THE PRECISE ACTIVE ALIGNMENT SUPPORT SYSTEM FOR ACCELERATOR STRUCTURES

H. Matsumoto, Shigeru. Takeda, N. Sato, KEK, Tsukuba, Japan
T. Shintake, H. Kitamura, RIKEN, Harima, Japan
A. Suzuki, H. Yoshioka, TAKENAKA Co., Tokyo, Japan
M. Ohtsuka, N. Yoshimura, OHTSUKA Co., Tsukuba, Japan

Abstract

We have developed a very stable support stand using high strength concrete, and a very precise mover system based on a simple roller cam. At 13 weeks, the high strength concrete has a compressive strength (166 N/mm^2), which is 4.4 times higher than that of conventional concrete. The mover has shown ±0.1 µm absolute position repeatability over a ±1.0 mm region. We have confirmed that the combination should satisfy the requirements of the 500-GeV (C.M.) e^+e^- linear collider [1] and also those of new accelerators such as the injector linac for the FEL [2].

1 INTRODUCTION

The Japan Linear Collider (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 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 a very stable granite bedrock. A precise alignment system for the accelerator and the Q-magnets has to provide an accuracy within ±50 µm and ±1 µm respectively, and yet the method must be simple.

Two very important considerations for the support stand that are that it be vibration proof and have a low thermal expansion coefficient in order to provide a precise and stable support system for the long term. In fact, most accelerator components such as the rf structures and Q-magnets have their own major vibration sources (generated by cooling water flows, etc.). Other major sources are environmental noises from automobile traffic and so forth.

The usual steel box type support stand is widely using for accelerators, because the structure allows great flexibility and is available at reasonable cost. However, there is no massive structure and the stiffness is not high. Thus, from the vibrational stiffness point of view, the stand is the weakest link in providing for accurate alignment of the accelerator components. 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, granite's thermal expansion coefficient is on the order of 10^{-6} [/°C], that is almost same as sintered aluminum ceramic, and the large heat mass of granite tables dampens changes due to variations in the ambient temperature. 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.

We will use a roller cam type precise position mover system for the rf structures and the Q-magnets, since the design concept for the system is simple and sufficiently reliable to deploy on a large scale to do remote control positioning of several thousands of rf structures and Q-magnets [3, 4]. The roller cam differs from the conventional position movers such as the push-push screw adjuster, the wedge jack adjuster or kinematic suspension using multi-spherical joints.

In this paper, we will discuss the details of our experimental results on the new high compressive concrete and simple roller cam type mover system.

2 HIGH COMPRESSIVE CONCRETE

2.1 Concept to Development

In general, various conventional concretes have good characteristics that can provide a low thermal expansion coefficient and massive structure. However, it is well known that they can suffer from slow volume shrink, slow shape creep and hairline cracking.

Thus, we decided the performance targets for the new concrete for the support stands to be as follows:

(1) Increase the compression strength,
(2) Small volume shrinking after drying,
(3) Small creeping deformation of the shape,
(4) No hairline cracking as the material ages.
(5) No need of any sub frames, such as reinforcing rods.

To achieve the target performance, the concrete components (by volume percentage) were found experimentally. Table 1 shows a comparison of the main compositions for the resulting high compressive and conventional concrete.

The main components and also their relative amounts in the new concrete were optimized to obtain a very high compressive strength and a very small shrinking in volume while still meeting the other remaining requirements for a stable support. The new concrete has a liquidity very much higher than that of conventional concrete. This contributes greatly to increase the concrete density per unit volume.

Table 1: Comparison of conventional and new concrete.

ITEMS	New concrete	Conventional
Ratio of water and cement (%):	20	56.1
Content of fine aggregates (%):	52	49.3
Content (kg/m^3)		
- Water:	160	171
- Cement:	800	305
- Sand:	821	886
- Pebbles:	671	926
Chemical admixtures (kg/m^3)		
- High-range AE[1)]:	10.4	no content
- Highly durable[2)]:	8.0	no content
- AE water-reducing[3)]:	no content	3.05

1) High-range water-reducing and air-entraining admixture.
2) Highly durable admixture.
3) Air-entraining and water-reducing admixture.

We made four full size support stands; cylinders 500 mm in diameter and 680 mm tall as shown in Fig. 1. After grinding with a special machine, measurements of the top showed a surface roughness less than 10 µm on average, and a flatness of around 10 µm.

To compare the newly developed and conventional concretes we used Japan Industrial Standards (JIS) for our appraisal standards. Two full size samples were used to measure the compressive strength and the volume shrinking as a function of the time. To investigate the dry shrinking characteristics of the concretes, each sample had two reference points spaced 300 mm apart marked on the surface and located parallel to the central axis as shown in Fig 1. The variations in the distance between marks as a function of the material age were recorded.

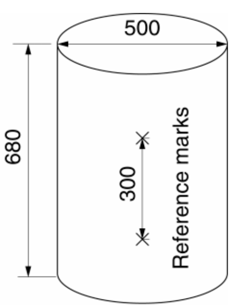

Figure 1: Sample concrete.

2.2 Experimental Results

We obtained very good experimental results from the new concrete. The measured typical compressive strengths and the dry shrinking of new and conventional concretes as a function of material ages are shown in Figures 2 and 3.

As can be seen in Fig. 2, at only 13 weeks the new concrete provides a compressive strength 4.4 times higher than conventional concrete, note that it is also higher than natural granite block. Fig. 3 shows that at a material age of only 13 weeks the variation curve for dry shrinking of the new concrete is almost saturated at 69 x 10^{-6}. The new concrete has only 38% of the dry shrinking value compared with conventional concrete. From this result, we clearly confirmed that the new concrete could replace natural granite tables for precise support stands.

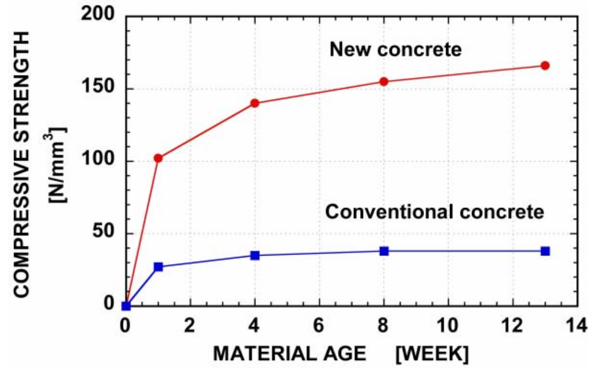

Figure 2: Comparison of the compressive strength of the new and conventional concrete as a function of material age. The new concrete provides 4.4 times higher compressive strength than conventional concrete at 13 weeks.

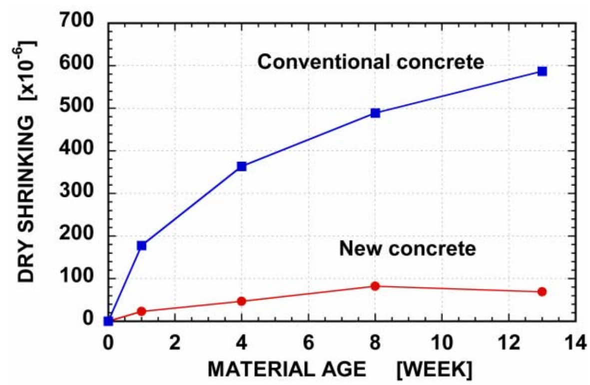

Figure 3: Comparison of dry shrinking in the new and conventional concretes as a function of material age. The new concrete maintains very small dry shrinking at 13 weeks.

Fig 4 shows the full size support table (Ø500 mm x 680 mm) made from this high compressive concrete. The surface roughness and flatness at top are both within ±10 µm. An alignment accuracy of ±10 µm was reached in less than 30 minutes of working time. The support stand will be glued onto the base granite using a mortar binder after alignment. We are now preparing to glue the support

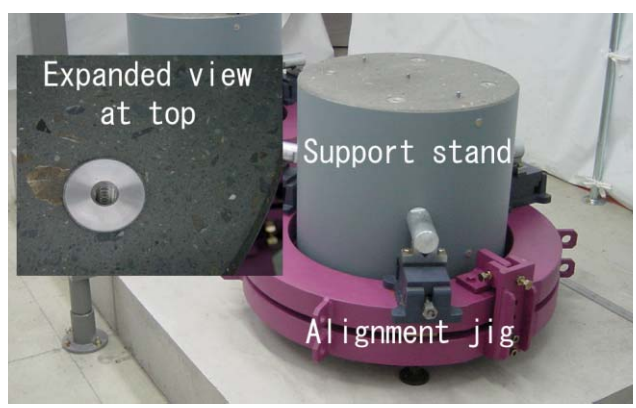

Figure 4: Full size support stand and attaching alignment jig were developed by Takenaka Co. The surface roughness and flatness are within ±10 µm.

stand in place, and then to make long-term position stability measurements.

3 ROLLER CAMS MOVER

This mechanism is designed to support a load of up to 500 kg, while providing smooth motion, free of hysteresis at the micron level. The new roller cams mover unit is comprised of two roller cams, their stepping motors drivers, two linear sliders and support frames. A conceptual drawing of the roller cams positioning system is shown in Fig. 5.

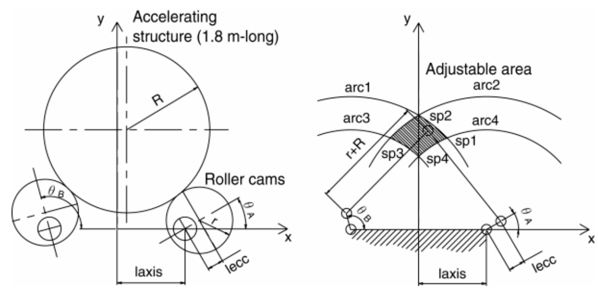

Fig 5: Conceptual roller cams mover positioning system.

We used 72 mm diameter roller cams to provide ±1 mm of positioning area. The dark diamond as pictured in Fig. 5 (right) shows the adjustable area, where each diagonal length is ±1.4 mm in the horizontal and vertical. A mechanical drawing of the roller cams mover unit is shown in Fig. 6. Two linear sliders are used to fix the initial positions in horizontal and vertical for the accelerating structure. We do not use V-blocks and flat plates fixed to the structure (such as is used in the magnet positioning roller cams system in the SLAC FFTB).

We measured the maximum adjustable range, and then a position repeatability of less than ±1 mm anywhere within the positioning range while loaded with a 50 kg dummy weight as shown in Fig.7. The position of dummy weight was measured by the attached electronic linear-scales as shown in Fig.7. Two roller cams units were used to manipulate the dummy weight. Each roller cams mover unit can be controlled individually to adjust for any axis as shown in Fig. 8. A position repeatability of around ±0.1 μm within ± 1 mm of the adjustable area was obtained.

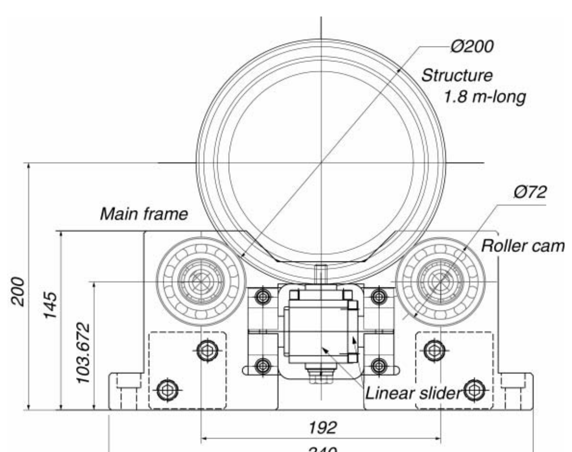

Figure 6: A cutaway drawing of the roller cams mover unit. 72 mm diameter roller cams give an adjustable range ±1.4 mm.

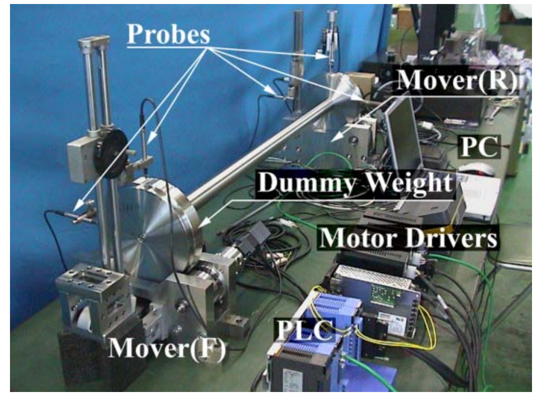

Figure 7: Measurement setup of the roller cams mover system was fabricated at Ohtsuka Co.

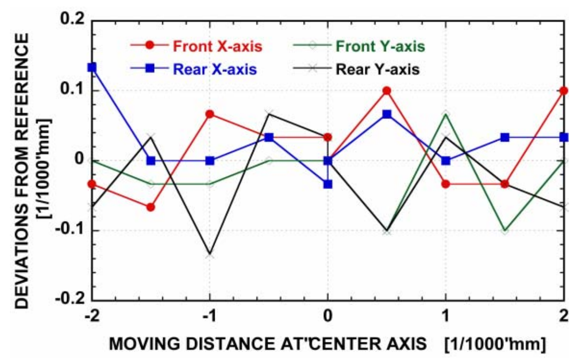

Figure 8: Deviations of roller cams mover from reference at short distance.

4 SUMMARY

The new concrete developed for this experiment shows a very high compressive strength, which is 4.4 times higher than conventional concrete, and which is also higher than natural granite stone. The dry shrinking variation curve of the new concrete was almost saturated at 69 x 10^{-6} at 13 weeks. The new concrete can be used without any additional reinforcement parts such as the iron reinforcing bars used with existing concrete structures. The new type roller cams mover system provides a position repeatability of ±0.1 μm, within the ±1 mm adjusting area. The measured adjustable area agreed with the expected theoretical results.

From those experimental results, we confirmed that the combination of the new concrete and new roller cams mover system would be suitable for a very precise alignment system.

5 REFERENCES

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