STABLE SUPPORT STANDS FOR ACCELERATORS*

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Abstract

We have developed a very stable support stand using high strength and durable concrete. At 13 weeks age, a compressive strength achieved 166MPa, which is 4 times higher than that of conventional concrete. And a drying shrinkage is only 147×10^{-6} at 26 weeks age. Further, we measured long-term alignment of a pair of support stands in laboratory, and then we found their alignment was very accurate. From this result, we confirmed that this new high strength concrete could replace natural granite tables for precise support stands of the 500-GeV (C.M.) e+e- linear collider[LC:1] and also those of new accelerators such as the injector linac for the FEL[2].

INTRODUCTION

Components of each beam line have to be aligned with high accuracy to prevent emittance dilution in the case of the LC. Usually, steel box type support stand, which allows flexibility and is reasonable cost, is used for accelerators. However, the steel box type support has problems such as low stiffness for vibration and high thermal expansion coefficient. Thus, we developed new high strength concrete, accurate adjusting system, and high strength mortar, which contribute alignment stability.

In this paper, we will discuss the physical properties of high strength concrete and high strength grout. Then, we will discuss the result of long-term stability test, and vibration transmissibility, which were carried out in our laboratory.

CONCEPT OF NEW SUPPORT STAND

Components

Layout of accelerators and stable support stands, and cross section of stable support stand is shown in Fig. 1. Support stand is made from high strength concrete, which is glued with high strength cement mortar onto the concrete slab or granite base. The roller cam type mover system is set on the top of support stand where grinded and polished with high accuracy. The distance of every two support stands were kept 1,080mm to support an accelerating structure.

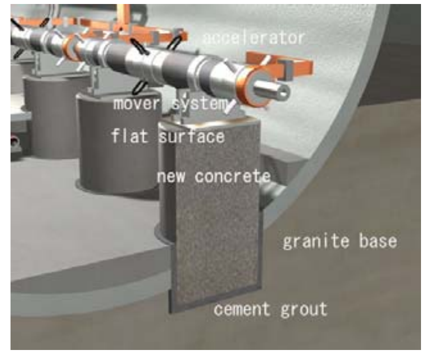

Figure 1: Layout of accelerators and stable support stands, and the cross section of stable support stand.

Alignment Control

Generally, concrete has good characteristics that can provide high stiffness and a low thermal expansion coefficient. However, conventional concrete shrinks by drying as its age, and cracks without reinforcing bars. Thus, we tried to increase the strength of concrete, and also decrease the drying shrinkage. Reducing water to cement ratio, and using high durable chemical agent, we success to achieve a new concrete for stable support stand.

In order to settle the support stand onto the concrete base, we developed a new alignment jig, which allows adjusting in three-dimension independently. Alignment control has to be done by using this alignment jig to satisfy the required alignment accuracy shown in Table 1. Alignment of the support stand was adjusted by the direction shown in Fig. 2.

Table 1: Required accuracy of alignment.

Factors	Required Accuracy
Flatness of top	±0.02mm
Height	±0.5mm
Inclination	±0.1mm/300mm
Horizontal Displacement-X	±0.5mm
Horizontal Displacement-Y	±2mm

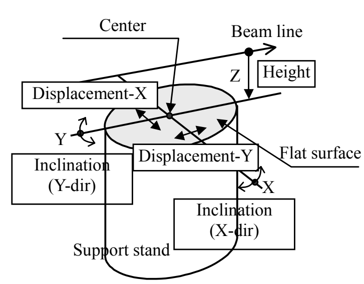

Figure 2: Alignment control direction of support stand.

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PHYSICAL PROPERTIES OF NEW CONCRETE

Compressive Strength and Drying Shrinkage

To compare the compressive strength of newly developed high strength concrete and conventional concrete, we made cylinder specimens 100mm in diameter, and 200mm tall based on Japan Industrial Standards (JIS). Compressive strength of new concrete and conventional concrete is shown in Fig. 3. At 13 weeks age, the strength of new concrete achieved 166[N/mm^2], which is 4.4 times higher than that of conventional concrete, note that it is also higher than natural granite block.

To compare the drying shrinkage of new concrete and conventional concrete, we made specimens sized 100×100×400mm. Also, we made full size support stands to investigate the drying characteristics in the laboratory. Each specimen had two reference points spaced 300mm apart on the surface and located parallel to the central axis. As test results shown in Fig. 4, drying shrinkage increases as a function of testing age. At 26 weeks drying age, the shrinkage of new concrete specimen achieved 294×10^{-6}, which is about 40% of conventional concrete, note that full size support stand still smaller than the new concrete specimen, because full size support stand has less surface to its volume than the specimen does.

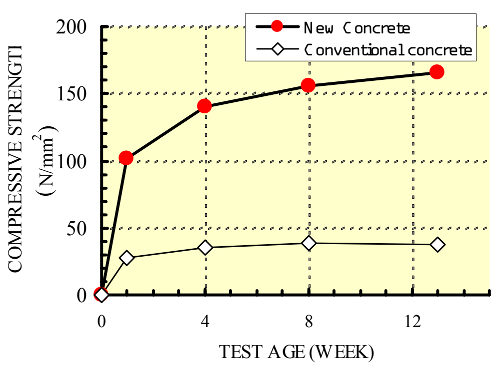


Figure 3: Test result of compressive strength.

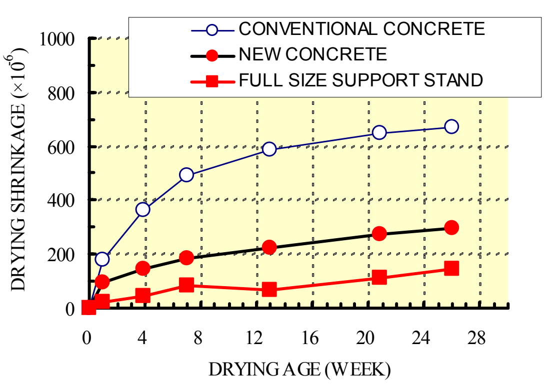


Figure 4: Test result of the relationship between drying shrinkage and drying age.

Thermal Expansion Coefficient

To estimate the thermal expansion coefficient of new concrete, core specimens 100mm in diameter, and 450mm length were taken from full size support stand. Each specimen had two reference points spaced 300mm apart on the surface, and covered with epoxy paint to prevent drying. In Fig. 5, the relationship between the strain of core specimen and the temperature inside of core specimen is shown. As strain increases linearly as a function of temperature, thermal expansion coefficient can be calculated 1.2×10^{-5}[/°C] by least square method, which is slightly bigger than the order of 10^{-6} [/°C] that of sintered aluminium ceramic.

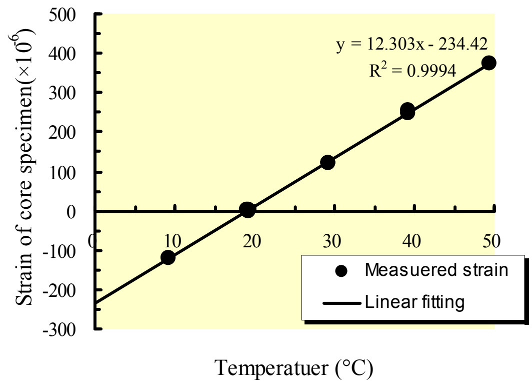


Figure 5: Relation measured core strain and temperature.

STABILITY OF SUPPORT STANDS

Long Term Stability Measurement

After adjusting the alignment as shown in Fig. 6, support stands were glued onto the concrete slab by grouting with high strength cement mortar. And we started alignment stability measurement. Optical instruments were used to measure the level and displacement-X. Inclination was measured by two digital inclination gauge at right angle each other.

Figure 6: Adjusting alignment of support stand

As the changing of height for over 400days is shown in Fig. 7, change of the height was within 0.3mm. And the inclination was within 0.15mm/m. Alignment was very accurate, while the laboratory was no-air-conditioned.

These results show high stability of the stable support stand made of new concrete.

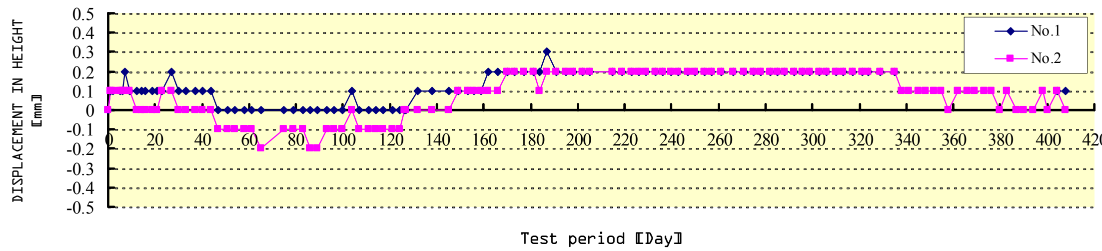


Figure 7: Test result of the alignment measurement for over 400days.

Transmissibility Measurement

Typical conventional support stand, which is put granite stone table as shown in Fig. 8. Two accelerometers are located on the slab and the table to measure transmissibility of the support stands. The input force is applied by hitting impulse hummer which load cell is implemented in. Fig. 9 shows the transmissibility of acceleration from the floor to the upper surface of the support stands. Horizontal vibration around 15 Hz and vertical vibration around 50 Hz are emphasized due to natural vibration mode of the conventional support stand. On the contrary, no resonance phenomenon is measured at new support stand.

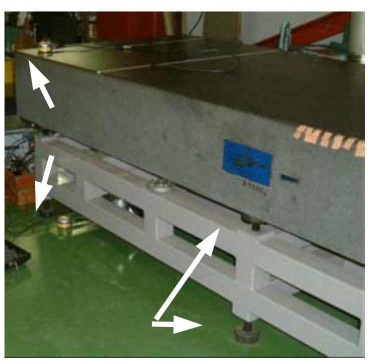
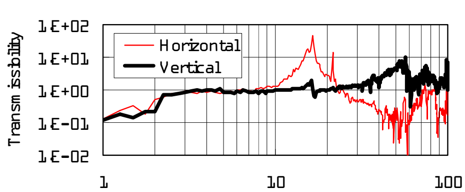
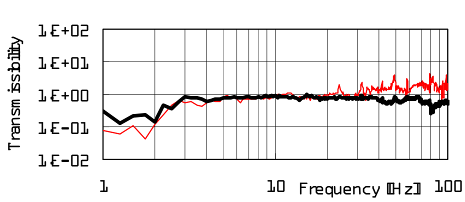


Figure 8: Typical conventional support.



(a) Conventional steel support stand



(b) Stable support stand

Figure 9: Measured transmissibility of acceleration.

The pseudo static stiffness of the support tables are estimated by the measured accelerance (or inertance), which is given by the transfer function of an input force to an acceleration response of the table. As the pseudo static stiffness can be seen in Fig. 10, stiffness of new support stand is much higher than the convention, while stiffness of the conventional support is less than $2.0*10^7$ N/m. Vertical stiffness of the new support stand shows to be higher than $1*10^8$ N/m which is the stiffness of the concrete slab where support stand is installed.

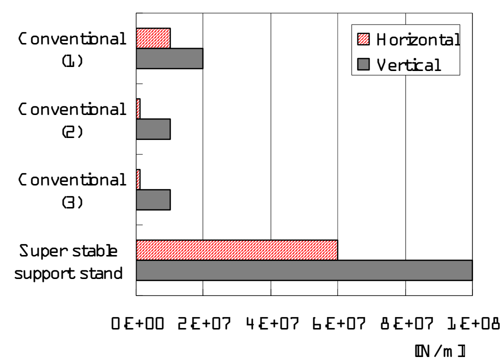


Figure 10: Measured pseudo static stiffness of the support stands.

SUMMARY

New concrete shows high performance in compressive strength at 166[N/mm^2], and drying shrinkage at only 294×10^{-6}. Using this new concrete support stand, the alignment is accurate and stable for long period, and stiffness for vibration is very high. These results show good applicability for e+e- linear collider and new accelerators.

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[2] T. Shintake, “SPring-8 Compact SASE Source (SCSS)”, The International Symposium on Optical Science and Technology, 29 July–3 August 2001, San Diego, California, USA