FLOOR LEVEL MOTION AND WATER PRESSURE IN THE SOIL OF THE KEK-PS TUNNEL

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Abstract

An intensity upgrade project of the KEK-PS main ring has been performed for recent years in order to serve the high intensity beam for the long-baseline neutrino oscillation experiment. Although the beam intensity came to 6.5 x10^{12} ppp for utility up to now, magnet alignment is one of the most important issues to restrict further upgrade. The magnets were aligned in 0.1 mm in the KEK-PS main ring. However, the subsidence and upheaval of the PS tunnel floor has been observed. Continuous measurement of the relative quadrupole magnet level has been done once a year, and detectors for the floor tilt were set up. Further, the time domain reflectmetry (TDR) probes to measure the soil moisture and tensionmeters made by Porous Ceramics to measure the water pressure in the soil, detector of the electric resistivity in the soil and a rain gauge are mounted in the soil. Status of this work is reported.

1 CURRENT STATUS OF THE KEK-PS

The KEK-PS complex comprises two 750-keV Cockcroft-Walton pre-injectors, a 40-MeV injector linac, a 500-MeV booster synchrotron and a 12-GeV main ring. It has been operated successfully to serve a proton beam for 25 years. In order to increase the beam intensity for the need of new physics researches, especially the long-base-line neutrino-oscillation experiment (K2K) [1], an intensity upgrade studies have been performed [2]. We noticed that the magnet alignment was one of the key issues of stable and reliable acceleration. During the magnet re-alignment work in 1996 summer shut down, fast ground motion (daily) was observed and it seemed depend on the rainfall. In order to confirm this phenomenon, measurements of the floor tilt in the ring and the moisture in the soil above the tunnel have been going on [3]. We noticed that there were not only fast motion but also slow motion (monthly).

2 OBSERVED GROUND MOTION AND EVIDENCE

Re-alignment for the vertical direction of the main ring quadrupole magnets was carried out several times and corrections were done. We found the evidence of the slow ground motion in the main ring tunnel during these works and the beam orbit fluctuation. Followings are the evidence of the floor motion.

First evidence

During the re-alignment work (vertical only) performed in the summer shutdown, 1996, a significant unconformity of the magnet height occurred in the weekend [4]. During the weekend, it rained heavily.

Second evidence

Beam orbit fluctuation were recorded with the weather condition during PS operation from November 5 to 25, 1996 [5].

Third evidence

For the preparation of the K2k experiment the PS was shut down for six months in 1998. The closed orbit after the shut down was different from that before, although all of machine parameters were same as those before shutdown [3].

Fourth evidence

During the measurement and re-alignment work in the summer shutdown, 2000 [6], the benchmarks were marked on the outside wall in the tunnel prior to alignment work. The benchmarks moved significantly between the end of August and the end of September [3].

We suppose that the ground water might correlate the ground motion in the main ring tunnel. However, no anomaly was observed in the wells, which have been set to monitor the water surface level.

3 MEASUREMENT OF THE GROUND MOTION

The main ring tunnel comprises eight separated floors (named A1, A2, B1, B2, C1, C2, D1, and D2), and they are not symmetric as shown in Fig. 1. In order to watch the floor level motion, tilt meters using accelerometer are set on the borders of C2-D1 and D1-D2. One more tilt meter was later set on the D1 floor to observe the slope of D1 in August 1998, but it has been breakdown from September 2000. Figure 2 shows the deviation of these floors versus hours from the beginning of October 1997. There are several remarkable facts in this data as follows.

1) In the middle of October 1997, floor level between C2 and D1 changed rapidly (in 50 hours) by about 0.15 mm.

2) Continuous motion of the C2-D1 difference, which increased gradually up to 0.35 mm for a few months. This motion turned its direction from the middle of January 1998. This floor difference would causes closed orbit

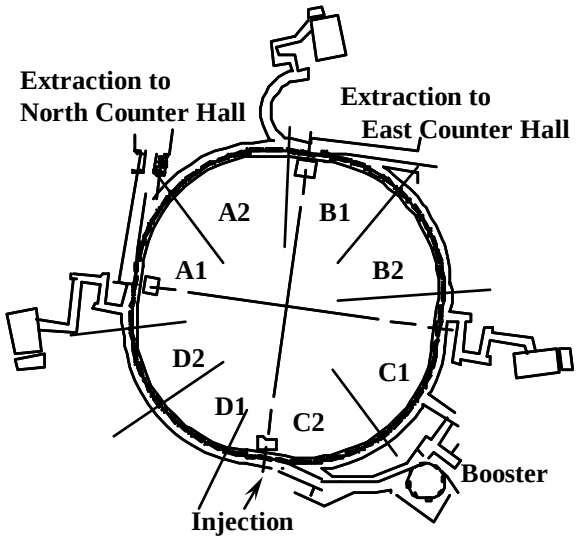

Figure 1. The main ring tunnel comprises eight separated floors.

distortion of a few millimeters (rms.). Calculation result was consistent with the measurement one [7].

3) This motion turned its direction again from the beginning of August 1998.

4) The motion like this did not appear in 1999.

5) Many seismic vibrations (spike-like motion) are observed. The level difference returned to the one before earthquake in most cases; in rare cases, however, the deviation remained after earthquake. After November 2000, seismic vibrations are cut as complexity to see the graph.

6) The variation of D1-D2 is smaller than that of C2-D1 but these correlates to each other.

The KEK-PS tunnel was based on the 0.6 - 0.8 m lower than surface level and covered by the water-rich soil. We once considered that the groundwater caused the ground motion. The velocity of infiltration downward through the soil was found to be very slow. It takes typically several days for the water levels in the aquifer to change after rainfall. A tunnel of this type receives stress from the moisture contained in the soil bank.

We mounted the following devices in the soil bank : 1) TDR probes to measure the moisture, 2) tensilemeters made by Porous Ceramics to measure the pressure, 3) detector of the resistivity in the soil, 4) a rain gauge : are mounted in the soil bank. There are two kinds of TDR, which are short and long, to measure the shallow depth to 1.2m and the deep depth to 4-5m, respectively. The devices are set in the holes A, B, C as shown in Figures 3 and 4.

Figure 3 shows the contours of moisture in the soil bank in October 1998. There was rainfall of 25mm on October 21. The data suggest that the water in the top of bank does not infiltrate to the bottom by the obstacle of the confined air above tunnel and stays for many days and continues to press the tunnel through this air. Measurement results of the resistivity in the soil are consistent with the TDR measurement [3, 7, 8].

According to this speculation, air-exhaust pipes to reduce air pressure were buried horizontally and vertically. Measurement in September 1999 shows this effect as shown in Fig.4. It was not rainy for a while, and there were rainfalls of 27.5 mm on September 21 and 12.5 mm on September 22. On September 20, the contours of moisture in the soil bank are almost same as that of October 20, 1998. Even if just after rain, moisture of soil above the tunnel was only 40% and decreased to that of before rain after only five days. No large deviation of the floor level in December 1999 can be explained by the effect of these air-exhaust pipes.

There is an another speculation, which is an effect of dig and reclamation of the Neutrino beam line construction during 1998 shut down. Plant and facility department dug the ground a several meter deep and filled up after completion. The ground water vein had been cut during the construction.

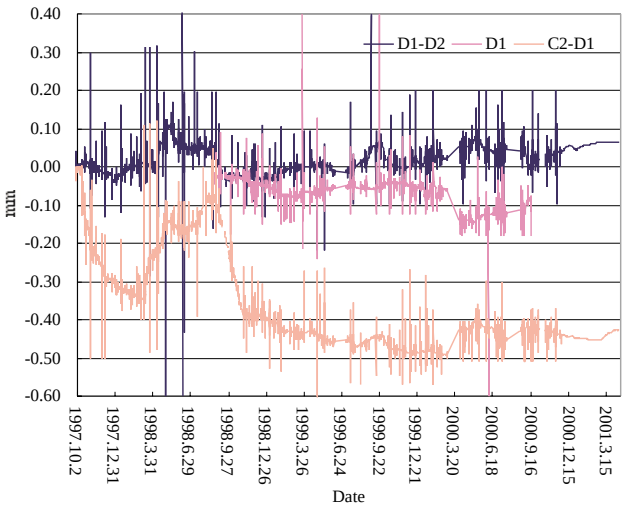

Figure 2. Motion of the borders of C2-D1, D1-D2 and D1 floor. Border of C2-D1 changed rapidly (in 50 hours) by about 0.15 mm in the middle of October 1997 and it increased gradually up to 0.35 mm for a few months. Many seismic vibrations (spike-like motion) were observed, but these are cut as complexity to see the graph after November 2000. Detailed explanation is written in the text.

4 CONCLUSION

The ground motion in the PS main ring tunnel mainly comes from the water in the ground. In the case of tunnels constructed in the soil bank, moisture in the soil bank plays an important role. It seems to move the floor plates in one or two days after rainfall. Continuous measurement is essential to confirm the long-range displacement and its correlation to the rainfall and underground water. Anyway, an observation of the motion in a few days with the range

of about 0.15 mm by tilt meters. This fact suggests that the motion of the order of 1 mm could occur rapidly.

The automatic or quick curing tool is necessary to correct the COD and/or frequent measurement and re-alignment of the ring magnets. These subjects should be deeply considered in a future accelerator to be constructed.

5 REFERENCES

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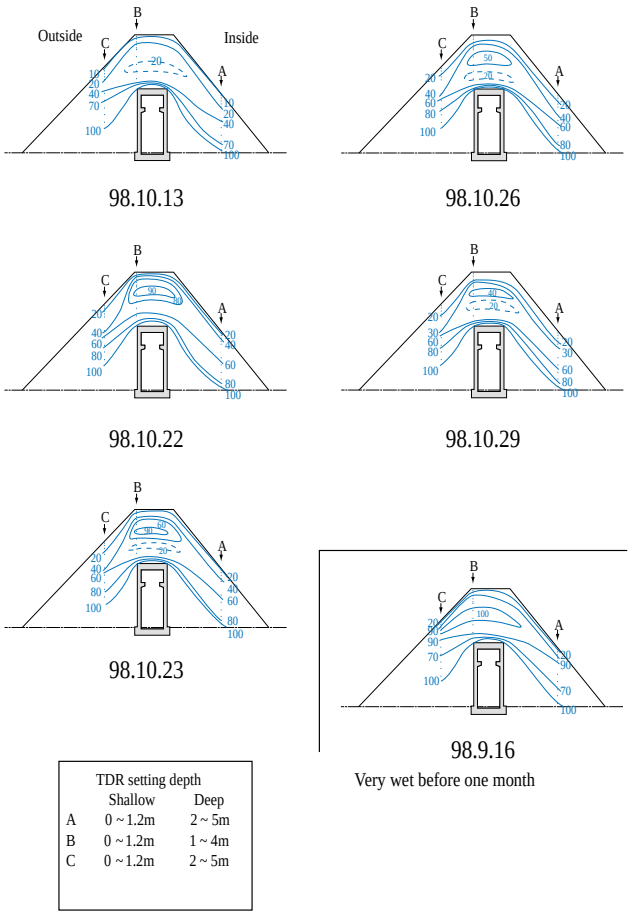

Figure 3: Contours of moisture in the soil bank in October 1998. It was rain of 25mm on October 21. These suggest that the water in the top of bank does not infiltrate to the bottom by the obstacle of the confined air above tunnel.

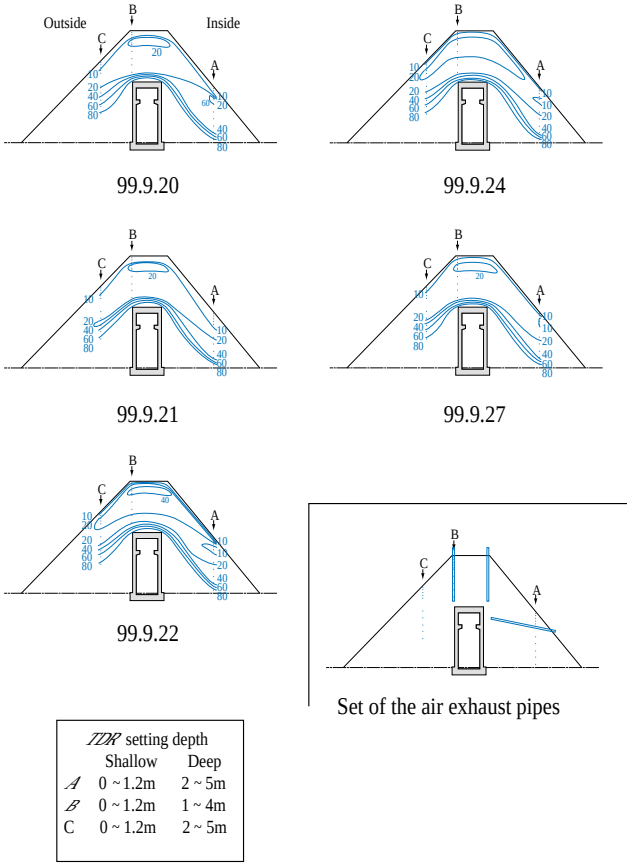

Figure 4: Contours of moisture in the soil bank in September 1999. It was rain of 27.5mm and 12.5mm for September 21 and 22. Just after rain, moisture of soil above the tunnel was only 40% and decreased to that of before rain after only five days.