

DISPLACEMENT OF J-PARC CAUSED BY MEGAQUAKE

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Abstract

Accelerators, beam lines, and experimental halls located in the J-PARC site were displaced by the 2011 off the Pacific coast of Tohoku Earthquake happened on 11th March, whose magnitude was nine, and its following many aftershocks. Site-wide network of measurement points distributed on grounds, buildings, and magnets was surveyed by using GPS survey system, precise digital levels, and laser trackers. The effect from the megaquake was reported for each J-PARC components, such as LINAC, Rapid Cycling Synchrotron (RCS), Main Ring (MR), neutrino and hadron beam lines, and experimental halls.

INTRODUCTION

The 2011 off the Pacific coast of Tohoku Earthquake has been the biggest earthquake in Japanese history of observation. The acceleration of 546 gal in horizontal plane and 412 gal in vertical one were observed at K-net Nakaminato [1] where was 10 km away in the south of J-PARC. According to the Geospatial Information Authority of Japan, the coast area of Ibaraki district moved one meter towards the Pacific Ocean and subsided 30 cm [2]. In J-PARC, the accelerator tunnels and buildings were damaged such as land subsidences, cracks on the walls, floors, and roofs. The measurement points for the survey network are prepared on concrete pillars on the ground and roofs of the buildings for the site-wide observation of accelerator complex. In addition, the accelerator tunnel has lots of auxiliary measurement points on the wall and floor to make precise magnet position survey. We measured all the accelerators components for the verification of magnet alignment.

MEASUREMENT RESULTS

GPS Survey

First of all, we carried out the global survey at the ground level by using GPS system in order to verify the displacement of accelerators and experimental halls. At the ground level, there are many subsidences especially around the buildings. Though the horizontal displacements of measurement points are more than 100 mm close to the large subsidences around the LINAC, they are 5 to 20 mm at most points in the other area. The accelerator tunnels are expanded east and west [3]. Fortunately, everything moved together and there was not fatal damage on accelerators, beam lines, and target systems. As the result, no vacuum pipe was broken on beam lines and the pressure had been kept in 200 Pa without any pumps during more than one month.

LINAC

The vertical displacements of floor benchmarks along the LINAC tunnel from July 2010 to April 2011 are shown in Fig. 1 which includes an ion source, RFQ, LINAC, the first arc beam line, and the second arc beam line. The worst point subsided more than 40 mm at the upstream point of SDTL section. The horizontal curve was also observed between the SDTL section and the ACS section. The entrance of the first arc was displaced 25 mm to the east. The realignment is going on from the SDTL section to the end of beam line. The largest vertical displacement is not corrected in 2011. The drift tubes and cavities will be aligned along this V-letter beam line. The vertical steering will kick up the beam for the orbit correction.

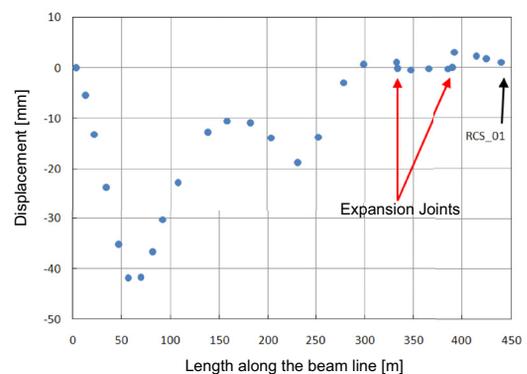


Figure 1: Subsidence of LINAC. Start point is used as the base.

Rapid Cycling Synchrotron

The vertical displacements of floor benchmarks in Rapid Cycling Synchrotron (RCS) from August 2010 to April and June 2011 are shown in Fig. 2. The RCS has three straight sections. One is for the beam injection, another is for RF cavities, the other is for the beam extraction. The benchmark RCS_01 is put at the start of injection straight and RCS_03 is put at the end of extraction straight. As the beam extraction area subsided, this tendency had been observed since the RCS construction. The displacements during 2 months seems to be due to the following aftershocks. The vertical displacements are small but comparable to the yearly fluctuations.

For the horizontal plane, the displacements of magnets were surveyed by using laser tracker. The horizontal displacements of magnets in RCS are shown in Fig. 3 where the displacements are multiplied by 1000 for convenience. The extraction straight and following arc is expanded to the

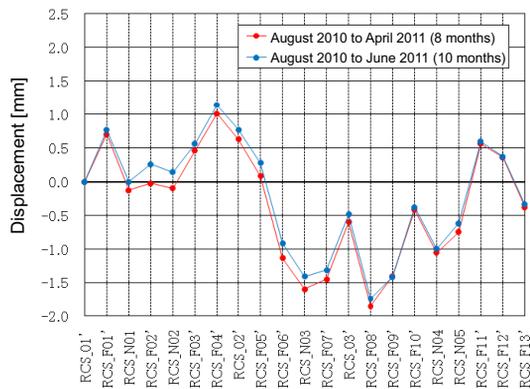


Figure 2: Subsidence of RCS. RCS_01 is used as the base.

outside. The amount of horizontal displacement is about 10 mm at the maximum. Re-alignment of magnets is not planned in this year.

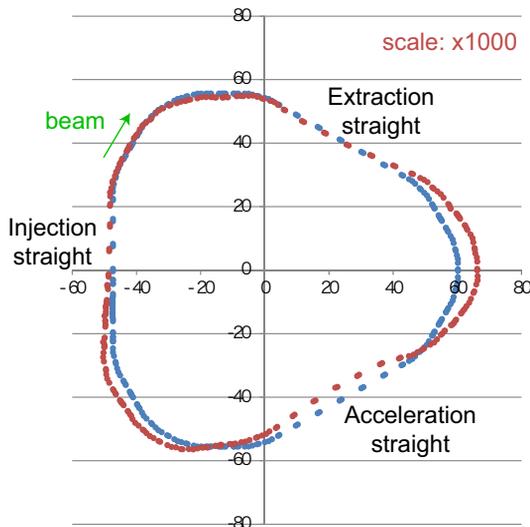


Figure 3: Horizontal displacements of RCS.

3-50BT and Main Ring

The beam transport line from RCS to the main ring is called as the 3-50BT line. The floor level of main ring is set 4.1 meters lower than that of RCS. It was found this step size shortened 5 mm, and the vertical displacement on the upper floor was 2 mm compared to the measured data in August 2010. The vertical displacements of main ring magnets are shown in Fig. 4. The main ring also has three straight sections for the beam injection, and slow and fast beam extractions, which are called as INS-A, INS-B, and INS-C, respectively. The pattern of vertical displacements corresponds to the bedrock contour deep in the ground [4].

The horizontal displacements of magnets in 3-50BT line and main ring are shown in Fig. 5 with the result of GPS survey, where the displacements are multiplied by 2000

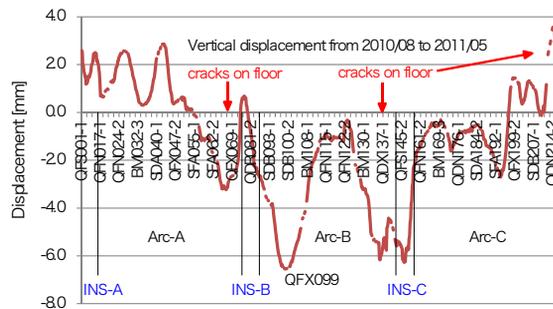


Figure 4: Subsidence of main ring. Level zero is arbitrary.

convenience. The tunnel structure of the main ring is not resistible to the horizontal force. The main ring is expanded in the direction of north-east and south-west. Since the horizontal displacements are too large for high intensity operation according to the simulation, all the magnets are re-aligned from August to October in 2011.

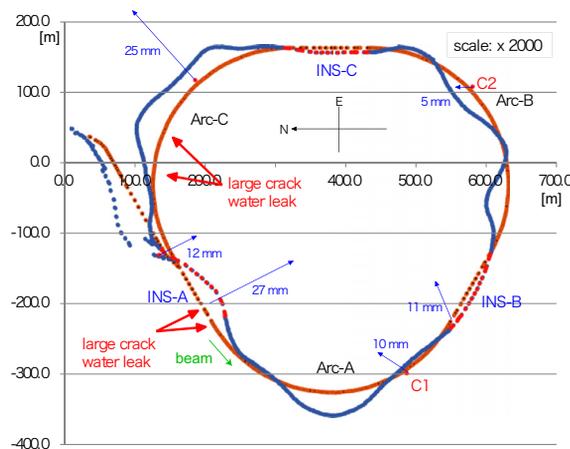


Figure 5: Horizontal displacements of 3-50BT line and main ring.

3NBT and MLF

The beam transport line from RCS to the Materials and Life Science Experimental Facility (MLF) is called as the 3NBT line. The vertical displacements from -10 to +2 mm were observed. The maximum horizontal displacement of 8 mm was also observed locally before and behind of the expansion joint. Since it is impossible to transfer the beam with such a large kink, all the magnets in 3NBT line are scheduled to be re-aligned.

Fig. 6 shows the vertical displacements at the measurement points distributed in the MLF floor. The MLF has two long neutron beam line which extend to the out of the original MLF building. Large steps are observed before and behind of expansion joints, as well. In the original MLF building, no serious damage was observed though some concrete shield blocks were moved slightly.

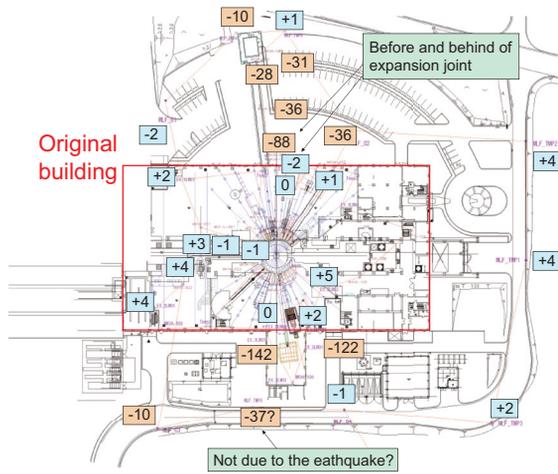


Figure 6: Subsidence of MLF.

displacement was caused by the quake. On the other hand, the vertical motion of experimental hall has been monitored after the construction. The apparent subsidence due to the quake was not observed [5].

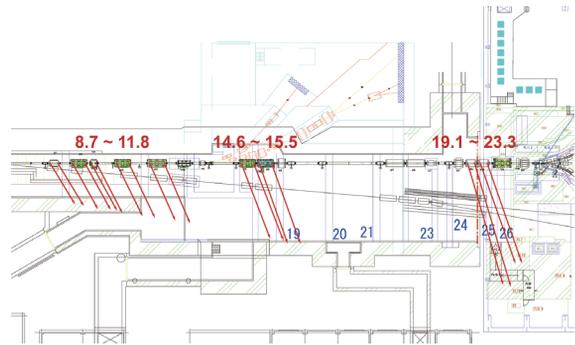


Figure 8: Horizontal displacements of hadron beam line.

Neutrino Beam Line

The vertical displacements of magnets in the neutrino beam line from July 2010 to May 2011 are shown in Fig. 7. Though the floor measurement point MHR38 is treated as a fixed point in Fig. 7, it subsided 7.2 mm with respect to the J-PARC height base at JRR-3. The effect of aftershocks seems to be small as seen in RCS. Large displacements were also observed at the expansion joints. The horizontal displacements were also several millimeters. The re-alignment of magnets are going on for 15 of 21 conventional magnets and all the superconductive magnets (14 set, 28 magnets).

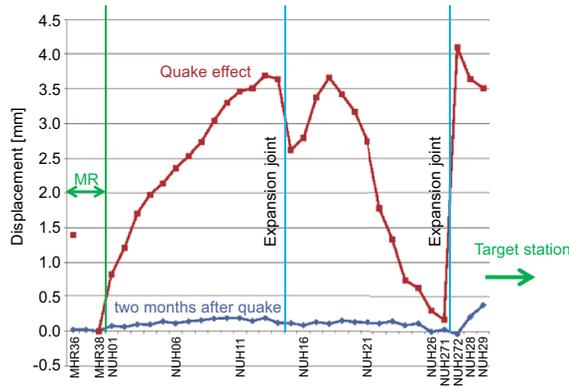


Figure 7: Subsidence of neutrino beam line. MHR38 is used as the base.

Hadron Beam Line

The hadron beam line was surveyed in May by using laser tracker. The hadron experimental hall also moved toward the Pacific Ocean, as the result, the beam line is curved to the right. The displacement is 23 mm for the horizontal plane at the end of the beam line. However, the hadron beam line and experimental hall have not been surveyed since May 2008. It is uncertain that this horizontal

SUMMARY

Though the megaquake damaged J-PARC site such as land subsidences, cracks on the buildings and accelerator tunnels, they didn't cause the fatal problem. As the distortion on the accelerator tunnel broke the machine alignment, re-alignment of drift tubes, magnets and other components is going on for the beam recovery in December 2011.

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