Basic Alignment System for SCSS

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ABSTRACT

We have studied geological characteristics and ground motions at the SCSS site in detail. SCSS (the SPring-8 Compact SASE Source) is a high peak-brilliance, soft X-ray free electron laser project [1]. We have also developed a very stable supporting stand which is made by high strength concrete, a very precise mover system based on a simple roller-cam and newly developed water level sensor based on a capacitance measurement. Standing on these fundamental developments, we are now preparing the basic initial alignment system for SCSS. We will report a present status of the system including an auxiliary pillar and a pulley system for WPS made out of super invar.

1. INTRODUCTION

SCSS is a linac-based machine for Self-Amplified Spontaneous Emission (SASE) Free-Electron Laser (FEL). It is used a high-gradient C-band (5712-MHz) main linac to generate a beam with energy up to 1-GeV followed by an in-vacuum short-period undulator. The first light will be expected, in the VUV region, in 2005; the next target is for 3.6-nm radiation in the water-window. The main linac will use high gradient acceleration to achieve a total active machine length of 40-m. Thus, we will use high gradient acceleration of more than 35-MV/m on a beam charge of 1-nC per bunch. The normalized beam emittance at the end of linac has to be kept to only 2-πmm∑mrad, this is two-orders of magnitude lower than the emittance from the usual electron linacs such as the injectors for KEKB and SPring-8. The C-band scheme was proposed by T. Shintake in 1992 for the e^+e^- linear collider project in Japan (JLC) [2]. JLC should have an extremely small emittance (an invariant emittance of 30 nm) to secure the required luminosity; thus precise alignment of machine components is essential to prevent emittance dilution. In the case of the C-band (5712 MHz) main linac, the tolerance translates to 50 μm for the maximum bow of a 1.8 m long accelerating structure. The components of each beam line have to be aligned with high accuracy. The standard deviation of any point over a range of the maximum betatron wavelength in the vertical direction should be better than 30 μm. To realize those requirements, the main linac will be built over the very stable granite bedrock. A precise alignment system for the accelerator is essential for the preservation of stable alignment. A severe precision is required but the method must be simple.

2. GROUND MOTION

Many studies on the ground motion were made for several accelerator. Any alignment errors cause an orbit distortion and which lead to reduction of the dynamic aperture of the machine. An extreme situation is emittance growth of the accelerating beam. Slow ground motion which frequency components are less than characteristic frequencies of the accelerator has been usually considered as not having serious effect on the machine operation, assuming complete space and time coherence of the ground motion. This assumption, however, not exactly works out for the weak geological structure as shown by relatively large *A* value of the *ATL* model [3]. The ground motion caused by daily or seasonal variation of the ground temperature, groundwater level variation, atmospheric pressure variation and earth tides have a large correlation length. The residual part of these variations, however, becomes inelastic component of the ground motion and looses the correlation since the source of the motion is removed. The ground motion spectrum excluded characteristic spectra is empirically given as,

$$P(f) = \frac{K}{f^2(f_0^2 + f^2)},$$

where $P(f)$ is a power spectrum in m^2/Hz, K is constant and f is frequency in Hz [4]. A constant f_0 depends on geological structure and changes from 0.1 Hz to 0.01 Hz. In the frequency range $f< f_0$, the measured power spectrum of the ground motion can be characterized by k/f^2. This coefficient k is a site dependent parameter and changes from 1 to 10^4 $\mu m^2 Hz$. At high frequency $f>0.1$ Hz, the power spectrum becomes very complex and is superimposed with the noises of various sources as following:

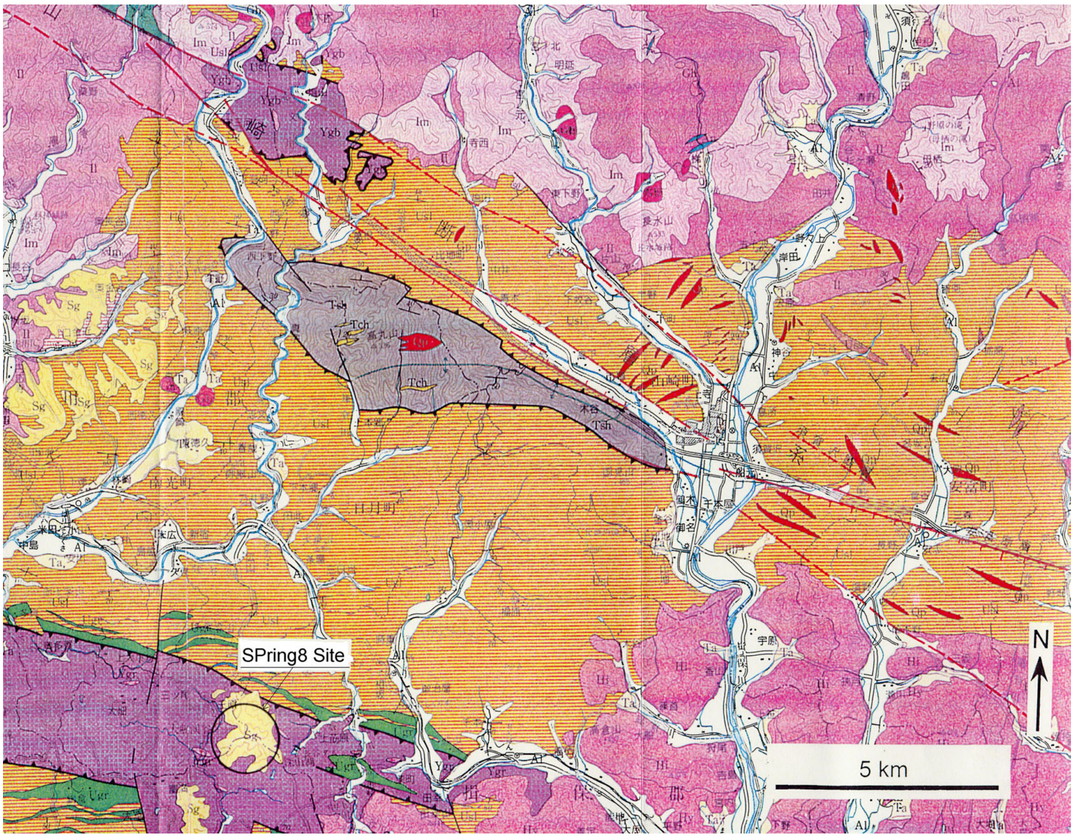

Figure 1: Wide area geological map around Spring8. The site of Spring8 (circled in black) is in the granite region.

(1) Artificial noises (cooling water system, air conditioner, power supply, traffic noises, public work etc.), (2) Ocean swell around 0.2 Hz, (3) Crustal resonance around 3 Hz and (4) Earthquake. The wavelength of these vibrations, except ocean swell, is as short as 200 m or less [5]. It is comparable to the betatron wavelength of the accelerator.

2.1 Geological Survey at SPring8

We made a geological survey for SCSS, since there is no detailed information except the data around the storage ring. Fig. 1 shows a wide area geological map around Spring8. It shows that this area is composed by several hard rocks and includes several fault lines. Then we have made a geological survey of the related area for SCSS. The methods of our survey are boring and the seismic reflection survey.

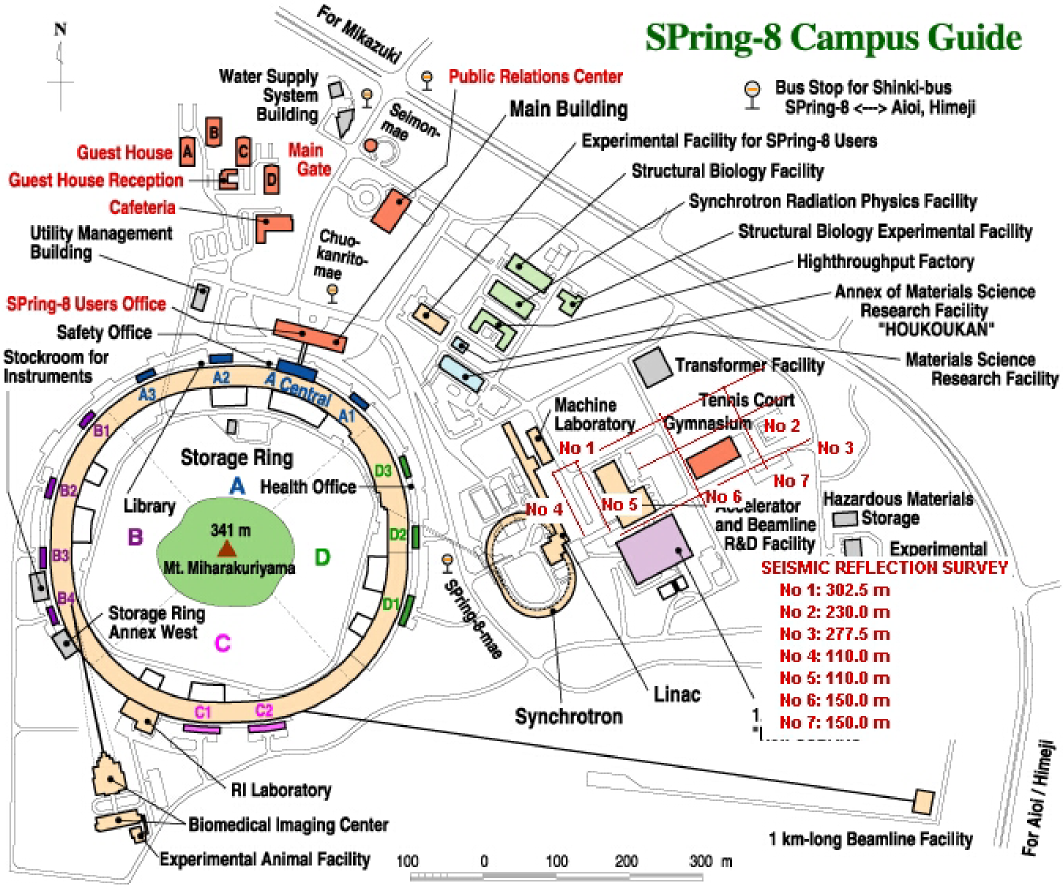

Figure 2: Spring8 campus and the area of seismic reflection survey.

Fig 2 shows the surveyed area (rectangular area by red numbering) includes the R&D Facility Building [RDFB]. Analyzed results using boring data and seismic reflection surveys are shown in Fig. 3. The figures show seismic velocities using several colors as shown in the figures. The horizontal axes correspond to the distances from west to east or from south to north for each observation line. The vertical axes show altitudes. We can find that the southwest region of the related site shows good geological feature for an accurate accelerator construction using the figures.

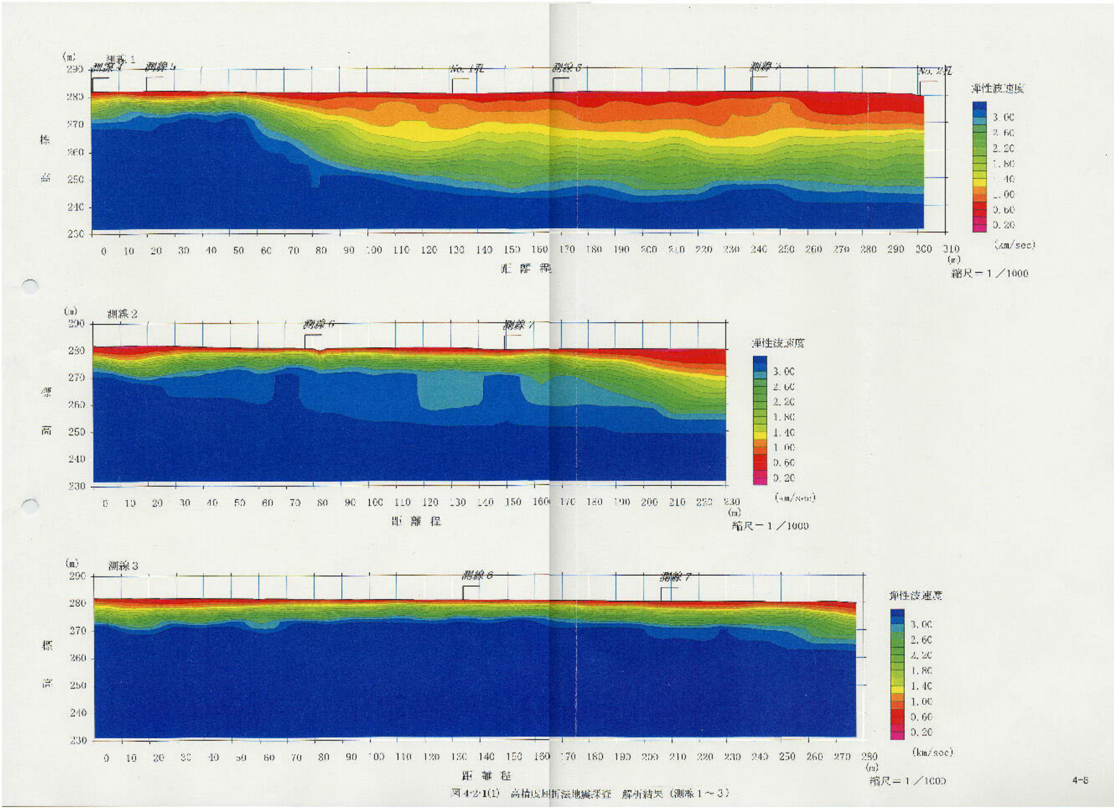

Figure 3-a: Seismic velocities shown by numerical order of the lines (No 1 to No 3).

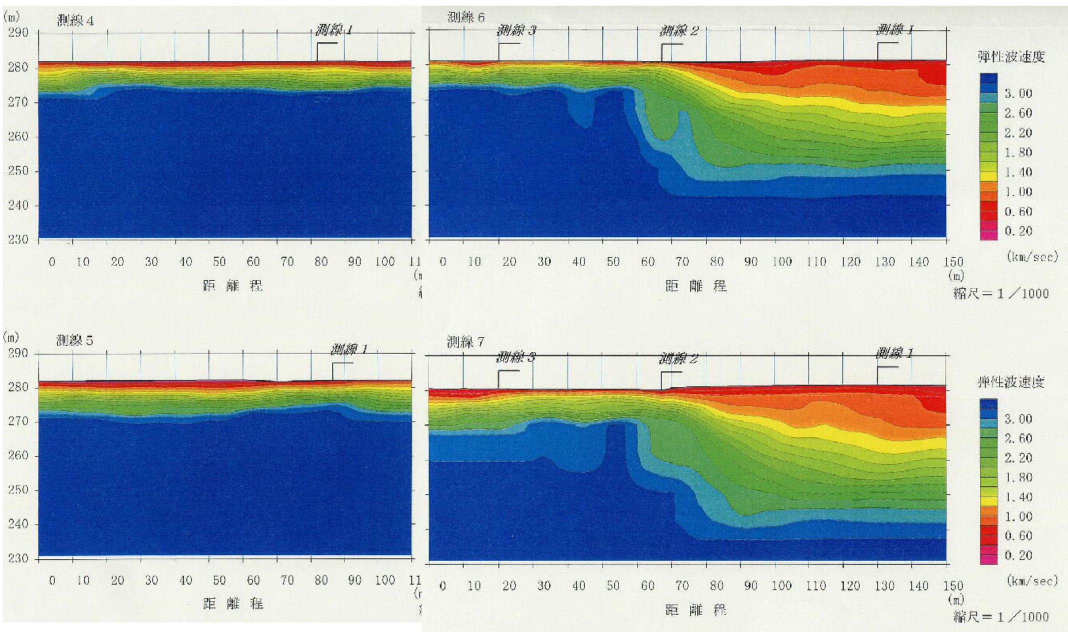

Figure 3-b: Seismic velocities shown by numerical order of the lines (No 4 to No 7).

Figure 3: Seismic velocities observed along the lines of Fig. 2 (No 1 to No 7).

2.2 Ground Motion at SPring8

We have made a study of long term drifts of the ground surface using bidirectional tilt-meters and the seismic noise level using 3D wideband seismometers.

2.2.1 *Long Term Drifts*

Long term drifts of the surface are observed on the ground floor of RDFB. This building is in the area of above mentioned seismic reflection survey. We observed the tilts using three geodetic platform tiltmeters (Model 520 of Applied Geomechanics Inc.). One of the tiltmeters (No 3 in Fig. 4) is set on the floor and at a distance of 5 meters from the eastern and southern end walls of the building. The second tiltmeter (No 2) and the third (No 1) are arranged from east to west at intervals of 10 meters. Typical experimental results are shown in Fig. 4.

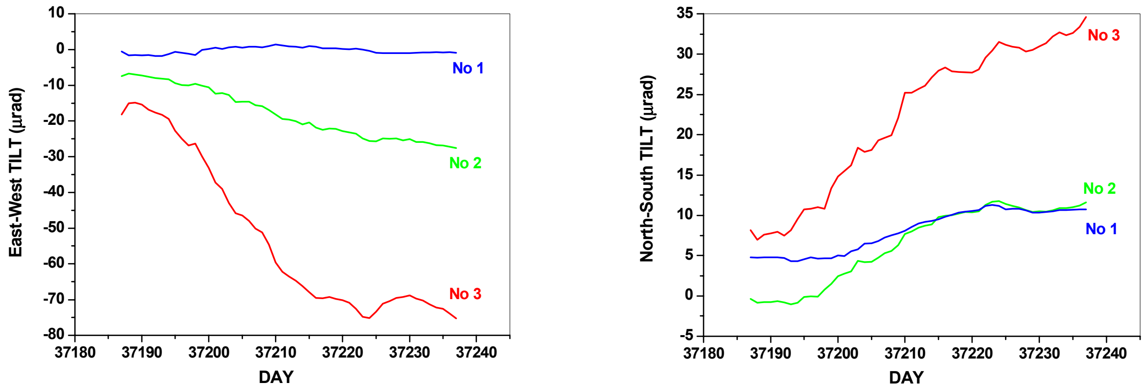

Figure 4: Long-term changes of the tilts and their setting position dependence.

We can find that the end sides of the building floor are tilting larger than the insides. These phenomena indicate the boundary region between the ground and the building being sensitive for the ground motion caused by the sunshine. The seasonal change of the underground water is also a factor of the long-term drift. A small daily fluctuation of the tilts may correspond to the distortion of the building by the sunshine.

2.2.2 *Seismic Noise Levels*

Seismic noise levels of the surface were also observed on the ground floor of RDFB. We observed the noise levels using three STS-2ís precise wideband seismometers (Streckheisen Inc.). One of the seismometers was set on the floor and at a distance of 5 meters from the eastern and southern end walls of the building. The second seismometer and the third were arranged from east to west at intervals of 10 meters (P1 corresponding to the east end and P3 to west end in Fig. 5). After this experiment, we set the one seismometer at P3 and the second and the third were arranged from east to west at intervals of 10 meters (P3, P4 and P5 in Fig. 5). Typical experimental results are shown in Fig. 5. Integrated spectra for vertical direction for all positions show same amplitudes on the whole. The sudden growth of the amplitude near the 30 Hz and 60 Hz is caused by operation of the nearby accelerator being in the southern building of RDFB. Although the effects of artificial noises are observed, especially in the north-south direction, the small amplitude of the seismic noise in the site of Spring8 is widely different from the requirement of SCSS.

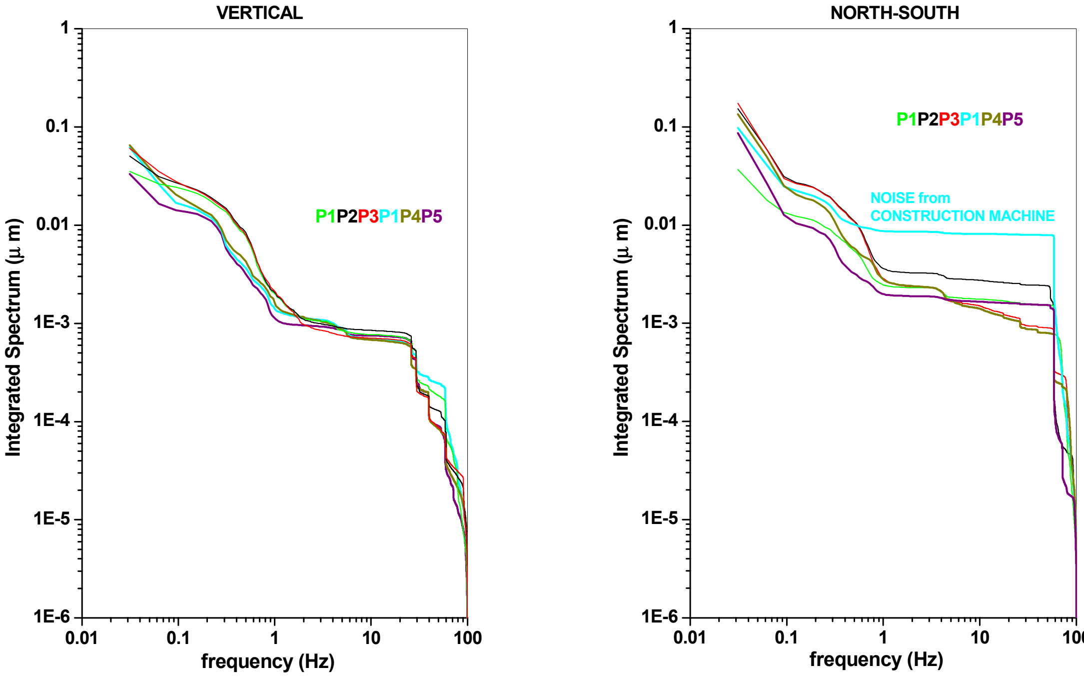

Figure 5: Integrated seismic noise amplitudes in the site of Spring8.

2.3 Long Term Drift and New Hydrostatic Leveling System

We have developed a new hydrostatic leveling system in order to study of long-term ground motions and apply to the initial alignment of the SCSS. Our requirements for the water level sensor are the followings: (1) insensitive to the temperature change, (2) low noise data acquisition system for long distance. A design of the sensor was made to fulfill the item No 1 using the method of the half filled water level and applying invar to the support of the capacitive sensor. A schematic description of the sensor is shown in Fig. 6. The sensor was produced by a German company (Micro-Epsilon Co. Ltd.). CAN-BUS was adopted for the signal transmission line instead of the usual analog signal transmission in order to fulfill the item No 2. Fig. 7 shows observed result of the present sensor (CLS-2-CAN) comparing with HLS.

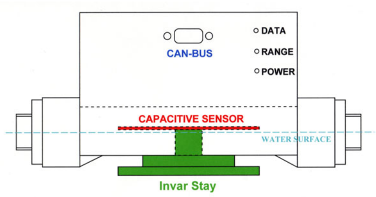

Figure 6: Schematic description of the new level sensor.

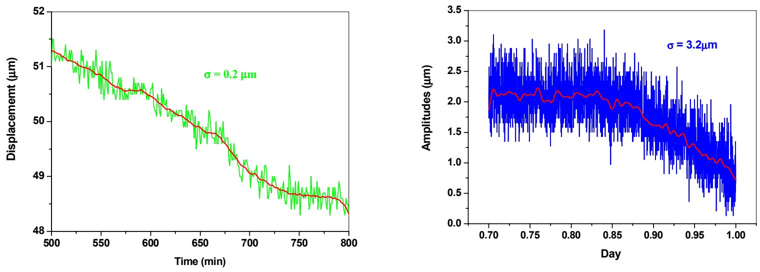

Figure 7: Comparison of the noise level between CLS-2-CAN and HLS.

The rms noise level of HLS is 15 times as high as the level of CLS-2-CAN. We are now doing a long-term test of the sensor to confirm the specification.

3. SUPPORTING METHOD

In the next generation e^+e^- linear collider, the components of each beam line have to be aligned with high accuracy. The standard deviation of any point over a range of the maximum betatron wavelength in the vertical direction should be better than 30 µm. To realize those requirements, the main linac will be built over a very stable granite bedrock. A precise alignment system for the accelerating structure and the Q-magnets has to provide an accuracy within ±50 µm and ±1 µm respectively, and yet the method must be simple. We have to consider three very important factors as following:

- The supporting stands never resonate to the vibration of the floor surface wave;
- Low thermal expansion coefficient is essential in order to provide a precise and stable support system for the long term,
- The structure is simple and gives small distortion and strain.

3.1 Steal Box or Steal Pipe

The steel box type or cylindrical pipe supporting stands are widely using for accelerators, because the structure allows great flexibility and is available at reasonable cost. However, they have no massive structure and their stiffness is not so high. Thus, from the vibration point of view, the stand becomes the weakest linkage on the dynamic accuracy of the accelerator alignment. Then we exclude these type stands or girders as a candidate of the support for the accelerator component of the linear collider.

3.2 Cylindrical Concrete Girder

At first, we have studied a cylindrical reinforced concrete girder for the e+e- linear collider. The length of each accelerating structure is 1.8 m and 4 structures are pre-aligned on a girder. The girder was designed to meet the following demands: (1) Simple structure, (2) High reliability, (3) Easy to control, (4) Lower production cost and (5) High stiffness. However, the girder becomes too heavy in order to get small creeping characteristics and big movers are needed. Detailed studies about the adaptation of the girder for the linear collider have been done by ourselves [6]. As a result of our study, we can say that the girder method is not good solution on the installation to the long and narrow tunnel and not sophisticated by the modern control system.

3.3 Concrete Base Table

It is well known that a natural granite standard table is very stable, because of its massive structure as well as high compressive strength. Thus, it has much better qualities for damping vibrations than a steel stand does. Furthermore, graniteís thermal expansion coefficient is on the order of 10^{-6} [/∝C], that is almost same as sintered aluminum ceramic. However, it is not easy to make the various shapes that are required for different accelerator components. Thus, we decided to develop a new concrete, which can be fabricated easily and yet otherwise perform like a natural granite table [7]. In general, various conventional concretes have good characteristics that can provide a low thermal expansion coefficient structure. However, it is well known that they can suffer from slow volume shrink, slow shape creep and hairline cracking. Thus, we decided to develop the production method of the concrete and to test the performance of the newly developed accelerator stands [7]. Two new supporting stands were made to test the mover using full size accelerating structure and installed on the floor of RDFB. Shrinkage process of the stand will be observed using WPS and super invar supporting pillar for the pulley system as shown in Fig. 8. The pulley is also made by super invar. Then, the measuring system is very insensitive to the ambient temperature change. After this study we will make a test of the roller cam type mover system using a model accelerating tube being same size and same weight as a real accelerating tube. We have made a test of the mover using a light dummy weight [7]. Then the next mission is long term test, check of reproducibility, pulse operation under the real size structure.

Figure 8: Initial setup to test the performance of the concrete stands. WPS is applied to observation of the concrete shrinkage.

4. SUMMARY

From above mentioned many experimental results we confirmed that the site of the Spring8 has no critical problem for the construction of SCSS. The application of the concrete supporting stands and the roller cam mover to SCSS will be expecting a suitable and accurate alignment system. Many application of the present water level sensor will also be expected.

5. REFERENCES

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