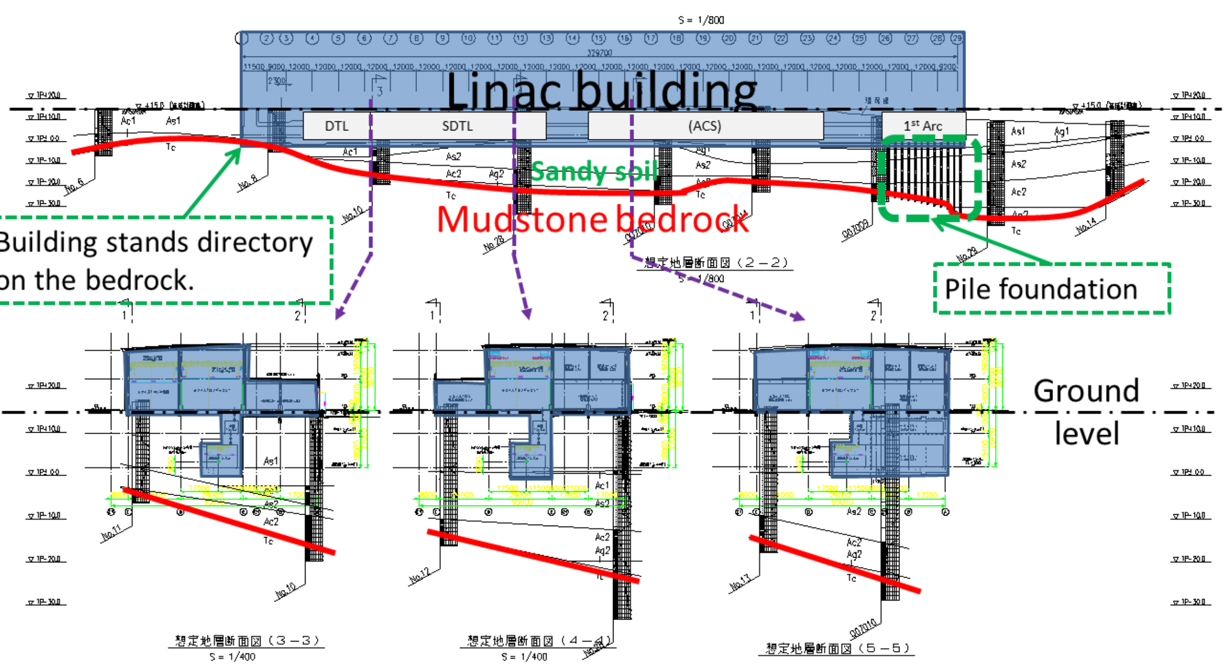

Figure 5: Foundation and soil distribution of the linac.

LASER TRACKER SURVEY OF THE ACCELERATORS AND RE-ALIGNMENT PLAN

Straight Section

The reference base of the cavities and magnets were measured by using the laser tracker (Leica LT600). Horizontal and vertical displacements are shown in Figs. 6a and 6b respectively. The vertical displacement is consistent to the floor elevation as shown in Fig. 2. There is about 25 mm horizontal deformation at the straight section.

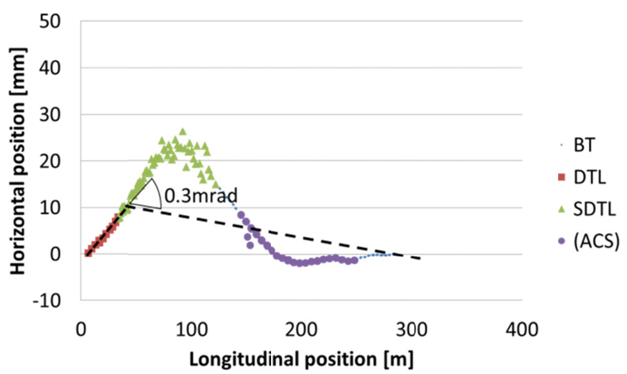

Figure 6a: Horizontal position of the accelerators in the straight section.

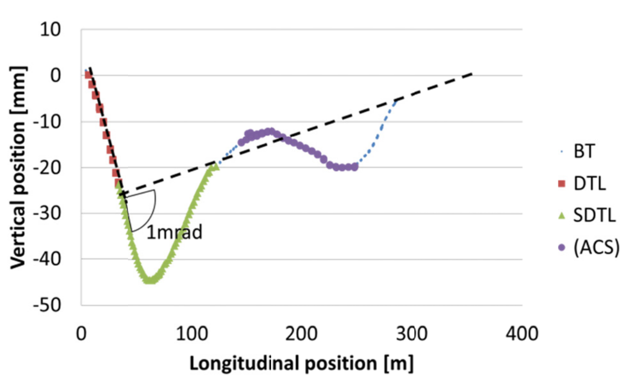

Figure 6b: Vertical position of the accelerators in the straight section.

The influence of the DT misalignments on the beam might be a fatal problem especially on the DTL cavity. Then, the platform of the DTL/SDTL cavity has a vibration-damping structure to reduce relative misalignment of the drift tubes when the cavity receives a strong acceleration. With this structure, a cavity is fixed on a platform which can slide on a linear rail in the horizontal direction. The horizontal motion of the platform is restricted with a spring and a shock absorber. A random distribution of a few millimetres at the SDTL section in Fig. 6a is due to the slide on this rail.

The dotted line shows the target re-alignment line in the straight section. It is necessary to move the DTL cavity by 20mm or more to align on the ideal straight line in the whole area of the straight section toward the dump. However, the range of the DTL movement is a few millimetres without re-wiring for DTQs. Then, aiming at an early restart of the beam operation, we decided to steer the beam at the steering magnets downstream of the DTL section horizontally and vertically [2].

Longitudinally, the accelerator tunnel was extended about 9 mm at the upstream part of the SDTL section, and 1 mm at the downstream part of the ACS sections. This extension will be absorbed smoothly by adjusting the magnets interval at the matching section (about 15m) between SDTL and ACS.

Displacement at the Expansion Joints

Figure 7 shows the relative position of the magnets after the first arc to the 90 degree dump. Displacements at the expansion joints areas follows:

- 0.8 mm in transverse, 1.1 mm in vertical, + 1.0 mm in longitudinal, 0.3 mrad in bend at the exit of the first arc.
- 9 mm in transverse, 3 mm in vertical, + 1.3 mm in longitudinal, -0.4 mrad in bend at the exit of the collimator section.

The beam transport section (from the first arc to the injection line to RCS) will be adjusted to maintain the proper injection angle and position to RCS.

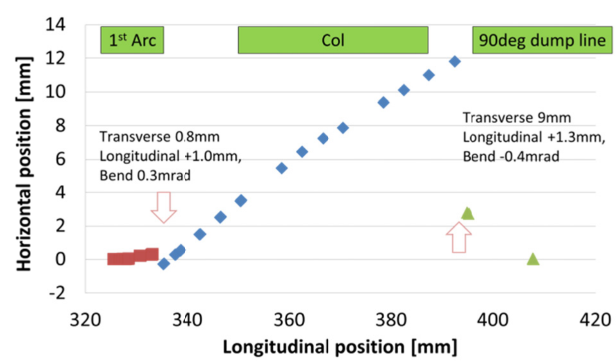

Figure 7: Relative position of the magnets after the first arc to the 90 degree dump.

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