DESIGN OF XFEL FACILITY IN HARIMA

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Abstract

The 700m-long 8-GeV XFEL launched by RIKEN is now under construction in Japan and will be operational in FY 2010. A especial feature of the XFEL is compactness while keeping high performance. It was accomplished by applying numerous breakthroughs in accelerator-driven light sources technology developed for SPring-8. In order to support the high-performance of XFEL, the building was designed with particular technological ideas. In this paper we introduce the design of the building foundation and ground improvement aimed to control the transformation of the floor to which the devices are fixed, and the design of air-conditioning for improved control of temperature change around the devices.

INTRODUCTION

In Japan, epoch-making accelerator facilities such as J-PARC, XFEL, Spring-8 and GHMC (small heavy ion cancer therapy center in Gunma-prefecture) have been constructed. R&D and design of ILC have been pushed forward by industry-university cooperation. On the other hand, as an accelerator has become large, its performance has become inseparable from the design and construction technology of the tunnel where it is installed. This report introduces key points of the accelerator tunnel design for XFEL, especially the building foundation and ground improvement design aimed to control a transformation of the floor to which the devices are fixed, and the design of air-conditioning for improved control of temperature change around the devices.

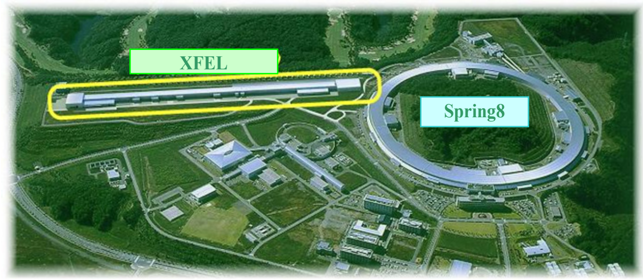

Figure1: Bird's eye view of XFEL in Harima[1]

TUNNEL STRUCTURE

For designing of the accelerator and undulator tunnel, enough attention should be paid to the following points. The first point is to control a transformation of the tunnel within a limit value to secure a performance of the accelerator. The second point is to prevent a cracking of tunnel concrete as much as possible not to affect a radiation protection. The subsoil of the site for XFEL is a rock bed of semi-hard rock and weathering sedimentary rock. The rock bed is covered with the fill stacked by the land development work as shown in Fig.2. The semi-hard rock is igneous rock which was created in Mesozoic from Jurassic to Cretaceous. Weathering sedimentary rock was created in Cenozoic Tertiary and has different properties between upper part and lower part.

The fill has about 50m

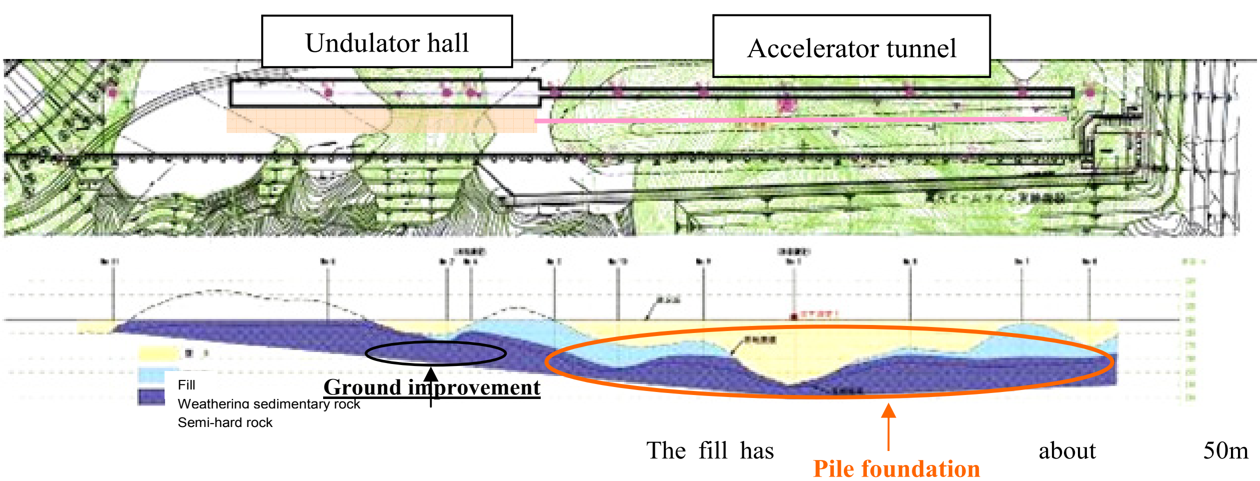

Figure2: Subsoil of XFEL site

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thickness at the middle part of the accelerator tunnel. We performed a loading test to measure a ground surface settlement using a concrete block of 5m x 5m x 6.5m at that point, As a result the settlement was over 60mm after 45 days from the beginning of loading. Also it was confirmed that the settlement continued during the rainfall. It was obvious from the result of the test that the spread foundation can not be adopted for the subsoil of the fill. Therefore, we adopted ground improvement foundation for the undulator tunnel area where a depth of the fill was short and a pile foundation for the accelerator tunnel area where a depth of the fill was long.

Planning of tunnel structure

A shrinkage of concrete in very long tunnel structure is forecast for the following factors.

1. Drying shrinkage
2. Shrinkage due to hardening and temperature change

These shrinkages cause cracks and tensile stress in the tunnel concrete instantly. As time passes, the tunnel become deformed by the earthquake and so on. We were afraid that a stability of the floor slab is influenced by a deformation in upper slab and wall of the tunnel. In order to prevent such problem, we provided the expansion joints appropriately at important points as shown in Fig.3.

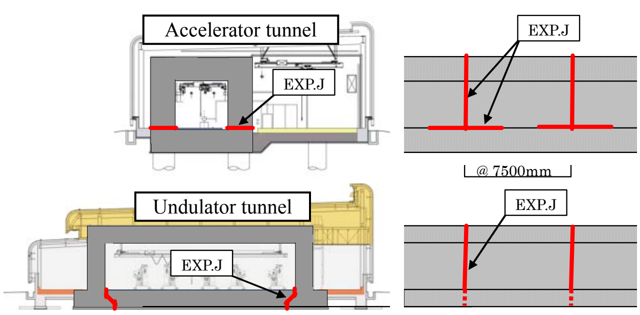

Figure3: Structural planning of tunnels

Planning of ground improvement

The ground improvement was performed by the replacement of the fill with mechanically stabilized crushed stones and compaction. Compaction was specified to be performed to a degree that a gravity reaches to 95% of the maximum gravity obtained in a laboratory test. Generally, strengthening material for ground improvement such as cement is added to the replaced material to construct improved ground. But the strengthening material is also a cause for long-term deformation of the ground due to drying shrinkage and creep. The effect of strengthening material was investigated to verify the characteristics of the deformation using the centrifuge experimental facility as shown in Fig.4 of the Research & Development Institute of TAKENAKA Corporation. In this test, a centrifugal force of 100G was loaded to 1/100 scale model of the fill which is 16m depth in actual size. A settlement of the scale model was measured in two cases, one with 2.5% of cement and another without it. The loading tests were performed four times. For twice of them the scale model was watered to investigate an effect of the groundwater.

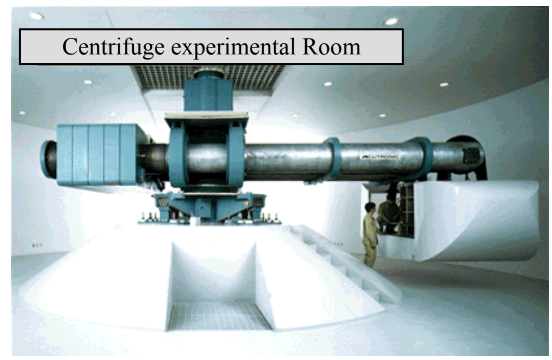

Figure4: Centrifuge experimental machine

A result of the tests is shown in Fig.5. In the case with cement additive, ground settlement at the first loading was one third of that of the case without cement additive. But at the loading test made two days later, a settlement of the model without cement additive was smaller than that with the cement. Also we found out that improved ground without cement additive tend to be affected by a groundwater. Because of the findings stated above, we used cement additive for the area around ravine which has comparatively rich groundwater and did not use it for other areas.

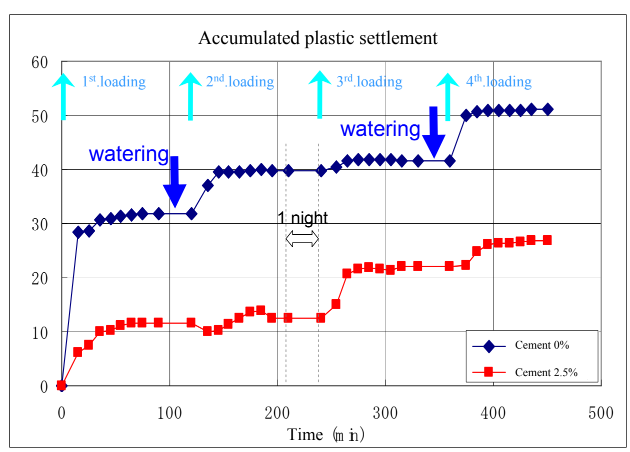

Figure5: A result of Centrifuge loading test

AIR-CONDITIONING IN TUNNEL

A high-performance air-conditioning is indispensable for stable operation and high performance of the machine, namely permanently steady oscillation of free electron laser, prevention of a transformation of the accelerator and undulator tunnel. Furthermore the air current fluctuation and the temperature change around the klystron gallery should be as small as possible by the air-conditioning of high precision.

Air conditioning of accelerator tunnel

A temperature in the attic of the accelerator tunnel must be maintained uniformly at 25°C throughout a year to prevent a deformation of the concrete by using fan-coil air-conditioning units as shown in Fig.6.

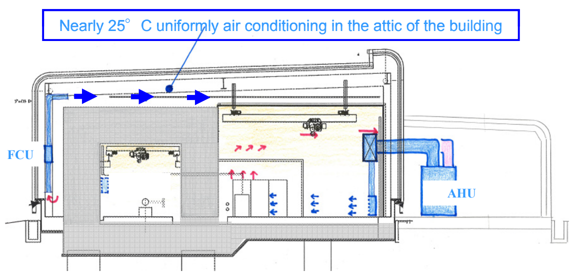

Figure6: Air conditioning system in the building

Air conditioning of klystron gallery

We have chosen the displacement air-conditioning system which was considered to be able to control the temperature stably for the purpose to minimise the air current fluctuation and the temperature change around the klystron gallery. The displacement air-conditioning system means a method of blowing air current of slow velocity (=0.5m/sec) from many diffuser outlets which are placed on the wall near the floor. Compared with ordinary air-conditioning which stirs the air of the whole room as shown in Fig.7, this system generates one-way air current from air outlets to inlets by cleverly using an ascending air current generated by a heat of the klystrons.

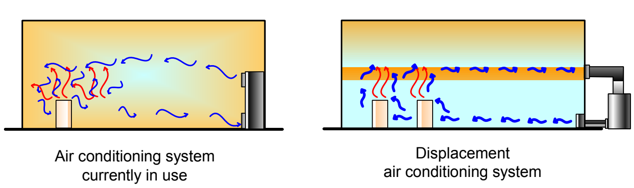

Figure7: Air conditioning currently in use system and displacement system

A distribution of temperature around the klystron was analyzed by using Flow Modeling Software FLUENT[2]. The result which is shown in Fig.8 suggests that the displacement air-conditioning system is very effective because it accomplishes uniform temperature distribution at every point in the cross section of the klystron gallery.

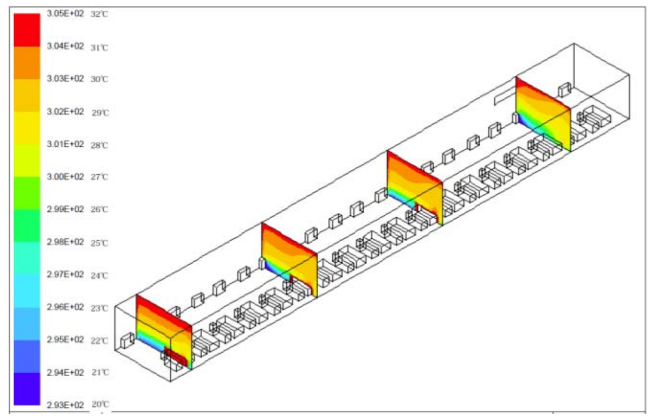

Figure8: Temperature distribution around klystron analyzed by using Flow Modeling Software FLUENT

SUMMARY

There are important key points for designing of the XFEL building. The goal is prevention of a transformation of the accelerator and undulator tunnels. We adopted several technical skills to achieve the goal. A selection of the right type of foundation in the right place of the XFEL tunnels was essential.. Also a provision of the expansion joints appropriately placed at important points in the tunnel structure was considered. Air-conditioning systems for the tunnel is also indispensable to achieve the goal. The displacement system is adopted as the very effective system to control the temperature stably for the klystron gallery.

ACKNOWLEDGMENT

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REFERENCES

[1] http://www.riken.jp/XFEL/
[2] http://ansys.jp/products/fluent/