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Geodesy for the Storage Ring of Spring-8

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Abstract

A 1.4 km circumference of the Spring-8 surrounds Mihara-Kuriyama Hill which is 50m higher than the storage ring level.We surveyed 12 reference points and 15 monuments in January and February 1993 before ring building is constructed. The number of measurements is 114 for angle and 106 for distance. These positions were determined within errors of ±2mm. Magnets are to be aligned by these monuments.

Survey Points

1)Reference points outside the ring

Ten geodetic points (SR1~SR10) are positioned outside the ring as shown in Fig.1. The style, which is Japanese standard fiducial point, is shown in Fig.2, these points have been used for the construction of the ring building and underground piping work.

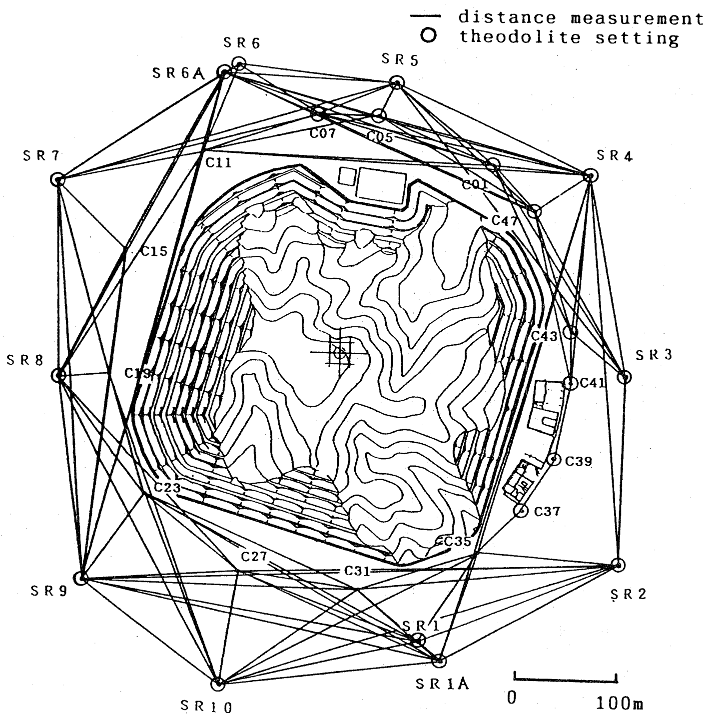

Fig.1 Surface Network.

2)Monuments

Construction of the storage ring building is divided into four phases. Thus, the magnets alignment must be started before the tunnel is completed. We made concrete monuments similar to Japanese tomb stone as shown in Fig.3(a). These 15 monuments (C01~C47) for the magnets alignment are placed at the intersected points of the straight lines on both side of the bending magnet.

Figure3(b) is the cross section of the tunnel. This concrete block is fixed by anchor bolts to prevent from shifting. The upper surface becomes the tunnel floor level when the tunnel is constructed.

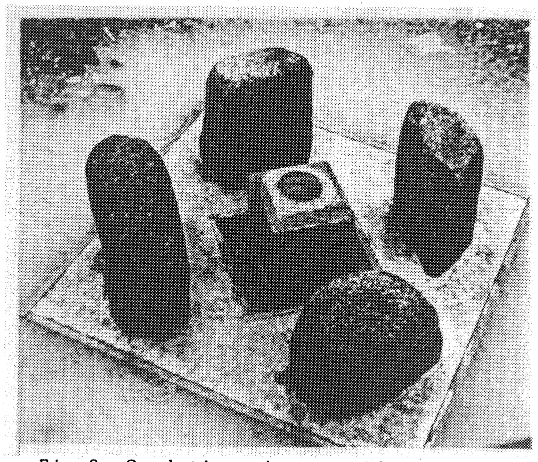

Fig.2. Geodetic point outside the ring.

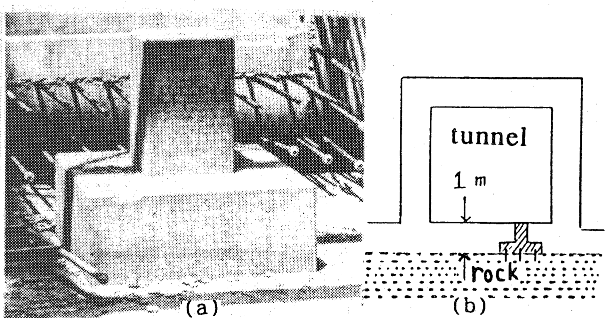

Fig.3.(a) Monument for magnet alignment.
(b)Cross section of the tunnel.

A plate is buried in the upper surface, a seal is sticked by easy survey on this plate as shown in Fig.4. The center of this seal became initial position for accurate survey.

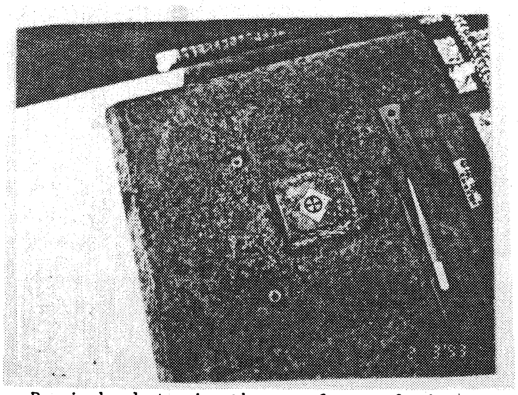

Fig.4. Buried plate in the surface of the monument.

3)Sub-points

SR1A and SR6A were placed so that the circumference is surrounded by quadrangle. A wooden pile is driven into the ground, and target seal was sticked on it.

Setting of tripod and stand

The automatic plummet (WILD NL accuracy 0.5mm at100m) was used for the setting of a tripod. Accurate adjustment in the horizontal plane has become easy by fixing metal fitting on the tripod as shown in Fig.5. Upper and lower bolts prevent the survey instrument from rolling when slight relaxing for fine shift. Figure 6 shows the tripods before fitting and after fitting.

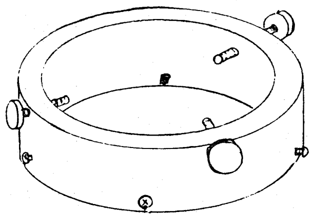

Fig.5. Metal fitting for accurate adjustment.

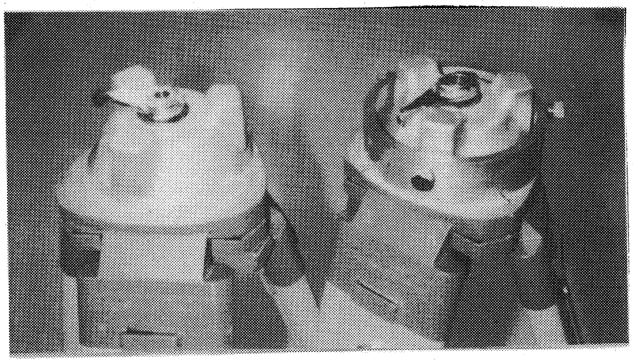

Fig.6. Tripods before fitting and after.

A stand was fixed on the monument as shown in Fig.7(a). However, two stands were used as shown Fig.7(b) because the sight is frequently interrupted by many obstruction. The acuracy of setting of survey instrument is probably lower than 0.5mm.

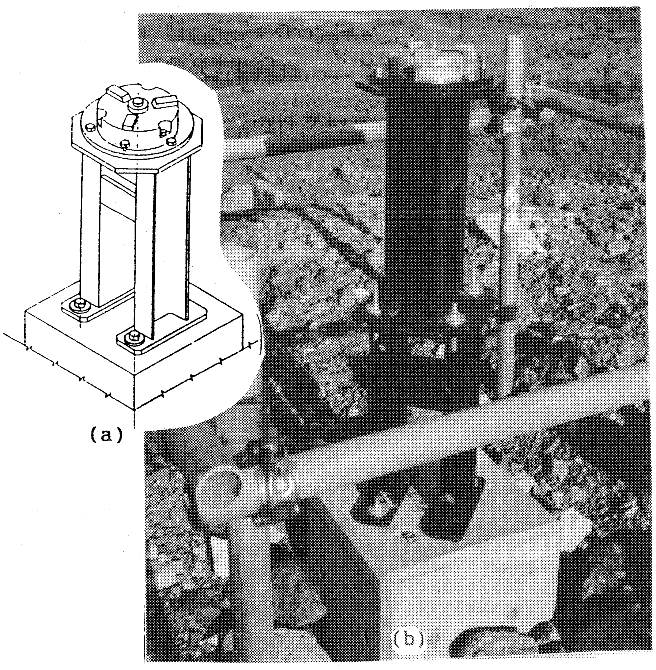

Fig.7.(a)A stand for survey instrument.
(b)Double stands.

Survey Instruments

The measurements were made using the following instruments.

1)Distance Meter
Kern Mekometer ME5000 accuracy 0.2mm+0.2ppm× distance (catalogue specification)

2)Angle Measurement
WILD T3000 standard deviation horizontal 0.5″ vertical 0.5″ (catalogue specification)

3)Target
Three reflectors were used for distance measurements and many home-made targets shown in Fig.8. were used for angle measurements.

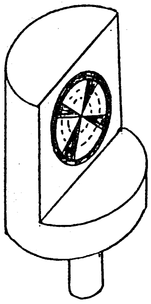

Fig.8.Target for angle measurement.

Survey Network

Figure 1 shows surface network of the measurements of distance and angle. A straight line means the distance measurement, and a theodolite for angle measurement was set at the point surrounded by circle.

Analysis

The line between SR2 and SR9 was chosen to be a " baseline". Observation equations were obtained from the measurements. These equations were solved by least squares method. This program is written by BASIC language for a personal computer. Main part of the program is cited from the survey textbook.[1] This program was so modified that can calculate the many positions by small memory.

Normal equation was solved using three methods, that is, Gauss method with partial pivoting, Gauss method without partial pivoting, modified Cholesky method. The calculation was carried out by double precision (fourteen significant figures). The result by modified Cholesky was bad, the results by the other two methods agreed with each other.

Results

The positions of the monuments are listed in Table 1. The coordinate axis X denotes the north direction and Y the east. The value in the parentheses is the standard deviation estimated from error matrix.

Table 1 Positions of Monuments obtained by survey and calculation.

	X (m) (North)			Y (m) (East)		
	initial	shift(mm)	Adjusted	initial	shift(mm)	Adjusted
C01	179.5025	2.1	179.5046(3)	144.7385	1.3	144.7398(5)
C05	223.5463	3.9	223.5502(3)	35.1767	1.6	35.1783(5)
C07	224.3007	1.7	224.3024(3)	-24.6299	3.4	-24.6265(5)
C11	185.8391	0.0	185.8391(3)	-136.2738	1.3	-136.2725(5)
C15	93.1239	-1.7	93.1222(3)	-209.4007	0.5	-209.4002(5)
C19	-24.6299	-0.9	-24.6308(2)	-224.3007	-8.2	-224.3089(4)
C23	-136.2738	-1.9	-136.2757(3)	-185.8391	-2.0	-185.8411(3)
C27	-209.4007	4.0	-209.3967(3)	-93.1239	-1.4	-93.1253(2)
C31	-224.3007	0.3	-224.3004(3)	24.6299	-2.1	24.6278(2)
C35	-185.8391	-0.4	-185.8395(3)	136.2738	2.3	136.2761(2)
C37	-144.7385	0.4	-144.7381(4)	179.5025	4.8	179.5073(4)
C39	-93.1239	-0.9	-93.1248(5)	209.4007	2.6	209.4033(5)
C41	-24.6299	12.4	-24.6175(4)	224.3007	1.3	224.3020(5)
C43	24.6299	0.7	24.6306(3)	224.3007	2.5	224.3032(5)
C47	136.2738	-0.4	136.2734(3)	185.8391	7.6	185.8467(5)

Error ellipses are shown in Fig.9. The monuments of C37,C39 and C41 are in the ring building, thus these error ellipses are larger.All error ellipses are smaller than the circle of radius 1mm.

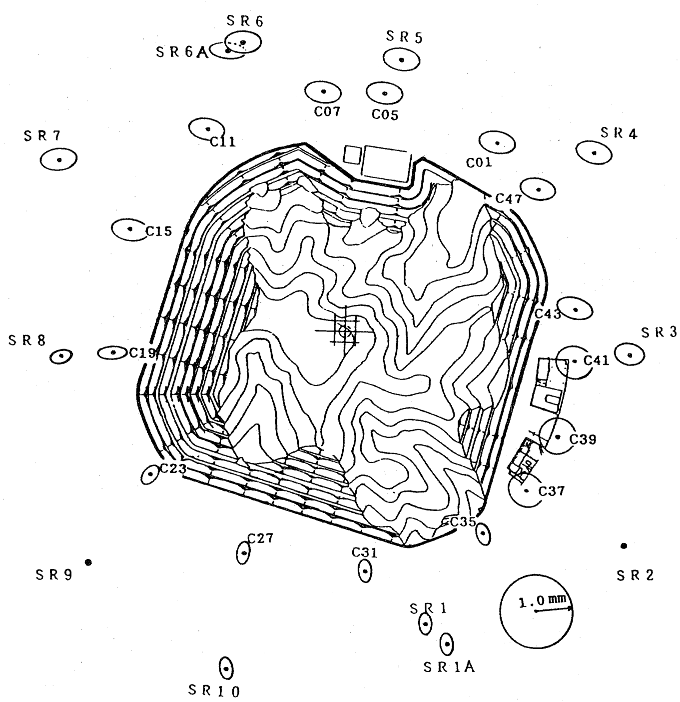

Fig.9. Error ellipses.

The example of the differences between the measured values and calculated ones from adjusted position is shown in Table 2. The standard deviations of these diferences are 1.1 arc sec for angle and 0.28mm for distance.

Since the error were rather smaller than expected, simulation including the measurement error was carried under the same surface network. The error distribution is assumed to be normal one. The error of simulated mesurement is chosen so that the simulated difference between the measured values and calculated ones from adjusted position coincide to the above values, i.e., 1.1 arc sec and 0.28mm. These values of standard deviations were obtained when using angle error 0.6 arc sec and distance error 0.3mm+0.5ppm×distance.

The representative shifts from the true values in the X and Y directions were obtained from one simulation using the standard deviation of shifts of 27 points. Figure 10 shows the distribuion of these shifts from fifty times simulation. This result agrees with the error ellipse as shown in Fig.9.

Including the error accompanied with setting of the tripod and the stand, the center coordinates of the seal on the monuments are thought to agree with the adjusted values of Table 1 within the error ±2mm.

Concluding Remark

1)The survey should be carried out before the building construction.
2)The concrete pillar is suitable for the fiducial point. Much time was used for setting the tripod at the Japanese fiducial point.
3)The distance measurements are easy if using several reflectors.
4)A stand the height of which is 1~1.5m is necessary if the construction has started.

Acknowledgements

We would like to thank the staff called "JV" of building construction for their help, we also acknowledge the construction team of SPring-8 for their support.

Reference

1)T.Hosono and N.Inouchi "Kijyunten Sokuryou" (Nihon Sokuryou Kyoukai, 1992) in Japanese.

Table 2 Example of differences between the calculated values from adjusted positions and the measured ones. (a) angle measurement (b)distance measurement

(a) angle measurement

Angle.Point	Adjusted(deg)	Measued	Adj.-Meas (sec)
SR2-SR3-C43B1	127.52876	127.52862	0.5
SR2-SR3-C01B1	145.46562	145.46594	-1.2
SR2-SR3-C47B1	148.71380	148.71408	-1.0
SR2-SR3-SR4	168.05535	168.05563	-1.0
SR3-SR4-SR2	5.76114	5.76093	0.8
SR3-SR4-C43B1	16.63971	16.63990	-0.7
SR3-SR4-C47B1	66.00090	66.00125	-1.3
SR3-SR4-C01B1	105.05390	105.05446	-2.0
SR3-SR4-C11B1	103.19726	103.19739	-0.5
SR3-SR4-C05B1	115.17364	115.17406	-1.5
SR3-SR4-SR5	125.04924	125.04939	-0.5
SR3-SR4-C07B1	112.25726	112.25761	-1.2
SR4-SR5-C01B1	15.27188	15.27175	0.5
SR4-SR5-C47B1	17.70820	17.70792	1.0
[illegible]C05B1	91.08028	[illegible]	[illegible]
[illegible]	133.22189	[illegible]	[illegible]
SR2-SR9-C23B1	[illegible]	306.88426	[illegible]
SR2-SR9-C19B1	[illegible]	278.75071	-1.0
SR2-SR9-SR6A	287.56715	287.56721	-0.2
SR2-SR9-C11B1	287.79888	287.79913	-0.9
SR2-SR9-C15B1	279.30142	279.30160	-0.6
SR2-SR1A-C35B1	317.01390	317.01381	0.3
SR2-SR1A-SR1	254.03177	254.03184	-0.2
SR2-SR1A-C31B1	250.17861	250.17843	0.7
SR2-SR1A-C27B1	231.98879	231.98879	-0.0
SR2-SR1A-C23B1	237.48069	237.48044	0.9
SR2-SR1A-SR4	315.42663	315.42671	-0.3
SR2-SR1A-SR9	220.28554	220.28584	-1.1

Angle fitting = 1.12sec

(b)distance measurement

Point	Adjusted(m)	Measued	Adj.-Meas.(m)
SR1-SR2	206.2373	206.2374	-0.0001
SR1-C31B1	74.8019	74.8021	-0.0002
C39B1-C41B2	70.1087	70.1085	0.0002
C39B1-C37B1	59.6465	59.6463	0.0002
SR3-SR4	193.1476	193.1479	-0.0003
SR2-SR4	371.1255	371.1258	-0.0003
SR4-C43B1	149.3696	149.3702	-0.0006
SR4-C47B1	64.1822	64.1825	-0.0003
C43B1-C01B1	174.1157	174.1155	0.0002
SR4-C01B1	93.6997	93.6993	0.0004
SR3-C47B1	177.0350	177.0346	0.0004
SR3-SR5	353.6371	353.6370	0.0001
SR5-C47B1	180.9608	180.9607	0.0001
SR5-C05B1	35.8814	35.8810	0.0004
SR5-C07B1	81.3557	81.3556	0.0001
SR4-SR5	205.3964	205.3956	0.0008
SR5-C01B1	121.6404	[illegible]	-0.0000
[illegible]SR7	[illegible]	[illegible]	[illegible]
C27B1[illegible]	[illegible]	255.3360	[illegible]
C19B1-C23B1	118.0863	118.0865	-0.0002
C19B1-C15B1	118.6930	118.6930	0.0000
C35B1-SR4	373.3797	373.3797	0.0000
C35B1-SR1A	111.3245	111.3247	-0.0002
SR1A-SR4	484.6488	484.6489	-0.0001
SR1A-SR9	353.0178	353.0179	-0.0001
SR1A-SR2	196.7792	196.7790	0.0002
SR1A-SR10	212.5207	212.5213	-0.0006
SR1A-SR1	27.9772	27.9771	0.0001
SR1A-C23B1	327.1960	327.1959	0.0001
SR1A-C27B1	211.8419	211.8414	0.0005
SR1A-C31B1	102.6922	102.6921	0.0001
SR2-SR3	180.0007	180.0006	0.0001

Distance fitting = 0.28mm

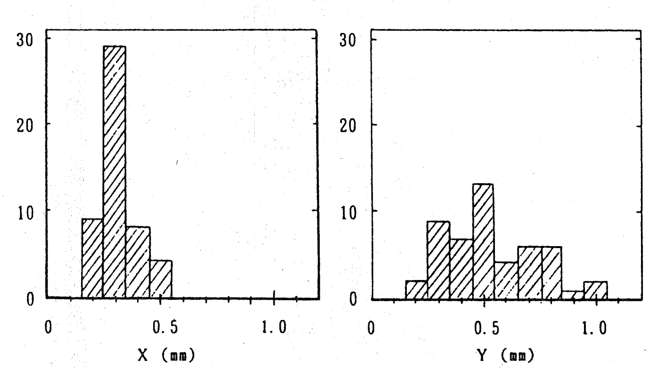

Fig.10. Error distribution from 50 times simulation.